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Democratic Socialist Republic of Sri Lanka

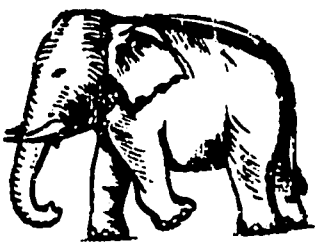
Ministry of Mahaweli Development

ENVIRONMENTAL ASSESSMENT

ACCELERATED MAHAWELI DEVELOPMENT PROGRAM

MID-TERM REPORT

1 FEBRUARY 1980



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1 February 1980

Mr. N. G. P. Panditharatne
Director General
Mahaweli Authority
COLOMBO

Dear Sir:

ENVIRONMENTAL ASSESSMENT
MID-TERM REPORT

We are pleased to submit herewith, for your review and comments, our Mid-Term Report, entitled "Environmental Assessment for the Mahaweli Accelerated Development Program".

We would like to take this opportunity to express our appreciation to the many government agencies and related institutions which cooperated with us to provide information and assistance in the preparation of this report. We look forward to discussing comments and recommendations from you and your staff concerning the contents of the report.

Respectfully submitted,

Michael T. Sobczak
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CABLE TAMSENG COLOMBO

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INTRODUCTION

This interim report describes the environmental assessment conducted to date of the proposed Accelerated Mahaweli Development Program. The report focuses on the major proposed head works for the Mahaweli Ganga and Maduru Oya and upon the downstream irrigation Systems A, B, C and D. (See Figure 1 - 1). Collectively, these project developments comprise the proposed action which the environmental assessment is concerned with; alternatives to this overall proposed action are not considered in this report. However, alternatives within the various components of the proposed action are evaluated.

In general, the presentation approach followed in this report involves subdividing the respective discussions for each of the environmental disciplines into three parts. The first part of each major section is concerned with a description and analysis of the existing conditions pertaining to the respective environmental factor or topic. The second part consists of an identification and evaluation of project impacts related to the environmental factors. Finally, the last part provides recommended actions to either minimize potential adverse impacts or to enhance beneficial aspects of the proposed projects.

The analyses presented herein are based on initial evaluations of existing data and essentially reflect specific recommendations of individual disciplines; therefore findings should be considered tentative and, in some cases, subject to revision in the final report submission which will be based on more detailed data and a more thorough integration of all aspects of the study. In general, however, it is anticipated that many of the basic issues will remain substantially unaltered.

It should be noted that in regard to the proposed irrigation projects, more detailed analyses of environmental aspects are possible

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for only Systems B and C. The feasibility studies for Systems A and D have not yet been submitted, and, in fact, it is not anticipated that these studies will be available prior to completion of the final environmental assessment report. Consequently, in both this interim report and in the final submission, the analysis of environmental impacts, pertaining to Systems A and D will be of a more generalized, qualitative nature.

SUMMARY

The following tabulation presents summaries of the major project impacts on the human and natural environment and a brief description of recommended actions to minimize adverse impacts and/or to enhance beneficial impacts.

IMPACTS	RECOMMENDED ACTIONS
Successful project implementation will result in highly benefici-' social impacts in terms of emp ment opportunities, higher inc and improved standards of livi to incoming settlers as well a for existing residents. Poten problem areas exist which may adversely affect the achievemet of the project's social objectives. A serious unresolved is is whether or not one hectare plots allocated to family units will be economically self-susta ing. The rapid implementation rate increases the probability that infrastructure and settler preparation may not always be available at appropriate times. Possible problems may also occu due to the isolation of the settlers, the limiting of women roles and an inability to devel a sense of community stability and cohesiveness. Other issues of concern involve labor shortages, land tenure conflicts and changes in production systems. These potential problems may singly or in combination contribute to settlement failures.	Recommended measures to minimize potential problem areas involve monitoring failure rates and causes to enable corrective planning measures to be instituted. Similarly, land tenure arrangements and financial status for settlers require supervision. Policies are needed to increase employment opportunities for all family members, to provide additional farm labor and for the transfer of failed settlers to other occupations to enhance inherent community stability. Women should be included in programs to increase understanding of the household as a financial unit and the responsibility of that unit in credit programs. Proper scheduling of infrastructure implementation is essential to meet settler needs, particularly in the initial settlement phases.

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IMPACTS	RECOMMENDED ACTIONS
A significant increase in both water-borne and insect vector (especially malaria) diseases can be expected with development of the project and the influx of a large human population to the region.	Health care and sanitation facilities are recommended throughout the project area. Safe, potable water supplies should be provided for construction personnel and incoming settlers. Malaria control programs are recommended for implementation including periodic house spraying. Regulation of water flows is suggested to limit breeding habitats of malaria carrying mosquito species. The overall health status of the population should be monitored especially in regard to insect vector and water-borne diseases.
Investigation has shown that large areas of the upper catchment are being severely eroded as a result of poor land use. Without adequate soil and water conservation practices, silting and sedimentation will continue to cause a deterioration of lands, tanks and villus.	A comprehensive soil and watershed management program should be implemented, especially in the upper catchment. General recommendations are made to develop institutional capabilities for the regulation and protection of the watershed. Adequate drainage systems need to be installed, and certain cultivated areas need rehabilitation programs.
Existing forests will be sharply reduced as clearing proceeds to prepare agricultural land. Both lumber and firewood demands for the area will increase as the population rises; in fact, the present timber resources cannot meet current domestic demands.	Firewood plantations are recommended near planned settlements and windbreaks will be suggested for certain areas. Riverine forests should be preserved to ensure that certain tree species of luxury grade be maintained and managed for sustained yield harvests.
Generally, the quality of surface waters are expected to be highly suitable for irrigation and livestock use and for the protection of aquatic life. Localized deterioration of water quality may occur as a result of increased solids levels in irrigation return flows. Nutrients and pesticides will accumulate in the downstream receiving waters. Salinity intrusion may be altered due to changes in river flows.	A monitoring program is recommended to identify problem sites in the command areas which can be subsequently resolved with changes in water application rates or improved drainage. The program will also permit the derivation of a conservation flow to dilute saline irrigation return flows, maintain aquatic habitats and control salinity intrusion in estuarine areas.

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IMPACTS	RECOMMENDED ACTIONS
The increased availability of aquatic habitats such as new tanks, canals, reservoirs and even paddy fields will result in a concomitant increase in fish populations and production. A secondary impact will be the increased demand for fishery products due to the population increase.	Planning measures are recommended to capitalize on the increased potential for fish production. Fish farming pilot projects are suggested for investigation. Recommendations are also made for research and applied low level technology to increase overall fishery production.
Existing fisheries in downstream areas such as the estuaries and some tanks may be reduced due to changes in flow regimes, the alteration of nutrient supplies and the increase in pesticides.	Conservation flows are suggested to dilute toxicants. Proper application of pesticides and fertilizers will minimize their accumulation in return flows.
Alteration in river flows will result in partial or even total drainage of the swamps (villus) in the floodplains. This will in turn diminish the value of the villus as wildlife habitats, domestic stock grazing areas and for fisheries.	It is recommended that small weirs or comparable structures be constructed in the outlets of the villus to prevent their dessication during low flow periods. This would maintain the highly productive villu habitats, thus continuing or perhaps enhancing their value for grazing, fisheries and wildlife usage.
Existing wildlife habitats and migratory routes will for the most part be replaced with the implementation of agricultural and settlement development schemes. Wildlife affected by this habitat reduction include eight endangered/threatened species (elephant, leopard, red face malkoha, mugger crocodile, bengal monitor, phython, purple faced langur and toque macaque) and a total of 36 species endemic to the island of Sri Lanka. A secondary impact will occur when conflicts arise between farmers and the larger mammals (especially elephants) which are gradually confined to small isolated areas. Elephants and wild boars can cause significant crop and forest damage as their natural food supplies and living area are reduced.	The establishment of one or more new National Parks, the preservation of existing wildlife reserves in their entirety and the delineation of migration corridors are recommended as an integrated conservation measure for remaining wildlife populations. Habitat improvement is suggested in selected areas to stabilize food supplies for animals presently inhabiting established and proposed reserves and for those animals living at the reserve peripheries. barriers and buffer zones for the wildlife reserves and corridors are recommended to limit wildlife conflicts with man. The present capacity of the Department of Wildlife Conservation should be increased and training programs expanded. Displaced wildlife including elephants and leopards should be accommodated in captive populations where possible.

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IMPACTS	RECOMMENDED ACTIONS
The change in vegetal cover will increase suitable habitat for a number of agricultural pest species including the rose winged parakeet, two species of munia and rats.	Control programs need to be instituted to limit pest proliferation. It is recommended that sugar cane, since it provides excellent nesting habitat for rice consuming munias, be planted in areas distant, or at least buffered from, rice paddy regions.

It should be emphasized that the Government of Sri Lanka has taken an active interest in promulgating environmental safeguards and conservation programs. Many of the recommendations presented here are a result of collaboration with the various government agencies and in some cases reflect the ongoing programs the agencies have initiated.

Economic Perspective

In this mid-term report, economic studies comprise a survey of the nature of the technical data available from the various environmental disciplines in order to develop appropriate methodologies for the economic analysis of environmental impacts and planning recommendations. Preliminary analyses from existing data relating to the impacts on forestry, fisheries and villus are presented to demonstrate the applicability of economic analysis in the assessment of environmental impacts. The analysis methodologies will be formalized in the final report to indicate cost effective means for mitigating negative impacts and for optimizing the use of environmental resources with an emphasis on the evaluation of alternative land uses.

Integrated Environmental Planning

In this mid-term report, recommendations generally reflect the analyses of individual environmental discipline or a collaboration between several disciplines. However, assessments relating to several environmental topics, including historical sites, climate, hydrology, minerals and pest management control, have not been completed to date and will be addressed in the final submission.

Following a thorough analysis of all of the significant environmental aspects relevant to the Accelerated Mahaweli Program, recommendations will be presented based upon an integration of inputs from each of the environmental disciplines. This would include, for example, the establishment of coordinated monitoring programs to meet the combined requirements for water quality, soils, pest control, wildlife and public health analysis. Similar recommendations may involve training programs, extension services, wildlife management plans, conservation flows, infrastructural needs, etc.

In the final report, particular emphasis will be placed upon deriving integrated land use planning recommendations and alternatives which will take into consideration the various development strategies. For this purpose a land use map will be presented showing the proposed land uses and supporting infrastructure recommendations in the available feasibility studies and from the Mahaweli Authority. With this map as a basis, the positive and negative impacts will be analysed and alternatives discussed. Land use recommendations will focus to a large extent upon agricultural uses, wildlife preserves, fuelwood plantations, forest reserves and especially watershed management. A land use/soil conservation map will be presented for the upper catchment, and recommendations for agricultural redevelopment, forest plantations and soil conservation measures will be made. A sample of this mapping technique and the methodology proposed for determining soil erosion problem areas is included in this mid-term report.

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CHAPTER 1

PROJECT DESCRIPTION

BACKGROUND

The Accelerated Mahaweli Development Program encompasses a total of 259,000 hectares (4% of Sri Lanka) and includes the construction of five or more large storage reservoirs to provide irrigation water for approximately 128,000 hectares of new land. Implementation of this comprehensive river basin project will enhance the nation's socioeconomic development by providing increased employment opportunities, expanding overall agricultural production and creating needed hydroelectric power.

HISTORICAL PERSPECTIVE

The diversion and use of the Mahaweli Ganga waters was originally carried out by the ancient inhabitants of the island. They diverted the river at Minipe, Kalinga and Kandakadu along the main river and diverted the Amban Ganga at Elehera and Angamedilla.

More recently, a number of recommendations have been made to divert the waters of the perennial Mahaweli Ganga in to the dry zone for irrigated agricultural development. Preliminary studies in this connection were first conducted by the Irrigation Department. The resources of the Mahaweli Basin were studied by the Canada-Colombo Plan Project and concurrently by the United States Operations Mission in the 1950's and early 1960's. As a result of these investigations, the FAO was subsequently requested to prepare a Master Plan for proposed developments of the Mahaweli Basin.

The FAO Master Plan was completed in 1968 and the first project implemented was the Polgolla diversion assisted by World Bank funds in 1970. The Polgolla Diversion and Bowatenna projects were both completed in 1976 and provided an

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additional 12,000 hectares of irrigated land in Irrigation System H.

MAHAWELI ACCELERATED PROGRAM

In 1977, the present government decided to accelerate the Mahaweli Development Program and cultivate 13,000 hectares of new lands and 32,000 hectares of existing agricultural land in irrigation systems labeled A, B, C and D in the Mahaweli and Maduru Oya Basins. The Victoria, Maduru Oya, Randenigala, Moragahakande and Kotmale storage reservoirs are proposed for construction in order to regulate the water for irrigation of the new project area and provide hydroelectric power. The locations of the proposed reservoirs and irrigation systems are shown on Figure 1-1.

Headworks

Details of the five major dams are presented in Table 1-1. In addition, several major reservoirs also under consideration include the Rotalawel reservoir, Ulhitiya reservoir, and the Kandakadu barage. The Rotalawel reservoir has a full storage elevation of 67 meters and a storage capacity of 240 million cubic meters (MCM). Similarly, the Ulhitiya Oya reservoir has a full storage elevation of 106.7 meters with a capacity of 110 mcm. The Kandakadu barrage will occupy an area of approximately 2900 hectares. In addition, a storage reservoir on the Amban Ganga has also been proposed at Angamedilla; however, the operating characteristics of this reservoir are not presently available.

Downstream Irrigation Systems

The downstream irrigation systems will irrigate a total of 175,500 hectares as shown in Table 1-2.

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Settlements

The Mahaweli scheme has adopted the principal of the 'cluster' for settlement development which refers to consolidating well planned hamlets into a village.

Several villages will be linked in a network to establish a township. It is estimated that about 100 settlers and their families will reside in each hamlet on 0.2 hectare of highland. Family units will be allocated one hectare of paddy land located in the immediate vicinity.

An estimated 140,000 families and other service staff totalling about 1 million people will move into the Accelerated Mahaweli Program area. All the necessary infrastructure such as roads, schools, hospitals etc. will be provided by the Government and it is expected that the settlers will establish other facilities such as a shopping center, community centers etc. through their own affort.

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TABLE 1-1.

CHARACTERISTICS OF MAJOR DAMS

Major Dam	Kotmale	Victoria	Randenigala	Moragahakanda	Maduru Oya
FSL M Meters MSL	728.7	934.5	228.7	195.1	97.6
HFL M Meters MSL	729.0	439.0	230.8	197.7	99.1
Dam Height Meters	107	108	84	River Section: 74 Saddle 1 : 56 Saddle 2 : 31	39
Area Inundated hectares	972	2,267	2,318	4,049	6,282
Capacity Million Cubic Meters	408	592	776	854	515
Installed Capacity MW	150 (200)	210/420	75 (100)	40	9.75
Annual Energy GWH	390	693	370	200	36
New Area Irrigated Hectares		24,000	36,000	20,000	47,200
Date of Completion	1983/ 1984	1984	1985/ 1986	1985/ 1986	1982/ 1983

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TABLE 1-2

AREAS IRRIGATED IN ACCELERATED PROGRAM

(Hectares)

System A	Origin of Water	Existing Schemes	New Schemes	Total
A	Kalu Ganga Reservoir	5,700	14,600	20,300
	Rotalawela Reservoir	-	7,300	7,300
	Pallewela Reservoir	-		14,900
B	Maduru Oya supp. by Victoria	2,700	47,800	50,500
C	Victoria Reservoir	1,300	29,800	31,100
D	(Including System G AD, D Part D2 D/G (System G)		2,800	
	Elehera, Minneriya, Kandalla, Giritale, Kantalai, Rss	30,000		30,000
		39,700	135,800	175,500

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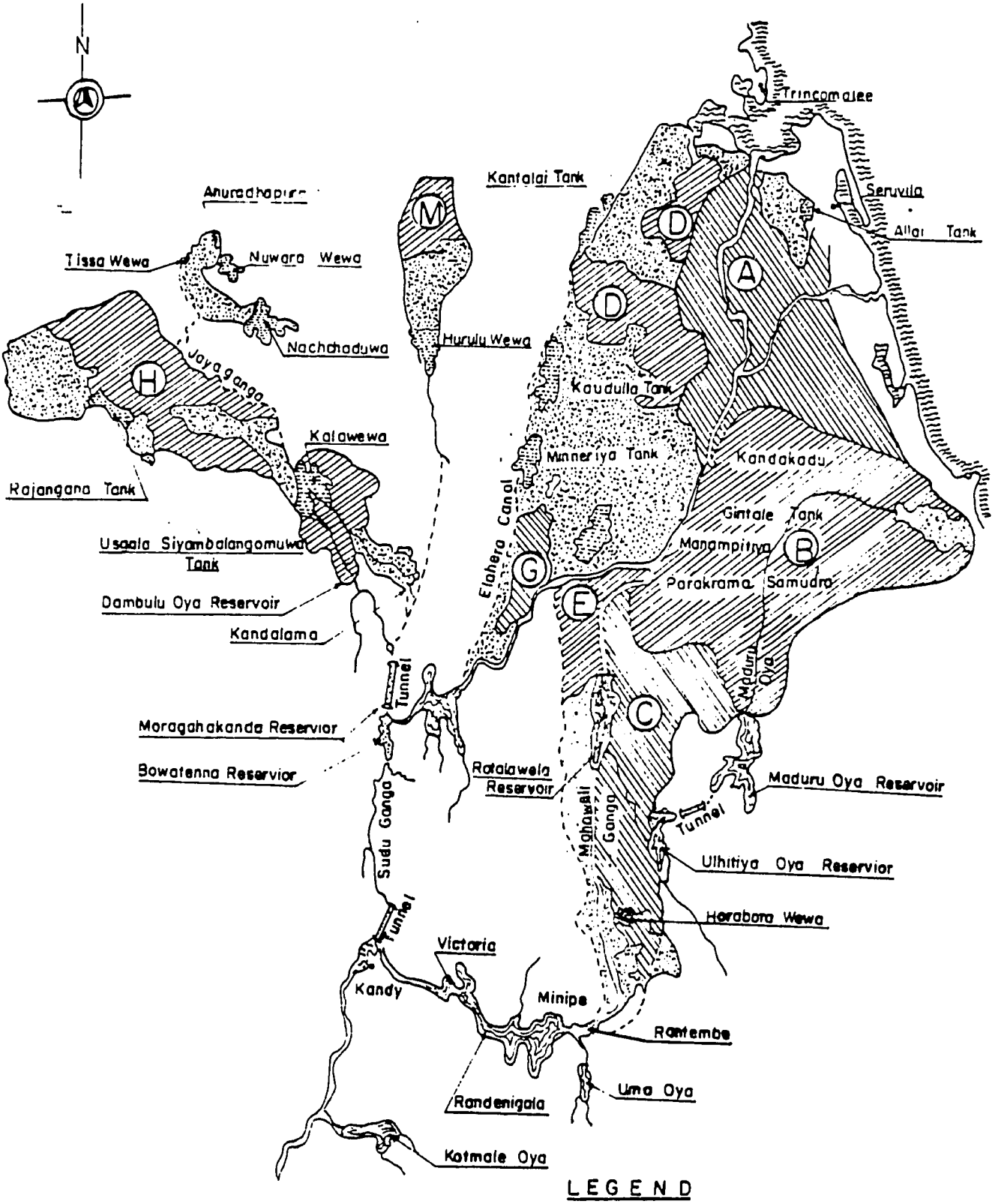

FIGURE 1-1

MAHAWELI ACCELERATED PROGRAM AREA

CHAPTER 2

WATER QUALITY

EXISTING CONDITIONS

General

The available water quality data for the project area are compiled in Table 2-1 for rivers and streams, Table 2-2 for tanks, villus and lagoons and Table 2-3 for groundwater. These data were obtained from a number of sources which are coded on Tables 2-1, 2-2 and 2-3 as follows :

Code	Source
1	U.S. Operations Mission (1961)
2	Amarasiri (1965)
3	Amarasiri (1973)
4	Pattiaratchi and de Silva (1972)
5	Water Resources Bureau (1979)
6	Ceylon Association of Science, Presidential Address
7	Government Analyst's Department (records)
8	Irrigation Department (records)
9	National Water Supply and Drainage Board (records)
10	Dr. G. Shut (field notes)
11	TAMS (samples collected by TAMS in November 1979 and analysed by Occupational Hygiene Division of the Labor Department and by the Irrigation Department).

Localities of the surface water collections, according to the above listed sources, are graphically depicted on Figure 2-1. Groundwater sampling stations are not included on Figure 2-1 because the well and bore-hole locations have not been clearly defined.

There have been very few comprehensive, sustained water quality studies conducted for surface waters or groundwater in the Mahaweli Accelerated Development area. The most

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detailed studies involving seasonal analyses for selected water quality parameters were completed by the U. S. Operations Mission (1961) for single stations on the Upper Mahaweli Ganga, the Amban Ganga (at Elahera) and a few of the large irrigation tanks; by Amarasiri (1972) for some major irrigation tanks; and by the Government Analyst's Department at the Kotmale Dam Site. The remainder of the water quality data is derived from occasional, isolated samples collected for analysis from various locations in the project area.

Irrigation Use Criteria

Criteria have been recommended for the classification of the quality of water for irrigation use by the U.S. Department of Agriculture or USDA (1954) and the FAO (Ayers and Westcot, 1976). These criteria are summarized in Tables 2-4, 2-5 and 2-6.

Generally, the more commonly occuring problems with the quality of irrigation supplies are associated with high levels of salinity (as measured by electrical conductivity) and/or a high proportion of sodium in comparison with other inorganic constituents - chiefly, calcium, magnesium and bicarbonate.

Salinity - Salinity problems arise if salts from the applied irrigation water accumulate in the crop root zone and yields are adversely affected. With shallow water tables, salinity problems may also occur due to upward movement of water and salts from the ground water as the water evaporates from the soil or is used by the crop. For most crops, salinity problems, due to the quality of the irrigation water, do not occur at conductivity levels of less than 750 micromhos/cm. Detailed conductivity criteria are presented in Tables 2-4, 2-5 and 2-6.

Very low salinity waters (conductivity less than 200 micromhos/cm) can also cause problems resulting in reduced

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soil permeability (Ayers and Westcot, 1976). Low salinity waters dissolve all sources of calcium from the surface soil causing finer soil particles to disperse, to fill pore spaces and seal the soil surface.

Sodium Problem Evaluation - In irrigation supplies, a high level of sodium in relation to other ions can result in the formation of alkali soils with very low permeability. The most common method of evaluating the relative amount of sodium in the water has been with the calculation of a Sodium Adsorption Ratio (SAR), described by USDA (1954) as the following :

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

where Na = Sodium in meg/l and Ca + Mg = Calcium plus Magnesium in meg/l. Problems do not usually occur with waters having SAR values up to about 10.

Permeability problems are also related to the carbonate (CO_3) and bicarbonate (HCO_3) content in the irrigation water. In waters containing high concentrations of bicarbonate there is a tendency for calcium and magnesium to precipitate carbonates and, as their levels are reduced, the relative proportion of sodium is increased. This effect has usually been evaluated by the determination of the Residual Sodium Carbonate (RSC) method which involves the use of following formula :

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

Water with an RSC value of more than 2.5 is usually considered unsuitable for irrigation purposes.

Bicarbonate levels of as low as 1.5 can also cause problems when fruit crops are sprinkle irrigated during periods of very low humidity and high evaporation (Ayers and Westcot, 1976). Under these conditions, white deposits are formed on the fruit or leaves which reduce the marketability of the fruits.

A refined procedure for estimating potential sodium hazards which combines the concepts of SAR and RSC has been suggested by FAO (Ayers and Westcot, 1976). This involves a calculation of an Ajdusted Sodium Adsorption Ratio (Adj. SAR) as follows :

$$\text{Adj. SAR} = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \left[1 + (8.4 - pHc) \right]$$

where $pHc = (pk_2 - pkc) + p(Ca + Mg) + p(Alk)$, and

$(pk_2 - pkc)$ is obtained from using the sum of Ca + Mg + Na in meg/l;

$p(Ca + Mg)$ is obtained from using the sum of Ca + Mg in meg/l; and

$p(Alk)$ is obtained from using the sum of $CO_3 + HCO_3$ in meg/l.

The $(pk_2 - pkc)$, $p(Ca + Mg)$ and $p(Alk)$ values are then converted to standardized units (Ayers and Westcot, 1976) before determining the pHc. The pHc is a theoretical, calculated pH of the irrigation water.

Project Area Waters - Quality for Irrigation

Where sufficient data were available for the project area waters the RSC, SAR and Adj. SAR were calculated and entered in Tables 2-1, 2-2 and 2-3. In addition, where possible, the waters were classified in terms of their conductivity and SAR values according to USDA (1954) recommendations which are given in Tables 2-4 and 2-5.

Rivers and Streams - From the existing river and stream data (Table 2-1) the waters of the Mahaweli Ganga, Kotmale Oya, Amban Ganga and Maduru Oya are at present well suited for irrigation use. These waters are characterized by very low RSC, SAR and Adj. SAR values. They also exhibit low mineral content or salinity as evidenced by the conductivity levels. Most of the conductivity levels, especially from the Mahaweli Ganga, are less than 200 micromhos/cm which could

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cause some permeability problems. Waters from the Amban Ganga and Maduru Oya have significantly higher mineral content than that found in the Mahaweli Ganga. However, the data are limited, with most of the information on the Mahaweli Ganga from the upstream hilly areas where salt levels in most flowing waters are typically low.

As expected, salinity levels near the mouths of the Mahaweli Ganga (Mutur) and Maduru Oya (Valaichchenai) are comparatively high due to tidal effects. Although these locations are represented by single samples, the salinity levels apparently would not, at times, limit use of these waters for irrigation purposes provided that the crops were relatively salt tolerant and adequate drainage was provided.

A few of the crop toxicity criteria (Table 2-6) are exceeded in occasional samples collected from the rivers and streams of the project area. The most conspicuous of these are the exceptionally high iron levels found in the Mahaweli Ganga at Mannampitiya and in the Maduru Oya at the Dam Site. However, this may not be a common phenomena since a second sample at the Maduru Oya Dam Site had a very low iron level.

Tanks, Villus and Lagoons - In general, water quality in the project area tanks indicate that these water supplies are presently suitable for irrigation use. Low RSC, SAR and Adj. SAR values are found for all of the tanks. However, a few of the tanks exhibit some elevated salinity levels, particularly at the Allai Tank and the Vakaneri Tank both of which are downstream tanks located near the coast. Other tanks including the Parakrama Samudra, the Kantalai Tank and especially the Minneriya Tank exhibit occasional salinity levels which exceed the C1 classification according to the USDA (1954).

Tanks, in general, have a much higher mineral content than that in the adjacent rivers and streams in the region. In addition, the seasonal measurements made by Amarasiri (1973)

clearly show the effect on increasing tank salinities of the drawdown and increased evaporation rates during the dry season months.

Villus generally have waters which are suitable for most irrigation purposes, although high salinities are often found as a result of the extensive drawdown periods which occur annually. The salinity level in the Upaar Lagoon precludes its use for irrigation, which is expected, due to its direct ocean connection. However, the salinity levels here are undoubtedly higher than they normally would be due to the presence of the low culvert bridge at the lagoon entrance. This impedes normal tidal flushing of the lagoon, and combined with high evaporation rates, results in an unusual increase in salt content.

Groundwater - Most of the wells sampled exhibit properties which are suitable for irrigation use. However, several of the wells from System C, including Well 12 (sampled 8/78) and Well 14 (sampled 7/79), had high salinity levels and very high RSC, SAR or Adj. SAR values which would probably prevent their use in most circumstances for irrigation.

Similarly, several coastal wells, notably at Trincomalee and Batticaloa, had very high salinity levels which would limit their use for irrigation. Aquifers here are undoubtedly being recharged, at least partially, with sea water.

Wells sampled near Hingurakgoda also exhibited a relatively high saline content with the result that chloride concentrations are elevated which could cause some crop toxity problems.

Livestock and Domestic Use

Based on the recommended toxic substance criteria of the National Academy of Sciences and National Academy of Engineering (1972) and of the U. S. Environmental Protection Agency (1976), the project area groundwater and surface waters

(including tanks, villus, rivers and streams) which have been sampled, are all suitable drinking water sources for livestock. The only exception would be the waters of the Upaar Lagoon which have a salinity concentration far in excess of safe consumption levels for animals.

The surface waters are apparently suitable for swimming, bathing, clothes washing and other related domestic uses. However, this assumption requires confirmation with additional testing, especially for coliform bacteria counts.

Similarly, the quality of the well waters for human consumption needs verification with coliform bacteria, metal toxity and other analyses. From the existing data, it is apparent that several wells in the area would be questionable potable supplies because of high saline content. Waters with total dissolved solids levels of more than 500 mg/l (roughly equivalent to a conductivity of about 700 micromhos/cm) and/or chloride levels of over 7 meq/l are usually considered objectionable due to the salty taste. Project area wells which fall into this category include Wells 14 and 20 in System C and some wells in Kaduruwela, Hingurakgoda, Trincomalee and Batticaloa. The iron concentration found in the Mahiyangana bore-hole also exceeds the safe drinking water criteria of 0.3 mg/l.

Aquatic Life Standards

The surface waters in the project area generally exhibit qualities which are above standards normally associated with health fish faunas. The data reveal a few isolated instances where safe levels for aquatic life are exceeded. These include an infrequent high ammonia level and the high iron concentration found in the Mahaweli Ganga and the Maduru Oya. The recommended iron level for the protection of aquatic organisms is 1.0 mg/l (U. S. Environmental Protection Agency, 1976), an amount exceeded six times in the available iron data. The iron

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present however may not be highly toxic to aquatic life if it exists in combined forms.

Pesticides

Until recently (about 1976), chlorinated pesticides including DDT, BHC, heptachlor, endrin, aldrin and dieldrin were employed for pest control purposes throughout Sri Lanka. The chlorinated (or organochlorine) pesticides are very persistent, often remaining for years before they breakdown to harmless by-products. Organophosphorous pesticides, on the other hand, while still very toxic degrade rapidly, remaining in soils only a few days or weeks.

Most of the organochlorine pesticides had been replaced here by the organophosphate types; however, some organochlorine insecticides are still in use in the country. Ramasundaram et al. (1979), from the Central Agricultural Institute in Peradeniya, have recently completed a national survey of organochlorine insecticide residues and found, for example, DDT and BHC residues in 61 and 43 per cent, respectively, of vegetable samples examined. In this study, water samples taken at several locations including Parakrama Samudra, Giritale Tank and Minneriya Tank did not contain DDT, but had traces of BHC, dieldrin, heptachlor and endosulphan.

In November, 1979, TAMS collected water samples throughout the project area which were analysed for chlorinated pesticide residues by the Central Agricultural Research Institute. The results of this analysis are presented in Table 2-7. Note that the figures are given in micrograms/l (ug/l).

These concentrations are relatively high, especially for DDT, and they often exceed mortality level thresholds for some aquatic organisms (U. S. Environmental Protection Agency, 1976). These data require additional verification, since as pointed out by Ramasundaram et al. (1979), water pesticide analyses are

easily contaminated and the methods have not yet been standardized in the country.

IMPACT ANALYSIS

Water Quality of the Proposed Reservoirs

Thermal Stratification - Large, standing bodies of water comparable to the reservoirs proposed for construction in the project area would be expected to exhibit a thermal stratification between the surface and bottom waters. Thermal stratification occurs as surface waters are warmed by solar radiation with the result that warm, lighter water forms a layer over deeper, cooler and denser segments of a reservoir. This creates thermal and density gradients from the top to the bottom of the reservoir which inhibit mixing between the upper and lower waters.

Typically, temperate lakes exposed to extreme variations in climate exhibit a sharply delineated thermal stratification with summer surface temperatures of 20 - 25°C and bottom temperatures of only 4°C. However, in these lakes, the seasonal climatic changes produce uniform surface and bottom temperatures which equalize respective water densities and enable winds to more or less thoroughly mix upper and lower reservoir layers. This mixing or "overturn" may occur once or twice annually and sometimes more frequently.

On the other hand, tropical lakes usually exhibit weak vertical temperature gradients and little seasonal change of temperature at any depth. However, even thermal differences of a few degrees centigrade in a tropical lake are capable of causing the formation of stable density layers which can persist throughout the year. This has been observed for most of the man-made lakes in southern India (Ganapati, 1972, 1973). Overturns are irregular events, and deep tropical lakes, like the proposed Kotmale, Victoria and Randenigala Reservoirs, usually

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undergo only partial mixing of the lower layers unless a storm occurs with exceptionally high wind velocities. However, the relatively short hydraulic retention times for the proposed reservoirs combined with the seasonally high winds in the project area will probably result in one or more complete turnovers for the shallower reservoirs (Moragahakanda, Rotalawala, Ulhitiya Oya and Maduru Oya).

Temperature data from the man-made lakes in southern India reveal that surface temperatures range from 24-33°C and bottom temperatures from 22 to 30°C (Ganapeti, 1973). The vertical differences vary from 0.3 to 6.6°C. These differences are sufficient to cause stratification because the change in density for a temperature difference of 1°C between 29° and 30°C is 2-3 times as great as that for the same difference in temperature between 14° and 15°C.

Surface temperatures for the proposed reservoirs would be expected to be similar to those found in the man-made lakes of southern India. This in general agreement with the existing tanks in Sri Lanka (Table 2-2). Stratification patterns will also be similar to the Indian reservoirs, although because of the great depth of the up-country reservoirs bottom temperatures in those lakes will probably be somewhat lower.

Chemical Stratification - In addition to thermal stratification, the proposed reservoirs will exhibit vertical chemical stratification as well. The main parameter of concern is dissolved oxygen. Oxygen levels in the uppermost layer of the reservoir should be relatively high due to the contact of surface waters with the atmosphere and because of the photosynthetic activity of free-floating algae. Oxygen is an end product of photosynthesis and is released by algae into the water. On the other hand, oxygen concentrations in water below the upper layer will decline significantly. This will be due to two principal factors. One is that as depth increases in the reservoir, the effectiveness of sunlight pene-

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tration decreases rapidly. This limits photosynthesis activity, and thus oxygen releases, to a zone of water relatively close to surface. Second, the chemical process involving the decomposition of organic matter, especially algae, as it settles to the bottom of the reservoir, consumes oxygen. These chemical processes will occur at a faster rate in tropical reservoirs in comparison to temperate ones; because at the expected bottom temperatures of the proposed reservoirs (roughly 20-30°C), the rate of biochemical reactions will be 4-9 times greater than in a temperate reservoir which will have a deep water temperature of 4°-10°C (Ganapati, 1972).

As time passes, continuous decomposition activity depletes dissolved oxygen in the lower layers of a reservoir. Overturns will annually replenish oxygen throughout a reservoir due to turbulent mixing and exposure to the atmosphere. However, if partial overturns occur for the deeper reservoirs, the bottom waters may have very low oxygen concentrations for long periods of time.

In the southern India lakes, oxygen concentration in the surface waters are usually high, ranging from 3.5 to 8.8 mg/l. (Ganapati, 1972). However, the bottom layers exhibit considerable depletion in all of the reservoirs, especially in the summer months when oxygen levels may drop to less than 1 mg/l. These reservoirs range in depth from 9 to 43 meters.

Similar oxygen gradients would be expected to occur within the proposed project area reservoirs. The upper zone of higher oxygen concentration may be extended slightly downward in the lower or downstream part of the reservoir. This may occur since turbidity causing sediments will settle in the upstream reaches of the reservoir; thus permitting deeper light penetration and a corresponding expansion of the area of photosynthetic activity. Consequently, the proposed reservoirs would be expected to have oxygen concentrations of between 5 to 10 mg/l occurring in surface waters and down to a level of roughly 10-15 meters of water. Below this point, dissolved

oxygen will be reduced and may fall to less than 1 mg/l at the bottom of the reservoir, particularly during the dry season.

The virtual absence of dissolved oxygen from the deeper portions of a reservoir will result in the formation of reduced chemical compounds such as odor-causing hydrogen sulfide and ammonia. These substances will be formed mainly from the leaching of organic sediments which have accumulated on the bottom of the reservoir. Thus, these compounds would be expected to appear in higher concentrations near the bottom with a diminishing gradient formed as the oxygenated surface layers are approached.

For most fish species and other aquatic life, exposure to less than 1 mg/l of dissolved oxygen and/or to even small amounts of hydrogen sulfide and other reduced substances, results in mortality or at least strong avoidance behavior. Thus, most aquatic organisms, especially fish species, which are present in the reservoir will find suitable habitat conditions in only the upper layer near the surface. Only the more tolerant species will inhabit the deeper reservoir waters.

Downstream Reservoir Releases - The quality of the immediate downstream releases will be dependent upon the water quality conditions within the reservoir and, in particular, at the depths where the intake release structures will be located. Due to the anticipated nature of the thermal and chemical stratification of the proposed reservoirs, water released from the surface over the spillways should be of relatively high quality, i.e. well oxygenated and buffered.

On the other hand, water released from lower levels of the reservoirs will be of comparatively poor quality. Oxygen concentrations may be very low and reduced substances such as hydrogen sulfide will be present. Water of this nature usually has a dark color, and often an objectionable odor; it may also be harmful to aquatic life.

Due to head requirements for power generation, it is expected that water will be released from lower levels of most reservoirs. Thus, relatively poor quality water will occur below the dams. However, because of the high gradient, torrential nature of the rivers, water released from the dams should be reaerated, and quality improved within a short distance downstream.

Level of Productivity - The degree of production of organic matter within the reservoir ecosystems will be largely dependent upon the availability of nutrient salts to aquatic plants and especially to floating or attached algae. The level of productivity can affect water quality conditions throughout a reservoir including the rate of oxygen depletion in deeper waters. Higher production implies increased decomposition rates as algae die off, and thus a more rapid reduction of oxygen concentration occurs.

In the filling stage of the reservoirs a large amount of nutrients will be available from topsoil, leftover vegetation or ashes remaining after clearing and burning. Thus, in the first few years of reservoir operations algae growth would be expected to be very high.

Typically, most reservoirs, especially warm tropical ones, will be highly productive during the initial 4 or 5 years of operation. Following this period, the proposed reservoirs would be expected to exhibit a decline in production levels as the nutrients available from the inundated land settle to the bottom and are prevented from recirculation by density stratification. Consequently, the deeper up-country reservoirs which are likely to undergo only partial overturns will lose a substantial amount of their nutrients to the bottom sediments. Thus, these reservoirs will probably be less productive than the shallow, low-country reservoirs where more complete overturns are expected which will replenish the surface water with nutrient salts needed for algae production.

Following the initial years of high photosynthetic activity, productivity in a reservoir usually levels off and thereafter depends upon the supply of nutrients, and in particular phosphates, which are recycled from sediments or which enter from outside sources. Phosphates and other nutrients enter a reservoir from leaching of natural minerals, direct absorption from the atmosphere, rainfall, human and animal waste disposal and from runoff through fertilized cropland and pastures.

The available data are too limited to accurately predict nutrient loadings for the proposed reservoirs. The few phosphate readings from the project area waters indicate that nutrient salt concentrations are relatively low, although sufficient to stimulate algae growth. Observations of dense algae blooms on many of the existing tanks in the region indicate that nutrient supplies are relatively high in some localities.

All of the proposed reservoirs will act as nutrient (and sediment) traps, retaining nutrients which would normally reach downstream areas. Due to the sequential arrangement of the reservoirs, a progressive downstream reduction in the river supply of nutrients will occur. Thus, downstream reservoirs will have to rely to a large extent upon nutrient inflow from their individual catchment areas. This may be particularly evident for the Randenigala Reservoir, since the Victoria Reservoir will prevent river nutrients from reaching it. However, if withdrawals from the Victoria Reservoir are near the bottom of the lake, then some of the nutrients trapped on the bottom may be released into the Randenigala Reservoir and thus increase its fertility. A similar series of events may occur below the Randenigala Reservoir and the Ulhitiya Oya Reservoir in relation to the nutrient supplies to the further downstream reservoirs.

An additional source of nutrient salts will be available to the proposed reservoirs because of the anticipated annual drawdown of the water levels. This will expose inshore sediments,

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leaf litter and other organic debris which will oxidize due to atmospheric contact. The ensuing inundation of the exposed drawdown zone will then provide nutrient salts in a form suitable for algae usage. If drawdowns are of a sufficient length of time, terrestial herbs may take root; when the area is re-inundated the decomposition of this grassy vegetation will provide further nutrients to the reservoir. Similarly, an important source of nutrients are those assimilated from dung originating from grazing animals along the shorelines or even within the drawdown zones of the reservoirs. This is obviously one of the most significant nutrient sources for many of the existing tanks in the project area.

Summary of Anticipated Reservoir Water Quality - All of the proposed reservoirs are expected to undergo vertical thermal and chemical stratification, with reduced oxygen levels occuring in the bottom waters for some part of the year. The reservoirs will probably overturn once or more annually although the deep reservoirs including Kotmale, Victoria and Randenigala will not have the thorough surface to bottom mixing expected in the shallow, low-country reservoirs. The latter, due to increased nutrient availability through recycling and drawdown should be more productive than the deep reservoirs.

Impacts Related to Irrigation Use

Quality of Initial Sources - The quality of the initial irrigation supply sources including the new proposed reservoirs and the upstream river sections should remain highly suitable for irrigation purposes. They are not expected to undergo any significant water quality changes which would alter their value for irrigation usage. These waters, due to their very low mineral content, could cause some soil permeability problems, although impacts of this nature are likely to be very localized. High iron content of these waters could also be detrimental to crop yields, but further investigations will

be necessary to clearly identify iron levels since this metal forms many complexes with other ions.

Effects on Major Tanks - Likewise, the major tanks in the project area, including Parakrama Samudra, Minneriya, Kaudulla and Kantalai should maintain suitable quality for irrigation. The quality in these tanks should improve slightly due to the increase in the water volumes which will pass through them (Table 2-8). This will tend to dilute salinity concentrations in the tanks. According to NEDECO (1979) ANNEX B, none of these tanks should receive appreciable return flows from upstream irrigation systems. This will tend to preserve the present high quality in these tanks.

Effects on Medium Tanks - Generally, the medium and smaller sized tanks within the project area are expected to continue as high quality sources for irrigation of their command areas.

However, some degradation of the water quality in the downstream tanks such as Punai, Vakaneri and Allai may occur, particuarly during dry season months, as return flows from upstream irrigation systems enter them. The return flows undergo a progressive downstream accumulation of salts which may result in an increase in the overall solids content in these tanks. The salinity in both the Vakaneri and Allai Tanks is already relatively high. However, the data to support this are limited, and, in any event, a substantial increase in salt concentrations would be necessary to inhibit their effectiveness as irrigation supply sources.

Return Flow Reuse - In a few localized areas water quality in return flows may deteriorate significantly, preventing their immediate reuse for irrigation. This may occur where salt accumulates due to improper drainage or in areas, where sodic sub-soils exist which, when irrigated, release sodium into drainage waters. However, in most of the project area,

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adequate drainage and the flushing action of heavy rains during the wet season should prevent salt build-up in the soils or high sodium problems.

A detailed water quality study of the irrigation and drainage water within the recently implemented System H is nearing completion. The study is being conducted as a combined effort of the chemistry department of the Colombo University Campus and the UNESCO Man and the Biosphere program. The data produced from this work, when available, will provide a base for the evaluation irrigation reuse problems in the project area.

Impacts of Salinity Intrusion - There is no available information describing the nature and extent of tidal intrusions in the lower Maduru Oya and Mahaweli Ganga estuaries. However, it is anticipated that the proposed water regulation scheme will result in an alteration of downstream dry season flows. The planned annual diversion of water from the Mahaweli Ganga and the Maduru Oya is likely to result in a significant reduction of dry season river flows with a corresponding increase in the extent of the tidal wedges.

Increased salt concentrations in the already highly saline lower river sections would probably make these waters unsuitable for irrigation use. More impertantly, perhaps, the salinity levels in the adjacent groundwater could increase and result eventually in salinity accumulations in the soils in the downstream areas near the mouths of the rivers. Both of these areas presently have fairly extensive paddy cultivation operations. Increased soil salinities could reduce rice yields in these fields. This could be particularly significant in the mouth of the Maduru Oya if the irrigation supply from the Vakaneri Tank were to increase in salinity from upstream return flows. Thus, high salinity irrigation water would be applied to saline soils, further reducing crop output.

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Effects of Altered Nutrient Supplies

Nutrient Loading on Major Tanks - The existing major irrigation tanks, Parakrama Samudra, Minneriya, Kaudulla and Kantalai, will undergo significant changes in water balance with the implementation of the Accelerated Scheme. The existing and proposed morphological and operational characteristics of these tanks are presently in Table 2-8. Although the high and low water levels will not differ appreciably from the existing ones, the amount of inflow and outflow for the tanks will increase significantly.

In order to evaluate the impact on the potential change in eutrophication of the tanks, a sensitivity analysis was made using the nutrient loading model derived by Vollenweider (1973). This simplistic model has been used successfully on many reservoirs for determining phosphorous loading levels which, when exceeded, may result in undesirable eutrophic conditions (i.e. algae blooms, aquatic weed prolification and deteriorated water quality). Vollenweider empirically defined "dangerous" loading tolerance levels based on encountered ranges of mean reservoir depths and hydraulic retention times. The derived formula for the dangerous level of phosphorous loading is :

$$L = 0.022 \frac{\bar{z}}{Tw} + 0.30$$

where L = phosphorous loading in $g/m^2/yr$,

$\bar{z}$ = mean depth (volume ÷ area of the lake), and

Tw = hydraulic retention time (lake volume ÷ outflow volume).

Absolute values for existing phosphorous loadings on the tanks cannot be made due to the paucity of data. However, the Vollenweider model can give an indication of the effect on phosphorous loading due to the proposed changes in inflow-outflow volumes for the tanks. For each tank, the hydraulic retention time will decrease, i.e. the flushing rate will increase. The resulting effect on phosphorous loading will, in each case,

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be to lessen the effect of the present danger levels (Table 2-8). Thus, the proposed alterations in tank operations to meet increased irrigation demands are unlikely to adversely affect the potential for increased eutrophication of these lakes. In fact, the increased flow through volumes of water should decrease potential eutrophication rates slightly for most of the tanks.

Effects of Return Flow Nutrients on Smaller Tanks and Villus - Unlike the major irrigation tanks in the project area, many smaller tanks and especially villus are expected to receive relatively large amounts of nutrient salts from irrigation drainage waters. The irrigation return flows will contain high nutrient levels due to the fertilizer runoff from paddy and other crops. This will probably result in a significant increase in eutrophic conditions for many small tanks and most villus. Algae blooms and an overall degradation of existing water quality is likely to occur in these water bodies.

Impacts on Estuaries - The construction of a series of large reservoirs on the mainstream Mahaweli Ganga and Maduru Oya will result in a significant reduction of nutrients which normally reach the estuarine portions of these two rivers. The reservoirs will act as effective nutrient traps. On the other hand, irrigation return flows are likely to contribute nutrient salts to the rivers which will be carried down to the estuaries. However, these will be inorganic nutrients; much of the organic nutrients will remain in the upstream reservoir sediments.

The net effect may be an increase in inorganic nutrient salts which could stimulate algae blooms and a loss of organic nutrients which play a separate role in the estuarine food web. This, combined with a change in river flows, will result in an overall alteration of the organic production and energy cycles of the estuarine ecosystems. Normally,

changes in the nutrient balance and cycling patterns in estuaries have a detrimental effect on aquatic life, especially fish and shrimp species which utilize estuaries as breeding or nursery grounds.

Impacts on Livestock Use/Aquatic Life Standards

Most of the effects due to water quality changes as they pertain to aquatic life have been discussed in prior sections or will be covered in the chapter on FISHERIES. However, one particular serious potential impact on aquatic life not previously mentioned is the likely increase of pesticide levels in project area waters receiving agricultural runoff. The proposed large scale cultivation schemes will require considerable pesticide use to enhance crop yields. Organochlorine pesticide levels may already be relatively high in project area waters. An increase in these pesticide concentrations in tanks, villus, rivers and estuaries may have significant adverse impacts on fishery resources and other aquatic life. Impacts of this nature are often exacerbated by the continuous accumulation of pesticide residues in the tissues of aquatic organisms.

Similarly, an increase in pesticide concentrations in project area surface waters, especially in villus, could limit their use for livestock consumption. In addition, increased tidal intrusion may render some downstream river sections and groundwaters unsuitable for livestock drinking purposes. In general, however, water quality alterations in the project area waters are not expected to significantly reduce livestock usage.

Impacts on Domestic Use

Surface waters in the project area, including those in the proposed irrigation and drainage systems, should remain suitable for swimming, bathing, clothes washing and related domestic uses. However, the use for bathing and swimming

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will depend upon the provision of adequate human waste disposal systems. Without them, it is likely that contamination of the surface waters with human wastes will occur and thus increase the potential for the spread of various waterborne diseases (See the chapter on PUBLIC HEALTH for further details). In addition, it is unlikely that surface water in the project area will be suitable for human consumption, especially the return flows from irrigation use, since these waters will have high pesticide concentrations and elevated nitrate levels which can cause serious, and occasionally fatal, poisoning of infants due to methemoglobinemia.

