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Republic of Sri Lanka
Ministry of Mahaweli Development

Mahaweli Development Board

Maduru Oya Project Feasibility Study

Interim Report

Acres International Limited, Niagara Falls, Canada

March 1979

154, Dean's Road,
Colombo-10.

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Honourable Gamini Dissanayake,
Ministry of Mahaweli Development,
T. B. Jayah Mawatha,
COLOMBO-10.

Honourable Minister:

MADURU OYA PROJECT
INTERIM REPORT

We are pleased to submit, herewith, fifty (50) copies of the Interim Report; Maduru Oya Project Feasibility Study. It is hoped that the interim findings contained therein will provide assistance to your Government, as requested in November, 1978, in preliminary discussions regarding possible international financing arrangements for the project. Subject to our requirements for certain basic data being met on schedule as agreed, we will submit a draft Feasibility Report to you on or about September 30, 1979 and the final Feasibility Report by March 31, 1980.

Due to limits imposed by the extent of basic data available to us at this time, our findings are, of necessity, heavily qualified. As the soils and topographic mapping proceeds in the months ahead, the reliability and quality of our observations will progressively increase.

We wish to draw your attention to the need to establish, at the earliest possible date, an Experimental-Demonstration Farm within the project area. Firm evidence is required on crop selection and soil and water management on the Non-Calcic Brown soils unique to this area to enable successful settlement planning.

Continued.../2.

ACRES INTERNATIONAL LIMITED
5259 Dorchester Road, P.O. Box 1001, Niagara Falls, Canada L2E 6W1
Telephone 416-354-3831 Cables ACRESCAN Niagara Falls
Telex 061-5107 ACRES NFS

Toronto, Burlington, Calgary, Halifax, Niagara Falls, Vancouver, Winnipeg

Continuation

We acknowledge gratefully the fullest co-operation and assistance extended to us by all Government departments and related agencies and look forward to discussing the contents of this report with you and your staff in the coming months.

Respectfully submitted

John C. W. Ritchie
Deputy Team Leader

Baldur H. Kristjanson
Team Leader

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SUMMARY AND CONCLUSIONS

This report describes the studies carried out to date regarding the technical and economic feasibility of the Maduru Oya Project, which is an integral part of the accelerated Mahaweli Scheme.

The Project consists of a link tunnel to divert water from the Mahaweli Ganga into the Maduru Oya Reservoir, a concrete or rockfill dam to impound the water and an irrigation and drainage system in the downstream area to allow the productive use of the water for agricultural purposes.

At the time of writing this report the status of individual components of the feasibility study was as follows :

Land Classification

Topographic maps at a scale of 1:3168, with two-foot contours were available for about 25 per cent of the development area. The entire area is covered by 1:10,000 maps with 5 metre contour intervals plotted from aerial survey photographs taken in 1956. However, these were prepared without adequate ground control. No Land Classification Maps had been prepared for any part of the project area due to lack of semi-detailed soil mapping and appropriate topographic information. However, semi-detailed soil surveys of seven sample strips in Area B were completed in March, 1979. These provided indications of the complexity of the soil pattern. During January and February 1979 field examinations were made of soils in the area to establish characteristics relevant to land use capability determination. A broad division of the irrigable lands into four Land Class Groups was made. These groups were "Lowlands", "Intermediate Lands" with fine textured soils and poor drainage, "Intermediate Lands" with coarse textured soils, and free draining "Uplands."

Agricultural Production Potential

A review was made of the crops which are potentially suitable for the soils encountered in System B, subject to the limitations imposed by the lack of Land Classification Maps. These limitations are severe in a number of respects. On the Non-Calcic Brown category of soils, for example, constituting over 20 per cent of the commandable area, very little hard evidence is available regarding their productivity. While it is believed by respected sources that the potential of these soils under appropriate management may be satisfactory,

there is no firm evidence upon which to quantify the productivity possibilities of these soils. A cropping pattern based on this limited information has been proposed and forms the basis of the agricultural benefit assessment.

Agricultural Benefits

Crop budgets were developed for a limited range of crops. In these budgets rice production is dominant and the extent of other crop production is conditioned not only by natural factors such as soil capabilities and availability of water but also by marketability factors. Benefits based on the assumption that within a 5 to 7 year period, recommended practices would be adopted and that all necessary supply and marketing functions would be in place and operating at satisfactory levels.

Irrigation and Drainage

Work has concentrated on investigating appropriate water distribution and drainage methods for the area, and on reviewing preliminary design work undertaken by Mahaweli Development Board. The lack of Land Classification Maps and delays in producing topographic mapping have made it impossible to do any new design work on the distribution and drainage system.

Link Tunnel

The design of link tunnel has proceeded to the Tender Document stage.

Cost Studies

Studies of local construction costs have been completed, and the results applied to the design information information available for the various project elements.

Settlement Planning

Reconnaissance surveys of existing conditions have been undertaken by the project sociologist. Detailed surveys are being carried out by Mahaweli Development Board.

Project Economics

Economic analyses have been performed using the information available from the various components of the study.

From the foregoing description of the data base from which the observations in this report have been made, it is clear that considerable field work remains to be done before reliable indicators can be had of the economic viability of the Maduru Oya Project. By the end of September 1979 it is expected that sufficient soil and topographic data will be available to provide land use ratings for about 60 per cent of the area. At that time a preliminary economic viability estimate can be made with a reasonable degree of confidence.

CONCLUSIONS

Using the limited information summarized above, the following preliminary conclusions have been drawn.

Land Classification

Approximately 54,000 ha are irrigable and commendable. It is estimated that, of this total, 10,000 ha are freely draining upland soils, 28,000 ha are imperfectly draining intermediate soils and 16,000 ha are poorly draining lowland soils.

Agricultural Production Potential

After allowances for homesteads, unirrigated vegetable plots and irrigation works, an area of 46,000 ha is estimated to be cropped with an average cropping intensity of 1.64

The cropping pattern proposed is based on the following assumptions:

1. Lowland areas will be double-cropped with paddy
2. Intermediate areas (fine textured soils) will be cropped with paddy in the Maha and field crops in the Yala.
3. Intermediate areas (coarse textured soils) will be cropped primarily in the Maha with field crops selected for their suitability in rotation.
4. The uplands will be double cropped in field crops, again selected for their suitability in rotation.

Agricultural Benefits

Crop budgets indicate that the following returns or ranges of returns can be expected from the project area under conditions of good management:

	M./ha
Paddy	6800 - 7850
Soybeans	2800 - 4600
Groundnuts	4450
Vegetables *	6550
Tobacco	11850
Cassava	8500
Kenaf	9400
Cotton	7100
Vegetables/fruits **	19000

* not irrigated
** irrigated

Irrigation and Drainage

At this time it is felt that the lowlands and the intermediate areas can be irrigated with surface methods. Good drainage control will be essential to the successful use of surface irrigation in the intermediate areas having coarse textured soils. The upland areas will probably require sprinkler irrigation, due to their erodibility and probable high infiltration rates.

Cost Studies

The economic costs of the principal elements of the project are estimated as follows :

	M. x 10^6
Dam	861
Tunnel	256
Irrigation and Drainage System	2068
Portion of Upstream works	237
Social Infrastructure, Settlement Pilot Farm, Project Management Infrastructure	353
Total	3775

Settlement Planning

It is estimated that a total of 39,300 families could be settled on farm units, the majority of which are 1.4 ha in area. About 30,000 of these families would have at least one [illegible]

Project Economics

Only direct agricultural benefits and energy production benefits from the dam have been quantified at this time, although all major costs have been included. Quantifiable benefits from livestock, fisheries and forestry will be included in the Feasibility Report. The substantial social and employment benefits arising from the successful settlement of the project area have not been quantified and therefore are not included in the analysis.

- Using the estimated average yields, the internal rate of return of the project is 10.3%. This is expected to increase to over 11% when livestock, fisheries and forestry benefits are considered.
- The Forest Reserve (gross area about 6500 ha) has not been considered in the basic analysis. A recent decision has been made to make this area available for irrigation. A preliminary examination was made of the effects on the overall project's internal rate of return if the 3500 ha block of good upland soils (RBE) within the reserve can be cropped with sugar cane. Based on benefit calculation made for System C^2, the rate of return was found to increase from 10.3% to about 11%. Further detailed analysis will be required, however, to determine the feasibility of establishing a sugar mill in System 'B'.

KEY OUTSTANDING ISSUES

1. The extent of irrigable land of each land class group.

   This question can be resolved with a good degree of confidence when soil and topographic maps have been completed at an adequate scale to allow the preparation of Land Classification Maps.

2. The extent of commandable land.

   This question can be resolved when topographic mapping is available to allow design of the main canal system. The use of sprinklers on upland soils may allow an increase in the commandable area beyond that commandable by gravity.

3. The feasibility of using sprinkler irrigation on upland soils.

   The wind data now being collected at the climatic stations recently established at Kandulla and Diyasenapura will assist in further assessments. The experiments planned in the coming months in System 'C' on the overhead irrigation of sugar cane will provide invaluable information as well.

4. The agricultural productivity of the Non Calcic Brown soils.

   This question will remain substantially unresolved until the Experimental-Demonstration Farm has been in operation for at least two years.

5. Livestock, Fisheries and Forestry benefits.

   These benefits are expected to be significant and will be quantified for inclusion in the Final Report.

6. The settlement pattern.

   The Land Classification Maps are fundamental to settlement planning. Socio-economic surveys now being undertaken by MDB are also essential to this task.

7. The rate of settlement.

   The rate at which water becomes available to lands in System 'B' may exceed the practical limits of actually settling farm families. Settlement experience and the proposed accelerated settlement program will be reviewed in the preparation of the Feasibility Report.

RECOMMENDATIONS

1. Establishment of an Experimental-Demonstration Farm on the Non Calcic Brown soils in System 'B' should be given urgent attention. A suitable site has been located close to an existing water source, enabling cropping to begin before completion of the Maduru Oya dam and canal system.

2. To complete this Feasibility Study to acceptable standards, detailed topographic and soils mapping is required. This mapping, which is now under way, should be given high priority to allow it to be completed on schedule. This will allow the submission of the draft Feasibility Report by September 30, 1979 and the final Feasibility Report by March 31, 1980.

3. The information being collected in the socio-economic survey now under way in System 'B' is essential to adequately assess pre-project conditions. The early completion of this survey with an adequate degree of detail should therefore be encouraged.

1 - INTRODUCTION

1.1 - Study Background

The high priority given by the Government of Sri Lanka for the settlement and development of lands in System B, traversed by the Maduru Oya, led to a request by the Government to the Canadian International Development Agency (CIDA) to provide terms of reference for a feasibility study of the Maduru Oya Project. CBA Engineering Ltd. was engaged by CIDA to write a Reconnaissance Report for the Maduru Oya Project. This report, which was submitted in August 1978, forms the basis for the Terms of Reference of this study. The Central Engineering Consultancy Bureau (CECB) was given the responsibility for the design of the Maduru Oya dam, spillway, power facilities, irrigation outlets and reservoir. The remainder of the works required and all relevant aspects of an effective use of the land, water and human resources involved in a successful settlement of the region constitute the elements of the feasibility study under discussion in this report.

Acres International Ltd. undertook to carry out the work as set forth in the Terms of Reference, the full feasibility report to be completed by March 31, 1980. In order that the Government could hold exploratory meetings regarding possible financing alternatives, Acres was requested to submit an Interim Report on March 31, 1979. This proposal was agreed to, based upon the following considerations:

1. That it be understood that this report would be truly interim in nature, since few of the critical tasks would have been completed.

2. An analysis would be made of project costs based on Acres' studies of local and International Contractor construction costs. The cost of the dam would be based on a review of CECB's cost estimate, while the cost of the Link Tunnel would be based on Acres' design. The cost of the irrigation system would be based on preliminary layouts available at the time of report preparation.

3. A preliminary assessment of project benefits would be made. This would be based on a preliminary assessment of feasible crops and crop budgets for each soil capability group. The estimate

of the extent of each major group would be based mainly on existing low-intensity soil and topographic mapping.

4. A preliminary assessment of project economics would be made, based on the above.

The main constraint on producing a comprehensive and detailed feasibility study is the lack of sufficiently detailed topographic and soils data. This was recognized by all concerned at the outset and these deficiencies are being overcome with all possible speed. The purpose of the Interim Report is to obtain first approximations of the benefits and costs of the Maduru Oya Project.

1.2 - The Project

The Maduru Oya Project is an integral part of the Mahaweli Development Scheme. It has been designated as being of high priority by the Government of Sri Lanka. The Mahaweli Development Scheme is a major attack on some of the principal problems facing Sri Lanka in the immediate as well as the longer term future. These include the need to achieve greater self-sufficiency in such basic foodstuffs as rice and sugar; the need to strengthen the country's foreign exchange position; to mitigate high levels of unemployment and underemployment and last, but not least, the need to foster strongly-based regional economies. Thus, the resettlement aspects of the Scheme are in fact quite central to the Government's objectives.

In physical terms, the main elements of the Maduru Oya Project include the dam, link tunnel and canal systems. The dam is to be a rockfill or concrete gravity structure, some 41.5 metres in height above the foundation and 1020 - 1050 metres in length along the crest. The reservoir so formed will have a live storage capacity of 457 million m^3, compared to an average annual inflow of 385 million m^3.

To augment the natural runoff and provide irrigation water for more land in the downstream development area, water will be diverted into the Maduru Oya basin upstream from the dam. This water will originate in the Mahaweli Ganga at Minipe, and will be,conveyed by the Minipe right bank trans-basin canal to the Ulhitiya Oya and Ratkinda Oya reservoirs. From these reservoirs, the water will enter a 5800 metre long, 5.1 metre diameter Link Tunnel, which will deliver the water to the Vila Oya, a minor left bank tributary of the upper Maduru Oya.

Irrigation water is to be discharged from the dam through separate powerhouses into the Left and Right Bank Main canals.

The Left Bank Main Canal, which will serve an irrigable area of about 27,000 hectares, will be about 58 kilometres in length. Major branch canals will total further 75 kilometres. Laterals and farm ditches, major and minor drainage works, and land improvements will also be required.

The Right Bank Main Canal will serve a smaller irrigable area of about 18,000 hectares. It will be some 53 kilometres long, and major branch canals will total about 33 kilometres. As for the Left Bank, other works will include laterals, farm ditches, drainage channels and land improvements.

Reference has been made to the fact the settlement aspects of this project are of primary concern to the Government of Sri Lanka. Rational national planning generally requires that specific attention be paid to creating and supporting balanced regional development. In the case of Sri Lanka, where substantial areas of the country are sparsely populated and in many respects are only peripherally involved in the mainstream of economic activity, it is understandable that national objectives should now include an upgrading of the performance of such areas as a matter of urgency.

More advanced countries face similar political and socio-economic imperatives. In the case of developing countries the basic problem is in reconciling to the satisfaction of potential lenders the relatively low rate of economic return that may be expected during the first years of such endeavours with the real returns in terms of human development, political stability and longer-term national growth potential.

The Mahaweli Development Scheme, being the centre-piece of the broader national development objectives, encompasses the Maduru Oya Project. It follows that activities within the Maduru Oya Project must support and, where possible, augment the achievements of the Mahaweli Scheme as a whole. In this respect it is important that the findings of this study be assessed by others within the broader context of the Mahaweli Scheme and of national development.

2 - THE SOILS AND LAND CLASSIFICATION

2.1 - The Environment

The geology of the area is characterized by Pre-Cambrian rocks which can be separated into the following two groups:

(a) The Vijayan series of hornblende gneiss, biotite gneiss and hornblende biotite gneiss with the associated pegmatites and migmatites which dominate the project area.

(b) A transitional zone of rocks between the Vijayan series and the Khondalite series, made up of hornblende biotite gneiss, charnokites, biotite gneiss and thin calc - silicate lenses which are found mainly in the southwest.

These very ancient rocks have given rise to a mature, mantled and undulating peneplain which merges imperceptibly to the north and northeast into the Pleistocene and Miocene sediments of the coastal plain. Large prominent isolated erosional remnants or monadnocks and prominent ridges rise to heights of over 500 metres (Gunners Quoin) above the general level of the surrounding plain which varies in elevation from about 80 metres above sea level in the south to under 30 metres in the extreme north. The thickness of the mantle covering the peneplained rock is often thin and sometimes non-existent as in areas of rock knob plain and out-cropping flat rock.

Two very different soils have developed on the Pre-Cambrian rocks. On those rich in ferromagnesian minerals belonging to the Vijayan series and especially to the transitional zone, shallow to moderately deep reddish to brown, sandy clay loam soils have developed, on slopes which often exceed two per cent and sometimes four. These soils normally occur in association with prominent rock outcrops. On the rocks relatively poor in ferromagnesian minerals but rich in quartz, moderately deep to shallow, gray brown, moderately coarse textured soils occur. These overlie impermeable rock and usually occur on slopes not greater than two per cent.

Associated with these soils are imperfectly to poorly drained bottomland and old alluvial soils of variable but usually sandy texture. A relatively wide band of imperfectly to very poorly drained recent alluvium (with

the exception of the narrow but moderately freely draining low levee bank soils) occurs along the Maduru Oya and the right bank of the Mahaweli Ganga (which forms the western boundary of the project area).

The old alluvial soils, although showing a dendritic pattern and for the most part occupying relatively low land, are not now necessarily associated with the present day drainage. The Maduru Oya for example, which follows the general strike of the rocks and roughly parallels the Mahaweli Ganga as far north as Welikanda, suddenly swings eastwards to flow to the sea. There are strong indications that it continued northwards in the past, to link with the Mahaweli Ganga near Kandakuda. This river migration seems to have been common and the braided nature of the present river courses would tend to support this view. Unfortunately, the indeterminate drainage of much of the old alluvium has resulted in a salinity buildup, which is a problem especially in areas where the subsoils have been found to be alkaline.

The climate, which is characterized by uniformly high temperatures throughout the year, is monsoonal and therefore strongly seasonal. The wet season is dominated by the northeast monsoon (Maha) and lasts from October to April. The heavy rains slacken in January and a lack of precipitation can be experienced through February and March. The dry season is dominated by the southwest monsoon (Yala) and lasts from May to September. This strongly fluctuating climate has a marked effect on soils and vegetation and dictates potential land use.

During the Maha the imperfectly draining lowland, alluvial and old alluvial soils, partly because of indeterminate drainage, become exceedingly wet, and through evaporation of water in Yala are saline or liable to become saline. Most of the elevated, sandy, quartz-rich soils are underlain at depths of not much more than a metre by impermeable rock. They quickly reach field capacity and remain waterlogged throughout the Maha but dry out quickly in the Yala, and naturally support a poor grass scrub vegetation locally known as parkland. The naturally forested reddish to brown sandy clay loams, usually associated with steeper slopes, shed water, not only because of slopes but due to their much lower infiltration rates. These soils under cultivation can further aggravate the excessive wetness of the associated lowlands during Maha. Because of the composition of these reddish-brown soils,

especially the nature of the clay fraction, they also dry out rapidly in the Yala but unlike their gray brown sandy counterparts, which remain friable, they become exceedingly hard and difficult to cultivate.

It is obvious that geology and climate have imposed limitations on the soils as to their agricultural development. Drainage is a definite requirement to remove the excess water which the Maha brings. Applied irrigation water in the Yala should be as frugal as possible- otherwise, the undesirable wetness presently associated with the Maha will result. It has therefore been decided that for present purposes, the land should be divided into four broad groups as follows:-

(1) the freely draining upland red brown sandy clay loams - 'Upland'.

(2) The seasonally waterlogged by nevertheless upland sandy soils - 'Intermediate lands'.

(3) The wet bottom-lands - 'Lowlands'.

(4) Unusable - 'Unsuitable'.

2.2 - Soil and Topographic Mapping

2.2.1 - Existing Soil Maps

Moorman and Panabokke [1] identified fifteen great soil groups in Sri Lanka, six of which were shown occurring in the Maduru Oya Project area on the two miles to one inch reconnaissance soil map (1966), produced by the Land Use Division of the Irrigation Department (LUD) in association with FAO as follows:

(1) The Reddish Brown Earths(RBE)
(2) The Non Calcic Brown Soils (NCB)
(3) The Low Humic Gley Soils (LHG)
(4) The Alluvial Soils (AL)
(5) The Old Alluvial Soils (OAL)
(6) The Solodized Solonetz Soils (SS)

This map was produced by using 1/40,000 aerial photography combined with field checking at a density of one soil profile observation to about 300 ha. In late 1977, using more recent

1/26,500 scale photography, LUD reinterpreted the information on the soils, and identified and characterized the main soil series. They produced a soil map with sixteen mapping units (fourteen soil series or associations of soil series and two miscellaneous land units), again at a scale of two miles to one inch. As a check, they also conducted a medium intensity survey of approximately 7,500 ha stretching from the Maduru Oya near Welikanda eastwards to the right bank of the Mahaweli Ganga. This map was produced at a scale of 1/26,500. It indicated that, within the limitations of scale and the very broad nature of the mapping units, the LUD two miles to one inch map is accurate. Unfortunately, this sample area survey, although attempting to map depth phases where critical, still did not map some of the important soils at series level.

Table 2-1 compares the areas of soils mapped on the 1:26,500 sample survey map with the area of soils within the same boundary on the 2 miles to 1 inch (1:127,000) reconnaissance map. The following observations can be made from this comparison:

The more detailed map shows a greater area of Reddish Brown Earth and less Non Calcic Brown soils. This can be traced largely to the lower concave slopes where the four imperfectly drained RBE's (Alawakumbura, Mawa Kulam, Padumunda Kulam and Horaborawewa series) are mapped as occupying 13.8 per cent of the sample area as against 5.3 on the reconnaissance map. These four series are part of the Reddish Brown Earth catenary sequences which consist of 23.4 per cent of the mapped area as upper convex slope, 13.8 per cent lower concave slope, and only 0.7 per cent valley bottom.

In contrast, 17.6 per cent of the area is mapped as upper convex slopes with Non Calcic Brown soils, but only 1.5 per cent as lower concave slopes of Galwewa or Boattewawa series. As all the lower concave slope soils are very similar, with only slight differences (especially in texture) differentiating them, this apparent discrepancy would not have a significant effect on the land capability assessment.

TABLE 2-1

SOIL MAPPING UNIT AREA/AREA OF SAMPLE AREA

SOIL MAPPING UNIT SAMPLE SURVEY MAP 1/25,000	LAND GROUP	SAMPLE SURVEY MAP 1/25,000 % OF SAMPLE AREA		% OF UNIT/LAND GROUP		GREAT SOIL GROUP	SAMPLE SURVEY AREA 2 MAP TO 1/25,000 % OF SAMPLE	% OF UNIT/ LAND GROUP
Ulhitiya	U	7.3	23.4	30.0	96.3	Reddish (1) Brown Earth	16.0	100
Nawampitiya	P							
Welayaya	I	16.1		66.3				
Muthugalla	A							
Alutnuwara	A D	0.9		3.7		Alluvial	NR	NR
Subtotals		24.3		100.0			16.0	100
Madru Oya	I	17.6	15.1	46.0	45.9	Red Calcic Brown	33.6	86.4
Nelikanda	N							
Galewela	T	1.5		3.9				
Bostewela	E							
Alawatugoda	R	10.0	13.6	26.1	36.0	Reddish Brown Earth	5.3	13.6
Nawakulam	M							
Padamundakulam	E	3.6		9.5				
Horakolawewa	D							
Nentaram	I	3.9	5.4	10.2	14.1	Alluvial	NR	NR
Bulatlotbe	T	1.5		3.9				
Subtotals	E	38.3		100.0			38.9	100.0
Handapanwila	L	1.1	10.6	36.4		A l l u v i a l	11.9	32.6
Hewampitiyawillu	O	2.9						
Katuwandila		2.9						
Tintirt Aru	V	3.2						
Galgar Villu		0.5						
Arasinagar	L	3.4	17.9	61.3		Old Alluvial	24.6	67.4
Ulpothawewa	A	6.3						
Mongama Ela		2.8						
Pochchanda	N	5.4						
Mailadentiya	D		0.7	2.3		Low Humic Clay	NR	NR
Kuda Oya								
Kanagawela								
Perilleveli								
Kanulawela								
Subtotals		29.2		100.0			36.5	100.0
Miscellaneous Land Types		8.2		100.0		Miscellaneous Land Types	8.6	100.0
Totals		100.0		N/A			100.0	N/A

Notes: (1) Based on an estimate of 75 per cent of the area mapped as Reddish Brown Earth falling into the Upland Land Group.

N/R = Not Recorded

N/A = Not Applicable

In general, the overall mapping done on the sample area supported by the seven sample strips (see Section 2.2.3), indicates that the reconnaissance map is reasonably accurate and does not provide any justification for alteration to it until more medium intensity soil mapping of System B has been completed.

2.2.2 - Present and Future Topographic Mapping

The most useful of the existing topographic maps, covering the whole project area, are th one inch to one mile maps, with contours at 100 foot intervals, and the two inches to one mile maps, with contour intervals every twenty feet up to 600 feet elevation and then every 100 feet thereafter. The latter map was revised from the 1956 photography and reprinted in 1965. These maps are obviously inadequate for feasibility and planning studies. Unfortunately, the 1 : 10,000 scale maps with 5 metre contour interval made from 1956 aerial photographs without ground checks are unreliable. There are some detailed maps in the southwestern portion of System B and at scattered locations elsewhere. These maps, which have a scale of 1 : 3168 and a contour interval of two feet are shown on Figure 2. It is the intention of the Survey Department to cover all presently unsurveyed areas during 1979 with ground surveys and produce maps at 1 : 5,000 scale with a contour interval of one metre.

2.2.3 - Present and Future Soil Mapping

Although the existing maps are useful at the prefeasibility level, more detailed soil maps are required which can be matched to the 1 : 5,000 topographic maps presently being surveyed. These maps will allow the production of land capability maps which are urgently required for feasibility studies and detailed planning. These maps are fundamental to the successful implementation of an irrigated agriculture settlement project of this type. With this in mind, LUD have surveyed seven sample strips over half a mile in width and up to over three miles in length, at medium intensity, and have produced 1 : 5,000 or in some instances 1 : 6,336 scale soil maps. With the help of the sample strips, further medium intensity mapping will be undertaken in 1979 by LUD, and by aerial photography interpretation it is planned to extend medium intensity mapping to

the whole of the Maduru Oya Project area before the end of 1979. The 1:5,000 topographic mapping referred to in Section 2.2.2 will be required for use as base maps for the soil maps.

2.3 - Generalized Description of the Soils

Figure 3 is an adaptation of the reconnaissance level soil map with non-commandable areas as defined by MDB's preliminary main canal system design. It serves to illustrate the general distribution of the Upland, Intermediate and Lowland Soil Groups. The gross and irrigable areas of these soil groups are summarized in Table 2-2.

2.3.1 - Upland Soil Group

This group, which is never waterlogged for any appreciable time, consists of well to moderately well drained Red Brown Earths and upper levee bank soils and is estimated to cover about 20 per cent of both the gross land area and gross commandable land area. The LUD recognized that the soils of the group range in depth and identified the following phases:

Soil Phase	Depth to a Prominent Gravel Layer (cm)	Depth to Bedrock (cm)
Shallow	Less than 30	Less than 60
Moderately shallow	30 - 60	60 - 90
Deep	60 - 90	90 - 120
Very Deep	Greater than 120	Greater than 120

The shallow and moderately shallow phases are unsuitable for irrigated agriculture. Unfortunately, large areas of shallow, steeply sloping (greater than four per cent), gravelly or high (and therefore, uncommandable), Reddish Brown Earth soils occur. It is estimated, therefore, that only about 11 per cent of the net commandable irrigable area will consist of RBE soils.(This area could increase if the area set aside for Forest Reserve is included in the project area. An estimated 3500 ha of irrigable RBE soils are located here - it is the largest block of good RBE soils in the area). Several different series of freely to

TABLE 2-2

PRELIMINARY ESTIMATE OF NET COMMANDABLE IRRIGABLE LAND

	GROSS LAND AREA[1] (HA)	ESTIMATED TOTAL IRRIGABLE AREA[2] (HA)	GROSS COMMANDABLE LAND AREA[3] (HA)	NET COMMANDABLE IRRIGABLE AREA	
				ADAPTED FROM NEDECO[5] (HA)	ESTIMATED BY ACRES (HA)
Upland (Freely Draining)	28,900	14,500	20,700	12,600	10,300
Intermediate (Imperfectly to Poorly Draining)	55,000	35,700	43,000	26,300	28,000
Lowland (Imperfectly to Very Poorly Draining)	31,600	23,700	21,300	11,600	16,000
Sub Total	115,500	73,900	85,000	50,500	54,300
Unsuitable	21,100	62,700	9,500	44,000	40,200
Net Total	-	-	94,500	94,500	94,500
Gross Total	136,600	136,600	-	-	-

(1) Source: LUD July 1978 - Soils and Cropping Potential of Systems ABC and D of the Mahaweli Project.

(2) Irrigable by either gravity or pumping, regardless of location.

(3) Source: 1978 - Comments on the Draft Mid Term Report of NEDECO - Dr. K.A. De Alwis (LUD)

(4) Excludes existing irrigated land.

(5) Source: 1979 - Revised Mid Term Report of NEDECO

moderately freely draining Reddish Brown Earth Soils have been identified by the LUD, the most important of which, in the Maduru Oya Project area, are the Wilayaya and the Ulhitiya series. Unfortunately it is not possible to subdivide the area mapped as Reddish Brown Earths on the reconnaissance maps into the different series, as they have yet to be mapped out over an appreciable area. The Wilayaya series is a moderately well drained, usually moderately deep, dark brown, sandy clay loam, containing many hard manganese concretions below 15" to 30" and underlain by whitish decaying parent material. Gravel lenses can occur within the profile. A variant characterized by occasional sub-angular quartz pebbles, usually on the surface, has been identified and called the Muthugalla series.

The Ulhitiya series is well drained, also moderately deep, dark reddish brown, sandy clay loam, with a gravelly subsoil, in which quartz is dominant but feldspar and mica flakes are present, overlying reddish to yellowish decaying parent material. The Manampitiya series is similar but varies in the amount of quartz present.

These well and moderately well drained Reddish Brown Earths occupy the upper end of a catenary sequence which includes imperfectly and poorly drained hydromorphic variants (Low Humic Gleys).

Also included among the Upland soils, but of alluvial origin, is the well drained, narrow Mahaweli Ganga levee soil (the Alutnuwara series) consisting of deep, yellowish red, fine sandy loams, and its Maduru Oya counterpart, the moderately well drained, deep, brown to yellowish brown, loamy sand and sandy loams of the Pulatiebbe series.

Finally, but of no value for irrigated agriculture, is the well drained, shallow, dark brown to dark red, ironstone gravelly, Mulwatte Kulam series which occurs in isolated patches and is included in the Reddish Brown Earth group of soils.

2.3.2 - The Intermediate Soil Group

This group of soils, which occupies just over 50 per cent of estimated gross commandable area is naturally waterlogged for a long period of the year during the Maha. It consists of imperfectly drained Reddish Brown Earths, Non Calcic Brown and back slope levee soils. It is estimated that about 35 per cent of the soils mapped on the reconnaissance map in this group are unsuitable for irrigated agriculture. The imperfectly drained Red Brown Earths occur as part of the catenary sequence to which the freely drained Ulhitiya, Wilayaya series etc. form the upper members. Four series - the Alawakumbura, Maha Kulam, Horaborawewa and Padumunda Kulam have been identified. The Alawakumbura series which is moderately deep to deep, yellowish brown, mottled sandy clay loam containing many manganese concretions is gleyed at depth, and overlies whitish decaying parent material. It varies slightly in colour from the dark brown to yellowish brown, rather heavier textured, Mawa Kulam series. The Horaborawewa series is a deep dark grayish brown to yellowish brown mottled, sandy clay loam with quartz and feldspar gravel and mica flakes in the subsoil which becomes gleyed at depth of greater than 120 cm. It is distinguished from the Padumunda Kulam series by the dominance of quartz in the subsoil.

The imperfectly drained Non Calcic Brown (NCB) soils are represented by the Maduru Oya series which consist of moderately deep, dark grayish brown to pale yellowish brown loamy sand to sandy loam with distinct brown mottles and some soft manganese concretions, over impermeable, quartz-rich, acid rock. A high percentage of the sand is coarse. There is some evidence that a second series, the Welikanda, occurs where the clay content in the subsoil exceeds fifteen per cent. This, however, may only represent a transition zone to Reddish Brown Earth. More field work will be required before the existence of this second series can be firmly established. Two other series occupying the lower concave slopes have also been tentatively identified. This seems to be a greater series breakdown than is justified, except for depth, which is a phase difference.

The imperfectly drained alluvial soils of the Intermediate land is

represented by the Hembarawa series which consists of brown to yellowish brown, mottled sandy clay loams, over fine loamy sand to sandy loam at depth. This soil merges into the imperfectly to very poorly draining soils of the floodplain.

2.3.3 - The lowland Soil Group

This group of soils which occupies about 23 per cent of the gross commandable area, is naturally waterlogged throughout the Maha and for a part of the Yala. Flooding after heavy rains can be expected. About 25 per cent of the soils mapped on this group are estimated to be unusable for irrigated agriculture.

The soils are imperfectly to very poorly drained Alluvial, Old Alluvial, Low Humic Gley and Solodized Solonetz soils. A large number of series have been tentatively identified among which the Handapanvila and its poorly and very poorly drained associated series, Hewampitiyavillu and Katuwanwila are alluvials of the Mahaweli Ganga floodplain. The Handapanvila series consists of deep, dark brown, mottled clay loam, overlying increasingly mottled sandy loam which eventually becomes gleyed at depth. The associated series are deep, dark gray to gray gleyed clays, overlying gleyed sandy clays, with the later of the two series subject to prolonged flooding during the Maha and into the Yala. Associated with the Maduru Oya are two poorly drained and one imperfectly to poorly drained soil. The Timbiri Aru consisting of black to dark brown clay loam overlying mottled sandy clay, is gleyed at depth and occupies the gentle back slopes of the low river levee. The other two series are poorly drained, dark grayish to gray gleyed loamy sand to sandy clay loams.

The Old Alluvial soils in old tributary valleys also vary in texture and drainage. Whereas the Ulpothawera series is imperfectly drained, pale brown to greyish brown, loamy sand and sand, underlain by gleyed sandy clay loam; the Moogamana Ela series is poorly drained, gleyed gray to dark gray, sandy clay with a thin sand layer on the surface. It is possible that other series of lighter texture may occur.

The Solodized Solonetz soils, which occur on nearly level land, consist of light brownish to white sand, overlying gray to olive gray, mottled alkaline clay which sometimes shows columnar structure. The Pochchakadu series which shows a gilgai surface is considered a little better drained than the poorly drained Vakaneri series.

The remaining soils of the lowland are the Low Humic Gleys, occupying valley bottoms. Five poorly drained series, varying in texture, have been tentatively identified. They are all deep grayish or bluish gleyed soils in which a buildup of salinity could take place through evaporation if the natural drainage is sufficiently disrupted and flushing during the Maha is prevented.

2.4-The Physical and Chemical Characteristics of the Major Soil Groups

2.4.1 - Physical Characteristics

Existing data on the physical properties of the Reddish Brown Earth soils which make up the greater part of the 'Upland' indicate that bulk densities are higher than average for soils of similar texture. Available water capacities have been determined at 0.1 atmosphere, which is locally considered to be representative of field conditions. While an average value of 3.94 cm per 30 cm was obtained, this falls dramatically at the 0.33 atmosphere level to 1.2 cm per 30 cm, indicating the relatively low tension at which most of the water is held. Infiltration rates are moderate under forest conditions, from 2.2 to 4.3 cm per hour, but drop to moderately slow rates, from 0.7 to 1.7 cm per hour, when cultivated* Under furrow irrigation, erosion can be a very serious problem, even on slopes which do not exceed four per cent (the suggested upper slope limit for irrigated cultivation), unless careful husbandry methods are employed. Sprinkler irrigation will therefore probably be required.

Because of the nature of the clay fraction and the particle size distribution, the soils become hard and difficult to cultivate when dry. Drying occurs very rapidly due to the low tension at which the water is held. On the other hand, they are very

* provided erosion or cultivation methods have not exposed gravel lenses.

sticky and equally difficult to work when wet. It is therefore important that the soil should be worked only when moist. This should be possible by using a system of pre-irrigation to produce moist conditions.

The Non Calcic Brown soils, which make up a large proportion of the 'Intermediate Land', are always friable because of the high sand and low clay content. The bulk density of these soils is normal for the textural class. Available water capacity is about 3.25 cm per 30 cm according to estimates prepared for the FAO report. The water holding capacity is again low but infiltration rates are very high, being greater than 10 cm per hour. The nature of the impermeable rock base on which these soils occur, together with the high infiltration rate means that these soils which are normally only moderately deep, rapidly become waterlogged in the Maha, and because of the low water holding capacity quickly dry out in Yala, when the rains stop. If these soils are to be successfully cultivated, a system of land management must be found which will produce a much improved soil water relationship in the root zone at least during the growing period of the crop. It is essential that an experimental and demonstration farm be established on this soil type as soon as possible to test the various possible techniques of land and water management. Conventional surface irrigation can only produce the waterlogged conditions typical of the Maha, which are reflected in the very poor natural vegetation cover. Therefore, a method of irrigation which allows careful control of water application should be employed if maximum cropping is to be achieved.

The 'lowland' soils vary considerably in texture. They are imperfectly to poorly drained soils and are suitable for paddy either because the local water table is sufficiently high, or heavy textured clay subsoils allow the lighter textured surface horizons to be quickly topped up with water. Infiltration rates are low in the Low Humic Gley soils with sandy clay loam subsoils and on the Solodized Solonetz soils except where cracks in the subsoil are encountered.

2.4.2 - Chemical Characteristics

There are no chemical limitations to the use of the Reddish Brown Earth soils for crop development. The pH of these soils is normally around 6.0 and the base saturation over sixty per cent. The cation exchange capacity, which varies with the clay content, is consistent with a kaolin dominated clay fraction, and in most instances is in double figure milliequivalents per 100 g of soil. The organic matter content of the A1 horizon is about two per cent and available phosphorus is low. With suitable fertilizer dressings, a wide range of crops adapted to the climate could be successfully grown.

The pH of the Non Calcic Brown soils varies between 5.0 and 6.5. The cation exchange capacity is in single milliequivalents per 100 g of soil. In terms of clay, however, the CEC rises to over 60 me. per 100 g of clay, indicating a clay of the montmorillonite type. Exchangeable potassium and magnesium are relatively high, indicating a low degree of leaching consistent with the imperfectly draining condition of the soil, due to the impermeable rock on which it occurs. Base saturation is over 50 per cent, but organic matter is low to very low, especially in parkland areas.

The Old Alluvial soils, which occur in wide valleys and nearly level plains in association with the Solodized Solonetz soils, vary in both their physical and chemical properties. The cation exchange capacities of both groups of soils depend on clay content and are over 50 me per 100 g of clay. In the Old Alluvial soils, the soil reaction becomes more acid in the subsoil, dropping below pH 5.5, but it becomes highly alkaline, rising to around pH 9.0, in the Solodized Solonetz soils. Values for exchangeable magnesium are high in the subsoils of both groups. Exchangeable sodium, although occasionally high at depth in the Old Alluvial soils, is always high in the subsoil of the Solodized Solonetz soils. Exchangeable sodium exceeds 15 per cent in the subsoil and electrical conductivity of the soil water extract (1:5) shows medium salinity. Under conditions of improved drainage and good irrigation, salinity would be greatly reduced. It is therefore considered that two

crops of rice can be grown per year on these two soils provided the top soil is sufficiently deep and good water management is practised. Unfortunately, the sandy topsoils of these soils are extremely low in organic matter, nitrogen and available phosphorus, and will benefit from higher levels of fertilization than those used on good paddy rice soils. Green manuring would be useful.

The Low Humic Gley soils associated with the Reddish Brown Earths are from 70 to 90 per cent base saturated and can have secondary calcium carbonate in the subsoil. The pH is normally between 6 and 7 but rises to as high as 8.4 in horizons with secondary carbonates. Exchangeable sodium percent (ESP) is less than 15, but drainage will be required to ensure that a build up of salinity does not take place with irrigation. The Low Humic Gley soils, although associated with the Reddish Brown Earth soils, have somewhat higher cation exchange capacities, which apparently reflect an increase in the percentage montmorillonite in the clay fraction, which is consistent with their poor drainage properties.