The latter problem may also arise in existing wells which are downstream from irrigated crop lands. Percolation into the aquifers of irrigation waters can result in high levels of pesticides, nitrate and other toxic substances appearing in wells which are used as drinking water supplies. Salinity may also increase to unpalatable levels in groundwater via the same transport mechanism. These should be relatively isolated impacts, although potentially significant ones, especially where present wells already exhibit comparatively poor water quality conditions (Table 2-3).

RECOMMENDED ACTIONS

Proposed Reservoirs

There is little which can be done to prevent or significantly improve the poor water quality conditions which are anticipated, due to stratification, for the deeper parts of the reservoirs. Artificial reaeration of the bottom layers of reservoirs with great depths would be impractical and would not be economically feasible.

Immediate downstream releases from the proposed reservoirs are also expected to be of low quality. The quality of these releases could be improved by means of installation of

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multi-level towers for reservoir outlet releases; however, the hydro-power requirements of the proposed reservoirs preclude use of these type of towers. As stated above, the release water should be reaerated by the natural steep river bed gradients. However, this may not occur for all of the proposed reservoirs. In the latter case, it may be advisable to install an artificial reaeration device, such as a baffle system, downstream from a dam which would facilitate oxygenation of the water through atmospheric contact. The need for this type of structure can be further investigated following commencement of operations at the reservoirs.

Due to the nutrient trapping effect of the dams, the productivity of some downstream reservoirs may be diminished by a reduced nutrient supply. To increase potential productivity of the reservoirs, cattle grazing should be encouraged on the shorelines and within the drawdown zones of the proposed lakes. Lake productivities can be further enhanced by seeding the drawdown areas with fast growing herbs, which will produce a large amount of organic detritus following re-inundation. Productivity can also be increased by the introduction of sewage or other organic wastes or possibly by means of an artificial upwelling pump.

Quality of Water for Irrigation Use

Soil salinity, permeability and perhaps even toxicity problems (high iron levels) may occur due to the quality of the irrigation or reuse water in some localized cultivation areas. Yield reductions which result from these kinds of problems can be minimized by altering cultivation or irrigation practices. This could include some of the following :

- more frequent irrigation to maintain better water availability in the upper root zone;
- improved drainage of surface and sub-surface waters;

- use of more salt tolerant crops;
- change of irrigation method;
- improvement of the slope or level of land to allow for more uniform water application;
- determination of leaching requirements and use of extra water for adequate leaching;
- alteration of seeding patterns, fertilizer applications, etc.;
- change or blend water supplies; and
- addition of chemicals such as gypsum, sulphuric acid and sulphur dioxide to irrigation water to improve the sodium to calcium ratio.

Conservation Flows

It is recommended that dry season conservation flows be maintained in both the Mahaweli Ganga and Maduru Oya to limit salinity intrusion near the mouths of these rivers. At present, it is uncertain what the dry season flows will be in the rivers following reservoir construction and diversions for irrigation use. Return flows will contribute to the dry season river discharges, but the amount of water which may return to the river systems after irrigation application is estimated at from 20 to 30 per cent (NEDECO ANNEX B, 1979). Thus, releases from the proposed reservoirs may be necessary to augment the dry season flows.

In addition to controlling tidal intrusion, the conservation flows will also provide the following benefits :

- prevention of the formation of isolated pools in the river bed which are prime anopheline mosquito breeding habitats;
- dilution of saline return flows; and
- maintenance of riverine habitats for aquatic life.

It is recommended that a salinity intrusion study be made of the existing tidal range in the lower Mahaweli Ganga and Maduru Oya which would include sampling for temperature and electrical conductivity or salinity in the estuaries. Samples need to be collected in depth profile along an axis of the lower river beds at high and low water slack periods, for both spring and neap tides, and for various freshwater discharges. Once the extent of the present tidal wedges have been identified, some conservation flow recommendations can then be formulated.

Pesticides

The large proposed cultivation schemes may result in a significant accumulation of pesticides in various receiving waters. This could have serious effects due to the cumulative magnification of pesticides through the food chain on fish, wildlife, cattle and even local residents.

A strong recommendation is made here to limit the use of the persistent organochlorine pesticides throughout the project area. Organophosphate pesticides degrade relatively rapidly, and thus, their hazardous effects are considerably less than those of the organochlorine varieties. Organophosphate pesticides should be employed where possible and, if necessary, the use of organochlorine pesticides should be strictly controlled.

Water Quality Monitoring Program

It is recommended that a multipurpose water quality monitoring program be implemented for the project area.

This program should include repeated sampling within the project area to establish more reliable baseline data on existing conditions, especially as they pertain to agricultural use. In this regard, detailed studies should be made of the present irrigation systems. These studies can provide clues to the quality of return flows which can be expected from planned

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irrigation in the area.

Once cultivation programs are underway, monitoring should be made of irrigation supplies and return flows to identify potential salinity, sodium or toxicity problems. These problems can then be ameliorated by changes in various irrigation or management practices to improve crop yields. Also, proper fertilizer and pesticide application rates and techniques can be investigated.

The monitoring program should also investigate downstream reservoir releases to determine the need for installation of reaeration devices. Nutrient analyses should also be conducted and productivity evaluated for the proposed reservoirs in order to determine the need for nutrient enrichment of these water bodies.

Monitoring should be extended to include analyses of domestic use sources, including potable waters. Close surveillance should be maintained for coliform bacteria, nitrates, pesticides and other toxic substances which may enter groundwater supplies following implementation of irrigation systems and settlements.

At present, there is no governmental agency which is conducting a water quality sampling program in the Accelerated Program Area. Laboratory facilities are limited, either by staffing or equipment. A new laboratory will be necessary to conduct the proposed monitoring program. It is suggested that this laboratory be combined with a soils laboratory and centrally located within the project area. The laboratory could be directed through the Irrigation Department, Central Agricultural Research Center, Water Resources Board or other government agencies.

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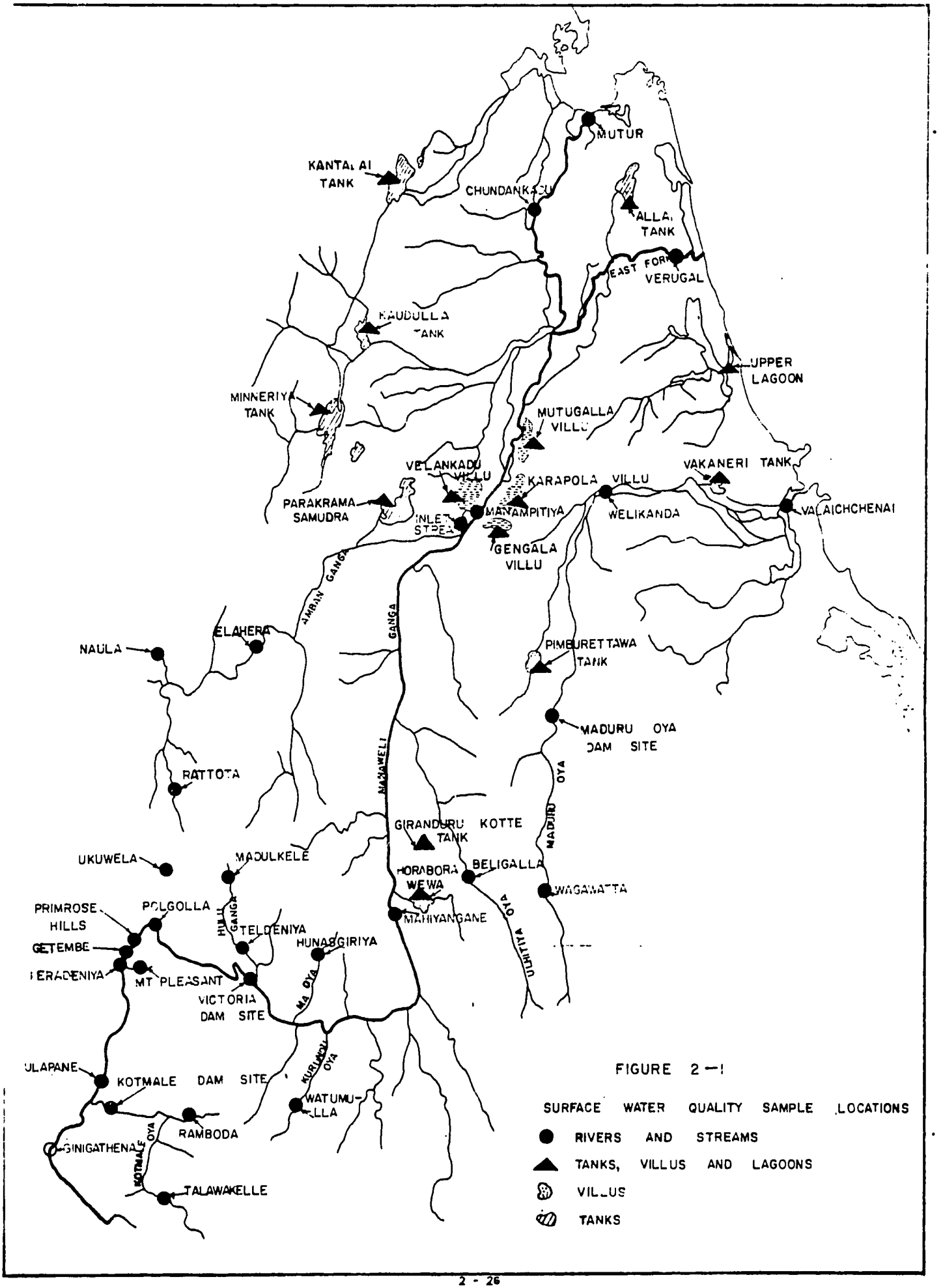

FIGURE 2-1

SURFACE WATER QUALITY SAMPLE LOCATIONS

- ● RIVERS AND STREAMS
- ▲ TANKS, VILLUS AND LAGOONS
- VILLUS
- TANKS

Table 2 – 1

Water Quality from the Project Area

Rivers and Streams

Sample Location	Date	Source	Temp. °C	D.O. mg/l	pH	Hard. mg/l	E.C.	TDS mg/l	SS mg/l	Turb. JTU	mg/l As	B	Fe	meq/l Ca	Mg	Na	K	CO_3	HCO_3	Cl	mg/l SO_4	NO_3	NH_3	PO_4	RSC	SAR	Adj. SAR	Agri. Use Class	Comments
Mahaweli Ganga at Ginigathena	None	6			6.8	10	15	10.5*	14.5*											0.17								C1	
Mahaweli Ganga at Ginigathena	10/79	11	24.5	7.8	7.6		32																					C1	
Mahaweli Ganga at Ulapane	10/79	11	23.5	7.0	7.1		30																					C1	
Mahaweli Ganga at Peradeniya	5/78	9			7.0	13	35	24		25.5			5.0						0.22*	0.23		T	0.08					C1	High Fe
Mahaweli Ganga at Peradeniya	4/79	9			7.6	33	78	53		18			0.6						0.80*	0.23		T	–					C1	
Mahaweli Ganga at Getambe	None	6			6.8	15	20	14*	26*											0.11								C1	
Mahaweli Ganga at Primrose Hills	11/60	1			7.6		35							0.15+		0.14	0.13									0.51		C1-S1	
Mahaweli Ganga at Primrose Hills	12/60	1			7.7		50																					C1	
Mahaweli Ganga at Primrose Hills	1/61	1			7.5		60																					C1	
Mahaweli Ganga at Primrose Hills	3/61	1			7.4		55																					C1	
Mahaweli Ganga at Primrose Hills	4/61	1			6.9		35																					C1	
Mahaweli Ganga at Primrose Hills	5/61	1			7.6		35																					C1	
Mahaweli Ganga at Primrose Hills	6/61	1			7.3		30							0.34+		0.08	0.03									0.19		C1-S1	
Mahaweli Ganga at Primrose Hills	7/61	1			7.0		40							0.25+		0.11	0.02									0.31		C1-S1	
Mahaweli Ganga at Polgolla	5/79	9			6.2	25	115	74		64			1.6						0.72*	0.39		T	0.13					C1	Low pH, High Fe
Mahaweli Ganga at Polgolla	6/79	9			7.2		45	30		20			0.4						0.40*	0.28		T	–					C1	
Mahaweli Ganga at Polgolla	7/79	9			7.4	12	52	34		15			1.2						0.40*	0.23		T	0.55					C1	High NH_3
Mahaweli Ganga at Ukuwela Power Outlet	5/79	9			7.0	20	45	30		8			0.7						0.16*	0.34		T	–					C1	
Mahaweli Ganga at Victoria Dam Site	11/79	11	24.5	8.0	6.8		60	•						0.35	0.13	0.12			0.61						0.13	0.24	0.10	C1-S1	

Table 2 - 1
(Continued)

Sample Location	Date	Source	Temp. °C	D.O. mg/l	pH	Hard. mg/l	E.C.	TDS mg/l	SS mg/l	Turb. JTU	As (mg/l)	B (mg/l)	Fe (mg/l)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	K (meq/l)	CO_3 (meq/l)	HCO_3 (meq/l)	Cl (meq/l)	SO_4 (mg/l)	NO_3 (mg/l)	NH_3 (mg/l)	PO_4 (mg/l)	RSC	SAR	Adj. SAR	Agri. Use Class	Comments
Mahaweli Ganga at Mahiyangane	11/79	11	26	7.7	7.0		95							0.53	0.22	0.15		-	1.15						0.40	0.24	0.24	C1-S1	
Mahaweli Ganga at Manampitiya	4/79	7			8.0	50	181*	127*	110		<0.02	0.20	12	0.85	0.16	0.65+		-	1.29	0.28	4			0.04	0.28	0.91	1.00	C1-S1	High Fe
Mahaweli Ganga at Manampitiya	11/79	11	28	7.2	6.8		90							0.53	0.22	0.21		-	0.94						0.19	0.34	0.27	C1-S1	
Mahaweli Ganga near Chundankadu	11/79	11	30	5.4	7.0		132							0.66	0.34	0.22		-	1.35						0.35	0.31	0.34	C1-S1	
Mahaweli Ganga at Mutur	11/79	11	29.5	5.4	7.0		2120							1.23		13.2		-	1.81									C3	High HCO_3, salinity
Mahaweli Ganga-East Fork at Verugal	11/79	11	29	5.7	6.9		107							0.50	0.20	0.18		-	1.15						0.45	0.30	0.27	C1-S1	
Kotmale Oya at Dam site	3/63	7			7.2	14	40	35	35	45									0.24	0.17		T	0.02					C1	
Kotmale Oya at Dam site	6/63	7			7.2	10	25	25	20	10									0.20	0.17		T	0.01					C1	
Kotmale Oya at Dam site	6/63	7			6.4	10	50	40	90	140									0.20	0.28		T	0.04					C1	Low pH
Kotmale Oya at Dam site	3/70	7			7.2		50	22	20	8			1.2						0.16	0.17		T	0.26					C1	High NH_3
Kotmale Oya at Dam site	9/77	7			7.2	9	18	17					-	0.10	0.08	0.23+			0.16	0.20	3				-	0.77	-	C1-S1	
Kotmale Oya at Dam site	12/77	7			6.7	10	19	13					0.3	0.46	0.04	0.25+			0.18	0.23	3				-	0.50	-	C1-S1	
Kotmale Oya at Dam site	10/78	7			6.7	10	27	24					<.05	0.12	0.07	0.33+			0.30	0.17	3				0.11	1.07	-	C1-S1	
Kotmale Oya at Dam site	10/79	11	22.5	8.2	7.0		32.5																					C1	
Kotmale Oya at Talawakelle	None	6			7.1	10	15	10.5*	9.5*											0.14								C1	
Kotmale Oya at Talawakelle	10/79	11	21	8.6	7.1		30																					C1	
Trib. to Kotmale Oya at Ramboda	None	6			7.0	10	12	8.4*	11.6*											0.14								C1	
Trib. to Kotmale Oya at Ramboda	10/79	11	20	8.2	7.0		16																					C1	
Trib. to Mahaweli Ganga at Mt. Pleasant	None	6			7.0	10	40	.28*	18*											0.17								C1	
Hulu Ganga at Madulkele	4/79	10	24.5		7.2		49																					C1	

Table 2 - 1
(Continued)

Sample Location	Date	Source	Temp. °C	D.O. mg/l	pH	Hard. mg/l	E.C.	TDS mg/l	[illegible] mg/l	Turb. JTU	mg/l As	B	Fe	meq/l Ca	Mg	Na	K	CO_3	HCO_3	Cl	mg/l SO_4	NO_3	NH_3	PO_4	RSC	SAR	Adj. SAR	Agri. Use Class	Comments
Hulu Ganga at Teldeniya	None	6			7.0	25	40	28*	20*											0.20								C1	
Ma Oya at Hunasgiriya	None	6			7.0	10	27	18.9*	13.1*											0.23								C1	
Kurudu Oya at Watumulla	6/79	9			7.0	20	35	24		6			0.50						0.26*	0.17		?	0.04					C1	
Ulhitiya Oya near Beligalla	11/79	11	27	7.4	7.2		158							0.84	0.31	0.46		-	1.73						0.58	0.61	0.79	C1-S1	High HCO_3
Amban Ganga at Elahera	11/60	1			7.4		75	60						0.21+		0.17	0.09									0.52		C1-S1	
Amban Ganga at Elahera	12/60	1			7.7		175	110																				C1	
Amban Ganga at Elahera	1/61	1			7.7		170	105																				C1	
Amban Ganga at Elahera	2/61	1			7.6		110	70						0.02+		0.17	0.05									1.08		C1-S1	
Amban Ganga at Elahera	3/61	1			5.0		200	125																				C1	Low pH
Amban Ganga at Elahera	4/61	1			8.1		225	146																				C1	
Amban Ganga at Elahera	5/61	1			8.0		200	125																				C1	
Amban Ganga at Elahera	6/61	1			7.7		180	115						1.92+		0.31	0.04									0.32		C1-S1	
Amban Ganga at Elahera	7/61	1			8.0		170	105						1.75+		0.20	0.03									0.21		C1-S1	
Amban Ganga at Elahera	4/79	10	29		7.3		270																					C2	
Amban Ganga at Elahera	11/79	11	26	7.8	7.0		82							0.52	0.24	0.14		-	0.98						0.22	0.23	0.21	C1-S1	
Amban Ganga at Rattota	None	6			7.0	15	40	28*	24*											0.14								C1	
Amban Ganga at Rattota	1972	4					100																			1.00		C1-S1	
Amban Ganga at Rattota	4/79	10	26		6.3		108																					C1	
Trib. to Amban Ganga at Naula	4/79	10	30.5		7.3		370	•																				C2	

Table 2 - 1
(Continued)

Sample Location	Date	Source	Temp. °C	D.O. mg/l	pH	Hard. mg/l	E.C.	TDS mg/l	SS mg/l	Turb. JTU	mg/l As	mg/l B	mg/l Fe	meq/l Ca	meq/l Mg	meq/l Na	meq/l K	meq/l CO_3	meq/l HCO_3	meq/l Cl	mg/l SO_4	mg/l NO_3	mg/l NH_3	mg/l PO_4	RSC	SAR	Adj. SAR	Agri. Use Class	Comments
Maduru Oya near Wagawatta	11/79	11	27	7.5	7.2		82							0.40	0.19	0.34		-	1.03						0.44	0.63	0.57	C1-S1	
Maduru Oya at Dam site	4/79	7			7.8	23	136*	95*	95		<.02	0.10	10	0.30	0.16	0.87+		1.29	0.28	2				0.08	0.83	1.81	1.45	C1-S1	High Fe
Maduru Oya at Dam site	5/79	7			7.3	53	227*	159*	6		<.01	<0.10	0.16	0.62	0.44	1.42+		1.70	0.71	4				0.08	0.64	1.95	2.15	C1-S1	High HCO_3
Maduru Oya at Welikanda	11/79	11	29.5	5.4	7.4		300							0.92	0.42	0.76		-	1.77						0.43	0.93	1.21	C2-S1	High HCO_3
Maduru Oya at Valaichchenai	11/79	11	31.5	7.1	6.9		1700							1.21		12.6		-	1.73									C3	High HCO_3, salinity

* = Calculated

T = Trace

+ = Combined values

Table 2 - 2

Water Quality from the Project Area

Tanks, Villus and Lagoons

Sample Location	Date	Source	Tem. °C	D.O. mg/l	pH	Hard. mg/l	E.C.	TDS mg/l	Tur. JTU	Si (mg/l)	Al (mg/l)	As (mg/l)	B (mg/l)	Fe (mg/l)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	K (meq/l)	CO_3 (meq/l)	HCO_3 (meq/l)	Cl (meq/l)	SO_4 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)	RSC	SAR	Adj. SAR	Agri. Use Class	Comments
Upaar Lagoon	11/79	11	31	7.1	7.5		32430													3.29									High HCO_3 salinity
Gengala Villu	11/79	11	29	3.7	6.7		175								0.68	0.36	0.69			1.64					0.60	0.96	1.15	C1-S1	High HCO_3
Karapola Villu	11/79	11	31	5.7	6.7		260								0.84	0.42	1.00			1.56					0.30	1.26	1.51	C2-S1	High HCO_3
Kutugalla Villu	11/79	11	32	6.4	6.8		875								1.68	1.21	1.60			1.07					-	1.33	1.86	C3-S1	High salinity
Velankada Villu	11/79	11	32	5.0	7.1		500								2.46	1.80	1.40		0.41	5.27					0.99	0.96	2.11	C2-S1	High HCO_3
Velankada Villu Inlet Stream	11/79	11	30	5.9	7.3		180								0.94	0.51	0.30		-	2.06					0.61	0.35	0.49	C1-S1	High HCO_3
Horabora Wewa	11/79	11	32	9.6	8.1		175								0.64	0.35	0.77		-	1.93					0.94	1.09	1.31	C1-S1	High HCO_3
Giranduru Kotte Tank	11/79	5			7.4	134	300	276							1.70	0.99	0.72			3.21	0.20	T	T		0.52	0.62	1.12	C2-S1	High HCO_3
Allai Tank	11/79	11	30.5	4.7	7.7		525								0.90	0.42	0.63		-	1.85					0.53	0.78	1.01	C2-S1	High HCO_3
Pimburettawa Tank	5/79	7			7.0	57	194*136*	1				<0.01	<0.1	0.08	0.72	0.41	1.06			1.70	0.48	1.5		0.04	0.57	1.41	1.55	C1-S1	High HCO_3
Vakaneri Tank	11/79	11	33.5	11.0	8.4		425								0.79	0.39	1.20		-	1.73					0.55	1.56	1.87	C2-S1	High HCO_3
Parakrama Samudra	11/60	1			7.9		190	120								0.42+	0.19	0.08								0.41		C1-S1	
Parakrama Samudra	12/60	1			7.4		190	120																				C1	
Parakrama Samudra	1/61	1			7.4		190	120																				C1	
Parakrama Samudra	2/61	1			7.5		160	100								0.29+	0.26	0.05								0.68		C1-S1	
Parakrama Samudra	3/61	1			7.9		180	112																				C1	
Parakrama Samudra	4/61	1			8.0		190	120																				C1	
Parakrama Samudra	5/61	1			7.7		200	125																				C1	
Parakrama Samudra	6/61	1			7.9		200	125								2.07+	0.45	0.07								0.44		C1	
Parakrama Samudra	7/61	1			8.5		225	146								2.22+	0.40	0.06								0.38		C1	
Parakrama Samudra	8/65 8/66	3			8.2		221			9.55					1.12	0.78	0.37	0.09		2.22	0.24	3.0			0.32	0.38	0.57	C1-S1	Averages of 1 yr samples High HCO_3
Parakrama Samudra	12/65 2/66	3					175																					C1	Average
Parakrama Samudra	6/66 8/66	3					263																					C2	Average
Parakrama Samudra	11/79	11	30	7.3	7.7		165								0.92	0.49	0.27			2.14					0.73	0.32	0.48	C1-S1	High HCO_3
Parakrama Samudra Downstream Irrigation water	5/64	2			8.1		225			8.50	0.02			0.02	1.06	0.84	0.38	0.06		2.25	0.36		0.02		0.35	0.39	0.62	C1-S1	Average of 1 yr samples High HCO_3

Table 2 - 2
(Continued)

Sample Location	Date	Source	Tem. °C	D.O. mg/l	pH	Hard. mg/l	TDS mg/l	Turb. JTU	Si (mg/l)	Al (mg/l)	As (mg/l)	B (mg/l)	Fe (mg/l)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	K (meq/l)	CO_3 (meq/l)	HCO_3 (meq/l)	Cl (meq/l)	SO_4 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)	RSC	SAR	Adj. SAR	Agri. Use Class	Comments
Minneriya Tank	11/60	1			8.4	250	160							1.05*		0.64	0.29								0.88		C2-S1	
Minneriya Tank	12/60	1			8.0	230	148																				C1	
Minneriya Tank	1/61	1			7.9	200	125																				C1	
Minneriya Tank	2/61	1			7.8	220	145							1.78*		0.31	0.07								0.33		C1-S1	
Minneriya Tank	3/61	1			7.6	250	160																				C2	
Minneriya Tank	4/61	1			7.9	250	160																				C2	
Minneriya Tank	5/61	1			8.0	250	160																				C2	
Minneriya Tank	6/61	1			8.1	250	160							2.19*		1.33	0.16								1.27		C2-S1	
Minneriya Tank	7/61	1			8.3	250	160							2.25*		1.20	0.14								1.13		C2-S1	
Minneriya Tank	8/65 8/66	3			8.2	240		6.70						1.20	1.09	0.44	0.11		2.52	0.39	3.5			0.23	0.41	0.70	C1-S1	Average of 1 yr samples High HCO_3
Minneriya Tank	12/65 2/66	3				191																					C1	Average
Minneriya Tank	6/66 8/66	3				312																					C2	Average
Minneriya Tank	11/79	11	30.5	8.2	7.1	95								0.52	0.29	0.17		-	1.15					0.34	0.27	0.57	C1-S1	
Minneriya Tank Downstream Irrigation water	5/64	2			8.0	272		6.35	0.05				0.04	1.11	1.13	0.58	0.08		2.52	0.54		0.03		0.28	0.55	0.88	C2-S1	High HCO_3
Kaudulla Tank	11/79	11	29	6.3	7.2	155								0.81	0.45	0.30			1.61					0.35	0.38	0.49	C1-S1	High HCO_3
Kantalai Tank	8/65 8/66	3			8.0	218		4.80						0.88	0.82	0.43	0.13	-	1.97	0.45	4.0			0.26	0.47	0.66	C1-S1	Average of 1 yr samples High HCO_3
Kantalai Tank	12/65 2/66	3				163																					C1	Average
Kantalai Tank	6/66 8/66	3				286																					C2	Average
Kantalai Tank	11/79	11	32	7.7	6.9	162								0.73	0.51	0.31			1.81					0.57	0.39	0.55	C1-S1	High HCO_3

* = Calculated
= Trace
= Combined values

Table 2 - 3

Water Quality from the Project Area

Groundwater

Sample Location	Date	Source	pH	Hard. mg/l	E.C.	TDS mg/l	SS mg/l	Turb. JTU	mg/l Fe	meq/l Ca	Mg	Na	K	HCO_3	Cl	mg/l SO_4	NO_3	NH_3	RSC	SAR	Adj. SAR	Agri. Use Class	Comments
Mahiyangana Bore hole	6/79	9	6.8		225	150		16	1.0					3.60*	0.34		T					C1	High HCO_3, Fe
System C Well 5	8/78	8	8.4		423					2.42	2.50	0.88	0.07	5.26	0.49				0.36	0.56	1.29	C2-S1	High HCO_3
System C Well 6	8/78	8	6.5		138					0.34	0.21	1.15	0.03	1.08	0.55				0.53	2.19	1.53	C1-S1	
System C Well 7	8/78	8	7.7		169					0.55	0.25	0.89	0.05	1.17	0.73				0.37	1.41	1.27	C1-S1	
System C Well 8	8/78	8	7.5		176					0.32	0.69	0.71	0.10	0.78	1.03				-	1.00	0.80	C1-S1	
System C Well 9	8/78	8	7.6		114					0.34	0.38	0.80	0.05	0.83	0.24				0.11	1.33	1.20	C1-S1	
System C Well 10	8/78	8	7.6		85					0.42	0.11	0.50	0.01	0.98	1.25				0.45	0.97	0.68	C1-S1	
System C Well 11	8/78	8	8.1		367					1.55	1.29	1.90	0.04	1.56	0.97				-	1.59	2.54	C2-S1	High HCO_3
System C Well 12	8/78	8	8.1		578					1.02	1.08	1.70	0.03	6.65	1.03				4.55	1.66	3.32	C2-S1	Very high RSC; High Adj, SAR, HCO_3
System C Well 13	8/78	8	7.4		104					0.53	0.06	0.46	0.01	1.17	0.24				0.58	0.85	0.68	C1-S1	
System C Well 14	8/78	8	7.3		106					0.42	0.28	0.71	0.02	1.76	0.73				1.06	1.20	1.44	C1-S1	High HCO_3
System C Well 16	8/78	8	8.1		176					0.55	0.62	1.10	0.02	2.35	0.49				1.18	1.44	2.02	C1-S1	High HCO_3
System C Well 17	8/78	8	7.9		155					0.69	0.57	0.58	0.02	1.78	0.73				0.52	0.73	0.95	C1-S1	High HCO_3
System C Well 18	8/78	8	7.9		367					0.81	3.39	2.00	0.03	3.72	1.03				-	1.38	2.90	C2-S1	High HCO_3
System C Well 19	8/78	8	8.2		324					2.04	1.31	0.75	0.05	3.72	0.97				0.37	0.58	1.16	C2-S1	High HCO_3
System C Well 20	8/78	8	7.4		190					0.64	1.06	0.49	0.02	2.32	0.97				0.62	0.53	0.80	C1-S1	High HCO_3
System C Well 21	8/78	8	7.8		310					0.76	1.23	1.80	0.04	3.33	0.85				1.34	1.80	3.06	C2-S1	High RSC, HCO_3, Adj. SAR

Table 2 - 3
(Continued)

Sample Location	Date	Source	pH	Hard. mg/l	E.C.	TDS mg/l	SS mg/l	Turb. JTU	mg/l Fe	meq/l Ca	Mg	Na	K	HCO_3	Cl	mg/l SO_4	NO_3	NH_3	RSC	SAR	Adj. SAR	Agri. Use Class	Comments
System C Well 1	7/79	5	7.2	198	400	373				2.15	1.81	1.09	0.08	4.41	0.31	T	-		0.45	0.77	1.62	C2-S1	High HCO_3
System C Well 3	7/79	5	7.0	158	460	359				2.25	0.90	1.70	0.05	3.88	0.70	T	-		0.73	1.35	2.70	C2-S1	High HCO_3
System C Well 6	7/79	5	7.0	107	300	242				1.65	0.49	1.00	0.05	2.72	0.34	T	-		0.58	0.97	1.55	C2-S1	High HCO_3
System C Well 7	7/79	5	6.8	91	250	163				1.00	0.82	0.83	-	2.02	0.31	-	-		0.20	0.87	1.31	C2-S1	High HCO_3
System C Well 11	7/79	5	7.4	150	370	310				1.55	1.15	0.96	-	3.33	0.28	24.0	-		0.33	0.78	1.48	C2-S1	High HCO_3
System C Well 12	7/79	5	6.4	72	180	156				0.70	0.74	0.78	-	1.79	0.17	-	-		0.35	0.92	1.29	C2-S1	High HCO_3, Low pH
System C Well 14	7/79	5	7.6	208	1600	1284				1.35	2.80	11.96	0.69	13.37	0.25	96.1	-		9.22	8.30	20.75	C3-S2	Very high RSC, Adj. SAR, HCO_3, salinity
System C Well 16	7/79	5	6.2	60	170	142				0.30	0.90	0.78	-	1.59	0.27	-	-		0.39	1.01	1.21	C1-S1	High HCO_3, Low pH
System C Well 17	7/79	5	6.4	60	200	182				0.55	0.66	0.96	0.08	2.10	0.28	-	-		0.89	1.23	1.60	C1-S1	High HCO_3, Low pH
System C Well 4	7/79	5	6.8		500																	C2	
System C Well 10	7/79	5	6.0		500																	C2	Low pH
System C Well 20	7/79	5	6.6		750																	C3	
System C Well 22	7/79	5	6.6		570																	C2	
Polonnaruwa Well	None	6	8.1	300	600	420*	18*		0.10						0.82		T	0.01				C2	
Polonnaruwa Well	None	6	7.4	260	480	336*	96*								0.65							C2	
Kaduruwela Well	None	6	7.4	355	480	336*	96*								0.65							C2	
Kaduruwela Well	None	6	7.2	390	650	455*	35*								1.18							C2	

Table 2 - 3
(Continued)

Sample Location	Date	Source	pH	Hard. mg/l	E.C.	TDS mg/l	SS mg/l	Turb. JTU	mg/l Fe	meq/l Ca	Mg	Na	K	HCO_3	Cl	mg/l SO_4	NO_3	NH_3	RSC	SAR	Adj. SAR	Agri. Use Class	Comments
Hingurakgoda Well	None	6	8.1	95	200	140*	0*								0.31							C1	
Hingurakgoda Well	None	6	7.2	850	1500	1050*	210*								7.62							C3	High Cl, High salinity
Hingurakgoda Well	None	6	7.2	685	1700	1190*	280*								14.11							C2	Very high Cl, High salinity
Hingurakgoda Well	1972	4			500															0.20		C2-S1	
Kinneriya Well	1972	4			300															0.80		C2-S1	
Dutch Point Well	None	6	7.2	300	600	420*	5*								2.14							C2	
Trincomalee Well	None	6	7.2	255	1250	875*	65*								6.32							C3	High Cl, salinity
Trincomalee Well	None	6	8.2	825	7500	5250*	410*								59.24							-	Very high Cl, salinity
Valichchenai Well	None	6	7.7	145	350	245*	100*								0.87							C2	
Palameennadu Well	None	6	7.4	300	500	350*	62*								1.04							C2	
Batticaloa Well	None	6	7.6	250	500	350*	14*								1.24			0.03				C2	
Batticaloa Well	None	6	7.8	650	5000	3500*	0*								17.96							C4	Very high Cl, salinity
Kallady Well	None	6	7.2	60	125	88*	38*								0.34							C1	

* = Calculated
T = Trace

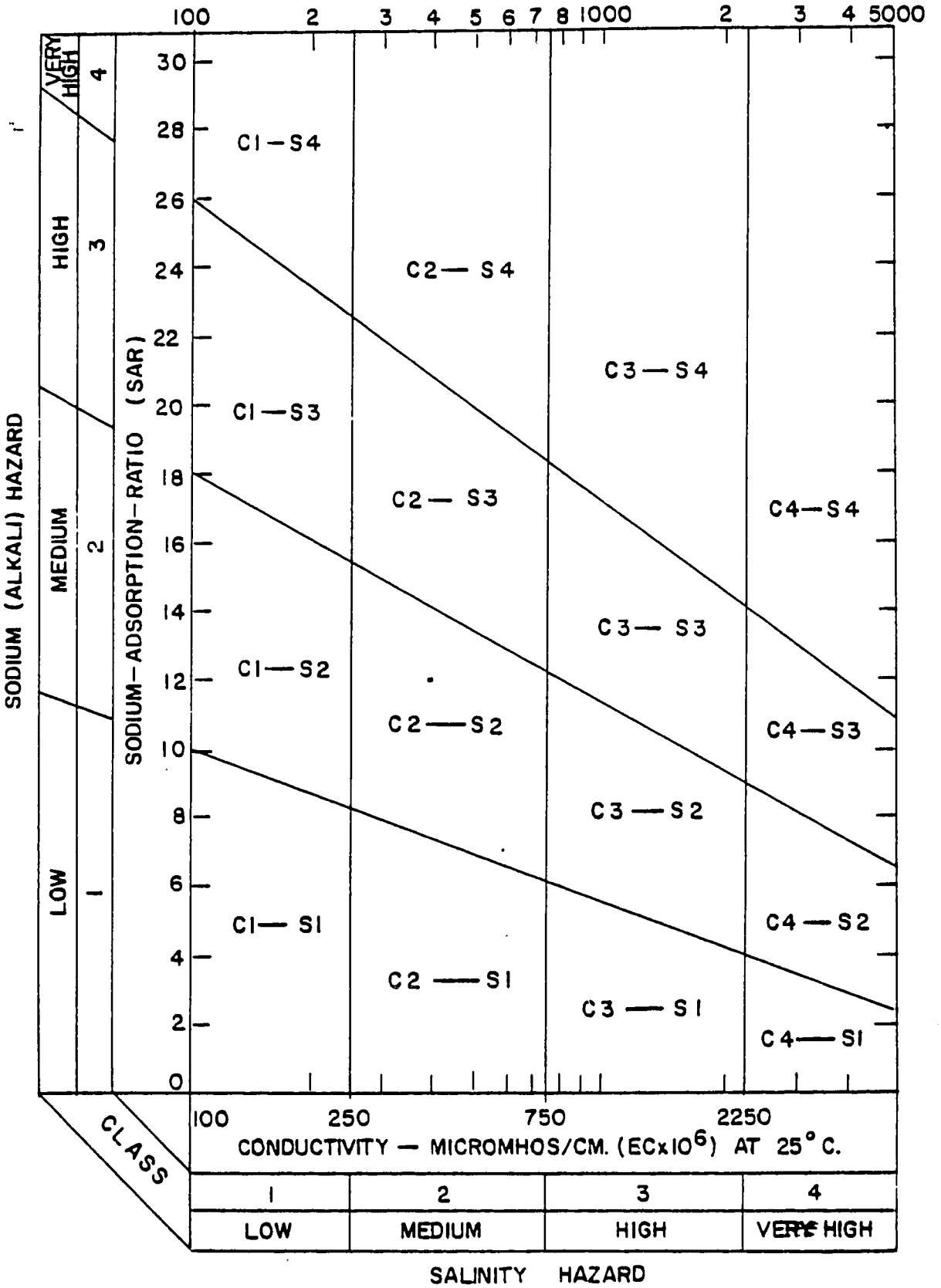

TABLE 2—4

DIAGRAM FOR THE CLASSIFICATION OF IRRIGATION WATER FROM THE U. S. DEPARTMENT OF AGRICULTURE (1954)

SEE FOLLOWING TABLE 2—5 FOR DEFINITION

Table 2 - 5

Significance and Interpretation of Quality Class Ratings

Presented in Table 2 - 5 and for Residual Sodium Carbonate

SALINITY

Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

High-salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

Very high salinity water (C4) is not suitable for irrigation under ordinary conditions, but may be used occassionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

SODIUM

Low-sodium water (S1) can be used for irrigation of almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.

Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high ion-exchange capacity, especially under low-leaching conditions, unless gypsum is present in the soil. The water may be used on coarse-textured or organic soils with good permeability.

High-Sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management-good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very High Sodium Water (S4) is generally unsatisfactory for irrigation purposes except at low and periodic mediu salinity, where the solution of calcium in the soil or use of gypsum or other amendments can make the use of these waters feasible.

RESIDUAL SODIUM CARBONATE

Level (meq/l)	Classification
< 1.25	Generally safe for irrigation use
1.25-2.50	Marginal for irrigation use
> 2.50	Not suitable for irrigation purposes

Source : U.S. Department of Agriculture (1954)

Table 2 - 6
Guidelines for the Interpretation of Water Quality for Irrigation.
From Ayers and Westcot (1976) for the FAO.

Irrigation Problem	Degree of Problem		
	No problem	Increasing Problem	Severe Problem
Salinity			
EC (micromhos/cm)	< 750	750-3000	> 3000
Specific ion toxicity (affects sensitive crops)			
Sodium (Adj. SAR)	< 3	3-9	> 9
Chloride (meq/l)	< 4	4-10	> 10
Boron (mg/l)	< 0.75	0.75-2.0	> 2.0
Miscellaneous effects (affects susceptible crops)			
NO_3-N (or) NH_4-N (mg/l)	< 5	5-30	> 30
HCO_3 (meq/l) - overhead sprinkling	< 1.5	1.5-8.5	> 8.5
pH	Normal Range	6.5 - 8.4	
Recommended maximum levels			
For selected trace elements			
Aluminium - Al (mg/l)	5.0		
Arsenic - As (mg/l)	0.1		
Iron - Fe (mg/l)	5.0		

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Table 2 - 7

Chlorinated Pesticide Residues in Project Area Surface Waters

(Results are in micrograms /liter)

Sample Location	Aldrin	Dieldrin	BHC (Total HCH)	Endosulfan	Total DDT
Mahaweli Ganga at Victoria Dam Site	0.01	0.06	0.17	-	0.05
Mahaweli Ganga at Mahiyangana	0.03	0.04	0.15	0.14	0.23
Mahaweli Ganga at Manampitiya	0.01	-	0.13	-	0.07
Mahaweli Ganga ear Chundankadu	0.14	-	0.23	-	1.63
Mahaweli Ganga at Mutur	0.07	-	0.22	-	0.41
Mahaweli Ganga East Fork at Verugal	0.06	-	0.21	-	0.34
Kotmale Oya at Dam Site	0.02	0.04	0.21	0.06	0.47
Ulhitiya Oya near Beligalla	0.04	0.05	0.17	0.02	0.07
Maduru Oya near Wagawatta	-	-	0.13	-	0.17
Maduru Oya at Welikanda	0.04	0.20	0.16	-	0.20
Maduru Oya at Valaichchenai	0.06	-	0.19	-	0.38
Upaar Lagoon	0.06	-	0.19	-	0.31
Gengala Villu	0.04	-	0.24	0.03	0.21
Karapola Villu	0.07	0.06	0.19	0.10	0.38
Mutugalla Villu	0.12	0.13	0.19	-	0.22
Velankada Villu	0.02	-	0.20	-	0.14
Velankada Villu Inlet Stream	0.01	0.14	0.20	0.04	0.27
Horabora Wewa	0.02	0.04	0.17	0.07	0.06
Allai Tank	0.07	-	0.15	-	0.48
Vakaneri Tank	0.07	-	1.56	-	0.14
Parakrama Samudra	0.04	-	0.22	-	0.13
Minneriya Tank	0.04	0.03	0.17	-	0.25
Kaudulla Tank	0.02	-	0.18	-	0.12
Kantalai Tank	0.06	-	0.23	-	0.53

Source: Samples were collected by TAMS in November, 1979 and analyzed by the Central Agricultural Research Institute, Peradeniya.

Table 2 - 8

Morphological and Operational Alterations for Existing Major Tanks

Characteristics		Parakrama Samudra		Minneriya Tank		Kaudulla Tank		Kantalai Tank	
		Present	Future	Present	Future	Present	Future	Present	Future
High water level Elevation (m)		58.5	58.5	93.7	93.7	69.5	69.5	56.9	56.9
Low water level Elevation (m)		51.5	51.8	82.1	82.4	64.0	64.3	46.5	47.4
Mean Water Level	Elevation (m)	55.1	56.1	90.3	89.7	66.9	65.9	54.5	53.8
	Area (km^2)	15.0	17.6	17.0	15.8	12.5	8.8	13.7	12.1
	Storage (mcm)	57	73	81	75	27	18	51	44
	Mean Depth (m)	3.8	4.1	4.8	4.7	2.2	2.0	3.7	3.6
Mean Annual Inflow (mcm)	Natural Inflow	26	26	61	61	21	21	69	69
	Irrigation Return Flows	0	0	-	0	0	0	0	0
	Releases from upstream source	123	197	480	604	157	306	109	184
	Total Inflow	149	222	541	665	178	327	178	253
Mean Annual Outflow (mcm)	Irrigation Releases	145	213	143	149	173	322	164	245
	Releases to Downstream Tanks	0	0	392	504	0	0	0	0
	Evaporation - Evapo-transpiration	6	6	6	6	6	5	5	5
	Flood Spills	0	0	-	3	0	0	9	2
	Total Outflow	151	220	541	663	179	327	179	252
Hydraulic Retention Time (yr)		0.38	0.33	0.15	0.11	0.15	0.06	0.28	0.17
Dangerous Level of Phosphorous Loading ($gm/m^2/yr$)		0.52	0.57	0.70	1.24	0.62	1.03	0.59	0.77

Source : NEDECO (1979) Annex B
Vollenweider (1973)

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CHAPTER 3

FISHERIES

EXISTING CONDITIONS

Fish Fauna of Sri Lanka

There are about 60 species of fish found in the freshwater of Sri Lanka (Munro, 1955; Fernando and Indrasena, 1969; Fernando, 1973). About half of these species are cyprinids, including small very abundant minnows like Barbs, Rasbora and Danio which serve as forage for large carniverous fishes.

About 20 of the freshwater species are valued as food fish (Indrasena, 1965; Fernando and Indrasena, 1969). These are the following :

SCIENTIFIC NAME	COMMON NAME
Barbus dorsalis	Long Snouted Barb
Barbus sarana	Olive Barb
Carassius carassius	Crucian Carp
Cyprinus carpio	Common Carp
Labeo dussumieri	Common Labeo
Tor khudree	Mashier
Clarius teysmanni	Spotted Catfish
Wallago attu	Freshwater Shark
Ompok bimaculatus	Butter Catfish
Heteropneustes fossilis	Stringing Catfish
Macrones spp.	Catfish
Ophiocephalus striatus	Striped Snake Head
Ophiocephalus marulius	Giant Snake Head
Etrophis suratensis	Banded Etroplus
Tilapia mossambica	Tilapia
Anabas testudineus	Climbing Perch
Osphronemus goramy	Giant Gourami

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SCIENTIFIC NAME	COMMON NAME
Glossogobius giuris	Bar-eyed Goby
Macrognathus aculeatus	Lesser Spiny Eel
Mastacembelus armatus	Spiny Eel

At least 15 foreign species have been introduced as potential food fish (Fernando, 1976; NTS, 1979) of which 4 have established sizeable populations. These are Common Carp, Crucian Carp, Tilapia and Giant Gourami. Tilapia (T. Mossambica) has increased freshwater catches significantly since its introduction, and this species normally comprises 50 to 90 per cent of the catch by weight from tanks and villus (Fernando and Indrasena, 1969; Department of Fisheries and Department of Census and Statistics, 1973; Fernando, 1976).

Endemic Fish Species

Crusz and Nugaliyadde (1978) report that there are a total of 16 endemic fish species which occur on the island of Sri Lanka. Most of these can be found in the wet zone of the country.

Data on endemic fish species (as well as other endemic flora and fauna) pertaining to their distribution within the Mahaweli Accelerated Program area were gathered at a workshop as part of the "Endemic Species Seminar" sponsored by TAMS in December, 1979 and held at the Natural History Museum in Colombo. The data collected represent the most up-to-date information concerning the distribution of endemic fishes within the project area. These data are summarized in Table 3-1 along with other relevant ecological information about the species. Of the 8 endemic fishes listed in Table 3-1, all but one have relatively widespread distribution in other parts of the country. The Sri Lankan Barb, which is a newly identified species, is restricted to a few small tributaries within the Amban Ganga drainage.

Most of the endemic fishes inhabit small up-country torrential streams. Two species, Two Spot Barb and Mountain Labeo undergo annual upstream spawning migrations. The Mountain Labeo may in fact move out from tanks and up the main rivers to its breeding grounds.

Inland Fisheries Development

The Sri Lankan Ministry of Fisheries has recently established an "Inland Fisheries Division" with the basic objectives of promoting and developing fishing activities on inland water bodies (including brackish water areas). Various development plans are presently being formulated including the assemblage of reliable statistics, upgrading of existing breeding stations and the sponsoring of some research and pilot projects. In addition, this new division is associating with the Mahaweli Development Board to coordinate fisheries development for the entire accelerated program area.

The Ministry of Fisheries has set a production target of 50,000 tons for inland fisheries which it plans to attain over the next 5 years. The total inland fisheries production is presently estimated at about 16,000 tons per annum. A general breakdown of the proposed production increase is as follows :

	TONS	
Freshwater	Present	Target
Major and medium tanks	12,000	35,000
Minor tanks	1,000	5,500
Others	-	1,000
Brackishwater		
Deep lagoons and estuaries	2,000	6,500
Shallow lagoon and tidal	1,000	2,000
Totals -	16,000	50,000

River Fisheries

Data concerning the fish fauna of rivers and streams is very limited for Sri Lanka. Interviews recently conducted with local residents and biologists reveal that the more commonly found fish species in the Mahaweli Ganga are the following :

SCIENTIFIC NAME	COMMON NAME
Anguilla Nebulosa	Long Finned Eel
Barbus folamentosus	Filamented Barb
Barbus sarana	Olive Barb
Cypinus carpio	Common Carp
Labeo dussumieri	Common Labeo
Labeo fisheri	Mountain Labeo
Rasbora daniconius	Common Rasbora
Tor khudree	Mahsier
Garra lamta	Stone Sucker
Wallago attu	Freshwater Shark
Macrones keletius	Dwarf Catfish
Ompok bimaculatus	Butter Catfish
Ophiocephalus Marculius	Giant Snake Head
Ophiocephalus striatus	Striped Snake Head
Tilapia mossambica	Tilapia
Osphronemus gouramy	Giant Gourami
Mastacembelus armatus	Spiny Eel

Local residents also report the capture of large freshwater shrimp (Macro brachium) from the river at different times of the year. In addition, in the lower reaches of the river a number of salt water species are often found including sharks, rays and an occasional sawfish. Several of the river species are known to undertake annual upstream spawning migrations, especially the Labeo species and the Mahsier.

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There are no commercial fisheries operations on the Mahaweli Ganga, Maduru Oya nor any other stream in the project area. Even subsistence level fishing activities are limited except in the mainstream Mahaweli Ganga. Here occasional handline fishing is observed; some sport fishing occurs in the Upper Mahaweli particularly for the Mahsier which can reach a size of up to 25 kilograms. No records are maintained of the fish catches from rivers or streams in the country. An arbitrary estimate of fish yields from the country rivers and streams was given by Indrasena (1965) as roughly 5 kg/ha/yr.

Villu Fisheries

Villus in the lower reaches of the Mahaweli Ganga form a major part of the river floodplain. Villus are highly productive and are excellent spawning and nursery habitats for many fish species. A number of fish species tend to spawn in these warm, shallow waters as they rise during the wet season. Consequently, eggs hatch simultaneously with the inundation of surrounding land which results in the availability of a large amount of organic water for feeding the juveniles (welcomme, 1979).

Few studies have been conducted on the fisheries of the villus. Fernando (1969) reported that at the Karapola Villu (near Manampitiya), fish catches from 1960 to 1966 ranged from 25 to 50 tons or a yield of roughly 35 to 70 kg/ha, respectively. The common species in the catches were Tilapia, Labeo, Freshwater Shark, Butter Catfish, Banded Etroplus, Snake Heads, Giant Gourami and Barbs. A recent interview (November, 1979) with fishermen at the Karapola Villu indicated that the same species are still being captured plus the freshwater shrimp and a few eels. There are 25 virtually full-time fishermen presently operating at the villu. Gill nets set from canoes are the main gear utilized. During the peak fishing season (January - April), fishermen take about 10 kg per day; in the remainder of the year, average daily catches are about 2-3 kilograms. Combined with part time fishing activities, the total annual catch in recent years has been about 40 tons/year, or around 57 kg/ha.

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These figures compare favourably with others given as estimates for villu fish yields. Indrasena (1965,1970) gave an average catch for the Mahaweli Ganga floodplain of about 34 kg/ha. The Ministry of Fisheries uses an estimates of 56 kg/ha (50 lbs/ac) for all villus when determining annual national catches.

Paddy Fields and Irrigation Channels

During floods, paddy fields, like villus, serve as large areas of open water where many fish species breed (Fernando, 1969). Considerable numbers of small sized fish have been caught in this habitat, and Fernando (1956) reported a total of 24 species occuring in the western lowland rice fields. Larger, food fishes including Butter Catfish, Common Labeo and Freshwater Shark have been found in the irrigation canals.

Tank Fisheries

More than 80 per cent of Sri Lanka's inland fishery catch is from tanks; most of this is from the low-country major irrigation tanks. The deep, up-country reservoirs have very low, often negligible, fish yields (Fernando, 1969; Fernando and Fantado, 1975). Low-country, medium tanks also contribute to inland fishery output, but activities in these and the smaller seasonal tanks are usually confined to occasional or subsistence level fishing.

Fishery operations, of varying intensity, using gill nets and beach seines have been underway at the major tanks for 25-30 years (Fernando, 1969). These remain the prevalent catch methods, although cast nets, handlines and occasional traps are also employed. Fishing is done from the shoreline or from canoes and small rafts.

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At most of the tanks, fishermen sell their catch directly after capture to traders or vendors who transport the fish to nearby market centers for sale. The Department of Fisheries and Department of Census and Statistics (1972) reported that 65 per cent of the landed catch was sold fresh to consumers, 32 per cent was sold after salting and drying or smoking, and 3 per cent was used for home consumption.

With the introduction of Tilapia (T. Mossambica) in 1951, commercial fishing became well established at a number of the major tanks. Marine fishermen migrated to the freshwater tanks, at first seasonally, and later developing full time fisheries operations. The seasonal emigration of marine fishermen to some tanks still occurs.

Tilapia expanded rapidly after being stocked and comprises up to 90 per cent of the catch at some tanks. Other species which contribute appreciably to the catches include the Banded Etroplus, Labeo, Barbs, Freshwater Shark, Giant Gourami and Catfishes. The distribution of species by weight in catches for the major Sri Lankan tanks is given in Table 3-2.

The major tanks in the project area include Parakrama Samudra, Minneriya Tank, Kaudulla Tank and Kantalai Tank. These tanks, especially Parakrama Samudra, contribute a significant amount of the inland fish catch for the country. Available information concerning catches, number of fishermen, etc. for these tanks is summarized in Table 3-3. In general, catch data for the existing tanks are of varying reliability. The Ministry of Fisheries is presently re-structuring the catch data gathering program to improve the quality of fisheries statistics for future management planning.

The existing data does reveal several trends. One is that catches increased significantly since the introduction of

Tilapia to the tanks. Further, there appears to have been no significant decline in any of the indigenous fish fauna following the stocking with Tilapia (Fernando, 1969). The catch data also indicates that many of the existing tanks are under-exploited. In addition, fluctuations in catch probably reflect the number of individuals fishing rather than natural variation in the fish stocks. This is evident from the changes in catch which result from the periodic migration and emigration of coastal fishermen (HTS, 1978).

Data provided by the Ministry of Fisheries (1979) indicate that the major tanks in the country had fish yields in 1978 ranging from about 20 kg/ha to over 500 kg/ha. The average yield for these tanks is estimated at 182 kg/ha (163 lb/ac). Collectively, more than 1000 fishing crafts operate on the tanks with an average annual catch of about 11.5 tons per boat.

Comparable data are not available for any of the medium or smaller seasonal tanks. The Ministry of Fisheries estimates that these tanks produce yields of about 56 kg/ha (50 lbs/ac). This estimate is conservative; Fernando and Ellepola (1969) report yield figures of 79 and 112 kg/ha (70 and 100 lbs/ac) for two small tanks near Polonnaruwa. Seasonal "mud fishing" i.e., hand collection of fish, is common where small tanks dry out annually (Fernando, 1969).

Estuarine Fisheries

Fishing activities are well developed in the estuarine portions of the Maduru Oya and Mahaweli Ganga. These areas, like others along the coast, provide nursery grounds for shrimp (*Penaeus* sp.). On the east coast, shrimp fry enter inshore waters in December-January and the peak catches are made from March to May (Ministry of Fisheries, personal communication).

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Principle fishing grounds are the inshore lagoons and estuaries. Shrimp yields for Sri Lanka have been estimated at roughly 170 kg/ha for the inshore waters (Ivannov, 1964).

The estuaries are also breeding, nursery of feeding grounds for a number of economically valuable food fish species, including Anchovies (Anchoviella), Whitefish (Chanos Chanos, Bonefish Elops, Mullet (Mugil), Perch (Lates), Snappers (Lutjanus) and several Jacks (Caranax). These comprise the main fin fish catch from the intertidal waters on the east coast (Ministry of Fisheries, personal communication).

According to the Department of Fisheries and the Department of Census and Statistics (1972), there are over 18,000 fishing management units (boat gear and crew) operating from Trincomalee. Of these, about 350 fish inshore waters, chiefly in Koddiyar Bay. About 150 full-time fishermen were recently observed from the town of Mutur. A similar number conducts fishing activites around the Valaichchenai area. The main gear employed are cast nets and gill nets worked from canoes. Beach seines are also used.

Aquaculture

Fish culturing or farming is very limited in Sri Lanka. At present, eel and shrimp farms are being operated by private concerns; but these are only on an experimental basis.

Several other culturing operations have been attempted, mainly by the fishery research stations which are maintained by the Ministry of Fisheries. One successful attempt produced nearly 2,000 kg/ha of mullet and milkfish at the Pitipana Station (Pillai, 1965). The fishing stations, have successfully bred a number of species including tilapia, common carp,

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chinese carps, gourami and others. In addition, several pilot projects have recently been initiated including polyculture of carp and tilapia in ponds and cage culture.

However, with freshwater fish market prices low, it is unlikely that interest can be generated in pond culture operations, and for the present, the status of aquaculture development in Sri Lanka may be considered only experimental.

IMPACT ANALYSIS

Formation of Proposed Reservoirs

Changes in Species Composition - The formation of the proposed reservoirs will result in the replacement of riverine ecosystems with lacustrine ones with a subsequent elimination of some fish species and an enhancement of others. Species which prefer running water habitats or require highly oxygenated, hard gravel substrates as breeding or feeding grounds would not be expected to survive a transition to a lake environment. On the other hand, fishes which occur in the rivers, but are found primarily in quiet waters along the shoreline or in backwaters, will not only survive the impoundment but may increase their population sizes substantially.

Changes in species composition following inundation of rivers in Southeast Asia have been reported by Bhukaswan and Pholprasith (1976), Natarajan (1976), Sreenivasan (1976) and Sirinivasan and Sreenivasan (1976). Generally, these studies report a significant increase in catfish and carp species after creation of reservoir pools. Concomitently, there was a decrease in the abundance of many riverine species, with a noticeable disappearance of some fishes, particularly the Mahsier.

Comparable shifts in the fish community structure are anticipated for the proposed reservoirs. The fish species which are likely to dominate the reservoirs are those which presently inhabit tanks, villus and other quiet water habitats. Thus, the predominant natural reservoir food fish populations will be comprised of Tilapia, Banded Etroplus, Labeo, Barbs, Giant Gourami, Snake Heads and the catfishes especially the Freshwater Shark (Wallago attu) which has appeared in large numbers in several man-made lakes in Asia. On the other hand, it is likely that Mahsier and a number of other species will be eliminated from the river sections which undergo impoundment.

Projected Yields - Several estimates have been made of annual average potential fish yields for the proposed reservoirs. These are the following :

SOURCE	ESTIMATED YIELDS kg/ha/yr
ACRES (1979)	150
HTS (1979)	100
NEDECO (1979) ANNEX F	400
Ministry of Fisheries (1979)	280

These estimates vary considerably, reflecting the basis of their selection. All of them are arbitrary estimates established by a comparison with the present yields realized from tanks in the country. These yield estimates have been applied uniformly to all of the proposed reservoirs (except the ACRES estimate which was selected for the Maduru Oya Reservoir only).

In order to account for individual morphological and productivity differences in the proposed reservoirs, a seperate method of estimating potential fish yields (i.e. the potential

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harvestable fishery resource) is applied here. The method takes into consideration anticipated physical and bio-chemical features of the proposed reservoirs. It is based on a ratio involving the electrical conductivity (or dissolved solids concentration) and the mean depth of a reservoir.

This ratio was described initially as a "morphoedaphic index" (MEI) by Ryder (1965) for use as a rapid method of yield assessment for northern temperate lakes. The MEI has since been modified for application to tropical lakes through a regression analysis by Henderson and Welcomme (1974). The MEI has been widely used as an approximation of potential yields for reservoirs in Africa, South America, United States and Canada (Welcomme and Henderson, 1976).

A regression analysis relating MEI values and fish yields from tanks Sri Lanka was recently completed by Wijeratne and Costa (1979). The relationship is as follows :

$$C = 19.0677\ MEI^{0.7050}$$

where C = potential fish yield in kg/ha/yr; and

MEI = conductivity in micromhos/cm ÷ mean depth in m.

Using this formula, the available water quality and the reservoir morphological information, the potential fish yields of each of the proposed reservoirs was calculated. These figures and the supporting data are presented in Table 3-4. Total annual estimates for potential fish landings at the proposed reservoirs are also included in Table 3-4 and were based upon the mean areas of the reservoir.

The calculated yields clearly indicate that the deep, up-country reservoirs are likely to be much less productive in terms of fish output than the shallower, low-country ones.

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This corresponds well with information concerning fish yields from other reservoirs throughout Southeast Asia and within Sri Lanka (Fernando and Furtado, 1975; Fernando, 1976). The deep reservoirs in Southeast Asia produce low fish yields of only 10-40 kg/ha in comparison with the shallower lakes. Low fish yields in deep reservoirs are the result of low levels of incoming nutrient supplies, pronounced thermal and chemical stratification and a limited shallow inshore area which is usually the most highly productive zone of a reservoir.

Fisheries yields from a reservoir are of course affected by other factors besides mean depth and total dissolved solids input. An important factor will be the age of the reservoir. In the first 4 or 5 years, yields are often substantially higher than in later years. One reason for this is that during the initial flooding large amounts of organic matter are suspended, serving as direct fish food or as a nutrient supply for algae. The subsequent large algae growths may trigger a chain reaction in the food web of the reservoir which can be manifested by accelerated fish growth and reproduction. An additional reason for high initial fish production could be that the rising waters stimulate nearly continuous spawning behaviour in some species. The onset on river flooding stimulates immediate spawning responsives from many species, and thus, this behaviour may be accentuated by reservoir filling. However, initial high fish yields in Asian reservoirs have not always occurred. This may be due to a lack of suitable fish species in the areas inundated or a failure of fishermen to mobilize soon enough to take advantage of the high productivity in the first few years of reservoir operations.

Other factors which will affect fish production include an irregular shoreline which may occur along the edges of the reservoirs. This will enhance fishery development by

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providing added cover and feeding grounds. On the other hand, the anticipated steepsided character of the up-country reservoirs will limit the amount of shallow inshore areas which are common spawning grounds for many species.

Drawdown can also have a deterimental effect on fisheries by exposing eggs and nests of inshore areas. However, this should not be a significant factor, because most species which will inhabit the proposed reservoirs will spawn during periods of reservoir filling. Drawdowns may, in fact benefit fish populations by providing organic detritus for feeding juvenile fish as waters rise.

In summary, the proposed reservoirs, are expected to exhibit varing fish yields, with much higher catch realized from the shallow, low-country reservoirs. Potential fish yields in the reservoirs should range from about 20 to 35 kg/ha/ya for the deeper reservoirs and from around 100 to 300 kg/ha in shallow ones. All of the reservoirs will produce fish yields which are significantly higher than that presently taken in the river sections they will inundate. The yields there are probably 5 kg/ha/yr or even less.

Impacts on Migration Patterns

The series of dams which will be constructed on the rivers and streams in the project area will effectively block upstream fish migratory movements. Several species will be adversely affected, although it is difficult to adequately assess the overall effects on fish movements because little is known of the migration patterns in the island waters.

One species which may be significantly affected is the Mahsier (Tor khudree) a popular game. fish. The Mahsier has been observed by local residents and biologists to

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undergo seasonal upstream spawning migrations. The presence of the proposed dams combined with an inability of the Mahsier to adapt to lake habitats will probably result in a significant decline in the population of this species in the Mahaweli Ganga.

Other fishes which may be adversaly affected by interference with migration patterns are probably the endemic Mountain Labeo (Labeo Fisher) Olive Barb (Barbus sarana) and Long-Snouted Barb (Barbus dorsalis). These species are all believed to migrate annually up the main rivers to spawn in very small hill streams. The Barbs often leave tanks or villus to enter upstream rivers and streams. Occaisonally large concentrations of these fish are found in very small streams. The numbers are often so large that monkeys have been observed capturing them by hand (Dr. W. Dittus personal communication).

Young Eels also migrate upstream annually, returning after several years to spawn at sea. The higher upstream dams will undoubtedly block their passage, although they may be capable of negotiating the smaller downstream ones.

In addition to fish species, the freshwater shrimp (Macrobrachium) will also have its migratory patterns affected by the dams. This impact may be mostly due to the construction of the downstream Kandakadu Barrage which could block breeding migrations to and from the estuary.

Downstream fish movements will also be blocked by the proposed dams. However fish may be swept over the spillways or drawn into the power intakes. Generally, about 75% fish which pass through power turbines will survive, the remainder usually perish due to physical injury.

Impact on Tank Fisheries

Major tanks fisheries should be littled affected by the proposed project. Flushing rates will increase, but other operations should not change appreciably; and return flows from irrigation systems are not expected to enter the Parakrama Samudra, Minneriya Tank, Kaudulla Tank or Kantalai Tank.

Some of the medium and smaller tank fisheries may be adversely effected due to the inflow of pesticide run-off from irrigation projects. In particular, the downstream tanks such as the Vakaneri and Allai tanks may eventually be seriously affected as pesticides accumulats in tissues of food fish species.

A number of tank fisheries will be benefitted by the project due to increased availability of water. This impact will be more adequately investigated for the final report.

Impact on Villu Fisheries

Since many of the villus will receive irrigation return flows, pesticide accumulations could become a problem for the villu aquatic biota. The increased nutrient inflow from agricultural run-off will affect the productivity of the villus, very likely accelerating if to produce highly eutrophic conditions. The resultant deterioration of water quality in the villus would have overall negative impacts on the fisheries resources such as changing species composition, inhibiting life cycle pattern, causing partial fish kills of tainting fish flesh.

A reduction of overall downstream river flows will result as a corresponding decrease in the water surface areas of many, if not all of the villus. This, of course would limit

fish yields from the villus accordingly. If, for example, the present mean annual villu surface areas (about 8,200 ha total) were decreased by 40%, the loss in fish yield (based on a present yield of 50 kg/ha) would be over 150 tons per year. This represents a loss to the villu natural capture fisheries.

In addition, villus have a high potential for fish culture (see following section), provided water levels are maintained for a growing season (6 to 8 months). A drop in villu water levels due to river flow reductions would significantly decrease the value of these habitats for fish culture operations.

Impacts on Estuarine Fisheries

The alteration of natural flow regimes coupled with a downstream accumulation of agrochemicals is likely to have on overall negntion effect on the estuarine fishery resources at the mouths of the Mahaweli Ganga and Maduru Oya. This may be especially evident for the shrimp nursery grounds, since shrimp juveniles require a delicate balance of organic matter cycling. Changes in the nutrient loading of the estuaries is liable to upset this balance with an overall detrimental effect upon shrimp and fish populations. A more detailed assessment of impacts on the estuarine fisheries will be undertaken in the final report. (See, CHAPTER 4 WETLANDS)

Impacts on Endemic Fish Species

Most of the endemic forms occuring in the project area inhabit small, upland streams. Some of these habitats may be inundated by the up-country proposed reservoirs i.e. Kotmale, Victoria, and Randenigala Reservoirs. This would probably eliminate endemic species occuring there, since few of these fishes appear to be adaptable to reservoir habitats. In general,

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the loss of these habitats would not be considered a highly significant impact, since the endemic fish species affected also occur in high numbers in many other river drainages throughout the country. The endemic species populations in tributaries of the Mahaweli Ganga and Maduru Oya which are not inundated, are expected to remain unaffected by project developments.

The Mountain Labeo (Labeo fisheri) may, in fact, be doubly affected since the proposed dams will inhibit its normal upstream migration route. The Sri Lankan Barb (Barbus Srilankensis), the most restricted of the endemic fish in the area, should be relatively unaffected by the project; since no developments are presently planned which would involve the Kalu Ganga drainage system. Two endemic species, Leaf Lates (Belonita signata) and especially the Smooth Breasted Snake Head (Chana orientalis), will probably benefit by the project since they prefer quiet waters, and thus their populations are likely to expand with the formation of the reservoirs and the presence of large paddy areas.

RECOMMENDATIONS

Planning for Fisheries Development

Overall, the potential for fisheries development in the project area is very high and its realization, in fact, may become essential as the demand for protein increases in the future years of settlement growth. Fish presently are the predominant source of protein in the rural communities of Sri Lanka. The average annual per capita consumption of fish by the rural population is about 12 kg. With full development of the Mahaweli Accelerated Program area, an additional 12,000 tons of fish beyond the present production will be needed to meet the annual demand of the incoming settlers.

Some of this demand can be met by improving yields from existing sources; however, maximum yields are already being harvested from the marine fisheries operations and the present freshwater catches (mostly from the major tanks) are all marketed and consumed locally. Consequently, it is likely that the majority of the required 12,000 tons will have to come from the development of new fishery resources.

It appears that a master plan for fisheries development within the project area is needed. Some programs, including the development of a new fish breeding stations, a stocking plan and permanent settlement of fishermen, have been initiated in varying degree for the existing system H irrigation project. These programs are being developed through the combined efforts of the Inland Fisheries Division and the MDB. However, comparable planning for the accelerated program area has only been at a very preliminary level. In the following sections, recommendations are discussed for the mitigation of adverse project impacts on fisheries, some new potential fishery resources to meet future demands and for fisheries development planning in general for the project area. These recommendations and the cost of various implementation plans will be elaborated on further in the final report.

Proposed Reservoirs

Contribution to Required Demand - The total capture fisheries yield which could be provided from the combined outputs of the major proposed reservoirs (Table 3-4) is estimated at roughly 2570 tons per annum. However, the yields from the three up-country reservoirs (Kotmale, Victoria and Randenigala) are likely to be marketed outside the agricultural development regions of the project area. This could reduce available yields to the new settlers to about 2,450 tons/yr.

Further, if the proposed Rotalawela and Moragahakanda Reservoirs are not constructed, the available yields will decrease to only 1,640 tons/yr.

It is apparent that the estimated need for fish products within the project area will not be met solely by the natural capture fisheries of the new reservoirs and other sourses, discussed in following sections, will have to be utilized. In any event, the potential yields from the proposed reservoirs will be subtantial. Moreover, in order to capitalize upon this potential resource, several planning measures may be necessary.

Nature of the Reservoir Fisheries - It is recommended that planning for fisheries development of the new reservoirs be conducted with the aim of promoting small-scale fishery operations, comparable to those on the existing major tanks. This would involve the use of small fishery management units, consisting of a single fishermen with perhaps an assistant operating from non-motorized canoes and using primarily gill nets along with handlines, cast nets, beach seines or traps where they are applicable.

This type of fishery is labor intensive and attracts more individuals, since input costs and maintenance are low. Use of large, relatively expensive boats especially ones equipped with outboard motors, are not recommended. The additional costs for the boats, motors, fuel, etc. and especially maintenance problems are an unnecessary burden to the fishermen. Further, the small scale operations are well suited to effect maximum exploitation of the fishery resources on what will be relatively small sized reservoir areas. Collection gear, however, can be modified, with new gears introduced to harvest the different fish stocks. It is recommend that gear selectivity studies

be initiated once the reservoirs are operational in order to determine the most appropriate gill net mesh sizes, the best trap designs etc.

Subsidy and extension programs will also be needed to fully develop fishery potential on the new lakes. These programs have been proposed as part of the Inland Fisheries Division's plans for country-wide fisheries development (Ministry of Fisheries, 1979). Likewise, the programs are intended for implementation to enhance all forms of fishery development in the Mahaweli Accelerated Scheme.

Removal of Reservoir Vegetation - The MDB has planned to clear as much vegetation as possible from the proposed reservoir sites. There are various issues concerning fisheries development which require consideration in the planning of vegetation removal from a reservoir site prior to inundation. Trees and other woody vegetation which remain within a reservoir after flooding often impede lake navigation and usually prevent or limit fishing activities because of damage to nets and other gear. On the other hand, this vegetation provides a suitable substrate for food-chain organisms used by fish for food and also serve as protective cover and spawning sites for many species.

Recommendations made here take both of these conflicting aspects into consideration along with the nature of the proposed reservoirs. It is essential that much of the woody vegetation be removed from all of the proposed reservoirs if effective fishing of the natural stocks is to take place.

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Moreover, to enhance natural fish productivity in the reservoirs, especially for the deep up-country ones, it is advisable to permit small tracts of forest to remain in selected areas of the reservoirs. Approximately 5% or perhaps slightly more of the inshore drawdown zone vegetation should be maintained. However, it should be subdivided into small blocks of 5 and 10 hectares, which are seperated by open water (where vegetation has been removed) zones of one-half kilometer, or more.

A clearing pattern of this nature will permit utilization of all types of fishing gear with minimal risk of damage and simultaneously provide a feeding and nursery area to replenish natural fish stocks. This clearing plan will be well suited to small scale fishing activities. Fisherman can employ cast nets and seines in the cleared, shallow inshore areas, use gill nets at the edges of the vegetation blocks and traps within the vegetated areas.

Introduction of Species - While indigenous fish populations are likely to contribute a sizeable portion of the reservoir yields, it is likely that other species will have to be introduced in order to maximize outputs.

The most likely candidate for stocking in the new reservoirs is the common Tilapia species, Tilapia mossambica which is already prevalent in many of the freshwater areas of Sri Lanka. The MDB in collaboration with the Ministry of Fisheries is planning to construct a new fish station in Dambulla for the purpose of producing Tilapia fingerlings to stock in the waters of the System H area. The MDB has indicated similar intentions for the accelerated programs area, and the Ministry of Fisheries is embarking on a program to raise and stock Tilapia in many of the island inland waters-mostly tanks.

It is suggested that within these proposed planned stocking programs, consideration be given to the fact that Tilapia mossambica is a prolific breeder in Sri Lankan waters and that repeated stocking of the species into tanks and reservoirs may be unnecessary since its own reproductive potential may be sufficient to maintain high populations in the reservoirs. Thus, Tilapia mossambica may be introduced into the proposed reservoirs in order to allow the establishment of self-sustaining populations, while other species can be considered for annual stocking and restocking programs.

Tilapia mossambica has been introduced widely throughout Southeast Asia and is likely to appear in many of the new reservoirs even if it is not intentionally stocked. One problem which is often associated with Tilapia introductions is that due to its high reproductivity, crowding may occur which results in stunting of the growth of the individual fish which in turn limits their marketability. This has been observed in a number of reservoirs and especially in small ponds in Asia. However, it is not known to happen with Tilapia populations in Sri Lankan reservoirs (Fernando, 1976). This may be due to high fishing intensity and/or high predator pressure, both of which control Tilapia populations and thus prevent or limit stunting (sreenivasan, 1967, Balarin and Hatton, 1979). In fact, predators are often deliberately stocked with Tilapia to control their growth rates in fish culture operations. Natural predators which are likely to occur in the proposed reservoirs include the Snake Heads and various catfishes, especially the Freshwater Shark (Wallago attu). The latter is an especially voracious predator which may reach up to 6 feet in length and whose stomach contents have occasionally been observed to include human limbs (Alikunhi, 1957).

Since Tilapia have not been found to stunt in Sri Lankan reservoirs and natural predator control is apparently

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adequate to limit over-population, it is recommended that Tilapia mossambica be stocked initially into the proposed reservoirs; although repeated annual stocking is not recommended since the species should establish permanent breeding populations.

One further concern in the stocking of Tilapia mossambica is that the species is unlikely to be successful in the three up-country reservoirs. Its growth and reproduction have been very low in the existing hill tanks (Fernando, 1976). On the other hand, different Tilapia species which are better adapted for deeper waters and/or colder habitats may be amenable to the up-country reservoirs. These Tilapia species include Tilapia sparmanni, an omnivore, and Tilapia galilaca which feeds on phytoplankton.

Common Carp (Cyprinus carpio) is also a likely candidate for the upland reservoirs. However, it is not recommended to stock this species in shallower reservoirs, since it often destroys inshore fish nests. Crucian Carp (Carassius carassius) would be another possible species for introduction into deeper reservoirs since it breeds and thrives well in that type of habitat.

For the low-country reservoirs, exotic species which may be considered for introduction would include other Tilapia species (Tilapia rilotica and Tilapia zillii, both of which have been introduced here previously), the Indian Carps and the Chinese Carps. A more detailed evaluation of potential fish species for reservoir stocking will be made for the final report. Some comparable data may be available then on a proposed experimental stocking program involving Tilapia and Carp species in various combinations presently being initiated by the Ministry of Fisheries. This type of polyculture experimentation is highly endorsed, and it is recommended

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that further trials be attempted in order to develop sound stocking policies for both the proposed reservoirs and the existing tanks in the project area.

Additional introductions in project area water should be considered for the control of mosquito larvae since malaria may be a substantial problem. Mosquito fish or Gambusia have been recommended for introduction to assist mosquito control (KTS ANNEX Z, 1979), but a species native to Southeast Asia called the Lesser Top-Minnow (Panchax panchax) is considered superior to Gambusia (WHO, 1973). This species is native to Sri Lanka and could be easily captured and transferred to the project area waters.

Fish Ladders

At the present time, it is not recommended that consideration be given to installing fish ladders or comparable conveyances to permit upstream passage of fish during spawning migrations. There are few species adversely affected by blockage of migration routes; and none of these species are of exceptional economic value. If further study warranted by-pass devices, it is likely that they could be installed after the dams are constructed. One area in which investigations should be considered is for the Kandakadu Barrage where the continued passage of estuarine species including Macrobrachium may significantly benefit upstream fisheries.

Rivers and Estuaries

The negative impact on river and estuarine fishing resources due to the accumulation of run-off agrochemicals can be mitigated in part by the maintenance of downstream conservation flows, the judicious application of fertilizers and the use of rapidly degradable pesticides in place of the persistent organchlorine types. Further recommendations and discussion on these topics can be found in CHAPTER 2 - WATER QUALITY.

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It is not recommended that any measures be instituted to further intensify fishing activities in the estuaries of the Mahaweli Ganga and Maduru Oya. These areas are presently heavily fished.. In fact, some regulations may be warranted in terms of mesh size or limited fishing seasons in order to protect fish and shrimp stocks.

Tanks and Villus

The major irrigation tanks in the project area have been designated for improved fisheries management programs by the Inland Fisheries Division. This includes additional stocking and subsidy programs for boats and gear. However, even with these plans, the Ministry Fisheries (1979) estimates that increased fishery output for these tanks above present yields will probably be less than 500 tons per year.

Medium and smaller tanks are also scheduled for future upgrading of their fishery outputs. Roughly, the areas of these tanks in Systems B and C total about 3500 hectares (ACRES, 1979; HTS ANNEX I, 1979). Assuming that there are additional unexploited tank areas of 1,500 hectares within the project area (details will be provided in the final report), and using the average yield figure from Table 3-4 of about 130 kg/ha/yr, then the medium and smaller tanks potentially could produce 650 tons for consumption. This amount could probably be increased, even doubled to 1300 tons, with high intensity stocking and proper management of the smaller tanks.

Villu fishery resources, along with those of some of the downstream medium tanks, may be adversely affected by the runoff of pesticides and fertilizers. Monitoring of these chemicals is recommended as mentioned in the previous chapter on WATER QUALITY. In addition, it may be feasible to route return flows

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around some villu and tank areas to prevent their pollution with agrochemicals. It is suggested that this possibility be investigated along with the potential feasibility of installing weirs at villu mouths to prevent their dessication in the dry season (see following chapter concerning WET LANDS). Increased fishing intensity at the existing villus is possible, provided gear and markets become available. Yields could probably be doubled from roughly 50 to 100 kg/ha/yr which would increase the overall output by over 400 tons per annum.

Irrigation Canals

Fisheries, at least at the subsistence level, can also be developed within the irrigation canal system. The canals themselves will support some species, while pools or backwaters which are created naturally or for storage along the canals may be very suitable habitats for food source species. Stocking of these waters is thus recommended where feasible.

Aquaculture

From the preceding sections, an estimate of the overall potential yields from new fishery resources within the project area can be determined as follows :

SOURCE	POTENTIAL YIELD (tons)
New Reservoirs	2,570
Major Tanks	500
Medium, Smaller Tanks	1,300
Villus	400
Total =	4,770 tons

Consequently, even assuming full reservoir development and proper efficient management programs, the project area waters will still produce less than one-half of the 12,000 ton/yr future demand. Thus, additional sources of fish production will be necessary.

A program to investigated aquacultural potential within the project area is highly recommended if future fish product demands for the region are to be met. A series of pilot projects should be implemented to determine the most feasible fish farming techniques which can be used for the area. Some of these, including cage culture and a few pond experiments, are under way or at least planned by the Inland Fisheries Division. A more extensive program is needed however. Particular attention should be given to the use of small seasonal village tanks which follow an annual filling and draining cycle which is easily aduptable to many fish farming methods. The Ministry of Fisheries (1979) estimates that small reasonal tanks can yield over 1000 kg/ha/yr if stocked with 6000 fingerlings per hectare.

Some additional pilot studies to be considered would include :

- integrated poultry or pig raising and fish farming systems;
- polyculture experiments with different combinations of various species including tilapia, Indian carps, Chinese Carps, shrimp, etc.
- development of shrimp and mullet farming in the estuaries, and
- use of pen enclosures for raising high value species.

The latter proposal has met with a high degree of success in number of Southeast Asia countries. Fish pens installed in shallow water bodies have been highly productive. For example, use of pens on 15% of the villu surface area in the region could produce a total of about 2,500 tons per annum or more. This could contribute significantly to regional fish demands and a study of the feasibility of pen culture is highly recommended for the project area waters including new reservoirs, existing major and medium tanks and villus.

Stocking Program

Many of the recommendations made to improve fishery yields in the project area waters will be greatly dependent upon the availability of fingerlings and/or fry to stock new water bodies or to augment existing fish populations. The available fingerling supply from existing fish stations in the country is about 5 million per year. The Ministry of fisheries (1979) estimates that to achieve the goal of 50,000 tons/yr for inland waters, a fingerling supply of from 50 to 75 million will be required.

Similarly, a large number of fingerlings will be needed to fully develop fishery potential in the project area. This, in turn, will necessitate the construction and operation of one or perhaps two fishery research stations or hatcheries to produce the fingerling supply. Estimates of the fingerlings and hatcheries required will be made in the next phase of this study.

Settlement of Fishermen

To fully realize potential fishery resources in the project area, a relatively large numbers of fishermen will need to be mobilized. Acres (1979) estimates that about 200 full-time

fishermen can be supported in System B following project implementation. With full reservoir development and improved management of other inland waters, the estimated 4,770 tons/yr yield could support around 1,300 full time fishing families.

Settlement plans for fishermen have been made by the MDB for the System H area. These include attracting coastal fishermen to migrate to the inland tanks and then settle permanently there in specifically designated fishery villages. The fishermen will also be given a small plot of land for agricultural use. This concept may be very successful in establishing permanent fishing communities near the larger tanks, since it eliminates the landless status which fishermen are often relegated to and promotes stability by providing added family income. A comparable scheme is thus recommended for the accelerated program area.

Table 3-1

Endemic Fish Species in the Project Area

SPECIES	DISTRIBUTION and ABUNDANCE	HABITAT	COMMENTS
TWO SPOT BARB (Barbus bimaculatus)	Common in wet zone especially Gin, Kalu and Kelani Gangas. Present in upper Maduru Oya and small tributaries of Mahaweli Ganga. Found at the bottom and top of Gunner's Coin.	Small, clear, rocky substrate streams of up to 5 m in with. Moves up torrents all the way to stream head-waters to spawn.	The endemic status of this species is somewhat in question since it may also occur in southern India.
CUMMING'S TWO BANDED BARB (Barbus cummingi)	Very common throughout the wet zone and the North Central Province. Could possibly occur in upstream tributaries of the Mahaweli Ganga.	Small, clear, fast, flowing hill streams.	
SRI LANKAN BARB (Barbus srilankensis)	Very restricted distribution. Confined within Amban Ganga Drainage to several small tributaries to the Kalu Ganga.	Small streams. Gem operations and resultant siltation is causing disruption of its limited habitat.	This species has been just recently discovered. The description of this species was submitted for press in January, 1980.
CHERRY BARB (Barbus titteya)	Very common in wet zone drainages even down to tidal areas. Could possibly occur in the upper part of the Mahaweli Ganga Drainage.	Small, often very narrow streams down to 0.25 m wide. Clean water, pool habitats with dense aquatic plants.	
LEAF LATES (Belontia signata)	Very common and widespread in the wet zone. Found in the Amban Ganga and Mahaweli Ganga System.	Inhabits both streams and ponds. It is a predator and is even found in paddy fields.	
SMOOTH BREASTED SNAKE HEAD (Channa orientalis)	Very common in the North West, North Central and Western Provinces. May occur in the Mahaweli Ganga Drainage.	Found in ponds or turbid backwaters adjacent to streams. Prefers quiet waters with large amounts of detritus.	The endemic status of this species is somewhat in question, since it may also occur in India.

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Table 3-1

(Continued)

SPECIES	DISTRIBUTION and ABUNDANCE	HABITAT	COMMENTS
STONE SUCKER (Garra lamta)	Very Common in all wet zone drainages. Probably the most wide-spread of all endemic fish species. Found in dry zone rivers as well including Maduru Oya and Mahaweli Ganga.	Found in both small hill streams and in lower main streams. Prefers rocky substrates.	
MOUNTAIN LABEO (Labeo fisheri)	Relatively widespread. Found in the Matale Oya system near Dambulla. Occurs in Mahaweli Ganga System including the main river below Kandy.	Prefers clear, fast flowing water. May migrate upstream to spawn.	

Source : Endemic species seminar sponsored by TAMS in December, 1979. Data on fishes provided by H.H. Costa, P.R. Karunaratne, R. Senanayake, S.De. Silva, G. Shut.

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Table 3-2

Species Composition of Fish Catches from Different Reservoirs and a Villu in Sri Lanka

Reservoir or Villu	Year(s)	Total Catch (kg)	Percent Fish Catch by Weight							
			Introduced	Indigenous to Freshwaters					Introduced	
			Tilapia	Etroplus	Labeo	Wallago	Other Predators	Barbus	Goramy	Common Carp
North Central Province										
Parakrama Samudra	1964-66	1 516 010	77.4	6.6	15.3	0.7	1.0	0.6	0.1	0
Minneriya Tank	1964-67	563 906	90.7	1.4	5.0	0.4	1.2	0.6	negligible	0
Karapola Villu	1964-67	84 490	65.0	3.7	10.3	5.4	8.3	2.3	4.9	0.06
Eastern Province										
Senanayake Samudra	1961-64	498 592	40.3	8.5	44.7	4.5	0.05	1.6	negligible	0
Southern Province										
Muruthawela Tank	1974	21 223	81.0	4.0	0	0	5.6	6.4	2.7	0
Ridiyagama Tank	1974	541 641	95.0	1.3	0	0	2.0	1.0	0.08	0
Badagiriya Tank	1974	648 485	91.0	2.7	0	0	2.6	1.4	1.3	0
Udirkiriwewa	1974	48 008	2.0	71.0	0	0	10.7	11.4	4.8	0
Java Province										
Chandrikawewa	1974	33 570	84.0	5.2	0	0	3.7	3.5	3.7	0.001
Java Sabaragamuwa Provinces										
Udawalawe Reservoir	1974	473 597	96.0	0.5	0	0	2.0	0.3	0.7	0.02

Source : Fernando (1976)

Table 3-3

Data Pertaining to Existing Major Tanks in the Project Area

Tank	Year (s)	Yield (kg/ha/yr)	Output (Tons/yr)	Fishing Crafts	Number of Fishermen
Parakrama Samudra	1961 to 1964	225	1,511		
	1972	260		49	88
	1975	475	1,201		
	1976	498	1,237	52-93	
	1977	452	1,124		
	1978	322	800		
Minneriya Tank	1955 to 1967	75	564		
	1972	82		25	52
	1975	219	559		
	1976	127	319	15-38	
	1977	110	275		
	1978	159	400		
Kaudulla Tank	1972	28		20	34
	1975	405	1,028		
	1976	257	640	18-65	
	1977	154	383		
	1978	120	300		
Kantalai Tank	1961 to 1962	50	96		
	1972	44		62	64
	1976	18	42	12-20	
	1977	18	42		

Sources : Mendis (1964), Department of Fisheries and Department of Census and Statistics (1972), Mendis (1976), HTS Annex Z (1978), Ministry of Fisheries (1979)

Table 3-4

Estimated Potential Fish Yields for the Proposed Reservoirs Based on the Morpho-Edaphic Index from Wijeratne and Costa (1979).

RESERVOIR	MEAN WATER LEVEL 1/				Electrical Conductivity 3/	ESTIMATED FISH YIELDS	
	Elev.	Area	Storage	Mean Depth 2/		kg/ha/yr	Annual Reservoir Total
	m	km^2	mcm	m	Micromhos/cm		Tons
KOTMALE	690	5.2	120	23.1	33	25	13.0
VICTORIA	420	13.0	624	48.0	60	22	28.6
RANDENIGALA	219	19.5	810	41.5	95	34	66.3
MORAGAHAKANDA	176	18.0	280	15.5	169	103	185.4
ROTALAWELA	63	25.0	70	2.8	108	250	625.0
KANDAKADU BARRAGE	30.5	29.0	-	2.5	136	319	925.1
ULHITIYA/ RATKINDA OYA	105.6	20.2	122	6.0	107	145	292.9
MADURU OYA	944	34.8	536	9.7	138	124	431.5

1/ Mean water elevations, reservoir areas and reservoir storages are estimated from area-capacity curves and using the 50% levels presented in the duration tables in NEDECO (1979) ANNEX O. RUN 372 was selected for Kotmale, Victoria and Randenigala Reservoirs and RUN 374 for Moragahakanda Reservoir. Estimates for Rotalawela Reservoir were derived from an average of the high and low water elevations and using the area capacity curve in NEDECO (1979) ANNEX O. The Kandakadu Barrage is assumed to always remain at full storage. Data for Ulhitiya/Ratkinda Oya and Maduru Oya Reservoirs, are from NEDECO (1979) ANNEX B.

2/ Mean depth is calculated as mean storage ÷ mean area, except for the Kandakadu Barrage where the mean depth is approximated since storage data is not available.

3/ The EC values used were taken from available water quality data. Mean values were used where possible and/or simple mass balance estimates were made using inflow data from NEDECO (1979) ANNEX B.

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CHAPTER 4

WETLANDS AND AQUATIC WEEDS

INTRODUCTION

Wetlands are areas which are covered by water or have saturated soil moisture conditions over a significant portion of the annual climatic cycle. Their characteristic feature is an importance of or dominance of water tolerant plants (hydrophytes) in the biological community. In this way they differ from more permanently wet and usually deeper water covered areas such as lakes and from less often wet, essentially terrestrial habitats but there are frequently rather subtle intergradations between these different kinds of habitat as will be evident in this consideration of the wetlands of the Mahaweli Ganga area. Wetlands vary considerably in their characteristics according to factors such as duration of wet condition (hydroperiod), depth of flooding, salinity of water and quantities of nutrients available.

Certain kinds of wetlands, especially those of alluvial floodplains, deltaic plains and tidally affected lands, are the most highly productive zones of the biosphere. This was the conclusion of Whitaker and Likens (1977), in their survey of primary productivity of world ecosystems. They found that such swamps and marshes have a mean net primary production of 3000 g of organic matter (dry weight) per m^2 per year. This figure is 20 percent higher than the next highest category which is the algal reef ecosystem and three times higher than the mean for all world ecosystem. Thus there can be no doubt that these wetlands are a very important component of the biosphere. Their high net primary production sustains numerous other organisms, including human beings, by complex food web relationships.

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This tendency for high production under wet conditions has shaped human culture in various ways. Wet rice agriculture is a notable example. To engage in this practice people have over millenia engineered various ways of using wet areas and artificially created wetlands for this purpose. As in any other form of agriculture numerous unwanted species have proliferated as weeds in the paddy fields, irrigation systems and drainage systems and have caused great hindrance to achieving high production.

The following section describe existing conditions and future anticipated conditions with regard to wetlands in the project area including wet paddy cultivation areas and the areas of aquatic weeds that are associated with them. Additionally, measures will be suggested for dealing with some problems that already exist or may later arise.

EXISTING CONDITIONS

General Description of Wetland and Aquatic Weed Habitats

Marshy areas, or villus, occur in the Lower Mahaweli floodplain and deltaic plain and occupy depressions between natural levee ridges of the channels of the Mahaweli and its various active and former distributaries or between these levee ridges and adjacent upland areas. The floodplain villus are typically characterized by water tolerant grasses and a wide variety of aquatic plants. The deltaic plain villus tend to have trees as well, especially along their margins.

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The first of the villus going downstream are the inter-connected Handapan and Bendiya Villus a few kilometers upstream from the Mahaweli river bridge near Manampitiya. At this point the alluvial valley begins. The deltaic plain may be said to begin with the first distributary, the Kandakadu Aru, which takes off from the right bank and flows on the western side of the Mahaweli before it rejoins not the Mahaweli but another Mahaweli distributary, the Verugal Aru. Locations of the villus are shown on Figure 4-1.

The combined flow of these merged streams enters the sea near Verugal. Some of this water is diverted at the Verugal anicut for irrigation works. Below the Verugal Aru there is one other major distributary, the Koddiyar Aru, which reaches the coast at Mutur. Both this and the main channel discharge into Koddiyar Bay, a large and deep re-entrant of the continental margin formed at the head of a submarine canyon. The shore region of Koddiyar Bay near the mouths of the Mahaweli Ganga is a sandy beach ridge terrain of variable width with mangrove swamps fringing small lagoons and tidal streams. The shore of extreme western Koddiyar Bay opens into the elongated and shallow Tambalagam Bay and its surrounding mangrove swamps. Tambalagam Bay is of interest because it receives run-off waters and irrigation return flows from the Kantalai Tank of System D and will receive additional amounts after project implementation. Mangrove swamps also occur in various large and small lagoons along the Indian Ocean shore. The southern limit of the mangrove area of concern in this report is the estuary at the mouth of the Maduru Oya known as the Valaichchenai Aru.

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Extensive tracts of wet paddy cultivation exist in areas irrigated by water which is stored in the several large tanks and numerous smaller tanks of the area. These areas are cropped primarily in the wet season and a smaller area is cultivated in the drier period as well. Aquatic weeds invade these paddy fields, their associated irrigation channels and drains, and the smaller tanks. In a few areas these are chronic problems, but generally their abundance is limited by the dry season conditions. Only where water is abundant for a large part of the year such as in areas of obstructed drainage, certain smaller tanks, double cropped areas and villus, do the weeds tend to be persistent.

The tanks, especially shallow ones, are wetlands of a kind. Some shallow tanks have many resemblances to villus at least in their aquatic plant communities. But such shallow tanks are seldom more than a few hectares in extent. The Allaf Tank of System A is a notable exception. This large shallow tank has many of the features of a villu which apparently is what it was before it became a tank, as suggested by its morphometry.

The deeper tanks (which are generally the larger tanks) may have little or no resemblance to any of the kinds of wetlands described here. This appears to be the case primarily because of their rather extreme fluctuations of water level. Even deep water tolerant wetland species such as Nymphaea do not do well in the high water conditions; and low water conditions lead to extensives dessication of the tank beds. When exposed, the few grasses and annuals that can invade the drawdown zone are subject to heavy grazing. For these reasons the drawdown zones of large tanks tend to have a barren appearance due to their thin vegetation cover.

Villus

Water Levels - Water which enters the villus comes from three sources. There are rainfall, runoff from adjacent higher areas and river water which enters during high river stages. The fluctuation of water level in the villus is a complex result of changing rainfall patterns and river stages. During rainy periods water levels in the villus may be higher than the river level and where there are interconnecting channels there is an outward flow to the river. When the river is high, the flow may be the reverse although heavy rains may produce outward flow even during high river stages. When villus are receiving river waters, their water is quite turbid with fine-textured river borne sediment. At other times the water is usually quite clear although heavy rains may carry in much sediment from adjacent uplands.

Most of the villus have direct connections to the Mahaweli or its various distributaries by means of small channels. When the river is low, much, but usually not all, of the water of the villu may flow out through these channels. Usually these channels are so small and shallow that a certain amount of water remains in the villu. This water may also be lost through evaporation and transpiration during the driest months, but some of the villus do retain certain amounts of water year round in most years. Others become dry or virtually so for short periods nearly every year. Even when surface water is gone there may still be wet soil conditions.

Vegetation - The distribution of vegetation in the villus of the alluvial valley tends to show a characteristic pattern which is related to the hydroperiod and the depth of flooding. On the margins where wet conditions are brief and depth of flooding slight, there are creeping grasses such as Cynodon dactylon and various essentially terrestrial annual

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plants which are capable of surviving the brief inundations or can produce new growth from seed rapidly enough to occupy this zone during drier periods. Father from the margin, the depth of flooding increases, and various truly hydrophytic species appear including some that can grow well in terrestrial conditions also. Alternanthera sessilis and Polygonum sp. are common in this zone and may be found at different times growing in or out of the water. Jussiaea repens, Scripus grossus, Juncus effuses, Ipomoea aquatica and Monochoria hastata are commonly present in this zone. The commonest species are various grasses, including Panicum repens, Hygrohiza aristata, Brachiaria spp., Sacciolepsis interrupta, Echinocloa colonum, Paspalum vaginatum, Oryza app. and Paspalidium spp. Some of these grasses, especially Hygrorhiza, extend into deeper water where floating leaved forms such as Aponogeton crispum, A. natans, Nymphoides sp. and the submerged floating plant Ceratophyllum demersum occur. Nelumbo nucifera which has floating and emergent leaves is sometimes abundant in this zone. Beyond this zone in still deeper water and more prolonged inundation period an association of Nymphaea stellata and Ceratophyllum demersum is characteristic.

The floating aquatic plant community can move in and out of all of these zones with the rising and falling of water level. Common floating plants are Salvinia molesta and Trapa bispinosa. Pistia stratiotes and Azolla pinnata are sometimes abundant. Spirodela polyrhiza and Neptunia oleracea occur occasionally. Some villus are at times heavily covered by Salvinia (floating fern).

Some trees occur in wet conditions around the margins of the floodplain villus. Among these are Terminalia arguna, Madhuca longifolia, Barringtonia asiatica and Mitragyna parviflora. In the deltaic plain villus, depth of inundation at times of flood peaks is not so great since the flood waters spread far

and wide over the delta lands. Here trees are more common and more widespread over the villus and include, besides the above, extensive areas of Hibiscus tiliaceus. Villus in this area are transitional with what are essentially areas of swamp forests.