In the remaining group of soils, the Alluvial soils vary in texture and drainage. The cation exchange capacity is of the order of 60 me per 100 g of clay and base saturation is upwards of sixty per cent. Soil pH is normally near 6.0 and aside from the possibility of a salinity build up in low spots which could be prevented by drainage, the chemical characteristics present no problems to the cultivation of suitable crops.

2.5 - Land Classification

2.5.1 - General

After examining the soils and considering the possible types of land use, it appears that the dual land classification system used in 'System C'[2] would also best suit the requirements of the study of 'System B'. Adopting this dual classification system also has the merit of maintaining continuity in adjacent study areas.

The system follows the general principles laid down by the United States Bureau of Reclamation (USBR), but with modifications

where necessary to meet local requirements. The USBR system recognises six classes of land, four of which are irrigable, one of which is temporarily non-irrigable, and one of which is a non-irrigable. In this dual system, land suitability for rice together with, but distinct from crops other than rice (upland crops), is indicated using four main land classes. This dual system is advantageous where rice, which has different land requirements to upland field crops, is likely to form an important element of the overall cropping pattern. This not only allows areas which are only suitable for rice production to be delineated, but also lets land which can be used to grow rice in preference to upland crops (if desired) be clearly indicated. Furthermore, land can be categorised as to its overall suitability for rice cultivation as well as for upland crops. This dual system, therefore, assists development planners in arriving at the optimum cropping pattern for any particular area of land.

The criteria used to differentiate the classes of land refer mainly to topography, soil texture and profile characteristics. Derived characteristics in the form of available water holding capacity, infiltration rate and hydraulic conductivity are also included in the classification but can only be applied for soil series on which tests have been carried out.

2.5.2 - The Land Classification Criteria

Topography

Topography affects both the cost of land development and that of crop production to an extent that becomes limiting on steep or irregular slopes. There are two aspects to topography, one of slope and the other of micro-relief. An increase in slope not only causes an increase in development cost but also in the erosion hazard and the difficulties involved in establishing suitable water control. Experience on the Reddish Brown Earth soils in neighbouring parts of Sri Lanka indicate that the erosion risk and the cost become unacceptably high on slopes of

greater than four per cent. Within 'System B', most of the slopes greater than four per cent are associated with the Reddish Brown Earth soils.

Micro-relief affects the amount of work and therefore the cost of obtaining a suitably level field. Small areas of gilgai development occur associated with Solodized Solonetz soils in the form of the Pochchakadu series. The cost of levelling this land is likely to be high and the danger of exposing the alkaline subsoil exists, especially when micro-relief is great. It has therefore been concluded that 15 cm cut and fill should be chosen as the upper limit for land levelling.

Texture

Soil texture refers to the texture within the root zone. Its main importance lies in its effects on available water, ease of cultivation, and to a lesser degree, the capacity to retain nutrients as expressed in the cation exchange capacity (CEC). The coarsest acceptable texture for irrigation is a sandy loam, as textures coarser than this have a limited available waterholding capacity and a low CEC. Soils with textures as coarse or coarser than loamy sand are considered to be marginally suitable for cultivation, while the fine sandy loams, sandy clay loams and sandy clays are not texturally limiting in any way.

Depth to Limiting Horizon

Due to the nature of the soils, particular attention should be paid to the depth of root development, or rooting depth. Rooting depth refers to that depth of soil within which roots may develop without undue restriction.

Within the soils in 'System B', rooting depths are best developed in the moderately fine and fine textured soils, and exceed 60 to 70 cm where possible. In the coarse textured soils, roots are often confined to the top 20 cm of soil. Gravel or alkaline clayey horizons are important, as they often form impenetrable barriers to root development. The depths of soil to the layer severely limiting

root penetration have been set at two levels(Table 2-3) for the various upland land classes according to the predominant textures of the upper horizons. Depth of soil is less important for rice and a limiting depth has yet to be evaluated.

Derived Characteristics

These refer to soil characteristics which have only been measured at a few sites but which have been related to individual soil series. Three factors - the subsoil permeability, the infiltration rate and available water holding capacity - are involved, and a programme of study for the soils of 'System B' is presently being pursued. It is expected that the high permeability rates likely to be encountered on some of the presently uncultivated soils will fall as soil consolidation resulting from irrigated cropping takes place.

Land classification criteria for upland crops and paddy are summarized in Tables 2-3 and 2-4.

2.5.3 - Land Classification Groups

Land classes with similar characteristics can be grouped together according to their suitability for particular cropping patterns. The following groups can be identified with the limited information available at this time:

(a) Moderately fine textured soil, with well to moderately well drained profiles, which because of their 'Upland' topographic situation and textural properties are considered to be much better suited to the cultivation of upland crops than to rice Possible land classes in this group are U1/R2s, U2ht/R3st, U3ht/R3st and U3ht/R6st;

(b) Moderately coarse textured soils, with moderately well to imperfectly drained profiles. Because of their 'Intermediate' topographic situation and textural properties, plus derived characteristics, are suited (provided the drainage is improved) to upland cropping. They are not suited to rice because of the difficulty of applying lowland paddy irrigation methods. However, they may be irrigable using careful surface methods in the Maha for the production of upland crops. Work to be done on the experimental-demonstration farm will be needed to confirm this.

TABLE 2-3

LAND CLASSIFICATION CRITERIA (CROPS OTHER THAN RICE)

CRITERIA	SUBSCRIPT	CLASS U1	CLASS U2	CLASS U3
Soil Factors**				
Texture of root zone	(heavy-s1)	Medium textures	Loamy sand (less than 15 per cent clay) to permeable clay	Loamy sand (less than 15 per cent clay) to slightly permeable clay
	(light-s2)	SL to CL	LS less than 30 cm	LS less than 60 cm
Alkalinity of topsoil 0 to 40 cm depth	"a"	ESP less than 10	ESP less than 15	ESP 15 to 25
Profile drainage	"d"	Well to excessively	Moderately well or better	Imperfectly drained or better
Depth to layer severely limiting root penetration	"h"(S1)	90 cm	60 cm	45 cm
	(S2)	105 cm	75 cm	60 cm
Nature of limiting horizon		------Coarse sands and gravels----------		----------
Salinity		----------	EC_e less than 4 mahos	EC_e less than 8 mahos
Topographic Factors	"t"			
Slope		less than 2 per cent	Less than 2 per cent	Less than 4 per cent
Micro-relief		no levelling required	slight levelling may be required	moderate levelling may be required. 15 cm average cut and fill.
Derived Characteristics				
Subsoil permeability		----------	30 mm	More than 1 mm
Infiltration final intake rate corrected for evaporation			More than 0.03m/day More than 2 mm/hr	More than 0.001m/day More than 1 mm/hr
Available waterholding capacity for minimum rooting depth			More than 15 cm	More than 10 cm

Class 6 Non irrigable land with soil, topographic or drainage characteristics not meeting minimum requirements for other land classes.

** Based on 120 cm soil profile or effective depth where limiting horizon occurs.

Fine textures are: SC, C, Sic, CL heavy, SiCL heavy.

Medium textures are: SCL, CL, light, SiCL, L, SiL, Silt, SL heavy.

Source: Preliminary Feasibility Report of the Victoria Scheme (1978)

TABLE 2-4

SPECIFICATIONS OF LAND CLASSES FOR RICE

CRITERIA	SUBSCRIPT	CLASS R1	CLASS R2	CLASS R3
Soil Factors				
Texture surface 0-30 fm	"s"	either fine textures*	medium or fine texture textures**	Loamy sands or finer throughout profile, (loamy sand less than 15 cm)
Profile 30-120 cm		Fine textures less than 30 cm medium texture provided profile drainage requirement is met.	Medium or fine textures with more than 30 cm fine texture	
Profile drainage	"d"	Poor to moderately well	Less than well drained	Not limiting
Depth to Limiting horizon	"h"	More than 60 cm	More than 60cm	More than 60 cm
Nature of Limiting horizon		Sand or gravels	Sand or gravels	Sand or gravels
Salinity		ECe less than 4 mahos	EC_e less than 8 mahos	EC_e less than 8 mahos
Alkalinity of topsoil 0 to 40 cm depth	"a"	ESP less than 15	ESP 15 to 25	ESP 15 to 25
Topographic Factors	"t"			
Slopes		Less than 2 per cent Normal farm levelling only required	Less than 2 per cent slight levelling may be required	Less than 4 per cent moderate levelling may be required 15 cm average cut and fill.
Derived Characteristics				
Subsoil permeability Infiltration final intake rate		Less than 0.06 m/day Less than 10 mm/hr	Less than 0.06 m/day Less than 10 mm/hr	Less than 0.10 m/day Less than 15 mm/hr
Available waterholding capacity		Not limiting	Not limiting	Not limiting

Class 6 Non irrigable land with a soil, topographic or drainage characteristics not meeting minimum requirements of the other land classes.

* Fine textures are: SC, C, SiC, CI heavy, SiCL heavy

** Medium textures are: SCL, CL, SiCL, L, SiL, Silt, SI heavy

Source: Preliminary Feasibility Report of the Victoria Scheme (1978)

(Possible Land Classes in this group are U2 s_2d/R6st and U3S_2td/R6st).

(c) Fine to moderately fine textured soils, with imperfectly drained profiles, at 'Intermediate' elevations in river valleys, suited to rice production and to upland cropping, with improved drainage. (Possible land classes in this group are U2s_1d/R1 and U2s_1d/R2s)

(d) Fine to moderately fine textured soils with imperfect to poor drainage, suited or well suited to rice production. Two crops a year will be possible if sufficient water is available. (Possible land classes in this group are U3s_1d/R1 and U3s_1d/R2s).

Applying the above four groupings to the areas summarized in Table 2-2 allows the derivation of the preliminary land classification summary presented in Table 2-5. The commandable areas in each group can be used to estimate agricultural benefits from the application of irrigation.

TABLE 2-5

PRELIMINARY ESTIMATE OF COMMANDABLE AREAS SUITABLE FOR IRRIGATION

	LAND CLASS GROUPING	GROSS LAND AREA (HECTARES)	ESTIMATED NET COMMANDABLE* IRRIGABLE AREA (HECTARES)
UPLAND	(a) Moderately fine textured soils with moderately well to well drained profiles - Suitable for upland cropping	28,900	10,300
INTERMEDIATE	(b) Moderately coarse textured soils with moderately well to imperfectly drained profiles - Suitable to fairly suitable for Upland cropping	25,600	13,000
	(c) Fine to moderately fine textured soils with imperfectly drained profiles - Suitable for paddy in Maha and upland cropping in Yala	29,400	15,000
LOWLAND	(d) Fine to moderately fine textured soils with imperfectly to poorly drained profiles - Suitable for two crops of paddy per annum	31,600	16,000

* Excluding land already irrigated

3 - AGRICULTURAL PRODUCTION POTENTIAL

The assessment of agricultural production potential for the Interim Report has been based on a review of available published and unpublished data with limited field reconnaissance. Particular attention has been paid to crop selection and rotation in relation to soil characteristics and suitability for development under irrigation, to yield potential and to cultivation methods for selected crops (including land preparation requirements, seed and fertilizer requirements, crop protection and harvesting).

Other factors determining production potential have also been taken into account but have not been the subject of detailed analysis at this stage. Such factors include subsistence and nutritional consumption requirements, commercial marketing possibilities (including import substitution and export potential), as well as existing small farmer experience, agro-industrial possibilities, and Government policy objectives. Only limited attention has been paid to other key determinants of production potential including extension and research, input distribution, crop storage, transport, processing and marketing.

The assessment of agricultural production potential contained in the Interim Report (and the assessment of benefits) is therefore preliminary and subject to review following completion of detailed investigation into all aspects of agricultural development in System B. Detailed investigation is continuing and will be included in the Feasibility Report.

3.1 - Land Use

Using the existing data on soils and topography a fourfold division of the net commandable area has been produced (Table 2-5). It is summarized as follows:

(a) Fine to moderately fine textured, imperfectly to poorly drained soils. These "Lowlands" are suited to growing two crops of rice.

(b) The fine to moderately fine textured, imperfectly drained soils, at Intermediate elevations, in river valleys and plains. These are suited to rice in the Maha, because of their drainage characteristics. While a second crop of paddy could be grown in the Yala where water is non limiting, it is considered that an upland crop during this season would be preferable, using surface irrigation. This Land Class Grouping is hereafter referred to as "Intermediate Fine"

(c) The moderately coarse textured, moderately well to imperfectly drained soils have problems of drainage in the Maha because of their moderate depth, over flat impermeable rock, and high infiltration rates. Provided the drainage of these soils can be improved, they should be suitable for upland cropping under supplementary surface irrigation in the Maha. The Land Use Division of the Irrigation Department (LUD) has recently said of these soils - "At present there is a lack of data on the yields of upland crops that can be expected on these soils (under research farm or smallholder farm conditions) and on the agronomic and water management practices required by these soils." [15]. The low nitrogen level of the soils favours loguminous crops or flue-cured tobacco. This Land Class Grouping is hereafter referred to as"Intermediate Coarse."

(d) The moderately fine textured, moderately well to well-drained "Upland"soils (RBE's) are capable, with irrigation, of growing a wide variety of crops both in Maha and Yala. Unfortunately, because of the depth of soil and the erosion risk coupled to the infiltration characteristics, surface irrigation cannot be generally recommended. The depth of soil is often already critical, and any erosion would put this land out of productive cultivation. Also it is imperative that the level of the water table on the lower slopes is kept under control. Water applied upslope should not cause problems of drainage downslope. The use of sprinkler irrigation is therefore recommended for most of these soils.

In addition, along the inside of the levee of the Right Bank of the Mahaweli there are large areas of very poorly drained land which cannot be successfully drained in Maha. The area has been estimated by LUD to amount to 8000 ha in total. It is best suited to the development of livestock production (including dairying) in Yala. This would be in association with adjacent upland and drained intermediate land, and using crop residues from cropped land.

3.2 - Possible Crops

3.2.1 - Rice

Rice is the staple cereal crop of Sri Lanka. There has been a deficit

in the rice production needed to meet domestic consumption requirements which has been forecast to extend into the late 1980's and possibly into the 1990's. It is the crop with which existing farmers in the project area and incoming settlers are most familiar. Rice has a high potential yield under irrigation, and is well suited to the Lowland and the Intermediate Fine Land Class Groups. Rice also provides an attractive economic return in relation to other possible crops. It is therefore recommended as a major crop for both subsistence consumption and commercial production. It would be cultivated under surface irrigation on the available Lowland area of 15200 ha in both Maha and Yala seasons with an overall cropping intensity of 1.78. It is also recommended for the the Intermediate Fine soils comprising 14300 ha in the Maha season only (with an upland crop of groundnuts and soyabeans in the Yala).

At the national level, average paddy yields over the Maha/Yala crop under both irrigated and rainfed conditions increased during the 1960's, but have remained at 2.3 - 2.4 tonnes/ha throughout the 1970's. During this period High Yielding Varieties (HYV's) with a yield capability at the farmer level of 4.5 to over 5.0 tonnes/ha have been in widespread use. In the late 1970's varieties with a 40-50% greater yield potential have become available. Actual performance on farm has been constrained to date by existing standards of cultural practice (especially timely planting and weed control), as well as water management, availability and use of inputs, and availability of farm power. Increased use of inputs, critical to achieving the potential yields of the HYV's, was limited for most of the past decade by the low controlled price of rice.

In some tank irrigation schemes under smallholder conditions using modified cultural practices and with substantial, though by no means optimal, levels of inputs, paddy yields in recent years appear to have reached 4.0 - 4.5 tonnes/ha over substantial areas.

In their capacity as authors of the Implementation Strategy Study of the Mahaweli Programme, MEDECO have recently reviewed the paddy yields now being achieved in Sri Lanka. Evidence was presented

to them, based on data collected in existing tank irrigation schemes, that relatively high paddy yields are now being attained under better-than-average conditions in Sri Lanka. MEDECO have therefore adopted the following yields for paddy after five years of development, assuming delivery and effective use of an improved package of inputs and technical services.

Soil Type	Maha	Yala
LHG/AL/RBE	4.3 tonnes/ha	4.5 tonnes/ha
OAL/SS	3.4 tonnes/ha	3.6 tonnes/ha

These yields have been adopted for use in this report, and have been weighted according to approximate proportions of soil types to give the yields shown in Table 3-1.

3.2.2 - Groundnuts

Groundnuts are presently grown on a limited scale in Sri Lanka, currently some 7000 ha, mostly in the Dry Zone. Groundnuts are used for human consumption, primarily as "snacks". Oil is not produced because insufficient quantities of nuts are available, and because of the availability of cheaper coconut oil. With the failure of coconut oil production to expand to meet domestic consumption requirements, the main future prospects for groundnuts could be in the vegetable oil expelling industry for domestic consumption. There are also significant export opportunities.

From the agronomic point of view, groundnuts can be grown in the project area in rotation with paddy on the Intermediate Fine soils, in rotation with other upland crops on Intermediate Coarse (NCB) soils, and are particularly suited to cultivation on the Upland (RBE) soils. There is considerable potential for increasing yields using improved varieties on well-drained soils. Groundnuts are proposed for cultivation under surface irrigation on 7150 ha of Intermediate Fine soils in the Yala season in rotation with the Maha paddy crop and an alternate Yala crop of soyabeans. They are also proposed for single cropping on 2900 ha of the better drained Intermediate Coarse (NCB) soils in rotation with tobacco

and cassava. In addition, some 2450 ha of groundnuts would be cultivated on the Uplands (RBE) in the Maha, and 4900 ha in the Yala, using sprinkler irrigation.

At the national level, unshelled groundnut yields have shown little improvement in recent years, averaging 0.8 - 1.0 tonnes/ha, primarily because seed quality is low. The FAO[16] considered that an unshelled yield of 2.0 tonnes/ha should be possible for a rainfed crop, and over 4.0 tonnes/ha with supplementary irrigation. Yields of over 4.5 tonnes/ha (unshelled) have been recorded for research station conditions*. Under improved input and management conditions, NEDECO estimates yields from improved varieties by small farmers at 1.6 tonnes/ha (unshelled) in the Maha on the Intermediate Coarse and Upland soils, and at 1.8 tonnes/ha on Intermediate Fine and Upland soils in the Yala. The System C report[2] estimates average shelled yields under similar conditions (including the package of inputs) for System C at 1.25 tonnes/ha, or an unshelled yield of 1.6 - 1.8 tonnes/ha (at 70 - 80% shelling percentage). The average NEDECO yield and input package have been adopted for use in this report.

3.2.3 - Soyabeans

Soyabean has been cultivated in Sri Lanka only since 1972 when 47 ha was recorded. The area increased to 177 ha in 1973, and subsequently averaged just over 1000 ha annually between 1974 and 1977. The Government's Soyabean Development Program, with external donor support, aims to develop production of soyabean and a range of cheap soyabean food products (flour and dairy) "acceptable to and within the purchasing capacity of the poorest segments of the country".[17] In addition, the Government wishes to develop soyabean production for the vegetable oil extraction industry (there are two existing pilot scale plants). Soyabean can be grown successfully and profitably in the Dry Zone, and development of production is proposed for the project area in support of the national policy.

* The Maha Illuppallama Research Station, located in System H, south of Anuradhapura.

Soyabean can be grown in both crop seasons. It is proposed for cultivation in rotation with the Maha paddy crop and an alternate Yala crop of groundnuts on the Intermediate Fine soils, with 7150 ha available under surface irrigation in the Yala. In addition, 2450 ha of Upland (RBE) soils would be available for soyabean in the Maha and a further 2450 ha in the Yala, within the proposed Upland crop rotation.

The average soyabean yield on the total of 4060 ha cultivated between 1974-1977 was a little under 1.0 tonnes/ha. In field trials, yields over 4 tonnes/ha have been obtained and the best yielding cultivars should be capable, under irrigation, of yielding from 2 - 3 tonnes/ha on the Reddish Brown Earths. NEDECO estimates yield under project conditions at 1.9 tonnes/ha on the "Intermediate Fine" soils, and 2.0 tonnes/ha on the Uplands (RBE) soils, while the yield used in the System C report [2] was an average of 1.25 tonnes/ha for Upland soils. For this report, somewhat lower yields than those proposed by NEDECO have been adopted.

3.2.4 - Tobacco

Some 6 - 7000 ha of flue-cured tobacco have been cultivated annually in Sri Lanka between 1970 - 1977, while the area planted to air-cured tobacco has expanded rapidly from 80 ha in 1974 to 1789 ha in 1977. In addition, some 4800 ha are planted to beedi tobacco annually. Tobacco is a crop known to many farmers and returns are high relative to other crops. Present production meets local demand, but expansion will be necessary to keep pace with growth in that demand, and there are significant export possibilities for high-quality flue-cured Virginia leaf.

The prospects for growing tobacco in a suitable rotation on the Upland (RBE) soils in System B are good. It is proposed to include 2450 ha as a Maha crop in the Upland rotation which includes groundnuts, soyabeans, kenaf and cotton. It is also proposed to develop an additional 1450 ha of the better grade Intermediate Coarse (HCB) soils (with good drainage and low salt content) for tobacco cultivation. Tobacco would not be grown more than once in four years on the same plot of land.

Yields of flue-cured tobacco have ranged from about 0.5 tonnes/ha to just over 0.6 tonnes/ha dry leaves between 1970-1976, but averaged an exceptional 0.8 tonnes/ha in 1977. NEDECO has estimated that under better water management conditions and with appropriate inputs and technical support, yield levels would reach 1.1 tonnes/ha. A slightly lower yield of 1.0 tonne/ha. and a similar input package has been adopted for use in this report.

3.2.5 - Cassava

Cassava is now grown in Sri Lanka primarily as a subsistence rainfed crop for human consumption, using some 60 - 75,000 ha annually in the period 1970 - 1977. It is a crop with which many Dry Zone farmers are familiar. There is potential for the development of commercial production and processing of the crop for export (for animal feed) with favourable economic returns.

Cassava production would be developed on an available 1450 ha of moderately deep well-drained Intermediate Coarse (NCB) soils in rotation with groundnuts and tobacco. The crop would be grown during the Maha for harvesting and drying in the Yala. Cassava is not normally irrigated, but the availability of supplementary irrigation would lengthen the growing season and assist yield improvement.

Cassava is capable of producing exceedingly high yields under conditions prevailing in Sri Lanka and yields of 45 - 60 tonnes/ha have been recorded. Cassava yields nationally are currently estimated at 20.0 tonnes/ha, but available improved varieties (MU series) with improved husbandry practices would allow yields in the area of 25 tonnes/ha to be attained by small farmers.

3.2.6 - Kenaf

Small farmers in the Dry Zone have traditionally grown kenaf as a rainfed wet season crop on a semi-cultivated basis both for domestic purposes and for the local manufacture of twine and rope. However, it is not grown by small farmers in pure stands, and the area under smallholder production is not known. Systematic

development of commercial production is being undertaken in the project area at the National Paper Corporation Mill at Valachchenai and at its nearby experimental farm. In recent years some 400 ha have been developed on an experimental/commercial trial basis to provide long fibre for pulp production. Kenaf is a relatively undemanding crop for small farmers. Net returns to commercial production are favourable, and current domestic demand for retted kenaf to substitute for imported jute for sacking and imported long fibre for pulp has been estimated at about 25,000 tonnes annually.

Kenaf is suitable for rotational cropping on the well-drained Upland (RBB) soils under normal Maha rainfall. However, supplementary late Maha irrigation would guarantee yields in years of rainfall failure. It is proposed to develop 2450 ha for kenaf cultivation in the Upland cropping pattern including groundnuts, soyabean, tobacco and cotton.

Yields as high as 7.5 tonnes/ha dry stalk have been recorded from a Maha crop. Under improved cropping conditions 9 tonnes/ha of dry stalks should be obtainable. This yield has been used to represent average conditions in the calculation of agricultural benefits.

3.2.7 - Cotton

Most cotton in Sri Lanka is grown under rainfed conditions. The area in rainfed production fluctuated considerably in the 1960's and early 1970's. It subsequently increased steadily from 1016 ha in 1974 to 3257 ha in 1977. The area under irrigated cotton, concentrated in southern Sri Lanka, was some 200-300 ha per annum in the period 1973-1977. Domestic production of cotton is only a small fraction of consumption requirements and market prospects are excellent. It is Government policy to expand production rapidly.

Cotton may grow reasonably well on the better MCB soils. This requires investigation on the proposed Experimental-Demonstration Farm (See Section 3.6). However, it is considered that within the project area, cotton production could best be developed on suitable areas of deep, well-drained Upland (RBB) soils using ridge cultivation.

It is proposed to develop some 2450 ha for cotton on the Uplands as a Yala crop under sprinkler irrigation. The cotton would be grown in the Upland cropping pattern which includes groundnuts, soyabean, tobacco and kenaf. Cotton would not be grown on the same plot more than once in four years.

Yields on rainfed cotton have been low, averaging 360 kg/ha seed cotton on the 7971 ha cultivated between 1974 and 1977. Yields on the small area of irrigated cotton have been higher, averaging 546 kg/ha seed cotton on the 1307 ha cultivated in the period 1973-1977. Best results achieved were in 1976, with 906 kg/ha on 265 ha. Local expert opinion suggests that there are "no technological restrictions which would inhibit the development of cotton in 1978 and onwards,"[20] and suggests that 1.2 - 1.9 tonnes/ha seed cotton is a realistic estimate of prospective yields. In this connection it has been stated that several farmers produced yields of 2.5 tonnes/ha under irrigated conditions in the Uda Walawe area in the mid-1970's. With the solution of certain technical problems (including the establishment of seed reserves of pure-line, high-yielding cotton, adequate storage under low temperature and humidity conditions, resumption of high quality research activities with proper professional levels of staffing at Angunakolapelessa and adaptive research within System B, it should be possible to get the crop off the ground and achieve a yield level of 1.9 tonnes/ha seed cotton.

MEDECO[21] has established a target yield for the project of 1.6 tonnes/ha as achievable through considerable improvement in the quality of present management and other supporting services. A more conservative yield estimate of 1.2 tonnes/ha has been adopted for the Interim Report. This average yield level should be possible with well-based extension work incorporating modern technology, and following adaptive work on the proposed Experimental-Demonstration Farm.

3.2.8 - Pulses

Pulses, particularly cowpea, black gram and green gram are grown in Sri Lanka in substantial quantities. In recent years the area sown has increased from 3812 ha in 1972 to 56,365 ha in 1978. This is primarily due to changes in the guaranteed price in the case of

cowpea and green gram, but is also associated with changing import levels.

Over the period some 56% of the area has been in cowpea, 25% in black gram and 18% in green gram. Pulse crops are well-known to farmers, are traditional food crops, and serve as a major source of protein in Sri Lankan diets. Pulses will be an essential component of subsistence consumption in the project area and limited surplus production can readily be sold in the domestic market.

Pulses would form part of a chillies, onions and vegetables (brinjal, okra, capsicum, tomato) rotation which together require some 2900 ha of better Intermediate Coarse (NCB) soils. Pulses can be grown in both seasons and water requirements are relatively small. Preliminary proposals in the Interim Report do not allow for irrigation of these crops which will be grown in the Maha. However, the potential for a Yala crop, with supplementary irrigation, will be given further consideration and should be tested on the Experimental-Demonstration Farm.

At the national level, mostly under rainfed conditions with minimal inputs and considerable virus disease and insect pest problems, average yields on the total 1972-1977 acreage have been 723 kg/ha for cowpea, 607 kg/ha for green gram and 721 kg/ha for black gram. NEDECO [21] estimates average yields on NCB soils at 1.0 kg/ha for Maha and 1.2 kg/ha for the Yala using proper disease and pest control measures, and improved inputs. The NEDECO yield and input package has been adopted for use in this report.

3.2.9 - Chillies

The estimated area planted to chillies was about 20,000 ha in the early 1970's, increasing to 44,000 in 1976 and 1977. Chillies are an important part of the local diet and will be an essential component of subsistence consumption in the project area. Favourable returns can be obtained from the crop.

Chillies would be grown in rotation with pulses, onions and vegetables on 2900 ha of better NCB soils. The potential for a Yala crop on

NCB soils using supplementary irrigation will be given further consideration and should be tested on the Experimental-Demonstration Farm. Chillies would also be cropped in the Upland homestead plots with onions, vegetables and fruits (bananas, coconuts, mangoes, guavas, avocadoes, limes) on some 1000 ha of Upland RBE soils. They would be sprinkler irrigated and cropped in both the Maha and the Yala.

Average yields of chillies have fluctuated at the national level around 500 kg/ha in the period 1971-1977, but reached as high as 727 kg/ha in 1977, an exceptional year. A substantial improvement in yields is anticipated under project conditions with improved inputs and technical services. On rainfed NCB soils in the Maha, a yield of 1.1 tonnes/ha is anticipated, and on the Upland (RBE) homestead plots, a yield of 1.5 tonnes/ha is anticipated under sprinkler irrigation in both the Maha and the Yala. Yields and associated input and management requirements are comparable to those suggested by NEDECO [21] for System B, and by the Victoria team for System C[2].

3.2.10 - Onions

Onion production is largely concentrated in the Dry Zone in the north of Sri Lanka. About 5700 ha was planted to red onions in both 1971 and 1972, and the area had increased to 8200 ha by 1977. In addition, some 200 - 300 ha annually was planted to Bombay onions in the same period. Onions (and garlic, for which no statistics are available) play an important role in traditional diet and must be produced primarily for subsistence consumption in the project area. Again, they offer a favourable return.

Onions would be grown in the pulses, chillies and vegetables rotation on the 2900 ha of better NCB soils under rainfed conditions in the Maha. A Yala crop under supplementary irrigation will be considered in ongoing studies. Onions would also be cropped in the homestead plot rotation on the 1000 ha of irrigated Upland (RBE) soils in both seasons.

Yields of red onions have averaged some 9.7 tonnes/ha annually in the period 1971 - 1977*. Under project conditions with improved inputs and management, yields of 8.1 tonnes/ha are anticipated on NCB

* excluding 1976, when yields dropped to 5.4 tonnes/ha, due to a specific pest problem.

soils under rainfed conditions, and 10.0 tonnes/ha on Upland (RBE) soils under sprinkler irrigation in both the Maha and the Yala.

3.2.11 - Vegetables

A wide range of vegetables are produced in the various climatic zones of the country, but no official statistics are available as to area or volume of production. Vegetables form an essential element of subsistence consumption, and commercial possibilities exist for non-perishable varieties produced. in the System B area.

Vegetable production, primarily of brinjal, okra, capsicum and tomato is included in the pulse, onion, chillie rotation on 2900 ha of NCB soils in the Maha. As previously stated, potential for irrigated cropping during the Yala is to be reviewed. Vegetables are also included in the Upland homestead plot rotation on 1000 ha of Upland (RBE) soils under irrigation in both the Maha and the Yala. Average consolidated yield is conservatively estimated at 10.0 tonnes/ha in both the Maha and the Yala on both soil types.

3.2.12 - Fruits

Limes

Limes are the most important of all citrus species in Sri Lanka, but no official statistics are available as to the area or the volume of production. Production methods are haphazard. Limes are an important item of domestic consumption, are in relatively short supply, and offer favourable returns.

Production should be developed primarily for subsistence consumption and for the local market in the project area. The possibility of large scale development of commercial lime production, on NCB as well as RBE soils, to produce pure lime juice and lime oil will receive detailed consideration in preparing the Feasibility Report.

Lime production would initially be developed within the 1000 ha of Upland (RBE) homestead plots. Based on research experience with yields of 50 - 100 lb/tree at 215 trees/acre it is estimated that a minimum yield of 12.0 tonnes/ha of fruit would be obtainable on homestead plots, with irrigation.

Bananas

Bananas grow well in Sri Lanka and will undoubtedly have an important place in production for subsistence consumption and for the local market. Production is likely to take place predominantly on homestead plots. Possibilities for expansion of production will be examined in the coming months.

Coconuts

The non-irrigated sandy and free-draining NCB soils should be exploited by planting as many coconut trees as possible, primarily for subsistence consumption and also for the local market.

3.2.12 - Other Crops

Crops included in the preliminary proposed cropping pattern for System B have been discussed in the preceding paragraphs. They were selected following consideration of a wider range of crops, some of which were excluded from the proposed cropping pattern. The main crops considered but excluded are sugar cane, coarse grains, sunhemp and cashew.

A preliminary review of sugar cane suggested that, despite the national need for substantially increasing sugar production, conditions in System B were agronomically less suitable than other available areas. This is mainly because of the absence of low temperatures required for ripening cane, leading to low sugar yields. In addition, while the RBE soils in System B are suitable for sugar cane, they are not available in sufficiently large blocks, which would be required to economically supply a mill*. There could be sound social reasons which would overrule agronomic considerations and sugar cane trials should be initiated in the project area to determine the quality attainable and assess the economic returns from this crop relative to other alternatives.

Coarse grains, particularly maize and sorghum, are known to farmers and could be grown in System B in the Maha and the Yala respectively. Maize in Sri Lanka is mainly produced at present as a rainfed crop in the Dry Zone. From 1974 - 1977, the area cultivated has fluctuated

* Subsequently Acres was advised by the Government of the availability of a block of 3500 ha of RBE soils in the Forest Reserve following the recent cyclone damage to young teak. The area will be investigated for suitability for cane production in the coming months. A preliminary analysis of the incremental benefits obtainable from sugar cane production in this area is included in Chapter 11, however.

between 30,000 - 40,000 ha, with average annual yields increasing from 0.6 tonnes/ha in 1974 to 1.1 tonnes ha in 1972. There is some potential for increasing domestic consumption, but increased yields would require the development of suitable irrigation and cultivation techniques. The sorghum acreage in Sri Lanka has fluctuated between 990 - 3757 ha annually in the period 1974 - 1977, with an annual average yield of 1.4 - 1.7 tonnes/ha on harvested acreage. The crop is highly susceptible to depredation by birds while the potential for increasing yields under irrigation require investigation.

Sunhemp offers possibilities as a substitute for imported fibre in paper manufacture, and is a good green manure crop. It would be suitable for inclusion in the Upland rotation with groundnuts/cotton/tobacco/kenaf and as a rotation crop for light paddy soils. Development work is required on the crop to determine yields and suitable cultural practices with and without irrigation.

There are substantial export possibilities for cashew nuts which can be grown on the poorest soils, provided they are well drained. The Feasibility Report will include proposals for the development of small plots of cashew (and other tree crops) on the NCB soils and on small pockets of out-of-command RBE soils.

3.2.14 - Summary of Yields

Table 3-1 summarizes the estimated average yield used in projecting agricultural benefits for the major crops which are included in the proposed cropping pattern. It also summarizes estimates prepared by NEDECO for System B in November 1978[21] and as subsequently revised. The projected build-up of crop yields to the estimated average yield given in Table 3-1 is as follows:

(a) Rice - The target yields would be achieved over a five year period:

Year 1 - 60%
2 - 70%
3 - 80%
4 - 90%
5 - 100%

TABLE 3-1

CROP YIELDS ON MAJOR LAND CLASS GROUPINGS[1] (TONNE/HA)

CROP	SEASON	LAND CLASS GROUPING	ESTIMATED AVERAGE YIELD[2]	NEDECO ESTIMATE[3]	
				PUBLISHED	LATEST[4]
Paddy	Maha	Lowlands	4.0	3.3	4.0
Paddy	Yala	Lowlands	4.2	3.0	4.2
Paddy	Maha	Intermed. Fine	3.9	3.2	3.9
Soyabeans	Maha	Uplands[5]	1.5	1.5	1.5
Soyabeans	Yala	Intermed. Fine	1.5	1.7	1.9
Soyabeans	Yala	Uplands[5]	1.9	1.8	2.0
Groundnuts (unshelled)	Maha	Intermed. Coarse	1.7	1.2	1.6
Groundnuts (unshelled)	Yala	Intermed. Fine	.7	1.7	1.8
Groundnuts (unshelled)	Maha	Uplands[5]	1.7	1.6	1.6
Groundnuts (unshelled)	Yala	Uplands[5]	1.7	1.8	1.8
Tobacco (dried)	Maha	Intermed. Coarse	1.0	1.0	1.1[6]
Tobacco (dried)	Maha	Uplands[5]	1.0	1.0	1.1[6]
Cassava[7]	Maha	Intermed. Coarse	25	-	-
Kenaf[7]	Maha	Uplands[5]	9.0	-	-
Cotton	Yala	Uplands[5]	1.2	1.6	1.6

Notes:
1. See Table 2-5 for description of Land Class Groupings.
2. Used in economic analysis for the "base case".
3. These yields have been adjusted to reflect the approximate proportions of "normal fertile" and "low fertile" soils in each Land Class Grouping.
4. These yields were obtained from the NEDECO study team on March 28, 1979 and reflect their thinking at that time.
5. Uplands are assumed to be irrigated by sprinkler; others by surface methods.
6. Tobacco not originally proposed for Maha cultivation.
7. These crops were not examined in detail by NEDECO.

(b) For all other crops the target yields would be achieved over an eight year period:

Year 1 -	60%
2 -	63%
3 -	67%
4 -	72%
5 -	77%
6 -	85%
7 -	94%
8 -	100%

(c) After achievement of the target yields, yields are projected to increase at 1% annually reflecting the improving performance of farmers.

3.3 - Proposed Cropping Patterns

The proposed cropping pattern related to cropped area for each Land Class Grouping is summarized in Table 3-2. It is based on an annual two-crop rotation coinciding with the traditional Maha and Yala, and has the following features:

(a) For the Lowlands, comprising 15,200 ha, which will be waterlogged for long periods of the year, the cropping pattern consists of paddy in both the Maha and Yala.

(b) For the Intermediate Fine areas, comprising 14,300 ha, paddy is selected as the Maha crop because of the soil drainage characteristics, the readily available market, and farmer preference. Paddy could be cropped in the Yala where water is non-limiting, but percolation losses will tend to increase and groundnuts and soyabeans are considered to be preferable. The possibility of a Yala paddy crop will be reviewed.

(c) For the Intermediate Coarse areas totalling 8700 ha, it is proposed to develop a groundnut/tobacco/cassava cropping pattern on the 5000 ha which would be irrigated in the Maha. Tobacco would be cultivated every fourth year. It is considered that soil and water conditions will not permit a commercial Yala crop on these soils but it would be advantageous to broadcast a green

TABLE 3-2

PROPOSED CROPPING PATTERN

LAND CLASS GROUPING	CROP ROTATION	CROPPED AREA[1] (HA)	CROPS MAHA	CROPS YALA		CROPPING INTENSITY % MAHA	YALA	ALL
Lowlands	A	15,200	Paddy	Paddy		98	80	178
Intermed. Fine	B	7,150	Paddy	Soyabeans	Grown in	98	80	178
	C	7,150	Paddy	Groundnuts	Rotation	98	80	178
Subtotal		14,300						
Intermed. Coarse	D	2,900[2]	Pulses/ Chillies/ Onions/ Vegetables			98	-	98
	E	2,900	Groundnuts		Grown in Rotation	98	-	98
	F	1,450	Tobacco			98	-	98
	G	1,450	Cassava			98	-	98
Subtotal		8,700[3]						
Uplands	H	2,450	Kenaf	Groundnuts	Grown in Rotation	98	80	178
	I	2,450	Tobacco	Soyabeans		98	80	178
	J	2,450	Soyabeans	Groundnuts		98	80	178
	K	2,450	Groundnuts	Cotton		98	80	178
	L	1,000[4]	Vegetables & Fruits			98	80	178
Subtotal		10,800						

1. Derived from the areas shown in Table 2-5, with 5 per cent reduction to allow for irrigation infrastructure.
2. Within the commandable area, but not irrigated.
3. Of which 5800 ha is irrigated.
4. Out of command but assumed to be irrigable by sprinkler.

manure crop if feasible. This should be investigated on the proposed Experimental-Demonstration Farm. It is proposed that the remaining 2900 ha of these soils have a Maha pulse/ chillie/onion/vegetable crop but without irrigation. Irrigation potential for this entire Land Class Grouping will be the subject of further investigations prior to the presentation of the Feasibility Report.

(d) The Upland areas totalling 10,800 ha, can grow a wide variety of crops in both the Maha and Yala under irrigation. The cropping pattern on the 1000 ha of homestead plots will include onions, chillies, vegetables and fruits (including perennial crops) and individual farmer practice is likely to vary widely. The cropping pattern on the 9800 ha proposed for commercial production includes kenaf, tobacco, groundnuts, soyabeans and cotton. Kenaf and tobacco offer favourable returns, while the legume crops will improve soils. Tobacco and cotton will be grown on the same plot at most every fourth year. The development of soyabean and cotton production is an important objective of Government policy.