Area of Villus - Since complete aerial photographic coverage of the area is not yet available, it is not possible to give an accurate estimate of the area of villus at the present time. From estimates of the area of villus made during feasibility studies of the irrigation systems composing the project area, it is apparent that they comprise approximately 12,000 hectares. The report by Hunting Surveys, Ltd. (1961) states that there were 40,000 acres (16,200 hectares) at that time which would imply that a sizeable diminution of villu area may have already occured. A Fisheries Ministry paper on development of inland fisheries (Fisheries Ministry, 1979) gave an estimate of 10,000 acres (4,050 hectares) which is obviously an underestimate. Without detailed vegetation surveys it is not possible to make an accurate estimate of the size of swamp forest areas, but it is probably around 3,000 hectares.

Livestock and Wildlife - Water buffalo and cattle are very important species in villu ecology due to their heavy utilization of these lands for grazing. Fishing is an important activity as well. People also gather edible plants from the villus to a certain extent as well as materials used in weaving.

The villus support a large variety of wildlife year round and are especially important habitats to many other species during the dry season when surrounding lands are particularly non-productive and lack water. Details concerning wildlife in the project area are presented in Chapter 9.

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Mangrove Swamps

Distribution - Mangrove swamps occur in a narrow coastal strip. Those likely to be affected by the project extend from Tambalagam Bay along the southern shore of Koddiyar Bay and down the Indian Ocean shore almost to Batticaloa (Figure 4-1). The mangrove swamps have already been substantially impacted by cutting, conversion to other use, and obstruction of tidal exchange. The recent cyclone (November 1978) also did considerable damage to the remaining mangrove forests especially in the southern part of the area. The remaining mangrove swamps and the estuarine water bodies around which they exist support important fisheries resources in the Koddiyar Bay area, the Valaichchenai Aru estuary at the mouth of the Maduru Oya and in the coastal waters between these places.

Various authors have described mangrove associations for particular areas of Sri Lanka or in a general way for the island as a whole (Tennant 1859, Abeywickrama 1963, Aruchelvam 1968, and Kugathasan 1969). None of these studies specifically refers to the area of concern in this report. It is clear from these and other studies (Gaussen et al., 1968) that mangrove swamps throughout Sri Lanka have been subject to heavy exploitation for a long time and that virtually no effort has been made to protect or reforest these areas.

Mangrove Vegetation - It is apparent that the mangrove swamps adjacent to the project area are substantially different from those described from other parts of the island. This is reflected in a less diverse group of species among which only a few account for most of the vegetation cover. Some species have probably disappeared entirely from the area but since previous accounts are lacking this cannot be

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proven. The genus Bruguiera which is a valued source of firewood, charcoal and pole timber throughout tropical Asia and which is represented elsewhere in Sri Lanka, is absent or rare in the area, probably due to overexploitation. Some types of mangroves, including Bruguiera, do not reproduce well from seed especially when heavy cutting leads to extensive clearing. The seedlings are heavily preyed on by crabs and other organisms and clearings may also be quickly invaded by species which form exceptionally dense thickets such as Acanthus ilicifolius and Hibiscus tiliaceus which further reduce reseeding of cut over areas. Thickets of these two species are very common in the area in cut over areas where stumps of other species are still present indicating that these changes have occurred.

The major species which exist in the area are Rhizophora mucronata, Avicennia marina and Acanthus ilicifolius. Lumnitzera racemosa, Aegiceras corniculata and Scyphiphora hydrophyllacea are relatively common. Sonneratia caseolaris is an uncommon species.

According to Dr. Balasubramaniam of the botany department at the University of Sri Lanka at Peradeniya there is a very rare endemic species, Sonneratia aperala, which is known to exist only from several specimens in the project area near Mutur. This was reported to him by the Dr.W.Macnae, one of the world's leading authorities on mangrove swamps.

Mangrove associates including Acrostichum aureum and Hibiscus tiliaceus exist along the inner margins of the mangrove swamps in the zone of transition to riverine forest. Just inland of these there are scattered small stands of the giant reed, Phragmites karkis. The higher, less frequently flooded parts of the tidal lands are hypersaline barren flats which are extensive in the area. Along the fringes of these, halophytes such as Arthrocnemum indicum and Suadea monoica are common along with Acanthus ilicifolius.

Other Wetlands

Smaller shallow tanks of the area often support an aquatic plant community that is similar to the villu community but usually of a reduced variety of species. Such tanks may have wide fluctuations of water level and may become completely dry in the dry season which results in a selection for species capable of withstanding dessicated conditions. Those with rhizomes that endure the dry period tend to become dominants. Nelumbo nucifera is a good example and it is often the principal species in the shallowest tanks or in the shallower parts of tanks. In deeper water situations Nymphaea stellata, another form with drought resistant rhizomes, is common. Species of Aponogeton are also common in shallower and intermediate depths and are also favored by their drought resistant underground organs. Other plants that can survive dry conditions for prolonged periods are also abundant. These include many of the same grasses typical of the villus and forms such as Polyganum sp. In such tanks, Ceratophyllum demersum is common. Floating forms are also abundant in some of the more permanent tanks including the problem species, Salvinia molesta.

The high level irrigation canals which distribute the water from larger tanks in the area usually are constructed with bunds on their downslope side. Where they cross terrains of low slope, water may spread over wide areas on the opposite side, and wetland areas characterized by various grasses and Typha javanica exist. Certain other areas of wetlands exist where bunds of irrigation channels cross depressions in the terrain and create impounded drainage conditions. Typically these become areas for water weeds and will be described in the section following.

Areas of Water Weed Infestation

Water Hyacinth - The occurrence of water hyacinth around the Kaudulla Tank is an informative case to consider as an illustration of how these weeds can be spread and established in an area. Since other occurrences in the surrounding area are not known, it appears probable that this plant was introduced into the area by human agency probably prior to 1969. That it survived and began to spread owes much to certain conditions found in this area. The Gal Oya and the Minneriya-Kantalai Yoda Ela which intersect in this vicinity provide water and nutrients to the area year round. Impounded drainage on the western side of the Yoda Ela as a result of bunds and other obstructions to flow created slack water areas favorable to water weed proliferation. Human settlements in this area may have added nutrients to these impounded areas and stimulated growth of water weeds. The blockage of the Gal Oya just below Gal Oya Junction by a road crossing which allows only culvert flow at lower river stages is an example of the kind of obstruction that can favor the establishment of water weeds. This immediate area seems to be the center from which the water hyacinth has spread. (See Figure 4-1).

What is already happening in system D is a very good illustration of what the impact of a water hyacinth invasion can be like. In the vicinity of Gal Oya Junction water hyacinth has been present for at least nine years, perhaps longer. At the present time it occupies extensive areas of water surface and grows in very robust from with leaf petioles up to nearly a meter in length in some specimens. Denser floating mats are heavily invaded by Mikania scandens a vine which twines about the hyacinth plant to form a tangled mat. Typha is even present in this mat.

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Water hyacinth extends from Gal Oya Junction along the Minneriya - Kantalai Yoda Ela and is said by irrigation engineers in this district to enter the Kantalai Tank frequently although it is not presently known to have escaped from the Kantalai Tank into its command area as it did from the Kaudulla Tank. The Minneriya-Kantalai Yoda Ela is a principal feature of the entire project. The occurrence of water hyacinth in this important artery for transport of irrigation water has very serious implications.

Downstream of the Kaudulla Tank water hyacinth is extensively spread. In the Kaudulla Oya, the principal drainage way below this tank, water hyacinth roots in the soil of the banks when the water is low and grows as a terrestrial plant only to renew its aquatic habit when the water rises. From this channel and also through the irrigation channels it has entered the smaller scale irrigation and drainage ways where its effects are most damaging. In these drains it frequently occurs together with dense stands of Scirpus grossus and frequently with heavy growth of Ipomoea aquatica. Buffalo observed feeding in these drains were selectively feeding on the Ipomoea and leaving the water hyacinth alone. The growths may be so thick that they more or less completely block the drainage and backed-up drainage water overflows into fields carrying the water hyacinth with it.

Several miles downstream of the Kaudulla Tank local residents say that it arrived in their area only about four years ago (1975). It now occurs virtually throughout the command area close to the principal drainage way. It is estimated that its removal at present costs about 2500 rupees per acre of water surface covered, but generally funds are inadequate to remove more than a minor part of it. Local residents have been asked to remove it themselves but such efforts have seldom materialized.

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There is no particular reason to believe that what has happened in System D will not also happen in the other systems. When it does extensive crop losses can be expected. The Kaudulla Oya discharges into the Mahaweli Ganga in which water hyacinth can be expected to spread into all connected water bodies downstream by the river currents.

Floating aquatic plants may provide the substrate to support the growth of other wetlands species with a non-floating habit. A good example of this can be seen at the Gal Oya Junction where the dense stands of robust water hyacinth are heavily overgrown by the trailing vine Mikania scandens which binds together the water hyacinth into stable mats. Panicum repens and even Typha is rooted in this mat. Such aggregations of floating plants with non-floating species rooted in them are referred to as sudds, a name derived from the large swamp in the Sudan known as the Sudd where such occurrences are common.

Floating Fern - Tanks in System B which have heavy growths of floating ferns (Salvinia) often show sudd formation. In these, small sedges (Cyperus sp.), Ipomoea aquatica, Polygonum and Panicum species colonize the dense floating growth of Salvinia. Patches of this assemblage of plants can be seen floating about on the tank surface where they often cover nearly the entire area.

Salvinia molesta is widespread throughout the area. It frequently covers the surface of small tanks and villus. Areas of impounded drainage due to bunds associated with irrigation and flood control works are usually wholly or partly covered. In many areas it occurs in rice fields, especially those of poor drainage or those that have been affected by flooding. It is very abundant along the Lower Mahaweli Ganga drifting along in the current and becoming stranded in large masses in the vegetation of the banks.

It should be noted for those not familiar with Sri Lanka, that Salvinia is usually present here in its third phase growth form which is quite different in appearance and far more robust than the second phase growth form usually seen in more temperate latitudes.

Other Aquatic Plants - Typha javanica is also widespread throughout the area. It is especially common in rice fields with poorer drainage conditions and some such areas have been virtually abandoned to this weed. It occurs as well in the minor irrigation and drainage works where its flow blockage effects are severe. Owing to the tough, solidly rooted abundance or rhizomes characteristic of Typha it is extremely difficult to eradicate.

Rice fields with poor drainage have a large variety of aquatic weeds besides the above. Even Nymphaea stellata is seen in extreme cases. Such places are usually being actively invaded by Typha. Nymphoides indicum, Asteracantha longifolia and Scirpus grossus may be common. These fields are only marginally productive and are often abandoned but remain as centers for spread of aquatic plants to nearby areas.

Rice fields of better drainage may also have large numbers of weeds with large numbers of sedges and grasses among them. These include species of Panicum and Echinocloa, large numbers of sedges of the genus Cyperus, Leersia hexandra, and Eragrostis tenella.

Larger and intermediate scale irrigation channels sometimes have weed problems. The banks are usually lined by Panicum and Echinocloa species which float outward over the water surface. Ipomoea aquatic can also send long streaming shoots out over the water surface.

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Potamogeton sp. occurs in some areas as a submergent that floats near the water surface. Hydrilla verticillata and Vallisneria spiralis are sometimes extremely abundant. Aponogeton crispus, A. natans, A. monostachyon, Najas minor and Jussiaea repens are sometimes common.

The minor irrigation ditches which feed the rice fields have heavy growths of various water tolerant plants which must regularly be cleared by the farmers. Panicum and Echinocloa species are again very abundant. Typha is common as well and in many areas Pennisetum typhoides is very abundant in the ditches. Other common forms are Commelina salicifolia, Alternanthera sessilis and Mimosa pudica.

Many of the same species which occur in the better drained paddy and in the minor irrigation works occur as well on the paddy field bunds. These bunds cover a large area of land and when they are not kept trimmed, which is more often than not the case, they represent an abundant source of seed for weeds. This is also true if they are only trimmed after seed has already matured.

IMPACT ANALYSIS

Effect of Changing River Flow

At full development of the diversion schemes described by NEDECO (1979) about 60 percent of the total annual Mahaweli Ganga flow (as measured at Manampitiya) will be diverted. Much of this flow will be diverted to other drainage basins and not return to the Mahaweli Ganga. Of the remainder probably only 20-30 percent is likely to re-enter the Mahaweli as irrigation return flow and perhaps less than this during the dry season. Although the NEDECO study in its environmental

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section (Annex K) states as a recommendation for protection of fisheries that "the minimum discharge of the Mahaweli should not drop below the historical minimum," it is nowhere clear from the various project reports that such a drop can be avoided.

Historically, the minimum discharge of the lower river usually occurs in March. Since this will be immediately after the period of greatest water accumulation in the reservoirs it may be possible to keep the flows for March at their historical levels, but then will follow a six month long period (April to September) of heavy demand for diversion waters with no net accumulation in the reservoirs (except for a minor increment in August). It is difficult to forsee any other result than a fall of river flow during much of this period to levels even lower than the March level. This low water level will not only be lower but more prolonged as well. During exceptionally dry years there may be almost no flow in the lower river.

NEDECO (1979) indicates that in early stages of the Mahaweli scheme (prior to full diversion) there may be more dry season flow than usual in the lower river. This may be based on the view that return flows will be large in tha dry season. This may not be substantiated and needs further documentation, but at any rate, this would only postpone dry season river flow reductions for a short time if longer range plans for greater diversion of water from the Mahaweli basin are completed. In this study it must be assumed that they will be.

Water balance studies are not yet available which predict the effects the proposed diversion will have on river stages in the lower Mahaweli (for instance at the Manampitiya gaging station). This would allow much better judgement of the effects on the floodplain lands. Lacking this, it is necessary to proceed qualitatively in a description of the environmental impacts of changed river flows.

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Villus - The annual cycles of rainfall and river flooding are basic factors in the existence of villus in their present forms. These bring about prolonged periods of flooding in the low-lying areas and also transport nutrients into them, supporting a high level of net primary productivity which in turn supports high populations of wildlife and fish. Around the villus there are also sizeable populations of domesticated grazing animals which depend largely on this primary production source as do those families whose food or livelihood depends upon grazing animal or fisheries resources. This dependence of animals and humans on the villus is especially critical during the dry season and drier than normal periods.

The impact of the reduced flow of the lower Mahaweli on the villus will be a substantial reduction in their area by an indeterminate but probably large amount. The reduction of high river flows will mean that the higher, less frequently flooded areas of the villus will no longer be subject to inundation and will no longer have the characteristics of wetlands. Different kinds of terrestrial vegetation will become established or the villus may become altered in other ways such as by cultivation of paddy or utilization for other purposes.

Reduced dry season flow will lead to prolonged exposure of some formerly water covered villu areas to such an extent that even larger areas may essentially lose their character as wetlands. These areas will be flooded only briefly by the diminished river floods. Much reduced areas will retain essentially wetland characteristics.

The decline in area of these important habitats will lead to a loss of wildlife from the area in terms of number of individuals and probably in numbers of species as well. The same can be expected with fish and other aquatic organisms including those exploited locally in fisheries. Cattle and water buffalo will decline in numbers due to the loss of area

of highly productive grazing land, aggravating a trend that already is affecting the area. The buffalo population in System D has declined by two thirds and the cattle population by one fourth in the last several years largely as a result of loss of grazing land. The reduced areas of villus will be subject to very intense grazing until the number of animals declines to a new equilibrium level.

The buffalo is an especially important species in the villu ecology and has special importance in human ecology as well since it provides draft power, fertilizer and food. Pathak (1979) has shown that when buffaloes are used for tillage and threshing the ratio of power output to power input for paddy production is higher than when tractors or human power alone is used. Pathak notes that this has obvious significance in a time of dwindling oil resources.

Due to reduced river flow the Mahaweli can be expected to show a greater tendency to cut laterally into earlier alluvial deposits. Slumping of banks on the natural levee lands will diminish the extent of certain lands adjacent to the channel including some villu areas. Bridges and other public works may be endangered or lost due to lateral wandering of the diminished river over its former channel area. In System H, for instance, the Kala Oya has destroyed a recently constructed bridge a few kilometers downstream of the Kala Wewa. This may have resulted in part from a greater tendency of the channel to migrate following reduction of flow from increased diversion of water.

Mangrove Swamps - Reduced river flow will also affect mangrove swamp areas. Less river water entering the coastal area will lead to generally higher salinity conditions in the estuarine region especially during periods of low river flow which will become more prolonged. Since the low river flow conditions coincide with the dry period, salinity increases may be large.

Even now the intertidal area is characterized by extensive areas of barren hypersaline tidal flats in the areas that are less frequently flooded by the tides. When salinities increase such barren flats will increase in area and spread over areas now vegetated by mangroves. There may also be a tendency for mangroves to spread into areas where basically fresh water conditions now prevail as salinities increase; but since these areas are for the most part already in utilization in various ways by people now in the area such saline incursions will probably be limited. At any rate, any new mangrove areas that may come into existence through salinity intrusion will do so at the expense of other land uses such as paddy areas or grazing lands.

Another impact on the mangrove swamp will be of a secondary kind. With the influx of greater numbers of people into the area as settlers and from the economic stimulus of the project on the whole region, there will be a considerable increase in demand for firewood, charcoal and structural timber. This will lead to greater cutting of mangroves unless effective measures of protection and conservation are taken. Such cutting is apparently already going on at an excessive rate in the area with no conservation practices. Heavily cutover areas in mangrove swamps do not readily regenerate naturally. In the higher parts of the intertidal area cutover areas may become barren flats due to increased evaporation and salt accumulation in the soil. In other areas regeneration will be hindered by growth of thicket forming species and predation on seedlings by various organisms.

Economic assesment of the potential resource loss in the project is hampered in various cases by the fact that many resources that may be lost are as yet underdeveloped or have been overexploited to the point where their continued viability is dubious. The mangroves are a good example of a case of overexploitation with little effort to protect the resource for later generations. Mangrove reforestation is a difficult

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undertaking even when active conservation programs exist. Where they do not exist, as in Sri Lanka, there is little that can be expected except a continuing decline. This has broader ramifications with respect to fisheries which are linked to these resources.

Turner (1977) has shown an interesting relationship that indicates that the catch of shrimp is correlated with the area of intertidal vegetation (mangrove swamps and salt marshes) and that the yield of shrimp per hectare of intertidal vegetation increases approaching the equator because of the larger amounts of solar energy. Sri Lanka for instance, is shown to have a high yield of shrimp per hectare of intertidal vegetation of the order of 170 kg/hectare, a figure exceeded by only a few places in the world. Thus the loss of a hectare of mangrove would result in the loss of about this amount of annual shrimp production. Since shrimp trawling also results in fish production that may be 4-6 times larger the loss may be far greater for the total fishery. As Turner states "The economics of mechanized trawling in developing countries are such that the shrimp catch pays for most of the effort expended catching shrimp and fish. Even if these same fish were not estuarine-dependent and were present after removal of intertidal areas, in most instances it would not be economical to harvest them."

Impact of Return Flows and Drainage Waters

A number of changes that will result from the project will tend to increase local runoff from upland areas into low-lying areas such as villus, paddy fields and drainage ways. Some of the upland areas will be cleared of forest vegetation to be placed in agriculture. This will have an immediate effect of increasing runoff from the cleared areas. Many of the crops that may be cultivated require good drainage for best production so it is necessary to design plantings so that local heavy rainfalls or prolonged wet periods do not lead to water-logged soil conditions. This also requires increasing runoff into lower

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areas. Sediment from eroded soil and nutrients from fertilizer are also discharged by this runoff to the lower lying areas where they may have various adverse impacts primarily from sedimentation and eutrophication.

Human settlements on uplands also have significant impacts on runoff since they are areas that must have good drainage also and are areas of heavy water use. This runoff includes the waste-water of the human settlements which may lead to eutrophication and disease transmission to the areas receiving the runoff from the settlements. Treeless settlements with tiled roof housing and extensive paved areas, to give an example, will obviously discharge water faster than the same areas would if they were covered even with light forest.

It is apparent that return flows from irrigation and drainage will be a threat to the preservation of the villus in their present state. This is so for various reasons. For example, the fact that the villus are the lowest-lying features in the landscape of the alluvial flood plain (except for the river channel itself) makes them obvious places for discharge of irrigation return flows and drainage waters. Or, as another example, the reduced volume of flow of the lower Mahaweli Ganga will mean that the waters entering the villus from return flows and drainage will become proportionately of much greater importance in the overall water budget of the villus due to less river water entering them.

Eutrophication is a technical term for the process of nutrient accumulation in a biological system. It is chiefly applied to aquatic systems, where critical levels can be reached that may have devastating effects on the stability of the system. This is so because aquatic systems have production level maxima that are related to the speed of oxygen circulation through the system. This circulation of oxygen has finite limits which are set by water flow velocities and diffusion rates of oxygen.

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Since diffusion of oxygen is slow, still water aquatic habitats may be especially limited in their overall level of production while flowing water habitats are less so.

In temperate climates one of the first indications of eutrophication of a water body is the appearance of large numbers of phytoplonkton. In tropical and subtropical areas this stage may quickly pass to a stage in which floating aquatic vegetation begins to proliferate on the surface. When such growths become dense they shut off light and restrict circulation of the water so that poor oxygen conditions develop very quickly in the water beneath the floating plants. When the production level of an aquatic system progresses through eutrophication to the point at which oxygen circulation is no longer adequate to sustain it, then mortalities of certain elements of the aquatic fauna may result.

The Handapan Villu which is the most upstream of the villus is likely to be one of the most heavily impacted of all. This villu will receive return flow and runoff from a large area of System C via the stream called the Hungamala Ela. The Handapan Villu is not presently connected to the Mahaweli Ganga. Possibly a direct connection once existed but this may have been severed by the construction of a tank near Yakkure. Currently this villu overflows into the adjacent Bendiya Villu which has had until recently rather direct connections but these are obstructed now by road crossings which have confined flow to small culverts and reduced flow velocities to such an extent that the channels have become choked with sand. Thus, the Handapan and Bendiya Villus are more or less isolated from the river except at times of high flooding. Runoff and irrigation return flows which will be entering them in abundance following the implementation of System C agricultural development will tend to keep these villus flooded. They will also bring about eutrophication, proliferation of aquatic weed species,

sedimentation, accumulation of various pesticides and possible salinization around the villu margins.

Around villus in the uppermost less frequently flooded margins there is often a zone of relatively little vegetation cover. To some extent this is due to heavy grazing but it also seems probable that these are zones of occasional high soil salinities expecially during the dry season with retardation of plant growth due to salt. It is to be expected that with greater amounts of drainage and irrigation return flow waters entering the villu depressions such salinization is likely to increase and affect a broader zone around the diminished villus. This will negatively affect the quality of these lands for grazing animals by reducing grass production. The possibility that these soils are already salinized should be checked by field measurements during the next dry season.

Impact From Aquatic Weeds

The introduction of large amounts of additional water and fertilizer and the creation of large areas of new aquatic habitat will inevitably increase the numbers of aquatic plants in the area. Of these, particular problem species can be expected to vigorously proliferate. The three majpr problem species, water hyacinth, Salvinia and Typha, can be expected to spread rapidly through the system; in fact, they are already doing so. Other problem species, especially numerous grasses and sedges, will become more of a nuisance. Extensive efforts to control all of these species will be required and will add to the cost of operating the irrigation and production systems.

Where eutrophication is particularly a problem due to return flows, runoff from upland areas, wastewater or other sources, chronically poor water quality and persistently dense growths of water weeds can be expected. Smaller tanks and the diminished villu

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areas that will remain after the project will be especially vulnerable to these kinds of changes as indeed many are already. Such conditions may reduce potential fisheries resources of these areas.

The large reservoirs associated with the hydropower and irrigation schemes may also be invaded by water weeds. The occurrence of water hyacinth in Gregory's Lake near Nuwara Eliya is supportive of the view that water hyacinth could possibly occur on these reservoirs. Similar reservoirs in many parts of the world have been invaded by water hyacinth and Salvinia. Salvinia will probably occur also in the lower reservoirs. Out-breaks of water weeds would not occur if catchment areas could be protected from extensive deforestation and settlement. In this project, this may be possible only for the Kotmale catchment, but even here this will require extensive reforestation and may not be attainable.

It may take several years for water weed problems to become severe and chronic in the reservoirs due to a time lag during which nutrients will be accummulating in the system. If water weed cover becomes extensive, oxygenation of the reservoir water will become poorer and limit their value for fisheries.

Water weed infestations such as those already known to occur on smaller tanks in System H and System B can be expected to occur with increasing frequency. Smaller tanks which receive appreciable amounts of runoff and irrigation return flow such as the Vakaneri Tank of System B will be even more seriously and quickly affected.

Reduced flow in the lower Mahaweli Ganga will favour more extensive growth of Salvinia which is already common in the river channel. Diminished flow velocity will mean that these plants will not be carried downstream and out to sea as rapidly

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as before while their growth rate will increase from greater quantities of nutrients in the river water. The possibility exists that Salvinia may spread at times of lower water flow to cover the entire river surface as is the case in certain other Sri Lankan rivers such as the Deduru Oya at the present time. Below the Kandakadu Barrage where water flow in the lower river will at times be most sharply reduced these proliferations can be expected to be most severe. In the 2900 hectare reservoir behind the Kandakadu structure, Salvinia is also likely to become abundant. Since water hyacinth is already well established and spreading near to these areas it should be expected that it will probably enter the lower river and the Kandakadu Reservoir where its effects will be even more severe than Salvinia.

Waterbodies covered by floating water weeds are often said to lose water more rapidly than open water bodies. Published estimates of the magnitude of this effect for water hyacinth vary widely over a range of about 1.4-6 times greater than water loss from open water. This variation in measurement of transpirational effects make it uncertain how much water loss can be due to transpiration. However, even the lower range of the estimates would signify a loss of 40% of water resources in areas heavily infested by water hyacinth.

The reasons for this higher water loss are not certain. The most recent research (Linacre 1976) had indicated that higher water losses are to be expected only in situations where advective energy transfer is especially important. Thus, narrow canals, small wet depressions along canals, small tanks and small areas of paddy where advection is likely to be great would be areas of heaviest water loss due to water weed infestation.

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Pistia stratiotes, another floating weed recently introduced into Sri Lanka, is already fairly widespread in the area especially along the villus and will probably become more common in the future. This weed deserves special mention because it is known to create breeding conditions favourable for Mansonia mosquitos which are responsible for the spread of filariasis, a disease also known in its later stages as encephalitis. Pistia also provides a breeding habitat for encephalitis - carrying mosquito species.

Impact of the Kandakadu Barrage

A low level dam on the lower Mahaweli slightly upstream of the settlement of Kandakadu is being considered in the overall plan. The purpose of this structure would be to divert water for irrigation in System A. In plans to date, it is estimated that during times of higher river flow the reservoir behind this structure would cover about 2900 hectares. On the eastern side several villu areas will be flooded while on the western side a bund is proposed to limit the rise of water over those lands.

Since the depth of flooding produced will be relatively shallow, the affected villu areas may retain certain of their present wetlands characteristics. The typical villu vegetation should spread to higher levels along the margins while in the areas of highest depth of flooding it may be flooded out so that essentially lake habitat will exist. These kinds of changes that might be expected may be profoundly modified however by proliferation of water weeds to such an extent that they exclude the other wetlands species and deteriorate water quality conditions. This must, in fact, be regarded as a rather likely development for several reasons stated below.

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The Kandakadu Reservoir will be large and shallow. It will have a high flow through of Mahaweli river water for much of the year. Considerable amounts of irrigation return flow and drainage water will be part of this flow through at most times of the year. Salvinia is already a problem in the villus that will be flooded. Water hyacinth is spreading in this direction only a short distance away. These very opportunistic weeds are likely to proliferate in the nearby highly suitable habitat that will be created. Salvinia may spread from the very beginning. These developments may reduce the effectiveness of the Kandakadu structure and the conveyance canals leading from it as parts of the overall irrigation scheme.

The bund on the western side will impound drainage over a large area, including the area of the Diwulana Villu, one of the larger villus and one of those most heavily utilized for grazing. The obstruction to drainage will create even wider outbreaks of water weeds. Water weeds from these areas and the reservoir itself will spread downstream in the lower Mahaweli and all its distributaries even more effectively than they already do at present.

Formation of New Wetlands

Creation of new wetlands will result from some features of the project. The canals will cross varied terrain and in many places drainage obstructions may be created by the canal bunds. Such places will collect water for varying periods of time and where this is long enough wetland vegetation will appear. In lower lying areas with high seepage rates wetland areas may occur even at some distance from the canals. Generally, on the side of the canals with higher terrain there is no canal bund; thus, where depressions in the terrain are crossed water may spread outward from the canal into these places at sufficiently frequent times to create wetlands of varying sizes.

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These conditions can be seen presently along the existing canals such as along the Minneriya-Kantalai Yoda Ela. Travelling along the road down the bund which is situated on the eastern side of this large irrigation canal it is possible to see areas of impounded drainage where water has been trapped in depressions behind the bund. On the opposite side of the canal, water is more or less confined to the canal itself where slopes are higher, but when areas of lower slope are traversed the water spreads outward over areas that are sometimes rather large.

Many such areas at present are not flooded sufficiently and/or frequently to develop true wetlands characteristics. Along the Minneriya-Kantalai Canal described above, for instance, the low lying areas on the western side into which water spreads during high flows, remain forested with trees essentially like those areas that are seldom, if ever, flooded. For many areas this will change when flows through the canals become greater and more constant throughout the year, and such areas will become true wetlands with varying kinds of hydrophytic vegetation while the forest will be diminished. These areas will to some extent replace wetland losses from other impacts of the project, but the total area is not expected to be great. Also they may create certain problems including water wastage and become centres for spread of various aquatic weeds which can obstruct the canals.

The older and new large tanks of the project will not lead to the formation of any appreciable areas of new wetlands, since these will all be subject to wide fluctuations of water level and will have drawdown zones that are relatively barren as is the case around existing large tanks. The Minneriya-Kantalai Tank will be an exception, since it is planned to have a relatively constant water level over the year. If this condition is actually achieved it can be expected that

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wetlands will develop around its margins especially where terrains of low slope intersect the shore zone. The large reservoirs will also have large fulctuations of level and will not have new wetlands formed around them.

Certain areas designated for future rice cultivation will be subject to flooding due to topographic conditions. In System B, for instance, ACRES (1979) estimates there will be 1,480 hectares of such land. In a few cases, these lands may be of sufficient size to constitute valuable wildlife habitat but the majority will be small sized plots and so affected by eutrophication that they are far more likely to become areas of chronic water weed infestation. Some areas that are presently used as paddy or which are planned to be used in this way are now, or will be, difficult to drain sufficiently well to be kept free of water weeds. Such areas as has been described earlier are only marginally productive and are often abandoned to weeds which then spread from these places to other parts of the irrigated areas.

RECOMMENDED ACTIONS

Control of Water Use

Perhaps the most effective way to mitigate in any substantial way some impacts of the project on wetlands or the impacts of water weeds on the project is to reduce the total amount of water needed to accomplish the basic goals in agricultural production. The NEDECO (1969, Annex K) report states :

> "Increase of the flow (of the lower Mahawali Ganga) at the dry period will be beneficial for fish and other animals, as the minimum flow in the river may well be the limited

factor for the number of species. If however, after the implementation of the complete Mahaweli scheme the waters of the Mahaweli virtually run dry during certain periods, t .s will have a disastrous effect on the fauna. Moreover, with little flow on the river salt water intrusion is likely to become a problem. The historical low level of the river will be a safe minimum discharge in the planning of the future river regime." (Parenthesis added for clarity).

As discussed previously, provisions have not been made dicating how this flow maintenance can be accomplished. It is recommended that dry season conservation flow be maintained for the rivers which will minimize salinity intrusion and could at least partially limit dry season drainage of the villus. Conservation flows are discussed in Chapter 2, WATER QUALITY. These flows can be maintained by release from the proposed storage reservoirs. However, their effectiveness can be enhanced and adverse impacts further mitigated by achieving a high degree of control of water use and high water use efficiency in all aspects of the project. Because of the critical importance of this issue several ways of approaching this problem are discussed below. Because of the frequently expressed opinions that high water use efficiency can probably not be achieved it should now be noted that this is a real problem that the following methods will not necessarily substantially overcome and that the negative environmental impacts resulting from heavy water use in the project may not be successfully mitigated in any way.

Water use effectiveness should be given a priority equal to water storage and provision. In this way maximum effectiveness of storage capacities already realized or later added can be made. It is unlikely that high water use effectiveness can be achieved if expansion of agriculture is too rapid into new lands. It is also unlikely that it can be achieved if water

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is provided to an area before it has an appropriate distribution and drainage system to make effective use of it. Thirdly, providing an excess of water when there are other limitations such as labor or traction power will lead to great water use inefficiency. To avoid these pitfalls efforts to improve drainage or irrigation inadequacies should proceed simultaneously with the construction of new reservoirs and canals and not be delayed until these facilities are ready or considered as add-ons in a later phase of the project. This should be done initially for land already in cultivation. To attempt to develop more and all at once could lead to delays from resource limitations due to the intensive construction activity that would have to take place simultaneously in all parts o the project area. Such delays would probably result in great water use inefficiency.

A major economy of water use that could be achieved is through proper timing and sequencing of paddy preparation for planting. It would probably be best to supply water first to upland fields and allow field preparation to subsequently proceed in lowland area. This would require careful attention to effective modes of labor organization.

Control of Villu Discharges

In order to regulate discharges and to limit dry season drainage, water could be held artificially in most villu areas by the construction of low level weirs in the outflow streams. This would assure a certain amount of water storage after the fall of the river from its high stage and after the end of wet season rains. In this way a certain amount of the reduction of area of the villus following the river diversions could be avoided.

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Return flow from irrigation and drainage which enters the villus also complicate the problem of mitigative action for villu preservation. Low level wiers for instance to hold water in the villus would have at the same time the effect of greater storage of return flow and drainage waters with some predictable consequences, such as eutrophication, water weed infestations, pesticide build up and possible salinization. This could be avoided if the return flows and drainage waters are routed around the villus or improved in quality through careful control of excessive nutrients and other contaminants. Since wiers will obstruct flow in the channels there will be sedimentation of sand and silt in the channels near the wiers which will require removal, probably each year.

Control of Aquatic Weeds

In addition to careful control of water use that has already been discussed, other measures for water weed control should be undertaken. Spraying with herbicides is not necessarily harmful in a direct sense to the environment in all cases and in some cases may be necessary. There are however secondary consequences of herbicide use even if the type used is itself innocuous. The plants killed by the herbicide remain in the drain or water body where they may continue to obstruct flow. The decomposition of large masses of dead vegetation may consume excessive amounts of oxygen in the water and lead to poor water quality for a prolonged period. Also the nutrients contained in the plants are released to the water on decomposition where they add to continued eutrophication and renewed water weed growth. In paddy fields herbicides have definite limitations in usefulness since many common weeds are grasses as is rice, and therefore cannot be selectively eliminated by spraying.

Physical removal of water weeds from infested areas is a method that has much to recommend it since it eliminates the problem of physical obstruction of irrigation works, high oxygen demand of decaying plant debris and also reduces eutrophication since nutrients are removed from the aquatic system. Removal of water weeds requires much labor so it is best applied in areas that are chronically infested. It also becomes less expensive if some way of utilization is found.

The extent to which eutrophication can be controlled is uncertain but it is clear that some things can be done. The design of settlement sanitation facilities is an obvious case and one which can offer public health benefits as well.

Drainage water and irrigation runoff entering the villus might be enhanced in quality in other ways. Some of the former villu land around the margins of the diminished villus following project implementation could be set aside to be used in various ways to attempt to do this. One approach would be to apply these waters in a controlled manner such as overland flow for the intensive cultivation of pasture grass to alleviate to some extent the pasture scarcity that the project will create. One or another of the water tolerant forage grasses that are abundant in the villus should be readily adaptable to these managed conditions. By means of bunds, overland flow could be controlled and directed to achieve a long flow path over an extensive area. Such methods have been applied in various ways in many parts of the world in order to improve water quality and have been successful. The water flowing through these systems is substantially lower in nutrients and biological oxygen demand. Salinization could be a problem in such an undertaking, but since large amounts of water would be available at times to flush out salts it may prove possible to control this problem. Similar systems using some kind of water tolerant trees might also be effective and allow production of wood at the same time.

Careful attention should be given to problems resulting from large concentrations of animals such as with dairy farms, livestock feed-lots or chicken farms. In some areas of the world nutrients lost from large animal concentrations are partially recycled through harvesting of water weeds grown in controlled enclosures or tanks or simply gathered from nearby infested places. China is a notable example of this form of control. The weeds are used as pig fodder, green manure or made into compost. A better forage plant such as Ipomoea acquatica can also be cultivated in this way. This plant is also widely consumed as a vegetable by people in many parts of the world, including Sri Lanka. Alternanthera sessilis, another plant used very much as food in Sri Lanka should also grow well in controlled enclosures in which nutrient rich waters can be applied to achieve water treatment and food or fodder production simultaneously. Many ideas of this kind along with illustrations of actual existing practices in various parts of the world are given in the U.S. National Academy of Sciences publication Making Aquatic Weeds Useful (1976).

Obviously, the success of such methods of deliberate cultivation of aquatic plants depends critically upon the question of effective usage of the plants so produced. Design of culture systems should take this closely into account. In one situation green manure usage might be most effective while in another methane production would have most benefit and/ in still another composting may be most effective.

Successful composting of water hyacinth has been done in Sri Lanka by the Home Gardens Unit of the Agriculture Department. This compost has also been successfully used by them in the rearing of nursery plants and also was sold for a slight profit. Since their costs of production were rather high because of the necessity of trucking the plants from the point,

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of harvest to the composting site it is clear that costs could be further reduced by deliberate cultivation in controlled enclosures with composting adjacent to the enclosure. Biswas (1976) provides information that indicates that composted water hyacinth has twice as much nitrogen and phosphorous as composted cow manure.

Although some emphasis is given above on the importance of finding ways of reducing cost or even making profitable the work required for reduction of eutrophication, it should be pointed out that they may still be worth doing even if at a relatively high cost. The benefits in terms of public health, protection of fisheries and protection of rice crops would justify their being subsidized.

One form of biological control is the deliberate seeding of competing species which are less harmful or even beneficial in some way. As an example, Azolla pinnata is a common member of the floating aquatic plant community in Sri Lanka. Azolla pinnata has within it a symbiotic blue-green algae, Anabaena azollae, which is nitrogen fixing. Because of this nitrogen fixing ability, the Azolla pinnata - Anabaena azollae association is deliberately introduced into paddy fields in various parts of Asia, especially in Vietnam, in order to provide nitrogen to the paddy. It is important to note that although the primary motive of seeding the paddy fields with Azolla may be for nitrogen, there is another important role which it may be providing that is also beneficial to the paddy. The deliberate and careful seeding of Azolla at the appropriate time makes it an effective competitor with aquatic weed species. By rapidly spreading, the introduced Azolla absorbs nutrients and other materials that would foster growth of aquatic weeds. Since it is a surface floater it can retard the growth of submerged aquatics and other weeds by shading. This shading

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also can reduce oxygenation of the paddy field water and further retard weed growth. Oxygenation of the water is also reduced to some extent by the reduced oxygen diffusion through the air-water interface due to the extent of the surface area covered by **Asella.**

Areas within the irrigated lands that become subject to chronic flooding and water weed growth as a result of irrigation, and paddy fields that are marginally productive or become abandoned due to excessive water weed growth due to poor drainage, should be converted to a more suitable use. Fish ponds might be constructed in such areas. In some it might be useful to attempt to establish swamp trees whose shade might reduce the water weed growth and abundance.

Shading may be important for bio-control of water weeds in other ways. Shading would be especially appropriate along narrower irrigation and drainage ways. Appropriate planting along the sunnier side of such canals would reduce photosynthesis of the aquatic weed species and reduce their growth rate. Since any such plantings will consume water, those that can be effectively utilized locally should be given precedence. Poles or perhaps firewood could be produced in significant quantities especially if sprouting (coppice-regenerating) species are used. Tall crop species such as maize or sugar cane may be used where appropriate as well.

Mangrove Conservation

Efforts to mitigate the anticipated impacts on mangrove swamps should involve reforestation and protection from excessive cutting. Noakes (1955) gives an excellent description of the kinds of problems that arise in reforestation of mangrove areas. Seedlings must be physically protected and invading

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thicket forming species kept under control. Cutting should be reduced to acceptable levels by some means. This is clearly difficult to accomplish, but tactics that might be effective would be to provide other sources of firewood if necessary from outside the area or in new plantings nearby but outside of the mangrove area.

Substitution of other energy sources for wood should also be explored. Demonstrations of solar cooking techniques and marketing of equipment for using this energy should be arranged. Construction of bio-gas producing sanitary facilities should be encouraged. Wood conserving stoves should be demonstrated and built in the coastal communities. Stoves capable of using rice husk or other agricultural by-products should be tried. In short, any and all possibilities for substitute energy supplies should be investigated and where possible made available to the area. Perhaps electricity from the dams should be allocated preferentially to areas where critical problems related to excessive use of wood for fuel exist, such as the mangrove zone around Koddiyar Bay. In this way impacts partly due to the dams could partly be mitigated by the energy from the dams.

Secondary development resulting from the project should be controlled in various ways. Particularly all efforts at so-called "reclamation" of mangrove swamp lands for conversion to other use should be stopped. Any efforts to bridge tidal streams should be done in such a way that tidal exchange is not impeded. No further construction of the concrete, low-level ford bridges with only small culverts for tidal exchange should be allowed. These obstructions to tidal exchange should be replaced by true bridges that do not block flow.

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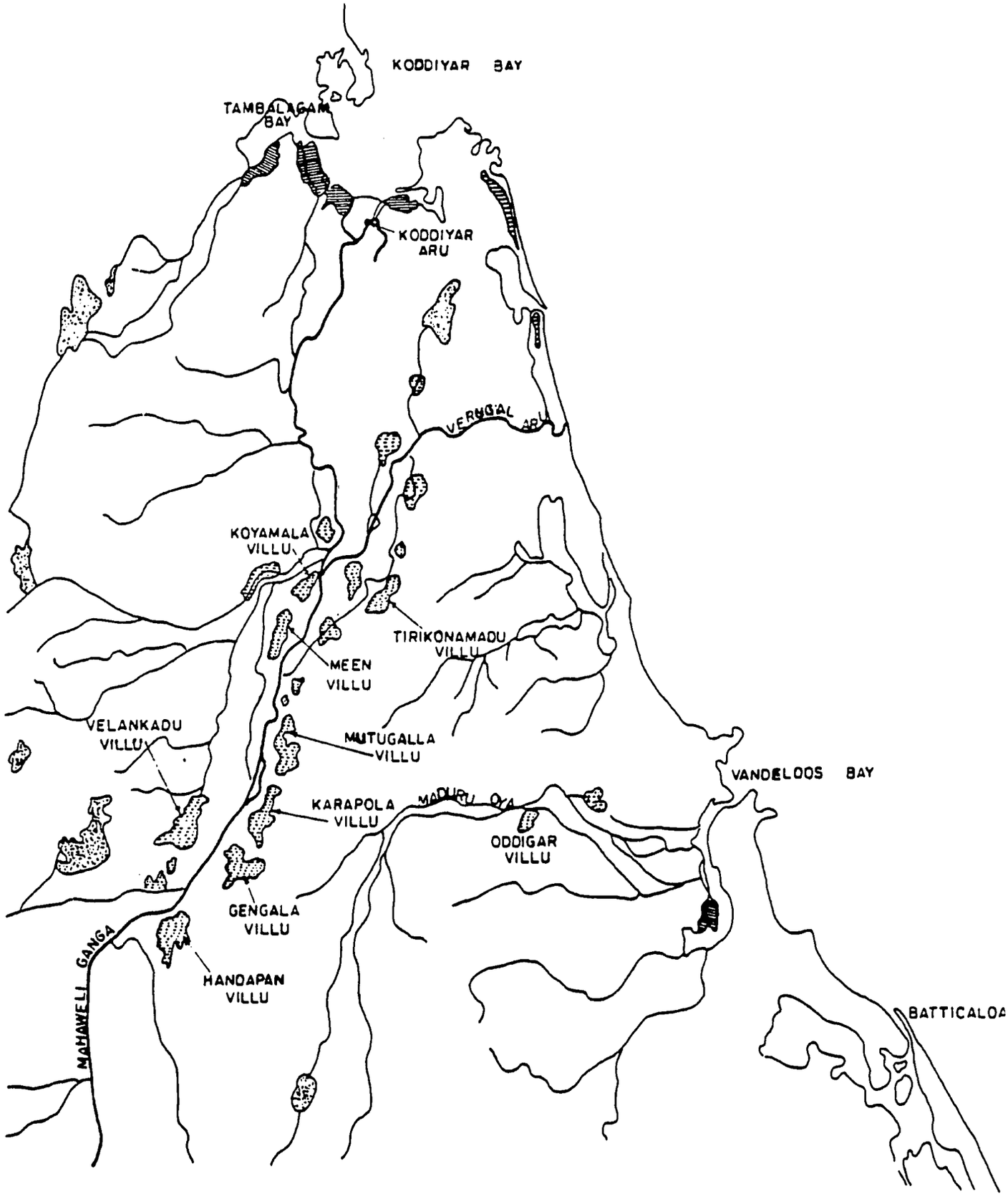

VILLUS

TANKS

MANGROVES SWAMPS

FIGURE 4 — 1

LOCATIONS OF VILLUS AND MANGROVES SWAMPS

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CHAPTER 5
SOIL CONSERVATION AND LAND USE

INTRODUCTION

The soil Conservation and Land Use assessment of the environmental impacts of the Mahaweli Accelerated Program is composed of two separate studies, - the upper-watershed area of the Mahaweli and, the Accelerated Program Irrigation Areas (Systems A,B,C and D).

This mid-term report deals with a cooperative study with forestry (see Chapter 6) for a mapping assessment of the present land uses, current soil conservation pradtices - both acceptable and non-acceptable - and, soil losses incurred as a result of improper land management practices in the upper-watershed area. It also deals with current progress in soil and land classification, with suggestions for additional investigations and future implementation.

EXISTING CONDITIONS

Soil and Land Classification

The feasibility study for System C by Hunting Technical services, Limited surveyed a total land area of about 69,000 hectares. Within this total land area the following agricultural land uses have been recommended of which 37,000 hectares or 53.6 percent would be available:

	hectares
Net command area suitable for rice	22,000
Gross command area " " upland crops	5,440
Net area suitable for sugar cane	9,580
Total irrigable and commandable System C	37,020

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In the feasibility report for the Maduru Oya Project the following areas are estimated to be irrigable and commandable

		hectares	hectares
Upland Soils			
Class I	-	5400	
Class 2	-	7380	
Total Upland	-		12,780
Lowland Soils (Rice Land)			
Class I	-	17,810	
Class 2	-	21,680	
Total Lowlands	-		39,490
Total irrigable and commandable, System B	-		52,300

Both Systems B and C still have areas which need additional soils and land classification data. About one-third of the area of System B - specifically the right bank of the Maduru Oya - will be covered during early 1980 with a detailed soil and land classification survey. Receipt of 1 : 5000 scale maps are necessary before this work can be completed by the Land Use Division (LUD) of the Irrigation Department. In System C, also during early 1980, LUD soil surveyors will continue field work in the northern forest area. Both topographical and soils maps will be used for a revised land classification of five or six field sheets which are located mostly in the northern part. This will ensure a uniform level of detail over the whole of the System C, providing more reliable mapping for all the lands.

Limited land use and soil information data are presently available for Systems A and D. Until main reports and annexes are made completely available, the environmental impact analysis will remain retarded and

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inconclusive. It is understood that only a preliminary report has been made on System A lands and that only after March or April to Mid-June 1980 will a feasibility soil and land classification be completed. The preliminary survey area of "A" is about 106,000 ha. of which 62% is covered with forest. Less than 10% of the area is under permanent agriculture consisting mainly of 8,000 hectares of river irrigated paddy yielding two crops per year. About 10% of the area is cultivated at a low level of intensity mainly of chena and lowe agriculture. An accurate estimate of the distribution and percentage of arable lands cannot be made until the feasibility study is completed.

The August, 1979 Main Report of the feasibility study for System D lists a total of 40,000 hectares of existing irrigated lands which, with the addition of a proposed 22,200 hectares of new lands, will make a total gross irrigable area of 62,200 hectares. No soils or land classification was made on this feasibility study; the soils information used was taken from the FAO/ Irrigation Department of Ceylon detailed reconnaissance soil survey carried out between May 1965 and November 1966. According to a soil type summary of the gross project area, a net irrigable area of about 50,300 hectares should be available. This does not include solonetz or shallow rocky soils.

Total irrigable lands which could be developed in those four accelerated areas (A,B,C and D) would be approximately as listed below:

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	hectares	
System A	30,700	----------(50% arability
" B	52,300	(approximately
" C	37,000	(excuding
" D	50,300	(Somawathie
Grand Total	170,300	(Chaitiya
		(Sanctuary)

Land Classification standards for bot land uses for irrigated agriculture, adapted from the U.S., Bureau of Reclamation, needs to be standardized for the entire Mahaweli Accelerated-area. System A studies use four suitability classifications for irrigable lands of which four classes have been recognized : Class 1 - highly suitable; Class 2 - moderately suitable; Class 3 - marginal; and Class 6 - non-suitable or non irrigable. System B has been given somewhat different land classification standards which are identified as indicated in Table 5-1. These include two upland irrigated classes; two lowland paddy rice classes; and one class 6 - non arable class. System C has been attributed a more extensive set of land class standards which are set forth in Table 5-2. There are three upland classes; one suspended class 5; one class 6 - non-arable, upland; three arable wetland rice classes and a class 6 - non-arable wetland rice class. System D has had no detailed land classification made, but the lands have only been categorized generally as upland soils, lowland soils, and other unsuitable lands for irrigation according to soil type and cropping potential as shown in Table 5-3.

Present Land Use

An over-all present land use inventory of the Accelerated Area, which includes land areas within all the Schemes A,B,C, and D, is only general, unstandarized and incomplete.

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Table 5-1

LAND CLASSIFICATION CRITERIA FOR SYSTEM "B" FEASIBILITY STUDY - LOWER CASE

Land Characteristics	Subclass Denotation	Upland Diversified Crop Production		Lowland Rice Production		Class 6
		Class 1 (1U)	Class 2 (2U)	Class 1 (1R)	Class 2 (2R)	
1. Soil texture*						
Surface	s	FSL-CL*	LS - C	FSL - C	LS - C	Non-arable lands which do not meet the minimum requirements of the other land classes.
Subsurface		SL-C	SL - C	LS - C	S - C	
2. Rooting Depth**						
Gravel Layer	s	90 cm	60 cm	60 cm	30 cm	
Bed-rock		120 cm	90 cm	90 cm	60 cm	
3. Available Water Holding Capacity	s	15 cm in top 120 cm	10 cm in top 90 cm	Not applicable	Not applicable	
4. Salinity (E.C.-mmhos/cm)	s	2	4	2	4	
5. Alkalinity***	s	SAR 10	SAR 15	ESP 15	ESP 20	
6. Cation Exchange Capacity (m.e./100 g)	s	10	5	10	5	
Topography	t					
Deep Soils 120 cms		4%	4%	2%	4%	
Moderately deep 90-120 cms		2%	4%	2%	4%	
Moderately shallow 90-90 cms		-	-	-	-	
Shallow 60 cm		-	-	-	-	
Drainage	d	well to moderately well	well to moderately well	poor to very poor	imperfect	

* Texture - FSL = fine sandy loam, SL = sandy loam, LS = sandy loam, C = clay
** Rooting Depth - estimated after land development
*** Alkalinity - SAR = Sodium Absorption Ratio, ESP = Exchangeable Sodium Percentage

Source : Maduru Oya Project, Feasibility Report
Annex B Soils and Land Classification, November 1979
Acres International Ltd. Niagara Falls, Canada

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Table 5-2

System C Land Classification

I - LAND CLASSIFICATION : DRYFOOT CROPS : SURFACE IRRIGATION

Soil type (Drainage)	Soil Depth Phase	Associated Gravel Depth(p)	SLOPE PHASE (t) 0-1.5%	1.5-3%	3-4%	4-6%	6%
RBEs, Well Drained	d:vd 120cm	90 cm	1	1	2t	3t	6t
	md90-120	60-90	1	2pt	3tp	6tp	6tp
	ms60- 90	30-60	3p	39t	6pt	6pt	6pt
	s 60	30	6p	6pt	6pt	6pt	6pt
RBE, Imperfectly Drained	d; vd 120 cm	90cm	3d	3d	3dt	6dt	-
	md 90-120	60-90	3dp	3dp	6dtp	6dtp	-
	ms 60- 90	30-60	6dp	6dp	6dpt	6dpt	-
LHG (poorly Drained)	d;vd 120cm	90cm	5d	5d	5dt	6dt	-

II - LAND CLASSIFICATION : WETLAND RICE

Soil type (Drainage)	Soil Depth Phase	SLOPE PHASE 9(t) 0-1.5%	1.5-3%	3-4%	4-6%
RBEs, Well-Drained	All depth phases but shallow	R2s	R3st	R6st	R6st
	Shallow Depth Phase	R2p	R3pt	R6pt	R6pt
RBE, Imperfectly Drained + LHG (poorly Drained)	All depth phases but shallow	R1	R2t	R3t	R6t
	Shallow Depth Phase	R2p	R3pt	R6pt	R6pt

Note : p, d, and t refer to depth, drainage, and topography (slope) subclasses respectively.

Subclasses 6 tp', 6pt' etc. are marginally downgraded.

Source: Feasibility Study, System "C"
Mahaweli Development Project
December 1979.

Hunting Technical Services Limited.

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Table 5-3

Gross Project Area for Different Soil Types in System D

(unit: ac)

	Soil Type	A/D	D_1	D_1	D_2	G	Total	Cropping Potential	
								Maha	Yala
1	R.B.E; Well drained	5,510	12,640	13,645	130	7,370	39,295	All upland Crops	All upland Crops
2	R.B.E. drained imperfect/poor	5,215	6,830	9,980	0	5,470	26,695	Lowland Rice Sugarcane/	Upland Rice Sugarcane/
3	L.H.G.	1,260	6,060	25,150	0	2,050	34,490	Lowland Rice	Lowland Rice
4	Alluvial; drained well /moderately	0	970	0	33650	570	5,190	Cash Crops (Tobacco, Vege.)	Cash Crops (Tobacco, Vege.)
5	Alluvial; drained imperfect/poor	3,760	970	3,465	10,550	0	18,745	Lowland Rice	Lowland Rice
	Sub-Total	15,745	26,640	52,240	14,330	15,460	124,415		
6	Solonetz	0	0	2,825	0	0	2,825	not suitable for Crops except improvement	
7	Shallow, Rocky	2,165	1,600	4,205	370	7,720	16,060	not for Cropping Area (homesteads/ Building, etc.)	
	Sub-Total	2,165	1,600	7,030	370	7,720	18,685		
	Total	17,910	28,240	59,270	14,700	23,180	143,300		

Notes: (1) R.B.E. (W.D) ; Chillies, Onion, Groundnut, Soyabean, Cowpea, Grams, Cotton, Sugar Cane, Turdha, Maize, Sorgham, Upland Rice, Fruit (deficiency of organic matter).

(2) L.H.G. ; Drainage would be beneficial.

(3) Alluvial (W.D) ; D_2 Area (4) Alluvial (imp/poor) (5) Chillies (intermediate soils is necessary) Cotton (raining problems)

Source: Feasibility Report on the Moragahakanda Agricultural Development Project, August 1979, Japan International Cooperation Agency.

Listed in Tables 5-4 through 5-7 are the summary presen land use inventories which are available as of this date.

Table 5-4

Surface Areas (in hectare) of Present Land Use in System "A"

Heavy jungle	36 596
Medium jungle	12 852
Light jungle	16 532
Sub Total	65 900
River irrigated rice	8 060
Tank irrigated rice	1 053
Chena cultivation	8 304
Levee cultivation	1 338
Sugar cane	780
Sub Total	19 535
Pasture	1 460
Villu	6 032
Idle clearings	4 607
Sub Total	12 179
Urban areas and homestead gardens	1 500
Rock outcrops	200
Roads and water surfaces	6 606
Sub Total	8 300
Grand Total (rounded)	106 000

Source: System A, Present Land Use and Vegetation Survey, (December 1979)

Joint Venture Randenigala Salzgitter Consult GMBH, Salzgitter Agrar and Hydrotechnik, Esson Electrowatt Engineering Services Ltd., Zuerich.

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Table 5-5

Surface Areas (in hectares) of Present Land Use in System "B"

	Hectares
FOREST	
Dense	1,300
Medium	49,800
Light	11,200
Plantations	4,400
Subtotal	66,700
CROPS	
Irrigated Rice (Paddy)	13,700
Chena	32,800
Subtotal	46,500
OTHER	
Large Farms	600
Homestead and settlement	2,900
Rockland	3,900
Tanks, Villus and Open Water	3,200
Subtotal	10,600
Total	123,800

It is estimated from Acres International Limited, 1979 latest figures that there are approximately 52,000 hectares or 42 percent of irrigable lands in Area "B", of which a net area for farms would be approximately 36,000 hectares.

Source: Maduru Oya Project Feasibility Report
Initial issue (November 1979)
Niagra Falls, Canada.

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Table 5-6

Surface Areas (in hectares) of Present Land Use in System "C"

	hectares
Forest (Total Area)	24,600
Paddy	2,330
Rice, rainfed	1,800
Chena Cultivation (varies 3000-4000 hectares annually)	4,000
Livestock Production (unknown)	
Approximate total	32,730

Source: Feasibility Study System "C"
Mahaweli Development Project
December 1979.

Hunting Technical Services, Ltd.

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Soil and Water Conservation

Upper Catchment Area of the Mahaweli - Erosion of soils of the upper catchment appeared very serious, as widened from field observations made by TAMS team members during the recent Maha season. Heavy silt run-off was noted in the swollen rivers which would have a direct impact on the proposed Victoria Reservoir. Some silting was noticeable in rice paddy fields downstream of the Mahaweli, and the Maduru Oya as a result of upstream erosion.

Erosion control in the Upper Catchment of the Mahaweli is a primary concern in the prevention of sedimentation of proposed downstream reservoirs. It is also necessary to reduce the loss of valuable top soil necessary for agricultural production.

Erosion damage is caused principally by the impact of rainfall on unprotected soils. Factors which add to the effect are gradient, soil types, vegetative cover and cultural practices. The erosive power of rainfall can be mitigated by a proper control and management of these factors

Acceptable Limits of Erosion - What level of erosion is acceptable, before corrective action is necessitated? The usual answer is that, the land is utilized on a sustained basis such that there is no retrogression or deterioration. This will be achieved

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Table 5-7

Current Irrigable Area, Cropped Area and Harvested Area in the Existing Field (ha) in System "D", the Moragahakanda Area (includes G, D_1, D_2, and A/D)

		Acreage under Specification			Acreage under Unauthorized Cultivation			/3 Whole Existing Lands		
		Irrigable Area	Cropped Area	Harvested Area	Irrigable Area	Cropped Area	Harvested Area	Irrigable Area	Cropped Area	Harvested Area
MAHA	Paddy	27,514	27,427	27,339	6,317	6,279	5,755	33,831	33,706	33,094
YALA	Paddy	27,239	27,153	26,694	5,243	4,539	3,402	32,482	31,692	30,096
	S.F.C.	275	274	270	135	115	87	410	389	357 /1
Sub-Total		55,028	54,854	54,303	11,695	10,933	9,244	66,723	65,787	63,547
Year-Round	Sugar Cane	3,000	2,700	2,550	-	-	-	3,009	2,700	2,550
Total /4		58,028	57,554	56,853	11,695	10,933	9,244	69,732	68,487	66,097

/1 : The harvested area of the S.F.C. (Subsidiary Food Crops) consists of Chillie (110 ha); Pulses (110 ha); Red Onion (70 ha); Soya bean (30 ha); Groundnut (20 ha) and Vegetables (17 ha)

/2 : Sugarcane is being grown through Estate cultivation.

/3 : Whole Total Area in hectares

/4 : No Summary Land Use is made for area remaining in forest or for other present land use

Source : Feasibility Report on the MORAGAHAKANDA Agricultural Development Project
August 1979 Japan International Cooperation Agency

when the rate of soil loss is no greater than the rate of formation of soil. The rate of formation cannot be precisely measured. The best estimates indicate that under disturbed conditions it will take in the order of 300 years to produce some 25 mm of topsoil. When disturbances, aeration and leaching action are speeded up by tilling, this will be reduced to something like 30 years. A formation rate of 25 mm in 30 years is approximately 1.8 Metric Tons/hectare/year, a figure that is frequently adopted as the target figure for maximum erosion. Naturally the acceptable loss will depend on the soil conditions. If the profile consists of a deep soil whose fertility is the same at all depths, then a loss of 25 mm of soil in 30 years is much less serious than if the profile consists of a few centimeters of soil overlying hard rock. Target figures are therefore seldom higher than 2 metric tons/hectare/yr and frequently are lower.

These low figures are related to good land management and erosion control practices to minimize soil loss through soil erosion.

A universal soil loss equation (USLE) has been developed by Nischmeier and Smith (1965) to assist in appraising these soil losses. The equation is A = RKLSCP where :

A = soil loss per unit area
R = rainfall factor
K = credibility gradient factor

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L = length of slope factor

S = slope gradient factor

C = soil cover or crop management factor

P = factor relating to erosion control practices

The credibility factor K, explained above is a measure of a soils susceptibility to erosion. Therefore it will largely depend on the physical characteristics of the soil.

The method was developed by Nischmeier et al (1971) for evaluating soil credibility using the characteristics of soil particles, such as particle size distribution, organic matter content, structural index and permeability. In this method a soil credibility monograph graphically solves an abridged equation that incorporates these physical properties of the soil. Such methods are useful in comparing the relative susceptibility of soils to erosion until experimental data becomes available. Table 5-8 shows the annual erosivity of some Sri Lankan soils estimated from the monograph prepared by Nischmeier et al (1971). Table 5-8 shows the calculated credibility (K) for the major soil regions (Joshua, 1977). This varies from 0.17 to 0.48. The relative susceptibility of soils to erosion may be found in Table 5-8.

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Table 5-6

Erodibility of Selected Soils in Sri Lanka

Rainfall station	Soil	Erodibility (K)	$(R \times K) \times 10^{-2}$
1. Ratnapura	red-yellow podzolic	0.22	172
2. Badulla	red-yellow podzolic	0.22	44
3. Katugastota	reddish-brown latesolic	0.17	61
4. Katinayake	sandy regosol	0.48	222
5. Anuradhapura	reddish-brown earths	0.27	54
6. Kankesanturai	red-yellow latosol	0.33	80
7. Batticaloa	non-calcic brown	0.35	129
8. Mannar	red-yellow latosol	0.33	79
9. Hambantota	reddish-brown earths	0.27	41

Source : Nischmeier et al 1977.

Joshua (1977) states that the erodibility of Sri Lankan soils is expressed by a relationship between the erosive power of rainfall (R) and the erodibility (K factor) of each soil. The erodibility factor (K) for a given soil is such that when multiplied by the erosivity (R) the product equals the soil loss from the soils under specified conditions. The factors LSC and P are associated with the length of slope, gradient, vegetative cover and erosion control practices. Reliable estimates of these factors may be obtained from U.S.D.A. Soil Conservation Service Technical Release No. 51, January 1975.

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There are some values of soil erosion losses due to tea production which are significant to note. The Tea Research Institute has estimated that as much as 280 metric tons of soil can be lost per hectare annually from tea lands that have been replanted on steep lands. The vulnerable periods for soil losses occur when the soil is bare (after the old tea has been uprooted and removed, until a Guatemala grass cover is established) and, from the time the Guatemala is uprooted until replanted tea has closed in. Losses of 224 metric tons per hectare containing 11 metric tons of organic matter will adversely affect the productivity of the eroded land. Studies by Hessels and Sikurajapathy (1965) on four plots at St. Coombe Estate represented by 1) lands bare after tea; 2) tea 1½ years old; 3) lands bare after Guatemala grass; and 4) tea 1½ years old, conclude that:

Soil losses due to tea planting can be conservatively estimated at between 165 to 330 metric tons per hectare annually plus the additional loss of 8 to 16 metric tons per hectare of organic matter incorporating a 180 to 360 kilogram nitrogen loss.

IMPACTS

A Pilot Project to Estimate Soil Erosion

Recognizing the soil erosion problem on the cleared forest lands, the tea lands, and the other miscellaneous farmed lands of the upper watershed area of the Mahaweli; and in order to bring the impact of this national problem to the fore-front; a small pilot project has been initiated by TAMS forestry and land use specilists.

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This will demonstrate the important inter-relationship of reforestation, proper land use, sound soil conservation and, land management practices. It will also show the necessity to overcome the lack of essential information on forestry and land use of the upper catchment area of the Mahaweli.

Actual land use of a sizeable portion of the upper watershed area has been mapped from 1979 aerial photos (1 : 20,000 scale), and is being transferred to 1 : 31,680 printed topographic maps, to which will also be added the soil boundaries of the principal soils. This coordinated - forestry land use soil conservation project will be well enough advanced to be partially analyzed for this midterm report. This will be for about 20,000 hectares, on the Rangala Southwest topographic map.

The following land use categories were used with the generalized legend derived from the land use classification adopted by the Commission on World Land Use Survey, International Geographical Union.

1. Settlements and Associated Non-Agricultural Land
2. Horticulture
   - 2H - Home Gardens.
3. Trees and Other Perrenial Crops
   - 3C - Coconut
   - 3Co - Cocoa
   - 3O - Orchard
   - 3R - Rubber
   - 3T - Tea
   - 3Tx - Poor or Abandoned Tea

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4. Cropland

- 4P Paddy
- 4Pd Permanent dry cropping
- 4S Shifting Cultivation (Chena)
- 4T Tobacco

5. Improved Permanent Pasture

6. Grassland and Scrubland

- 6S Savanna or Patana
- 6Sc Scrubland

7. Woodland or Forest

- 7P Plantation

8. Swamps or Marsh

9. Unused Land.

In the photo interpretation, in addition to the land use symbols, a symbol for the degree of slope was marked for each type. The slopes were calculated from the number of 100 feet contours per half-inch on the one-inch topographic maps. These slope symbols and categories are :

1. Slopes less than 20 percent
2. Slopes between 20 percent and 40 percent.
3. Slopes greater than 40 percent.

Boundaries of the three principal groups of soils found in the Upper Catchment were added to the map to complete the assessment of the potential for the erosion and soil losses. The three principal soil groups which are UNDP/FAO Great Soil Group Designations, are as follows and are listed in the order of the descending order of erosion:

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UNDP/FAO Great Soil Group Designations	Equivalent Soil Taxonomy (USDA) Classifications
1. Reddish Brown Earths	Ustalfs Rhodustalfs, Haplustalfs
2. Red-yellow Podzolic	Udults Tropudults
3. Immature Brown Loams	Tropepts Dystropepts

The principal soil on the Rangala Southwest area is the Red-yellow Podzolic soil group.

To facilitate the compilation of the land use data various land used types were also grouped in three classes in descending order of erosion resistance as follows.

I 1, 2H, 3Ca, 3T, 4P, 7, 7P, 8
II 3C, 3O, 3R, 4Pd, 4S, 6S
III 3Tx, 4T, 6Sc, 9

Table 5-9 below is a summary table of the Rangala Southwest sheet in which is tabulated the land uses, land use types, various classes of land use slope classes, and soil losses through soil erosion in metric tons per hectare :

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Table 5-9

Soil Loss by Erosion of Red-yellow Podzolic Soils
(Metric Tons per hectare)

Land Use Class	Type	1	2	3
I	2H	4.7	14.1	
	3T		7.0	
	4P	1.2		
	7		2.4	
II	3C	4.7	14.1	
	4Pd	30.7	91.5	
	6S		21.1	41.2
III	3Tx		106.4	
	6Sc		21.1	41.2

It will be noted that the greatest soil loss in this Rangala Southwest area is the poor tea category 3Tx of 106 metric tons per hectare, with the lowest being Paddy and next to lowest being "7" woodland or forest with a loss of only 2.4 metric tons per hectare.

As more areas are completed the soil loss will be calculated for other land use classes and types on the three different slope-classes. It is anticipated that one other land use type on the steep slope classes that will show particularly high values is the 4T (Tobacco) planted on over 40% slopes with no soil erosion control measures utilized.

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Reference is made to Chapter 6, Forestry, Where a more detailed description of the pilot project will be found. It is believed that the preliminary figures for soil losses in Metric/Tons per hectare are conservative and that as more experimental data and information become available the soil losses from erosion will prove to be even greater.

Forested and deforested areas, good tea and poor tea plantations, tobacco plantations and sites of both good soil conservation practices and poor soil conservation practices [illegible] have been visited in the upper watershed area and photographed in preparation for 35 mm. slide presentations. Nearly sixty sites were visited and photographed to illustrate both good and poor land use practices on this important watershed. To this will be added calculated soil losses of the main soils of the watershed area from the back ground of technical meterial found Joshua's paer (1977). This will complete the pilot project described above.

In addition to Joshua's work on soil erosivity another significant work of soil erosion research is being conducted on an FAO/ Dept. of Agri. sponsored water management Research Project on the Nannu Oya Watershed area of 10,000acres. Runoff is being measured on a detailed study of the main catchment and sub catchment and from three main plots of well managed tea (3 replications). Runoff and soil loss is being monitored as well as all management practices. Dr. Norman Hudson consultant from the National College of Agricultural Engineering, of Silsoe, Bedford England and P. Krishnaragah of the Soil and Water Division of the Department of Agriculture of Sri Lanka are the

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directly involved in this important cooperative research project. It is research projects such as those which give the sound technical basis for good land use and well designed and well executed land management practices.

Acclerated Area — Impacts — C. Soil erosion will increase on the upland areas of the accelerated areas unless careful attention is paid to design and layout of irrigation and drainage systems. The Reddish Brown Earths (RBE) are particularly susceptible to erosion. Annual irrigated cropping should be restricted with areas less than four percent slopes on all soils.

In System B, the soils are generally coarse textured with the exception of the recent alluvial of the two major river flood plains. These soils are sandy clay loams or coarser in texture, hence the available water holding capacity and cation exchange capacity tends to be low for soils occurring over the majority of the project area. Although salinity does not appear to be an inherent problem however with the introduction of irrigation water, salinity could build up in poorly drained areas. Therefore the provision of adequate drainage should be throughly investigated, to prevent this from becoming a significant problem — not only in System B, but in the other three systems of the Accelerated area as well.

The reddish to brown sandy loams, usually associated with the steeper slopes, cause shed water not only because of gradient, but also due to their lower infiltration rates. These soils under poorly managed irrigation could further aggrevate the excessive wetness of the associated lowlands during the Wahr monsonn season. Because of the

nature of the clay fraction (Kaolinetes) in the reddish brown soils, these soils dry out rapidly in the Yala monsoon season. Unlike their grey-brown sandy counterparts which remain friable, they become exceedingly hard and difficult to cultivate.

In System C poorly drained soils occupy and occur in larger ~~area~~ continuous areas ~~units~~ than the other two groups of soils. The proportion of irrigable upland in to lowland is 1 : 2 in the Northern portion; widening to 1 : 8 in the Southern portion. Relative relief is much greater in the Southern than the Northern portion. Slope irregularity as much as slope gradient is a major problem for irrigationplanning in System C.

More information must be forthcoming from Systems A and D, before an impact analysis can be made of the soil and classification and land use.

IMPACT ANALYSIS

General Considerations

The earliest civilizations emerged where soils were richest and water most available and died out when soil became waterlogged and saline through faulty irrigation; when watersheds had been deforested and when; soil erosion and silting had destroyed the very basis of agriculture. Today irrigation is as much a problem as a solution to improved agriculture. According to an estimate by the United Nations Food and Agricultural Organization (FAO), 70% of the irrigated land in Egypt, Iran, Iraq and Pakistan is affected by waterlogging and the build-up of salts. The problem is not confined to the tropics. It occurs in every country which develops substantial irrigation.

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The most economical and realistic soil conservation practices can be formulated by mitigating relative erosion hazards in an area or region rather than by giving a blanket recommendation to cover all plantation as is presently done. Operations involving erosion hazards such as replanting of old tea lands, pruning tea, and clean weeding by the use of the oversized "Karandi" hand tool can be timed for periods of minimum erosivity. Soil conservation measures such as establishment of cover crops and maintaining mulches canbe adopted according to information of soil erodibility. After pruning, close cultivation with the "Karandi" hand tool is made, and small weeds are gathered up dried and burned instead of leaving them to form a mulch and protect against erosion. This present management practice invites great soil loss until after the tea fully recovers from the pruning and again provides good soil cover protection.

Soil and Water Conservation

Upper Catchment Area of the Mahaweli - A knowledge of the relative stability and instability of the various soils of the Upper Watershed area of the Mahaweli Development is important toward developing a well-planned program for the reforestation and preservation of this important area. A stabilized upper watershed area of the Mahaweli is a critical and necessary part of the entire upstream and downstream development. Without a strict, timely, well-planned, well-managed, well implemented and organized reforestation-conservation program - all downstream development is doomed to failure, sooner or later. The GSL is aware of this need, but a detailed, and basically sound plan of implementation remains to be organized - one of sufficient technical strength and detail to avoid well-known ommissions, pitfalls, and errors of the past and to provide for sound land use for the future generations of Sri Lankans.

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Important basic data on the erosibility of soils in Sri Lanka has been and is being investigated by soils scientists. Future planning for appropriate land use of these soils is mandatory to save the soil and water resources of this country.

Recommended Action - Upper Catchment

The importance of managing the Mahaweli watershed, particularly in maintaining and managing begetation is critical to the successful implementation of the storage, irrigation and drainage ystems for the accelerated area that it needs more specific consideration.

The mitigation of floods and droughts begin on upland watersheds. Only by the maintenance and management of suitable vegetation and land-use practies upstream can agricultural land be protected from the extremes of too much or too little water. Vegetation not only holds water, r relcasing it slowly, but it and the mulches that can be created from it improve the physical characteristics of the soil. Litter and humus enhance soil structure, impede runoff, and increase the capacity of the soil to absorb moisture.

In Sri Lanka the highest amount of soil erosion is observed in the upland area in spite of relatively low soil erodibility. This is because of the long and steep slopes existing in this area. This is especially true of the upper watershed area of the Mahaweli.

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The first rule of water management for the Mahawoli development is the protection of forests, woodlands and tea lands and their restoration if they have been destroyed. This in turn means restraint on land use - one of the most awesome responsibilities in places where population is acute or will become so. To restrain deforestation, burning, mismanagement of tea lands, overgrazing or steep hill farming, where land is in short supply may seem prohibitively difficult. If it is not done the price is the further destruction of soils, wastage of natural resources, flooding, drought, disease and increased mortality rates.

In plantations of tea, woodlots, and where other crops are already successfully established on moderate slopes, improved land and crop management practices can achieve enormous reductions in soil erosion. In the United States, which losses 4.5 billion metric tons of topsoil each year, experiments have shown the effectiveness of contour plowing, crop rotation and manuring. In the case of potatoes, contour planting reduced the soil erosion rate from 32.3 metric tons per hectare to 0.22 metric tons. Cotton planted contiously on a seven percent slope resulted in an average annual loss of 46.4 metric tons of soil per hectare, while cotton grown in rotation on the contour reduced the loss to 13.5 metric tons. By adding manure or other organic matter such as leaves dry weeds, and other vegetation, to produce a topsoil mulch, to improve the more rapid intake of soil

moisture, soil erosion can be reduced by a factor of three or four fold. Although these figures may not be exactly relative to other climates and other soils, they are suggestive of what conservation measures can achieve. These techniques for preventing soil loss and depletion of natural resources have been known for a long time, but man often forgets or neglects them.

In the Forestry Section which follows a recommended plan is set forth to implement a constructive program of reforestation, erosion control, and bringing stability and higher productivity of the agricultural lands of the Mahaweli catchment basin. A large number of government agencies and private sectoral groups are concerned with the restoration of the basic natural resources of the upper watershed area of the Mahaweli, but there is no over-all coordinating planning body or comprehensive legislation or well-defined plan to bring this about in a reasonable and satisfactory manner. Sufficient numbers of well-trained technical people are in short supply. The soil conservation service of the Department of Agriculture is in charge of soil conservation measures, but only six technical people remain out of a total of some 64 people who originally had training in soil conservation. A realistic budget, sufficient trained personnel, a central planning and controlling organization, and precise and comprehensive legislation are all a necessary part to carry out an effective upper watershed plan for the Mahaweli development.

Recommended Action - Accelerated Area

In order to foster uniformity and efficiency in planning the irrigation development and other aspects of the Accelerated Areas within the Systems A,B,C, and D serious thought needs to be given to establishing uniform land classification standards and specifications. System "H" is a good example of land classification based on USBR

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specifications, wherein four arable classes were used with one temportrary non-arable-class 5, and one non-arable class-6.

Various management practices will permit the improvement of production from coarser textured soils however these will require higher water, fertilizer and labor imputs than will finer textured soils. This will apply to both upland soils and lowland paddy soils.

Paddy is especially recommended for the finer textured lowland soils, some upland or intermediate slope soils might be used for flooded paddy, but these would require higher amounts of water due to faster percolation rates than lowland soils.

Rocky and shallow RBE's should be usable to grow woodlot trees suitable for firewood. - Also the use of species that reproduce themselves to more completely protect soil from erosion in the replanting process should be considered.

Steeper topography limits the deeper phases of RBE's and these lands should not be cleared for annual crops because the risk of erosion is very high.

Very steep slopes of over 40% are better suited to perennial plantings such as forest trees of appropriate species to suit the planting conditions and local climate.

Judging from the dendritic patterns of soils, particularly in Schemes B and C and the relatively small difference in elevation in many areas between upland and lowland soils, a more adequate assessment of the drainage requirements is felt to be necessary - both for a technical design and a economic cost analysis. Expert advice on this should be required at an early date.

A sugar estate has been recommended in the feasibility study for the northern area of System "C". However, until a detailed land classification is made and the drainage problem completely analyzed and technically appraised for future land use, implementation would remain only one of a choice of possibilities. Furthermore, for a viable, agriculturally technically sound Sri Lankan sugar or sugar by-products industry, all promising adaptable lands should be considered, from which final areas would be selected. This would include significant contiguous blocks of land which would be characterized by deep-well-drained soils which are necessary for a high sustained productivity of sugar cane.

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CHAPTER 6

FORESTRY

INTRODUCTION

The Forestry task of assessing the environmental impact of the Mahaweli Accelerated Program is composed of two separate studies, the Upper Catchment and the Accelerated Program Irrigation Systems.

This Interim Report deals with the present land use and forestry mapping of the upper catchment and an outline of work planned for the Irrigation Systems.

UPPER CATCHMENT

Existing Conditions

Overview - One critical factor in the successful development of the Mahaweli Ganga for power and irrigation is adequate soil conservation of the catchment area to prevent siltation of reservoirs and to provide protection of water quality for irrigation.

Field reconnaissance by car and helicopter indicates that there is serious erosion taking place throughout the catchment area. In order to quantify the extent of the problem, a present land use and forestry map is being prepared from available 1979, 1:20,000 scale aerial photographs. The photographs covers about 75% of the catchment area and comprises 546 prints of which 252 pairs were annotated.

Mapping Method - Land use typing on the photographs was carried out using a generalized legend derived from the classification adopted by the Commission on World Land Use Survey, International Geographic Union.

Because of lack of time, the number of categories were reduced, and one category, 3 TX, was added to indicate poor or abandoned tea. The classification for the upper catchment is

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is presented below:

1. Settlements and Associated non-Agricultural Land

2. Horticulture

   2H Homestead Garden

3. Tree and Other Perennial Crops

   3C Coconut

   3Ca Cocoa

   3O Orchard

   3R Rubber

   3T Tea

   3TX Poor or Abandoned Tea

4. Cropland

   4P Paddy

   4P Permanent dry cropping

   4S Shifting Cultivation (Chena)

   4T Tobacc

5. Improved Permanent Pasture

6. Grassland and Scrubland

   6S Savana or Patana

   6Sc Scrubland

7. Woodland

   7P Plantation

8. Swamp and Marsh

9. Unused Land

In addition to the land use symbols, a symbol for the degree of slope was marked in each type. The slopes were calculated from the number of 100 foot contours per half inch on the 1' mile = 1" topographic maps. The slope symbols are presented

below :

1. Slopes less than 20 per cent;
2. Slopes between 20 per cent and 40 per cent; and
3. Slopes greater than 40 per cent.

The types and symbols are being transferred from the photographs by a scale-rectifying optical instrument to the 2" = 1 mile topographic maps.

Boundaries of the three principal groups of soils found in the Upper Catchment were added to the map to complete the assessment of the potential for erosion. The three soil groups are listed below:

1. - Reddish brown earths
2. - Red yellow podzolic
3. - Immature brown loam

These soils are listed in descending order of erosion resistance. A description of the soils may be found in Chapter 5, Soil Conservation and Land Use.

To facilitate the compilation of the land use data, the various land uses were also grouped in three classes in descending order of erosion resistance as follows:

I. 1, 2H, 3Ca, 3T, 4P, 7, 7P, 8
II. 3C, 3O, 3R 4Pd 4S 6S
III. 3TX 4T 6Sc 9

During the course of interpretation it became apparent that three categories of tea should have been used, namely good, intermediate and poor. Since this crop covers such an extensive area of the catchment, its importance in erosion control and the amount of effort to rehabilitate such a large part of it will become a major segement in the regional development plan. Well managed tea is carefully engineered with accurate terracing and

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properly spaced and sloped drains and, except for relatively short periods of pruning and fallow between replantings, is an erosion controlling crop. However, there are very large area of tea which partially fit in this category, partially show a breakdown in the terracing system with far less than a full cover of bushes, and partially appear almost abandoned. All three categories may appear in one estate.

Aerial photo interpretation also disclosed the continuing removal of forest at high elevation. The usual pattern on tea estates is to have a number of bold mountain tops or patches of scrub and grass land in the centre of the estates. This indicates that the forest on these areas has been removed for fuelwood in the past. In some estates plantations have been established either adjacent to the remanent timber or on the upper slopes of the plantation.

There has been one study of run-off and erosion in the recent past prepared for a M. Sc degree to the Postgraduate institute of Agriculture, University of Sri Lanka (Ponnudurai 1979). The study was conducted during the period 1975 - 1976 in the Kaneeliya-Dediyagala-Nakiyadeniya forest reserve in the southern wetzone uplands. This is considered to be the best wetzone forest in the country composed mainly of pipterocarpacea 24 to 27 meters tall.

Two adjacent catchments were selected the one partially logged one year prior to the project and one not cut for the previous 20 years. Logging removed approximately 40% of the vegetation.

The Study showed that the average monthly measured sediment in the two catchment streams was 242 per cent greater in the partially cut catchment compared to that in the uncut catchment.

This evidence taken together with the erosion evident on the denuded hilltops indicates that the regulation prohibiting cutting of natural forest over 5000 feet elevation should be enforced on private lands as well as public lands.

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Compilation of Existing Uses - Areas of each land use type are measured by a dot grid and grouped according to the three criteria mentioned above; namely land use class, soil class and slope class.

The first map to be completed and measured is Rangala South West. (Remaining maps are under preparation). This is located in the North West Corner of the Upper Catchment and is typified by medium class tea land, forest and scrub. Most of the slopes range between 20 and 40 per cent and a large proportion of the tea should be replaced by forest plantations or other soil conserving crops. Table 6-1 indicates that only 8.1% of the slopes are less than 20%. The whole of this map sheet is classed as No.2 soil, Red Yellow Podzolic, the median soil group for susceptibility to erosion. A copy of the Rangala sheet may be found in the packet of the end of the report.

Table 6-I

Present Land Use

Rangala South West

(hectares)

Land Use Class	Type	Slope 1	Slope 2	Slope 3	Total	Percent
I	2H	255	478	-	733	3.6
	3T	-	6984	-	6984	34.8
	4E	445	-	-	445	2.2
	7	-	6498	-	6498	32.3
Tot.		700	13960	-	14660	72.9
II	3C	178	40	-	218	1.1
	4Bd	757	291	-	1048	5.2
	6S	-	291	506	797	4.0
Tot.		935	622	506	2063	10.3
III	3TX	-	150	-	150	0.7
	6Sc	-	3004	219	3223	16.1
Tot.		-	3154	219	3373	16.8
G.Tot.		1635	17736	725	20096	100.0
Percent		8.1	88.3	3.6	100.0	

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Analysis of Soil Erosion Problems

The information obtained from the generalized land use map will enable an estimate to be made of the relative erosion hazard of the soils in the upper catchment using the calculation method used by Joshua (1977) for Sri Lanka. This calculation takes into account the erosive power of the rainfall for various stations on the island, erodability of major soils groups, slope and land management. Results are given in metric tons per hectare. The figures themselves indicate orders of magnitude of the erosion problem and indicate the areas most seriously in need of remedial action, thus allowing a sequence of priorities to be set up as a part of an overall regional redevelopment plan.

The universal soil loss equation is A = RKLSCP (Wischmeier and Smith 1965) where

A = the mass of soil loss per unit area
R = rainfall factor
K = erodability factor of different soils
L = length of slope factor
S = slope gradient factor
C = cropping management factor
P = factor relating to erosion control practices

An analysis of the Rangala South West map is shown in Table 6-2.

Table 6-2

Soil Loss through Erosion
(in tons per hectare)

Land Use		Slope		
Class	Type	1	2	3
	2H	4.7	14.1	-
I	3T	-	7.0	-
	4P	1.2	-	-
	7	2.4	2.4	-
	3C	4.7	14.1	-
II	4Pd	30.7	91.5	-
	6S	-	21.1	41.2
III	3Tx	-	106.4	-
	6Sc	-	21.1	41.2

When these figures are applied to the areas of the land use types on the Rangala South West map the average annual loss for the 20,096 hectares is 12 tons per hectare. The results derived from such a formula in the absence of corroborative measurements must be regarded as general orders of magnitude; however, they are so large that it can be taken that erosion is very heavy and corrective measures are ugently required.

Recommended Actions

General - Erosion control in the upper catchment is a complicated problem. It not only involves protection of the river and river developments but also crop diversification to arrest the decline of agricultural production and the provision of fuelwood and building materials. Even now there are local shortages of fuelwood inmmany areas of the upper catchment which affect the local population and the tea and tobacco industries.

Government Controls - There are a large number of government agencies concerned with various aspects of the redevelopment of the upper catchment but no coordinating body or comprehensive legislation. The Soil Conservation Service of the Department of Agriculture is nominally in charge of conservation measures but this is a small organization with one vehicle and a very small budget. Concise and comprehensive legislation and a strong controlling organization is required to organize and carry out an effective redevelopment program.

Watershed Management Plan - In order to redevelop the upper catchment an overall redevelopment plan is required. The first step in the preparation of such a plan is the preparation of a land capability map.

These maps are a combination of a series of overlays at a working scale of 1:10,000. The overlays are a present land use map, soils map, drainage map, land ownership map and topographic map. The combination of these maps provide the basis for the capability map which shows the best land use for each of the combinations of soil and topography. It also shows the

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areas most susceptible for erosion, allowing priorities for remedial measures to be listed.

With the land capability map a 10 year action program can be developed, listing work priorities, staff allocations and establishing annual budgets.

Legislation Required - Legislation should be designed according to the redevelopment program, granting powers enabling the plan to be implemented. This means certain control of land use on private land, control of the tea and other corporations concerned with activities in the upper catchment and provide both incentives as well as penalties to achieve good erosion control.

It is thought that a government corporation would be the best type of organization to develop the upper catchment. This body would be centralized and would have its own equipment, transport and maintenance facilities. They could second the best available people from government and industry and organize training facilities for the large number of specialists in the various disciplines involved.

Administration - A Corporation has the advantage of centralized accounting for effective control of the many activities involved. The corporate structure lends itself to the management and integration of a number of diverse activities.

The principal functions of the corporation would be the rehabilitation of tea lands, supervision of the crop diversification program and establishment of forest plantations. The Corporation would have marketing functions for the crop diversification program, and an extension function for small holders.

International funding will be required for such a large undertaking but should not present a problem if a detailed redevelopment plan is prepared to support the request.

ACCELERATED PROGRAM IRRIGATION SYSTEMS

Existing Conditions

It appears from a study of the four consultant

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reports that the area is still about 50% under forest. This forest is of poor quality with the exception of one area on the north-end of System C.

The methods of clearing thus far has been to cut and burn, most by would-be settlers hoping to be chosen officially when lands are allotted. When clearing is completed the only natural forest remaining will be wildlife reserves and parks plus small patches designated by the consultants to be left along rocky ridges.

Work Planned

A present land use map will be prepared from the 1:20,000 photography to provide a base map for plotting settlements, canals and waterways. This map is essential for the location of fuelwood plantations windbreaks and canal protection plantations. The available maps are sketchy, lack detail, and at a scale of 1:50,000 are unsuitable for presenting and analysing detail for a complex settlement scheme or regional development plan.

A forestry crew will be obtained from the Forest Department to carry out vegetational patterns in the Wildlife Reserves from which a floristic composition description will be made and successional stages will be inferred. This will be done from the point of view of habitat for wildlife.

An analysis of the forestry situation in the country will be made from available data and aerial sketch mapping. The present and future demand for building materials and fuelwood will be calculated. The supply and demand picture will be formed indicating the impact the deforestation of the Mahaweli area has had. Recommendations for plantations for various purposes will be made to meet future demand and the amount of timber that will have to be imported in the interim will be estimated.

Since the forest plantations will be very extensive, recommendations on training for the Forest Department will be suggested.

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CHAPTER 7
PUBLIC HEALTH

EXISTING CONDITIONS

Overview

Evidence on the pattern of health in Sri Lanka can be characterized as indicating a high incidence of diseases attributable to environmental conditions, a situation frequently found in less industrialized tropical countries; but, with heart disease being the leading identified cause of death, morbidity statistics are more typical of industrial countries. This inconsistency can be explained by the existence of a relatively effective health-care system in Sri Lanka and the resulting suppression of mortality but not morbidity from environmental diseases.

Published statistics on health in Sri Lanka have three major sources:

- patient records from admissions to government hospitals;
- death certificates; and
- special surveys.

Each source provides some insights but has a degree of limitations. Hospital data, which are used by the Ministry of health for morbidity and mortality statistics, have two primary weaknesses. They identify only one cause of hospitalization, which tends to exaggerate the occurence of acute diseases, such as those of the heart, and to understate chronic diseases, such as parasitic infections, that lead to the acute condition. Secondly, the population counted is biased towards those with serious illness because lesser illness are frequently treated by the private health-care sector, which provides a large share of the primary care, or they are treated on an out-patient basis at government institutions.

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Morbidity

Four classes of infectious diseases dominate admissions to government hospitals: bowel or diarrhoeal diseases, malaria, pyrexias (fevers) of unknown origin, and infectious hepatitis. All are typically linked closely to environmental factors (Figure 7-1). Bowel diseases are believed to consist of bacilliary and amoebic dysentaries, gastro enteritis, colitis, cholera, roundworm and hookworm infections, and they afflict about 40 percent of all persons seeking treatment at government medical institutions. In specific areas, such as in System C of the Mahaweli Development Program, the proportion is higher.

Malaria cases also rank high in admissions for all areas but particularly in the intermediate and dry zones. It is the highest cause of hospitalization for infectious diseases at some hospitals, such as at Polonnaruwa. Pyrexias of unknown origin are assumed to encompass typhoid fever, paratyphoid, arbo-virus diseases, rickettsial (tick borne) fevers, leptospirosis, and similar diseases related to environmental factors. Since most of the agents in three of the four classes of infectious diseases are bacterial or parasitic, they are generally responsive to treatment, a point apparent in mortality statistics.

Mortality

Using compilations by the Registrar General from death certificates, life expectancy was found to be 68 years in 1978, about 26 years more than the expectancy in 1946. Two causes of death not directly related to environmental causes, heart disease and accidents/suicides, now rank above diarrhoeal diseases as leading causes (Figure 7-2). In 1976, anaemia and malnutrician ranked fourth and malignancies, fifth. Between 30 and 40 percent of all cancers were of the buccal cavity, and the next most common site was the buccal mucosa, indicating a probable relationship between betel chewing and cancer and a relative lack of industrially-related cancers.

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Priority Diseases

During a Country Health Programming effort in 1978, the Ministry of Health used both objective and subjective criteria to rank 36 diseases and conditions by priority scoring. In a later proposal to provide health services to the Mahaweli development areas, the Ministry identified the highest ten diseases in the priority scoring as warranting primary concern:

1. Malaria
2. Gastro enteritis
3. Accidents, poisoning, and violence
4. Bacillary dysentary and amoebiasis
5. Anaemia
6. Avitaminosis and other nutritional deficiencies
7. Tuberculosis in all forms
8. Typhoid
9. Respiratory diseases
10. Venereal diseases

For purposes of analyzing specific potential disease problems related to a program which will involve large quantities of water for irrigation and domestic use, the major water-related diseases can be classified into two categories: water-borne or water-washed infections and water-related insect vector diseases. The list of diseases covered in the following sections is not comprehensive, mainly because the difficulties of diagnosis, weakness of the disease reporting system and the lack of available data on the appearance of certain diseases in Sri Lanka makes their presence only conjecture.

Water-Borne and Water-Washed Infections

Cholera - In 1974, 4556 cases and 333 deaths were attributed to cholera in Sri Lanka with a focus of the disease in the lower Mahaweli Valley, Anuradhapura, and slightly northward. Reported cases declined to 726 in 1976, but the disease remains endemic.

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Cholera is a serious intestinal disease characterized by sudden and acute diarrhea, vomiting, rapid dehydration, and circulatory collapse. Death may occur within a few hours of onset; and the fatality rate in untreated cases may be 50 percent; but appropriate treatment can lower the fatality rate to below one percent.

Cholera is transmitted by the ingestion of water contaminated with feces, or vomitus of patients or, to a lesser extent, food contaminated by unclean water. The most effective control of the disease is through the adequate treatment of domestic water supplies.

Typhoid Fever - In 1975, hospital records registered 10,656 cases of typhoid fever in Sri Lanka, and a significant proportion of "Pyrexias of Unknown Origin" are assumed to be undiagnosed typhoid fever. The largest number of cases was reported from Colombo, followed by the Kandy area. The Badulla Health Division also reported a large number of cases.

Typhoid fever is an infectious disease characterized by continued fever, headaches, either constipation or diarrhea lymphoid swelling, and other systemic symptoms. The fatality rate of about ten percent can be reduced to two or three percent or less by appropriate treatment.

The disease is transmitted by water or food contaminated by the urine or feces of a patient or carrier. Control measures include the protection and treatment of public water supplies, sanitary disposal of human excreta, fly control, and other sanitation practices.

Paratyphoid Fever - Paratyphoid fever is not distinguished from typhoid fever in Sri Lankan health statistics. This disease is characterized by continued fever, spleen enlargement, usually diarrhea and enlarged lymphoid tissues. It is transmitted by water or food contaminated by urine, feces or from a carrier.

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Bacillary Dysentary - In 1975, hospital records registered 2,135 cases, which is assumed to be a small proportion of actual cases. In an earlier survey of 333 children in Sri Lanka, 211 were found to be dehydrated; and about 12 percent of these were found to have the shigellae enterophathogen of bacillary dysentary (van Zul, 1966).

This is an acute bacterial disease primarily involving the large intestines and characterized by diarrhea, accompanied by fever and often vomiting and cramps. It can be fatal. Two-thirds of the cases and most of the deaths are in children under ten years of age.

Water Related Vector Diseases

In the succeeding sections, diseases transmitted by various intermediate host organisms (mostly by mosquito bites) which have an aquatic life history phase are discussed. Heavy emphasis is accorded malaria, since this disease is a predominant one throughout the country.

Malaria

Etiology - In Sri Lanka, malaria consists mainly of two forms: *Plasmodium falciparum* or malignant tertian malaria and *Plasmodium vivax* or benign tertian malaria. The *falciparum* form can produce fever, chills and sweating, headache, coagulation defects, shock, renal failure, and coma. About ten percent of the cases among untreated children and nonimmune adults are fatal, and death can occur within several days. Fortunately, this form of malaria is less common than *vivax*, which has many of the same symptoms as *falciparum* but to a less sever degree. Death is rare in the latter form except among young children or in cases complicated by other diseases.

Malaria is transmitted by female anopheline mosquitoes, which must first ingest human blood containing gametocytes of the malaria parasite. Sporozoites which develop after eight to ten days within the mosquito may thereafter be injected into any other human host where patent infection develops in about two weeks.

Malaria Control Prior to Residual Insecticides - Malaria epidemics have devastated Sri Lanka for centuries, apparently contributing to the collapse of the ancient civilization focusing upon Anuradhapura and Polonnaruwa (Briercliffe, 1935). River diversion projects created by these societies may have redistributed water in ways that favored breeding of Anopheles mosquitoes. Numerous epidemics have been recorded since 1858, when systematic records began to be maintained. Outbreaks were experienced each decade. The epidemic of 1935 was of such extraordinary magnitude that it elicited international attention. The episode was attributed to abnormally scanty rainfall which caused the major rivers to cease flowing and to form puddles in their beds.

Comprehensive control measures were instituted, largely aimed at Anopheles breeding in puddled river beds. At the height of the campaign, oil was applied weekly to 275 miles of rivers and streams, including portions of the Mahaweli Ganga and Maha Oya. The value of this treatment was questioned since "the secondary rise of malaria .... was greater near the stretches of the Maha Oya which had been carefully oiled ..... than in any other part of the epidemic area" (Biercliffe, 1935). Massive quantities of quinine were issued, amounting to about 13 million treatment-days supply, but the objective was solely curative.

Control Based on Residual Insecticides - With the World War II development of chemical insecticides having residual persistence, hopes rose that malaria could be eradicated. New epidemics followed each campaign until the Anopheles

became resistant to DDT, the least expensive and most persistent of the available insecticides. A similar pattern occurred elsewhere in Asia. Among major classes of chemical insecticides, only organophosphates, e.g., malathion, and the carbamates remain. Neither group can be expected to be as efficient because of low residual activity.

The first national malaria control program was planned in 1945; and by the end of 1946, DDT was being applied nationwide as a residual insecticide. The objective was to apply DDT to every house in malarious areas every six weeks at a rate of one gram per square meter. By 1950, 585,000 houses were being routinely sprayed with five percent DDT emulsion or lindane suspension every eight weeks. During the next few years, DDT, BHC or dieldrin suspensions were applied at three month intervals. The program appeared to be a success and, starting in 1951, regular spraying was suspended. By 1954, all routine spraying had ceased; only temporary or new habitations were sprayed. Spray teams were converted in 1955 to surveillance units stationed at 56 of the 256 medical institutions around the country.