Sophisticated techniques were not employed in establishing these cropping patterns. Cropping patterns and rotations will be subject to review in ongoing studies when agronomic, labour, cost and marketing determinants of the proposed cropping pattern will be examined.

3.4 - Cropping Intensity

Details of cropping intensities are given in Table 3-2 and have been adopted from NEDECO. The overall cropping intensity for the project is 1.64.

3.5 - Livestock

A major consideration in livestock development in System B is to ensure the maximum availability of draught animals for field operations and cartage, in addition to the production of milk and meat. The livestock feed production capability of System B on non-cultivable riverine ("Villu")

areas of the Mahaweli Right Bank and Maduru Oya, Upland parkland ("Damana") areas out of command, and within the cropped area from residues and fallow will determine the carrying capacity of the project area. This will assist, inter alia, in determining the relative roles of draught animals and tractors in meeting farm power requirements. Feed production capability is currently being examined, and the final assessment will depend on the outcome of the land classification mapping to be completed in 1980.

Meanwhile, a preliminary review of production potential for livestock products within the three milk/beef systems so far identified is given in Appendix B. The systems are as follows:

(a) Improved cross-bred buffalo, zero-grazing (cut and carry) from improved pastures (comprising a mixture of Para Grass and Signal Grass), with supplementary feeding from a cultivated shrub or tree legume (L. Leucocephala). In addition, crop residues, paddy straw, and fallow areas would be used but no concentrate feeding is envisaged.

(b) Improved cross-bred Zebu cattle (with the later introduction of a Bos taurus cross) grazing similarly improved pastures, also fallow areas, and using crop residues.

(c) Indigenous cattle grazing the "Villu" and "Damana" areas

The scale of intensified livestock development and the integration of the proposed systems with crop production or as a complementary system in the overall context of System B agricultural development will be examined in the Feasibility Report.

3.6 - Experimental-Demonstration Farm

The development of appropriate soil and water management techniques for the intermediate coarse textured soils (the Non Calcic Brown soils) will be essential to the overall success of the Maduru Oya Project. There is a lack of information on this subject at present, while numerous technical problems have been identified with these soils (high infiltration rates and poor drainage in particular). It is therefore recommended

that an Experimental-Demonstration Farm of about 40 hectares be set up at the earliest possible date. This farm should have the following objectives:

1. To experimentally evaluate the potential crops for this soil type.
2. To develop land management techniques which will improve the productivity of the soils under irrigated conditions.
3. To develop water management methods (water application and drainage) appropriate to this soil type.
4. To work with farmers using an "outreach" approach to demonstrate the techniques evolved on the central farm and to conduct further experiments under actual farm conditions.

An appropriate site for the Farm has been identified immediately to the west of the Pimburettewa Tank Scheme. Water could be supplied by pumping from the canal until gravity supply from the new main canal is possible. The proposed site, which covers an area of over 40 hectares, can include the full range of the Non Calcic Brown soils—both low and high (above 15%)clay content series. The drainage and topographic characteristics of the soil are typical of the other occurrences in the project area.

Discussions have been held with the Deputy Director (Research) of the Department of Agriculture, Dr. C.R. Panabokke, and with officials of the Ministry of Mahaweli Development regarding the implementation of the proposed farm. Based on these discussions, the following recommendations are made:

1. The key staff in the early (at least three) years of operation would be four highly qualified expatriates. These would be:
   - Project Farm Manager*
   - Agronomist
   - Irrigation Engineer
   - Agricultural Engineer/Workshop Supervisor

Counterpart staff members for the above positions will be required, as well as clerical staff, mechanics, labourers, etc. The counterpart

* Due to the heavy demands being placed on the skilled manpower resources of Sri Lanka by this and other development programmes, it is not assumed that this post can be filled by a native of Sri Lanka.

staff members would be persons with some scientific or vocational training, and would be expected to assume responsibility for the continuation of the work after the departure of the expatriates.

2. The central farm would be supplemented by a number of individual farm units throughout the project area. Farmers would be invited to co-operate through growing crops under a moderate degree of supervision from staff from the main farm.

3. The design of the farm should be initiated immediately, so that land, water, manpower and financing requirements can be identified and arrangements made for early implementation.

4 - AGRICULTURAL BENEFITS

4.1 - Introduction

An assessment of agricultural benefits for the Interim Report has been made at an early stage in the agriculture and agricultural economics work program. It is based on a review of secondary sources of information relating to market prospects, prices, crop production costs and physical input requirements in order to derive the preliminary estimate of net benefits required for project economic analysis. This estimate of benefits is subject to qualifications similar to those made in relation to agricultural production potential in Chapter 3.

The feasibility of proposed cropping patterns and rotations in relation to proposed farm sizes and target incomes, and in relation to farm labour supply (and possibilities for on-farm mechanization) will be examined during the course of ongoing studies, and necessary revisions made. Detailed proposals for the management and provision of agricultural technical services in the project area, including extension, training, research, input distribution and marketing in support of planned development will also be specified in the course of further studies.

4.2 - Crop Disposal

The agricultural output from the project area is summarized in Table 4-1. It will be disposed of in the project area for both subsistence consumption needs and for local market sales, in the domestic Sri Lankan market, and through exports. The economic price for each crop is related to the method of disposal.

Rice, kenaf and cotton are proposed as import substitution crops. It is anticipated that about 25% of rice production will be consumed by the newly settled population in the project area, and the balance of production will be absorbed in the domestic Sri Lankan market, making an important contribution to the achievement and maintenance of the national goal of self-sufficiency. Kenaf production will substitute for about 25% of current national imports of natural and synthetic long fibres used in gunny bag and pulp production - it is anticipated that project area production will be used primarily for gunny bag manufacture.

TABLE 4-1

CROPPED AREA AND AGRICULTURAL OUTPUT

CROP	CROPPED AREA[1] (HA)			TOTAL DOMESTIC PRODUCTION (TONNES)
	MAHA	YALA	TOTAL	
Rice (Paddy)	29500	15200	44700	165000
Soyabeans	2450	9600	12050	16000
Groundnuts (unshelled)	5350	12050	17400	25000
Tobacco	3900	-	3900	3800
Cassava[2]	1450	-	1450	12500
Kenaf[3]	2450	-	2450	6200
Seed Cotton	-	2450	2450	2400
Pulses				1525
Chillies				795
Onions	3900	1000	4900	2600
Vegetables				10500
Fruits				
Total	49000	40300	89300	246320

1. Not adjusted to cropping intensity - see Table 3-2
2. Dry cassava chips
3. Retted Kenaf
4. Assuming the average yields summarized in Table 3-1

Cotton production from the project area will make a limited contribution towards meeting the large domestic production deficit.

The production of pulses, chillies, onions, vegetables and fruits is primarily for subsistence consumption in the project area. About one-fifth of the total volume is for disposal in the domestic market outside the project area. These commodities are generally in short supply and no difficulty is anticipated in disposing of these relatively small quantities at projected prices. Vegetables and fruits included in the cropping pattern are non-perishable, an important consideration given the distance of the project area from urban markets. The disposal of soyabean production will depend upon the success of recently introduced Government policies to popularise consumption of soya products amongst low-income segments of the population. If consumer acceptance is not forthcoming, the output would be directed to the export market, or, in view of the relatively low returns, alternative crops would be substituted in the cropping pattern.

Groundnut production will be directed primarily at the export market for confectionery nuts, but disposal is also anticipated within the country both for subsistence consumption in the project area and in domestic markets. Depending upon the success of coconut industry development programs there may also be potential for disposal to the domestic edible oil-expressing industry.

Tobacco and cassava production are directed at the export market. Cassava would be dried and pelletized for export as animal feed.

A considerable volume of by-products will result from project production, including straw, rice bran, groundnut haulms, cassava tops and various types of oilseed residues including seedcake. It is anticipated that this will be used primarily within the project area for livestock production, with surpluses disposed of in the national market.

Detailed investigations of the market for all crops proposed for the project area, and of marketing channels and marketing organization will be undertaken in the course of further studies.

4.3 - Prices

IBRD long-term commodity price forecasts form the basis of price projections for many of the inputs and outputs. These forecasts are in 1978 currency

and have been adjusted to 1979 levels. Economic prices have been used for all inputs into agricultural production and for projected output. It is assumed that all subsidies (except for fuel) will be phased out by the time the project becomes operational. In the case of fertilizer inputs, the export parity price was used for urea (as the urea factory will be operational when System B is developed) while import parity prices were calculated for triple superphosphate and muriate of potash. All farm labour has been costed at the economic price of Rs.6.00 per day.

For the agricultural output from System B, import substitution prices were calculated for rice, cotton and kenaf while others were based on the export parity price with the exception of some fruits and vegetables sold in the local market. Crop prices are summarized in Table 4-2.

4.4 - Costs of Production

Crop budgets for all project crops other than kenaf and cassava are based on detailed crop budgets prepared by MEDECO[21] for the Mahaweli Implementation Strategy Study, and reviewed in the light of more recent work on System C[2]. Inputs have been related to projected yields, unit costs updated using 1979 prices, and new budgets prepared for kenaf and cassava. Revised costs of production for major crops in the cropping pattern broken down between major cost components are summarized in Table 4-3.

Inputs of improved seed, fertilizer, and crop protection chemicals (insecticides, herbicides, fungicides) are in line with Department of Agriculture recommendations for each crop. Farm power inputs and costs are based on the use of tractors (two-wheeled) and include an allowance for the cost of capital. The economic costs of animal draught power (buffalo or oxen) for non-farm operations appear to be similar to tractor power costs. In practice, it is anticipated that buffaloes will provide a high proportion of on-farm draught requirements for paddy, while oxen will provide draught for upland crops and for off-farm needs. The respective roles of animal and tractor power will be reviewed in relation to the availability (supply) of draught animals, feed availability, the interrelationship between draught requirements and milk/beef production

TABLE 4-2

CROP PRICES - FARM-GATE

CROP	PRICE RS/TONNE
Rice (Paddy)	3426
Soyabeans	4617
Groundnuts (unshelled)	5151
Tobacco (cured leaf)[1]	18660
Cassava (chips)	1303
Kenaf (retted)	5000
Cotton	12087
Chillies	15000
Onions (red)	4000
Limes	3897

1. Yield 10.0 tonnes green leaf/ha is equivalent to 1.0 tonnes cured leaf.

TABLE 4-2

COST OF PRODUCTION BY CROP
(RS/HA)

CROP	SEED & SEED TREATMENT	FERTILIZER	CROP PROTECTION	FARM POWER	LABOUR	OTHER[1]	TOTAL
Paddy	385	1499	1479	1193	1050	943	6550
Groundnuts	698	912	289	895	828	718	4300
Soybeans	443	1084	328	895	882	518	4150
Tobacco	315	1756	560	746	2418	1005	6800
Ragi	119	1063	–	895	1260	463	3800
Cassava	100	633	–	224	624	1319	2900
Cotton	408	1655	1608	895	1770	1064	7400

1. Includes packing materials and 10% physical contingencies

systems, and other factors. Labour inputs have been identified for all farm operations for each crop from land clearing and preparation through to harvesting. In addition, where appropriate, on-farm labour requirements for processing including threshing, shelling, retting, cutting and drying have also been identified and included in costs of production.

Costs of production do not include capital and operating costs of off-farm storage, transport and processing costs. The cost of these operations has been allowed for in arriving at farm-gate prices.

4.5 - Technical Services

The capital and recurrent costs of the provision of technical services are included in total project costs summarized in Table 10-6. Capital costs for the provision of infrastructure for project management total Rs.130.0 million. This includes offices, workshops, vehicles, staff housing and 1 - 2 Rural Development Training Centres required to implement the agricultural program. An additional Rs.13.0 million is included for the capital cost of the proposed Experimental-Demonstration Farm in the project area.

The recurrent costs of agricultural technical services are included in recurrent project management organization costs of Rs.32.0 million annually (Section 10.7). These costs include the salaries of Agriculture section staff such as Specialist Advisers, Agricultural Officers, Agricultural Instructors and AWS (farm level extension workers), the salaries of staff of the Production and Marketing section, of the Rural Development Training Centres, as well as vehicle operating and maintenance costs, building maintenance costs, stores and supplies, etc.

The costs of off-farm processing, marketing and input distribution are included in project costs through the calculation of farm-gate prices for agricultural outputs and inputs.

4.6 - Summary Agricultural Benefits

The net benefits per hectare by crop are given in Table 4-4 based on project yield estimates from Table 3-1, price estimates from Table 4-2 and cost of production estimates from Table 4-3.

TABLE 4-4

NET INCOME BY CROP

CROP	ROTATION[1]	SEASON MAHA KG/HA.	SEASON YALA KG/HA.
Rice (Paddy)	A	7150	7850
	B, C	6800	- [2]
Soyabeans	B, J	2800	2800
	I	-	4600
Groundnuts (unshelled)	C, E, H, J, K	4450	4450
Tobacco	F, I	11850	-
Cassava	G	8500	-
Kenaf	H	9400	-
Cotton	K	-	7100
Pulses/Chillies/Onions/ Vegetables [3]	D	6550	-
Vegetables/Fruits[4]	L	19000	19000

1. See Table 3-2.
2. - indicates not cultivated.
3. Weighted average return (based on area) - pulses (53%), chillies (15%), onions (3%), vegetables (29%).
4. Weighted average return (based on area) - chillies (20%), onions (20%), vegetables (20%), fruit (40%).

The total annual agricultural benefit would be Rs.543.0 million at full development based on target yields. However, this benefit will not be achieved in any specific year of project development because:

(a) development of the project area is phased with 50%, 25% and 25% of the area coming into production in project years 4, 5 and 6 respectively;

(b) the build-up to target yields is phased, and requires 5 years in the case of paddy, and 8 years in the case of all other crops;

(c) following the achievement of target yields for paddy and other crops, yields are subsequently assumed to increase at 1% annually over the life of the project.

The effect of phased development, different build-up periods to target yield, and assumed subsequent annual growth of yields results in the agricultural benefit stream summarised in Table 4-5.

TABLE 4-5

PROJECT AGRICULTURAL BENEFITS

PROJECT YEAR	TOTAL BENEFITS MILLION RUPEES
1 - 3	-
4	163
5	263
6	374
7	414
8	455
9	487
10	517
11	540
12	552
13	560
14	566
15	571
≈	≈
40	733

5 - SETTLEMENT PLANNING

5.1 - Number of Settlers

The preliminary assessment of land capability described in Chapter 2 and summarized in Table 2-5 forms the basis for a proposed farm allocation scheme incorporating the following principles:

1. Allocate one hectare of land suitable for at least one paddy crop per year to as many settlers as possible.
2. Settle families on intermediate lands, adjacent to vegetable and cash crop fields, and also reasonably close (1-1½ miles) to their paddy fields.
3. Allocate one hectare blocks of upland.

Table 5-1 summarizes the areas of land and the number of farms allocated, and indicates the type of land each farm would have. The farm population that could be supported under such a scheme would be as follows:

Lowlands	15,200 farms	76,000 persons*
Intermediate Lands	14,300 farms	71,500 persons*
Uplands	9,800 farms	49,000 persons*
Total	39,300 farms	196,500 persons*

This estimate is very preliminary and will be revised to reflect information now being collected on present population and land use and on land capability. The most suitable settlement pattern for the uplands will also depend on the feasibility of sprinkler irrigation and on the ability of small holders to effectively manage a sprinkler system.

The estimate of the number of farms is based on an average size of 1.4 ha, composed of 1 ha "basic farm" and 0.4 ha for homestead, vegetable/fruit plot and cash crop area. The latter area is double the size allocated in the 'H' project area. Indications are, however, that the 0.2 ha areas in the 'H' project are proving to be of insufficient size, considering the economics of farm operation and the spatial requirements for draught animals.

* Based on an average family size of 5 persons

TABLE 5-1

FARM ALLOCATION PATTERN

FARM TYPE	SOIL TYPE	NO. OF FARMS	FARM ALLOTMENTS (HA/FARM) NON-COMMANDABLE	COMMANDABLE, NOT IRRIGATED	IRRIGATED	TOTAL LAND ALLOCATED (HA) NON-COMMANDABLE	COMMANDABLE, NOT IRRIGATED	IRRIGATED*
A. Lowland	Lowland	15,200			1.0			15,200
	Intermed.Coarse - cash crops				0.2			3,000
	- veg. plot			0.1			1500	
	- homestead			0.1			1500	
	Total per farm			1.4				
B. Intermediate	Intermed. Fine	14,300			1.0			14,300
	Intermed.Coarse - cash crops				0.2			2,800
	- homestead			0.1			1400	
	- veg. plot			0.1			1400	
	Total per farm			1.4				
C. Upland	Upland - cash crops	9,800			1.0			9,800
	- homestead		0.1			1000		
	- veg,fruit plot		0.1			1000**		
	Total per farm			1.2				
Totals - Lowland						-	-	15,200
Intermed. Fine						-	-	14,300
Intermed. Coarse						-	5800	6,800
Upland						2000	-	9,800
	Grand Totals	39,300				2000	2900	45,100

* Irrigable, commandable area from Table 2-5, less 5% as allowance for irrigation infrastructure.

** Assumed to be commandable using sprinkler irrigation

To provide support and social services for the farm population, settlement beyond that of the actual farm population will be required.* The extent of the non-farm settlement component will depend, among other factors, on the total farm population, the settlement patterns adopted, the existence of regional communities in areas adjacent to the project area, the transportation network and the level of farm income that can be attained.

Estimates of the number of settler families to be attracted from outside the project area will foremost have to take into account the size and composition of the current area population not already formally settled.

5.2 - Basic Considerations

Sri Lankan experience** in settlement schemes makes it clear that a settlement project of the scope envisaged for the Maduru Oya Project must recognise the following factors:

1. Timing of settlement-delays in providing irrigation water, domestic water supplies, education, transport and health services inhibit settlement and exert hardships on the early settlers.

2. At present there are many examples of inadequate delivery of support services to settlers. The more important inadequacies are to be found in the functioning of multi-purpose co-operatives, credit programmes, extension services, purchasing, storage, marketing and the provision of supplies.

* It is recognized however that many non-farm functions could be carried out by the farm population.

** A preliminary field survey was carried out in Mahaweli Development Systems H1 and H2 during December 1978, to record specific detailed socio-economic information and to develop further understanding of the settlement process as it had taken place in situ. Results were reported in Preliminary Survey in Mahaweli Development Areas H1 and H2 of Socio-Economic Considerations Relevant to Future Settlement in System B, February 1979 - A.M. Samarasinghe and H.C. Abell. Further information was gathered during February at the Padaviya Settlement Scheme which has been in operation for twenty years and also at the Maudulla Irrigation Office, Minneriya. Other sources of information included References 9 and 10. See Appendix C.

Unless the means can be found to overcome these types of deficiencies, no projection of performance of the incoming settlers has much weight.

3. Prior to any consideration of settler selection it is essential to analyze the results of the socio-economic survey of the area which was initiated 2nd March, 1979 by the Settlement Planning and Development Division of the Mahaweli Development Board. It is expected that interviewing will be completed by the end of March 1979, and that checking of data and preliminary tabulation will be completed within the following few months. This survey will provide a valuable data base, on which criteria for land distribution to existing area residents may be established.

Without doubt the selection of settlers is an important consideration. The urgency of coming to decisions on basic questions increases daily, due to publicity given to intentions of the Government to make these lands available to large numbers of settlers. Some people are now moving into the area in hopes of establishing some degree of prior rights in the formal allocation of homesteads. Preliminary reconnaissance during February 1979 in the project area indicates that people now occupying land and carrying on cropping and/or livestock operations include Sinhalese, Tamil, Muslim and Veddah groups, some of whom are long-time residents while others have encroached as recently as eight months ago.

One of the factors to be considered in settler selection is the circumstances under which residents came into the area. It is known that a youth scheme was set up in 1965 at or near the project boundary (northwest sector); other residents entered the area under the Government Agent's authority; other people were assigned land under Village Expansion Schemes; there were some who came originally in search of land and have been encroachers for many years; some were allowed in as refugees following the communal trouble of August 1977. To the extent that it may affect resolution of the problem of settlers rights, the question of the legal status and citizenship of present land occupiers needs to be clarified.

In selecting new settlers from outside the project area, preference should be given to second generation people from previous settlement schemes. These experienced people can help introduce new concepts of water management, crop husbandry and formal organization to traditional area residents.

A further and important consideration in settler selection is the need to include people who can provide needed services and skills such as carpentry, vehicle repair and maintenance, pot making, fishing and personal services.

4. The spatial characteristics of settlement best suited in System B are as yet undetermined and in the first instance require completion of the land classification work.

Present settlement is in the form of villages ranging from 5 to 340 families (median of 65 families). Some villagers are long established with legal rights to land, while other villagers have been farming on state land.

Administration of the project area is presently carried out by three different administrative districts - Polonnaruwa, Batticaloa and Amparai. Polonnaruwa District has jurisdiction over about 70 per cent of the project area, and contains the Pimburettewa Tank Settlement Scheme. Batticaloa has jurisdiction over about 20 per cent of the area and contains the Vakaneri Village Expansion Scheme. Amparai District has jurisdiction over less than 10 per cent of the project area.

Basic Village Statistics for 1977 indicate that the total populations in the project area from these three districts was as follows: Polonnaruwa 14,247 (most of whom were Sinhalese); Batticaloa 23,645* (most of whom are Tamils) and Amparai 1,762 (most of whom are Sinhalese).

Attached are two reports (Appendices D and E) of interviews held 12 March 1979. One is in the village of Seelapura, which lies about ½ mile south of the Manampitiya-Valachchenai road on the west side of the main road leading into the proposed Maduru Oya dam site. This current information gives insight into the realities

* Includes G.S.201, 201A, 202, 207, 209, 210, 210A, 211, 212.

of present settlement and land use on encroached lands. The second interview took place with an encroacher in the Pimburettewa area.

5.3 - Management Considerations

The estimates of agricultural benefits resulting from irrigated cultivation in the project area assume that an appropriate and successful management programme can be developed and put in place. To ensure that the settlement process is successful and that benefits contribute to the national and regional economies in a timely manner, this programme must be developed within the first five to seven years of development. Similarly, provision must be made for the required marketing and processing facilities, for an effective extension service, for a credit system which is adequate to meet the farmer's needs and one which he respects sufficiently to honour repayment responsibilities and, finally, a social organization at the village level which encourages maximum farmer participation in the decisions affecting him.

In the case of such major crops as cotton, tobacco and soya beans, it will be necessary to put in place at the outset organizations with a high degree of autonomy capable of providing growers with all necessary inputs (seed, fertilizer, pesticides, technical guidance, credit etc.) as well as being responsible for the purchase, processing and marketing of these crops. During this initial period, as experience is being gained and methods and procedures perfected, consideration should be given to gradual transfer of these functions to farmer-owned and operated organizations.

Underlying the projections with regard to cropping patterns, yields, water management and crop husbandry, is the assumption that an Extension-Demonstration or Pilot Farm will be established, as proposed in Chapter 3. Concomitant with the establishment of the suggested organizations and Extension-Demonstration Farm is the need for adequate housing and social infrastructure (particularly education and health services) to ensure that technical and professional personnel can and do reside permanently within the project area and are accessible to settlers.

6 - HYDROLOGY AND WATER BALANCE

Water requirements for irrigated agriculture are computed by estimating the total depth of water needed over the growing season for each type of crop. This water satisfies plant evapotranspiration, open water evaporation, deep percolation and leaching requirements. The contribution of rainfall to meeting these requirements is then accounted for, leaving a net requirement to be satisfied by irrigation water. Gross water demands for the project are then calculated by summing the individual crop requirements and allowing for losses in the distribution system.

The water supply which is available to meet the irrigation demands is limited by the hydrology of the Maduru Oya basin and by the hydraulic capacity of the link tunnel which will transport water from the Mahaweli to the Maduru Oya reservoir.

To balance the irrigation demands against the available supply, computer simulation runs have been used to assess the performance of the system over a period of observed hydrological record. Each computer run can represent different combinations of irrigation demand, reservoir size and link tunnel capacity.

6.1 - Irrigation Demands

For the purposes of producing this Interim Report simple, recognized techniques have been used in the calculation of irrigation demands. It is proposed that more sophisticated methods be used in the preparation of the Feasibility Report.

6.1.1 - Crop Water Requirements

There are no full meteorological stations within the System B project area and past studies have used meteorological data from stations at Anuradhapura and Maha Illuppallama to calculate water requirements for System B. Both of these stations are situated in agro-ecological zone DL1 (see Fig.4) and are over

80 kms. (50 miles) from the northwest boundary of the System B area. The meteorological station at Batticaloa has sufficient long term data for the calculation of Penman evapotranspiration and is much closer to the project area. Unfortunately it is situated by the sea, and therefore has a much greater exposure to the Northeast monsoon. With a view to providing more representative crop water requirements, the Batticaloa data have been used for the Yala season, when the exposure of Batticaloa to the prevailing wind is the same as for System B. In the Maha season Anuradhapura wind data have been substituted for the November-April period.

At Batticaloa, temperatures are typically high throughout the year, with a mean maximum of 33.6°C in June (Yala) and 27.50°C in January (Maha). The respective mean minimum temperatures are 25.4°C and 23.2°C. Mean relative humidity is over 80% in the Maha season but falls to about 70% in the Yala season.

The most central raingauge in the project area is situated at Welikanda. The records at Welikanda are interrupted but missing data has been substituted using linear regression techniques. Mean annual rainfall is 1765 mm. Mean rainfall in June is 22 mm., but is frequently zero. Monthly data (both observed and estimated) are summarized in Table 6-1.

For the purposes of calculation of crop water requirements, the method outlined in FAO's 1977 Paper on this subject[3] has been used to estimate Penman evapotranspiration. Batticaloa data, modified as previously described has been used for this calculation which is summarized in Table 6-2. The resulting mean monthly potential evapotranspiration values have been compared with previous calculations for Anuradhapura, Maha Illuppallama and unmodified Batticaloa data in Table 6-3. This shows that the average annual Penman evapotranspiration calculated using the modified Batticaloa data is 6% higher than that calculated for Anuradhapura. This is consistent with the estimate made in 1978 by NEDECO[4] that System B evapotranspiration would be 5% higher

N.B. the above variation year + year !! month + month!

TABLE 6 - 1.

Maha

VELIKANDA
RAINFALL (MM)

Yala

Maha

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	214.9	70.9	196.6	19.6	70.4	0.0	0.0	110.7	183.4	157.2	163.6*	204.5	1391.7*
1951	714.2	112.5	45.2	154.4	106.4	0.0	0.0	43.7	57.0	127.5	467.1	262.1	2091.2
1952	524.8	58.4	36.3	93.0	63.2	0.0	64.0	0.0	4.6	113.5	268.2	247.9	1474.9
1953	296.4	17.0	0.0	57.1	0.0	55.4	165.4	150.1	110.0	263.4	344.9	504.2	1963.9
1954	496.6	127.8	107.9	93.2	51.1	0.0	20.6	42.9	0.0	230.9	146.3	407.4	1724.7
1955	341.9	182.6	7.9	191.8	21.6	0.0	0.0	64.8	213.1	73.2	82.3	253.5	1432.6
1956	243.8	60.7*	0.0	0.0	0.0	116.1	55.9	84.1	44.4	256.0	605.3	328.2	1794.5*
1957	152.4	402.5	0.0	0.0	101.9	0.0	28.4	7.4	37.6	172.5	578.6	1465.1	2946.1
1958	175.5	86.9*	95.8	150.6	194.1	0.0	119.4	97.3*	39.9	108.5	109.5	440.2	1617.5*
1959	323.1	0.0	0.0	31.5	35.6	0.0	5.1	78.2	45.5	220.2	281.7	270.8	1291.6
1960	372.9	641.6	25.4	119.4	55.9	2.5	176.3	0.0	50.8	96.3	466.6	160.5	2168.1
1961	407.7	326.9	118.9	0.0	78.7	0.0	116.8	0.0	109.2	149.9	436.9	564.1	2309.1
1962	102.1	7.6	55.9	22.9	69.1	0.0	129.5	7.6	86.4	325.4	263.7	355.6	1425.7
1963	438.4	441.5	109.0	102.1	0.0	0.0	0.0	15.5	146.0	273.3	466.6	573.0	2566.4
1964	201.9	205.7	107.9	1.3	127.0	0.0	165.1	141.0	0.0	209.5	41.9	112.0	1313.4
1965	97.5	444.5	13.2	94.0	7.6	0.0	0.0	114.8	0.0	73.7	439.4	274.3	1565.1
1966	250.6*	16.5*	121.9	26.4	45.5	32.8*	34.0*	303.5	108.2	537.2	491.5	184.4	2132.6*
1967	89.5	201.9*	50.5*	83.5*	36.3*	31.7*	31.7*	32.0*	37.8*	247.9*	445.3*	482.3*	1761.2*
1968	127.8*	0.0	116.1*	0.0	0.0	0.0	0.0	0.0	17.8	20.2	268.7	314.5	871.0*
1969	71.1	98.0	6.1	300.7	38.1	0.0	19.3	128.8	74.2	318.3	128.8	768.3	1951.7
1970	147.8	232.9	51.3	84.3	129.0	40.6	0.0	37.8	86.0	89.4	270.5	258.3	1429.5
1971	285.5	21.8	35.1	125.0	33.8	0.0	75.2	47.2	55.0	157.5	154.4	444.0	1435.1
1972	34.3	22.1	49.4	21.1	89.9	54.6	32.3	0.0	102.1	368.3	197.9	286.4	1243.3
1973	11.2	52.5	117.6	114.0	119.9	121.2	174.5*	50.0*	188.5*	175.3*	131.1*	1199.4*	2454.0*
1974	0.0*	52.0*	31.2*	137.9*	58.7*	31.7*	31.7*	34.8*	95.7*	24.1*	183.4*	225.8*	985.8*
1975	141.2*	165.9*	194.6*	180.5*	78.0*	31.7*	240.0*	71.4*	31.7*	200.4*	272.3*	364.5*	1972.1*
1976	219.5*	14.2*	5.3*	55.9*	31.7*	50.0*	38.9*	64.0*	74.9*	120.4*	578.9*	654.6*	1906.3*
1977	146.8*	47.9*	134.2*	181.9*	81.5*	33.8*	99.8*	64.0*	95.2*	249.4*	639.6*	492.5*	2271.5*
AVG.	235.7*	146.9*	65.2*	87.4*	41.6*	21.5*	65.1*	64.2*	74.5*	191.6*	318.7*	431.9*	1764.7*

* Estimated.

TABLE 6-2

ESTIMATE OF PENMAN EVAPOTRANSPIRATION
USING MODIFIED BATTICALOA DATA

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T_{mean}	25.4	25.7	26.8	28.0	29.0	29.5	29.1	28.6	28.4	27.3	26.3	25.5
ea	32.5	33.0	35.3	37.8	40.1	41.2	40.3	39.2	38.7	36.3	34.2	32.6
RH_{mean}	0.81	0.80	0.78	0.78	0.72	0.68	0.68	0.71	0.73	0.78	0.82	0.82
ed	26.3	26.4	27.5	29.5	28.9	28.0	27.4	27.8	28.3	28.3	28.0	26.7
ea-ed	6.2	6.6	7.8	8.3	11.2	13.2	12.9	11.4	10.4	8.0	6.2	5.9
$U_{1\ km}$	134	140	125	116	221	223	235	233	233	228	100	125
F(U)	0.63	0.65	0.60	0.58	0.76	0.77	0.80	0.79	0.79	0.78	0.54	0.60
1-W	0.26	0.25	0.24	0.23	0.23	0.22	0.23	0.23	0.23	0.24	0.25	0.25
(1-W)xF(U)x(ea-ed)	1.01	1.07	1.12	1.11	1.96	2.24	2.37	2.07	1.89	1.50	0.84	0.89
WR_n	3.09	3.72	4.39	4.49	4.22	4.08	4.03	4.17	4.23	3.91	3.41	2.90
WR_n+(1-W)(F(U)) (ea-ed)	4.10	4.79	5.51	5.60	6.18	6.32	6.40	6.24	6.12	5.41	4.25	3.79
C	0.93	0.99	1.10	1.10	1.05	0.99	1.00	1.03	1.02	1.02	0.99	0.92
ETo, mm/day	3.81	4.74	6.06	6.16	6.51	6.26	6.40	6.43	6.24	5.52	4.21	3.49
ET_o, monthly total, mm	118	133	188	185	202	188	198	199	187	171	126	108

Note: Anuradhapura wind data has been used for November to April inclusive only.

TABLE 6-3

COMPARISON OF PENMAN POTENTIAL EVAPOTRANSPIRATION ET_o
FOR MAHA ILLUPPALLAMA, ANURADHAPURA AND BATTICALOA (mm)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Maha Illuppallama, mm.	119	152	157	150	163	175	191	193	191	157	109	114	1871
mm/day	3.84	5.43	5.06	5.0	5.26	5.83	6.16	6.23	6.37	5.06	3.63	3.68	
Anuradhapura, mm	124	136	168	152	168	187	191	197	188	139	108	108	1866
mm/day	4.0	4.85	5.42	5.07	5.42	6.23	6.16	6.35	6.27	4.48	3.60	3.48	
Batticaloa, mm	138	148	205	198	202	188	198	199	187	171	140	123	2097
mm/day	4.44	5.27	6.60	6.59	6.51	6.26	6.40	6.43	6.24	5.52	4.66	3.97	
Batticaloa, mm	118	133	188	185	202	188	198	199	187	171	126	108	2003
modified mm/day	3.81	4.74	6.06	6.16	6.51	6.26	6.40	6.43	6.24	5.52	4.21	3.49	

than that of Anuradhapura area.

To estimate consumptive use by the various crops during each stage of growth, crop coefficients are used to convert the evapotranspiration of the reference crop (Penman evapotranspiration) to that of the crop in question. The crop coefficients adopted here are based on FAO paper No.24 and the coefficients used by the Land Use Division. The following coefficients have been used:

Lowland Paddy: (135 days from sowing), transplanting October.

Period (days)	60	45	30
Coefficient	1.1	1.05	0.95

Lowland Paddy: (105 days from sowing), transplanting April, October

Period (days)	60	15	30
Coefficient	1.1	1.25	1.0

Soyabeans/groundnuts: (105 days), planting April, October

Period (days)	15	20	50	20
Coefficient	0.65	0.85	1.05	0.80

Cotton: (150 days), planting March

Period (days)	30	45	45	30
Coefficient	0.65	0.85	1.1	0.55

For each crop, it has been assumed that planting is carried out over a one month period. By taking into account the average cropped area in each month and the stage of crop development, the crop coefficients summarized in Table 6-4 have been used.

6.1.2 - Effective Rainfall

For these preliminary calculations of effective rainfall, average monthly rainfall data from Welikanda have been used. For lowland paddy, the formula devised by the Land Use Division of the Irrigation Department has been used.

$$E.R. = 0.67\ (R - 25) \quad \text{----------(1)}$$

where E.R. = monthly effective rainfall (mm) (to maximum of 225)

R = observed monthly rainfall (mm)

c

TABLE 6-4

MONTHLY CROP COEFFICIENTS

CROP	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Paddy (135)	1.04	0.84	0.12									
Paddy (105)										0.55	1.1	1.08
Soyabean/groundnuts				0.55	1.1	1.05	0.91	0.13				
Cotton				0.35	0.91	1.05	0.79	0.1		0.35	0.91	1.05
			0.33	0.75	0.88	1.07	0.83	0.28				

This formula reflects the usability of a proportion of the monthly rainfall up to a maximum of 225 mm. Beyond this level, it is assumed that the storage capacity of the field has been exceeded. For other crops, the USDA/SCS method of estimating effective rainfall has been used[5]. It must be recognized that the calculation of the crop water requirements is based on scanty local data and relies heavily on use of data from stations outside the project area. If System B is to be developed and operated carefully, it is important that a full meteorological station be established within the project area, preferably at Welikanda. A price quotation for a suitable station was recently submitted to the government for consideration. This central station should be complemented by a network of four or five rainfall stations distributed throughout the project area.

6.1.3 - Irrigation Efficiency

Irrigation efficiencies are to a large extent determined by the level of management expertise which is applied. Therefore any estimates of irrigation efficiency at the feasibility stage are highly subjective and will be re-evaluated when the management system which is achievable for System B has been laid out in detail.

The overall efficiency in an irrigation system may be broken down into three components for convenience - the conveyance efficiency, the distribution efficiency and the field efficiency.

The conveyance efficiency is a measure of losses due to seepage and evaporation in the canal system, before the water reaches the fields. In System B it is anticipated that the main canals will pass through some very sandy soils in which conveyance losses are potentially very high. It is assumed that to prevent excessive canal losses and erosion a considerable proportion of the canal system will need to be lined with impervious material. With such lining throughout the system, the conveyance efficiency may be as high as 95%.

The distribution efficiency is a measure of how much of the water arriving at the farm gate is actually applied. Very often, there

is a "tail-end problem" in which a canal which has water taken off at points along its length still has water flowing away unused at the end of the canal. Another manifestation of the same problem is overapplication of water by users near the head of the canal, with the excess water being lost to the drainage system. Distribution efficiency also covers the day-to-day mishaps which occur in most irrigation schemes - gates being wrongly opened or opened for too long, for example. Thus the distribution efficiency is almost entirely a function of the degree of water management.

For the purposes of this report, a combined conveyance and distribution efficiency of 70% has been assumed. This is a subjective estimate based upon accumulated experience and other reports on irrigation in Sri Lanka. Prior to the preparation of the Feasibility Report, a programme of soil investigations along the main and branch canal routes will be carried out, by Irrigation Department personnel. In-situ permeability tests will be conducted and a more accurate assessment of potential seepage losses and canal lining requirements will be made. When more detailed designs of the canal system are made and the potential for the reuse of drainage water has been assessed, a more realistic estimate of distribution efficiency can be made.

Field efficiency is a measure of the amount of water applied to field which is actually used by the crop. Losses occur mainly due to runoff, percolation and evaporation. With lowland paddy, where the field is kept permanently flooded, the field efficiency can be estimated by simply considering percolation losses. For rice fields on lowland soils an average percolation rate of 3 mm. per day has been assumed, but on the sandier intermediate soils a percolation rate of 5 mm. per day has been used.

For non-paddy rice areas the estimation of field efficiency is much more complex. In view of the sandy nature of many of the intermediate soils and their consequent high infiltration rates, 50% field efficiency has been assumed for surface irrigation. On well drained Reddish Brown Earths, infiltration rates are so high that

it has been assumed that surface irrigation would not be used. Sprinkler or drip irrigation will be needed, and for this report sprinkler irrigation with a field efficiency of 75% has been assumed.

There is very little experience with the irrigation and physical management of the intermediate and upland soils found in System B. As a result, the above estimates of irrigation efficiencies are tentative.. Better estimates of irrigation efficiencies can only be made when some practical irrigation has been done on these soils. A programme of investigation of irrigation methods should therefore be carried out on any prospective pilot farm as a matter of high priority.

6.1.4 - Cropping Patterns

The irrigable area in System B has been divided into three types (see Table 2-5), being lowlands, intermediate lands and uplands. This classification is topographic and each group includes a variety of soil types.

The lowlands consist of the Low Humic Gley and Alluvial soils, which are the traditional paddy rice lands in System B. The intermediate soils are Non Calcic Brown soils, Alluvial and Reddish Brown Earths. This intermediate grouping has been sub-divided into fine and coarse soils. These lands are at present sparsely cultivated. The upland areas consist primarily of the Reddish Brown Earths.

It is proposed that on the lowland areas two crops of paddy rice per year should be grown - a Maha crop of a 135 day variety and a Yala crop of a 105 day variety. It has been assumed that planting and harvesting would each continue over a one month period. The assumed crop coefficients for the calculation of crop water requirements are shown in Table 6-4.

On the fine textured intermediate soils, it is proposed to grow a Maha crop of paddy rice and a Yala crop of a legume such as soyabeans or groundnuts . For crop water requirement purposes, soyabeans have been chosen as a reference crop.

The upland soils have been considered too free-draining to grow paddy rice and it is proposed to grow a Maha crop of soyabeans, groundnuts, tobacco or kenaf, and a Yala crop of cotton, groundnuts or soyabeans. For crop water requirement calculations, soyabeans have been used as a reference crop in the Maha season and cotton has been used in the Yala season.

To maximize the use of the best agricultural land in one hectare smallholder plots, it has been assumed that no smallholder homesteads will be situated on the lowlands, the fine intermediate soils or the irrigable uplands. Homesteads will be situated on the coarser intermediate soils or on the uplands which are out of command. For the coarse intermediate soils a crop rotation of two crops of soyabeans per year has been assumed for the calculation of water requirements to cover the wide range of crops which may be grown. It is not certain that surface irrigation can be successfully employed on these soils and a low field efficiency of 50% has been assumed. Field trials are essential to investigate the irrigation potential of these soils.

6.1.5 - Gross Irrigation Requirements

The calculation of the gross irrigation water requirements for the four different irrigation regimes, i.e. lowlands, intermediate lands, uplands and homesteads, is shown in Tables 6 - 5 to 6 - 8. The gross irrigation water requirements for the whole of System B are summarized in Table 6 - 9.

Batticaloa meteorological data modified by using Anuradhapura wind data in the Maha season have been used to calculate the Penman evapotranspiration. The Penman evapotranspiration has been multiplied by the crop factors shown in Table 6-4 to calculate monthly crop evapotranspiration requirements. Percolation in rice paddies and the requirement for land preparation has then been added to arrive at the gross field water requirement for each crop type.

The effective rainfall as calculated using the Land Use Division formula for paddy rice or the USDA/SCS formula for other crops is then subtracted from the gross water requirement to give the net field irrigation requirement. The relevant field efficiency is then applied to give the gross field irrigation requirement, which

TABLE 6-5

CALCULATION OF WATER REQUIREMENTS

FOR LOWLAND AREAS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Penman evapotranspiration ETo, mm	118	133	188	185	202	188	198	199	187	171	126	108	
Crop factor, Kc	1.04	0.84	0.12	0.55	1.1	1.05	0.91	0.13	-	0.55	1.1	1.08	
ETp, mm	123	112	23	102	222	197	180	26	-	94	139	117	
Percolation[1], mm	93	74	12	45	93	90	81	12	-	47	90	93	
Land preparation	-	-	60	120	-	-	-	-	60	120	-	-	
Water requirement	216	186	95	267	315	287	261	38	60	261	229	210	
Effective Rainfall	141	82	27	42	25	-	27	26	34	112	197	210	
Field Water Requirement	75	104	68	225	290	287	234	12	26	149	32	-	
Gross Requirement, mm	107	149	97	321	414	410	334	17	37	213	46	-	2136 mm
Gross Requirement x 10^6 m^3	16.2	22.6	14.7	48.6	62.7	62.1	50.6	2.6	5.6	33.3	7.0	-	326.0 x

Notes
1. Based on 3mm/day on fields under irrigation
2. Based on 70% conveyance efficiency
3. Double cropped paddy rice regime assumed
4. Cropped area is 15,155 ha. derived--(see Table 6-6)

TABLE 6-6

CALCULATION OF WATER REQUIREMENTS

FOR INTERMEDIATE AREAS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Penman Evapotranspiration ETo	118	133	188	185	202	188	198	199	187	171	126	108	
Crop factor K_c	1.04	0.84	0.12	0.35	0.91	1.05	0.79	0.1	-	0.55	1.1	1.08	
ETp	123	112	23	65	184	197	156	20	-	94	139	117	
Percolation[1]	155	122	19	-	-	-	-	-	-	78	150	155	
Land preparation	-	-	25	50	-	-	-	-	60	120	-	-	
Gross field water requirement	278	234	67	115	184	197	156	20	60	292	289	272	
Effective rainfall	141	82	27	62	52	22	50	20	34	112	197	225	
Net field water requirement	137	152	40	53	132	175	106	-	26	180	92	47	
Field irrigation requirement[2]	137	152	40	106	264	350	212	-	26	180	92	47	
Gross water requirement, mm[3]	196	217	57	151	377	500	303	-	37	257	131	67	2285 mm
Gross water requirement x 10^6 m^3	28.0	31.0	8.1	21.5	53.8	71.4	43.2	-	5.3	36.7	18.7	9.6	327.3×10^6

Notes:
1. Based on 5 mm/day on fields under irrigation
2. Based on 50% efficiency for surface irrigation on Yala crop
3. Based on 70% conveyance/distribution efficiency
4. Paddy rice - Soya Bean/groundnut crop rotation assumed
5. Cropped area is 14271 ha, derived by subtracting an allowance of 5% from the areas shown in Table 2-5, to allow for irrigation infrastructure.

TABLE 6-7

CALCULATION OF WATER REQUIREMENTS
FOR UPLAND AREAS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Summer evapotranspiration ETo	118	133	188	185	202	188	198	199	187	171	126	108	
Crop factor Kc	0.79	0.1	0.33	0.75	0.88	1.07	0.83	0.28	-	0.35	0.91	1.05	
ETp	93	13	62	139	178	201	164	56	-	60	115	113	
Land preparation	-	-	25	50	-	-	-	-	25	50	-	-	
Crops field water requirement	93	13	87	189	178	201	164	56	25	110	115	113	
Effective rainfall	93	13	44	72	50	20	49	40	25	110	115	113	
Net field water requirement	-	-	43	117	128	181	115	16	-	-	-	-	
Field irrigation requirement[1]	-	-	57	156	171	241	153	21	-	-	-	-	
Crops water requirement,[2] mm.	-	-	81	223	244	344	219	30	-	-	-	-	1141 mm.
Crops water requirement x 10^6 m^3	-	-	7.9	21.9	23.9	33.7	21.5	2.9	-	-	-	-	111.8x10^6 m^3

Notes: 1. Based on 75% efficiency for sprinkler irrigation
2. Based on 70% conveyance/distribution efficiency
3. Soya Bean/groundnut - cotton rotation assumed
4. Cropped area is 9809 ha, derived -- (see Table 6-6)

TABLE 6-8

CALCULATION OF WATER REQUIREMENTS
FOR HOMESTEAD PLOTS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Penman evapotranspiration ETo	118	133	188	185	202	188	198	199	187	171	126	108	
Crop factor, Kc	0.79	0.1	-	0.35	0.91	1.05	0.79	0.1	-	0.35	0.91	1.05	
ETp	93	13	-	65	184	197	156	20	-	60	115	113	
Land preparation	-	-	25	50	-	-	-	-	25	50	-	-	
Gross field water requirement	93	13	25	115	184	197	156	20	25	110	115	113	
Effective rainfall	93	13	25	62	52	20	49	20	25	110	115	113	
Net field water requirement	-	-	-	53	132	177	107	-	-	-	-	-	
Field irrigation requirement[1]	-	-	-	106	264	354	214	-	-	-	-	-	
Gross water requirement,[2] mm	-	-	-	151	377	506	306	-	-	-	-	-	1340 mm
Gross water requirement $\times 10^6$ m^3	-	-	-	8.9	22.2	29.8	18.0	-	-	-	-	-	78.9

Notes:
1. Based on 50% field efficiency for surface irrigation
2. Based on 70% conveyance/distribution efficiency
3. Vegetables are main crop but crop factors for soya bean - soya bean rotation have been used
4. Cropped area is 5885 ha. derived -- (see Table 6-6)

TABLE 6-9

CALCULATION OF SUMMARY OF GROSS IRRIGATION WATER REQUIREMENTS x 10^6 m^3

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	IRRIGATE AREA, HA
Lowlands	16.2	22.6	14.7	48.6	62.7	62.1	50.6	2.6	5.6	33.3	7.0	-	326.0	15155
Intermediate Lands	28.0	31.0	8.1	21.5	53.8	71.4	43.2	-	5.3	36.7	18.7	9.6	327.3	14271
Uplands	-	-	7.9	21.9	23.9	33.7	21.5	2.9	-	-	-	-	111.8	9809
Homesteads	-	-	-	8.9	22.2	29.8	18.0	-	-	-	-	-	78.9	5885
Total	44.2	53.6	30.7	100.9	162.6	197.0	133.3	5.5	10.9	70.0	25.7	9.6	844.0	45120

is in turn divided by a conveyance/distribution efficiency factor of 0.7 to give the gross water requirement at source. These requirements, which are expressed in millimeters, are converted to total water requirements by multiplying by the appropriate cropped areas.

6.2 - Hydrology of the Maduru Oya

The Maduru Oya basin experiences a tropical climate, falling under the influence of the Northeast (December - February) and Southwest (May - September) monsoons. The Northeast monsoon (Maha) brings most of the annual rainfall, and therefore runoff, in the catchment area. The Southwest monsoon (Yala) is typically dry due to the orographic effect of the Central Highlands of Sri Lanka. Rainfall in the intermonsoon periods can be caused by either convective or cyclonic storms.

6.2.1 - Rainfall Data

Daily rainfall data for long periods (over 100 years in two cases) are available for several stations near the project area. Double mass curve analyses were performed on these stations to assess the reliability of the data and to detect any significant changes in inter-station relationships. The stations named in Table 6-10 were selected for use in these studies after considering the following factors:

- proximity to the study area
- proximity to a more reliable station
- amount of missing data
- consistency of data as evidenced by the double mass curve ana[illegible].

A total of [illegible] ations with reliable records covering the period of 1950 through 1977* were found. The locations of these stations are shown on Figure 5, and the periods of record are summarized in Table 6-10. Observations at two of the most useful stations from an agricultural point of view (Welikanda and Vakaneri) were unfortunately discontinued in recent years. Observations at

* This period was chosen by MEDECO for analysis of the hydrologic records in the entire Mahaweli Development Area. It has been used in this study to produce results which are comparable to those computed by MEDECO.

TABLE 6-10

RAINFALL STATIONS LOCATED
NEAR SYSTEMS B

Station Name	Period of Record		Missing Data	
	Begin	End	Total Months	Major Periods Missing
Batticaloa	Jan. 1869	-	0	-
EkiriyankUmbura	Jan. 1943	July 1977	14	Aug. 1959 - Dec. 1959
Horaborawewa	Nov. 1909	-	18	Feb. 1971 - Feb. 1972 Aug. 1972 - Oct. 1972
Polonnaruwa	Jan. 1940	-	5	-
Trincomalee	June 1869	-	0	-
Vakaneri	Oct. 1900	Nov. 1972	18	Jan. 1968 - Dec. 1968 Oct. 1969 - Dec. 1969
Welikanda	Jan. 1942	June 1973	21	Feb. 1967 - Jan. 1968

Welikanda have begun again, and the Meteorological Department has indicated that the Vakaneri station can be reactivated shortly.

Tables 6-1 and 6-11 through 6-16 summarize the monthly rainfall at these stations over the 28 year period 1950 to 1977. Missing data at Welikanda, Polonnaruwa and Vakaneri were estimated using seasonal linear regression relationships developed with nearby stations. Missing data at Ekiriyankumbura and Horaborawewa will be estimated in a similar manner for the Final Report.

6.2.2 - Streamflow Data

Two stream gauges have been in operation on the Maduru Oya in the recent past. The characteristics of these stations are summarized in Table 6-17. This table indicates several problems with the data from these stations.

1. Flows were measured to establish rating curves over short periods and were discontinued almost twenty years ago. Shifts over time in the rating curves (which are likely, as both gauges are located at unstable sections) will thus be undetected.

2. The rating curves were established for relatively low flows. No attempts have been made to measure high flows, nor to check extrapolations of the derived rating curves using topographic information.

3. Observations were discontinued at the damsite station in 1957. It is not possible to compare the old rating curve with one established under present conditions.

To assist with the assessment of the rating curve, a program of flow measurements has been undertaken by the Irrigation Department at the two sites to allow construction of the new rating curves and, if possible, adjustment of records for the period of no flow measurements.

Maha

TABLE 6 - 11.

Yala

BATTICALOA
RAINFALL (MM)

Maha

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	240.8	144.6	192.8	66.5	20.8	1.8	6.1	211.1	3.8	76.5	112.5	250.7	1334.8
1951	572.3	297.6	130.3	71.6	18.3	24.9	27.7	4.3	18.3	45.0	281.4	357.9	1759.7
1952	539.7	136.7	28.2	26.2	20.1	13.5	56.9	2.5	6.6	83.6	274.1	224.8	1412.7
1953	424.9	87.9	45.7	29.5	0.0	9.1	51.8	64.5	61.0	199.9	234.4	471.2	1709.9
1954	306.8	125.5	135.4	129.0	28.4	14.5	33.0	24.6	1.8	189.7	362.2	365.8	1716.8
1955	195.3	305.6	20.8	68.8	62.0	20.3	74.4	179.6	34.8	286.8	163.8	161.8	1577.1
1956	208.0	129.9	28.7	16.5	2.5	84.1	129.3	92.7	136.4	267.2	338.6	233.9	1658.6
1957	256.3	509.5	0.3	21.1	57.7	9.9	37.8	18.3	14.7	176.0	515.1	1180.3	2588.0
1958	226.8	105.1	71.6	41.9	36.3	0.3	25.6	129.8	18.8	148.1	304.3	435.4	1540.0
1959	110.5	34.0	9.1	192.3	27.2	44.4	0.0	16.2	25.1	256.8	342.1	386.3	1442.2
1960	432.6	661.2	113.0	104.4	29.0	45.0	199.6	23.6	91.4	84.3	344.2	172.2	2300.5
1961	381.5	375.7	0.0	0.0	118.1	12.2	50.5	43.7	86.1	42.9	591.3	702.8	2407.9
1962	565.7	98.4	75.2	113.0	97.0	0.0	7.1	103.6	60.7	226.8	415.0	261.1	2035.8
1963	515.4	191.5	224.5	67.1	12.4	9.1	19.1	62.7	13.7	197.4	836.2	748.3	2897.4
1964	411.5	95.3	178.3	23.1	136.7	0.0	223.0	42.4	0.5	103.9	114.8	313.7	1647.2
1965	69.1	226.5	16.0	45.5	60.5	0.0	49.0	116.6	17.5	160.3	587.5	663.7	2011.9
1966	237.5	170.2	134.6	28.7	7.1	56.6	13.7	91.4	113.3	563.6	380.0	409.4	2206.2
1967	165.6	176.8	106.7	81.0	4.1	24.6	46.0	68.1	95.2	135.9	544.1	672.3	2120.4
1968	132.8	0.0	189.2	21.8	31.2	2.8	41.7	59.2	46.5	50.5	151.9	135.9	863.6
1969	155.7	56.6	0.3	97.5	22.6	7.6	3.0	91.2	67.6	342.1	159.5	817.1	1820.9
1970	459.0	325.8	93.7	54.6	33.5	0.8	74.2	113.0	164.1	58.9	263.9	299.5	1939.0
1971	387.6	64.5	36.1	27.9	2.5	4.1	64.8	33.9	22.6	181.6	249.4	501.4	1581.4
1972	66.3	61.0	37.3	17.5	80.3	62.7	50.3	8.9	130.3	430.8	340.1	328.2	1613.7
1973	2.3	44.2	169.2	29.5	12.7	89.7	9.9	58.7	70.4	235.5	269.2	550.4	1481.6
1974	3.8	47.5	17.5	79.5	25.1	14.7	26.2	44.2	75.7	53.6	196.1	525.8	1109.7
1975	112.3	114.6	114.0	46.2	6.9	8.3	16.5	112.0	34.3	162.8	498.0	256.5	1475.2
1976	452.1	38.1	26.7	5.8	22.6	0.8	4.6	19.8	12.4	150.6	11.2	590.0	1334.8
1977	43.5	113.0	96.0	48.5	92.2	25.4	36.6	17.5	36.6	221.5	276.6	605.3	1617.7
AVG.	275.0	158.5	79.7	55.5	38.1	20.7	50.2	66.3	52.7	183.4	327.1	450.8	1757.3

TABLE 6 - 12.

EKIRIYANKUMBURA
RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	277.1	224.5	211.8	56.6	117.9	0.0	0.8	198.4	85.3	207.8	121.9	102.1	1602.2
1951	1054.0	179.8	130.6	89.9	69.6	6.0	2.3	5.3	92.7	261.6	412.8	387.6	2666.2
1952	436.1	55.1	69.3	166.9	65.3	0.0	137.7	0.0	18.8	126.2	373.6	181.6	1628.6
1953	265.2	136.1	42.4	192.0	12.4	21.6	170.7	24.9	11.2	251.7	209.3	-	-
1954	344.0	338.3	71.1	179.8	104.1	10.9	18.0	64.8	123.7	234.4	217.4	514.4	2241.0
1955	850.6	455.4	147.6	195.3	218.7	0.0	0.0	384.3	353.3	0.0	225.0	181.1	2993.4
1956	230.1	61.5	88.1	47.8	25.9	158.7	52.6	115.6	46.2	211.8	341.1	358.6	1738.1
1957	307.1	311.9	1.5	41.4	108.2	0.0	36.8	55.1	34.3	280.9	704.1	1356.1	3237.5
1958	217.2	64.5	185.2	187.2	163.3	0.0	52.8	131.3	77.7	147.1	230.1	867.9	2324.4
1959	201.7	158.0	0.5	343.7	153.4	112.5	31.7	-	-	-	-	-	-
1960	536.2	1006.6	37.8	268.2	85.1	18.0	218.4	29.5	68.6	131.1	182.4	240.7	2831.6
1961	315.5	263.4	127.3	185.2	56.9	21.8	62.2	0.0	215.6	145.0	691.1	524.8	2608.8
1962	323.6	132.6	92.2	174.0	151.9	25.1	24.1	265.7	96.8	219.7	258.8	276.6	2042.2
1963	591.1	222.8	48.8	180.8	65.0	22.6	68.6	139.4	248.7	270.0	590.5	586.2	3034.5
1964	484.6	435.1	120.1	108.5	94.2	38.4	185.9	31.5	26.6	325.4	95.0	327.2	2272.8
1965	170.4	434.3	107.4	306.1	210.1	0.0	11.9	265.2	63.2	344.9	461.8	462.0	2838.4
1966	279.7	98.6	-	195.6	24.9	35.8	68.1	123.4	88.9	295.7	244.6	306.1	-
1967	282.4	352.6	140.5	44.4	41.1	76.7	0.0	31.0	195.8	252.2	648.2	361.9	2427.0
1968	208.5	12.2	193.0	63.0	73.4	94.0	5.6	131.1	96.8	180.3	336.5	302.5	1697.0
1969	448.6	217.2	62.2	249.4	25.4	0.0	50.5	215.4	100.1	243.3	266.2	846.6	2724.9
1970	389.7	320.8	63.0	181.1	244.3	0.0	78.7	117.1	112.0	216.2	-	-	-
1971	551.2	114.5	95.8	88.9	-	0.0	0.0	191.3	190.5	243.6	143.0	528.1	-
1972	273.6	270.5	9.7	107.7	103.4	14.0	23.4	23.4	147.3	484.1	402.6	789.2	2653.8
1973	74.7	33.8	69.6	1.8	174.8	137.9	43.7	6.6	161.8	-	345.4	859.3	-
1974	76.2	354.1	-	-	-	28.7	3.0	35.6	101.3	2.3	-	227.8	-
1975	163.8	91.7	168.4	13.5	27.9	31.7	78.0	117.9	198.1	71.1	246.4	134.1	1342.6
1976	233.4	26.7	60.2	175.0	42.4	81.3	196.3	0.0	74.7	133.3	318.5	220.5	1562.4
1977	19.9	109.7	65.8	71.4	92.5	202.9	218.7	-	-	-	-	-	-
AVG.	341.9	233.2	-	-	-	40.5	65.7	-	-	-	-	-	-

- Missing Data.

TABLE 6 - 13.

HORABORAWEWA
RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	234.9	110.5	92.7	37.6	90.7	0.0	7.6	26.7	38.1	141.0	207.8	253.5	1241.0
1951	1051.1	109.2	66.5	75.4	30.5	0.0	32.0	129.5	108.2	193.5	514.4	581.4	2891.8
1952	666.0	87.6	34.0	268.5	130.8	0.0	76.7	19.1	164.1	126.2	321.1	246.4	2140.5
1953	425.4	241.3	124.5	191.0	0.0	33.5	57.1	47.0	63.2	200.7	264.2	544.6	2190.5
1954	346.7	374.6	177.8	147.3	50.8	0.0	10.2	41.1	0.0	342.6	262.9	603.3	2357.4
1955	870.7	344.9	209.3	179.3	12.7	0.0	0.0	60.2	110.2	69.8	172.5	284.0	2313.7
1956	238.5	81.0	106.9	121.9	0.0	82.8	0.0	19.3	0.0	190.2	651.5	456.4	1998.7
1957	376.2	281.2	16.5	33.5	33.0	6.3	32.8	8.6	88.6	301.8	636.5	1304.5	3119.6
1958	415.5	152.4	210.6	199.9	43.2	5.8	8.4	45.2	45.5	55.6	345.2	503.4	2030.7
1959	244.9	84.1	55.6	205.5	220.7	24.9	3.3	71.1	97.0	414.0	447.3	683.3	2551.7
1960	569.0	845.0	22.6	261.9	143.8	0.0	151.4	25.4	13.7	247.4	362.5	173.5	2814.1
1961	515.9	195.1	144.3	343.2	54.6	6.3	14.2	5.3	52.8	197.9	603.8	560.8	2694.2
1962	394.0	169.7	177.8	244.3	174.5	4.3	10.9	339.1	46.5	163.3	275.3	338.3	2338.1
1963	455.4	319.8	113.5	158.7	61.2	0.0	42.4	2.3	184.4	238.5	494.8	641.3	2712.5
1964	514.4	419.4	159.0	70.4	79.2	3.8	112.8	104.4	37.3	110.2	185.2	411.5	2207.5
1965	208.5	515.8	103.4	231.4	65.0	10.2	1.5	229.9	0.0	305.8	454.9	412.2	2536.7
1966	358.1	96.5	255.3	81.0	44.2	12.2	3.3	84.1	111.5	323.6	356.9	307.6	2034.3
1967	275.6	299.2	130.0	54.6	11.2	49.8	2.8	4.1	54.6	251.5	749.0	379.0	2261.4
1968	267.5	18.0	290.3	88.1	8.6	6.1	10.9	0.0	26.7	222.5	200.2	342.6	1501.6
1969	362.7	189.2	35.8	253.2	43.9	0.0	4.6	182.1	120.6	365.5	119.4	704.6	2381.8
1970	554.6	532.1	105.2	145.0	85.1	4.3	2.5	21.1	64.3	40.1	288.3	290.8	1931.4
1971	357.6	-	-	-	-	-	-	0.0	0.0	-	-	-	-
1972	-	-	72.6	-	-	16.5	38.1	-	-	-	427.7	507.5	-
1973	134.1	448.8	75.2	69.1	38.6	58.4	59.9	10.7	95.2	183.4	530.4	621.5	2325.4
1974	5.0	139.4	37.8	176.5	109.5	5.1	38.6	26.9	46.2	52.3	85.9	522.2	1244.6
1975	225.0	161.0	135.1	104.6	130.0	11.9	147.6	49.5	116.1	67.1	194.8	317.0	1659.9
1976	326.9	53.3	57.7	117.1	39.9	54.6	56.4	75.4	30.5	78.5	310.4	224.5	1425.2
1977	60.5	66.3	181.6	67.3	84.1	4.1	107.9	29.7	173.6	254.3	280.7	290.6	1599.9
AVG.	-	-	-	-	-	-	-	-	-	-	-	-	-

- Missing Data.

TABLE 6 - 14.

POLOPDASHIA
RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	134.4	150.6*	146.2	14.0	61.7	0.0	0.0	82.3	18.8	117.6	171.7	178.0	1097.8*
1951	500.4	105.7	75.4	134.9	13.7	0.0	55.4	41.4	147.6	62.2	384.0	265.2	1789.2
1952	463.8	127.5	46.5	135.3	97.0	0.0	52.8	0.0	105.4	179.1	185.7	227.1	1618.2
1953	224.0	89.4	73.2	214.6	0.0	51.1	171.4	36.1	135.1	265.7	244.9	436.0	1940.3
1954	296.9	97.5	211.6	112.5	0.0	0.0	90.9	64.8	0.0	199.6	184.4	578.1	1836.4
1955	269.9	105.7	31.0	127.6	44.4	0.0	0.0	134.1	174.2	164.6	102.6	147.3	1297.6
1956	125.5	65.8	59.7	104.9	0.5	111.6	12.2	55.1	4.3	224.0	311.9	300.7	1373.6
1957	112.8	315.5	0.0	71.1	127.3	2.3	81.8	18.0	14.7	178.3	612.6	1218.7	2753.1
1958	192.0	91.2	103.6	81.3	60.2	0.0	0.0	159.8	31.2	212.1	226.8	397.5	1555.7
1959	268.0	15.2	9.1	96.5	29.2	21.6	0.0	30.0	118.9	371.3	338.6	269.5	1587.9
1960	274.8	409.2	84.8	306.6	164.3	0.0	140.2	23.9	37.6	101.1	264.7	129.0	1936.2
1961	422.9	259.8	103.6	115.6	140.7	6.9	0.0	0.0	9.1	144.5	348.7	513.3	2065.3
1962	207.5	65.5	71.9	95.8	76.2	0.0	4.8	27.2	127.0	168.9	205.5	222.3	1272.5
1963	488.7	257.3	101.6	216.9	39.4	1.8	47.8	5.1	134.1	188.2	490.5	432.1	2403.3
1964	162.6	220.7	255.5	79.2	36.6*	0.0	103.6	46.5	72.9	87.1	147.1	155.2	1367.0*
1965	105.4	412.2	2.3	181.9	158.7	21.6	10.0	151.9	0.5	241.3	595.4	574.0	2445.3
1966	241.8	17.5	161.5	239.3	2.5	2.5	5.3	119.6	52.1	421.9	295.7*	397.3*	1957.8*
1967	65.5	180.1*	52.8	87.6	10.9	0.0	0.0	0.8	15.0	259.8	466.6	505.5	1644.6*
1968	134.1	0.0	121.9	98.6	1.3	0.0	0.0	15.5	32.5	189.5	313.9	213.1	1120.4
1969	111.0	42.2	28.2	271.0	0.0	0.0	96.5	87.4	34.3	269.7	189.2	709.4	1759.0
1970	179.8	302.8	18.8	196.8	137.7	95.2	0.0	103.4	35.0	219.7	488.7	326.9	2105.4
1971	176.3	101.6	160.5	168.1	30.2	0.0	148.8	282.7	2.5	200.2	180.1	798.1	2249.2
1972	40.1	0.0	0.0	138.2	132.3	0.0	11.7	0.5	407.2	617.5	579.4	435.4	2362.2
1973	20.3	116.8	44.4	36.6	88.9	66.0	348.0	44.7	382.3	183.9	391.4	1256.5	2980.2
1974	0.0	55.4	33.0	144.8	65.5	0.0	0.0	7.6	151.1	25.4	192.3	236.7	911.9
1975	149.1	174.0	204.0	191.5	112.8	0.0	508.0	94.8	0.6	210.1	285.5	382.0	2312.7
1976	230.1	15.2	3.8	58.9	0.0	44.7	17.3	78.7	105.4	126.2	606.6	685.8	1972.8
1977	153.9	49.5	145.0	190.8	121.4	4.8	165.9	83.6	154.7	261.4	670.1	515.9	2516.9
AVG.	205.1	137.3*	84.7	139.6	62.6*	15.3	73.7	64.2	89.3	210.4	335.5*	446.7*	1864.6*

* Estimated.

Mar

TABLE 6 - 15.

Yala

RINGCHALEE
RAINFALL (MM)

May

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	59.9	195.7	15.7	26.7	176.8	0.0	16.3	153.2	57.1	136.4	442.7	219.2	1409.7
1951	314.7	94.5	51.3	99.5	61.7	1.0	36.6	50.0	62.0	206.0	417.6	179.8	1574.5
1952	471.2	45.7	3.5	65.8	59.9	0.0	141.0	23.6	21.8	182.1	207.8	124.2	1344.4
1953	232.4	67.6	20.8	106.2	1.3	58.4	138.2	150.4	87.6	205.7	265.0	215.6	1539.2
1954	197.1	22.6	38.4	99.1	57.7	15.5	34.3	137.9	72.4	137.3	229.4	570.7	1612.9
1955	325.4	160.8	0.8	222.8	105.9	0.0	51.3	125.0	79.6	57.9	133.1	283.5	1545.3
1956	91.2	34.8	8.4	21.3	0.0	43.2	96.0	183.1	151.1	252.5	324.1	231.6	1437.4
1957	160.8	98.6	0.0	0.0	53.3	0.5	53.1	49.8	65.0	332.7	953.5	757.2	2522.5
1958	132.3	50.3	37.3	90.4	85.1	0.0	31.0	153.9	208.8	385.4	263.4	273.1	1711.7
1959	159.1	4.1	1.5	67.1	68.3	98.0	10.9	56.9	80.8	305.1	484.6	143.5	1470.9
1960	561.5	307.1	59.4	66.0	56.6	3.3	168.9	7.1	141.2	81.0	243.8	114.6	1710.7
1961	276.4	84.3	38.6	71.9	94.2	2.5	109.5	58.4	66.3	124.7	563.6	549.7	2040.6
1962	313.0	89.9	44.7	14.7	73.7	0.0	10.7	91.7	51.3	347.5	277.6	139.2	1459.0
1963	659.1	138.7	159.5	50.5	60.2	59.9	120.6	125.0	138.9	162.8	523.7	329.2	2578.4
1964	71.9	37.0	32.8	23.9	7.1	0.0	155.2	125.5	15.0	148.8	150.6	216.9	1935.3
1965	33.8	551.4	95.5	77.0	59.2	0.0	2.3	328.4	109.7	301.0	404.9	444.0	2407.2
1966	126.0	32.5	139.7	54.6	10.7	0.0	4.1	50.3	47.5	404.1	274.3	392.4	1526.2
1967	52.3	140.0	25.7	23.2	0.8	31.2	70.1	48.5	78.0	304.0	403.6	435.9	1618.2
1968	81.0	0.3	177.0	73.9	4.1	2.3	0.0	26.4	73.4	173.7	304.8	165.1	1082.0
1969	80.3	106.7	0.0	33.8	16.8	0.0	6.1	85.1	25.9	413.3	348.5	638.6	1760.0
1970	159.3	78.2	49.3	85.9	66.5	22.5	1.0	279.1	31.2	255.8	551.7	279.1	1865.4
1971	276.1	71.4	14.0	13.2	18.5	4.6	219.2	134.9	272.8	145.3	134.6	796.8	2103.4
1972	50.2	15.5	2.8	5.5	119.1	94.5	147.1	24.4	165.9	565.7	477.5	259.8	1909.8
1973	0.8	11.2	39.0	0.9	110.7	181.1	13.2	103.7	54.4	435.4	54.6	683.8	1693.7
1974	11.7	64.9	6.3	82.1	96.5	0.0	51.1	51.8	210.3	26.2	113.3	395.2	1113.5
1975	96.5	61.7	46.5	18.3	36.8	28.4	37.8	73.4	31.0	115.6	412.5	317.0	1275.6
1976	17.5	9.4	0.7	34.5	28.4	25.4	50.0	99.1	96.3	175.0	264.7	400.6	1210.6
1977	48.0	157.7	57.4	44.4	66.8	54.6	17.5	12.7	157.0	209.8	376.2	342.9	1545.1
AVG.	173.1	96.2	45.2	56.8	57.0	26.2	64.0	100.7	94.6	235.6	340.8	353.5	1648.7

Mahe → Yaka → Mahe →

TABLE 6 - 16.

VAKANERI

RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950	207.0	70.6	244.3	15.7	39.6	0.0	1.0	158.5	75.7	131.3	194.3	300.7	1438.9
1951	890.5	133.9	43.4	118.1	38.6	0.0	38.6	9.7	40.6	97.3	452.9	206.2	2069.8
1952	365.3	107.2	59.8	78.5	23.6	0.0	44.2	29.0	20.8	79.2	330.7	281.4	1430.8
1953	234.7	52.6	77.2	85.1	0.0	28.2	298.7	91.4	128.8	248.2	251.5	560.3	2056.6
1954	367.0	59.2	128.3	148.8	61.2	0.5	23.6	24.6	17.5	80.0	219.2	417.6	1547.6
1955	305.5	252.5	2.8	89.4	59.4	0.0	3.6	195.4	55.1	330.7	180.6	305.8	1690.6
1956	266.7	142.7	31.5	40.1	0.0	52.6	121.2	150.1	59.9	233.4	493.8	296.9	1889.0
1957	214.4	435.4	0.5	1.8	139.4	0.0	82.3	4.6	8.4	188.0	479.6	1245.9	2848.4
1958	123.0	58.4	124.5	101.6	103.4	0.0	70.4	251.0	29.0	153.9	87.4	414.5	1522.0
1959	393.5	33.5	36.1	69.3	155.7	121.4	0.0	36.8	116.8	270.5	399.0	498.9	2136.1
1960	645.2	548.6	52.6	66.8	141.5	12.4	174.3	12.2	18.0	58.2	288.3	243.8	2262.4
1961	331.7	345.7	140.5	70.1	109.7	3.6	46.0	29.2	118.6	76.7	460.2	506.0	2238.0
1962	303.3	45.0	48.3	29.2	97.5	0.0	74.4	32.5	68.3	408.7	396.0	384.0	1887.2
1963	490.7	244.6	145.5	93.0	56.1*	33.5	61.2*	109.2	111.8*	155.2	633.8	594.6	2734.3*
1964	239.1	259.6	193.5	21.3	128.3	21.6	214.9	13.2	10.4	127.0	89.9	217.2	1586.2
1965	88.1	309.5	3.0	48.3	46.2	0.0	50.0	208.8	0.0	179.8	740.4	670.3	2384.6
1966	319.5	29.0	232.4	22.6	22.1	29.2	14.0	175.8	142.0	502.7	572.0	450.1	2511.3
1967	159.0	105.7	118.4	41.4	38.6	4.8	0.0	57.4	55.6	225.0	613.4	581.7	1999.0
1968	142.7*	14.5*	131.1*	108.7*	34.0*	33.3*	33.3*	42.2*	52.3*	195.6*	314.7*	218.2*	1320.5*
1969	169.8	152.6	0.0	209.0	7.9	0.0	4.6	110.7	34.0*	272.3*	118.9*	692.9*	1743.7*
1970	201.9	511.1	46.0	13.5	21.6	0.0	0.0	81.3	96.5	27.9	312.9	229.1	1341.9
1971	349.6	38.1	1.0	42.4	66.0	0.0	5.8	10.7	12.2	11.9	80.8	315.0	1324.6
1972	11.4	0.5	2.8	0.0	208.0	167.6	0.0	147.6	184.9	112.3	107.2	430.8	1373.1*
1973	53.6*	126.2*	56.9*	49.8*	85.3*	71.9*	237.0*	59.2*	257.0*	190.2*	388.0*	1216.2*	2772.4*
1974	14.5*	67.3*	46.0*	152.9*	71.6*	33.3*	33.3*	37.6*	121.7*	38.6*	198.4*	240.8*	1055.9*
1975	156.2*	180.8*	209.5*	197.6*	99.3*	33.3*	330.7*	89.9*	33.3*	215.4*	287.5*	379.7*	2213.4*
1976	234.4*	29.0*	18.0*	70.9*	33.3*	59.4*	43.4*	79.2*	95.0*	135.4*	594.6*	670.3*	2063.0*
1977	161.3*	61.7*	153.2*	196.8*	104.4*	36.1*	130.3*	82.0*	125.7*	264.4*	655.3*	507.7*	2477.5*
AVG.	267.2*	154.8*	83.5*	78.0*	71.2*	26.5*	74.5*	80.0*	74.5*	178.9*	355.3*	481.3*	1925.7*

* Estimated.

TABLE 6-17

SUMMARY OF CHARACTERISTICS
OF MADURU OYA STREAMFLOW
GAUGING STATIONS

Location	Drainage Area (Km^2) 1	Stage Observations Begin	End	Missing	Maximum Est'd Flow (m^3/Sec)[2]	Flow Measurements Begin	End	Max. Stage (ft.)	Max. Flow (m^3/Sec)
Maduru Oya at Damsite	452	Feb. 1951	Sept. 1957	2 mo.	416	Nov. 1951	Mar.1957	9.50	156
Maduru Oya below Damsite	459	Jan. 1978	present	-	27	Oct. 1978	present	N.A.[3]	N.A.[3]
Maduru Oya at Welikanda	966	Feb. 1946	present	15 mo.	1800	Nov. 1953 Dec. 1978	June 1960 present	11.0 N.A.[3]	202 N.A.[3]

1. Measured from 1 inch = 1 mile maps

2. Estimated by extending rating curve beyond measured range and using the observed stage

3. N.A. - Not available

6.2.3-The Available Natural Water Supply

Table 6-18 summarizes the measured and estimated* flows at the Maduru Oya Damsite. These flows ban be used with reasonable confidence as input to reservoir operation studies, although it may be possible to make adjustments to the flows to reflect shifts in the rating curves detected by the flow measurement program which is presenly under way. Any such adjustments will be presented in the Final Report.

6.2.4 - Flood Hydrology

Flood studies have been conducted by CECB[6] to derive design floods at the damsite for spillway design and construction flood handling purposes.

These studies, which are based on unit hydrograph methods, can be found in the CECB Report. The flood studies to be carried out as part of this Feasibility Study relate primarily to the delineation of flood-prone areas in the irrigation area.

Streamflow records in the Maduru Oya basin are unreliable for flood analysis due to the lack of flow measurements at high stages, and due to overbank flows which occur at Welikanda at moderately high flows. The program of flow measurements now under way, combined with hydraulic calculations using topographic information now being collected, will permit studies using unit hydrograph methods of the flooding situation under present conditions. The area found to be subject to inundation will be compared with high water marks observed along the Polonnaruwa - Valachchenai Road during the November 23 - 24, 1978 cyclone. These marks have been marked with paint and surveyors working in the area in the 1979 field season will record their levels on the 1: 5000 maps which will be produced as a result of their field work.

The flood regime under future conditions (with the Maduru Oya Dam built) will be examined by routing observed and simulated extreme floods through the reservoir, and combining the routed floods with observed or computed flood flows originating from the uncontrolled

* by CECB, mainly using a regression relationship with flows observed at Welikanda.

TABLE 6 - 18

OBSERVED AND ESTIMATED FLOWS
AT MADURU OYA DAMSITE

units?

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
44/45	10.4	74.9	37.4	13.4	2.8	9.1	2.8	1.7	1.4	1.0	0.9	0.7	156.5
45/46	14.1	110.1	47.5	55.8	49.8	35.9	33.7	17.8	2.9	2.5	1.9	1.5	376.5
46/47	13.6	37.3	108.0	193.9	20.7	14.1	14.8	6.6	2.2	0.7	2.2	0.0	424.2
47/48	3.0	0.7	70.3	69.6	11.8	4.4	14.0	11.8	0.5	0.0	0.0	0.0	186.3
48/49	3.7	20.0	90.3	98.4	12.6	7.4	12.3	5.2	0.2		8.1	1.5	257.8
49/50	1.5	17.8	150.2	71.0	22.9	59.2	7.4	9.6	0.9	0.0	0.0	0.0	340.6
50/51	8.1	7.4	17.0	333.3	1.5	10.4	8.8	3.7	5.9	3.7	3.0	3.0	404.8
51/52	3.0	53.2	56.2	159.1	37.0	7.4	9.6	9.6	4.4	3.7	0.0	0.0	343.4
52/53	1.0	22.1	9.7	71.7	12.2	26.6	49.7	7.5	1.8	12.1	3.1	7.0	224.6
53/54	25.5	22.2	59.0	98.6	103.8	24.3	13.2	11.6	2.2	0.1	2.1	0.2	363.0
54/55	2.2	6.8	85.0	134.3	76.2	18.1	17.2	15.5	2.2	0.8	11.0	11.7	381.2
55/56	5.8	6.3	12.3	35.3	8.6	6.5	1.7	0.1	1.7		1.0	0.1	79.2
56/57	8.4	24.2	54.0	58.6	106.9	13.8	3.0	3.5	0.1	0	0	0	272.5
57/58	0.0	78.5	690.8	92.5	36.3	9.6	16.3	9.6	0.7	0.0	0.7	0.0	854.1
58/59	1.5	10.4	51.8	28.9	7.4	1.5	7.4	3.7	0.7	0.0	0.0	0.0	113.2
59/60	5.9	26.6	81.4	97.7	273.8	26.6	24.4	20.0	10.1	6.4	3.6	1.6	518.2
60/61	37.7	17.4	99.2	56.2	12.6	13.3	21.5	3.7	0.7	6.2	3.8	2.2	274.2
61/62	1.4	179.5	145.6	43.4	21.5	18.0	15.3	12.8	10.0	7.3	6.2	5.3	466.1
62/63	5.4	40.8	69.6	111.0	59.2	20.0	18.5	35.5	5.9	5.2	1.5	3.2	383.9

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
63/64	4.2	118.3	131.0	102.0	67.7	22.3	18.9	15.2	11.3	8.3	5.7	3.5	508.1
64/65	3.3	4.2	40.0	23.7	88.9	14.8	25.2	14.8	4.4	3.0	11.8	3.7	237.8
65/66	5.2	71.0	90.0	66.6	38.5	35.5	16.3	14.1	3.7	0.7	15.3	6.7	362.5
66/67	46.6	94.0	42.2	62.9	45.1	31.0	11.8	6.6	3.0	0.7	0.7	4.6	349.3
67/68	14.1	125.1	142.1	82.1	15.5	22.2	12.6	6.7	4.4	0.7		6.7	432.2
68/69	10.4	34.8	44.4	68.8	48.1	9.6	22.0	8.9	2.2	0.7	5.2	3.0	258.3
69/70	25.2	37.7	231.6	139.9	98.4	25.2	0.7	30.0	8.9	0.0	0.0	10.4	607.6
70/71	17.0	19.2	84.4	114.7	22.0	26.7	25.2	20.7	13.3	14.8	14.8	16.3	386.3
71/72	28.9	3.9	94.5	3.0	5.9	4.4	7.4	8.9	1.5	0.7	0.7	0.7	160.6
72/73	63.6	168.0	317.5	38.5	18.5	5.2	2.2	3.0	8.1	6.7	2.2	6.8	640.2
73/74	35.5	87.3	244.0	85.9	20.7	11.1	10.4	45.8	4.4	2.2	1.5	15.5	563.9
74/75	6.7	3.7	82.1	74.0	30.3	72.5	12.6	3.7	0.7	3.7	18.7	0.7	309.4
75/76	0.7	20.7	348.6	349.3	28.9	3.7	9.6	5.2	0.7	1.5	1.5	0.7	771.2
76/77	0.7	27.4	71.0	22.2	3.7	4.4	1.5	2.2	2.2	2.2	0.7	1.5	139.9

Notes: From 52/53 to 56/57 Observed Flows at Maduru Oya Damsite.