A sharp increase in diagnosed malaria infections followed in 1956. The country was then divided into endemic and spidemic zones; and in 1957, DDT spraying was resumed where infection appeared to be endemic. By 1958, only 1037 malaria infections were idagnosed among 63,866 hospital admissions.

The apparent success encouraged Sri Lanka in 1958 to adopt a formal eradication program. All habitations in the endemic zone were treated with DDT suspensions at the rate of 0.5 - 1 g/m^2 and this continued until May 1963. Malaria seemed to have disappeared, permitting the program to enter a brief period of consolidation. Only 17 cases of malaria were diagnosed that year, and eight of these were considered to be imported from the Maldives.

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Again, local outbreaks were soon recognized; and, by the end of June, the country had reverted to a modified attack phase of eradication. The problem appeared to focus in jungle regions, and the strategy was to protect human communities in contact with jungle. Houses within jungle clearings and those within one-half mile of the jungle were sprayed. Houses in demonstrated foci received two grams DDT/m^2. Passive case detection, based on fever patients attending hospitals, provided the main survillance mechanism.

This pattern of epidemiological intelligence loses effectiveness at a distance from major towns, "becoming practically absent in the remote areas. This makes a special case... for a complementary service to screen effectively the residents of rural areas, particularly those in remote jungle or newly opened areas, by domicilary visits for active case-detection" (Rao et al. 1964). In spite of continued transmission, spraying was to have been totally withdrawn during 1964. But, because indigenous infections continued to appear, the modified attack phase continued.

Between 1964 and 1968, public health workers tended to ignore the malaria problem. Apparently, however, the strategy of "barrier spraying" was sufficiently informal that, significant endemic foci remained unrecognized and untreated.

By late 1967, the existence of a new P. vivax epidemic had become evident, and by January of 1968, there was little doubt that the epidemic had major proportions. The main focus of infection centered in the North-Central region of Sri Lanka in Matale, Polonnaruwa and Anuradhapura districts. A second focus lay in the South-East, in Monaragala and Hambantota districts. These were the loci of the 1906, 1912 and 1935 epidemics, and maximum prevalence of all four spisodes occurred in the months of January and February. The 1967 epidemic was unique in Sri Lanka and in the tropics

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generally because of the predominant role of P.vivax. The relative scarcity of P.falciparum has not been explained. In any case, attributed deaths were rare due to widespread availability of drugs.

The satisfactory explanation of the initial cause of the 1967 epidemic has not yet been documented. Excess rainfall was recorded nationwide in October through December of 1967, and deficit rainfall occurred in January and February of 1968 (Ray et al., 1968). The spidemic started during the period of excess rainfall and this tends to negate the concept that epidemic malaria in Sri Lanka is exclusively caused by drought. However, it may be that river levels varied independantly of the nationwide pattern of precipitation. The notable deficit in rainfall early in 1968 probably magnified and prolonged the epidemic. In addition, the widely publicized discovery of a large gem near Elahera resulted in transient migration of men to that jungle region, and this may have helped to spread infection throughout the island.

Sri Lanka returned to an intensified attack phase of eradication following a WHO evaluation in 1968. More than ten times the amount of DDT was applied during each of the years 1968 through 1970 than was applied in the year before the epidemic (1966). Surveillance by passive case detection was intensified after the program was implemented in November of 1968. This program failed. Prevalence of malaria seasonally attained higher levels in 1968-1969 than in 1967-1968, and peaked to even higher levels in 1969-1970. Resistance had destroyed the usefulness of DDT against A. culcificacies. Limited quantities of malathion were sprayed beginning in 1970.

During the period 1971 to 1975, the country suffered another massive increase in malaria transmission, and the eradication program was resumed. Massive applications of DDT continued until 1976 in spite of increasing evidence of the ineffectiveness of this pesticide. Malathion, which had been

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applied in limited quantities since 1970, was adopted as the principal insecticide in March of 1975. Satisfactory results stimulated additional coverage by September of 1975 and further extension in November of 1976. This pattern of progressively increased malathion coverage continues to this day and the recorded prevalence of malaria has correspondingly declined.

These results encouraged a malaria assessment team convened during 10 - 28 February 1976 to recommend "an intensive malaria control programme as soon as possible." Malathion, as well as fenitrothion, would be banned for any nonhealth use. Recent observations on A. albimanus in El Salvador indicated development of resistance from agricultural use of pesticide selected for malaria control. Such use was percieved as a potential threat to malaria control in Sri Lanka. The use of anti-malarial drugs was also seen as an important adjunct to the program.

Current Control Program - By November of 1976 the government of Sri Lanka, USAID, the British and Netherlands governments had each signified basic agreement for launching an intensive malaria control program based on these precepts. A new operational plan was drafted and then implemented in August, 1977.

The basic objective of the new "Intensive Malaria Control Programme" was to eradicate P.falciparum and to reduce the prevalence of P.vivax to an acceptably low level which would, thereafter, be sustained. This objective was to be accomplished in five years and would require that all houses in malarious parts of Sri Lanka be sprayed four times during each of the first two years. It was anticipated that spraying during 1979 would be reduced to two cycles in certain regions and progressively eliminated by 1981. The criteria for withdrawal would depend mainly upon parasitological assessment including both passive (PCD) and active (ACD) case detection. Passive case detection involved all fever

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patients reporting to each of 235 clinics or hospitals. Active case detection focuses on malarious regions isolated from these "indicatory institutions". One ACD agent becomes assigned to each 4,000 to 10,000 people and each house is visited monthly. In order to make their services acceptable to the population, ACD agents now distribute anti-malarial drugs.

The plan includes reduction of mortality and morbidity by a five-day course of chloroquin or amodiaquin therapy offered to all persons found infected with malaria. Primaquin will be administered solely in hospitals. In practice, tablets sufficient for the five-day treatment are now freely distributed to suspected cases. Supplies are provided to community leaders in isolated settlements and to local apothecaries. In the Mahaweli Region, some 60 - 70 such "volunteer centres" have been supplied with drugs. During 1978, 20,096,031 anti-malarial tablets were distributed by the government. About 12 million people reside in malarious regions of Sri Lanka.

Habitat Preferences of Vectors - *Anopheles culicifacies* has long been recognized as an important vector of malaria in Sri Lanka (Sivalingam, 1960). "The optimum breeding place for this species is a (sandy) stream running over flat country (and which is) almost empty (due to) drought. The water must be clear.... (and) there must be a portion ..... on which sunlight plays for a good number of hours ..... Very small collections of water in the sand are much favoured; foot or hoof marks are frequently full of larvae ..... provided they are in the sun. It is useless to look for *A. culicifacies*, except in sunny places" (Clemesha, 1934). This breeding habit correlates with the riverine distribution of epidemic malaria in Sri Lanka and with maximum transmission following drought.

Recently, personnel of the Anti-Malaria Campaigns, confirmed that in Sri Lanka *A. culicifacies* do not exploit paddy fields. Of 1084 larval *Anopheles* spp. collected in

such sites, only 107 were A. culicifacies. Of these, 88 were taken from an exposed pit in one fallow field. (Wickramasinghe, unpublished). This confirms that in Sri Lanka A. culicifacies fails to exploit rice irrigation. Larvae of nine other Anopheles species may be more abundant in such locations. Newly cut trenches and borrow-pits provide additional breeding sites for A. culicifacies (Carter, 1930), as does seepage from irrigation structures.

Vector Identification - About 20 Anopheles species are extant in Sri Lanka. Anecdotal evidence supports the classical concept that A. culicifacies is the sole local vector; each outbreak of disease may be explained by the proximity of potential breeding sites. A. culicifacies is the main species collected around human habitations and Anopheles biting man indoors are almost invariably of this species. However, man-biting collections seldom yield more than ten speciments of this species per night. Generally, biting specimens are collected only once in several nights. Females of this species seem to be strongly endophillic, resting in houses between blood meals.

Two points of evidence support this conjecture:

- Gravid and semi-gravid females are abundant in unsprayed houses (Table 7 - 1).
- Females that fed out-of-doors on animals are commonly collected indoors (Table 7-2). A. subpictus is the only other Anopheles that is commonly collected in houses but females of this species rarely contain human blood, and rarely are taken in biting catches. Thus, of potential vectors only A. culicifacies in Sri Lanka appears to have frequent contact with man.

Vector Effectiveness - Another form of evidence indicates that in Sri Lanka A. culicifacies is an unusually effective vector of malaria. The incubation period of

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Plasmodium sp. in the vector (extrinsic incubation) is about eight days. Thus, a potential vector must live for at least ten days before it may transmit. The mean expectation of life of Indian A. culicifacies is estimated at only 2.5 days, requiring huge populations before the species can transmit. In contrast, estimates based upon parous-rate of Sri Lanka A. culicifacies suggest that the corresponding longevity of certain local populations may approach 18 days. This would suggest that Sri Lanka A. culicifacies is an extraordinary dangerous vector, rivaling the notorious A. gambae of Africa in vectorial capacity.

Another factor tends to decrease the capacity of Sri Lankan A. culicifacies as a vector of malaria. Since the species is not highly anthropaphillic. About one-half blood-fed specimens collected in human habitations contain non-human blood. Presumably, human hosts were at least as available as non-human.

Taken together, these observations suggest that malaria transmission in Sri Lanka is highly domicilliary. Although, A. culicifacies breeds mainly in river bottoms, adults of the species reside close to man. This presents a paradox because it has been well established that men are much more commonly infected with malaria than are women (Table 7-3). The male to female infection ratio is about 1.5 to 1. Since men in Sri Lanka have more contact with jungle than do women a nondomicilliary cycle is suspect.

A possible jungle vector of malaria in Sri Lanka is Anopheles elegans, a Leucorphyrus species allied to A. balabaceusis. This latter species is a dangerous vector of chloroquin-resistant malaria is Southeast Asia. Indeed, in one site in a jungle near Kandy, 83 A. elegans were collected. Of these, five contained malaria (Nelson et al, 1971).

sporozoites and ten contained oocysts. These malaria organisms were presumed to be Simian parasites because a monkey, injected with sporoites from one of these mosquitoes proved to be malarious. However, no evidence was presented that the monkey was previously non-infected. In fact, the monkey was ultimately diagnosed as having a mixed infection with P. shortti, P. frazile and another unidentified blood parasite. That one mosquito might transmit three parasites is most unusual. This Anopheles species should be reexamined as a vector of human malaria.

Susceptibility of Vector Mosquitoes to Insecticides - DDT seemed highly effective as an insecticide against A. culicifacies during the 1950s, and no suggestion of impending ineffectiveness was recorded until 16 years after its initial use in Sri Lanka. Then, the first standardized "discriminating dose" insecticide susceptibility tests were applied, but a system of regular testing was not instituted until 1968.

In the first recorded test, two of the five localities sampled contained a few A. culicifacies that did not die, and similar results were recorded in 1966 (Table 7-4). DDT continued in use throughout the 1960s and real resistance problems began to be evident by 1968. The effectiveness of DDT had declined marked by the time of the epidemic of 1967 - 1968; and, by the next year, high levels of resistance were widespread.

Unfortunately, DDT continued in use until 1976 in spite of overwhelming evidence that selective pressure was driving A. culicifacies toward the resistant stage. No evidence of reversion to the susceptible stage had been derived even in 1978, two years after use of DDT had ceased.

Discriminating dose techniques of insecticide testing were applied to A. culicifacies using other potential public health insecticides. These included malathion,

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fenitrothion, and dieldrin (Table 7-5). Each of these toxicants in 1978 killed all mosquitoes tested at the time and dose schedules adopted. By 1979, malathion had been used in Sri Lanka for eight years, the last three years involving extensive applications of more than a million pounds (Table 7-6). Malathion, thus, appears to remain useful in the anti-malaria campaign.

If Malathion is applied four times a year, treated walls should remain highly toxic to mosquitoes for at least three months. However, malathion spray does not render walls sufficiently toxic (Table 7-7). Even within the first 30 days after application, about one-quarter of such bioassay mosquitoes escape death.

In the event that malathion resistant A. culcifacies are discovered in a particular portion of Sri Lanka, the malaria control program hopes to locally eliminate the resistant population using fenitrathion intensively applied to all local human habitations. Experience with other Anopheles species in Brazil, Egypt and Sardinia provide optimism that such an eradication campaign is practical. All authorities do not share this optimism. At enormous expense, a DDT susceptible species was almost eradicated from a sharply demarcated region in Sardinia. However, a different species population was highly domestic and had only recently become established. Furthermore, experience with malathion-resistant A. culicifacies in India indicate cross-resistance with fenitrothion (Herath, 1979). If the two insecticides are "positively correlated" in Sri Lankan A. culicifacies, fenithrothion would be ineffective for this purpose.

Filariasis

Bancroftian Filariasis - Bancroftian filariasis caused by the worm Wuchereria bancrofti, is endemic in the south-western coastal strip of Sri Lanka between Negambo and Matara. This is the most densely populated part of the

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country, containing Colombo and its suburbs. Present population of this region numbers about 2.5 million people with a ten percent microfilaria rate (Table 7-8). Of 589 filariasis patients in Dehiwela Clinic in 1975, more than 500 had swollen arms or legs and 21 had frank elephantiasis. Fever and lymphangitis were common. Transmission of the W. bancrofti worm has also been reported away from the coastal belt on the Peradeniya University campus near Kandy (Wijetunge, 1967). The worms all transmitted through mosquitoes bites of Culex pipiens quinquefasciatus.

Large populations of C. p. quinquefasciatus must be present before W. bancrofti can become endemic. In Calcutta, more than 315 bites per person per night were recorded when the microfilaria rate was between 12 and 14 percent (Gubler and Bhattacharya, 1974). In Peliyagoda, near Colombo, 54 C. p. quinquefasciatus bites/man/night were recorded (Samarawickrema, 1967). Such dense vector populations require large, relatively stable bodies of water heavily charged with organic matter. Cesspits, blocked drainage ditches, catch basins and husk soakpits are most frequently associated with such mosquito populations.

Currently, there is no effective program to reduce transmission of W. bancrofti in Sri Lanka. However, an extensive program of active case detection is now in place in the endemic region. However, current methods permit recognition of only about 1/10 of the microfilaria carriers residing in endemic regions. When identified, infected persons are provided diethylcarbamazine theraphy. The program helps to prevent extreme manifestations of filarial disease by identifying and treating some of the most heavily microfilaremic residents of the coastal belt.

Brugian filariasis - Brugian filariasis was once scattered in discrete foci over much of Sri Lanka (Abdulcader, 1967). The worm, Brugia malayi, was transmitted mainly by

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Mansonia spp. mosquitoes closely associated with tanks containing water-lettuce, Pistia stratioides. Larvae and pupae attach to submerged portions of this plant from which they obtain air. A total of 21 foci of this infection were identified, and each was successfully resolved by selective destruction of Pistia using the herbicide Phenoxylene 30. Recognized human infections were treated with diethylcarbamazine. The infection appears to have been eradicated from Sri Lanka.

Dengue Fever and Hemorrhagic Fever

Dangue virus of at least two serotypes is prevalant throughout Sri Lanka (Hermon and Anandarajah, 1972). Antibody to Groups B togavirus, which includes dengue, was present in almost half of the general population during 1966 and 1976.(T. Vitarana, MRI, unpublished). While residents of Colombo city appeared to be most at risk, the disease is generally distributed throughout the northern dry, wet, and intermediate zones.

Dengue fever is rarely fatal, and infection by each of the four serotypes confers life-long immunity against that strain of virus. An episode of dengue fever is highly debilitating; but the patient recovers within one week and without subsequent complications. Thus, uncomplicated dengue fever does not greatly effect the economy of an indigenous population. Transient persons, on the other hand may suffer greatly during their visit, and this concerns the tourist industry.

Hemorrhagic fever syndrome (DHF) occasionally complicates dengue fever such that the life of the patient is at risk. In Sri Lanka, a total of 69 episodes of DHF have been recorded since 1965, of which 15 resulted in death. Factors predisposing to DHF remain controversial (Maheswaran et al, 1976), and it may be that the syndrome is more common than is now realized.

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Dengue fever transmitted by Aedes aegypti and A. albopictus mosquitoes and an additional jungle cycle has been suggested for Malaysia. In Sri Lanka, Aedes aegypti seems to be the main vector, and the chief breeding site is water retained in disused automobile tires, particularly when stored under trees. In Colombo, disused tires comprised 50 percent of breeding sites of this species (Gubler, 1979). Additional sites included discarded food containers, coconut husks, etc.

Encephalitis

Japanese B encephalitis (JE) is an enzootic, mosquito-borne, viral disease enzootic in much of Asia, particularly where pigs are abundant. Hundreds of asymtomatic cases generally occur for each patient experiencing encephalitis. However, the disease is severe. About a third of patients die while others retain delibilitating neurological sequellae.

An epidemic of JE was reported from Kurunegala in 1971. There were 76 assumed cases of which only ten survived (Vitarana, personal communication). Serum surveys indicated that the virus is present along the coast 30 miles south and 45 miles north of Colombo. Pigs are reared in this region. Epidemics of this disease can be devasting. For example, an outbreak in Uttar Pradesh, India in 1978 is said to have caused 448 deaths (MMWR, 1978). The Sri Lankan vector is unknown, but Culex tritaeniorhynchus is present and this is a pioneer vector on the Asian mainland.

Other Mosquito-Borne Viruses

Chikungunya virus is a group A togavirus that produces a dengue-like disease in man. Like dengue, it is transmitted by A. aegypti, and is known to cause epidemics mainly in the south-western coastal belt of Sri Lanka. Epidemics have been recorded in 1965 (Mendis, 1967) and (Munasinghe, et al, 1966). At about this time, 10.6 percent of the

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general population circulated antibody against group A viruses (Vesenjak-Hirjan et al, 1969). Interestingly, the highest rates were reported from Trincomalee (35%) and this suggests that other group B viruses may be present in the Mahaweli delta. The list of zoonotic togaviruses that may affect residents of newly cleared jungle is extensive.

Scrub Typhus

Scrub typhus (tsutsugamushi) is a rickettsial disease transmitted by larval chigger mites. It is zoonotic in small rodents and typically affects persons in newly cleared jungle or residing at the jungle edge. One notable Sri Lanka epidemic affected numbers of a British army division manoeuvering, in 1943, in the southern part of the island (Kalrz, 1947). After four days in the jungle, 756 persons became ill with 85 percent having primary lesions. The disease had previously been recognized in Sri Lanka. *Leptotrombidium deliense* is considered to be the local vector (Lewis and Killick-Kendrick, 1973), but (Radford, 1946), in a more recent list of ectoparasitic arthropods of Sri Lanka fails to list any chiggers taken from man (Senadhira, 1969).

At present, Sri Lanka lacks ability to diagnose rickettsial diseases (including Q fever). Considering the magnitude of the mortality category "pyrexia of unknown origin", local rickettsial expertise should be encouraged. Scrub typhus, as well as one or another of the tick-borne typhus infections, may well pose an important health hazard to man in the region now being cleared of jungle by the Mahaweli Project. "Hyperendemic foci (of scrub typhus) appear to have been encouraged more than anything else by man's use of the land"(Andy, 1967).

Sandfly-Borne Disease

Kala azar (Visceral leishmaniasis) a severe chronic disease of man, is enzootic in dogs in India. Infection is

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transmitted in southern and eastern India by sandflies, mainly Phlebotomus argentipes and this vector species has been reported from Sri Lanka (Lewis and Killick-Kendrick, 1973). However, no leishmanial infection has definitely been recognized in Sri Lanka. One case report of kala azar in an English girl who had lived in Sri Lanka suggests that the disease may be present in the country (Chapman, 1973). However, the girl may have acquired infection while travelling elsewhere.

In any case, Asian leishmaniasis differs from that of African or the Americas in that it is zoonotic in the village rather than in some sylvan or other feral focus.

Bed-Bugs

Bed-bugs are effectively controlled by applications of residual insecticides so residents of houses sprayed for control of malaria rapidly benefit. Village interviews and discussions with the personnel of the Anti-Malaria Campaign indicate that the freedom from bed-bugs is invariably appreciated by local residents, thereby increasing their receptivity to spraying campaigns. In many cases the odor associated with Malathion appears tolerated solely because of bed-bug control while freedom from malaria is less easily appreciated.

In Sri Lanka, as in many parts of the world, bed-bugs soon became resistant to DDT and there is now anecdotal evidence that they are becoming resistant to malathion. Public Health Inspectors in Trincomalee and Anuradhapura Districts have recently reported to the Anti-Malaria Campaign that local residents have been to refuse spraying because of bed-bug annoyance in sprayed houses. The inspectors considered this to be an important impediment to adequate malathion coverage of village.

Several villages in both affected regions were visited in order to evaluate this complaint. Houses in

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both localities apparently well sprayed were heavily infested with bed-bugs. Living bugs were abundant in cracks in walls that were heavily coated by spray applied one month earlier. This apparent problem was widespread, and people had begun to effectively remove malathion spray from walls of houses as soon as it was applied. In reply to questions as to their motives in removing this spray, they cited (1) possible toxic effects of the spray on small children; (2) the unsightly and odorous nature of the spray, and (3) an apparent increase in bed-bug annoyance beginning about two weeks after each house had been sprayed. They believed that the spray aggravated the problem.

This evidence of resistance is conjectural and must be confirmed by laboratory study

Several villages were visited to the south of Anuradhapura and Trincomalee and residents were questioned about their reactions to bed-bugs. Residents of a village near Kalawewa felt that the insecticide spray had recently been changed because bed-bugs had begun to return. They suggested that the spray even smelled differently. In contrast villagers near Miripitiya and Elahera stated that bed-bugs were no longer a problem.

If bed-bugs resistance to malathion exists, it will spread and intensify if the present spray pattern continues. The effect, therefore, will be to reduce the effectiveness of the spray campaign.

Schistosomiasis (Bilharziasis)

Schistosomiasis is not a disease currently found in Sri Lanka, but it is a serious illness frequently associated with large irrigation projects in Asia, Africa, Middle East, and Latin America.

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There are four agents of schistosomiasis: Schistosoma mansoni, S. haematobium, S. japonicum, and S. intercalatum. S. mansoni occurs in Africa, the Arabian peninsula and Latin America. S. haematobium occurs in Africa, the Middle East and several small foci in India. S. japonicum occurs in Asia, including the Philippines, Thailand and China. S. intercalatum is only found in parts of West Africa. Transmission of all of these agents depends upon the release of eggs into water by the urine or feces of a mammalian body. The eggs hatch in the water, and the liberated larvae must then find a suitable freshwater snail host, the species of snail varying with the specific agent. Free-swimming larvae emerge from the snail after several weeks, and only then can they penetrate human skin and perpetuate the infection.

Government Hospitals

As in any developed health-care system, Sri Lanka has a hierarchical hospital structure, including 351 dispensaries, 84 rural hospitals, 110 district hospitals, nine provincial hospitals, and a network of specialized institutions, such as tuberculosis, leprosy, and mental hospitals. Health care, including drugs, is free; and personnel standards are comparatively high for the economic status of the country. The system, however, has become increasingly overextended as facilities have expanded to meet demand while, simultaneously, health-care personnel — especially physicians — have migrated abroad to countries offering higher salaries. The movement to the Middle East has become particularly widespread, and the exodus of physicians over the past five years has reported equalled or exceeded the number of new physicians being graduated from the educational institutions of Sri Lanka. In addition to limiting the quality of available health care, this situation has reportedly reduced the patience of remaining physicians with the completion of forms used in the compilation of statistics. Free drugs, on the other hand, has meant that drugs can be prescribed without the constraint of cost so patients can accumulate drugs for use when illnesses reoccur, thus reducing visits to hospitals and the need to report the more frequently occurring diseases.

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IMPACT ANALYSIS-

Health Perspective

In broad health terms, the "state of well-being" can be expected to improve. If the Project is completed as described, agricultural production will rise, incomes will increase, nutricion can improve, and an impetus will be provided for coping with the myriad socioeconomic problems of under development. In a narrower sense, however, some preconditions for disease will be increased. A large, heterogeneous population will be assembled, bringing together human carriers for numerous infectious tropical diseases. Physical and social conditions will be unsettled, resulting in improvisation and high health risks. Populations will be exposed to previously isolated disease factors now existing in the scrub jungle.

Superimposed on the imported and existing infectious diseases will be the hazards to health posed by contemporary industrial agriculture. People will receive an increased exposure to chemical pesticides, and runoff from agricultural lands will carry nutrients from the chemical fertilizers. Transportation facilities and industries linked to agriculture, such as processing plants, will involve occupational diseases and potentially hazardous environmental conditions.

Projections from System H - Spread of Water-Borne Diseases

Introduction -- Only one irrigated settlement area, System H, has been developed and settled under the direction of the Mahaweli Development Board. For this study, evidence of the health status of settlers in this area was obtained from two sources, personal observations and interviews by the study team and analysis of statistical reports:

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Percy Silva, Jayathi Perera, and W.N. Wilson, Mahaweli Settlement Area H Socio-economic Survey - Yala 1977/Maha 1977-1978: Statistical Abstract (Colombo: National Science Council, 1977-1978)

The value of the latter was enhanced by a tour of the study area provided by Dr. Silva and some of his staff.

Village Health - From a total health viewpoint, the settlers can be described as rapidly dispersing along an extended socio-economic continuum, but the growing settler is marginally productive, appears malnourished, is poorly housed, lacks safe water supplies or sanitary facilities, and probably experiences a pattern of diseases equivalent to the pattern existing before resettlement but with a higher risk of epidemic due to higher settlement density. However, health care appears readily available with modest barriers of cost. Quality could not be ascertained but it seems to be considered satisfactory by the settlers. When asked, a small number replied that they preferred — funds permitting — the private practitioner to the government facility, because they considered the drugs to be stronger.

Diarrhea was not among the diseases registered by Dr. Silva's survey, but fevers constituted by far the largest category of registered illnesses. This was followed by pains in the bone joints, stomach ailments, and chest pains.

Houses are generally temporary structures of wattle with straw or palm-leaf roofs. Most house holders reported obtaining water from canals, and about 12 to 14 percent of the settlers succumbed to the convenience of building their shelters by their paddy fields, not on their hamlet allotments. Very few houses had latrine structures, but some had a pit. Most had been issued a latrine slab, but they were rarely installed.

While limited extension and credit services have been provided to the settlers no advice, assistance or regulation of any type to assure the new village communities a supply of disease-free water was reported.

Market Town - Galwewa is being developed as primary administrative and commercial center for the new settlement area. The Mahaweli Development Board has a field office here, and marketing, banking, and cooperative stores have been established. A new hospital is being constructed, and a government dispensary is operating.

A piped water supply has been installed. To maintain pressure, a water tank has been placed near the twon center. Until early August 1979, a tank truck regularly pumped water from a nearby canal and carried it to refill the tank in the center of the town. In August, a new town well went into operation consisting of a concrete caisson about ten feet in diameter sunk into a marshy area adjacent to a drainage canal. Apparently to assure adequate seepage into the well, a ditch had been dug from the canal to the well. The top of the well was open, and appeared to have collected refuse although fish were alive in the water. It should be noted that the adjacent drainage canal, like others in the area, is used for washing pesticide applicator equipment, tractors, for bathing, washing clothes, watering livestock, providing privacy for defecation, and a drinking water supply for many farmers and their families.

The town's government dispensary is now provided with water from this town well. However, on days when the pump malfunctions the stored water supply is exhausted, and the dispensary must close. This type of event was reportedly not rare. Morale at the dispensary was low partly because housing had not yet been provided for the dispensary's staff.

Across the yard from the dispensary a new hospital is under construction. For disposal of all wastewater from the hospital, a holding tank had been constructed at one end. The stated plan is to periodically pump wastewater from the holding tank into one of tank trucks and transport it for disposal into, presumably, a drainage canal. On the other hand, if the tank truck did not arrive at the hospital before the holding tank became filled, the hospital wastewater -- which is normally highly contaminated with pathogenic and toxic materials -- would overflow into a depression by the hospital entrance.

Summary of System H Health Conditions - Widespread and serious contamination of all water supplies serving the settlers of System H appears to exist. Settlers relying upon irrigation canals are ingesting and immersing in water that is presumably heavily contaminated with human fecal material, animal wastes, and high concentrations of chemical pesticides and various other organic substances. Because of the projected handling of hospital wastewater, there may be direct contamination of this water supply with the concentrations of the most pathogenic organisms that occur in the community.

The town of Galwewa is being supplied with water that, at worst, is the same as above. At best, the filtration effect of laminar seepage of water along the exterior wall of the caisson will filter part of the contamination, such as dysentary amoeba. However, the supply source is also vulnerable to direct contamination from the open caisson. Settlers digging wells are exposed to fecal contamination of water supplies because of the unsanitary construction of these wells, particularly the lack of aprons or parapets, the use of dipping buckets, and open tops. They are also a hazard to the safety of children, adults, and animals.

The widespread absence of sanitary facilities, such as latrines, increases the probability of water-supply contamination and exposes the population to various water-borne diseases and numerous infections, such as hookworms, associated with inadequate sanitation. Unless improved sanitary systems and safe potable water supplies are provided in the Accelerated Programme area, it is likely that water-borne disease problems comparable to those which have arisen in System H, will occur.

Impacts Related to Malaria

Changes in Mosquito Breeding Habitat - The proposed development program provides the potential for diverting water from the major river basins, thereby reducing flow in the river beds. If used insensitively, this could increase potential breeding sites for *A. culicifacies*. Seepage from irrigation channels will increase breeding still more.

Open sun-lit pools created by such seepage are presently found in the Mahaweli Project area, and some of the pools are known to contain *Anopheles* larvae. Related problems center around irrigation channels near Kalawewa, eroded during the cyclone of 1978, creating numerous potential breeding sites.

On the other hand, the system of water impoundments now being constructed along the Mahaweli Ganga, Amban Ganga and Maduru Oya also presents the opportunity for regulating flow in these water courses. The Anti-Malaria Campaign together with the Mahaweli Project have already conducted an important experiment in water-level management. Water is periodically released from the Polgolla Diversion Dam such that the bed of the Mahaweli Ganga is flushed. Recent observations suggest that this flushing reduces larval *A. culicifacies* breeding in the river bed by about one-half for a distance of up to ten miles downstream (Wickramasinghe, unpublished). The effect upon biting has not been evaluated.

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Further study is required and additional initiatives should be attempted. The history of water-level fluctuations in the Mahaweli should be carefully analyzed and correlated with Malaria related events. It may be that some unexpected pattern of flow will appear to be significant and this should be analyzed. Two possible strategies of water-level management should be considered: stream-bed flushing or water level stabilization.

Effects of the Present Control Program - Malaria control in the Mahaweli Project area cannot be considered in isolation from that in the rest of Sri Lanka. Ultimately, the project will involve portions of at least two-thirds of the country's area. Malaria epidemics in adjacent surrounding regions will inevitably affect the project area.

The present intensive campaign involves a calculated risk. Malathion-resistant *A. culicifacies* and chloroquin-resistant *P. falciparum* might become established in Sri Lanka before *P. faciparum* could be eliminated from the area and *P. vivax* permanently reduced to acceptable levels. The original malathion-based control plan called for a time-limited campaign of intensive insecticide and drug administration, followed within five years by complete withdrawal of residual spraying and routine drug administration. Withdrawal was to have begun during 1979, but this goal has not be reached.

Malathion and fenitrothion resistant *A. culicifacies* are already present in India, and drug resistant *P. falciparum* is common in Southeast Asia and present in Eastern India. These circumstances indicate that resistance problems may spread to Sri Lanka, especially in view of the massive quantities of agrochemicals now being used.

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Impacts of Malaria - Caused Morbidity - In addition to the effects of malaria caused mortality, morbidity due to malaria is an important impediment to economic progress in Sri Lanka. Each time a person suffers a malarial attack, he is incapacitated for about three or four days, and this may occur three or four times each year. Since at least 700,000 people now suffer this pattern of disease, the general population is burdened by about ten million person-days lost to malaria each year. If half of the general population is gainfully employed, then about five million person-days of work would be lost each year. Agricultural workers are a particular risk of economic loss since episodes of illness may coincide with some critical period of planting or harvest.

The impact of malaria on health may also provide less apparent burdens. These include chronic anemia, immune complex nephrosis, and complications of chemotherapy. Thus, retinitis, active dermatitis and spontaneous abortion may be additional chronic clinical manifestations. These decrease worker productivity and require expenditure for clinical services.

Malaria Impacts in System H - The recent sociological study in System H of the Mahaweli Development Programme included an analysis of the behavior of rural people seeking curative medical services (Silva et al, 1977; 1978). Farmers were questioned each week about the health status of their households and, specifically, regarding self-diagnosed malaria. These people considered malaria to be the most common disease of their families with an average of about five spisodes of attack per family per year (Table 7-9). Only about four percent of the persons considered to have malaria reported to the clinic in Kekirawa or to government malaria control representatives. During 46 of these episodes of malaria, the patient sought curative care and, of these, two-thirds (travelling on foot or by bicycle), went no further than five miles from home (Table 7-10). During a visit

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to this region, local residents were questioned about their attitude toward malaria. Several responded that ready availability of drugs made further travel unnecessary. In any case, they believed that local apothecaries supplied more potent drugs than did government institutions, so cure would be more rapid.

Since the start of the present intensive campaign, consumption of anti-malarial drugs in Sri Lanka has increased dramatically (Table 7-11). At present, the government alone is supplying a mean of two tablets per year for every resident of malarious regions. Much of this drug supply is being distributed in isolated communities by a system of "Volunteers". These are school teachers or other nonmedical community leaders, who are not asked to report suspected malaria cases to the government.

The standard non-institutional treatment for malaria (proven or presumed) in Sri Lanka involves a five-day course of oral chloroquin or camoquin, and ambulatory patients are given a supply of the drug sufficient for the entire treatment once malaria is diagnosed. Residents of various communities questioned near Anuradhapura, Polonnaruwa and Trincomalee stated that people rarely took the entire five-day course. After two or three days of treatment, symptoms generally subside. The remainder of the drug supply is reserved for possible future need. Thus, malaria is now perceived as a minor problem that can be self-diagnosed and is commonly self-treated. Again, this series of events is likely to be repeated in the Accelerated Programme area.

Impacts of Other Vector Diseases

Filariasis - At present, due to the inavailability of suitable breeding habitat, there seems little opportunity for mosquito-carrying filariasis to exploit the Mahaweli Project region. In the event that such a population developed,

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eosinophilic lung would be an early manifestation of the presence of active transmission. Stable foci of patient infection would take decades to develop.

Dengue Fever - Mosquito vectors which transmit the Dengue virus breed in small pools of stagnant water which are often formed in automobile tires, discarded containers, coconut husks, etc. At present, local residents tend to accumulate used tires near their homes, and huge quantities of tires are stored out-of-doors around Sri Lanka. Worn tires appear to be valued, and are even transported by bicycle in rural areas. Tires will continue to accumulate, especially in areas experiencing economic advance. Thus, residence of Mahaweli Programme areas may be exposed to increasing *A. aegypti* populations. Rainfall is a prerequisite to development of container-breeding mosquitoes, and the dry zone may not be conducive to this problem. Consequently, the potential for the spread of Dengue fever with the development of the proposed project is relatively high.

Chikungunya Virus, Scrub Typhus and Bed-Bugs - All of these diseases may spread with the development of the project area. Chikungunya virus is prevalent in nearby Trincomalee and scrub typhus often occurs in newly cleared areas. Similarly, a spread of bed-bugs would be anticipated with the large number of settlements planned.

Schistosomiasis - Schistosomiasis is not presently found in Sri Lanka. However, widespread concern exists among authorities in Sri Lanka that an infected Sri Lankan migrant to the middle East could return to Mahaweli irrigation areas and contaminate the water. It is not clear that a suitable snail host for either *S. mansoni* or *S. haematobium* exists in Sri Lanka. There is the further concern that suitable snails may possibly be imported, for example, in a shipment of fish, produce, etc. However, even if snails suitable for *S. japonicum* were brought from elsewhere in Asia, it is likely

they would be of the genus Oncomelania; but S. mansoni requires the genus Biomphalaria and S. haematobium, the genus Bulinus. Consequently, the spread of Schistosomiasis is not expected to occur as a result of project implementation.

Encephalitis and Leishmaniasis - The spread of encephalitis following project implementation can only be speculative. It is not likely that the project development would affect transmission of leishmaniasis.

RECOMMENDED ACTIONS

General Design

There are no inherent and uncontrollable threats to health posed by the Mahaweli Development Programme plans for Systems A-D that cannot be controlled by judicious planning, alert surveillance, and rapid responses to initial infections. The proposed project will offer an opportunity to a large population for increasing incomes, raising nutrition, financing improved health care, expanding educational opportunities, and in general enhancing the overall well-being of the population, which is the essence of health.

There are, however, vulnerable aspects to the Program. A large population from all regions of Sri Lanka will be assembled as the jungle is cleared. These people will bring some regional infections and will lack immunity to others. They will initially live in physically and socially unsettled condition, increasing health risks. The threat to health is further intensified by the focus of diseases, especially malaria, but including tetanus, typhus, and gastroenteritis diseases, known to be endemic in the System areas.

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Specific Problems

From the proposed plans for Systems A-D and the demonstrated implementation of plans in System H, three health related issues must be resolved. Failure to cope with these will produce large health care costs, cause serious production losses, and, possibly, precipitate unnecessary economic and social stress.

Water Supply - Statistics and field surveys indicated that disease attributable to contaminated water supplies are grossly excessive straining the health-care delivery system, suppressing productivity, and decreasing human morale. Inadequate sanitation measures and substandard housing to a lesser degree, also represents a threat.

Malaria Control - Investigation of the current malaria control program in terms of its future effectiveness to control malaria in the Mahaweli Program areas suggests:

- Malaria incidence is not being reliably registered by indicator institutions and, thus, the malaria statistics no longer reflect true incidence
- Signs of probably bed-bug — and, possibly, mosquito resistance to malathion insecticide are already appearing. In the absence of an active monitoring program to measure it, the probability of resistance early in Mahaweli Programme operation must be assumed.
- Self-diagnosis and immense distribution of malaria drugs raises the possibility of eventual malarial resistance to drugs.
- In the absence of sufficient basic ecological and trasmission knowledge about malaria in Sri Lanka, a long-term, efficient and effective malaria control program to protect the viability of the Mahaweli Program cannot be designed and implemented.

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Health Care Services - Total health care services in System H appear consistent with the vital needs and economic resources in the area, particularly if case loads could be reduced -- perhaps eventually by as much as 50 percent -- by safe water supplies. However, an "early-warning" system for identifying exotic diseases and the monitoring of health-care facility availability may be necessary.

Water Supply

Potable Water Supply - Every settler, including those in commercial-government centers, should be assured a reliable and safe water supply in place prior to settlement. Since most settlements will be dispersed over 0.2 hectare lots, the cost of piped water outside of towns is assumed to be prohibitive. Numerous small water treatment plants maximize operational costs and risks. Thus, wells appear to be logical solution for most situations.

In areas where bed rock is close to the surface and shallow wells may become dry in the height of the dry season, the Water Resources Board apparently is considering deep wells penetrating the rock zone, an enormously costly solution, instead of a mixed solution of a few deep wells (low risk, high cost) and many shallow wells (high risk, low cost). In areas with relatively homogeneous, stable clay soils, for example, communities could easily be provided with inexpensive hand augers for bored shallow wells. Thus, the only capital cost would be the well pipe and strainer point, the hand pump unit, and some type of base plate or well cover.

Sanitary Waste Disposal - Every village house and commercial facility should be provided with sanitary facilities for disposal of human wastes. Assuring a sanitary facility requires more than simply providing a villager, who has probably never used a latrine, with a floor plate. There must be some action to assure that the latrine pit is dug and the plate in installed with a water seal prior to occupancy.

Housing

Every settler should be provided with the basis for clean, safe, and rationally located housing. This does not mean that a house should be provided, but it does mean that a substantial beginning for a high-standard house should be in place when the settler arrives. This could, for example, mean a concrete floor slab or even a house shell. Whatever the provision, however, materials with appropriate credit for completing the house construction should be made available to settlers at the lowest possible cost with proper supervision to point of completion.

Malaria Control

Spraying - To retain the viability of malathion insecticide for future malaria control in the Mahaweli Development Program areas, a special panel should be convened immediately to:

- Review the spraying procedures and policies; and
- Plan a malaria control program focusing on — but not being restricted to — the Mahaweli areas.

Research Needs - An in-depth malaria research program linked to a new surveillance effort should be organized, adequately equipped, and given the institutional support to undertake long-term, problem-oriented projects.

The lack of even basic knowledge of malaria ecology, including transmission, has handicapped the development of balanced, long-term control strategies. Vectors other than *A. culicifaces*, especially in jungle areas are unknown. If another vector, such as *A. elegans*, is identified, control technique based on breeding pattern must be designed. The correlation between seasonal water levels in major streams and *A. culicifaces* populations needs to be determined. The natural

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parasites and predators of A. culicifaces and their relative effectiveness under different conditions should be investigated. The longevity, therefore the transmission effectiveness, of A. culicifaces and the long-term response pattern genetically with exposure to different chemical insecticides also needs study. These studies can only be undertaken with appropriate manpower, facilities, and reward systems.

Flow Regulation - A special commission should be designated to commit resources and arbitrate conflicts in future water release programs, including the possible need for new structures on tributaries not affected by the Mahaweli Development Programme, to control the breeding of A. culicifaces.

In future years when the Mahaweli Development Program is operating, water control in river beds may be the logical technique to prevent the recurrence of malaria epidemics due to rapid increases in A. culicifaces populations. However, water released during summer months may conflict with water demands for irrigation. Also, optimum control may require releases on other streams not planned for development. Thus, some special-purpose structures may have to be constructed.

Health Services

In March 1979, the Ministry of Health submitted A Proposal for Health Services in the Operational and Accelerated Mahaweli Development Areas to the Mahaweli Development Board. Existing health conditions were reviewed, and a number of recommendations, both general and specific, were made. General recommendations included:

> Priority attention to the possibility of settling the farmers in permanent houses on the allocated settlement areas;

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- Provision of safe and adequate water supplies;
- Promotion of environmental sanitation and environmental protection;
- Pre-settlement medical screening of settlers;
- Setting up of a Health Monitoring System at hamlet level;
- Setting up a very sensitive Malaria Surveillance System;
- Priority assignment of health staff to the development areas and the provision of nonmonetary incentives;
- Utilization of volunteer health workers;
- Performance of specified curative functions by field staff;
- Improvement of the health management system;
- Improved contact between preventive and curative staff; and
- Adoption of a simplified reporting system.

Specific recommendations concentrated on health care services and facilities:

- A Midwife and two or three volunteer health workers recruited from among the settlers serving every five hamlets or 3000 population;
- A Central Dispensary serving every five villages or 15,000 population;
- A Peripheral Unit with 48 beds, clinic room, and ambulance;
- A District Hospital with 90 beds, ambulance, and jeep;
- Referal facilities; and
- Special facilities, including six Ayurvedic Dispensaries and one Ayurvedic Hospital with 120 beds.

In addition, the Proposal identified six "Priority Health Interventions and Targets" considered most necessary for the Mahaweli Development area:

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- Provision of adequate safe water;
- Immunization of infants;
- Provision of latrines;
- Health education;
- Spraying of dwellings with insecticides;
- Early detection and treatment of veneral diseases.

Special attention is given throughout the Proposal to the potential problem related to malaria as the development proceeds.

At present, clearly formulated policies regarding the provision of health care services, especially potable water supplies, suitable waste disposal system and adequate housing, have not been promulgated by the Ministry of Mahaweli Development for the Accelerated Program . Scheme. It is recommended that the plans presented above including the proposals of the Ministry of Health, be incorporated into overall settlement planning for the project area.