Missing data are estimated using a correlation relationship established with the records at Welikanda.

Source - CECB, "Maduru Oya Reservoir Project Report", Colombo, 1979.

portion of the catchment downstream from the dam. Maximum flood flows so computed will be converted to peak stages using information derived for unregulated conditions, thereby allowing a delineation of the flood-prone area under regulated conditions.

A preliminary examination of presently available flow records and the simulation program used by CECB to study the operation of the Maduru Oya Reservoir indicates that significant flood reduction will be attributable to the reservoir. The program uses monthly flows and can be itself only serve as a general indicator of the reduction of downstream flood peaks. However, it does show that the most years the flow volume during the month of maximum flow at Welikanda would have been reduced to 40 to 50 per cent of its observed magnitude if the dam had been in place. This is consistent with the proportion of the drainage area at Welikanda controlled by the dam (47 per cent), and will probably be reflected in the more detailed analysis of daily peak flows yet to be done.

6.3 - Reservoir Operation Studies

Both CECB and NEDECO have conducted reservoir operation studies to determine the optimum combination of dam height, link tunnel capacity and Minipe Right Bank Canal capacity. These studies have been carried out with two different simulation programs with different structures and covering slightly different hydrological periods. They have used irrigation demands for System B computed by NEDECO and the Land Use Division of the Irrigation Department, using cropping patterns which differ from that proposed in this report. Table 6-19 summarizes the key characteristics of the two models.

The variables to be studied have th following interrelationships for a given level of System B irrigation demand:

- As Minipe Right Bank Canal capacity increases, diversion through the link tunnel becomes possible in more months of the year, since more water can be delivered in months of high System C demand. This allows the link tunnel capacity to be reduced.

TABLE 6 - 19

SUMMARY OF PROGRAM CHARACTERISTICS

Program Origin	Hydrological Period	Time Step	Shortage Allowed	Delivery Limitation	Ulhitiya[1] Storage
CECB	Oct. 1946 - Sept. 1976	1 month	None	Minipe RB Canal & Tunnel Cap'y	Not considered
HEDECO Runs 1,2	Jan. 1950 - Dec. 1977	1 month	15% 10%	Tunnel Cap'y Alone	Considered
HEDECO Runs 3,4	Jan. 1950 - Dec. 1977	1 month	None	Minipe RB Canal & Tunnel Cap'y	Considered

1. A shortage factor can be specified which permits the reduction of irrigation demands whenever reservoir levels are low. In practice, this results in a reduction in water delivery in most months of the simulation.

- As the link tunnel capacity increases, the maximum dam height can be decreased, and vice versa.
- As the dam height, link tunnel capacity or Minipe Right Bank Canal capacity increases, the frequency of irrigation water shortage decreases.

The ultimate objective of the reservoir studies should be to arrive at an optimum combination of the three variables, while allowing a reasonable margin of additional capacity for increased irrigation demands. Owing to the preliminary nature of the irrigation system design and cropping pattern proposed herein, the calculated irrigation demands must also be regarded as preliminary. The simulation studies done to date have therefore been examined to assess the nature of these relationships and to determine whether the presently planned dam height, tunnel capacity and Minipe Right Bank Canal capacity constitute a limitation on irrigation development in System B. The average monthly irrigation demands used as input for the simulation studies as calculated by NEDECO and the Land Use Division (LUD) are summarized in Table 6-20, along with the demands computed for this study. The latter demands are about 11 per cent lower than those computed by NEDECO, and about 25 per cent lower than those calculated by LUD. The simulation runs which NEDECO made in 1978 with their demands, however, allowed a 15 per cent reduction in the demands to be simulated in almost every month, resulting in simulated demands which were somewhat lower than the Acres demands. It is these simulated demands which can be used to indicate the demand which can be met over the simulation period. Table 6-20 includes estimates of the monthly demands actually simulated in the NEDECO runs quoted here.

The NEDECO program was used to examine a number of combinations of possible tunnel capacities and Maduru Oya dam heights. The results, which are quoted in CECB's February 1979 report[5] indicate that the optimum combination is a tunnel capacity of 26 m^3/Sec and a Full Supply Level (FSL) of 97.5 m. This condition is represented by Run No.2 on Table 6-21. A comparison of the irrigation demands actually simulated in this run with Acres calculated demands (Table 6-20) indicates that Acres demands

TABLE 6-20

SUMMARY OF GROSS IRRIGATION WATER REQUIREMENTS /

Source	Monthly Average Demand (10^6 m^3)												Summary (10^6 m^3)		
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Yala (Apr-Sep)	Maha (Oct-Mar)	Annual Total
HEDECO	51	67	10	80	182	192	171	15	1	89	67	26	641	310	951
HEDECO Run 1	49	63	9	70	156	163	148	13	1	77	60	24	551	282	833
IWD Run C-11	57	108	75	32	113	198	214	116	39	47	69	57	712	413	1125
IWD Run 2	---------- Detailed printout not available ----------												641*	397*	1038
IWD Run 3	50	95	66	28	99	174	188	102	34	41	61	50	625	363	988
IWD Run 4	52	99	69	29	104	183	198	107	36	43	64	52	657	379	1036
HEDECO Run 5	16	21	3	24	55	58	51	5	0	28	21	8	192	97	289
ACRES	44	53	31	101	163	197	133	5	11	70	26	10	610	234	844

* Estimated

TABLE 6-21

SUMMARY OF SIMULATION RUN RESULTS

Run No.	Program Origin	Input Parameters					Simulation Results			
		Minipe RB Canal Cap'y m^3/sec	Ulhitiya-Maduru Oya Tunnel Cap'y m^3/sec	Maduru Oya Full Supply Level (m)	Irrigation Demands: Calculated By	Irrigation Demands: Annual Volume (10^6 m^3)	Avg. Annual Irrig. Delivery (10^6 m^3)	No. of Shortages: Months of Total	No. of Shortages: Years of Total	Avg. Ann Spill Volume (10^6 m^3)
1	NEDECO	NC[3]	24	97.5	NEDECO	951	833	0	0	106
2	NEDECO	60	26	97.5	LUD	1125	1038	0	0	33
3	NEDECO	NC[3]	30	97.5	LUD	988[1]	988	0	0	251
4	NEDECO	NC[3]	34	97.5	LUD	1036[1]	1036	0	0	292
5	NEDECO	NC[3]	0	97.5	NEDECO	300[1]	289	0	0	64
6	CECB	57	28	97.5	LUD	1125	1082	25/360	13/30	63
7	CECB	57	31	97.5	LUD	1125	1106	14/360	9/30	102
8	CECB	57	34	97.5	LUD	1125	1117	5/360	3/30	145
9	CECB	62	28	97.5	LUD	1125	1065	29/360	17/30	62
10	CECB	62	31	97.5	LUD	1125	1120	4/360	2/30	123
11	CECB	62	34	97.5	LUD	1125	1125	0	0	180

Notes: 1. Reduced by a constant percentage in each month until an acceptable level of failure is achieved.

2. Note: NEDECO runs consider the effect of storage in Ulhitiya-Ratkinda reservoirs.

3. Not calculated.

would also have been satisfied by this combination of tunnel capacity and FSL.

The first NEDECO runs were based on the assumption that any demand made on the Mahaweli at Minipe could be met. Further runs were executed by NEDECO (Runs 3 and 4) and CECB (Runs 6-11) considering limitations in the supply at Minipe imposed by upstream regulation and System C demands. These runs indicate that a tunnel capacity of about 30 m^3/Sec would be needed to provide in all years the irrigation requirements. calculated by Acres, and about 34 m^3/Sec would be needed to provide the full LUD requirements.

It can be concluded from these studies, therefore, that the tunnel capacity of 34 m^3/Sec which has been chosen to allow detailed design to proceed does not appear to impose a restriction on the development of System B for irrigation. An increase of about 33 per cent over the demands calculated for this report could still be fulfilled with the tunnel capacity now planned. In view of the uncertainty surrounding the water requirements computed by Acres, and the possibility of actual water requirements exceeding those computed, it is justified to proceed with detailed design of the tunnel using this design capacity.

7 - DESCRIPTION OF HEADWORKS

The design of the headworks has now been carried to an advanced stage. Tender Documents for the dam and link tunnel are to be completed by May 31, 1979, and it is planned to award the contract for construction of both by the end of 1979. Construction is scheduled to begin in early 1980. The design of the dam and associated works has been carried out by the Central Engineering Consultancy Bureau (CECB), while the design of the link tunnel has been the responsibility of Acres since September, 1978. CECB's report of February 1979[6] describes in detail the studies which led to the selected dam designs. This report therefore presents only a summary of the CECB designs, but presents the design features of the link tunnel known at the time of writing in considerably more detail.

7.1 - Dam and Associated Works

CECB's February 1979 report presents three alternative types of dam - earthfill, rockfill and concrete gravity. Cost analyses indicate that a concrete gravity dam would be the cheapest alternative, and an earthfill dam would be more expensive and present more difficulties during construction. At a meeting of the CIDA Engineering Review Board[7] held in February 1979 in Grenoble, France, it was decided to prepare Tender Documents for both the rockfill and concrete gravity dams. This decision was taken because the Review Board felt that the technical and cost advantages of neither type of dam was clear. The type of dam could be chosen on the basis of the bids received.

Figures 6 and 7 show the layout and typical sections of the principal features of the concrete gravity and rockfill dams. Not shown are one low earthfill saddle dam on the right bank of the reservoir, some 3 km from the dam, and another two saddle dams on the left bank, some 2 km from the damsite. The left bank powerhouse is incorporated into one of these saddle dams.

The design characteristics[6] of the elements which are common to both alternatives are as follows:*

* The design characteristics shown are based on a dam having a maximum operating level of 97.5 m. The recent decision to lower the dam by 2.0 metres in recognition of the additional reservoir storage volume revealed by recently completed topographic mapping is reflected only in the final cost estimate given in Chapter 10.

Hydrology

Average annual natural inflow	385 million m^3
Average annual augmented inflow (with link tunnel capacity of 34 m^3/sec)	1121 million m^3
Maximum observed discharge	382 m^3/sec
Maximum Probable Flood	4270 m^3/sec
River Diversion Flood (100 years)	2038 m^3/sec

Reservoir

Full Reservoir Elevation (FRE)	97.5 m
Minimum Operating Level	85.0 m
Gross Storage to FRE	515.0 million m^3
Live Storage Capacity	457.0 million m^3

Saddle Dams

Two minor saddle dams on the left and right banks of the reservoir closed by small dykes having lengths of 60 and 300 m respectively.

Left Bank Outlet Works

The powerhouse, which is incorporated into an additional earthfill saddle dam, is located about 2.8 km northwest of the damsite. An irrigation bypass with stilling basin is provided. The key design parameters are as follows:

Design Water Elevations:	Maximum Operating Headwater	: 97.5 m
	Minimum Operating Headwater	: 87.0 m
	Maximum Tailwater	: 77.7 m
	Minimum Tailwater	: 76.5 m
	Maximum Net Head	: 19.3 m
	Minimum Net Head	: 9.0 m
	Rated Head	: 15.5 m
Discharge Capacity :	Powerhouse - Rated Capacity - 42.0 m^3/sec	
	Irrigation Bypass - 49.5 m^3/sec.	

Turbines: Two - Vertical shaft, Kaplan type turbines, rated head = 15.5 m
Rated speed = 250RPM. Power per unit, rated head = 3.25 MW

7.1.1 - Concrete Dam Alternative

A straight gravity dam of maximum height 41.8 m and crest length 1050 m is proposed at a location slightly upstream of an ancient bund. Figure 7 shows the general layout and a typical section of this alternative. The right bank powerhouse is incorporated into the downstream toe of the dam. The principal design parameters of the concrete dam are as follows:

Dam

Type	-	Concrete gravity dam
Crest Elevation	-	101.75 m
Principal dimensions:		Length along crest - 1050 m
		Maximum height above foundation - 41.75 m

Spillway

Type - overflow, incorporated into the dam

Crest Elevation - 97.5 m

Length - 257.0 m

Maximum Flood Conditions - Discharge - 2240 m^3/sec

- Flood lift - 2.70 m

Right Bank Outlet Works

Location - Right side of the dam, with powerhouse located at the downstream toe.

Contents - Intake conduit (through the dam), penstock, powerhouse with irrigation bypass and stilling basin

Design Water Elevation: As for Left Bank Outlet Works

Discharge Capacity: Powerhouse - Rated Capacity - 21.0 m^3/sec

Irrigation Bypass - Maximum Capacity 35.4 m^3/sec

Turbine: - One vertical shaft, Kaplan type turbine, rated head = 15.5 m rated speed = 250 RPM. Power at rated head = 3.25 MW

7.1.2 - Rockfill Dam Alternative

A central core rockfill dam of maximum height 41.5 metres and crest length 1020 metres is proposed for the same location as for the concrete gravity dam. Figure 8 shows the general layout and a typical

section for this alternative. The right bank powerhouse will be constructed at the downstream side of the right abutment, with a pressure tunnel excavated through the abutment conducting the water to the powerhouse. The spillway is a gated chute spill type, and is located in the left abutment of the dam. Rock excavated for the spillway will provide the material for the dam. The principal design parameters of the rockfill dam are as follows:

Dam

Type - Rockfill dam with central core

Crest Elevation - 102.5 m

Principal Dimensions - Length along crest - 1020 m

Maximum height above foundation - 41.5 m

Spillway

Type - Gated chute spill, located on the left abutment.

Crest Elevation - 90.0 m

Length - 27.0 m - 3 gates 9.0 m x 7.5 m

Maximum Flood Conditions - Discharge - 1720 m^3/sec

- Flood lift (above 97.50 m) - 1.9 m

Right Bank Outlet Works

Location - Right abutment

Contents - Intake pressure tunnel, surge chamber, penstock, powerhouse with irrigation bypass and stilling basin.

Design Water Elevations: As for Left Bank Outlet Works

Discharge Capacity: As for concrete dam

Turbine: As for concrete dam.

7.2 - Link Tunnel

The link tunnel allows the diversion of water from the Ratkinda Oya Reservoir to the Maduru Oya Reservoir. Water is conveyed to Ratkinda Oya Reservoir via the Minipe Right Bank Canal and Ulhitiya Oya Reservoir, from the main stem of the Mahaweli Ganga at Minipe.

7.2.1 - Hydraulic Aspects

Studies to determine the tunnel's hydraulic capacity have been carried out, and are summarized in Section 6.3. Controlling upstream and downstream water levels are determined by the operating limits of the Ratkinda Oya reservoir (upstream) and Maduru Oya

reservoir (downstream). The condition used for hydraulic design has been the simultaneous occurrence of minimum operating level in Ratkinda Reservoir. The reasons for this decision are threefold:

1. Simulation studies show that the Maduru Oya reservoir can be expected to be at maximum level for from one to six months in every year. Ratkinda Oya reservoir is expected to operate within a narrow range of levels, and the monthly variations will depend heavily on the System C demands. Thus the probability of the coincidence of the critical levels is difficult to assess until the System C demands are known with more accuracy, and until simulation studies which expressly consider the Ratkinda Reservoir levels have been completed.

2. The bed of Vila Oya at the outlet of the tunnel is at an elevation of 94.0 metres. The hydraulic limitations imposed by the channel dimensions, slope and elevation will therefore limit the minimum water level at the tunnel outlet to a relatively high level.

3. For the gate dimensions chosen, discharge is "free" (no submergence) and thus the water level in Vila Oya will not affect the tunnel flow. The minimum upstream level is thus the controlling factor.

In summary, the hydraulic design criteria for the link tunnel are as follows:

<u>Upstream Conditions</u> (Ratkinda Oya Reservoir)

Flood Level	-	107.25 m
Maximum Operating Level	-	106.68 m
Minimum Operating Level	-	104.42 m
<u>Tunnel Capacity</u>	-	34 m^3/sec

<u>Downstream Conditions</u> (Maduru Oya Reservoir)

Flood Level	-	100.2 m
Maximum Operating Level (Reservoir)	-	95.5 m*

* Late March, 1979 decision to drop maximum reservoir level from 97.5 to 95.5 m.

The hydraulic design of the tunnel was undertaken to determine the size of the tunnel required to pass a flow of 34 m^3/sec with an upstream reservoir level of 104.42 m and a downstream level of 95.5 m. Consideration was given to lining the tunnel for hydraulic reasons, although full lining is not required for structural reasons (see Section 7.2.3). Table 7-1 summarizes the assumptions used in the calculations and the tunnel diameters selected for each of the four lining conditions considered. The assumed tunnel cross-section is the "straight-legged horseshoe"type.

Two control conditions are possible with this tunnel - upstream control, resulting in free flow (atmospheric pressure) through the tunnel, and downstream control, resulting in pressure flow.

The upstream control option has the following features:

- The tunnel invert must be kept at "grade" to maintain free flow conditions.
- Gravity dewatering for inspection is possible.
- Only one major structure, at the inlet, is required.
- Careful control of the gates is necessary to maintain free flow conditions. A sudden rise in upstream reservoir level, without an attendant reduction in gate opening, would result in sudden transition from partly full to full flow. Structural damage is possible from such a condition.
- No surcharge of tunnel capacity is possible under high head conditions.

The downstream control option has the following features:

- The tunnel invert can be dropped to avoid poor rock.
- Gravity dewatering of the tunnel for inspection is not possible if the invert is dropped.
- Stoplog slots and trashracks are required at the inlet portal, and a control structure with gates and stoplog slots is required at the outlet.
- Consideration must be given to hydrostatic pressure over the length of the tunnel, particularly near the outlet.
- Control gates do not require frequent adjustment.
- Additional discharge capacity is available under high head conditions.

TABLE 7-1

SUMMARY OF HYDRAULIC DESIGN OF LINK TUNNEL

TUNNEL TYPE	LINING CONDITION	DESIGN CONDITIONS					DESIGN RESULTS	
		WATER LEVELS (M)				MANNING'S N	GATES	
		UPSTREAM MINIMUM	DOWNSTREAM MAXIMUM	UPSTREAM MAXIMUM[1]	DOWN-STREAM MINIMUM[2]		NUMBER, SIZE, TYPE	DIAMETER[3]
Free Flow	Unlined	104.42	97.5[4]	106.68		.029	2 - Vertical Lift	6.0
Pressure Flow	Unlined	104.42	97.5[4]	106.68		.029	1 - Vertical Lift	5.5
	Shotcrete	104.42	97.5[4]	106.68		.023	1 - Vertical Lift	5.0
	Lined	104.42	97.5[4]	106.68		.016	1 - Vertical Lift	4.5
	Invert Paved	104.42	97.5[4]	106.68		.026	1 - Vertical Lift	5.1

1. When Maduru Oya Reservoir is at FSL = 95.5 m.
2. When Maduru Oya Reservoir is below 94.0 m.
3. For unlined tunnel, D = mean driven diameter
   For shotcrete lined tunnel, D = Diameter before application
   For concrete lined tunnel, D = inside diameter.
4. Does not reflect recent decision to lower dam height by 2.0 metres.

7.2.2 - Topographic and Geological Aspects

Figure 8 shows the link tunnel area in plan, while Figures 9 and 10 show the topographic and geological conditions which affect its design. The areas near the inlet and outlet portals are characterized by gently rolling topography. Overburden consists of a one to two metre thick layer of clayey silty sand. Bedrock, consisting primarily of precambrian granitic gneiss, is exposed sporadically in the portal areas. Near the outlet a dolerite dike cuts across the alternative alignments. The bedrock is heavily weathered, up to a depth of 10 metres in some areas.

A program of geophysical and geological surveys was undertaken to examine the geological conditions along the proposed tunnel alignment. Geophysical surveys were run along the length of the tunnel trace proposed by Acres in September 1978, along a minor deviation from this trace, and along three transverse lines in the outlet channel area. In addition, surveys were run in the inlet areas of the trace proposed by CECB.

Drilling of twelve boreholes (see Figure 8 for their locations) to the proposed tunnel invert was carried out by Irrigation Department crews. Most of the holes were drilled in the inlet and outlet areas, to confirm geophysical information on the unweathered bedrock profile. Laboratory tests were run on selected core samples.

Overburden characteristics were examined by digging test pits and test trenches in the inlet and outlet areas and conducting laboratory and field tests. These tests aimed at assessing slope stability and permeability characteristics in the proposed open cut sections.

The exploration program allowed the following conclusions to be reached:

- The geophysical profiles can be considered reliable, as very good agreement was observed between borehole logs and the geophysical data.
- The Rock Quality Designation (RQD) of the unweathered bedrock is "Good" to "excellent". The permeability of the rock is practically zero.

- The following slopes can be assumed to be stable:

Sound fresh rock	:	1 H to 6 V
Weathered rock	:	2 H to 1 V
Clay	:	2.5 H to 1 V

- The rock in the vicinity of the dolerite dike has been heavily fractured and jointed. This zone, about 210 metres wide, is considered a poor quality zone and will require full concrete lining with steel ribs for added support.
- With the above exception, no zones of poor rock are known to exist along the favoured alignments. Support requirements over most of the tunnel length will therefore be minimal. Allowances should be made for pattern rock bolts in the tunnel roof over about 40 per cent of the tunnel, with additional support allowances for minor unforeseen weak zones.

7.2.3 - Alternatives Considered

A total of nine alternative tunnel configurations on three different alignments (Figure 8) were considered before arriving at a final design. These alternatives, the characteristics of which are summarized in Table 7-2, were:

Pressure Tunnel

The pressure tunnel variants all incorporated a dropped invert to allow most of the tunnel excavation to be done in sound bedrock. Six alternatives were considered:

1. The Acres Trace - basic alignment, with a relatively long outlet open cut.
2. The Acres Trace - basic alignment, with a relatively short outlet open cut.
3. The Acres Trace - deviated variant, with a relatively long outlet open cut.
4. The Acres Trace - deviated variant, with a relatively short outlet open cut.
5. The CECB Trace, with a relatively long outlet open cut.
6. The CECB Trace, with a relatively short outlet open cut.

TABLE 7-2

SUMMARY OF TUNNEL ALTERNATIVES

ALTERNATIVE NO.	ALIGNMENT	TUNNEL TYPE	LENGTHS (M) INLET OPEN CUT	TUNNEL	OUTLET OPEN CUT	TOTAL
1	Acres Basic	Pressure Flow	920	4740	1140	6800
2	Acres Basic	Pressure Flow	920	5730	150	6800
3	Acres Deviated	Pressure Flow	920	4800	1250	6970
4	Acres Deviated	Pressure Flow	920	5900	150	6970
5	CECB	Pressure Flow	500	5990	1400	7890
6	CECB	Pressure Flow	500	6540	850	7890
7	Acres Basic	Free Flow	1870	3780	1150	6800
8	Acres Deviated	Free Flow	1870	3350	1750	6970
9	CECB	Free Flow	500	5570	1820	7890

Free Flow Tunnel

The free flow alternatives have a higher invert level over most of their lengths than do the pressure flow variants, to allow free flow conditions to be maintained. Three alternatives were considered:

1. The Acres Trace - basic alignment.
2. The Acres Trace - deviated variant.
3. The CECB Trace.

The hydraulic features of the pressure flow and free flow alternatives have been discussed in Section 7.2.1. Structurally, the pressure flow alternatives offer significant cost advantages in that most of the tunnelling can be carried out in good quality rock, making lining unnecessary. This is clearly illustrated by the geological profile in Figure 10. However, the free flow alternatives can be inspected more easily, since their higher inverts allow the tunnel to be drained by gravity. The pressure flow alternatives must be dewatered by pumping.
For the pressure tunnel alternative, four versions of a tunnel along the alignment proposed by Acres were analysed. These alternatives aimed at testing the sensitivity of the tunnel's cost to measures taken to avoid the area of poor quality rock near the outlet. The economics of deep open cut excavation versus tunnelling in poor rock also influenced the outcome. The CECB trace was included for comparison, although its greater overall length (about one kilometre) made it less economical than most of the alternatives considered for the Acres trace. Table 7-3 summarizes the cost comparisons which resulted from the analysis of the nine alternatives*. The figures shown in Table 7-3 allow the following conclusions to be drawn.

1. The free flow alternative has large cost disadvantages and potential problems with deep open cuts which dictate the choice of a pressure flow tunnel.

* Not shown in Table 7-2 are cost comparisons which clearly indicate that an unlined tunnel 5.5 metres in diameter is less costly and can be constructed more quickly than a 4.5 metre diameter concrete lined tunnel or a 5.0 metre diameter shotcrete lined tunnel.

TABLE 7-3

COMPARISON OF TUNNEL COSTS (MILLION RUPEES)*

	ALTERNATIVE NUMBER								
	PRESSURE FLOW						FREE FLOW		
	1	2	3	4	5	6	7	8	9
Inlet and Outlet Channels									
Common Excavation, Clearing	8.2	3.6	8.5	3.6	8.1	5.8	11.6	14.2	10.0
Weathered Rock Excavation	21.0	2.4	28.7	2.4	14.2	6.0	29.6	53.6	21.5
Rock Excavation	29.8	10.5	33.5	10.5	24.2	8.6	41.1	61.5	27.8
Support and Slope Protection	5.9	1.5	8.0	1.5	4.6	1.3	9.4	14.7	7.7
Inlet Portal	1.4	1.4	1.4	1.4	1.4	1.4	3.1	3.1	3.1
Outlet Portal	4.1	4.1	4.1	4.1	4.1	4.1	0.3	0.3	0.3
Subtotal	70.4	23.5	84.2	23.5	56.6	27.2	95.1	147.4	70.4
Tunnel									
Rock Excavation	123.2	153.1	125.0	157.5	153.7	172.1	113.8	102.6	165.3
Rock Bolts, Mesh	7.4	8.4	7.5	8.7	8.7	9.5	6.2	5.6	8.5
Steel Supports and Lagging	5.1	15.6	5.1	15.6	15.6	15.6	5.7	5.7	5.7
Concrete Support	13.0	19.8	13.0	19.8	19.8	19.8	14.0	14.0	14.0
Grout, etc.	0.7	1.5	0.7	1.5	1.5	1.5	0.7	0.7	0.7
Subtotal	149.4	198.4	151.3	203.1	199.3	218.5	140.4	128.6	194.2
Mobilization	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Stream Diversion	2.6	1.3	2.6	1.3	2.6	1.3	3.9	5.2	2.6
Grand Total	228.9	229.7	244.6	234.4	265.0	253.5	245.9	287.7	273.7

* March 1979 costs. Excludes contingencies, escalation, camps, engineering and site management.

2. One of the four pressure flow variants along the Acres Trace will be the most economical.

3. The cost difference between the long and short open cut alternatives is minor.

4. Due to anticipated slope stability problems in the outlet area, the short open cut version of the Acres Trace (Alternative 2) is preferable.

7.2.4 - Tunnel Characteristics

The selected design is shown in Figure 9 and 10. The design characteristics are as follows:

Inlet Open Cut

- Open channel 920 metres in length. Maximum depth of cut 14 metres.
- Flood flows from creeks which cross the open cut alignment will be handled using low weirs with upstream sediment/debris traps, and armoured outlet channels.
- A sediment trap will be located near the end of the open cut section.

Inlet Portal

- Concrete structure with trashracks and slots for concrete stoplogs.
- Cleaning of trashracks will be by hand. The top of the trashrack opening is located two metres below the minimum operating level to prevent clogging with floating debris.
- Space is provided for a mobile crane to place stoplogs and remove heavy debris.

Tunnel

- Capacity is 34 m^3/sec under minimum operating head conditions. Capacity under maximum operating head conditions is about 40 m^3/sec.
- Diameter is 5.1 metres, with paved invert. Section is straight-legged horseshoe type.

8 - IRRIGATION AND DRAINAGE

8.1 - Review of Canal System Design to Date

A preliminary layout of the main canal system has been prepared by M.D.B. engineers. Both lined and unlined typical cross-sections for the Left Bank canal have been designed. The design of some major structures is at an advanced stage, but to date little work has been done on the minor structures or drainage system.

The preliminary main canal designs cannot proceed to a more detailed stage until a great deal more basic data are available. Gross water requirements for the project have not yet been finalised and detailed identification of the areas to be irrigated has not yet been possible.

No geotechnical information is available for the main and branch canal routes. It is expected that Irrigation Department teams will shortly carry out the following programme of test pit excavations at 1 km. intervals along the proposed canal route. For each test pit site, the following tests will be carried out:

1. Particle size analysis of sample from 50 cm and 150 cm depth.
2. Shear tests on undisturbed samples from the same depths.
3. Laboratory permeability tests on undisturbed samples from the same depths.
4. An in-situ field permeability test.
5. An infiltration test at the surface, about 5 m away from the pit.
6. An auger hole will be sunk in the pit bottom to canal bed level or bedrock.

The results of this soils testing programme are essential to assess accurately the need for lining of canals and to determine slope stability criteria. In addition, these tests will indicate the amount of rock excavation required. As rock excavation costs are approximately five times those of soft earth excavation, there will be strong economic arguements for adjusting the canal routes to minimize rock excavation. A programme of geophysical soundings will probably be required at a later stage to establish the bedrock profile in critical areas.

Many of the soils in the project area are highly erodible, and care must be taken in selecting the maximum permissible velocity in unlined canals. A design velocity of 0.6 m/s is recommended for the sandy soils, such as Non Calcic Brown soils. In the larger canals, this leads to canals needing shallow slopes with frequent drop structures, or steeper slopes with depths of less than one metre. The former alternative increases canal costs, while the latter causes maximum seepage and evaporation losses. Lining the main canals will allow smaller sections to be used, with steeper bed slopes. Very high velocities, up to 3 m/s, can be used. However, canals with such high velocities are very dangerous to people and animals that fall in them. The sides of lined canals are usually smooth and make escape from the canal difficult. If high velocities are used in lined sections, the canal must be fenced to prevent access by people or animals. If fencing is not considered socially acceptable it is recommended that velocities in lined sections should not exceed 1.5 m/s.

Because of the above factors and potentially high losses from unlined canals, the preliminary estimates of main canal costs contained in Chapter 10 are based on the assumption that all main canals and major branch canals will be lined with concrete. The hydraulic calculations have been based on a maximum velocity of 1.5 m/sec.

8.2 - Tertiary Supply Systems

There is a wide variation in the soil types encountered in the System B project area and consequently irrigation techniques will vary from one soil type to another. For the lowland areas which contain a large proportion of the Low Humic Gley (LHG) and Old Alluvial (OAL) soils it is proposed to grow two crops of paddy rice per year. The standard farm allotment will be 1 ha and a typical layout of a tertiary supply area can be seen in Figure 13. This layout is diagrammatic and canal, drain and farm boundaries will need to be adjusted in the field to suit topography. It has been assumed that a field channel will supply a 20 ha block. Maximum field irrigation requirement is 315 mm in May, if effective rainfall is discounted. The field channel has been sized to supply 50 mm of water to the 20 ha block over 24 hours. It is recommended that inflow to and outflow from the fields be controlled by gates and that water should only flow into the field channel once every

five days for 24 hours on a rotational basis. For this system to function efficiently, it is essential to have a high degree of management and discipline.

On the intermediate finegrained soils, the farm layout will be similar to that of the lowland areas, except that rice will only be grown in the Maha season. In the Yala season, either groundnuts or soyabeans will be grown and the fields prepared to allow a border strip type of irrigation to be carried out. The intermediate soils have higher percolation rates than the lowland soils and it is possible that water will be required more frequently than on the lowland soils. On the coarse textured Intermediate soils, it is anticipated that supplementary irrigation of Maha crops (groundnuts, tobacco and cassava) will be possible using surface methods. This must be confirmed by pilot farm trials.

On the upland soils, infiltration rates are very high and it has been assumed that surface irrigation will not be practically possible. It has been assumed therefore that sprinkler irrigation techniques will be used. There is also some doubt as to the practicality of using sprinkler techniques because of expected high wind velocities. However, there is evidence that wind velocities at night are much lower than in daytime and that effective sprinkler irrigation at night would be possible. The technical feasibility of using sprinkler irrigation is one of the problems which needs to be assessed by pilot farm trials before a final commitment is made.

A typical upland layout is shown in Figure 14. A spacing of 18 m between lateral positions and 18 m between sprinklers along the lateral has been assumed. A medium pressure system (nozzles operating at 2.8 kg/cms (40 p.s.i.) can apply 24 mm in 12 hours. The maximum field irrigation requirement is 241 mm for the month of June, or 8 mm/day. Thus the lateral can be operated in one position for 12 hours every three days. With the layout shown, one hydrant can serve six positions and thus one lateral can serve two-1 ha plots if irrigation is carried out both day and night. Water for irrigation would be pumped from a branch canal into a buried PVC pressure main upon which the hydrants would be mounted. The sprinkler laterals would be 100 mm diameter and made of aluminium.

8.3 - Drainage Requirements

Drainage is a considerable problem at present in the System B area. Although many of the intermediate soils are inherently free draining, their drainage is poor or impeded due to the local surface and

subsurface topography. Many of the intermediate areas are waterlogged during the Maha season and dry out during the Yala season. This leads to a build-up of salinity in some areas. It is essential therefore than an effective drainage system be constructed.

The principal purpose of the field drainage system in System B is to control the water table level. To have an adequate free draining zone, drains of 50 cm depth are recommended. In Figures 13 and 14, field drains are shown at approximately 400 m spacing and each serving an area of 20 ha. In addition to their role in controlling the water table, these drains with a maximum velocity of 0.6 m/s would be able to carry a storm water runoff duty of 15 l/sec per ha.*

The design of the main drainage system requires detailed topographic mapping which has not yet become available. It is proposed to design the main system and reliably estimate costs for the Feasibility Report. The costs estimated for this report and reported in Chapter 10 are therefore to be regarded as preliminary only.

8.4 - Water Management

Rice has been grown on organized irrigation schemes in Sri Lanka for over 2000 years. Methods of cultivation and water management have evolved over a long period and a concerted management effort will be needed to change traditional methods.

One of the major problems on existing irrigation schemes is excessive water use. Most farmers regard the use of water as a right and do not attach any value to water as a scarce resource. As a result, farmers try to keep water flowing through their paddy fields while maintaining sufficient depth of water to control weeds and to provide insurance against the occasional inability of the system to provide water.

To make the best possible use of water which has been transported at considerable expense to System B, a more positive management approach will be needed. This approach should incorporate rotational irrigation as the delivery method but with strong management at all levels. At the upper level, project management personnel must organize the distribution of water to the major groups of users in a way that assures the users of reliability of supply. At the field level, farmers must organize themselves into formal or informal user groups to ensure the fair sharing of water among individual farmers.

* NEDECO recommends 9.0 l/sec per ha on lowlands and 10.0 l/sec per ha on uplands.

In addition to the problems of introducing rotational irrigation, many of the areas in System B consist of soils which have never been irrigated before in Sri Lanka. On the free draining upland soils it is proposed to introduce sprinkler irrigation. If this technique is to be used by smallholder farmers, a very high level of training, maintenance and management is required. In order to prove these techniques to the farmers it is necessary to have a pilot demonstration farm where the new techniques can be developed to suit local conditions. It is essential that farmers undergo some form of training before operating sprinkler equipment. In addition, the operation of sprinkler equipment will require a substantial support organization for maintenance and supply of spare parts.

9 - ENVIRONMENTAL ASPECTS OF THE PROJECT

Major changes in land and water use are proposed in the Mahaweli Development Programme. Areas which are now either sparsely settled or are tree-covered will be brought under intensive irrigated cultivation. Because of the possibility of unforeseen detrimental side-effects of the development detracting from the Project's benefits, and because of a desire on the Government's part to conserve, where possible, rare or endangered species of wildlife, the environmental aspects of the development require examination during the planning stage.

9.1 - Administrative Background

The Mahaweli Development Board has established an Environmental Panel to advise it on environmental issues affecting the Mahaweli Development Programme. This Panel consists of representatives of MDB, the National Science Council of Sri Lanka, the University of Sri Lanka, interested Government departments and ministries (Wildlife Conservation, Plan Implementation, Irrigation, Forestry, Fisheries) and a public interest group - the Wildlife and Nature Protection Society. The Panel is to provide specific advice to MDB on the following:[8]

1. Development planning of the Mahaweli Project with minimum adverse impact.
2. Conservation of soil, flora and fauna and provision of fuel wood plantations.
3. Environmental assessment and impact studies in the different systems.
4. Environmental monitoring.
5. Education of MDB Staff and settlers on environmental conservation.
6. Environmental legislation requirements.

An Environmental Assessment of the overall Mahaweli Development is to be co-ordinated by the Environmental Panel, with funding provided by the U.S. Agency for International Development (USAID)

This major study is to commence in April 1979 and is scheduled for completion in April 1980. It is intended that this Environmental Assessment will encompass more detailed investigations of broad issues than would be possible by the consultants studying the component systems, and will permit analysis of impacts on areas affected by more than one system - the lower Mahaweli, for example. However, since some environmental analysis is desirable as part of the planning process, the Terms of Reference of this study include a limited amount of environmental work.

9.2 - Principal Areas of Concern

The areas which will require attention during this study include:

Terrestrial Environment

1. Soil Conservation

   Care will be required to limit development in erosion-prone areas, and to follow clearing, grading and farming practices which will minimise erosion. Salinity build-up on new and existing cropped areas must be avoided through adoption of appropriate development patterns and land drainage practices.

2. Forest Utilization

   Forest conservation in erosion-prone areas, allocation of firewood reserves (including planting of fast maturing species) utilization of cleared timber and development of appropriate clearing methods will contribute to the goal of erosion control and to the economic viability of the Project.

3. Wildlife Conservation

   System B contains significant numbers of wild elephants, as well as deer, sambhur, bear, leopard, civets and other smaller animals. Attention has focussed on the elephants, due to their size and cultural significance and to the steady reduction in habitat which is taking place throughout Sri Lanka. A large forest reservation has been set aside in System B. One objective of providing this reservation is to provide wildlife habitat.

Aquatic Environment

1. Reservoir Ecology

The development of the fisheries potential of the reservoir will provide a valuable source of protein and income. An examination of the probable reservoir ecology will therefore be necessary.

2. Wetland Ecology

Existing wetlands and new perennial wetlands which will be created as a result of irrigation water application will be affected by nutrients and pesticides contained in agricultural runoff. The resulting adverse effects on the fish resource will depend on the type and concentrations of chemicals applied and hence on the type of crop grown in the drainage area. Other areas of concern include nuisance growths of aquatic weeds and the expansion of breeding grounds for insects, particularly disease vectors.

3. Public Health

The availability of adequate supplies of domestic water and the control of water-borne diseases will be important contributors to the quality of life within the project area. Breeding grounds suitable for disease vectors can be minimized through consideration of the problem during the design stage. An eradication program for malaria mosquitoes should be devised during this period and implementation begun at the time of construction.

10 - PROJECT COSTS

Studies of construction costs for the major project elements have been carried out. Since Acres is preparing Tender Documents for the Link Tunnel, first attention was directed at the major cost items for this part of the project. This enabled a selection of the most economical tunnel configuration to be made, as described in Section 7.2. The cost estimates prepared by CECB for the two possible types of dam (concrete gravity and rockfill) were next reviewed. Finally, the cost of the major elements of the downstream works (particularly the main canals) was reviewed, using the very preliminary information on the quantities involved.

In all cases, the approach taken was to establish local prices for construction materials, machinery, fuel, labour etc. This information was combined with assessments of probable rates of construction progress and labour and supervision requirements to arrive at direct costs for various activities. Indirect costs, such as administration, overhead and profit, were computed separately and added to obtain a combined total cost. The total cost for each major item was then divided by the quantity involved to arrive at a unit rate. These rates could then be used for different quantities in the same order of magnitude. For the dam and the link tunnel, cost estimates were based on the assumption that a Canadian contractor would undertake the work. For the downstream works, it was assumed that a local contractor would undertake the work. These two assumptions reflect current official thinking on the implementation stage of the project.

10.1 - Unit Prices

Unit prices used in the estimates have been developed from first principles - calculating quantities of work to be done, and selecting units of equipment appropriate to carry out the work with flexibility and which are suitable for other work on the project. Material costs were developed using basic prices plus a percentage for spoilage, transportation and material handling. Labour costs were calculated by estimating the number of manhours that will be required to complete a quantity of of work, taking into account the productivity of both expatriates and indigenous workers. Operating costs were calculated to include spare

parts, fuel and lubricants, while "consumables" included blasting powder, drill steel, wire stemming material, etc. Construction material costs included air ductwork, pipes, cement, reinforcing steel etc. Indirect costs included supervision, administration and contractors on field engineering. Vehicles for supervision, office equipment, insurance, financing and profit were also included in this category.

Table 10-1 summarizes the financial costs of materials "at source" used in the analysis, while Table 10-2 lists typical unit rates developed for use in the analysis.

10.2 - Cost of the Link Tunnel

The costs of the eight alternative tunnel configurations shown in Table 7-3 are influenced by the methodology of construction. Cost estimates for excavation of the link tunnel were made on the basis of the criteria outlined below.

Because of the nature of the rock, careful rock excavation at portals and a considerable distance from tunnel entrances will be necessary. For the purpose of the cost estimates, the following construction methods have been assumed:

- From tunnel entrances for the first 40 feet:
  Ten - 4 foot rounds consisting of line drilling six inches on centre. 4 x 4 foot Pilot Hole, 10 x 10 foot Pilot Drift, full face excavation.

- From 40 feet to 100 feet:
  Twelve - 5 foot rounds consisting of line drilling nine inches on centre. 4 x 4 foot Pilot Hole, 10 x 10 foot Pilot Drift, full face excavation.

- From 100 feet to 200 feet:
  Twenty - 5 foot rounds consisting of line drilling nine inches on centre (drilling 13 feet). 4 x 4 foot Pilot Hole, 10 x 10 foot Pilot Drift, full face excavation.

- From 200 feet to 300 feet:
  Ten - 10 foot rounds consisting of line drilling twelve inches on centre, full face excavation.

- From 300 feet from each tunnel entrance through the whole tunnel length:
  Ten foot rounds, full face excavation.

TABLE 10-1

FINANCIAL COSTS OF MATERIALS AT SOURCE

ITEM	UNIT	COST (RUPEES)
Diesel Fuel	Imperial Gallon	5.6
Blasting Agent	Pound	11.25
Detonator Caps	Each	6.0
Reinforcing Steel	Short Ton	5200
Cement	Bag of 42 kg	18.5
Sawn Timber	Cubic Foot	25.0

TABLE 10-2

MAJOR UNIT PRICES DEVELOPED FOR ESTIMATES

ITEM	DEVELOPED FOR	UNIT	PRICE (RUPEES)
1. Clearing	Link Tunnel	ha	13,000
	Dam	ha	7,800
	Main Canals	ha	7,800
2. Common Excavation	Link Tunnel Open Cuts	m^3	58.5
	Main Canals	m^3	32.1
3. Rock Excavation	Link Tunnel Open Cuts	m^3	247
	Link Tunnel	m^3	988
	Main Canals	m^3	260
4. Concrete	Link Tunnel Portals	m^3	3,120 - 5,200
	Link Tunnel Support	m^3	5,200
	Dam (180 kg cement)	m^3	663
	Dam (250 kg cement)	m^3	725
	Main Canal Lining	m^3	2,275
5. Rock Bolts	Length 2 metres	each	120
	Length 3 metres	each	150
	Length 5 metres	each	220

Rock bolting, concrete lining, and shotcreting to be carried out in all areas as considered necessary. Equipment is assumed to be suitable for standard tunnel rock drill and blasting methods, including a ten drill jumbo and mucking machines. The excavation will begin at the inlet portal and proceed for 300 feet. The excavation will continue at the outlet portal and proceed upstream to meet the inlet excavation. This will prevent damage to the rock at the inlet portal.

The work force will be a joint effort of foreign and local labour. Project manager down to lead hand drillers are assumed to be expatriates, while drillers, compressor and operating engineers, electricians, labourers, mechanics, etc. are assumed to be indigenous workers.

Similarly, the following criteria were used to estimate the cost of the open cut sections at the intake and outlet:

- Clearing - It is assumed that clearing of the open cut section be carried out using local labour intensive methods instead of machine clearing.
- Overburden excavation - Assumed to be carried out as a machine operation, using front end loaders as prime movers and trucks as haulage units. Hand trimming to bare rock and side slopes is assumed to be carried out by local hand labour. In water saturated areas, drag lines may have to be used until a drainage system other than pumping can be developed.
- Rock Excavation - Pre-splitting sides of open cut channels will be necessary to create smooth, stable rock walls. Closely-spaced holes along the required contour, charged with low-strength explosives, will be required. Standard trench blasting methods can then be used (wagon drills and crawler drills). The fragmented rock will be loaded and hauled for further processing - crushing, grinding and grading - to supply the basic materials for the concrete plant and graded rock fill for side slope protection.

It is estimated that, using the construction methods outlined above, the tunnel can be completed 30 months after mobilization.

The cost shown for the selected alternative in Table 7-3 is based on preliminary assumptions of tunnel diameter and on the assumption that the tunnel invert would be unpaved. Further refinements in the design, including the selection of a smaller diameter* and the decision to pave

* Resulting firstly from paving the invert and secondly from reducing the height of the dam and thus increasing the available head across the tunnel.

TABLE 10-3

COST BREAKDOWN FOR LINK TUNNEL

ITEM	COST (MILLION RUPEES)	
Open Cuts - Inlet 920 m, Outlet 150 m		
Common excavation, clearing	3.6	
Weathered rock excavation	2.4	
Rock excavation	10.5	
Support and slope protection	1.5	
Subtotal	18.0	18.0
Inlet Portal		1.4
Outlet Portal		4.1
Tunnel - 5730 metres		
Rock excavation	140.3	
Rock bolts and mesh	8.4	
Steel supports and lagging	15.0	
Concrete support	18.2	
Concrete invert	7.6	
Miscellaneous	1.5	
Subtotal	191.0	191.0
Mobilization		6.5
Stream Diversion		1.3
Subtotal		222.3
Contingencies - 15%		33.3
Total		255.6

Notes: 1. Costs are expressed in March 1979 terms. No allowance for escalation has been included.

2. Camps, engineering and site management are excluded. They are assumed to have been covered by the estimate prepared by CECB for the main dam.

the invert, have since been made. These refinements do not materially affect the comparison of the alternatives, but they do affect the ultimate cost. Table 10-3, therefore, summarizes the cost of this alternative for the latest tunnel design features. The cost in 1979 currency of Rs.256 million has been used in the economic analysis.

10.3 - Cost of the Dam

In preparing the Interim Report, the CECB[6] estimates for both the rockfill dam and concrete gravity dam have been reviewed. The review incorporated an independent check of quantities and use of 1979 construction cost unit rates. The unit rates used by CECB are reported to be average rates which are expected to apply over the 1980-1982 construction period. Although the total costs estimated by CECB are higher than those estimated by Acres (as one would expect due to the incorporation of an escalation factor in the estimate) the difference is not significant (see Table 10-4). The CECB estimates have therefore been adopted as 1979 costs for consideration in the Interim Report. The CECB estimates for all elements* associated with the two types of structure are:

Rockfill dam	-	Rs.953 million
Concrete gravity dam	-	Rs.897 million

The cost of the concrete gravity dam alternative was used in the initial economic analysis. However, the financial cost quoted above is adjusted to include the economic price of cement and reinforcing steel. This results in an additional cost of Rs.34 million for the concrete dam with a total cost of Rs.931 million. This is still less than the cost of the rockfill alternative, and was used in the analysis for this reason. Adjustments for the economic price of diesel fuel were not made, as these are considered to have minimal impact on the results.

A decision was made late in March 1979 to lower the crest elevation of the Maduru Oya Dam by 2.0 meters. This decision was taken because recently compiled topographic information for the reservoir area has revealed that the same volume of live storage is available for the lower dam as was previously believed for the higher dam. The resulting cost saving is estimated to be about Rs.66 million, with an additional saving of

* Dam, spillway, powerhouses, saddle dams, etc.

TABLE 10-4

COMPARISON OF DAM COSTS

DAM TYPE	ACRES ESTIMATE (10^6 RS)	CECB ESTIMATE (10^6 RS)
Rockfill Dam - 1980 - 1982 prices	-	409.2
- 1979 prices	378.1	-
Concrete Dam - 1980 - 1982 prices	-	421.8
- 1979 prices	402.7	-

Rs.4 million resulting from the economic cost of cement and reinforcing steel. Thus the dam cost used in the final economic analysis presented herein is Rs.861 million.

10.4 - Cost of Downstream Works

Without detailed topographical mapping and soil maps for System B, it is very difficult to produce reliable estimates for the cost of the irrigation works. However, for purposes of the Interim Report, estimates of the cost of the main canals and other irrigation and drainage works have been made using the limited available design information.

10.4.1 - Main Canals

Some preliminary design information is available from MDB for the main and major branch canals. A cost estimate for constructing lined canals according to the hydraulic design criteria outlined in Section 8.1 was therefore performed. Soft earth excavation quantities were estimated very approximately, given the lack of adequate topographic mapping, to total about 7 million m^3. An allowance of 0.2 million m^3 of rock excavation was added for preliminary costing purposes. Concrete lining costs were based on a lining thickness of .075 m, with lining carried out immediately after excavation to avoid side slope slumping. A total cost of 650 million rupees, including overhead allowances, was estimated for the main and major branch canals. This cost converts to Rs.14,400 per hectare, which compares well with canal excavation costs developed by NEDECO in 1978. An increase in the overall cost of approximately 6 per cent would be expected if an international contractor were engaged to build the canals, due primarily to higher mobilization, demobilization and overhead allowances.

10.4.2 - Other Irrigation Works

Because of the lack of design information, the cost of the remaining irrigation works was computed on a "per hectare" basis. A basic rate of Rs.28,600 per hectare was derived*, assuming contractors using capital intensive methods are employed as for the main canals.

* Based on analyses conducted by NEDECO in 1978.

This cost includes:

- Major check structures in the main canals 300
- Main drains
- Canal service roads
- Land clearing and levelling
- Field and distribution channels, field drains, turnouts
- Surveys, studies, construction supervision and contingencies.

The assumptions used to compute the total system cost, which is summarized in Table 10-5, are as follows:

- In addition to the basic irrigation system, it will be necessary to install sprinklers on the upland soils, at a cost of about Rs.10,500 per ha.
- The homestead plot and the vegetable plot (¼ acre each per family) on the intermediate coarse soils are not irrigated.
- The vegetable plot for the upland farmers (¼ acre per family) is outside the commandable area but is assumed to be commandable using sprinklers.

The total cost of Rs.2068 million computed in Table 10-5 was used in the economic analysis as an economic cost.

10.5 - Other Costs

10.5.1 - Allocation of System 'C' Costs

Because there are additional costs associated with building the System C facilities with a capacity which enables the water requirements of System B to be fully satisfied, these additional costs are chargeable to the Maduru Oya Project. They include the following:

1. The cost of increasing the capacity of the Minipe Right Bank Transbasin Canal from that required to serve System C alone to that required to serve both systems.

2. The cost of the Ratkinda Dam which would not be necessary if only System C were developed.

3. The cost of the Ulhitiya-Ratkinda open cut, which conveys water to the Ratkinda reservoir.

TABLE 10-5

ESTIMATED COST OF IRRIGATION SYSTEM

	AREA (HA)	LAND USE	UNIT COST FOR BASIC IRRIGATION WORKS (RS/HA)	UNIT COST FOR SPRINKLER SYSTEM (RS/HA)	TOTAL COST (Rx10^6)
A. Main Canals	46,101	Crops	14,400	-	664
B. Drainage, Minor Works, Land Development -					
Lowlands	15,155	Crops	28,600	-	433
Intermediate Fine	14,271	Crops	28,600	-	408
Intermediate Coarse	3,485	Homestead	-	-	-
	2,943	Vegetables	-	-	-
	5,885	Crops	28,600	-	168
Uplands	9,809	Crops	28,600	10,500	385
	981	Vegetables/ fruit plot	-	10,500	10
		Total Estimated Irrigation System Cost.			2068 664 1404

Preliminary estimates by NEDECO[11] for these works are as follows:

	Million Rupees
Transbasin Canal	110
Ratkinda Dam & Open Cut	127
Total	237

The total cost of these improvements to the System C headworks amounting to Rs.237 million have been included as part of the total project costs in the economic analysis.

10.5.2 - Social Infrastructure And Settlement Costs

Social infrastructure costs include the costs of health, education, administration and other services necessary to meet the needs of the farm families. Settlement costs include subsistence, tools, and building and transport allowances during the early stages of settlement. NEDECO[12] have estimated that these costs are approximately Rs.16,000/- per family.

They also suggest that at least part of these costs are chargeable to the project on the basis that the agricultural benefits are unlikely to be achieved unless the social infrastructure is provided very early in the life of the project. Consequently they have allocated one-third of the social infrastructure costs as a charge against the project.

On the basis of an estimated 39,300 farm families, the total costs of the social infrastructure are estimated at Rs.629 million. For economic analysis purposes, one-third of this cost (Rs.210 million) has been allocated as a charge against the project. A much more detailed and reliable cost estimate for the social infrastructure and cost of settlement will be included in the Feasibility Report.

10.5.3 - Agriculture Support Facilities

Capital and recurrent costs of technical services in support of agricultural development (infrastructure, vehicles, housing, extension, staff, training, etc.) are included in Project Management Organization costs (para 10.7 and Table 10-6). Costs of processing, marketing and input distribution services are accounted for in the calculation of farm-gate prices for agricultural outputs and inputs.

10.5.4 - Experimental-Demonstration Farm

The cost of the experimental-demonstration farm is estimated to be Rs.13 million and has been included in the economic analysis as a project cost.

10.5.5 - Other Infrastructure

The cost of maintenance roads for the canal system are included in the cost of the irrigation works. Village road costs are included in the social infrastructure costs. The cost of major roads is not charged against the project, as they are assumed to be a part of the national road system.

10.6 - Summary of Capital Costs

Table 10-6 summarizes the major capital cost items that have been estimated for System B. The costs for the dam and tunnel can be termed economic costs as they exclude duties and taxes and have been adjusted to include the economic prices of cement and reinforcing steel. They have not been adjusted to include the economic price of diesel fuel as such an adjustment is judged to have minimal impact on the results. All other costs which are estimated on a per hectare or per family basis can be termed financial costs and have been used in the economic analysis. Again the difference between financial and economic costs for these items is judged to have minimal impact on the results.

10.7 - Recurring Costs

The following administrative and maintenance costs have been estimated for inclusion on the economic analysis:

Operation and Maintenance	
- Dam and Powerhouse	- Rs. 5 million
- Kirindo R.B. Canal, Rathkinda Dam (1 per cent of capital cost)	- Rs. 2 million
- Irrigation Works (2.5 per cent of capital cost)	- Rs.52 million
Experimental-Demonstration Farm	- Rs. 2 million
Project Management Organization	- Rs.32 million
Total	- Rs.93 million

TABLE 10-6

PROJECT COSTS USED IN ECONOMIC ANALYSIS
(MILLION RUPEES)

ITEM		ECONOMIC COST	PERCENT OF TOTAL	SOURCE
Concrete Dam		861	24.6	Revised CECB cost, plus Rs.30 million to account for the economic cost of cement.
Link Tunnel		256	6.0	Acres cost estimate.
Irrigation System				
- Main Canals	664			Acres cost estimate, based on preliminary MDB design.
- Distribution System, etc.	1404	2068	54.0	Based on "per hectare" costs developed by NEDECO, plus an estimated cost of Rs.10,500 per ha for sprinklers.
Portion of System C Costs Arising from Maduru Oya Project		237	6.2	Total cost of these works was estimated to be Rs.947 million by NEDECO.
Experimental-Demonstration Farm		13	0.3	Acres cost estimate.
Social Infrastructure and Settlement		210	5.5	1/3 of estimated social infrastructure cost @ Rs.16,000/family.
Project Management Infrastructure		130	3.4	Preliminary Acres estimate based on System C Report[2].
		3775	100.0	

3775
237
3538

11 - ECONOMIC ANALYSIS

11.1 - Introduction and Approach

The evaluation technique used to assess the economic viability of the Maduru Oya Project for the Interim Report is the internal rate of return approach. This allows the determination of whether the project will contribute significantly to the development of the national economy and thus justify the use of the scarce resources necessary for its achievement. This technique involves the comparison of cost and benefit streams over the life of the project and the calculation of the discount rate which equalizes the present worth of the cost and benefit streams.

With the use of this approach, benefits and costs must be quantified if they are to be included in the evaluation process. Often it is difficult to assign values to certain benefits and costs and thus a complete assessment of all benefits and costs is usually not possible. This is particularly true for a project of this nature which is predominantly a settlement scheme and where it is not possible to adequately quantify the substantial social benefits which are expected to be achieved.

11.2 - Key Assumptions

Foreign Exchange Rate

Since the analysis is undertaken in the Sri Lankan currency, it is necessary to convert the foreign exchange component of the cost into local currency. An exchange rate must therefore be chosen. For the economic analysis we have adopted exchange rates as follows:

$	1	US	=	Rs.16.00
$	1	Canadian	=	Rs.13.00

These rates are slightly above existing (official) exchange rates and their use implies that the Sri Lanka rupee is not overvalued to any great extent. This approach is in general agreement with the guidelines of both the Ministry of Finance and Planning and the Central Bank of Ceylon.

The MEDECO Master Plan team have suggested an exchange rate of $ 1 US = Rs.18.00 on the basis that the foreign exchange cost components should be shadow priced to reflect both the scarcity of foreign exchange and its true value to the economy. In the Final Report the effects which this higher exchange rate has on the economic conclusions will be tested. . . . Sensitivity analysis of this aspect for the System 'C' study suggests that the use of higher exchange rate had no appreciable impact on the results.[2]

Discount Rate

When using the "Net Present Worth" approach, which will be included in the Final Report, a discount rate must be chosen to compare the cost and benefit streams over time and calculate the net present worth of the project. Both the Ministry of Finance and Planning and the Central Bank of Ceylon as well as the World Bank have in the past used a discount rate of 10% for project evaluation in Sri Lanka. Recent analysis by Mr. Deepak Lal, who worked as an Advisor on Project Evaluatio to the Ministry of Finance and Planning, has suggested, however, that the opportunity cost of capital in Sri Lanka is in excess of 12% (13-14%) implying that the discount rate for project evaluation should be higher than that which has been historically used. Agricultural projects and settlement schemes which are of a long term nature and where many of the social benefits are difficult to quantify may well justify the use of a lower discount rate. A discount rate of 10% will therefore be used to calculate the Net Present Worth of the project for presentation in the Final Report.

Economic Prices

In the economic evaluation of projects of this nature, it is necessary to use economic prices instead of market or financial prices. This is necessary as market prices are affected by subsidies, taxes, or guaranteed support prices and thus do not adequately reflect the true value of the inputs or the agricultural products grown. Examples of commodities for which there is a wide gap between economic and financial prices include diesel fuel, which is heavily subsidized, and rice, which should be valued at the import price due to the foreign exchange

savings resulting from its production.

The cost of inputs and the price of the agricultural commodities produced are calculated at the farm-gate. In the case of agricultural produce, each product's price is based on import substitution (eg. rice) or export (eg. soyabeans). For the inputs, the economic cost is calculated on the basis of its true cost and thus the effect of subsidies* which are now in existence are not considered.

Time Frame of Analysis

The comparison of cost and benefits is undertaken over a 40 year time frame, a period considered to be the economic life of the project. All costs and benefits are expressed in 1979 constant currency. This assumes that prices on both the cost and benefit sides will rise in the same proportion in the future. Thus the relative values of the costs and benefits do not change.

The Maduru Oya Project will be operational sometime in the future and thus the prices of both inputs and outputs should be expressed in view of their future levels and not today's levels. Commodity price forecasts for the year 1990[13] which are prepared by IBRD have been used as basis for the calculation of the economic price of a number of inputs and outputs over the life of the project. These forecasts are expressed in 1978 currency and have been adjusted to 1979 levels.

Opportunity Cost of Labour

Because there is considerable unemployment in Sri Lanka, there is an argument for shadow pricing of labour because it would be non-productive otherwise. For farm labour (both hired and family), NEDECO [14] guidelines after adjustment to 1979 levels have been used in the economic analysis. All other construction and operational labour is taken at its actual cost. This is due to the fact that although there may be a case for decreasing the unskilled labour cost component because of high unemployment, there is a balancing factor which suggests that the market rates for skilled labour do not adequately reflect its scarcity and thus its cost component should be increased when expressed in economic terms. These two offsetting factors led to the decision to value construction and operational labour

* It is assumed that all existing subsidies (except for fuel) will have been phased out by the time the project is implemented.

at market or financial rates for purposes of economic analysis.

Share of Common Costs

To supply the amount of additional water required via the link tunnel to meet the demand of System B, it is necessary to spend additional funds on certain parts of System C. It is therefore appropriate to charge these additional costs against the Maduru Oya project. These costs consist of the following:

- The cost of increasing the capacity of the Minipe Right Bank Transbasin Canal from that required to serve System C alone to that required to serve both systems.
- The cost of the Ratkinda Dam which would not be necessary if only System C were developed.
- The cost of the Ulhitiya-Ratkinda open cut which conveys water to the Ratkinda reservoir.

Section 10.5.1 details the portion of the cost which has been assigned to System B.

11.3 - Economic Prices

Diesel Fuel/Transport Cost

The price of diesel fuel in Sri Lanka is heavily subsidized and the retail price is far below its actual cost to the country. NEDECO calculated the economic price to be Rs.9.66 per gallon, in mid-1978 prices and using an exchange rate of Rs.18 = 1 US Dollar. The price calculated for use in this study (March 1979 prices and using an exchange rate of Rs.16 = 1 US Dollar) was Rs.10.11 per gallon.

Lorry transport costs are heavily dependent on the capital cost of the vehicle - fuel costs were computed by NEDECO to be only 16.5 per cent of the total unit cost. Their calculations of overall transport costs were based on mid-1978 prices and an exchange rate of Rs.18 per 1 US Dollar. Adjusting for the lower exchange rate used in this study and for the difference between 1978 and 1979 costs results in almost identical 1979 transport costs. The following NEDECO transport costs were therefore used in this study:

5 tonne lorry	-	Rs.2.00/tonne - km
15 tonne lorry	-	Rs.1.44/tonne - km

Based on 75 per cent utilization of 5 tonne and 25 per cent utilization of 15 tonne lorries, the weighted rate is Rs.1.86 per tonne - km.

Labour

As indicated in Section 11.2, all labour costs except for farm labour costs are taken at the market rate. Farm labour - both hired and family - is shadow - priced and its economic price is taken at Rs.6/day. This is again based on NEDECO guidelines and has been increased by 10% to represent 1979 levels.

Construction Materials

NEDECO guidelines have been used for the economic prices for cement and steel for use in this report. These prices, which will be reviewed before use in the Final Report, are as follows:

Cement - Rs.800/tonne
Steel - Rs.6750/tonne (reinforcing steel only)

Agricultural Inputs

Because of heavy subsidies, the current prices of fertilizers do not reflect the actual cost to the national economy. The economic price of fertilizers is based on forecasts from the World Bank and have been adjusted for freight, transport, and marketing commissions to give economic farm-gate prices. The farm-gate prices are summarized as follows:

	Rs/tonne
Urea	3618
Di-ammonium Phosphate (DAP)	5330
Triple Super Phosphate (TSP)	4186
Muriate of Potash	2501

Land preparation can be undertaken by mechanical means (tractors) or by draught power. NEDECO guidelines for tractor power are as follows:

4- wheel tractors	Rs.71/hour
2- wheel tractors	Rs.17/hour

The crop budgets are based on the Victoria study estimates[2] and include tractor costs which are higher than the above rates. A detailed investigation of land preparation costs with mechanical and draught

power will be made for the Final Report.

Agricultural Produce

As indicated in Section 11.2, market prices for agricultural produce do not adequately reflect the actual benefits of additional agricultural output because of a number of distorting factors. Therefore economic prices should be based on either export of the crop or substitution of present imports. The choice of calculating the economic price based on export or import substitution is based on the forecast supply/demand balance of that commodity during the life of the project and the resultant surplus or deficit position.

For agricultural products which are internationally traded, the IBRD 1990 commodity forecasts[13] were adjusted to 1979 prices and further adjustments were made for freight, transport, etc. to calculate the farm-gate price of these commodities (based on export or import substitution). For products in which there is little international trade, the System C study[2] estimates have been used. The prices used to calculate the agricultural benefits are summarised as follows:

		Rs/tonne
A. Import substitution	- Paddy	3,426
	- Cotton	12,087
	- Kenaf	5,000
B. Export	- Soyabeans	4,617
	- Cassava	1,303
	- Groundnuts	5,151
	- Tobacco (green leaf)	1,866
	- Limes	3,897
	- Maize	2,048
C. Local consumption	- Chillies	15,000
	- Onions	4,000

For internationally traded commodities, the above economic prices reflect either an export orientation or import substitution. It is recognized that these positions might change over the life of the project. For example, rice might be an import substitution crop during the initial stages of the project and be exported during the

latter stages. At this point no consideration has been given to dual prices for any product. However, an overview of the expected supply/demand balance for each agricultural product over the life of the project will be included in the Final Report and consideration will be given to this aspect at that time.

11.4 - Benefit/Cost Assessment

The Maduru Oya Project will bring irrigation water to more than 46,000 ha of land which is presently not irrigated. Benefits to the project accrue primarily from the resulting agricultural production but other benefits are obtained as well. These include power, fisheries, forestry and livestock benefits. At this point many of the cost and benefit calculations are very preliminary - in one area (forestry) work has not yet begun. This analysis therefore only considers the agricultural and power benefits. However, all costs are included and consequently the results reflect the lower end of the estimated range of potential returns to the project.

Generally in benefit/cost assessments of this nature, "without project" benefits are calculated and these are subtracted from the "with project" benefits to calculate the net return from the supply of irrigation water. The "without project" benefits have not been included in the analysis, primarily due to the fact that a reliable estimate of the number of people living in the area is not available. However, the "without project" benefits are considered to be relatively small.

Offsetting the above omission is the fact that areas under the Pimburettewa and Vakaneri tank schemes have been excluded from the estimate of land area available for the project, and therefore, from the calculation of the agricultural benefits. Preliminary calculations indicate that the opportunity for increased agricultural production in these areas resulting from the project is significant. On balance, this overall approach is conservative and should reflect the lower end of the range of possible project returns, given the usual qualifications with respect to processing, marketing, and various input services.

The agricultural benefits of the project are detailed in Chapter 4 and are presented as the net return per hectare under various cropping patterns

and yield assumptions. The project capital costs and annual operating expenses are detailed in Chapter 10, along with the costs used in the economic analysis.

CECB [6] has estimated that the Maduru Oya powerhouse will generate an average of about 36.2 Gwh* annually. This will be classed as secondary energy as the water demands of the irrigation system are to be given first priority. Secondary energy can only be assigned a significant value when it displaces thermal generation in the power system. When it is only displacing hydro-power, water is being spilled elsewhere and the secondary energy has no value. In the system in Sri Lanka which is now predominantly hydropower, there is some question with respect to whether secondary energy will have value inthe system. In this report, the assumption is made that in the future some part of the system base load will be provided by thermal generation. This is in agreement with CEB load forecasts and the resultant system planning[2]. Consequently this secondary energy has been assigned a value at a rate equivalent to the operation and maintenance savings (including fuel) from the thermal alternative. This is estimated to be Rs.55/kwh (1979 prices) and thus the annual benefit is:

$$36.2 \text{ Gwh} \times \text{Rs.}55/\text{Kwh} = \text{Rs.}20 \text{ million}$$

This annual benefit accrues to the project in years 4 - 40 in the economic analysis. Thus all secondary energy output is assumed to be useful to the system in the project period.

Table 11-1 summarizes the annual capital costs, operating expenses, agricultural and power benefits, and the resultant cash flow for the Maduru Oya Project. The agricultural benefits are calculated on the basis of the yield estimates detailed in Chapter 3. The internal rate of return for the project based on this cash flow is 10.3%. When benefits from livestock, fisheries, and forestry are included, it is estimated that the internal rate of return of the Maduru Oya Project would increase to over 11%.

As a settlement project with substantial non-quantifiable social and employment benefits, the project with the above cost and benefit estimates provides a satisfactory economic return. The objective of the next stage of project investigations will be to confirm these estimates which, in fairness to all readers, have been made very early in the project analysis period.

* Gwh = 1,000,000 Kwh

TABLE 11-1

ECONOMIC ANALYSIS - CASH FLOW TABLE
(BILLION RUPEES)

YEAR	COST OF TUNNEL	COST OF DAM, POWER HOUSE, SPILLWAY	COST OF IRRIGATION WORKS	SHARE OF SYSTEM C COSTS	COST OF EXPERIMENTAL FARM	COST OF SETTLEMENT, SOCIAL INFRASTRUCTURE	PROJECT MANAGEMENT UNIT	RECURRING COSTS	AGRICULTURAL BENEFITS	POWER BENEFITS	CASH FLOW
1	85	207	248	55	13	-	-	-	-	-	(680)
2	85	207	269	119		-	-	2	-	-	(762)
3	85	207	517	63		105	65	4	-	-	(1127)
4			517			52	33	51	163	20	(470)
5			517			53	32	72	263	20	(391)
6								93	374	20	301
7									414		341
8									455		382
9									487		414
10									517		441
11									540		467
12									552		479
13									560		487
14									566		493
15									571		498
16									577		504
17									583		510
18									589		516
19									594		521
20									600		527
21									606		533
22									612		539
23									619		546
24									625		552
25									631		558
26									637		564
27									644		571
28									650		577
29									657		584
30									663		590
31									670		597
32									677		604
33									683		610
34									690		617
35									697		624
36									733		660

11.5 - Sensitivity Analysis

When, as in this case, assessment of the internal rate of return of the project is calculated early in the study period on the basis of limited information detailed sensitivity testing is not usually carried out. However, it has recently been decided that the Forest Reserve (gross area about 8500 ha) will be available for irrigation. Since this area incorporates a substantial block of good quality Upland (RBE) soil of about 3500 ha, a sugar mill becomes a possibility. Thus a preliminary analysis was carried out to assess the incremental agricultural benefits and system costs associated with the expansion of the project area to include 3500 ha under sugar cane.

The agricultural benefits were calculated on the basis of the return from estate production of sugar cane calculated for the Victoria report[2] - about Rs.17,750/ha. Additional costs included the main canals and distribution network, as well as the costs necessary to provide sprinkler irrigation. The analysis indicated that the net effect of sugar cane production on the 3500 ha in the Forest Reserve is to increase the project rate of return from 10.3% to about 11%.

This preliminary exercise indicates that the feasibility of establishing a sugar mill and estate in the Forest Reserve area deserves further investigation. Much work remains to be done, however, before feasibility can be firmly established.

12 - SCHEME IMPLEMENTATION

The implementation schedule of the engineering works associated with the irrigation and drainage system is constrained by a number of important factors:

1. The construction of the Maduru Oya dam. This must be completed before any water can enter the irrigation system. Present plans[6, 7] call for its completion in November 1982.

2. The construction of the Minipe Right Bank Canal, the Ulhitiya Oya Reservoir and the Ratkinda Oya Reservoir. All of these must be completed before Mahaweli water can enter the link tunnel. The Victoria Report[2] indicates that the former two items will be completed by June 1982, but the Ratkinda Dam will not be completed until July 1984. It may be possible to accelerate the construction of Ratkinda Dam to allow completion by early 1983.

3. The construction of the Link Tunnel. This must be completed before Mahaweli water can enter the Maduru Oya Reservoir. Present plans[6, 7] call for its completion on November 1982. The cost analysis summarized in Section 10.3 confirms that this is possible.

4. The construction of the Victoria and Kotmale Dams. This is necessary to provide a regulated flow at Minipe sufficient to supply the full requirements of both Systems B and C. The Victoria Report[2] indicates that the Victoria Dam can be completed by June 1984 if an arch dam is built; otherwise, the completion date will be June 1985.

5. The rate of progress on main canal and main drain excavation using mechanized construction methods. Calculations summarized in Section 10.4 indicate that the main and branch canals can be completed in four construction seasons. //

6. The rate of progress on tertiary system construction, land levelling, etc. Since this type of work can be carried out by smaller construction units using smaller equipment, its progress can, within limits, be adapted to the rate of progress of other elements.

7. Lead time for financing, design and tenders. Preparation of basic designs and tender documents for the dam and link tunnel is scheduled for completion by June, 1979. A minimum period of six months for tendering, assessment of bids and award of contract is normal when foreign contractors are involved. Completion of foreign currency funding arrangements is extremely difficult to forecast, being partly dependent on factors beyond the scope of the present discussion.

An implementation schedule which incorporates the constraints outlined above is presented in Figure 15. This program features staged implementation of the irrigation delivery system, recognizing the limited availability of irrigation water until Ratkinda Oya and Victoria Dams are completed. Such a staged program also recognizes the practical difficulties in settling such a large area in a brief period, and allows maximum possible experience to be gained on the pilot farm before commencement of cropping on the upland and intermediate areas.

Also included in Figure 15 are bar graphs which show the interpretation of the implementation schedule which has been used to formulate the flow of benefits and costs during the implementation period. This indicates that by 1983, about 50 per cent of the irrigation works will be operational and cropping under way. By 1986, all of the irrigation works should be operational.

The Feasibility Report will examine the question of implementation schedule in considerably more detail. Among the items to be covered will be:

- further work needed to plan and design the irrigation works down to the farm level.
- the construction program needed to implement the works, including an assessment of the construction equipment and manpower needed.
- the management organization needed to supervise the construction program.

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APPENDIX A - PADDY YIELDS IN SRI LANKA

NEDECO have recently received Government information regarding paddy yields which are being achieved under better-than-average conditions in existing irrigation schemes. This information combined with as yet unpublished data collected by Japanese consultants working on System D, led to the recent decision to revise upwards the expected paddy yields for the Mahaweli Scheme. NEDECO intends to compile this information and make it available by the end of April, 1979. A summary will be compiled at that time and issued as the revised Appendix A of this report.

APPENDIX B - POTENTIAL LIVESTOCK PRODUCTION

1. Potential Livestock Production

The main types of livestock in System B are indigenous zebu type meat cattle (*Bos indicus*, Sinhala breed), indigenous swamp buffalo (*Bubalus bubalis*), goats and poultry. Bovine production is considered to be most relevant to System B since it can utilize grazing resources, does not have management problems under intensive farming conditions and purchased concentrates are not essential.

Meat cattle and buffalo tend to be dual purpose with differing emphasis on draught, milk and meat (or surplus stock) production related to soil fertility and associated grazing resources.

Draught power is an integral part of irrigated and dryland farming and therefore draught animals are run on crop stubble, bunds and other waste areas. The animal, generally the buffalo, can be regarded as an outlay or as a receipt. If not owned, it has to be hired. Then it is a real cost input for such activities as ploughing, tilling, puddling and threshing. If owned it may be regarded as augmenting income from hiring out, with the by-products of milk, meat (or cash from sale of surplus stock) and manure (a source of organic material for crops and also potential for biogas production). For road transport, male cattle are generally used in preference to buffalo. So far as land use is concerned then, draught buffalo and cattle will be associated with arable areas, particularly paddy soils. The buffalo is not considered suitable to dryland cultivation because of its fewer sweat glands and wallowing habit and therefore cattle are used.

So far as other soil types are concerned, various levels of livestock production are possible (except on rocky outcrops) depending on fertility, flooding and stage of development. The animal can utilise natural pastures where cropping is not possible and convert these to valuable human foods both at the subsistence and commercial level. Present development constraints include

lack of resources relating to suitable breeds, access to grazing resources because of no assured stock drinking water supply or dense tree cover. Marketing problems, especially for milk production, are also a restriction.

The majority of milk production tends to be at subsistence levels. Most of the commercial production takes place on the 'Villu' areas of the Mahaweli Ganga (and to a lesser extent on the Maduru Oya) which, after being flooded for about three months, provide valuable grazing for most of the remainder of the year. Because they are flooded and very difficult to drain they have limited cropping potential. The associated dark brown loams to loamy sands of the flood plain, which are mainly poorly drained, carry mainly water loving species such as Paspalum vaginatum and Sacciolepsis interrupta as well as naturalized Brachiaria mutica.

When the "Villu" country is submerged or eaten out, alternative grazing has to be provided on adjacent upland areas mainly on Non Calcic Brown soils. These provide "Damana" or parkland type of grazing. Depending on the soil type and the stage of woodland succession, utilization may only be possible by specific clearing or after "Chena" farming (shifting cultivation). Poorer plant species such as "Illuk" (Imperata cylindrica) and sensitive plant (Mimosa pudica) occur on parkland. Sandy alluvials can also provide useful grazing, but at a lower carrying capacity. Cattle there may also have access to paddy stubble. These together with some large areas of parkland may not be accessible to "Villu" grazing because of distance or where development is centred around tanks.

Because of the distribution of rainfall, milk and meat production is seasonal and is also affected by nutritional, heat and disease stress. In the dry dessicating conditions from June through to October, the nutritive value of pasture on upland soils is insufficient for meat and milk production and indeed for maintenance; body weight losses as well as mortalities can occur. Reproductive efficiency is also adversely affected by this environment.

There are two approaches to increasing productivity. One is to

adapt the animal to the environment and the other is to modify the environment.

The draught buffalo's milk potential may be increased by crossing with the originally imported Indian Murrah breed, a river type but which may have common ancestry with the local animal since genetically the karyotype is similar. Draught cattle may also be crossed with Killari, Kangayam or Tamankaduwa breeds.

The milk production from the small indigenous Sinhala cattle may be raised by crossing with pure Indian zebu breeds such as Sindhi, Tharpakar or Sahiwal, or the Australian Milking Zebu (developed from the Sahiwal) as a first stage to give higher performance in the F1 and subsequent generations. At a later stage the temperate Jersey breed (Bos taurus)could be introduced into this upgraded animal. The Jersey is the most suitable European breed for crossing with its relatively small size being an advantage in this harsher climate and the higher fat content of milk, which is preferred by the population and has a greater market value. Thus the high yield of the European breed may be combined with the resistance of the local breed.

An alternative form of cross breeding is to continually rotate both Zebu and/or the Jersey in contrast to the new breed formation technique above.

The modification of the environment may be achieved technically by improving nutrition and disease control and by improving pasture and highland management. Under rain fed conditions improved pastures also deteriorate in quality during the dry season and consideration should be given to limited fodder conservation in the form of hay or silage.

The imperfectly drained Non Calcic Brown soils are suitable for the establishment of improved pasture species such as Para Grass (Brachiaria mutica) and Signal Grass (B. brizantha). The former can withstand water-logging and long term flooding. As a protein supplement Ipil-Ipil (Leucaena leucocephala , 20 - 25% crude protein and can be fed green or dried) is a leguminous shrub or tree which can tolerate low soil fertility, especially low phosphate status, and prefers low altitudes.

However, well drained soils are required for good growth and high yields. Water-logging or flooding is not tolerated. Hence Ipil-Ipil could be established on Red Brown Earths, around rocky outcrops unsuitable topographically for arable crops. Guinea Grass (Panicum maximum) is an improved species which grows on similar well drained lightly textured soils and does not tolerate water-logging.