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THREE-YEAR MOVING AVERAGE MORBIDITY RATES FOR THE COMMON INFECTIOUS DISEASES COMPILED ON NUMBERS (INDOOR) TREATED AT GOVERNMENT HOSPITALS

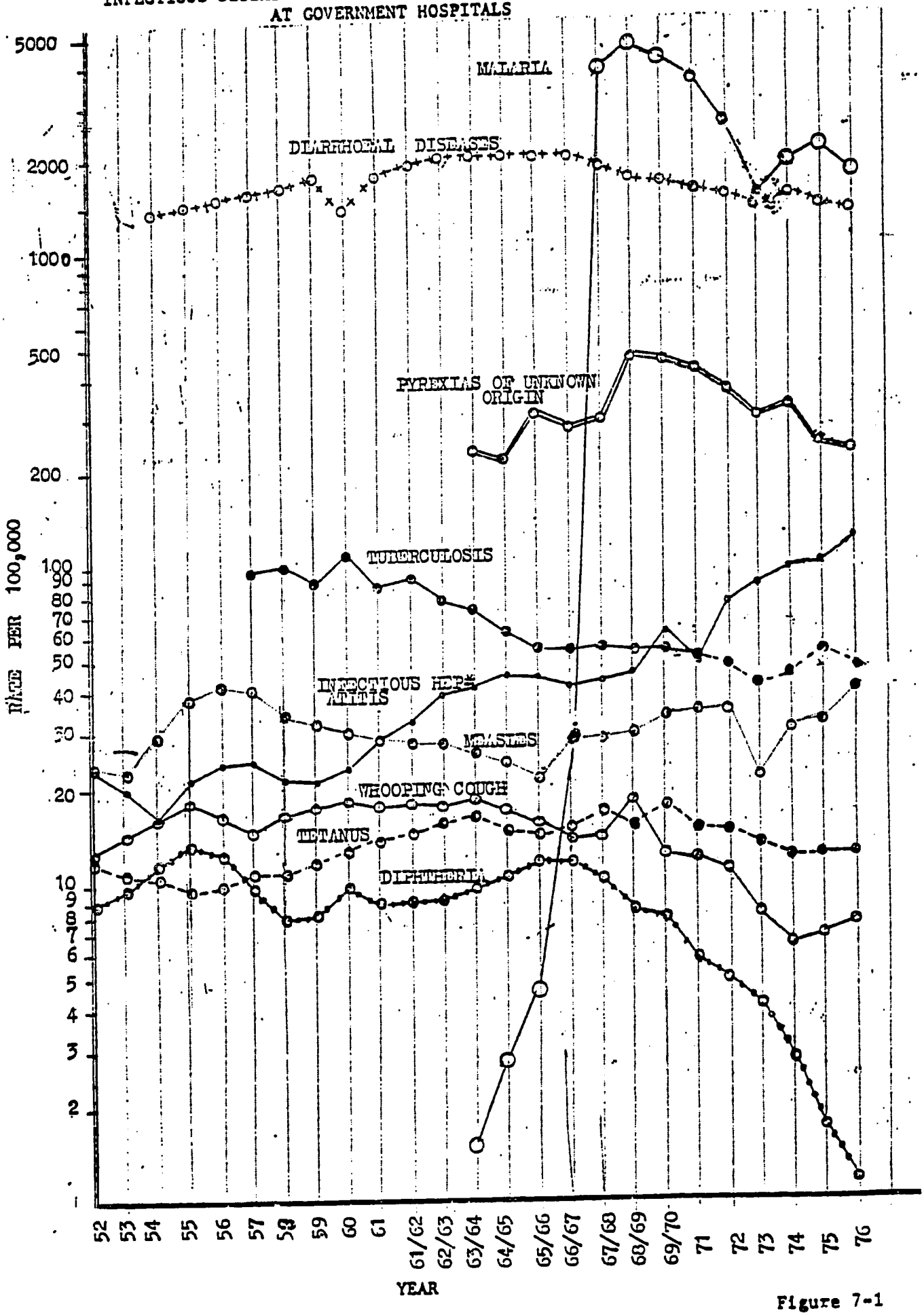

Figure 7-1

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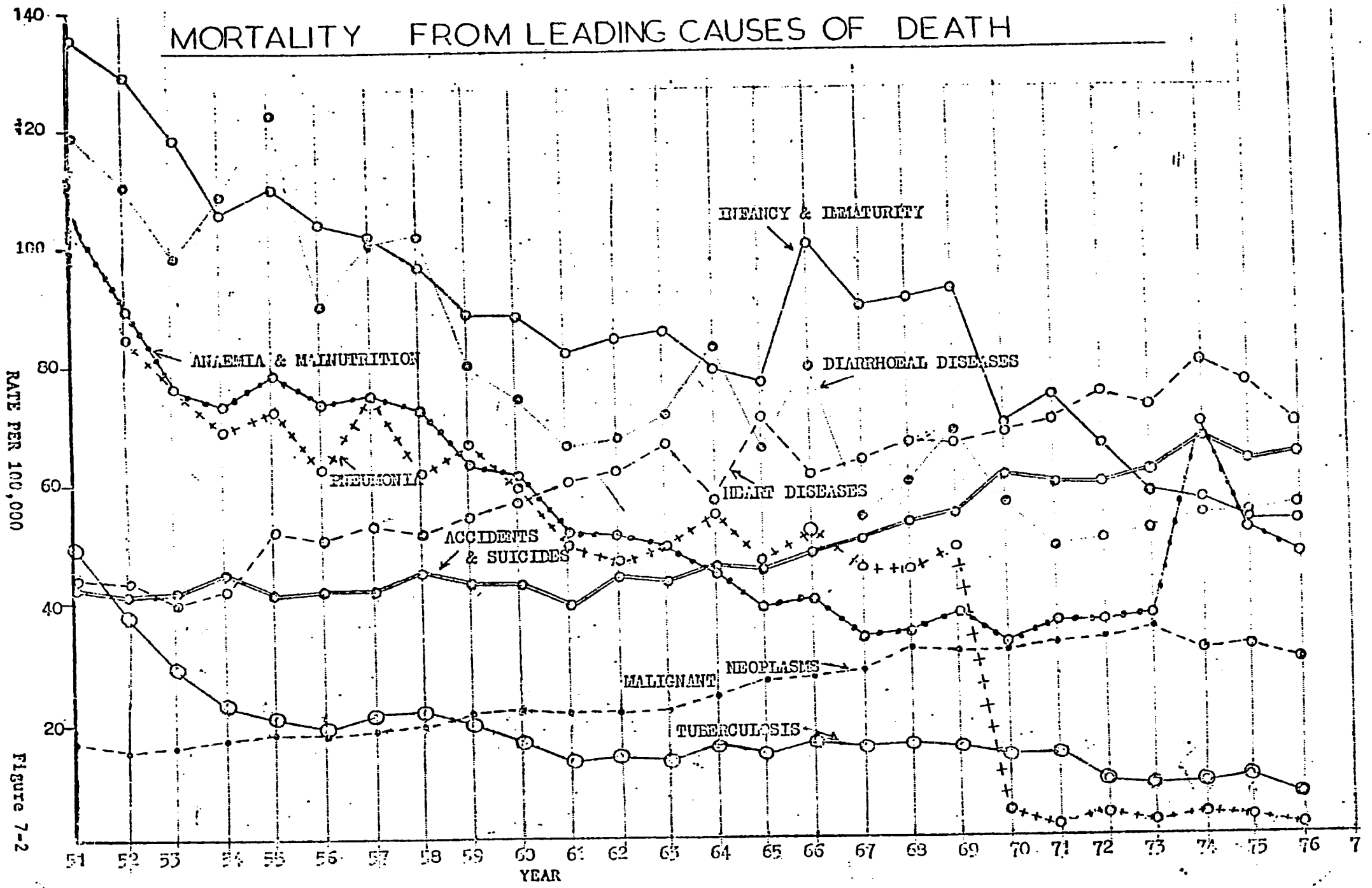

Figure 7-2

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Table 7-1

Reproductive State of *A. culicifacies* Collected in Human Habitations in Sri Lanka During 1971 - 72

Condition of DDT on Walls	No. of Mosquitoes	Percent		
		Bloodfed	Semi-Gravid	Gravid
Newly applied	2013	78.5	14.0	7.5
Overdue for spraying	664	56.5	19.7	23.8

Table 7-2

Source of Blood Found in Midguts of Engorged *A. culicifacies* Captured in Human Habitations in 28 Localities in Sri Lanka

Vertebrate Host	No. Diagnosed by Prescription Test	No. of Total
Man	420	49.5
Bovid	302	35.6
Dog	101	11.9
Pig	1	0.1
Sheep/Goat	4	0.5
Unidentified mammal	18	2.1
Bird	2	0.2
Total	848	-

Table 7-3

Age and Sex Distribution of Persons Infected with Malaria During 1978

Sex	Years of Age	No. Infected	Percent of Total Infected
Male	-	41635	59.7
Female	-	28050	40.3
-	0-1	646	0.9
-	1-5	7020	10.1
-	6-15	15313	22.0
-	15+	46706	67.0

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Table 7-6

Mortality of Adult *A. culicifacies*
Exposed to .4% DDT for 1 Hour

Year	No. of Tests	No. of Complete Kills	No. *A. culicifacies*	Percent Mortality
1962	5	3	360	99.4
1966	2	1	149	98.0
1968	5	0	387	69.7
1969	8	0	468	44.0
1970	13	0	777	40.1
1971	5	0	233	30.3
1972	14	0	484	36.8
1973	5	0	286	47.2
1976	3	0	467	36.5
1977	7	0	641	32.3
1978	9	0	446	41.0

Table 7-5

Insecticides that Killed All
A. culcifacies Tested in 1978
within 1 day After Exposure

Insecticide	Concentration	Hours of exposure	No. localities	No. Mosquitoes
Malathion	5%	1	15	416
Dieldrin	0.4	1	4	203
Fenitrothion	1.0	½	4	150

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Table 7-6

Amount of Insecticide Consumed
by Anti-Malaria Operations
(in pounds)

Year	DDT	BHC	Malathion	Fenithrathion	Anticipated Malathion Requirements (1)
1964	96,559	-	-	-	
1965	213,981	-	-	-	
1966	232,879	-	-	-	
1967	998,698	76,626	-	-	
1968	2,688,178	-	-	-	
1969	2,394,371	-	-	-	
1970	2,180,841	-	325,564	-	
1971	887,960	-	168,173	-	
1972	1,814,119	-	42,882	-	
1973	2,266,740	-	172,031	-	
1974	2,223,095	-	121,842	-	
1975	1,699,276	-	1,010,694	-	
1976	696,349	-	1,890,471	-	
1977	-	-	2,639,593	2,984	7,500,000
1978	-	-	4,540,262	10,608	7,500,000
1979					5,000,000
1980					3,000,000
1981					2,000,000

(1) Pounds of malathion anticipated in 1977 (Sri Lanka/WHO Agreement)

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Table 7-7

Bioassay Mortality of Various *Anopheles* spp. Held 1 Day After ½ Hour Exposure to Sand Surfaces Sprayed with 2g Malathion/m^2(1978)

Days After Spraying	Mosquitoes Exposed	
	No.	% dead
1 - 30	859	78.5
31 - 60	880	54.3
61 - 90	120	77.5
91 -120	70	35.7

Table 7-8

Prevalence of Microfilaria-Infected Residents of the Southwestern Coast of Sri Lanka

Residence	Diagnosed by			
	Membrane Filtration		Thick Blood Film (3)	
	No. tested	% micro-filaremic	No. tested	% micro-filaremic
Peliyagoda	248	12.5	294	4.8
Maligawatta	200	7.5	257	4.7
Kandana	106	5.7	111	0.9
Totals	554	9.4	662	4.0

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Table 7-9

Frequency of Self-Diagnosed Malaria in Several Rural Communities Near Kokirawa and Frequency of Reporting to Government Instituions

Harvest period	Total questioned	No. Families: Reporting illness	No. Families: Reporting malaria	No. Malaria Episodes: Total recorded by families	No. Malaria Episodes: Reported to Government institutions
Yala 1977	218	204	175	788	26
Maha 1977 - 78	128	118	35	47	7
Totals	346	322	210	835	33

Source: Silva et al

Table 7-10

Distance Travelled by Self-Diagnosed Patients Seeking Treatment for Malaria

Miles Travelled	No. Patients	Percent of Total
0 - 1	12	26
1 - 2	11	24
2 - 3	6	13
3 - 4	1	2
4 - 5	1	2
5+	15	37
Total	46	-

Source: Silva et al

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Table 7-11

Issue of Anti-Malarial Drugs
by the Anti-Malaria Campaign

Year	No. Tablets				Choroquine Injections
	Camoquin	Chloroquine	Primaquin	Daraprin	
1976	9,513,000	7,359,000	10,406,110	1,084,000	4,205
1977	16,744,000	540,000	20,335,000	985,000	2,505
1978	11,245,831	730,000	7,942,000	178,200	2,930

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CHAPTER 8

SOCIAL SCIENCE

INTRODUCTION

This chapter constitutes a preliminary effort to identify the major social impacts of the Accelerated Program of the Mahaweli Development.

One of the primary objectives of the Accelerated Program is social: to alleviate problems of landlessness and unemployment in Sri Lanka by providing plots to small holders on previously underutilized lands, which are either currently uncultivated for lack of sufficient water or are under chena cultivation.

If successful, the project will provide higher incomes and improved standards of living to the villagers currently living in the area. It will provide viable employment to the farmer settlers who are selected to settle the newly opened areas. After a number of years, the settlements will become viable communities which are pleasant to live in, and which are self-sustaining and autonomous. In addition, they will provide employment for shop-keepers, teachers, wholesalers, professionals and a range of occupations, necessary for the creation of integrated agricultural communities.

Largely in order to achieve the social objectives of increased employment opportunities for landless and poor, the decision has been made to limit the size of farm plots to one hectare. It has been estimated that this size plot can be farmed with family labor, by a settler family. Therefore, these small plots will provide independent employment for a larger number of settlers. In addition, it is assumed that the other primary objective, agricultural productivity, will be achieved by insuring the ~~intensive cultivation~~ of one hectare plots.

The social goals of the project, if achieved, constitute important positive social impacts. If they are not achieved, the

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negative social impacts will include the cost to settlers of relocating and abandonment of land. In this assessment it is necessary to consider whether the social goals are likely to be achieved. In addition, it is necessary to consider whether there will be unanticipated social effects which will need mitigative solutions.

EXISTING CONDITIONS

There are two distinct populations which will be most affected by the Accelerated Mahaweli Program. These are the people currently living in the project area and the settlers from outside who will be recruited into the area.

Current Residents

The Project Area is currently sparsely populated. Most of the land is state owned and cannot be alienated to private ownership except by government decree. There are traditional dry zone purana villages in the project area. Typically, these farming villages rely on two types of crops: 1) a rice crop produced below the village tank; and 2) upland crops relying on chena cultivaion. They also rely on fruits and vegetables cultivated on the homestead plot.

The distinctive feature of these villages are their self-sufficiency, their reliance on subsistence agriculture, and their relative isolation including, in some cases, inter-marriage among themselves. Villagers are considered to have legitimate title to these traditional village lands.

New villages in the area are of two principal types. There are residents of government or private company settlement schemes and new residents holding illegal title to land. These latter residents are considered encroachers, and their status remains to be decided in the Mahaweli Development Program.

As settlement planning proceeds for each of the designated systems, the Settlement Planning and Development Division has carried

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out socio-economic surveys of the systems. The surveys of Systems B and C are now complete, and the information which follows is based on these two surveys. (Mahaweli Development Board, Settlement Planning and Development Division 1979a, 1979b).

System C

System C contains a southern portion, roughly south of Aluttarama, which consists of developed agriculture including three development colonization schemes near the Sorabora, Mapakada and Dambarawa Tanks. The population of this area was enumerated at 23,340 in 1979. This area is considered already developed and not open to settlement and development under the Mahaweli Development Program. It will, however, benefit from the additional water supply provided by the project.

North of this zone, in Badulla District, there is sparce population totalling 5,197. This population includes some purana villages: Giranduru Kotte, Hebarawa and Aluththarama. It also includes the remnants of a Department of Agriculture and Land Commissioner's Department Youth Colonization scheme. The Ceylon Tobacco Company has developed a colony with intensive paddy cultivation. In 1966 the government allocated large extents of land in this area for agriculture to the private sector. These leases have since been withdrawn; the land is currently cleared but not cultivated. A number of new villages exist, made up of recent encroachers. Some are on lands which were earlier part of special leases. The number of encroachers is highest in this area.

The total population of the remainder of System C was enumerated at 1,239. The northern section is covered with jungle and contains the purana villages of Yakkure, Kalukelewa and Ellawewa. The central portion contains the purana village of Lamaniyawela. The only important settlement in the area comprises about 70 families below the Henanigala Tank.

A large proportion of land currently occupied is occupied by encroachers. Private ownership accounts for 39 hectares of paddy

and 21 hectares of upland. The largest unit of privately owned paddy land is 8 hectares. Other legitimate forms of land ownership include lands given out under the Land Development Ordinance (LDO) and Annual Permits for the cultivation of paddy and subsidiary food crops. See Table 8-1.

Table 8-1

Land Ownership - System C.
(in hectares)

	Paddy Land	Upland
Private Land	39	21
LDO Lands	130	171
Annual Permits	132	85
Encroachments	319	706

Source: MDB, Settlement Planning and Development Division 1979b

The population of System C is made up almost entirely of Sinhalese. According to reported income, 68 percent of the households earned below Rs.3,600 per year.

System B

System B contains a large number of Purana villagers. Karapola, Mutugala, Katawanwila, Alinchepatana, Soruwila, Alavakumbura, Manampitiya, Damminna Vilayaya, Akkuranai, Pettanai Kallichchai and Maduangani were identified as purana villages by the survey. The ethnic group balance is more diverse in System B than in System C. Some Purana villages are inhabited by Tamils. Two muslim villages (Alenchipatana and Katawanwila) are similar to Purana villagers in their isolation. According to this report there are four original Vedda villages: Millana, Dalukana, Ellewewa and Murutanai, but all four have lost their original character.

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There are two major colonization schemes in System B. The Pimburattewa colonization scheme was completed in 1976, comprising 1,400 families with 1.2 hectares of paddy and 0.8 hectare of upland each. A smaller scheme at Wadumanai was settled with 126 families. This latter scheme has not been entirely successful and many of the settlers have returned to their original villages.

Four other planned communities exist in System B. Three livestock farms at Trincomade, Kandakadu and Walikanda are located in the northern part. Two Kenoff farms have been opened at Welikanda and Punani by the Sri Lanka Cashew Corporation and the National Paper Mill Corporation.

The number of encroachers is large and growing. New villages, such as Kumarapura, Suoryodi and Pullegardi, have been established along the Polonnaruwa-Batticaloa highway. Encroachers have moved into the Pimburattewa Irrigation Scheme. In some cases the tenancy status is unclear. Under the food production campaign in 1973-77 lands under small tanks in Polonnaruwa District were allocated, but annual leases were never distributed. Many of these lands have since been abandoned.

In Batticaloa District, settlers left the tea and rubber plantations after communal disturbances in 1977 and settled at Mulliwatawan, Punchi-Kataragama and Myllantanni. Some of these settlers claim that they followed an announcement of new land availability in the local newspapers. Some of the settlers stated that they were settled by the Batticaloa Rotary Club and provided development assistance by them.

The total population of System B was enumerated at 25,515 at the time of the survey. This includes 6,760 residents of the Pimburettawa major colonization scheme. The Sinhala population account for 64.5 percent of this total, followed by 25.5 percent Tamil and eight percent Muslim. In general, the Sinhala population tends to be prevalent in the western portion, or Polonnaruwa District, while the Tamil population predominates in the eastern portion, or Batticaloa

district. The portion of Batticaloa district which comes within System B is sparsely populated, mainly because of the Maduru Oya floods. However, in the villages adjoining System B, there is a dense population.

The number of legitimate landowners living in the area is 1,148 (excluding settlers of Pimburettawa). Of these, only 126 own more than two hectares, and all but eight percent own more than 0.2 hectare. The number of encroachers was enumerated at 2,736, of which 26 percent have arrived since 1976. There are also a sizable number of absentee landowners; official sources list 2,285 people living outside System B with allotments over 2 hectares, under LDO permits and leases under the Crown Lands Ordinance.

According to reported income, over 51 percent of the families in the area earn less than Rs.3,000 per year. Another 25.8 percent earn between Rs.3,000 and 6,000 per year. The average family size is 4.8.

New Residents

New residents to the Accelerated Program area will include settlers, together with project management, professionals, shop keepers, agricultural laborers, craftsmen, merchants, construction workers and others. The new settlers will be selected according to criteria currently being developed by the Mahaweli Development Authority; many will probably be resettled from areas flooded by the Victoria and Kotmale reservoirs.

Estimates of the number of new settlers is based upon land use plans. Principally, the method involves estimating the amount of irrigable land which will be available in the system, and assuming one settler family for each hectare of irrigable land.

The estimated number of new farm families which will be settled in System C is 20,390 (Ministry of Mahaweli Development Hunting Technical Services, 1979, Q59). With five persons per family

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this represents an influx of 101,950 people by 1985.

The estimated number of new settler families to be settled in System B is 31,660, or using five persons per family, 158,300 people. To these figures should be added an additional 20 percent or 10,410 families (52,050 people) for both systems representing the non-farm population which will be drawn thereto. (Ministry of Mahaweli Development, Acres International, 1979).

The estimates for the entire Mahaweli Accelerated Program are currently 140,000 new settler families, and including other service staff, about a million people. (Fernando, 1979).

In selection of settlers for the accelerated program area, it is assumed that priority will be given to residents of Teldeniya town and Kotmale, areas which will be inundated by the Victoria and Kotmale reservoirs. Special priority may also be given to families among second generation settlers in nearby districts.

The general criteria for selection will follow those currently in use by the Mahaweli Development Board in System H. These are based on a point system taking into account age, size of family, tenurial status, occupation, health, cultivation practices, membership in village organizations and possession of other non-farm skills.

In general, the objective is to select, among the small farmers or landless, people who show agricultural and cooperative skills, in other words, people who will make successful settlers.

Settlement authorities have recently become aware of the need to actively plan for the arrival of non agricultural families. Currently, in System H, non agricultural families wishing to open shops or small factories in the project area may apply for an upland allotment. In the Accelerated Program area these new residents may be selected according to a system of criteria, on the model of the criteria for farming populations.

Professionals in the fields of health and education will be recruited through the normal process of national recruitment.

SOCIAL IMPACTS

The principle social impacts, which have been identified by current reports, sociological studies, and interviews with project officials, are outlined below. Areas were identified which look, at this time, most problematic since these are the areas in which some kind of action begun now can have the most effect. This does not imply that all social effects of the project are problem areas. As stated in the introduction, the impacts are of two principle types: 1) those which, if not overcome, will threaten the achievement of the social objectives of the Mahaweli Program; and 2) those which are by-products of the achievement of those objectives.

Financial Viability of the Settler Family Unit

The most serious unresolved issue is whether or not settler families installed on one hectare plots will be able to become economically self-sustaining.

It is generally known that in most colonization schemes, including System H, there is a tendency for many small farmers to go into debt, to mortgage their land, and to, in effect, become share croppers on their own allotments. This is illegal within the context of the Mahaweli Program, but its illegality does not prevent it from happenning, although it does seriously impede investigations to determine its extent and consequences. (MDB Settlement Planning and Development Division 1979b, p 8; Ministry of Mahaweli Development, Japan International Cooperation Agency 1979; Ministry of Mahaweli Development, Hunting Technical Services, 1979).

The estimates that a one hectare plot can provide an income for a family using labor is based upon theoretically determined household budgets. (Ministry of Mahaweli Development, Hunting Technical Services, 1979, Vol. Agronomy). The issue of concern here is what

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actually happens to the family units which will be settled in the Mahaweli Program. What proportion will give up their land legally or illegally, and what proportion will eventually drop out of the system. This question seems crucial for the success or failure of the whole project; however, it is felt that insufficient information is available on what has happened in past schemes and insufficient monitoring is being provided for the present scheme.

The most serious effects which could occur if large numbers of settlers are unable to survive financially are

- abandonment of lands;
- unproductive farming systems based on absentee ownership and share cropping arrangements;
- failure to achieve project goals of enhancing the well being and agricultural capacities of the farmer settlers; and
- inability of the legal system to regulate claims since the terminal status is illegal.

Provision of Basic Infrastructure

One of the major impacts which can be foreseen is disillusionment and stress in the first phase of settlement if basic social infrastructure is not in place at the time the settlers arrive.

Speeding up the rate of implementation increases the probability that basic infrastructure and settler preparation will not be available at the time that settlers arrive.

According to current resettlement procedures, families are brought to the site and housed in large buildings while they build their own houses on the assigned homestead plots. For the accelerated program the schedule includes bringing in potential male settlers to serve as a labor force for construction of canals and bunds with families to follow at the time of actual settlement.

There is considerable debate over how many services need to be available at the time settlers arrive. A minimal list should include: schools, roads, community centres, a source of drinking water, a shop where food and bare necessities can be purchased, minimal health services, a malaria spraying facility, latrines, means of transport within and out of the area, and adequate orientation and information to new settlers.

Failure to provide for the basic immediate needs of settlers will result in low morale, lack of trust in project management, and an increased rate of settlement failure.

Formation of Cohesive Communities

Past experience with settlement communities has produced situations in which settlers remain isolated and fail to develop a sense of a community even after years of living in the project. Examples include neighbours who do not know each other and lack of trust to leave home plots unattended. A related phenomen is failure to cooperate on irrigation facilities. Gates are frequently broken, water is over-utilized, and people at the tail end of the turnout get inadequate water.

The primary impact, if this situation is permitted to develop in the accelerated program area, will be a deterioration in quality of life, and a withdrawal from community participation. When settlers fail to participate in the decisions of the project, they revert to a situation of dependency on project management. This is frequently accompanied by resentment of management for not providing for all their needs.

Attraction and Provision for Non-Farming Activities

While 80 percent of the current inhabitants of the Mahaweli area are engaged in agricultural pursuits, the future population should have a large proportion of the population engaged in trade and

industry. If the development objectives are to be met, then the farming populations in the resettled zones will become involved in commercial farming. This cannot occur without expansion of the trade sector and possibly the processing industry in the area. This will require a sizeable influx of non-farming families and institutions.

Recently, plans have been formulated to set aside highland homeland allotments for non-agricultural families and for workers.

Failure to adequately attract and stimulate non-agricultural activity in the project zone will result in reversion to subsistence agriculture.

The effect of the influx of this population on the farming population needs also to be considered. Will farmers be able to sell their land and go into trade or rent land and go into trade? Will there be restrictions on the size of industries, as there is on the size of farms?

Roles of Women

Because the program is based upon the social unit of settler families, recent attention has been given to the importance of the wife in making the settlement successful. Based on this understanding, the wife's characteristics are now being considered as part of the selection criteria for settler applicants. The wife, however, is not recognized as a joint owner of settlement plots, although she can inherit under certain conditions.

Some past studies have several effects of settlement experience on women. They become relatively more isolated than they were in previous villages, because the women's community is smaller and less cohesive. They have more responsibilities, and, because there are fewer people to take care of children, they lose some mobility. They may work harder than previously in the fields. They

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tend to take responsibility for the garden plots. (Lund. 1978).

Farm Labor

Estimates for size of plot are based on the assumption that farm labor will be supplied by the settler and his family. In reality, this does not appear to be the way farm labor is organized. Rather, even on small plots, almost all rice farmers employ outside labor. A study in System H revealed that only six percent of all farmers cultivated their lands with family labor alone. Outside labor was especially necessary during sowing and harvesting when most persons were hired for wages plus food and sometimes lodging (Man and the Biosphere Programme, 1978). Project managers in the existing Pimburettewa scheme in System B have already noticed a shortage of hired agricultural labor in that area.

This raises the issue of the project responsibility for hired laborers drawn to the project by settlement. May they also, for example, be applicants for land in new settlement schemes?

Planning for Special Cases

General settlement policies are meant to be equitable to all. It is difficult to take into consideration, during the formulation of these policies, all of the special and individual cases.

The current policy with respect to persons living in the project area is that families will be compensated for their lands by provision of one hectare of irrigated land under the new system. Those who own more than one hectare will be paid compensation.

The following represent cases which have been identified and for which special planning may be necessary.

Encroachers - According to government policy some encroachers will be eligible for selection to be resettled. Some provision

will have to be made for those not selected.

Non-agricultural Labor Force - Not all families in the Mahaweli area are skilled agriculturists. Some may not wish to become farmers, and some may not be sufficiently skilled. There are, for example, fishermen for whom settlement schemes are endorsed in Chapter 3. What other options are open to those forced to resettle?

Traditional Villages - There is always stress involved in moving and in relocation. The premise is that upgrading agricultural lands, while preserving villages, will be a preferable alternative whenever this is possible. Study needs to be made of where and how this can be accomplished.

Project Failures - Not all candidates become successful settlers. Little is known about what happens to people who drop out of settlement schemes. What savings do they fall back on?

Unequal Productivity of Land - Not all land is of equivalent value. Little is known about the attitudes and reactions of those settlers given less productive plots.

Loss of Chena and Pasture Lands - Villagers currently rely upon a combination of chena cultivation, garden plots and paddy cultivation. In future systems they will lose the chena crops and pasture land. More should be known about real attitudes towards this change in production system.

Large Landowners - In past schemes it has taken considerable time for landowners to be compensated for lands owned in excess of one hectare. With the loss of land, these owners lose traditional status within the community. This would seem to be a problem for future cohesion of communities.

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RECOMMENDED ACTIONS

The following list is intended to suggest the kinds of action which might be taken to mitigate the problem areas identified above. It includes actions which are currently under consideration by the Government of Sri Lanka.

Viability of Settler Family Unit

This is an area which may require study to determine:

- the real land tenure arrangements in new and existing settlement areas;
- the amount of debt of settler families during the first five years and realistic estimates of the resources necessary for a new settler family;
- the percentage of farmer families expected to be financially sound in five years; and
- what happens to settler families who fail.

Mitigation measures include:

- policies to increase employment opportunities for all family members; (This includes current policies to utilize settler labor for irrigation maintenance and construction; it may include recruitment of, for example, teaching staff from within the project area.)
- provision of agricultural credit under realistic terms;
- community development programs currently emphasizing: income generating activities for women, understanding of principle of farm management and responsible utilization of agricultural credit; and
- increasing opportunities for failed settlers to move into other occupations within the project area.

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Provision of Basic Infrastructure

Based on a study of the real time table of settlement and provision of basic infrastructure, a possible action might be to slow the pace of the settlement to match provision of infrastructure and adequate orientation of settlers.

Formation of Cohesive Communities

Much of the current work in community development in System H is designed to alleviate this problem. Plans for mitigation include:

- organization of farmers based on turnout groups;
- organization of groups prior to settlement including acceptance of group applications;
- relocation of existing villages in new hamlets; and
- organization of community programs and activities.

Non-Farming Activities

This area needs review of policies to encourage commerce and industry within the accelerated program before specific recommendations can be made. Special emphasis should be made on creating markets for produce other than paddy.

Roles of Women

Classes especially for women are currently being conducted under community development activities.

Further attention might be placed on women's responsibility for household budgets and participation in family savings. Women should be included in programs to increase understanding of the

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household as a financial unit and the responsibility of that unit in agricultural credit programs.

Farm Labor

Study needs to be made to determine the number and financial condition of farm laborers who will be drawn to the Project Area.

Planning for Special Cases

Possible mitigation measures include:

- regularization of the status of encroachers;

- a survey which will help determine options for new agricultural families; (This is being considered in present planning whereby families will be asked their preference for adaption to the new settlements. Source: Mr. A. D. N. Fernando, Mahaweli Development Authority, personal communication.)

- early identification of villages which can be preserved without relocation; and

- division of land into plots of equivalent production value rather than equal size if such is practicable.

General Recommendations

Regional Planning - The settlement of a million people in an area currently sparsely populated will impose a drain on all the existing infrastructure, including market centers, roads, health and education, security systems, courts, and local government both inside and on the periphery of the project area.

The planning of these areas needs to be done from a regional

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perspective, and this work should be carried out concurrently with the design of canals and other irrigation structures.

Town Planning - Experience in System H is demonstrating that the layout of towns and hamlets is a complicated task.

In add provision for homestead plots and community buildings, provi be made for zoning for firewood plots, pasture land, ces, boutiques, and small industries. Also provision must for future flexibility with respect to community growth, diver development. Community participation must be sought as possible in these decisions.

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CHAPTER 9
WILDLIFE

EXISTING CONDITIONS

Introduction

Much of the information published on the fauna inhabiting the Accelerated Mahaweli Programme area refers to its general distribution over Sri Lanka and its taxonomy. There is very little site specific ecological information available for this area, particularly on the important elements of the fauna such as the elephant, leopard, bear and other large mammals. In order to augment the limited baseline information, TAMS has organized three wildlife survey teams comprising TAMS' wildlife ecologists, faculty members of the universities of Sri Lanka and other interested individuals. The major objectives of the field studies are given in Appendix 9.- I

Since mid-November 1979 the wildlife survey teams have spent about 230 man-days collecting field data from Systems A, B, C and D. This information was collected during the wet season and will be compared to data from the next dry season for analysis in the final report. However, initial results obtained from these surveys are incorporated in the following discussion where applicable.

Wildlife Habitats in the Project Area

The Accelerated Mahaweli Programme area includes a very large proportion of undeveloped land. Systems A, B, C and D for example comprise a total of 154,300 hectares of irrigable land of which 114,700 hectares are undeveloped areas. These areas essentially consist of a wide variety of wildlife habitats such as, villus, grasslands and numerous forest types. As a result a large proportion of this undeveloped land was

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proclaimed as wildlife reserves through legislation passed over the last several decades. At present there are wildlife reserves whose boundaries fall totally within the Accelerated Mahaweli Programme area (Table 9-1). A major portion of 32,800 hectares of the Veddikachchi Intermediate Zone is included within the overall development area. The Nelugala Corridor which is 10,400 hectares in extent falls entirely within System B, and the Somawathiya Sanctuary which is 22,275 hectares in area lies adjacent to this system. In addition, there are five established forest reserves (Figure 5-1) which significantly increase the total area of suitable wildlife habitats found within the Accelerated Programme area (Table 9-2).

Wildlife Diversity

The Accelerated Mahaweli Development area includes a wide variety of animals. The vertebrate fauna alone consists of several species of fish, amphibians and reptiles, a majority of the 251 resident bird species found in Sri Lanka, and large mammals, such as the elephant, leopard, bear, deer and sambhur. In addition, during the winter months at least 75 bird species migrate into this area from Europe and other distant places. Nearly 20 of these species belong to a single family but the full complement of migrants represents over 25 bird families (Table 9-3). Consequently, these visitors contribute variety to an already abundant fauna. Bird species observed in the recent TAMS wildlife surveys are listed in Appendix 9-II.

The fauna of the project area utilize a wide range of habitats as exemplified by the migrant birds. Shore birds such as sandpipers and plovers, and ducks, terns and gulls take up residence close to water. A large number of migrant wagtails occupy riverine habitats while the flycatchers, warbles and thrushes utilize forests and dense scrub. The kingfishers live in swamps and lagoons and the harriers frequent open marshes.

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Endemic Species

The project area is the natural habitat of a number of endemic animals, i.e. those found only in Sri Lanka and nowhere else in the world. In order to obtain the most current information on this unique component of Sri Lanka's fauna (and flora) in the project area, TAMS sponsored an Endemic Species Workshop in December 1979 at the Natural History Museum in Colombo.

The workshop was attended by representatives of several local and foreign institutions including the Department of Wildlife Conservation, Forest Department, Mahaweli Development Board, National Science Council, National Museum, the Universities of Colombo, Kelaniya, Matara and Peradeniya, Wildlife and Nature Protection Society, USAID and the Smithsonian Institution. The participants of the workshop identified 36 species of endemic vertebrates but indicated that many more may be found within the Accelerated Mahaweli Programme area (Appendix 9 - III). Their tentative list comprised five species of fish (see CHAPTER 3 FISHERIES), two amphibians, 18 reptiles, eight birds and three mammals. During the discussions it was pointed out that the Mahaweli Accelerated Programme area also included several endemic invertebrates and tree species but the participants felt that more information was required before the status, abundance and distribution of these species could be correctly assessed. Many of the participants indicated that riverine forests within the Accelerated Mahaweli Programme area were rich in endemic wildlife and expressed concern about the proposed clearing of these areas for agricultural development. It was agreed that extensive habitat destruction rather than direct killing posed the greatest threat to Sri Lanka's endemic wildlife.

The TAMS wildlife survey teams located two endemic amphibians and one reptile species hitherto unrecorded from localities within the Accelerated Mahaweli Development area

(Appendix 9-II). This increases the number of vertebrate endemics found within the project area to 39. The presence of 20 of these species was confirmed in the field, and sufficient data was collected on the habitat preferences of 16 of them (Table 9-4). These 16 species occupy a wide range of habitats from open grassland to high forest but each species sppears to have a narrow range of preferred habitat. Riverine forests was the preferred habitat of a majority of the species studied.

The endemic fauna of the localities visited recently were also studied between 1959 and 1962 by P.B. Karunaratne. Comparisons between the two studies indicate that many endemics such as the red-faced malkoha (P. pyrrhocephalus), Ceylon spurfowl (G. bicalcarata), purple-faced langur (P. senex) and an agamid lizard (Otocryptis weigmanni) are in general much less abundant now than before. These species are also absent from some areas of their previous range of distribution. The conversion of their natural habitat to agricultural land appears to be the reason for the reduction in numbers and area of distribution.

Endangered Species

The fauna of the project area comprises six endangered and two threatened animal species listed in the U.S. Federal Register (Table 9-5). This list includes the elephant and leopard. All of the endangered and threatened species found within the project area are found in other parts of Sri Lanka, and except for the toque macaque, purple-faced langur and the red-faced malkoha, are also distributed in other parts of the world. However, all eight species mentioned above are listed as threatened or endangered throughout their world distribution.

The TAMS surveys in the project area, have, through direct observations and indirect field methods, confirmed the presence of all eight endangered and threatened species. As indicated above, preliminary information from the field surveys suggest

that populations of red-faced malkoha and purple-faced langur are declining in certain parts of their distribution within the project area. Of the other endangered species the elephant was the most extensively investigated. Details pertaining to this species are presented in the following sections.

Elephant Populations - At the beginning of the nineteenth century there were an estimated 12,000 elephants in Sri Lanka (McKay 1973). In the 1840's and 1850's the British Colonial Government paid rewards for the destruction of 5,500 animals (Tennent 1863). During this period of decline, sport figured as one of the major reasons for the killing of elephants. Major Rogers, a mid-nineteenth century sportsman holds the record of having killed 1,100 elephants (Storey 1907). More recently, however, crop protection has been the chief cause for the killing of elephants. Between 1952 and 1957, 239 of the 475 known elephant deaths occurred during the alleged defence of crops (Sessional Paper No. 19, 1959). At present, there are probably a total of about 2,000 elephants in Sri Lanka (McKay 1973) of which an estimated 800 (40%) are believed to inhabit the project area (De Alwis, pers.comm.).

During the recent field investigations, an appreciably high degree of elephant activity was noted in several localities within the project area. The single largest concentration of elephants consisted of 88 animals, and was seen at Vellovillu which lies on the eastern border of Somawathiya Sanctuary. The behavior of these animals indicated that the aggregation consisted of several discrete social units varying in size from three to about 30 animals. Feces counts indicated high degree of elephant activity near Dimbulagala and along the main road leading to the Maduru Oya dam site. Both of these areas are found in System B. In System C a high incidence of elephant activity was noted at Henenegala kandiya and between Damanawila and Dehiattekandiya. Evidence of recent activity (i.e. approximately between 13 and 22 December 1979) was noted in six of the eight transects located to the north of Kuda Oya

and in at least one case, the intensity of activity was assessed to be relatively high.

Seasonal Movement and Habitat Use by Elephants - Interviews with local residents and available scientific information indicate several consistent patterns of elephant movements within the project area. The details of these patterns will be clarified on an area-by-area basis after data collection through the dry season.

In general, it appears that during the dry season several social groups of elephants periodically aggregate near permanent sources of water, such as rivers and tanks. In areas around the Hembarawa Tank (System C) and along the Mahaweli each aggregation sometimes consists of 100 to 200 animals. These aggregations utilize the perennial rivers and tanks for drinking purposes and for the grass at the water's edge. From these foci of activity each social group normally moves to somewhat different areas of nearby forests to supplement their diet with browse, but they return regularly to their dry season sources of water. The onset of the rains appears to terminate the elephant's period of dependence on perennial sources of water. Thus, in the wet season large aggregations tend to occur less frequently as social groups begin to disperse widely to areas which perhaps offer nutritionally rich food items.

The above pattern of movements has been described for the elephants of Wilpattu National Park by Eisenberg and Lockhart (1972) but McKay (1973) described a slightly different movement pattern for the Gal Oya elephants. The wet season dispersal of the Somawathiya elephants from the Mahaweli Ganga may be more related to factors other than food. In any case each social group appears to have at least two fairly large areas of intensive feeding activity. Some areas are used during the dry season while others are exploited during the wet season, and the social group moves between

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these areas on a regular basis. The total area used for feeding and movements is referred to as the home range of the group.

The size of the home range depends on several factors among which habitat conditions and size of the social group may be important, and this specific area is probably utilized for several generations by the social group. Consequently, each group exhibits a special attachment to its home range and cannot be easily moved out of this area. This view is supported by the Department of Wildlife Conservation's recent experience in attempting to drive elephants out of System H. Home ranges of neighboring groups however, may show different degrees of overlap and in these overlap areas the groups come into relatively close contact without conflict. Lone elephants also use specific areas of the habitat and sometimes intermingle with social groups which use the same area.

Crop Damage by Elephants - The extent of crop damage due to elephants was investigated in certain localities within the project area. Kantalai Sugar Corporation incurred a revenue loss of Rupees three million due to elephant activity between 1977 and 1979. Similarly, the livestock farms at Tirikonamadu, Kandakadu, Welikanda and Gālela regularly suffered considerable damage to their grazing area and property.

The wildlife survey team also assessed the extent of damage to paddy and other crops. The assessment was done in the agricultural area lying on the left bank of the Mahaweli between Hasalaka and Hettipola. Residents of four villages were interviewed and the information from Wilgomuwa provides some instructive trends (Table 9-6). In this village at least nine farmers suffered crop damage due to elephants on the nights of 17 and/or 18 December 1979. A total of 4.3 hectares of paddy was completely damaged and another 4.2 hectares were partially destroyed. Assuming an average production of about three tons of rice per hectare for this area and the price of paddy as Rs.1,900 per ton, the estimate of revenue loss

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due to complete damage incurred in the two nights amounted to Rs. 24,510. At least two of the farmers again suffered crop damage within the next ten days. Since all farmers of Wilgomuwa were not interviewed, the estimated extent of damage recorded must be considered minimal.

Either lone elephants or a single social group are generally responsible for recurring crop damage in any given village. Paddy fields at Wilgomuwa, however, were damaged by groups of six and 15 elephants (Table 9-6). In October 1979 both groups apparently entered a banana plantation and destroyed Rs.12,000 worth of produce in a single night.

The social organization of elephants and their naturally evolved systems of land tenure and habitat use help explain the temporal and spatial pattern of crop damage. Although some crop damage occurs during the dry season, it is far more frequent in the wet season. The elephant's dependence on permanent sources of water during the dry season and its wet season dispersal partly explain the temporal pattern of agricultural crop damage.

When home ranges of social groups of elephants are taken over for development, many groups lose all access to at least part of their home ranges. These displaced groups use the remaining areas of their home ranges and damage agricultural crops grown at the periphery of the developed area. The usual pattern of development also leaves certain land features (such as streams and rocky outcrops) found within the developed area in their natural state. Some of these natural land features, particularly streams, extend across the boundary of the developed area. This allows limited access for one or a few elephant groups to enter (e.g. along stream beds) portions of their home ranges which lie within the developed area. Consequently, agricultural crop damage occurs at the periphery as well as within the developed area and is the result of an elephant group's attachment to its particular home range.

Crop damage is most frequent during the early phases of development and it takes several years before even partial success is achieved in keeping elephants out of developed areas. As indicated before the Kantalai Sugar Plantations, which were established nearly 20 years ago, still suffer considerable damage from elephants.

Other Wildlife Species

As indicated earlier current information on many wildlife species is scarce. However, by the late 1950s the decline of several species had been documented (Phillips 1957). The factors which caused the decline were, human population increase, habitat encroachment, faster modes of communications and transport and commercial exploitation. Except for commercial exploitation other factors operate more intensively now, than nearly 20 years ago. Therefore, a continuing general decline of wildlife populations may be expected.

In addition to elephant and purple-faced langur discussed previously Phillips (1957) listed leopard, bear, sambhur, spotted deer, gray langur, toque monkey, flying squirrel and giant squirrel as some of the declining mammalian species. Among birds the comb duck and glossy ibis became extinct as breeding residents during the first 50 years of this century. Several birds of prey and water birds also showed substantial decline in numbers. Declining species of reptiles included the two species of monitor lizards and the swamp crocodile. Populations of three bird species, however, had increased i.e. house crow, black crow and mynah.

The recent field studies documented the population increase of rose-ringed parakeet, spotted munia and white-backed munia. Bird censuses in different habitat types showed that the parakeet and the munias were absent in undisturbed areas but present in disturbed habitats and forests near paddy or chena cultivation (Table 9-7). At Polonnaruwa,

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parakeets accounted for 50% of the total numbers of 24 species censused in areas near paddy cultivation. Available information suggests that parakeets and munias adapt easily to modifications of natural habitat and proliferate quickly to reach pest proportions.

Crop Damage by Other Species - Besides elephant other wildlife species such as parakeets, munias and wildboar have been identified as agricultural pests causing considerable economic loss. Parakeets appear to be the most serious pest to rice and other food crops. The extent of damage done by them and the munias is currently being estimated but the depredations of the wildboar has already been assessed. At Kantalai a systematic study of sugar cane damage showed an annual yield loss of 18% and a revenue loss of Rs.5.9 million due to wildboar activity (Rajendra 1973). In fact, at Kantalai the wildboar appears to cause more serious damage to sugar cane than elephant. The economic loss however, is cumulative.

Flora

Wildlife includes the flora as well as the fauna of an area. The Accelerated Mahaweli Development area contains at least three endemic genera of plants. A. Kostermans, Visiting Professor at the Department of Botany, University of Peradeniya has tentatively identified 53 endemic plant species and 23 endangered plants within the development area. Seventeen of these species are endemic as well as endangered. Furthermore, a number of plant species found in this area are regarded as prime candidates for the production of new drugs which may be used in the treatment of cancer and other human maladies (Table 9-8). Antifertility compounds have been identified in 18 plant species and the World Health Organization is presently investigating the extraction of these chemicals (Table 9-9). Many of the plants are also used in the traditional medical system called Ayurveda.

Existing Institutional Capabilities

The Department of Zoology at the University of Peradeniya have two faculty members who are qualified terrestrial ecologists. The other universities have specialists in marine and soil ecology and limnology. However, faculty members of all universities are fully occupied with lecture schedules and find little time for wildlife field research. A shortage of vehicles also limit their activities. In the past therefore, wildlife ecology was not taught as a special course at the universities. However, this academic year the University of Colombo has inaugurated a post-graduate program on environmental sciences. It is hoped that some students following this program will qualify next year and at least partly fill the need for wildlife ecologists in the country.

The Department of Wildlife Conservation is responsible for the formulation and execution of the fauna policy of Sri Lanka. This department has its central administrative office in Colombo and operates on an annual budget of about Rs.6½ million (U.S.$390,000). Nearly 85% of the budget is spent on salaries, permanent structures and capital equipment while nothing is allocated for scientific research (Appendix 9 - IV).

The cadre of the Wildlife Department includes six administrators, several clerks, typists and 412 field personnel. Only two people in the entire department hold basic zoology degrees and both are charged with administrative duties. The educational qualification of about 90% of the field personnel is eighth grade or lower.

The field personnel are entrusted with the responsibility of maintaining 58 wildlife reserves which come under the department's purview. About 65% of them are stationed in the five National Parks while the remainder are scattered over the other 53 wildlife reserves. This disparate distri-

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bution of personnel is partly due to the fact that the National Parks contribute a fairly large proportion to the total area of wildlife reserves and partly because of heavy tourist pressure on the National Parks. In any case, at present a large number of wildlife reserves are inadequately manned and thus poorly protected from habitat destruction, human encroachment and poaching. The problem of inadequate staff is aggravated by the lack of vehicles for transport and communication. The department has a pool of only 29 jeeps and three motor bicycles at its disposal. As such the officers manning many of the wildlife guard posts do not have any mode of conveyance. The net effect of the existing situation is that small and scattered groups of the department's personnel undergo a great deal of personal hardship and harassment to effectively discharge their official duties.

Social Values With Respect to Wildlife

> "The forest is a peculiar organism of unlimited kindness and benevolence that makes no demand for its sustenance and extends generously the products of its life activity; it affords protection to all beings, offering shade even to the axeman who destroys it" - Gautama Buddha.

> "O great king the birds of the air and the beasts have an equal right to live and move about in any part of this land as thou. The land belongs to the people and all other beings and thou art only the guardian of it" - Arahat Mahinda to King Devanampiyatissa circa. 300 B.C.

Conservation of nature and concern of wildlife are extremely old traditions in Sri Lanka and dates back to the spread of Buddhism in this country. Historically, therefore, a high social value has been placed on wildlife through religious and cultural practices. Nevertheless, some of the

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present trends of human endeavors bring men into severe conflict with wildlife. Thus wild animals are generally viewed as an obstacle to man's progress and destroyed, but it is interesting that this destruction most frequently occurs through indirect methods, such as habitat modification. Social values prevent the direct killing of wildlife although this sometimes does occur. However, the recent shooting of three elephants caused sufficient concern to be highlighted in the local newspapers for at least two weeks. This clearly shows that old practices die hard and traditional values are extremely difficult to change. Traditional values are maintained even in this age of economic progress.

The conflict between traditional values concerning wildlife and economic progress arises from the lack of understanding of the intimate relationship between wildlife and its habitat. Consequently, wild animals (and traditional values) are destroyed indirectly through habitat encroachment (and economic progress).

In the past, "development" programs were designed disregarding wildlife and problems related to it. After the implementation of the program, however, the task of facing wildlife problems has fallen directly on those who lived on the "developed" land, i.e. the Sri Lankan peasantry. Ironically those who faced the greatest problems were the same as those that the "development" program was designed to help most.

Traditional values play an important role in mitigating the gravity of improper planning and development. The peasant who is affected by wildlife problems usually resigns himself to his "karma" or fate. Sometimes frustration leads to a breakdown of social norms and the peasant may directly kill wildlife to save his livelihood.

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Current Awareness of Wildlife Problems

Although there is a general lack of understanding of the cause and nature of wildlife problems there is a growing awareness of these issues and a belief that they should be resolved. It must be noted that the very fact of this report indicates a new sense of awareness of the wildlife problems. The Accelerated Mahaweli Project was the first program in the recent history of development in Sri Lanka which included the Department of Wildlife Conservation in the discussions for planing agricultural development. Recent articles in the newspapers and radio talks on wildlife and conservation also reflect the current concern for wildlife and its problems. This augurs well for the future of Sri Lankan wildlife whose problems could be resolved through careful planning and some foresight. Resolution of these problems would also go a long way in benefitting human welfare.

IMPACT ANALYSIS

Habitat Alteration

General - The extensive elimination of natural habitats is undoubtedly the single most serious problem which threatens the survival of the wildlife found in the project area. Nearly 75 percent of the project area consists of undeveloped land comprising numerous types of natural habitats. Habitat alteration will result from changes in the pattern of water resources, deforestation and also probably from salinity intrusion in the lower reaches of the Mahaweli and Maduru Oya. At the local level this must not be considered as a problem for wildlife alone, but as an issue of paramount importance from the scientific, agricultural, economic and social viewpoints. Under the global trends of deforestation which were recently highlighted at a conference sponsored by the U.S. Department of State and USAID habitat destruction must be of international concern as well. The major conclusion which emerged from this conference reads as follows:

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"The world is being confronted by an extremely serious problem with immediate and long-range socioeconomic and ecological consequences as the result of the accelerating loss of forest and vegetative cover in the humid and semi arid lands within or near the tropical latitudes. Further the community of nations must quickly launch an accelerated and coordinated attack on the problem if these greatly undervalued and probably irreplaceable resources are to be protected from virtual destruction by the early part of the next century."

Modification of natural ecosystems will result in the reduction of present carrying capacity for most wildlife species and the consequent decline of their populations. Species which have a history of declining populations may be completely eliminated from the project area. The consequences of the loss of species is not entirely clear. It is evident however, that the species which will be eliminated are unknown or how these species would be of help to mankind in the future. Furthermore, it is possible that the genetic stock of wild plants for the production of fast growing agricultural crops may be substantially reduced or completely lost.

A few species which adapt to habitat change, e.g., wildboar, rats, parakeets and munias will proliferate further and may become more serious agricultural pests within the project area. This in turn, will adversely affect potential crop production.

Extensive elimination of natural ecosystems will crowd several animal species into the remaining parts of their habitats. Excessively crowded animals usually suffer from food shortage and over exploit their environment. At high population levels some species also exhibit a high frequency of behaviour patterns that are deleterious to their own populations, e.g., infanticide in the gray langur and the purple-faced langur (Rudran 1973). These factors can subsequently lead to significant declines in populations. Such declines have been documented for rodents, deer, primates and elephants in different parts of the world and may also occur within the project area.

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Effects on Forest and Wildlife Reserves - All five of the proclaimed forest reserves located within the project area have been taken over from the Forest Department and slated for development in the Accelerated Mahaweli Programme. The entire Nelugala Corridor, a large portion of the Somawathiya Sanctuary and the Veddikachchi Intermediate Zone falling within the project area are also slated for development. Forest and wildlife reserves comprise only 19 percent of Sri Lanka's total land area and do not meet the minimum requirements of forest cover. When Sri Lanka gained independence nearly 30 years ago 50 percent of the climatic zone which includes the Accelerated Mahaweli Programme area (i.e. Dry Zone) was forested. At present only 20 percent of the dry zone is forested. Habitat destruction under the Accelerated Mahaweli Project will further reduce forest cover and adversely affect wildlife populations.

Impact on Migrant Birds

Certain migrant birds such as the pitta, the orange-headed ground thrush and Philippine shrike have stringent site specific requirements and return to the same patch of habitat year after year. Populations of such migrants will be substantially affected by forest destruction and changes in the pattern of water resources. These two factors will deplete food resources and affect some of the other migrants as well. Migrant birds undertake relatively long migratory flights and a shortage of food as soon as they arrive here can have an immediate effect on their numbers. The lack of food leading to exhaustion and death can also occur on their return flight. Possibly to avoid this problem more and more migrant birds are remaining in Sri Lanka throughout the year. The blue-tailed bee-eater which was once a regular migrant is now a breeding resident. Many other birds, particularly the waders remain in Sri Lanka even after they assume their breeding plumage. The num-

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ber of species migrating to Sri Lanka has also increased in recent years. The influx of migrants may intensify inter-specific competition resulting in serious consequences to the resident bird fauna. Neither the influx of migrants nor the "enhancement" of the habitat for water birds should be considered as spin off benefits of the development program because a natural system has to be destabilized to achieve this situation. Furthermore, the question has been raised regarding the quality of water which would be available.