Grass may provide a sound alternative to bush follow in the "Chena" system and could be rotated for 3 - 4 years with crops such as sorghum or cassava. The latter has potential for animal feed by chipping and sun drying and the leaves can provide a high protein diet. On a similar basis grasses could be incorporated into the more intensive upland cropping plans.

2. Agro Industrial Possibilities

Milk Processing:

The National Milk Board already owns and operates a condensary at Gallela near Polonnaruwa which provides a potential market for fresh milk from a large area of the dry zone and is in a good position to serve any development in System B.

System B itself is served by National Milk Board tankers of 5500 litre capacity which collect fresh milk from chilling centres at Matugalla, Manampitiya, Sittandy and Chenkalady. These in turn are supplied by collecting points run by multipurpose co-operative societies, dairy co-operatives and government farms. The producer supplies milk to the collecting point mainly by transporting it by carrier bicycle, bullock cart or tractor. Spoilage is possible in this link of the chain and the minimum time to avoid this is four hours from the farm gate to chiller; this can become a constraint especially on rough bush tracks. On arrival at the collecting centre, the milk is tested for fat content, solids not fat, and keeping quality.

Condensed milk manufacture helps overcome the problems of seasonal supply by the producer and distribution channels which lack refrigeration. It also keeps for a longer time when opened than fresh milk.

There are essentially two processes of manufacture employed by the condensary. Both include the addition of 170 gm sugar per tin.

(a) Standardised fresh milk utilisation: Evaporate 0.69 litres fresh milk and add 0.03 kg skim milk to give one 393 gm tin condensed milk.

(b) Recombined process: Recombine 0.1 kg skim milk powder with 0.3 kg butter oil to give one tin.

Over the past, a significant proportion of the skim milk powder and butter oil has been donated by New Zealand, EEC and Canada. (The plant itself was donated by the New Zealand Government).

Collection of milk by the condensary from the dry zone has increased steadily over the period 1972-1976. It is estimated that about 48% of this collection is from System B or just outside the immediate area.

	Condensary Collection				
	1972	1973	1974	1975	1976
Litres/day	7209	12511	13819	21895	23999
Equivalent litres/yr (m)	2.6	4.6	5.0	8.9	8.8

In 1978, 12.8 million tins (equivalent to about 5027 tonnes) of condensed milk were manufactured. The present capacity is reduced because of plant age and is about 17.2 million tins per 300 day year. Hence its output with the aid of the recombining process was about 74% of present rated capacity.

At the conversion rates given above, it would take 11.9 million litres of fresh milk to supply the capacity of 17.2 million tins per year. Thus the 1976 collection figure of 8.8 million litres of fresh milk supplied 74% of the current rated capacity. Hence there is scope to increase collection by at least 25% and reduce dependence on food aid.

Buffalo Curd and Ghee:

The spoilage constraint applying to fresh milk can be overcome by the production of buffalo curd. As well as providing subsistence requirements, it is a low cost cottage industry supplying curd to local villages in clay pots. The pots are manufactured locally and assist the keeping quality of the curd itself. Ghee is also a cottage industry in certain areas of System B, (eg. Sittandy).

The skim milk by-product from ghee could be used as a livestock feed.

Meat Processing:

There is no meat processing industry in System B. Cattle destined for slaughter are railed to Colombo abattoir. The middle man purchases surplus cattle especially from non-commercial milk producers. The only spoilage before reaching the abattoir is from bruising during the rail journey. Because of limited local demand and lack of refrigeration, the only local processing envisaged is slaughter on village slabs under hygienic conditions and veterinary inspection.

The value of the animal's hide would be increased if a branding system including registration was implemented to replace the disfiguring one presently employed.

Feed Processing:

There is very little concentrate fed to livestock in the System now. If used it is likely to contain expressed coconut meal (poonac). It is unlikely that the livestock industry within Area B will expand to such an extent as to justify a mill and mixer of any significant capacity. However, production could be considered of soya bean meal and cotton seed meal with the main market in other areas better suited to dairying.

3. Projected Yields Including Alternative Input Assumptions

Projected yields in the use of livestock depend upon the purpose for which the animal is used, the grazing resource, and the system employed.

Draught Power:

This particular area of the dry zone is different to others because of the dendritic pattern of arable areas, the "Villu" grazing resource and the relatively poor upland soils of the "Damana" park land.

The draught animal is used mainly on the fragmented arable areas. As stated earlier it may be regarded as an input or a receipt

depending upon ownership. A study which included the Polonnaruwa District found that 60% of farmers owned buffalo and 9% owned tractors. There was an average of 5 animals in the owned buffalo herd which were mostly used for land preparation and tractors for threshing and winnowing. Based on a hire rate of Rs.20/- per pair of buffalo per day, 19.6 buffalo days per hectare were used for land preparation in addition to tractors (note current hire rates for buffalo are of the order of Rs.50/- per pair per day).

In an earlier study of the same district a much lower utilization of buffalo at 9.1 days per hectare and 4.2 tractor days was employed. It may be possible to have sufficient area in addition to paddy to run buffalo cows to breed draught bulls. If upgraded with Murrah and run on improved pasture plus the normal paddy straw, bunds, etc. this could be an important source of sideline income both from milk production and sale of surplus animals. In any expanded irrigation programme the breeding of draught power by participant farmers is an important factor.

The National Livestock Development Board has recognized the need to supply draught stock to arable agriculture because amongst other attributes mentioned above, unlike the tractor, animals do not rely on imported fuel or spare parts. They are self-reproducing and therefore represent a valuable saving in foreign exchange. To this end in 1977, the Board established a 2400 ha breeding system and holding station in System B. The major breed at present is the Tamankaduwa White* with a total of 500 cattle on 200 ha cleared so far. Further clearing is proceeding an an area of 75 ha has been sown to B. mutica and B. brizantha.

Milk/Meat Production:

On the "Villu/Damana" association, herd size tends to be larger and individual farmers may own over 300 cattle. However, a common occurrence is for an individual to own 10 - 15 cattle, with perhaps 3 in milk at any particular time during the year.

In this system, animals are collectively grazed during the day and largely night paddocked. Most of the cows are milked once a day in

* Derived from the Indian breeds Tharparkar and Hariana

the morning and sent out for grazing during the day to feed on public land with natural pastures, tank beds and roadsides. Around arable areas and tanks these larger herds graze on arable farmers' paddy straw or other crop residue.

It should be noted that there are also large government farms in or around the project area with improved pastures and stock indicating the levels of production which can be obtained with development (eg. Tamankaduwa Cattle Project).

Under a more specialised milk enterprise, the herd average annual yield is of the highest order in the performance indicator hierarchy. This also depends upon the frequency and reliability with which cows can be brought into and maintained in production. Therefore, calving rate and lactation length are important since every cow is milked when she has calved. The other factors affecting efficiency are age at first calf, productive life and mortality. The dual purpose system and poor environment mitigates against this since every cow is not milked because of lack of effective demand for milk, defective udders or adverse temperament.

In summary, it is possible to isolate three potential milk/beef production enterprise types with their associated yields and inputs.*

1. From cross bred Buffalo zero grazing (cut and carry) on improved pasture mixture of B. mutica and B. brizantha plus a row of L. leucocephala. The buffalo would also utilise paddy stubble crop residue and fallow areas. No concentrate feeding is envisaged.

2. From cross bred cattle zero grazing similarly improved pasture and also utilising stubble, etc.

3. From indigenous cattle grazing public "Villu/Damana" association estimated at 10,000 hectares.

An important self-help scheme to improve dairy production was opened by the Honourable Minister of Rural Industrial Development on 28th February, 1979. Called the Tamankaduwa Dairy Development Project

* Enterprise budget estimates are attached

and to be managed by the Polonnaruwa District Producers' Co-operative Society, the first of a total of 27 milk collecting centres was opened to give "Purana" farmers better access and incentive to market. The Freedom from Hunger Campaign Board has assisted with finance for equipment and carrier bicycles, tractors, etc.

Phase two of the project involves erection of holding-paddocks and 40 ha of communal improved pastures in each of 17 co-operative areas. Any cross-breeding scheme for the development of small holder areas requires provision of bulls or A.I. These may be organised as bull centres by the Department of Veterinary Services. Government farms established to multiply breeding stock may distribute bulls as well as a limited number of cross-breed preferably in calf-females.

Recommended Extension Inputs Required:

It is generally recognized that an economic environment conducive to livestock development must have government support involving a co-ordinated package.

Under the new Ministry of Rural Industrial Development, a committee was appointed in 1978 to prepare a Master Plan for animal husbandry and dairy development in particular. This committee has several sub-committees one of which is on milk production and marketing which reviewed earlier plans and suggested a strategy for future plans which is now under debate.

Points arising from committee reviews which could be of particular reference to System B include:

A. Past Plans

1. Several local government farms have been established to multiply breeding stock for distribution.
   eg. Cattle - Tamankaduwa (Sindhi Breed), Nelum Pewa (Sindhi Jersey/Sindhi, Tharparkar);
   Buffalo - Polonnaruwa (Murrah);
   Draught - Welikanda (Tamankaduwa-White).

2. The private sector, particularly the small farmer, is serviced most ineffectively in spite of the expansion of the infrastructure, increase in number of extension staff and establishment of new institutions such as S.I.D.A (Dairy Production Improvement Project) which assists artificial insemination services. (Note of importance to System B that according to the Artificial Insemination Office, Department of Animal Production and Health in 1978, only 209 and 176 cattle were inseminated in Batticaloa and Polonnaruwa Districts, respectively). The latter were mainly on government farms).

3. The milk collection network has been expanded.

4. The national herd of both cattle and buffalo continued to dwindle. (There is presently a ban on the slaughter of breedable female cattle or which could be used for draught purposes. There is a complete ban on the slaughter of buffalo).

5. Calf mortality continues to be high.

B. Future Development Possibilities Now Under Discussion:

(Ministry of Rural Industrial Development)

1. There is a serious lack of co-ordination between the various organizations associated with milk production. Production cannot be effectively carried out by a Government Department. There needs to be a tight fit between milk production and milk marketing if any progress is to be made. Hence production of milk and marketing should come under one canopy.

For intensifying production and marketing in the region, decentralization of administration is suggested by the establishment of a Regional Dairy Development Bureau (R.D.D.). The extension network, collecting network, multiplication farms, processing units and all staff associated are to come under the administrative control of the R.D.D. Bureau. This R.D.D. Bureau is to be under the administrative control of the

Dairy Development Board. Farmer participation in the R.D.D. Bureau and in the Dairy Board is provided to safeguard their interest.

The co-ordination between training of personnel at the University level for these programmes, the production of ingredients by the small farmer in the dry zone for producing livestock feeds, the processing of the feeds by the Feed Board, production of other forms of animal protein by the National Livestock Development Board, the provision of research on animal production, training of the farmer and other technical inputs by the Department of Animal Science and the Dairy Board is suggested to be ensured by a supreme body called the Livestock Development Corporation responsible to the Honourable Minister of Rural Industrial Development. The suggested organization to implement the programme is the Dairy Board.

2. There is a need to stop the dwindling of the National Herd.

3. The A.I. service which is most ineffective at the present time needs to be more effectively organized. The Veterinary Service in its present state of development is beyond the means of the small farmer.

4. More grass and legumes should be encouraged by offering subsidies.

5. The productive level in the Dry Zone should be raised by cross-breeding. Presently the impact of the Department in this regard is marginal. The concepts of Tract Breeding, Livestock Development Centres and Cattle Improvement Centres should be implemented effectively.

6. A limited number of cattle and buffalo particularly Indian breeds, should be imported to support dairy development in the Dry Zone. Such imports have been suggested and accepted in earlier plans but abandoned to concentrate on the development of the Mid-country Zones. (Frozen semen from such breeds as the Australian Milking Zebu could also be imported).

Livestock Enterprise Budgets

To project livestock enterprise budgets, assumptions are made in Table No.1 concerning herd efficiency or performance factors. From these, in Table No.2 a theoretical herd composition is derived for 1000 cows giving the equilibrium position at full development. This could represent the picture for a group of farms. It can be reduced to the average composition of a single cow unit as in Table No.3.

To obtain cow equivalents for use in carrying capacity calculations, certain factors as shown in the table are applied to each class of animal. For example one Murrah cow will have on the average 1.185 followers for a total of 2.185 and the total grazing pressure would be 1.689 cow equivalents.

Table No.4 gives the average annual surplus turn-off from a 1000 cow and single cow unit respectively.

Enterprise budgets detailing gross revenue per cow, unit costs and net incomes are given in Table Nos. 6, 7 and 8. Capital costs which have an annual maintenance and capital recovery factor are shown in Table No.9. It should be noted that on a cut and carry basis one cow and followers will require 0.33 ha. of improved pasture. Additional grazing is obtained from crop residue and bunds.

Net income per cow (Rs.3030) is highest for the Murrah buffalo cross primarily because of the premium value of milk for its high fat content.

The zebu temperate cross cow provides a net income of Rs.1347 and the indigenous cow Rs.419. However, the latter has minimal capital requirements because she is run on public land.

TABLE 1

HERD EFFICIENCY FACTORS

Factor		Enterprise Type		
		Murrah Buffalo	Zebu/Temperate Cattle	Indigenous (Zebu) Cattle
Age at 1st calving	(months)	40	30	40
Calving Interval	(days)	429	429	456
Calving Rate	(%)	85	85	80
Lactation Length	(days)	300	300	280
Lactating Cows	(%)	70	70	61
Dry Pregnant Cows	(%)	15	15	19
Dry Non-pregnant Cows	(%)	15	15	20
In Milk yield/hd/day	(L)	04	04	01
Herd Average (over whole year) Milk/hd/day	(L)	02.80	02.80	00.61
Mortality:				
Bull	(%)	02	02	05
Calf	(%)	10	10	10
Yearers & Replacements	(%)	02	02	05
Cow	(%)	05	05	10
Age of Turn-off:				
Cow	(yrs)	10	10	10
Bull	(yrs)	08	08	08
Bull : Cow	(%)	02	02	04
Surplus Turn-off:				
Live Weights (LW)				
Yearer Heifers & Bulls	(kg)	150	125	100
Cull Cows	(kg)	320	250	160
Bulls	(kg)	360	280	180

TABLE 2

EQUILIBRIUM HERD COMPOSITION BASED ON 1000 COWS
(At end of year after surplus turn-off)

Factor	Age Group (yrs)	Enterprise Type: Murrah Buffalo No.	Murrah Buffalo Class Total	Zebu/Temperate Cattle No.	Zebu/Temperate Cattle Class Total	Indigenous (Zebu) Cattle No.	Indigenous (Zebu) Cattle Class Total
Cows	03	149		149		176	
	04	142		142		158	
	05	134		134		143	
	06	128		128		128	
	07	121		121		115	
	08	114		114		104	
	09	109		109		93	
	10	103	1000	103	1000	83	1000
Bulls	03	04		04		08	
	04	04		04		07	
	05	03		03		07	
	06	03		03		06	
	07	03		03		06	
	08	03	20	03	20	06	40
Calves	Female	425		425		400	
	Male	425	850	425	850	400	800
Weaners:							
Heifers	01	155		155		194	
Bulls	01	04	159	04	159	08	202
Replacements:							
Heifers	02	152		152		185	
Bulls	02	04	156	04	156	08	193
Total			2185		2185		2235

TABLE 3

EQUILIBRIUM HERD COMPOSITION
FOR SINGLE COW & FOLLOWERS

Class	Cow Equivalent(CE) Factor	Enterprise Type: Murrah Buffalo		Zebu/Temperate Cattle		Indigenous(Zebu) Cattle	
		Actual	C.E.'s	Actual	C.E.'s	Actual	C.E.'s
Cow	1.00	1.000	1.000	1.000	1.000	1.000	1.000
Bull	1.00	0.020	0.020	0.020	0.020	0.040	0.040
Calves	0.50	0.850	0.425	0.850	0.425	0.800	0.400
Weaner Heifers	0.75	0.155	0.116	0.155	0.116	0.194	0.146
Weaner Bulls	0.75	0.004	0.003	0.004	0.003	0.008	0.006
Replacement Heifers	0.80	0.152	0.122	0.152	0.122	0.185	0.148
Replacement Bulls	0.80	0.004	0.003	0.004	0.003	0.008	0.006
Total		2.185	1.689	2.185	1.689	2.235	1.746

TABLE 4

SURPLUS TURN-OFF PER YEAR
PER 1000 COWS AND PER COW

Class	Age Group (Yrs)	Enterprise Type: Murrah Buffalo		Zebu/Temperature Cattle		Indigenous (Zebu) Cattle	
		Per 1000 Cows	per cow	Per 1000 Cows	per cow	Per 1000 Cows	per cow
Cull Cows	11	103	0.103	103	0.103	83	0.083
Cull Bulls	09	03	0.003	03	0.003	06	0.006
Weaner Heifers	01	227	0.227	227	0.227	166	0.166
Weaner Bulls	01	378	0.378	378	0.378	352	0.352
Total		711	0.711	711	0.711	607	0.607

TABLE 5

GROSS REVENUES PER COW

	Enterprise Type		
	Murrah Buffalo	Zebu/Temperate Cattle	Indigenous (Zebu) Cattle
Gross Revenue			
Milk			
Price/litre (Rs.)	3.86[1]	2.21[2]	2.21[2]
Production/cow/year(l)[3]	1022	1022	222.65
Subtotal Gross Revenue			
From Milk	3944.92	2258.62	492.06
Surplus Stock			
Price/kg. L.W.			
Culls & Bulls (Rs.)	3.30	3.30	3.30
Heifer (Rs.)	6.60	6.60	6.60

	L.W. (kg)	Gross Revenue (Rs.)	L.W. (kg)	Gross Revenue (Rs.)	L.W. (kg)	Gross Revenue (Rs.)
Cull cows	32.96	108.76	25.75	84.97	13.28	43.82
Cull Bulls	1.08	3.56	0.84	2.77	1.08	3.56
Weaner Heifers	34.05	224.73	28.37	187.24	16.60	109.56
Weaner Bulls	56.70	187.11	47.25	155.92	35.20	116.16
Subtotal Gross Revenue From Surplus Stock (Rs.)		524.16		430.90		273.10
Total Gross Revenue		4469.08		2689.52		765.16

1. 7% butter fat
2. 4% butter fat
3. All cows including dry non-pregnant and pregnant.

TABLE 6

COSTS PER COW

Item	Enterprise Type		
	Murrah Buffalo (Rs.)	Zebu/Temperate Cattle (Rs.)	Indigenous (Zebu) Cattle (Rs.)
Labour	-[1]	-[1]	70.00
Disease Control and Incidentals	30.00	30.00	30.00
Cow and Bull Replacement [2]	438.73	342.60	223.06
Building, Fencing and equipment:			
Maintenance[3]	22.50	22.50	3.60
Replacement[4]	122.03	122.03	19.52
Pasture:			
Maintenance	434.55	434.55	-
Replacement			
Clearing [5]	227.82	227.82	-
Grasses[6]	163.02	163.02	-
Total	1438.65	1342.52	346.18

1. Shadow priced at zero since a sideline activity requiring an estimated 0.2 man-years per cow including cut and carry. If valued at Rs.10/day this would represent an allocated cost of Rs.730 per year.

2. Capital Recovery Factor (C.R.F.) over 7 years at 10%, .2054.

3. 3% of original cost.

4. C.R.F. over 10 years at 10%, .1627.

5. C.R.F. over 40 years at 10%, .1023.

6. C.R.F. over 5 years at 10%, .2638.

TABLE 7

NET INCOME PER COW

	Enterprise Type		
	Murrah Buffalo (Rs.)	Zebu/Temperate Cattle (Rs.)	Indigenous (Zebu) Cattle (Rs.)
Gross Revenue	4469.08	2689.52	765.16
Costs	1438.65	1342.52	346.18
Net Income	3030.43	1347.00	418.98

TABLE 8

ESTIMATED CAPITAL COSTS PER COW

	Enterprise Type		
	Murrah Buffalo (0.33 ha. improved pasture) (Rs.)	Zebu/Temperate Cattle (0.33 ha. improved pasture) (Rs.)	Indigenous (Zebu) Cattle (public land) (Rs.)
Cow	2112	1650	1056
Bull	24	18	30
Shelter or night Paddock	600	600	20[1]
Equipment (buckets, troughs)	150	150	100
Improved Pasture			
Establishment [3]	618	618	-
Clearing[2]	2277	2277	-
Total	5781	5313	1206

1. Night paddock.
2. Clearing - Rs.6900/ha.
3. Ploughing and Planting - Rs.568/ha.
   Fertilizer - Rs.1304/ha. (251 kg/ha urea at Rs.3618/t
   126 kg/ha superphosphate at Rs.2043/t
   63 kg/ha muriate of potash at Rs.2501/t)

APPENDIX C

SUMMARY OF SURVEY IN MAHAWELI AREAS H1 AND H2

Intensive interviews were held with a stratified random selection of 21 settlers and their families in the Mahaweli Areas H1 and H2 during December 1978 and February 1979. The purpose was to record some specific detailed information and to develop further understanding of the settlement process from the point of view of the settlers and their families. This information has relevance for future settlement projects in System B and elsewhere.

Sample selection was based on two criteria: stage in the settlement process (based on whether the farmer had produced 4 crops or 2 crops or was handling his first crop) and social dislocation from their original homes and farmland (based on whether settlers had been brought in from outside the project area - referred to as "outside" settlers - or whether they were long term residents of traditional Purana villages in the area who were either "removed" to new homes and farmlands in the project area or were "resettled" through retaining their houses).

The settlers were provided with 2½ acres of farmland and ½ acre of highland in a designated hamlet location. "Outside" and "removed" settlers constructed their own temporary houses.

All settlers in the sample are Sinhalese and are Buddhist. Average family size was 5.2 persons; average age of male heads of households was 36.7 years and among female heads of households (most of whom were wives of the male head) the average age was 33.1 years. Average level of education for male household heads was 5.9 years of schooling and for female heads it was 4.7 years. Of the 21 families nine were at the early stages of the family cycle (either husband and wife only or husband, wife and children aged 14 or younger), there were nine families at later stages of the family cycle (husband and wife and either adult children aged 15 or older and/or other related adults); only three of the households were headed by an adult who was either an unmarried male or an elderly widow. Other adults lived in these three households. The household labour supply was measured by using the concept of productive man work units (P.M.W.U.). By this measure it was found that family labour supply

ranged from 1.75 to 6.25; the median P.M.W.U., was 1.75 and the average was 2.51.

There were noticeable differences between "outside", "removed" and "resettled" families in regard to these characteristics. The "resettled" families had the oldest and least educated male and female heads of household; the largest number of persons living in the households; were predominantly in the later stages of the family life cycle and had a relatively high family labour force. The "removed" settler families had the youngest and best educated male and female heads of households; the smallest number of persons living in each household; the smallest family labour force and were mainly all at the young stages of the family cycle. The "outside" families were mid-way between the two traditional categories of settlers in respect of age and education of household male and female heads and in the number of persons per family. These families were in different stages of the family cycle (predominantly in the older stages) but differed in having the highest average family labour force of all three settler categories.

Considerable detail was gathered in regard to the vital question of the supply and distribution of irrigation water. Two-thirds of the settlers interviewed said they had problems and most of these related to technical matters. These included: improper or incomplete construction of distributory canals, field canals and inlets; inadequate land levelling; lack of drainage and salinity of the soil; lack of sufficient irrigation water related to the location of some settlers with respect to the main water source and the lack of gates between distribution and field canals and defective distribution canals.

All of the settlers grow paddy on their irrigated farmlands. One reason is that, regardless of yields, this basic crop gives some assurance of a family supply of food. A few farmers had considered growing subsidiary crops on farmland during the Yala season but had not been able to do so because of inability to control excess moisture from seepage when only one or a few farmers along a field canal (turnout) were willing to raise subsidiary crops.

The extent to which other agricultural inputs were being used was investigated. Seeds of the high yielding variety of rice were in use by all of the settlers who had either harvested crops or were planting their first crop. Non-family labour was used by 14 of the 21 settlers (eleven hired labour, one hired labour and also practised attam, one used attam, and one settler used ande). Only four families relied solely on family labour; two had not yet commenced agricultural operations and one settler did not provide information about his labour practices. Draught power in use was reported as tractor (7 settlers), tractor and buffalo (1 settler), tractor and hand labour (1 settler), buffalo (7 settlers), hand labour (mammoty) 2 settlers. Two men had not yet prepared their land and one did not provide information. The recommended practice of transplanting had been used by 7 settlers and another 3 were starting this for the first time. Nine of the settlers broadcast paddy seed but some of these (3 men) said they had to use this method because of the presence of roots in the soil. Recommended chemicals were more widely used in that 17 settlers reported using insecticides and 12 reported using fertilizer.

It was found that proportionately more of the "outside" category of settlers (than of the traditional "resettled" or "removed") used both insecticides and fertilizer, habitually transplanted and reported the highest average yields of rice at both Maha and Yala seasons.

Reported paddy yields for the two crop seasons in 1978 varied widely. However, there was a remarkable difference between settlers on the basis of social dislocation. Outsiders obtained consistently higher yields in both seasons whereas Maha yields exceeded those of Yala for the other two settler groups.

The sales of paddy are chiefly handled through private buyers rather than the local co-operatives as was intended on this development project. This is due to the malfunctioning of the local co-operatives (lack of gunny bags, and/or of cash and/or of storage, etc.). This means that the settlers are receiving Rs.2/- to Rs.4/- less per bushel of paddy through sales to the local boutique owners and other buyers than if the co-operatives were functioning efficiently and buying at the set Government paddy purchase price of 37 cents per pound.

In regard to the size of farmland and harvested area the settlers indicated satisfaction with the 2½ irrigated acres of farmland but made it clear that the homestead area should be at least one acre rather than the present ½ acre. More space for homesteads is needed for house-building, storage sheds, building of latrines and wells, space for domestic fowl and animals and for growing needed subsidiary food crops.

It was observed that encroachers (usually relatives or friends of settlers) are building shelters and attempting subsidiary crop production along roadways and/or land areas which had been earmarked by the Mahaweli Development Board for other purposes.

Family living conditions at the present stage of development in areas H1 and H2 would seem to be at a pioneer stage. Houses are small (1 or 2 rooms) with either a separate kitchen or an open fire set on 3 stones at the rear of the building, construction is of mud and wattle with cadjan roofs — unprotected dug wells are the source of potable water, bathing is done in nearby canals or tanks, no concrete slabs for latrines have been provided to date.

Village facilities and services are rapidly appearing in the "rurban" centre of Galnewa which has a well-planned business centre where a variety of services and facilities are in operation or in preparation. The major concerns expressed by several of the settlers were that: local dispensaries were inadequately stocked with medicine; the road conditions prevented regular bus service which created hardships for children attempting to travel to a secondary school and for persons needing hospitalization; and the lack of goods and of service at local co-operatives.

In terms of social interaction the fact that 2 of every 3 settlers are longterm area residents (the "removed" and "resettled" categories) means that kinship and caste obligations and expectations largely determine their social interaction. The settlers who came from outside the project area are more concerned with the neighbourhood in which their new homes are located and are more conscious of the need to form and sustain informal organizations of mutual benefit. An example is given of an informal group of 20 "outside" settlers who have lands along the same turnout area.

These men, under the guidance of one of their members who is a respected informal leader, mutually decide on the fair distribution of irrigation water to each of their paddy growing allotments. No formal organizations seem to be operating at this point in time among the settlers who were interviewed.

APPENDIX D

INTERVIEW NO.I

Name of the Village : Seelapura

Interviewer : Mr. A. M. Samarasinghe
Date of Interview : March 12, 1979

As the male household head was away his wife was interviewed.

According to her information, her husband's parents have come here about 25 years ago and have been living here on government land as encroachers. Their original village is in Kurunegala District.

Now the informant and her husband are a separate family and living on encroached land of about ½ acre.

The total number of families in this village is about 45, and 16 of them are given 2 acres each of highland by the Government. Others are living on encroached land. The total population is about 300 persons.

The main source of income is from cultivation. Some people do paddy cultivation on the "Ande" system on land of about 1 - 2 acres. The adjoining village is a village settlement scheme, where land was given mainly to "Veddha" people (original Sri Lanka natives). These "Veddha" people have given their paddy lands to other villagers on "Ande". We met one "Veddha" person who was given 3 acres of paddy land and 1 acre highland by the government. But he is cultivating paddy only on about ½ acre area. The balance of the land is given on "Ande". "Ande" payment is made in cash - Rs.1000/- per acre for a season. Paddy cultivation is done only once a year, in the Maha. These paddy lands are grown under the Dalukana tank and the yield is about 50 bushels per acre.

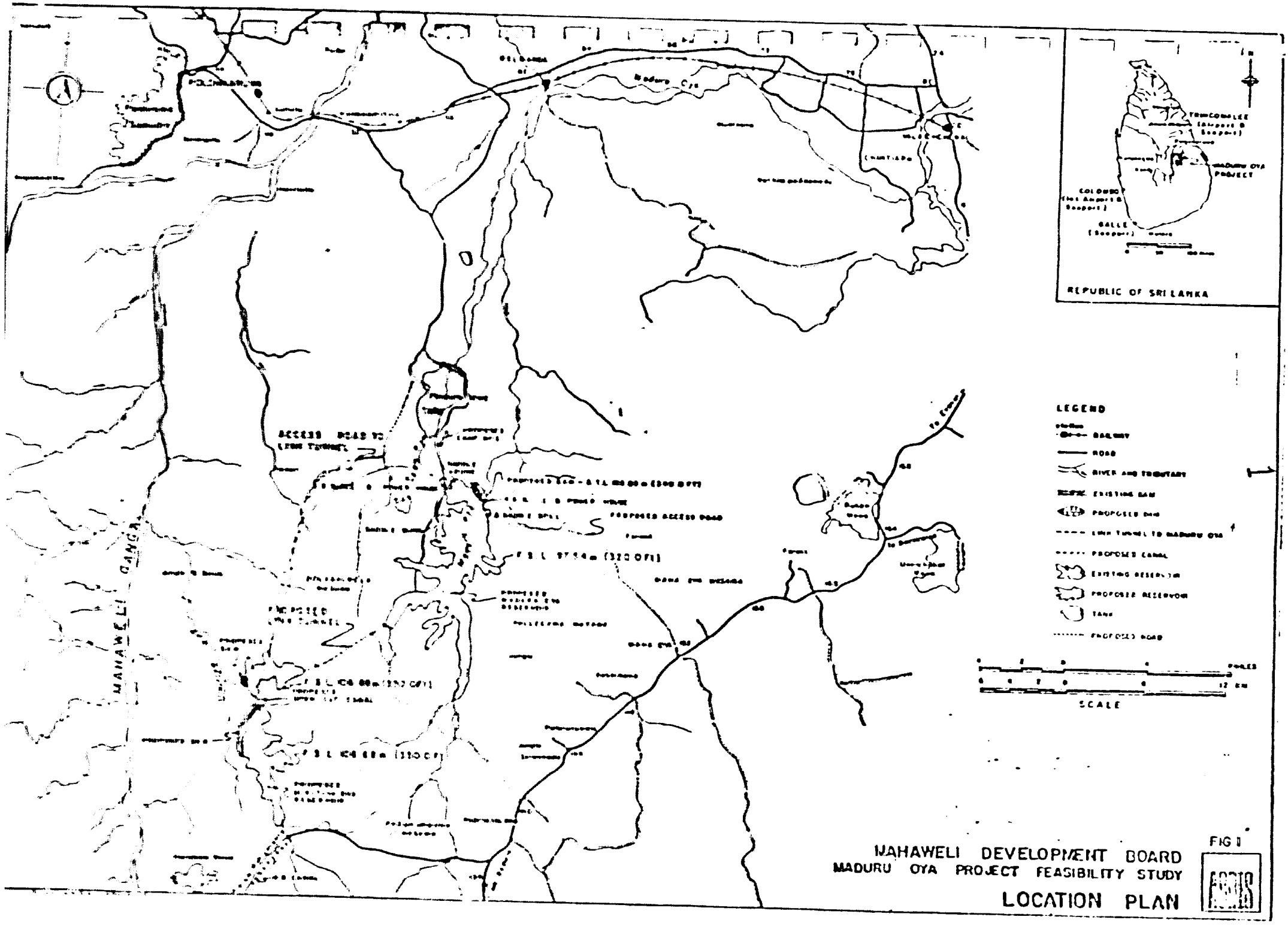
In addition to this, these villagers do chena cultivation and earn about Rs.1,000/- to Rs.2,000/- per year. Chena cultivation is done only once a year for about 6 months.

Some people collect cane from the jungle and sell it to the collecting centre as another means of income. We observed that some people (specially women) were weaving baskets from this cane.

When we were doing this interview we had an opportunity to have a group discussion and met a neighbouring encroacher who has 10 children. His major occupation is paddy cultivation under "Ande" in Dalukana village. In addition to this he is looking after 14 buffaloes. The buffaloes belong to a rich man in Manampitiya who pays Rs.15/- per pair of buffaloes per year as the "looking-after" fee. During the peak seasons the owner comes and takes the buffaloes to hire in his area and when the work is over he brings back the animals to the caretaker. The caretaker is allowed to use these animals for his cultivation work. They do not have special pasture land, so they take their cattle and buffaloes towards the river bank. These animals graze within an area of 1 - 4 miles.

People who had well maintained home gardens had about ½ acre in cowpea, ¼ acre in chillies and about ¼ acre in mixed vegetables. In addition to these they had well grown plantain trees. These gardens provide their daily home needs and sometimes a little surplus for sale.

FIGURES


REPUBLIC OF SRI LANKA
LEGEND
RAILWAY
ROAD
RIVER AND TRIBUTARY
EXISTING DAM
PROPOSED DAM
LINK TUNNEL TO MADURU OYA
PROPOSED CANAL
EXISTING RESERVOIR
PROPOSED RESERVOIR
TANK
PROPOSED ROAD
SCALE
MAHAWELI GANGA
PROPOSED ACCESS ROAD
MADURU OYA PROJECT
FIG 1
MAHAWELI DEVELOPMENT BOARD
MADURU OYA PROJECT FEASIBILITY STUDY
LOCATION PLAN

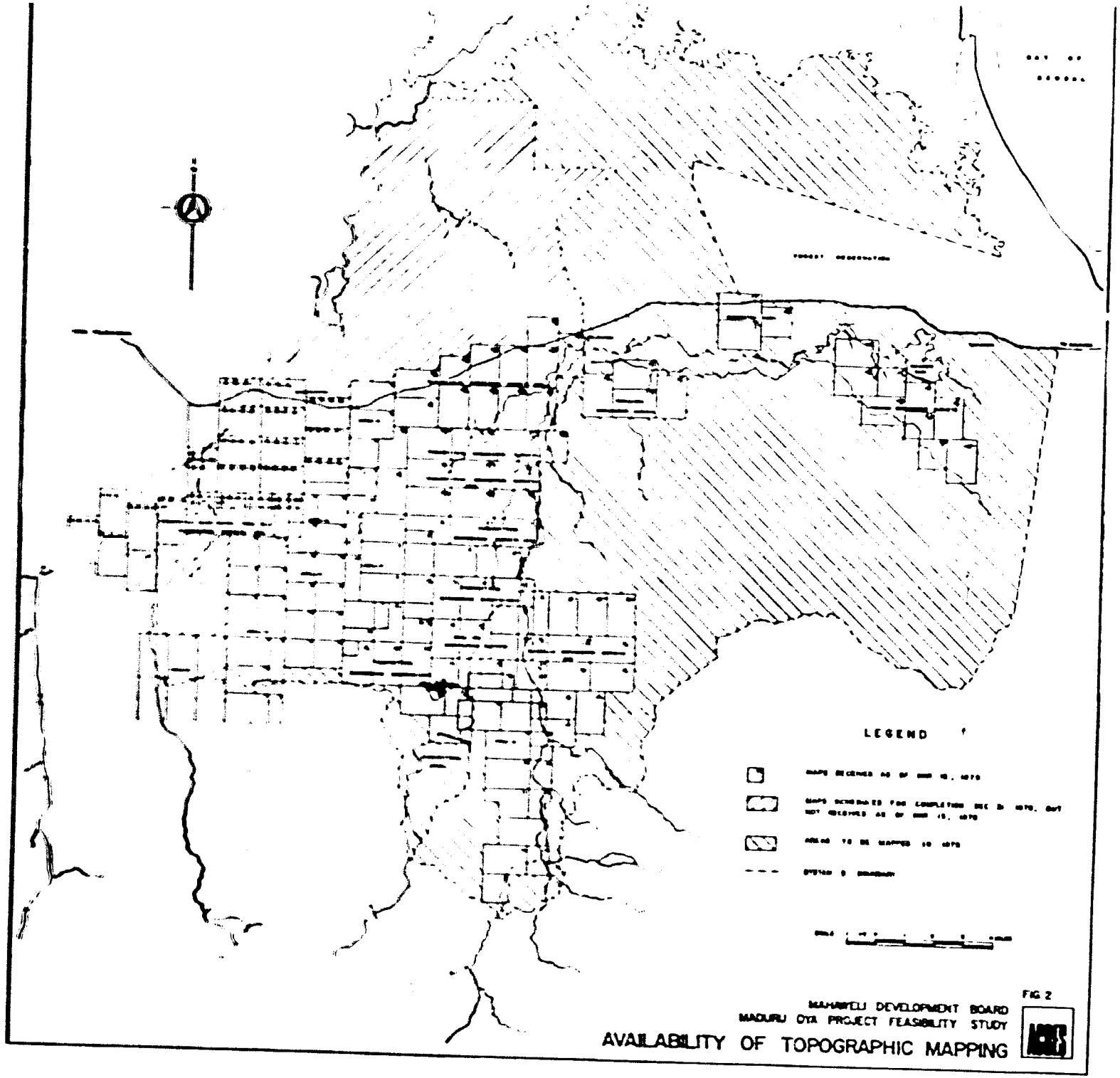
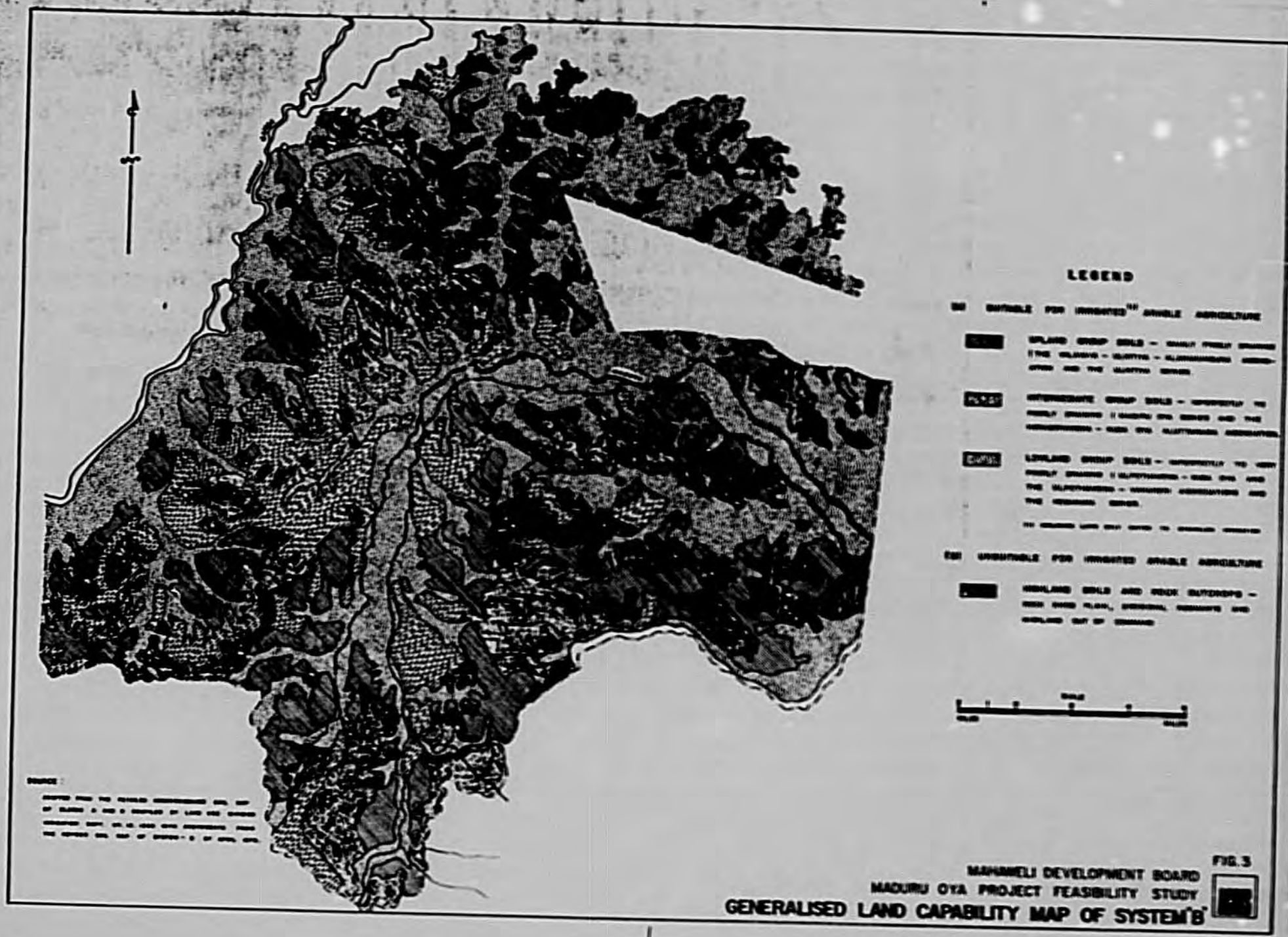


FIG 2

MAHAWELI DEVELOPMENT BOARD
MADURU OYA PROJECT FEASIBILITY STUDY

AVAILABILITY OF TOPOGRAPHIC MAPPING



MAHAWELI DEVELOPMENT BOARD
MADURU OYA PROJECT FEASIBILITY STUDY
GENERALISED LAND CAPABILITY MAP OF SYSTEM 'B'

FIG. 3

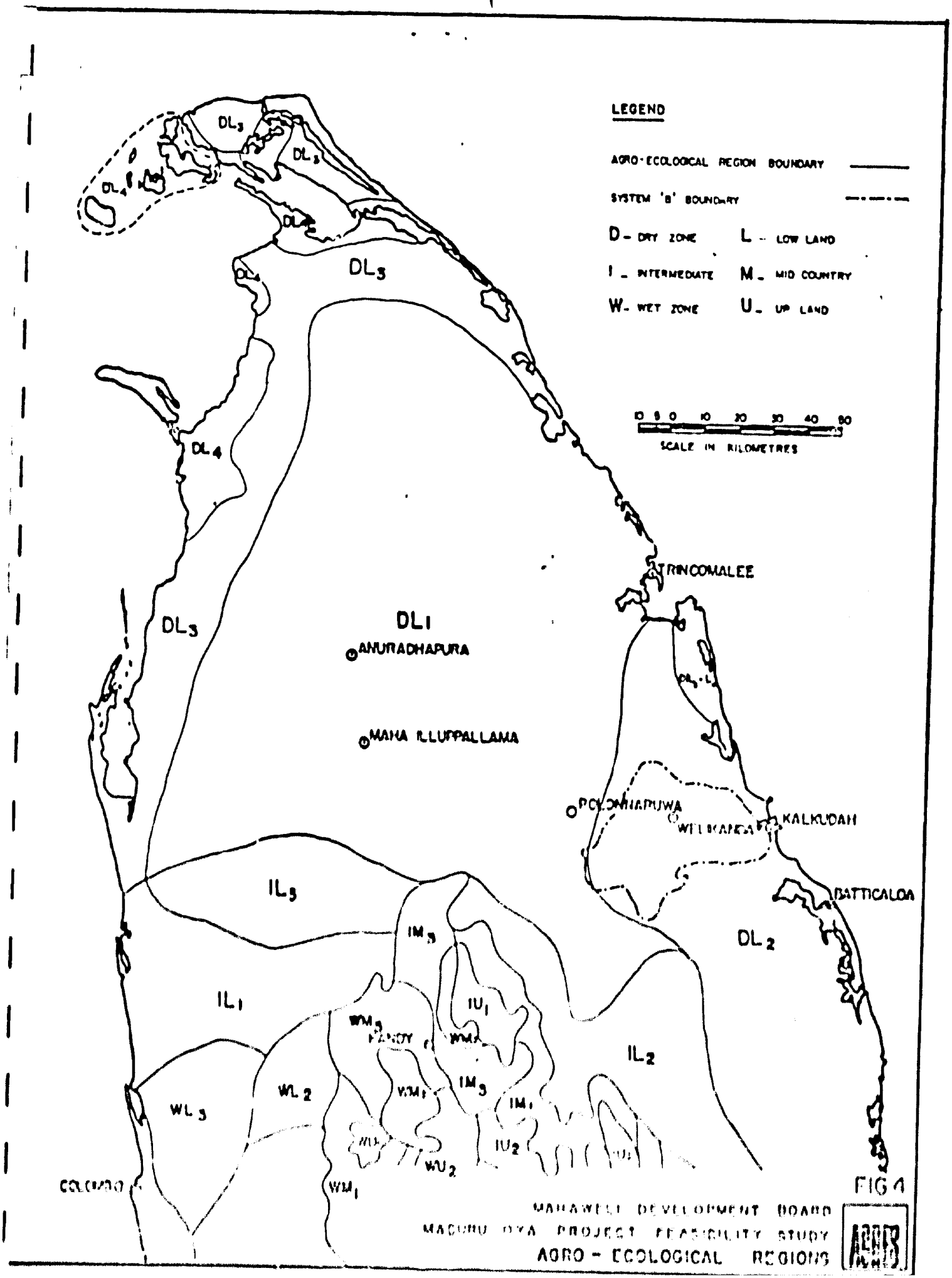


FIG 4

MAHAWELI DEVELOPMENT BOARD
MADURU OYA PROJECT FEASIBILITY STUDY
AGRO - ECOLOGICAL REGIONS

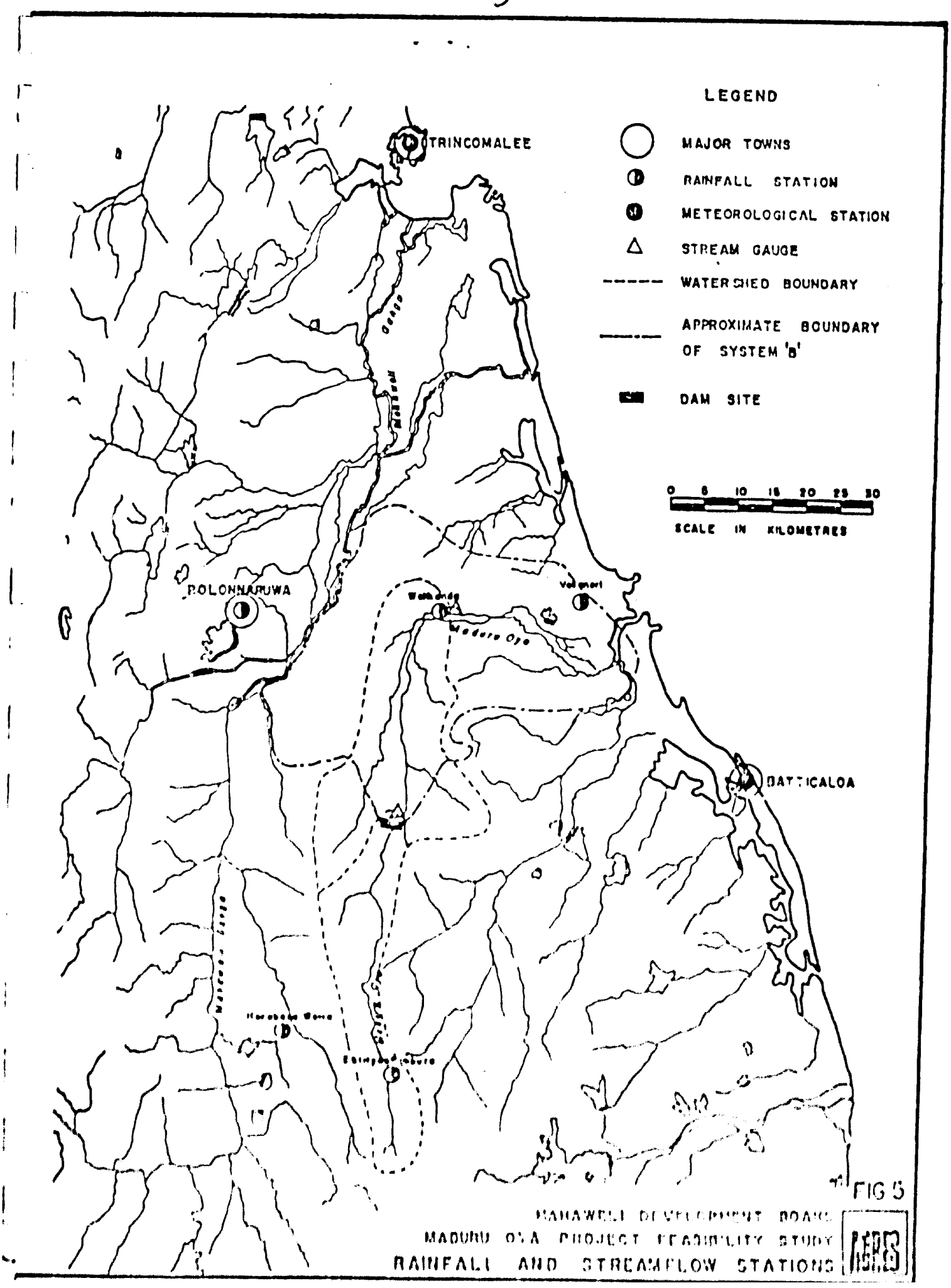
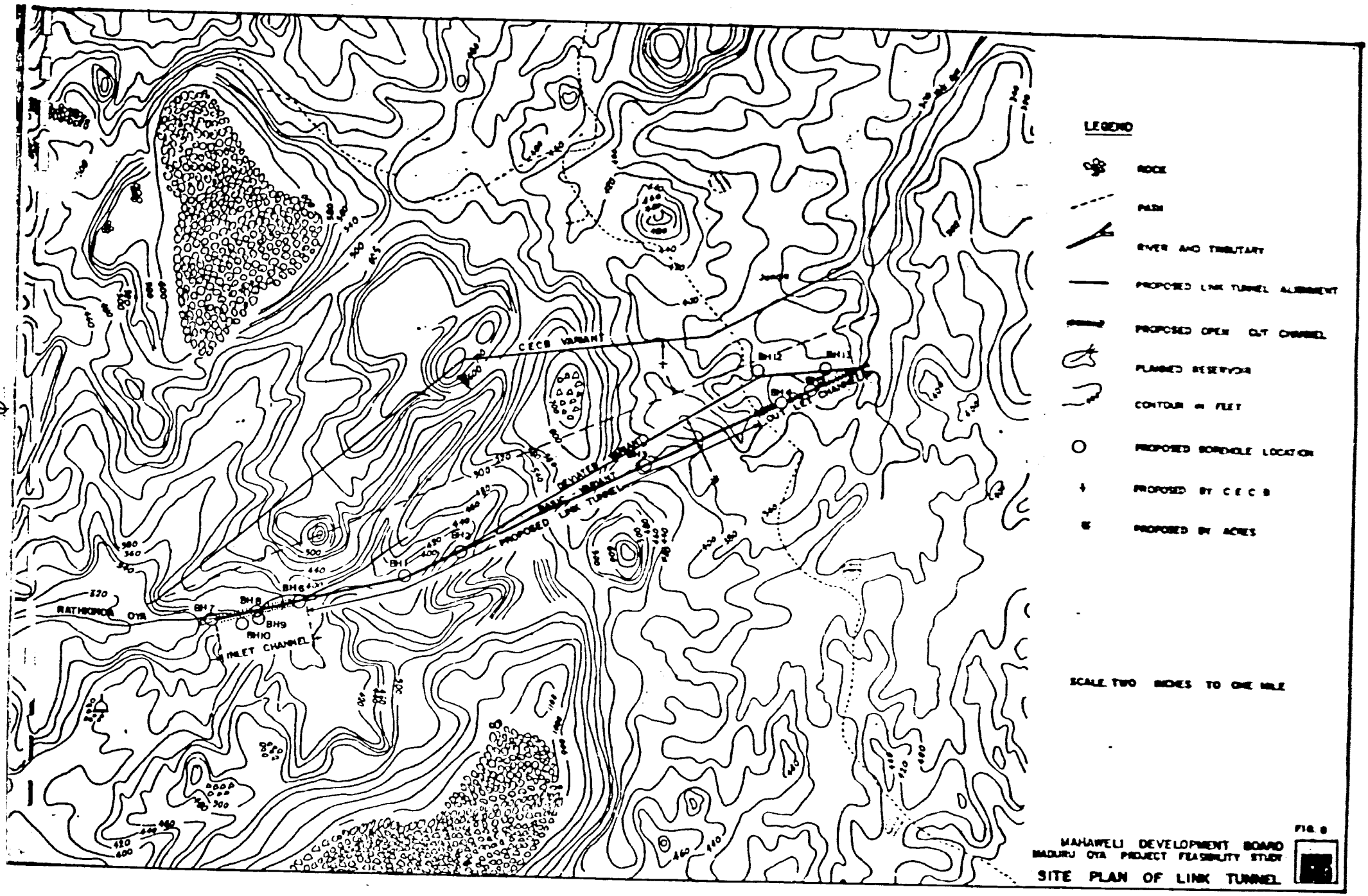


FIG 5

MAHAWELI DEVELOPMENT BOARD
MADURU OYA PROJECT FEASIBILITY STUDY
RAINFALL AND STREAMFLOW STATIONS


LEGEND
ROCK
PATH
RIVER AND TRIBUTARY
PROPOSED LINK TUNNEL ALIGNMENT
PROPOSED OPEN CUT CHANNEL
PLANNED RESERVOIR
CONTOUR IN FEET
PROPOSED BOREHOLE LOCATION
PROPOSED BY C E C B
PROPOSED BY ACRES
SCALE TWO INCHES TO ONE MILE
CECB VARIANT
PROPOSED LINK TUNNEL
INLET CHANNEL
OUT LET CHANNEL
RATHKONDA OYA
BH1
BH2
BH6
BH7
BH8
BH9
BH10
BH12
BH13
BH14
FIG. 8
MAHAWELI DEVELOPMENT BOARD
MADURU OYA PROJECT FEASIBILITY STUDY
SITE PLAN OF LINK TUNNEL

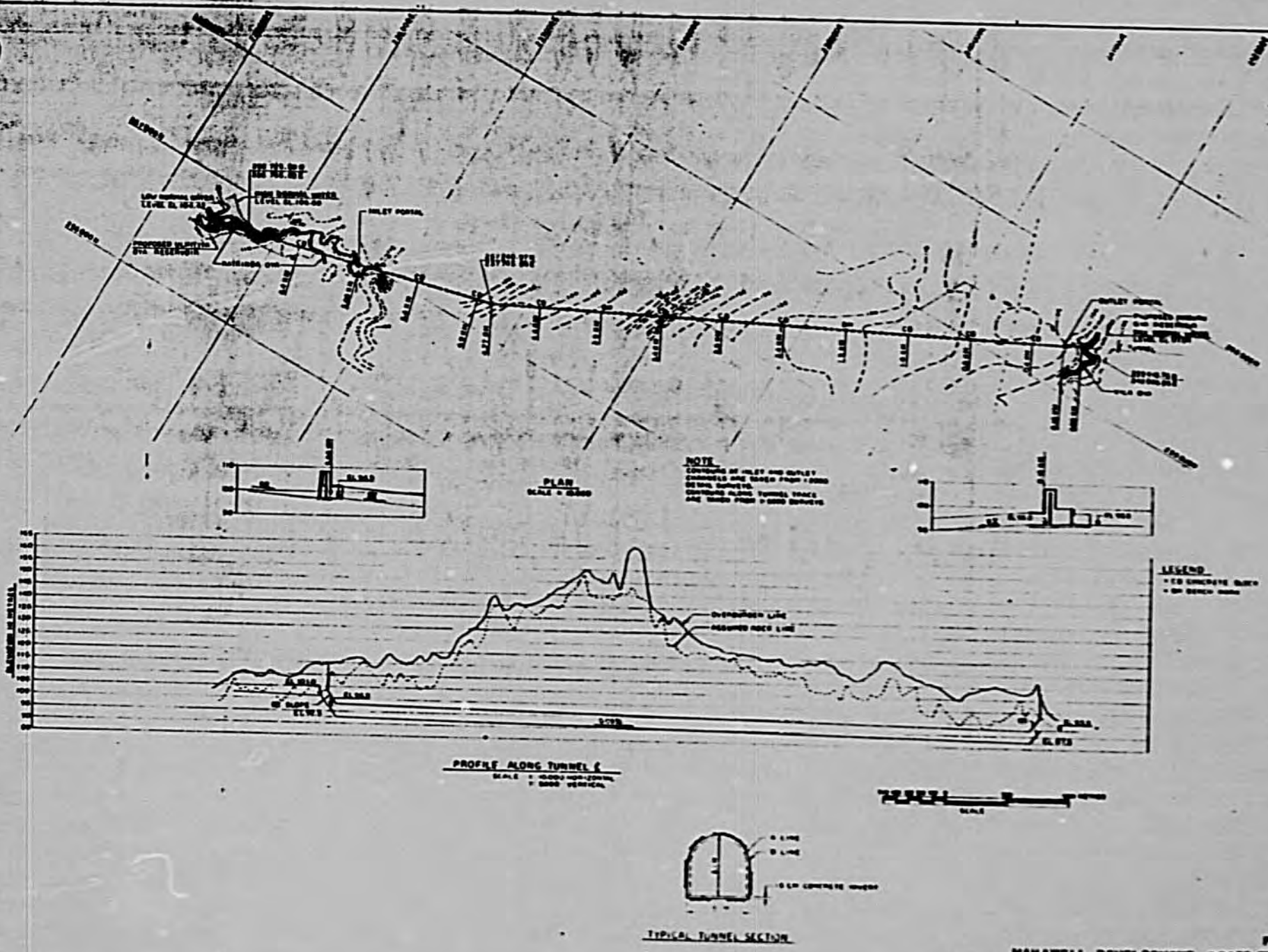
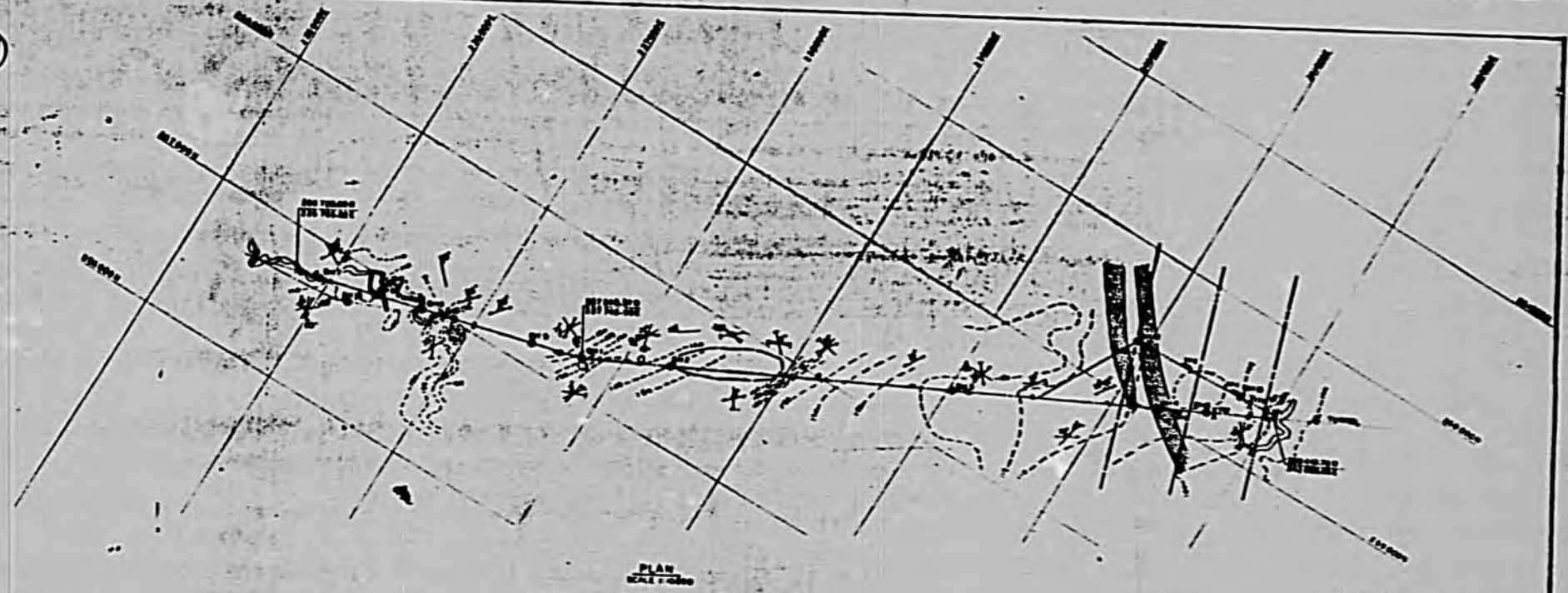


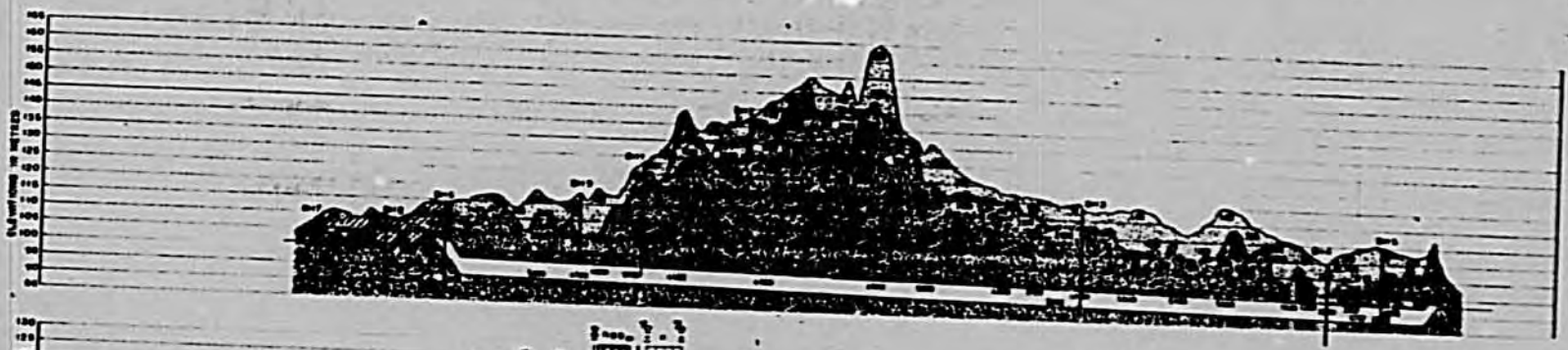
Fig 9

MAHAWELI DEVELOPMENT BOARD

MADURU OYA PROJECT FEASIBILITY STUDY

LINK TUNNEL—PLAN AND PROFILE





PROFILE ALONG TUNNEL ℄

LEGEND

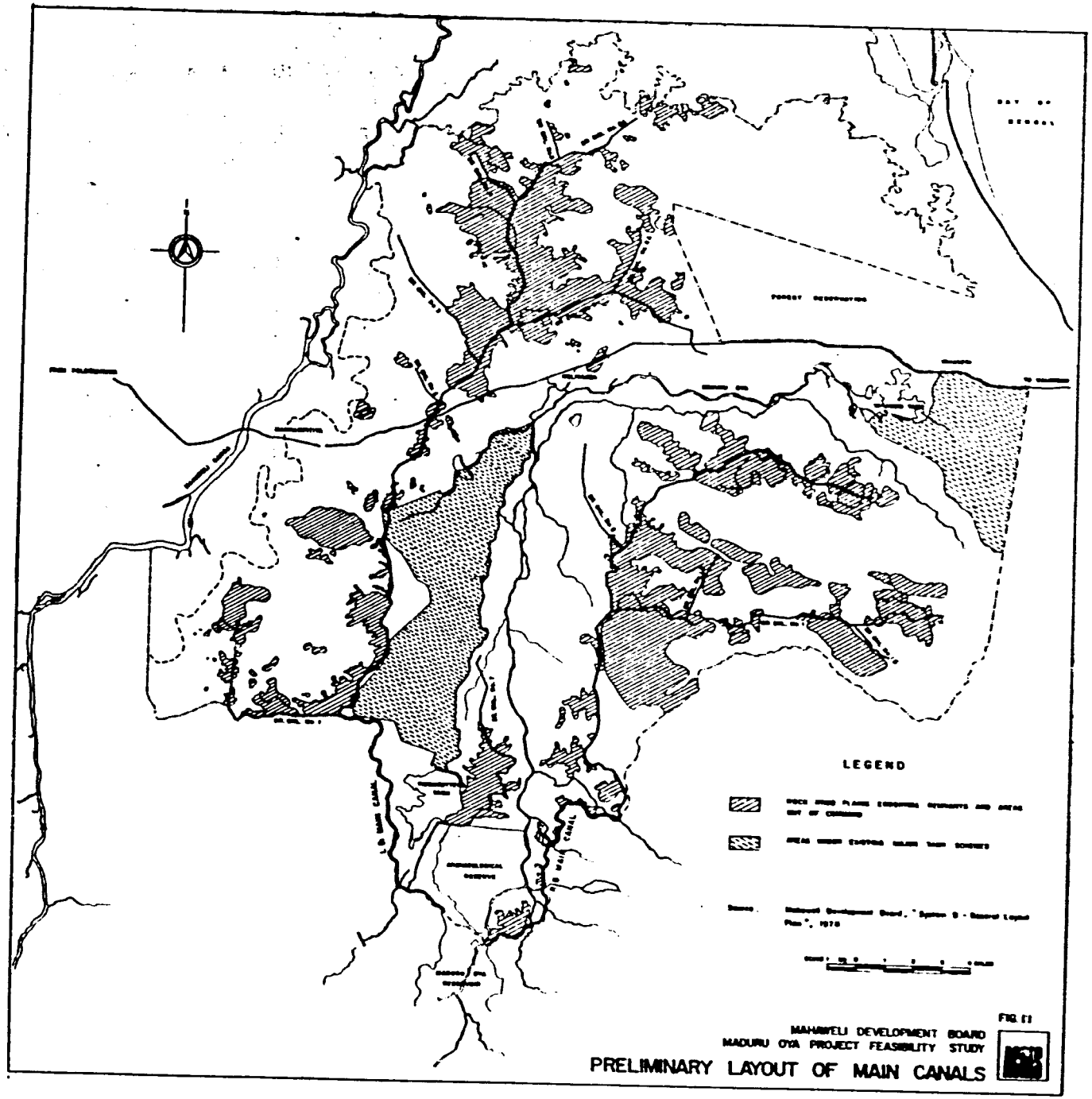
NOTES

1. THE BOUNDARIES BETWEEN ROCK AND DEBRIS HAVE BEEN ESTABLISHED AT THE BOREHOLE LOCATIONS. BETWEEN BOREHOLES THE BOUNDARY IS DEFINED FROM SEISMIC REFRACTION SURVEY.
2. THE DATUM FOR ALL LEVELS IS THE MSL DATUM OF THE GEODETIC LEVELLING OF SRI LANKA.
3. CONTOURS AT INLET AND OUTLET CHANNELS ARE TAKEN FROM 1:2000 DETAIL SURVEYS. CONTOURS ALONG TUNNEL TRACE ARE TAKEN FROM 1:5000 SURVEYS.

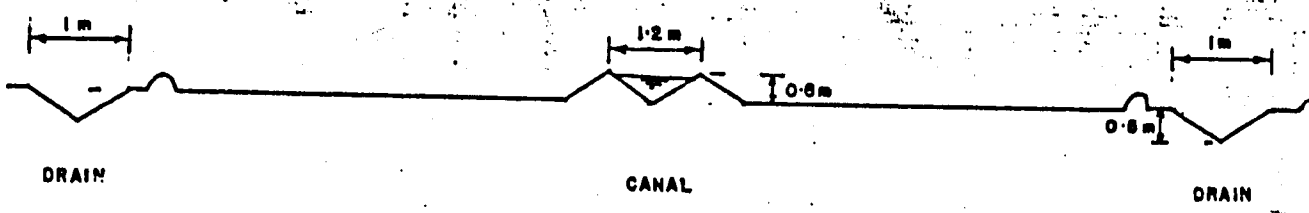
MAHAWELI DEVELOPMENT BOARD

MADURU OYA PROJECT FEASIBILITY STUDY

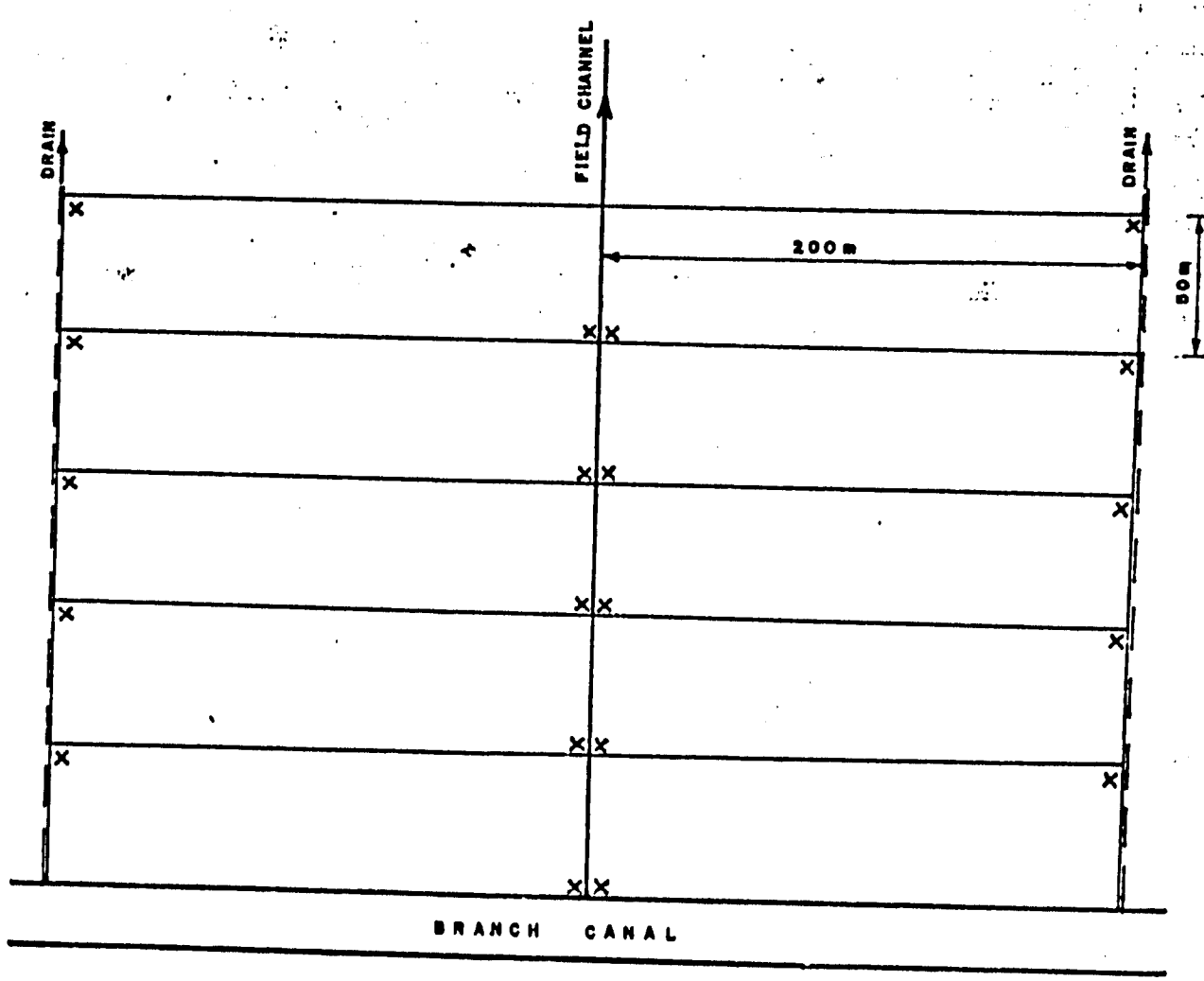
LII.X TUNNEL—GEOTECHNICAL FEATURES


LEGEND
FIG. 11
MAHAWELI DEVELOPMENT BOARD
MADURU OYA PROJECT FEASIBILITY STUDY
PRELIMINARY LAYOUT OF MAIN CANALS

SECTION



PLAN



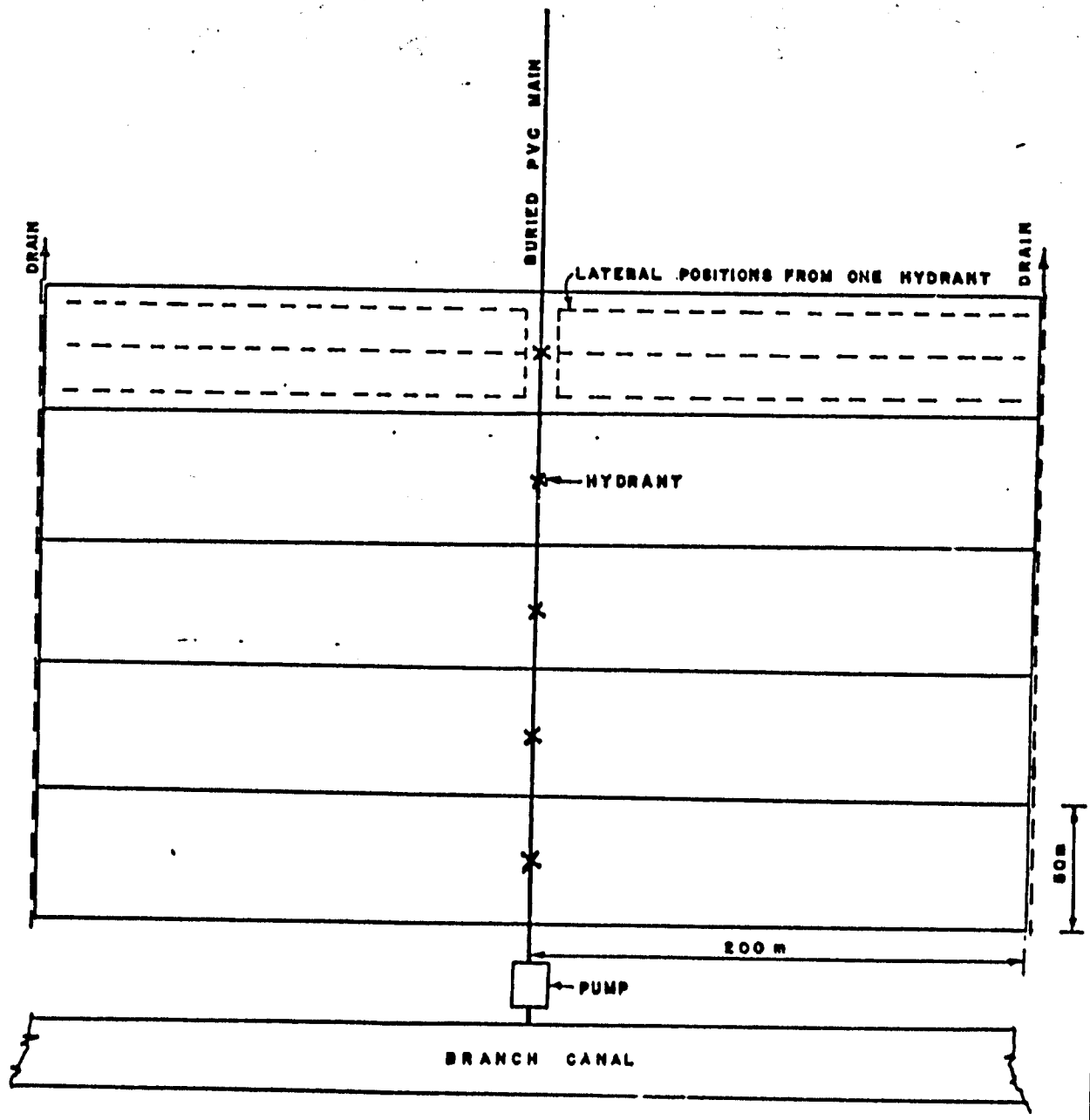
X-GATE

N.B. : NOT TO SCALE

Fig·12

MAHAWELI DEVELOPMENT BOARD
MADURU OYA PROJECT FEASIBILITY STUDY

TYPICAL LAYOUT OF LOWLAND FARM



N·B·: NOT TO SCALE

Fig·13

MAHAWELI DEVELOPMENT BOARD
MADURU OYA PROJECT FEASIBILITY STUDY

TYPICAL LAYOUT OF UPLAND FARM

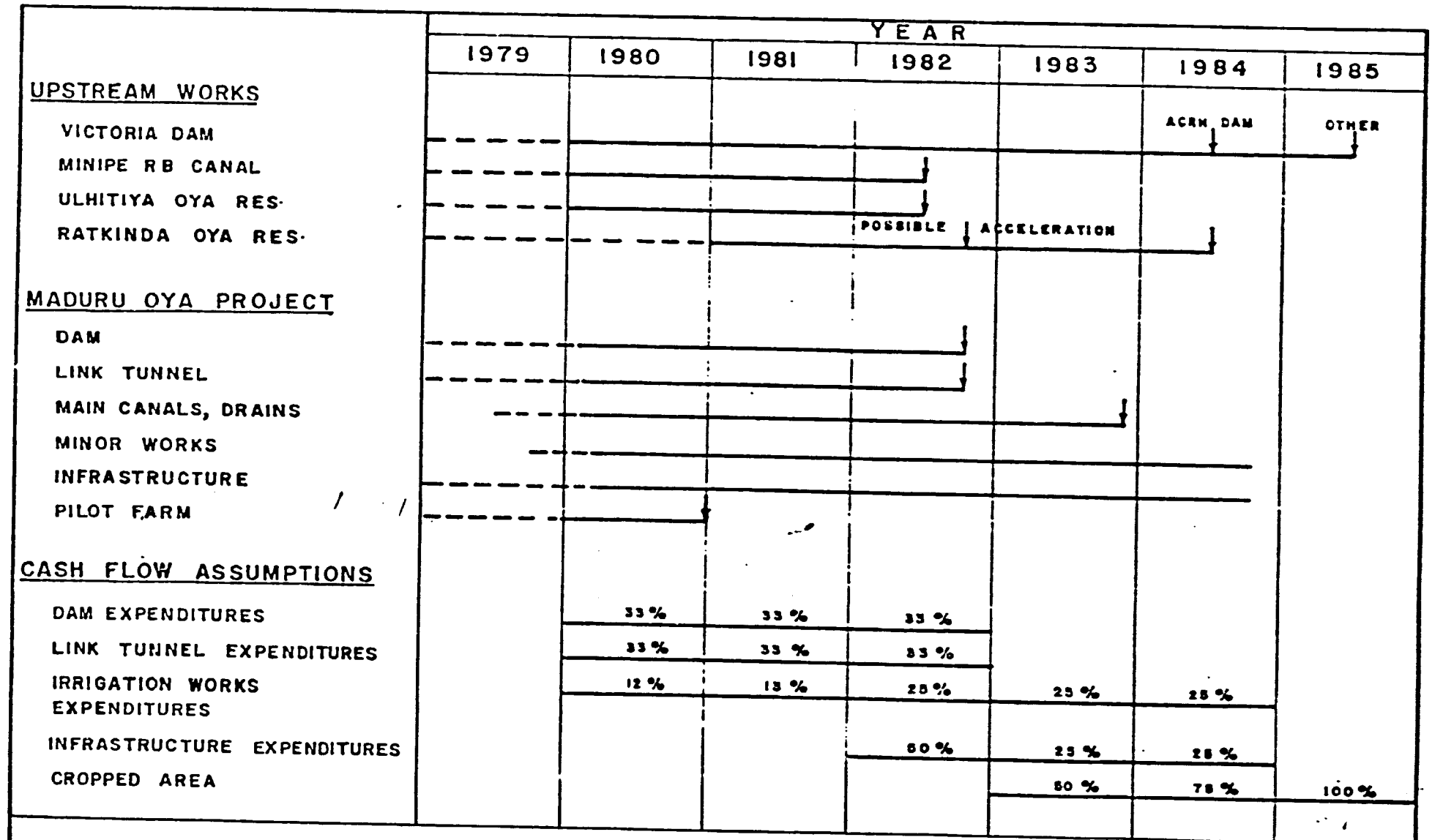


Fig14

MAHAWELI DEVELOPMENT BOARD
MADURU OYA PROJECT FEASIBILITY STUDY
POSSIBLE IMPLEMENTATION SCHEDULE