Impacts on Endemic Species

Endemism usually arises through prolonged isolation of populations living in relatively stable habitats. Habitat stability due to geographical isolation and relative uniformity of the environment allow endemics to evolve and occupy well defined and relatively narrow ecological niches. Consequently, endemic species are particularly sensitive to environmental perturbations such as habitat modification and increase in food competition, e.g., from migrant birds. Therefore, this unique complement of Sri Lanka's fauna will be considerably impacted by the proposed development scheme. It was indicated earlier that populations of four endemic species seem to have already declined; the other 35 species listed in Appendix 9.-III are also expected to decline in the project area. The elimination of riverine forests which appears to be the preferred habitat of many endemics will have the most serious effect on endemic populations.

Impact on Endangered Species

Species such as the elephant and leopard are listed as endangered because they already face the threat of extinction. Extinctions irreversibly reduce the diversity of ecosystems and makes them more susceptible to unwanted change. For example, the extinction of leopard would provide its prey species such as the wildboar the fullest potential to multiply

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rapidly and reach pest proportions. This unwanted change occurs even now, before the death of the last leopard, but extinction of this species would mean an irreversible loss of a biological phenomenon which is beneficial to man. The point, therefore, is that sufficient numbers of leopard should be allowed to survive so that mankind could benefit by a natural system of predator-prey interactions.

Species become endangered when the viabilities of their populations are low through all or part of their area of distribution. All eight threatened or endangered species found within the project area are listed as such throughout their world distribution (Table 9-5). Moreover, red-faced malkoha, purple-faced langur and toque monkey are endangered or threatened endemics (i.e., found only in Sri Lanka). Therefore, extreme caution must be exercised in dealing with the present population of these species as well as other endangered forms found within the project area.

One of the major problems faced by species threatened with extinction is the gradual reduction of suitable habitat. Continued reduction of suitable habitat within the project area will drive them closer towards extinction. On a broad scale, extinction results in the dying out or the end of a species, the end of a population, and the end of a line of evolution that may have developed over millions of years. On a geologic time scale spanning several million years extinction is a natural process, but during the last four hundred years man's activities have contributed to the extinction of three fourths of the species that died out. Thus, extinction is rarely a natural process anymore, but a man induced phenomenon which can be detrimental to his own welfare.

The details of the impacts on the elephant, which is the most conspicuous and culturally significant endangered species found within the project area are given below.

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Impacts on Elephant Populations - The initial phase of development will evict several social groups of elephants from at least parts of their home ranges. This deprives elephants of their natural food and crowds them into the remaining areas of their habitat. Food deprivation and excessive crowding of elephants lead to habitat destruction, which makes the area sub-optimal for elephants as well as several other species that depend on the same habitat. Evidence of this has been documented from the African elephants in Kabalega National Park, Uganda, and Tsavo National Park, Kenya. In Sri Lanka a case of habitat destruction occurred in 1975 in the Wanniyagama, Hurulu and Gal Oya Forest Reserves. This particular incident was probably precipitated by moderate crowding and a lack of food which was aggravated by a prolonged drought. Any further crowding of these areas may result in habitat destruction even under normal climatic conditions.

During the later phase of development, agricultural areas gradually surround the natural habitats of elephants. This gives rise to pockets of elephants which ultimately become completely isolated from other members of the population. The elephant population which was once distributed throughout Sri Lanka is now represented in the wet zone by only four isolated pockets comprising five to 15 animals. In the dry zone, McKay's investigations (1973) indicated that the isolation between elephants in and around Gal Oya, Lahugala and Yala may be almost complete. These pockets were larger than in the wet zone and included about 300, 150 and 150 animals, respectively. However, even within these subpopulations, there was evidence of further pocketing. For example, one of the six groups studied at Gal Oya was completely isolated due to agricultural expansion surrounding its home range. The TAMS wildlife survey team identified a group of about 20 animals which will probably become pocketed upon completion of the Victoria and Randenigala reservoirs. Similarly, many small groups which enter the agricultural areas between Hasalaka and Hettipola from the left bank of the Mahaweli will be pocketed by

Lockhart (1972) but McKay (1973) described a slightly different movement pattern for the Gal Oya elephants. The wet season dispersal of the Somawathiya elephants from the Mahaweli Ganga may be more related to factors other than food. In any case each social group appears to have at least two fairly large areas of intensive feeding activity. Some areas are used during the dry season while others are exploited during the wet season, and the social group moves between

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the development in System C. In the Bundala Sanctuary, the pocketing of about 60 elephants is complete or imminent. Some of these animals which ranged as far as Uda Walawe, Angunakolapelessa and Ridiyagama were recently driven and crowded into this small sanctuary. With further investigations, it is likely that pocketing will be identified as a phenomenon which is more common than has been heretofore realized.

Excessive pocketing should be recognized as the precursor to the decline of elephant populations. Isolated pockets consisting of a few elephants suffer the effects of inbreeding which results in reduced fecundity and a decline in numbers and viability. Pockets with larger numbers of elephants may or may not be viable, but they also face adverse consequences because pocketing is normally preceded by overcrowding. Thus, the existing pattern of development creates a situation of double jeopardy to the elephant, i.e., overcrowding and inbreeding in different parts of its distribution. The proposed development pattern will also have the effect of intensifying the already existing conflict between human interests and the elephant which further affects the survival of this species.

There are an estimated 800 elephants that inhabit the project area (De Alwis pers. comm.). About 400 of these could be accomodated in the wildlife reserves within and at the periphery of project area provided some wildlife management measures are implemented. The fate of the others could be varied under the existing patterns of development. Development may immediately eliminate individuals of some social groups, and thus, reduce the size and the viability of these groups. Other social groups would live in semi or completely isolated pockets of habitats. In areas where these groups are crowded they may destroy their habitat. In other parts crop damage by elephants could lead to retaliation by cultivators and result in further elephant deaths and wounding.

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Wounded elephants are usually ill-tempered animals. Consequently, they endanger and sometimes claim human lives. Thus, the cycle of conflict between humans and wildlife would be intensified. Ultimately, however, the 400 displaced elephants would probably die if their problems and the human problems they will create are disregarded. This would reduce the present estimated total elephant population of Sri Lanka by 20 percent, i.e., from 2000 to 1600 elephants. The remnant population, especially considering that it may be fragmented into a number of isolated pockets, may be too small to sustain the species indefinitely.

Impacts on Other Wildlife Species

This section deals with the impacts on wildlife other than the endemic fauna, endangered species and migrant birds found within the project area.

Although the problems of the elephant were discussed in some detail, it must be noted that several other species share the same problems. Elimination of natural ecosystems followed by habitat fragmentation and population decline can be expected to affect many species of mammals, birds, reptiles and amphibians within the project area. Some species which adapt to modification of their habitats will proliferate and become agricultural pests thereby causing considerable economic loss.

Animal populations usually maintain themselves at or near the carrying capacity of their habitat through natural processess such as emigration, immigration, mortality and natality. Within the project area habitat elimination and fragmentation will create barriers (i.e. agricultural areas) which will disrupt the emigration and immigration patterns of many species. Animals that are inately shy (e.g. leopard, sloth bear, jackal, mouse deer), those which are hunted (e.g. sambhur, spotted deer, muntjac), and species which are almost totally dependant on trees and forests (e.g. purple-faced

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langur, porcupine, giant squirrel, flying squirrel) will be the most seriously affected by the agricultural barriers to their immigration and emigration. Some species, especially nocturnal forms may move across these barriers (e.g. mongooses, civets, wildboar, some rodents), but if the barriers are too wide, the movements of these species will also be affected. Widespread disruption of emigration and immigration will affect gene flow and increase the probability of inbreeding. Consequently, the viability of wildlife populations and the species diversity of natural habitats will be reduced.

The reduction of species diversity through habitat elimination and modification are expected to have serious impacts on biological food chains. These food chains transfer energy from plants to animals through a stepwise process of eating and being eaten, and stabilize the population levels of predator and prey within a biological community. Thus the reduction of leopards would lead to an increase of its prey species. Similarly, the decline of insectivorous animals (amphibians, reptiles, birds, mammals and predatory insects) may result in the proliferation of insect disease vectors and agricultural pests. This increase would necessitate the use of pesticides and insecticides which will further disrupt biological food chains. The chemicals would be carried along the links of the food chain and most seriously affect the top predators of aquatic and terrestrial communities within the project area. This includes crocodiles, monitor lizards, storks, eagles, hawks, leopards and man. Thus habitat elimination will precipitate a series of escalating problems which threaten the welfare of wildlife as well as humans.

In addition to agricultural expansion, human needs of fuelwood will have an extremely serious impact on wildlife habitats and animal populations. Extensive tree felling will affect endangered and endemic plants and species which are valuable for medicinal purposes. Encroachment will also bring

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human activity in close proximity to wildlife and increase pressure due to hunting for food and commercial purposes. The star tortoise, crocodile, bengal monitor, peacock, jungle fowl, deer, sambhur, muntjac, mouse deer, hare, wildboar and leopard will be affected to different degrees due to hunting pressure.

Changes in the pattern of water resources and salinity intrusion may also have considerable impacts on wildlife habitats, aquatic forms and water birds. It must be noted that both species which disappeared from Sri Lanka's fauna in the recent past were water birds, i.e., glossy ibis and comb duck. The reason for their disappearance is unclear but it is possible that their dependence on aquatic habitats may have contributed to their extirpation.

Agricultural Pests and the Loss of Biological Controls

At present the elephant, wildboar, rose-ringed parakeet and two species of munia have been identified as agricultural pests which will have a negative impact on the proposed program of development. Munias nest and roost in the thick cover of sugar cane plantations. From these areas they emerge in large numbers and damage rice fields over extensive areas. The munia problem has been identified around the Kantalai and the Uda Walawe sugar cane plantations. This indicates that there would be substantial economic loss if sugar cane and rice fields are established side by side.

In 1975 encroachment of teak plantations into elephant habitat led to elephant raids and a loss of $75 million of future revenue. This incident must not be viewed as an isolated occurence but rather as a minimal estimate of economic loss if elephant habitat continues to be destroyed through agricultural expansion. Habitat destruction also appear to be the reason for the sudden and dramatic increase of parrots. About 30 years ago the rose-ringed parakeet was

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restricted to the dry zone where it was found in relatively small numbers. Now its abundance has reached pest proportions and its distribution has extended into the wet zone and the central highlands. Evidently, extensive deforestation has favored the parrot by reducing bird populations which compete with the parrot for food and nest holes. This loss of biological control through interspecific competition has led to the parrot becoming the most serious pest of rice and other food crops.

The wildboar problem presents another example of the loss of biological control and the importance of maintaining natural systems of predator-prey interactions. Analysis of predation by the Sri Lankan leopard showed that wildboar and spotted deer kills constituted 28% and 49% respectively of the total prey items captured (Eisenberg & Lockhart, 1972). While the spotted deer was captured less than twice as frequently as the wildboar, its density was more than ten times that of the wildboar. This suggests that leopard prefers wildboar to the spotted deer. In fact wildboar appears to be the most preferred of all leopard prey and the wildboar's relatively large litter size was probably evolved to offset this predation pressure. In the absence of predation pressure however, the wildboar has the potential of proliferating very quickly and becoming an agricultural pest. This occurs when natural ecosystems are modified in such a manner that they accomodate the prey species but excludes the predator, e.g. the modification of natural habitats to sugar cane plantations.

Natural ecosystems are reservoirs of many vertebrate and invertebrate species which act as biological control agents of pests as well as human disease vectors. They also provide commercial timber, fuelwood, medicinal plants, a host of natural products and a gene pool for the production of new varieties of agricultural crops. Moreover, natural ecosystems regulate water flow and prevent soil erosion and have a great deal of potential for promoting tourism. The total

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value of the service rendered by natural ecosystems cannot be easily assessed in economic terms, but their importance for human welfare cannot be over emphasized. More often than not the contribution of natural ecosystems to human welfare is realized only after they are destroyed.

REVIEW OF PROPOSED WILDLIFE MANAGEMENT PROGRAMS

As requested by the Environmental Panel of the Mahaweli Development Board, the Director of Wildlife Conservation has put forward a wildlife mitigation proposal (see Figure 5). This can be summarized as follows:

- the creation of Maduru Oya National Park in the catchment of the Maduru, Ratkinda and Ulhitiya Oyas.
- the establishment of a corridor from the proposed Maduru Oya National Park into Wasgomuwa.
- the establishment of a corridor from Wasgomuwa along the left bank of the Mahaweli into Somawathiya.
- the retention of the entire extent of existing wildlife reserves found within or on the borders of the Accelerated Mahaweli Project Area, e.g. Nelugala Corridor, Wasgomuwa and Somawathiya.
- the establishment of a corridor between Maduru Oya and Gal Oya National Park.

Since the Department of Wildlife Conservation is the only wildlife policy making body in Sri Lanka its proposal must be taken as the overnment's plan for mitigative measures. It must also be noted that the proposal is only a part of a much more extensive plan set forth in 1959 by a Government committee on the preservation of wildlife (sessional paper No. 19).

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The NEDECO team's study supported the first, third and part of the fourth recommendation and indicated that the second recommendation required further scrutiny. This study also mentioned that the Nelugala Corridor is ineffective because its southern end does not lead into a national reserve. However, the NEDECO team probably did not realize that the southern end leads to the riverine forest along the Maduru Oya. This habitat is essential for many endemic species and for elephants particularly during the dry season.

The NEDECO team made two additional recommendations related to the accelerated phase of the Mahaweli Programme. One is to enhance the communicating systems of wildlife reserves by establishing a forest reserve or jungle corridor from the northern part of the Wasgomuwa Reserve to the Minneriya-Giritale Sanctuary. The other is to extend the Somawathiya Sanctuary along the west bank of the Mahaweli so that it could be linked with the Mahaweli north forest reserve.

The feasibility report of System B development recommended that

- the three elephant corridors as proposed by the Director of Wildlife Conservation be implemented at least on a temporary basis until the wildlife and the elephants can leave or be translocated from the area of development.
- the speed and methods of project implementation be regulated to minimize impact on the environment and
- fertilization and sprinkler irrigation during the dry season to assure a perennial food supply for elephants.

The first and third recommendations are considered to be simplistic but the second recommendation is a good one. Wild animals do not leave their habitat permanently unless they

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are killed or translocated. At present translocation cannot be undertaken in Sri Lanka because of a lack of equipment, funds and technical expertise. In any case large scale translocation is unfeasible because alternative areas (or plans) are required to accommodate the displaced wildlife but insufficient areas have been allocated. The proposed Maduru Oya National Park can safely accommodate the animals already there. Enriching the habitat within this area will make this park more attractive only to those animals which range just beyond the periphery of the park. Therefore, animals which live further away from the park should be accommodated through other means. Habitat enrichment through extensive fertilization and sprinkler irrigation as implied by the feasibility report is a futile exercise in attempting to contain the elephants of System B. When crowded into a small area elephants do extensive damage to the habitat reducing its carrying capacity and adversely affecting other wildlife.

The Randenigala project report which is based mainly on the NEDECO team's findings correctly recommends that environmental monitoring be continued during and after the period of plan implementation. The report also recommends that three islands totalling 70 hectares which rise within the reservoir be made wildlife reserves. This however, is considered inadequate to mitigate wildlife problems arising from the dam construction at Randenigala.

The System C feasibility report makes two separate sets of recommendations for dealing with wildlife problems. One set is based on biological principles while the other places an undue emphasis on the establishment of the proposed nucleus sugar estate. The dichotomy is established by restricting the term encroachment to "spontaneous development" by chena cultivators and not applying it to forest clearing for the proposed sugar estate. This distinction and the discussion it generates is more than a matter of semantics and in a biological

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context any type of modification of natural ecosystems should be considered encroachment. It is the degree of encroachment and its effects on wildlife as well as development that are important for a balanced assessment of the problems and the recommendations of mitigative measures.

The first set of recommendations highlights habitat encroachment and suggests strongly that this must be arrested at once. An integrated approach to development is advised and the preservation of several small patches of forests in unirrigable areas is recommended. It is also recommended that if parrots are identified as agricultural pests substantial areas be kept under forest. Several other useful suggestions are included in this set of recommendations.

The second set of recommendations mainly argues against the Sri Lanka Government's plan for establishing a corridor between Wasgomuwa and the proposed Maduru Oya National Park. The reasoning against the Government plan is that habitat encroachment has already made the establishment of a completely forested corridor unfeasible. A corridor forested along its entire length would be the ideal, but one which includes the existing forests and some previously encroached areas assured of future protection would also suffice to link the two wildlife reserves. The report also states that no solution can be found for the elephants within System C although their numbers are estimated at or more than 200 in this area. Neither the fact that such large numbers of elephants can cause considerable economic loss, nor the fact that these numbers comprise a significant proportion of an endangered species population is taken into account. The report's suggestion that so many elephants be moved to areas outside System C is considered technically and biologically untenable.

RECOMMENDED ACTIONS

The important relation between human welfare and natural resource conservation was previously indicated. The following recommended actions are based on the premise that the proposed development should protect human welfare through the rational use of fast dwindling natural resources as well as fulfill human needs for food and employment opportunities. The protection of human welfare and the fulfillment of human needs are considered complementary rather than conflicting endeavors. Thus, it is strongly recommended that an integrated approach to development be implemented so that a balanced program of agricultural expansion, forestry development, soil and wildlife conservation could be evolved.

In general agricultural development in the Mahaweli Accelerated Programme area will shift the region from one ecological state to another. Remedial measures can be formulated for long-term land use considerations after development, and for short-term actions needed as large areas of wildlife habitat are removed. Long-term measures include a system of National Parks and connecting corridors; the short-term measures are in operation during the development process.

Current plans provide for the establishment of a system of wildlife reserves with connecting corridors, but a great deal of work must be done to accommodate the large numbers of wildlife which will be displaced during development. Current plans lack detailed information on how such plans will be implemented. Implementation of both the plan to establish and manage the reserve system adequately and that for accommodating displaced wildlife exceed current capacity.

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National Parks and Corridors - The Department of Wildlife Conservation has presented plans to assure the future of wildlife populations in the lower Mahaweli Region. In Summary, these include (see Figure 5):

- the retention of the existing reserves in their entirety, i.e., Somawathiya, the Nelugala Corridor and Wasgomuwa;
- the creation of the Maduru Oya National Park in the catchments of the Maduru, Ratkinda, and Ulhitiya Oyas;
- the establishment of a corridor from the proposed Maduru Oya National Park to Wasgomuwa and another from the Wasgomuwa along the left bank of the Mahaweli to the Somawathiya; and
- the retention in forest of the natural migration route of elephants south of Maduru Oya into Gal Oya National Park.

The proposed plans are recommended for implementation. To overcome the problems of habitat fragmentation, barriers to animal movement, inbreeding and the consequent decline of populations large wildlife reserves should be established. However, under the proposed development scheme the creation of such reserves may not be possible. Smaller wildlife reserves such as the Wasgomuwa, Somawathiya and the proposed Maduru Oya National Park may be adequate only if they are connected together, preferably by natural forests. Otherwise isolated wildlife habitats will behave like oceanic islands, and island fauna are known to be vulnerable to extinction especially when the size of the island is small. Links between wildlife reserves allow for faunal exchange of all species living in these areas. As such, these links must not be viewed as corridors for the movement of elephants alone. Faunal exchange through corridors minimizes the deleterious effects of inbreeding in isolated populations, increases the viability of all species and retards the process of species extirpation.

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The NEDECO team's recommendations to establish a forest reserve or jungle corridor between Wasgomuwa and Minneriya-Giritale Sanctuary, and to extend the Somawathiya Sanctuary along the west bank of the Mahaweli are also supported. To further improve the ecological integrity of the project area it is recommended to:

- immediately arrest all unplanned encroachment of natural habitats;
- regulate the speed and method of project implementation in order to minimize the impact on the environment;
- include an extent of high ground near Trikonamadu in the Somawathiya to accommodate the seasonal distribution of elephants from that reserve;
- establish a corridor along the right bank of the Mahaweli extending from the Somawathiya including Gunners Quoin, the Handapan Villu to Wasgomuwa;
- expand the proposed Maduru Oya National Park to include the areas out of command above the Maduru Oya Right Bank Canal, along the divide between the Maduru Oya and the Maha Oya, up to and including a portion of the Omunugala Forest Reserve;
- revise the designation of the existing reserves to that of National Park, so as to improve management flexibility and reduce tourist pressure on the existing National Parks of Sri Lanka;
- identify marginally productive and unirrigable lands and emphasize their first usage for wildlife reserves with buffer zones for livestock grazing and fuelwood plantations;
- declare riverine forests as wildlife and soil conservation areas. Forests around tanks and reservoirs could also be treated similarly.

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The last two recommendations could be integrated into community development and educational programs. Small reserves established by these recommendations could include passive recreation areas and nature trails with informative signs identifying interesting aspects of local wildlife. These areas can be "adopted" by neighborhood schools or other community institutions and maintained by Department of Wildlife Conservation personnel. Larger areas could be developed as National Parks. It is recommended that as many National Parks as possible be established to provide safe havens for wildlife, to reduce pressure from local and foreign tourists on the existing National Parks of Sri Lanka, and to promote further tourism. Moreover, the rise in the price of oil makes extended journeys to National Parks increasingly difficult. Therefore, a system of National Parks which is evenly dispersed over the island would reduce travel distance and allow local communities and foreign tourists to enjoy wildlife and passive recreational activities without much financial hardship.

The TAMS ongoing field investigations may identify and recommend additional sites for inclusion as wildlife areas.

The "Future Land-Use Map" prepared by the consultant for System B includes the Department of Wildlife Conservation's plan for a system of wildlife reserves and connecting corridors (see Figure 5-1). Wildlife reserves existing within the Accelerated Mahaweli Development Project area and not included on this map are the Veddikkachchi Intermediate Zone and the Polonnaruwa Sanctuary, both located in System D.

It is not possible to determine if the recommended actions would assure the long-term survival of species found within the project area. Effective protection and management will be required to assure the survival of the wildlife reserve system.

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National Parks and Corridors and Infrastructure Modification - It is recommended that as the development program is completed, the National Park-Corridor System be buffered to minimize conflicts arising from crop damage by wildlife. This can be accomplished by establishing livestock grazing zones, fuelwood plantations and through the placement of settlements between the Parks and intensive agriculture. In this manner, the centers of wildlife activity could be effectively separated from the foci of intensive agriculture. Wherever a canal or any development infrastructure crossed a corridor or park area, provisions must be made to include adequate crossing places. In some areas, major canals or roads may actually serve as the boundary of a corridor or park and in these situations it would be advisable to assure these act as barriers so as to reduce wildlife conflict.

The position of main canals planned for System B in relation to the existing Forest Reserves and the Nelugala Corridor are indicated on the consultant's "Future Land-Use Map". Site specific information on movements of wildlife are required to make specific recommendations for the modifications of the canal system to accommodate wildlife needs. Effective buffers are recommended for all boundaries of the reserve and corridor system.

Habitat Improvement in National Parks - Certain carefully planned measures can be taken to improve habitats in some Parks by such means as assuring a good distribution of water and grass that is available throughout the year. This will act to stabilize the resource base whereas now in most areas of the dry zone there is a considerable flux in resource availability resulting in seasonal movements of many species. The reservoirs to be constructed in the proposed Maduru Oya National Park with ephemeral grass growing at waters edge may act to stabilize resource availability and increase carrying capacity of the area for many wildlife species. The response to these changes, however, cannot be expected to be immediate and/or all inclusive.

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Groups or individuals of some species will no doubt continue in their traditional seasonal movements to areas outside the National Parks and Reserves. This can in part be accommodated through the establishment of corridors and the inclusion of habitats where seasonal concentrations occur. Further details of this will be available after the dry season observations are complete. As these are identified they will be included in the planned system.

Phasing Development, Temporary Corridors and Carrying Capacity - During initial development there will be a great disruption as wildlife habitat is removed, and it is essential that during this time the Park/Corridor system not be isolated. Connections should be maintained with areas that are being developed through the establishment of temporary corridors of natural vegetation. Forests along the banks of the Maduru Oya, which should remain in any case, and forests along the banks of most major streams can serve this purpose. In some circumstances, it will be necessary to phase development so as to reduce the chance of isolating wildlife in habitat pockets. This will necessarily be determined on a zone by zone basis. While it is possible to assure resource stability in Parks, the proposed National Park/Corridor system is a minor portion of the total area of what is now essentially a vast area of good wildlife habitat. It must be recognized that the proposed system cannot contain the majority of displaced animals and further, that care must be taken to not supersaturate, i.e., exceed carrying capacity, by attempting to force excess numbers of displaced wildlife into the system. Supersaturation of a reserve by large herbivors can be expected to result in habitat damage.

Displaced Wildlife - These extra animals will either die or if possible be accommodated in captive populations. A certain, sizable percentage or most species will surely die. Even if an attempt is made to accommodate all the purple-faced langurs (an endemic and a threatened species on the U.S. List)

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which will be displaced in captive populations, these leaf monkeys are too hypersensitive, and captive maintenance of wild caught adults is frequently not possible with our present level of knowledge and technology. Some of the elephants displaced with habitat destruction can probably be accommodated in the domestic population in Sri Lanka if there is the capacity to capture them. If, for some reason, the proposed wildlife reserve system or some portion of it is not included in final development plans, the numbers of elephants displaced will exceed domestic capacity. While it is possible to capture and maintain leopards in captivity, the number which will be displaced will probably stress or exceed the capacity of the World's zoos to maintain them. Indeed, in nearly every case, the large numbers of animals involved will strain, if not exceed, the capacity of captive population facilities to absorb them.

National Parks-Wildlife Management Planning Team

To harmonize the establishment of the proposed National Parks/Corridor system with agricultural development in the various systems, a National Park/Wildlife Management Planning Team will be required during the construction of the development infrastructure. Specifically, the team would be responsible for planning the coordination of the development of the proposed National Park/Corridor system with agricultural development and with the fabric of the Sri Lankan economy by redesigning tourist flows to reduce tourist pressure on existing National Parks and re-route them through the newly established Parks. The team would plan the infrastructure development in the proposed Parks/Corridors including roads, buffer areas, accommodations, and habitat improvement projects. It would be responsible for monitoring the response of threatened and endangered species as they are displaced through the destruction of their habitat and advise on which can be brought into the captive population and which accommodated by the Park/Corridor system. The team would advise on and assist in the

development of the technical capacity to capture and translocate displaced wildlife. The consequences of not providing a park planning and ddaptive wildlife management capability can have serious adverse effects for the program, socially and economically.

Expanded Wildlife and National Park Administration and Management Capacity - The Sri Lanka National Park and Wildlife Conservation staff is one of the best in Asia and Africa. The demands placed on the Department in dealing with the tasks involved in successfully establishing the new National Parks and with the problems created through the destruction of wildlife habitat over such a large area so rapidly will require an expanded wildlife administrative and management capacity. The ParkPlanning/Adaptive Wildlife Management Team would necessarily be composed of consultants and counterparts. In addition to planning, a major objective of this association is in technology transfer and development of techniques. It is further recommended that an Institute be established under the auspices of the Department of Wildlife Conservation to provide training for basic and mid-level staff. It is recommended that a diploma course be established in the University system for senior staff in the Department and a program of wildlife extension be established to assist farmers in agriculture/wildlife related problems. While the need for training and extension is recognized, this program will be interlocked with other programs in Sri Lanka and details will have to be planned with extensive consultations.

National Policy on Wildlife Conservation

The Hon. Minister of State has set up a committee on the formulation of a National Policy on Wildlife Conservation. This policy, which is due to be released by 1 March 1980, will include details of the revamping and expansion of the Department of Wildlife Conservation, the master plan for the National

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System of Nature Reserves and connecting corridors, and new legal measures to strengthen existing wildlife conservation laws. As far as can be determined in discussions with the Director of Wildlife Conservation, as of now these above remedial measures and recommendations are in accord with the National Policy.

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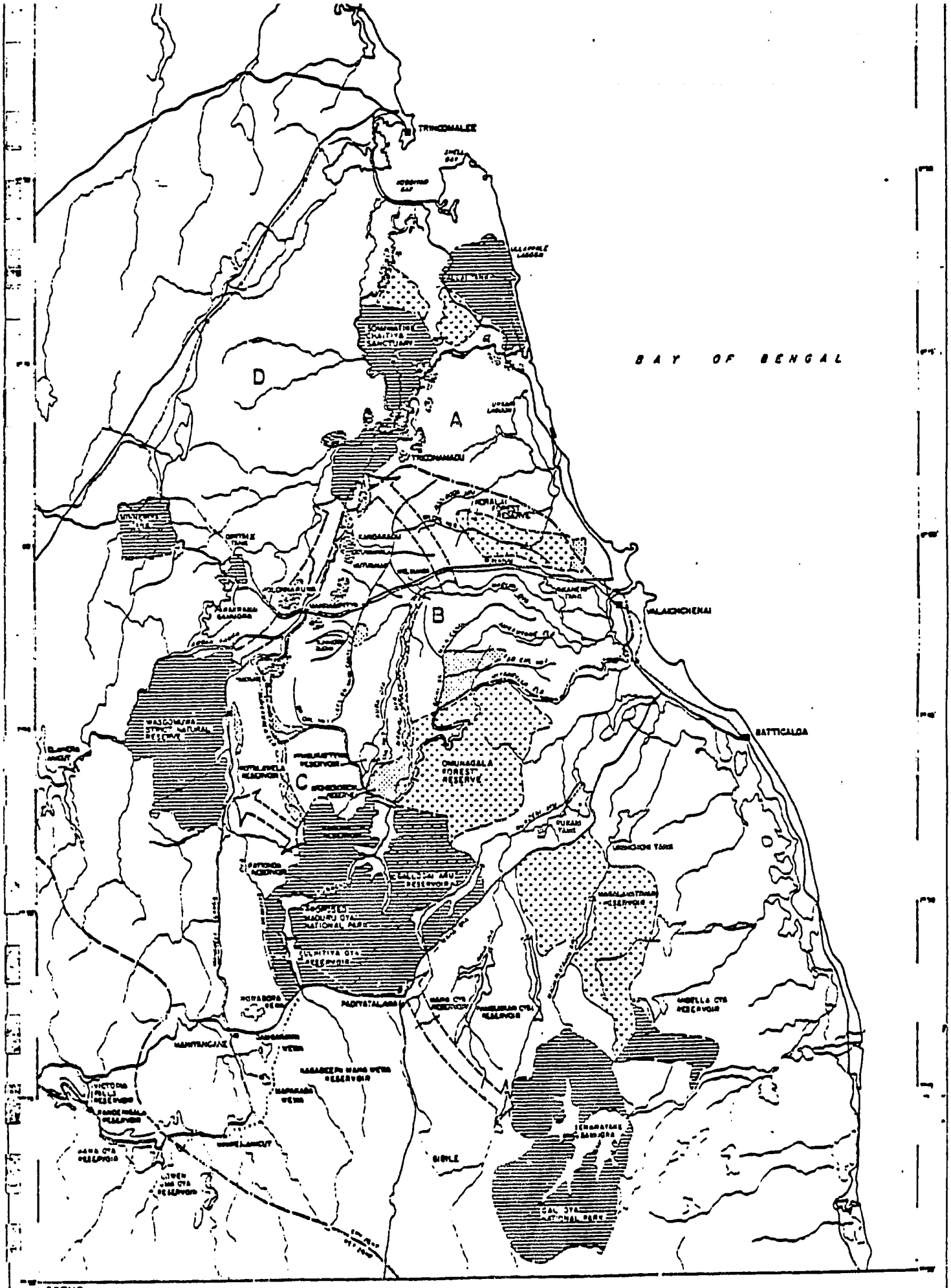

FIGURE 9 - 1

ACCELERATED MAHAWELI DEVELOPMENT PROJECT

FUTURE LAND-USE

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FIGURE 9-2

SYSTEM OF CORRIDORS AND WILDLIFE RESERVES PROPOSED FOR THE ACCELERATED MAHAWELI PROGRAM AREA BY THE DEPARTMENT OF WILDLIFE CONSERVATION

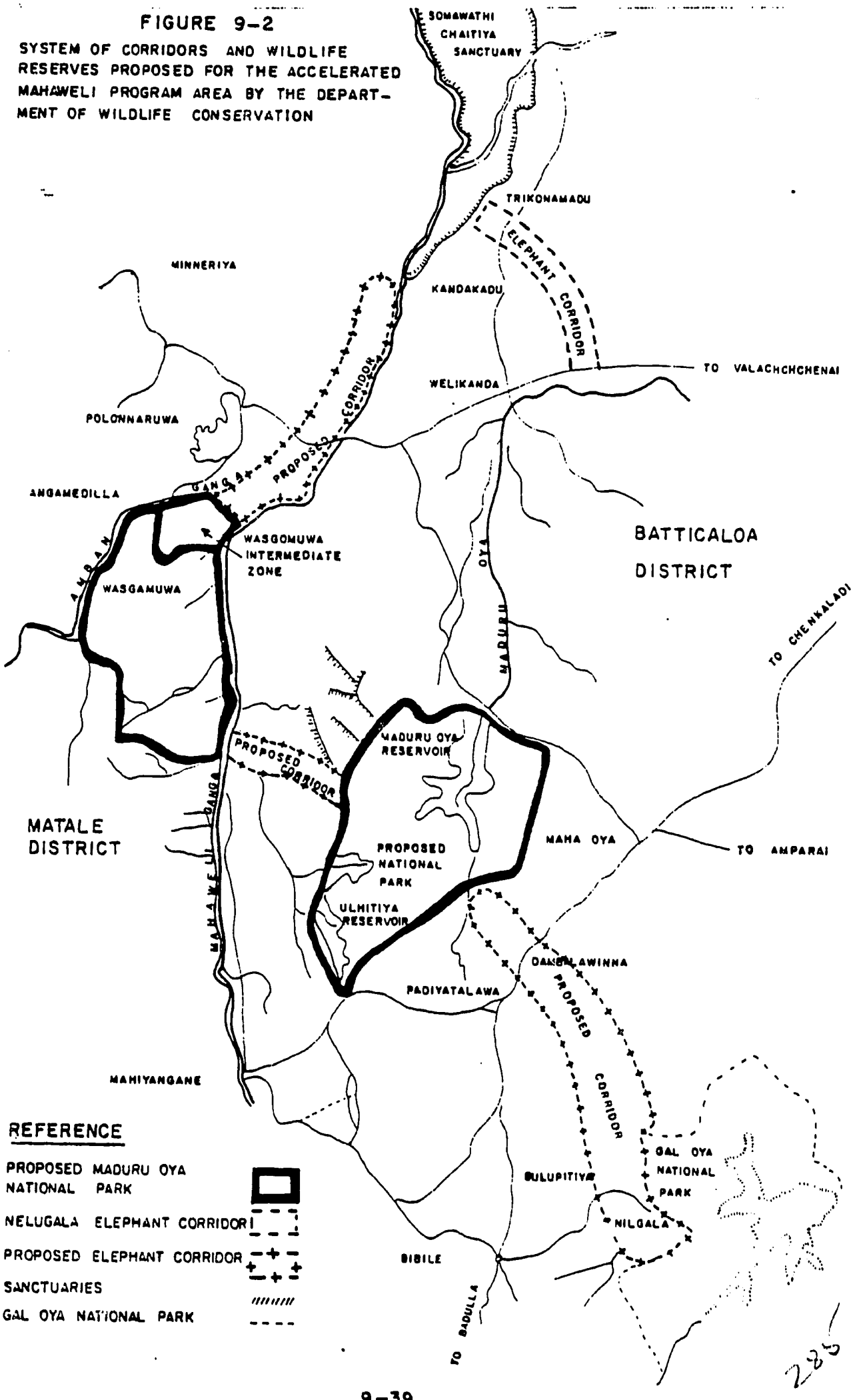

Table 9-1

Wildlife Reserves within Accelerated Mahaweli Program Area

Name	Status	Extent (hectares)	Date of Declaration	Reserve Boundaries
Somawathie	Sanctuary	22,275	9 Sep 1966	Completely within project area
Nelugala	Jungle corridor	10,400	16 Jan 1970	" " " "
Veddikachchi	Intermediate Zone	32,800	27 May 1938	Major portion within project area
Polonnaruwa	Sanctuary	1,520	27 May 1938	Partly within project area
Seruwila-Allai	Sanctuary	15,550	9 Oct 1970	" " " "

Source : Water Resources Map of Survey Dept. (1978) and Dept. of Wildlife Conservation's List of Wildlife Reserves.

Table 9-2

Forest Reserves Within Accelerated Mahawell Program Area

Name of Forest Reserve	Extent (hectares)	Date of Declaration
Mahawell Ganga North & South	8,650	22 Dec 1939
Yappiah-Verugal	4,350	3 Oct 1941
Chundankadu	4,350	1 Mar 1940
Omunugala	53,665	18 Mar 1927
Koralai	7,710	4 Jan 1929

Source: Forest Department

Table 9-3

Some Plants of Medicinal Value Found within the Accelerated Mahaweli Programme Area

Species	Medical use/active principle
Heliotropoum indicum	Anticancer
Mucuna prurita	Parkinsons disease/L - Dopa
Leucaena latisiligna	Parkinsons disease/L - Dopa
Terminalia chebula	Skin disorders
Hemidesmus indicus	Antipyretic
Azadirachta indica	Antimalarial
Solanum jacquini	Expectorant
Phyllanthus emblica	Liver disorders
Plumbago indica	Gastro intestinal disorders
Acacia catechu	Gastro intestinal disorders
Boerhavia diffusa	Diuretic
Dioscorea sp.	/Diosgenin
Datura sp.	Anti inflammatory/scopolamine

Note : Species list obtained from Natural Products for Sri Lanka's future-report of a workshop sponsored by the National Science Council of Sri Lanka and the National Academy of Science U.S.A.

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Table 9-4

Plants Containing Antifertility Compounds Found Within Project Area

Species	Family	Plant Part Containing Anti-fertility Compound
Caesalpinia bonducella	Leguminosae	leaf, root, stembark, stem
Caesalpinia pulcherima	Leguminosae	leaf, root, stembark, stem
Costus speciosus	Zingiberaceae	rhizome, root
Curcuma aromatica	Zingiberaceae	rhizome, root
Cyperus rotundus	Cyperceae	rhizome, root
Granjea madaraspatana	Compositae	aerial part, root
Herpetis monniera	Scrophulariaceae	whole plant
Momodica clerantia	Cucurbitaceae	stem, vine
Petiveria alliacea	Phytolaccaceae	leaf, root, stem
Plumbago zeylanica	Plumbaginaceae	leaf, root, stem
Portulace oleracea	Portulacaceae	whole plant
Ricinus communis	Euphorbiaceae	leaf, root
Rubia cordifolia	Rubiaceae	stem, root
Saraca indfca	Leguminosae-Mimusoidae	
Urena lobata	Malvaceae	leaf, root, stem
Achyranthes aspera	Amaranthaceae	aerial, part, root

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Table 9-5

Migrant Bird Species Found within the Accelerated Mahaweli Program Area and Habitat Preferences

Family	Common Name	No. migrant species	Habitat preference
Charadriidae	Plover, sandpipers	24	lagoons and villus
Motacillidae	Pipits Wagtails	8	Riverine forest
Laridae	Terns gulls	9	Lagoons & sea shore
Accipitridae	Eagles, hawks harriers	6	Forest, open marsh
Anatidae	Geese, ducks	4	villus & lagoons
Muscicapidae	Flycatchers	3	Forest
Hirundinidae	Swallows	1	open plains
Starcorariidae	Skuas	2	sea shore
Ardeidae	Herons, bitterns	1	lagoon & swamp
Turdidae	Chats, robins, thrushes	1	Forest
Sylviidae	Warblers	2	Forest
Laniidae	Shrikes	1	scrub grassland
Pittidae	Pittas	1	Forest floor
Meropidae	Bee eaters	1	open scrub
Pandionidae	Osprey	1	Sea shore & lagoon
Falconidae	Falcons	3	Cliffs & open areas
Rallidae	Rails	1	Marsh & swamp
Hydrovatidae	Storm petrels	1	Sea shore
Ciconiidae	Storks	1	Lagoons
Cuculidae	Cuckoos	4	Forest
Alcedinidae	Kingfishers	1	Lagoons
Oriolidae	Orioles	1	Forests
Total		76	

Sources : TAMS Wildlife Survey Team and Phillips (1978).

Table 9-6

Endangered and Threatened Species Found in the Accelerated Mahaweli Programme Area and Their World Distribution

Species	Known Distribution	Portion of Range Where Endangered or Threatened
	Endangered	
Elephant	India, Burma, Laos, Thailand, Cambodia, Malaysia, Sri Lanka, Vietnam	Entire
Leopard	Africa, Asia	Entire
Red-faced malkoha	Sri Lanka	Entire
Mugger Crocodile	Sri Lanka, Africa	Entire
Bengal Monitor	Iran, India, Burma, Afghanistan, Sri Lanka, Vietnam, Thailand, Malaysia	Entire
Python	Sri Lanka, India	Entire
	Threatened	
Purple-faced langur	Sri Lanka	Entire
Toque Macaque	Sri Lanka	Entire

Source : U.S. Federal Register January 17, 1978.

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Table 9-7

Micro-habitat Preferences of Some Endemics Located within the Accelerated Mahaweli Programme Area

Species	Habitat Preference
FISH	
Puntius bimaculatus	clear stagnant or running water
AMPHIBIANS	
Rana gracilis	temporary pools with reeds
REPTILES	
Rhinophis oxyrhynchus	burrows in open grassland
Gymnodactylus frenatus	rock outcrops
Geckoella yakhuna	forest floor leaf litter
Calotes ceylonensis	tree trunks in riverine forest
Otocryptis weigmanni	open riverine forest floor
Sphenomorphus fallax	soggy meadows
BIRDS	
Gallus lafayetti	forest, parkland, chena
Galloperdix bicalcarata	riverine forest
Loriculus beryllinus	emergent canopy of riverine forest
Psittacula calthorpae	emergent canopy of riverine forest
Pellorneum fuscocapillum	forest floor
Phaenicophaeus pyrrhocephalus	tall riverine forest
MAMMALS	
Macaca sinica	riverine forest
Presbytis senex	riverine forest

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Table 9-8

Percentage Abundance of Agricultural Pests in Total Avifauna of Different Habitat Types

Transect Location	Habitat Type	% Abundance of Bird Pests
Tirikonamadu	Scrub forest	5.6
Dimbulagala	Open forest	-
Elilona kanda	Closed forest	-
Polonnaruwa	Open forest near paddy	50
Giranduru Kotte	Closed forest near chena	18.4

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Table 9-9

Elephant Damage to Agricultural Crops and Property in Villages to the East of Hettipola-Hasalaka Road (Left Bank of Mahaweli)

Name of Farmer	No. of elephants involved	Area Damaged (ha.)	Date of Damage
Wilgomuwa Village - Damage to paddy			
Kapilaratne	15	1.01	17 December
L.B. Ekanayake	15	?	17 December
Karunaratne	6	0.20	17 December
Piyasena	6	0.40	17 December
R.B. Ekanayake	6	0.30	18 December
Ranasinghe	6	0.40	18 December
K.M. Muthubanda	15	(2.02 (complete) (2.83 (partial)	17/18 December
M.G. Ranbanda	?	0.20 (partial)	18 December
J. Ranbanda	7	1.21 (partial)	18 December

Heen Banda and Samaneri's incurred a loss of Rs. 12,000 due to elephant damage to their banana plantation in late October 1979 - about 20 elephants were involved and damage occurred in a single night.

Devagiriya Village - Damage to paddy and other crops			
U.G. Seya	1	0.4 (maize, cow pea, millet)	mid November
P.G. Surendra	3	0.2 (paddy)	2nd Week December
P.G. Setunge	1	0.2 (maize)	1st Week December
W.G. Punchiba[illegible]	1	0.2 (maize, cow pea)	2nd Week December
D.G. Lokubanda	1	? (partial damage paddy)	3 nights between 13-20 December
D.M. Wijeratne Banda	1	0.2 (paddy)	1st Week December
P.G. Mutubanda	3	0.8-1.2 (partial)	20 November 20 December
H.G. Mudiyanse	1	minor (paddy)	1st Week December
P.G. Jayatunge	7	0.6 (paddy partial)	2nd Week December
W.G. Samadara	3	0.2 (paddy, maize, manioc)	2nd Week December

R.D. Sirimanne's house was destroyed by an elephant during the first week of December 1979.

Bogawela Village - Damage to other crops			
B.G. Gunaya	3	0.2 (maize, manioc)	1st Week December
Namini Oya - Damage to paddy			
R.A.C. Jayatissa	3	0.6 (paddy)	18 December
Seneviratne Banda	3	0.8 (paddy)	18 December

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APPENDIX 9-I

Objectives of wildlife field study program.

Endemic Species

1. Compare past and present distribution of endemic species within project area
2. Assess relative abundances, microhabitat preferences and range of microhabitats used by endemic species
3. Assess impact on endemic populations through environmental change within project area

Endangered Species

1. Estimate elephant density and distribution in System B and C of project area
2. Group size and composition of elephant herds
3. Home range size of elephant herds and seasonal use of habitat
4. Migatory patterns of elephants within Systems B and C with special emphasis on movement between Wasgomuwa Strict Natural Reserve and proposed Maduru Oya National Park
5. Estimate elephant damage to agricultural crops and plantation forest

Villu Fauna

1. Estimate relative abundances of terrestrial vertebrate fauna using villus and water courses particularly in System A
2. Seasonal changes in the use of selected villus by terrestrial vertebrates
3. Food habits of terrestrial vertebrates using villus and water courses
4. Assess the degree of dependence of different terrestrial vertebrates on villu systems

Agricultural Pests

1. Compare relative abundances of known agricultural pests in disturbed and undisturbed habitats
2. Estimate abundances of probable competitors of agricultural pests in disturbed and undisturbed areas
3. Asses habitat preference, food habits and seasonal changes in diet, mortality rates and factors and movement patterns of agricultural pests
4. Estimate damage to agricultural crops by pests
5. Recommend methods of control of agricultural pests

Endemic Vertebrates Found within Mahaweli Accelerated Project Area

AMPHIBIANS

Family	-	RHACOPHORIDAE
1		*Polypedetes cruciger*
Family	-	CAECILIIDAE
		Ichthyophis sp. (at least one species)

REPTILES

Family	-	GEKKONIDAE
1		*Calatodactylus* sp.
2		* *Gymnodactylus frenatus* Gunther
3		* *Geckoella yakhuna* Deraniyagala
4		*Hemidactylus depressus* Gray
5		*Cnemaspis podihuna* Deraniyagala
Family	-	SCINCIDAE
1		*Dasia haliana* (Haly et Nevill)
2		*Anguinicephalus deraniyagalei*
3		*Anguinicephalus hickanala*
Family		AGAMIDAE
1		*Calotes liocephalus*
2		* *Calotes ceylonensis* (Muller)
3		* *Otocryptis weigmanni* Wagler

SERPENTOID REPTILES

Family - ANILIIDAE

1 * Cylindrophis maculatus

Family - ELAPIDAE

1 Bungarus ceylonicus

Family - BOIDAE

1 Pseudotyphlops philippinus

2 * Rhinophis oxyrhynchus (Schneider)

Family - COLUBRIDAE

1 Chrysipelea taprobanica Smith

Family - VIPERIDAE

1 Trimeresurus trigonocephalus (Sonnini et Latrelle)

Family - TYPHLOPIDAE

1 Typhlops sp (at least one species)

BIRDS

1 * Galloperdix bicalcarata (J.R. Forster)
Ceylon Spurfowl

2 * Gallus lafayetti Lesson
Ceylon Jungle Fowl

3 * Psittacula calthropae (Blyth)
Emerald-collared Parakeet

4 * Loriculus beryllinus (J. R. Forster)
Ceylon Lorikeet

5 * Megalaima flavifrons (Guvier)
Yellow-fronted Barbet

6 * Pellorneum fussocapillum (Blyth)
Brown-capped Babbler

7 * Phaenicophaeus pyrrhocephalus (Pennant)
Red-faced Malkoha

8 Zoothera sploptera (Blyth)
Spotted-wing Thrush

9 - II (Contd.)

MAMMALS

* Macaca sinica	Toque macaque
* Presbytis senex	Purple-faced langur
Paradoxurus zeylonensis	Golden Palm Civet

FISH

- Garra ceylonensis
- * Puntius bimaculatus
- Belontia signata
- Barbus srilankensis
- * Lebeo fisheri

* Presence of these species within the Accelerated Mahaweli Program Area were confirmed by sightings made by the wildlife field survey team.

Addenda

The wildlife field survey team has located the following additional endemics within the Accelerated Mahaweli Programme Area.

AMPHIBIANS

- Bufo atukoralei
- Rana (Hylarana) gracilis

REPTILES

- Sphenomorphus fallax

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APPENDIX 9 - III

List of Resident Birds Located in the Accelerated Mahaweli Programme Area

PODICIPEDIDAE	
Podiceps ruffcollis capensis Salvadori	Little Grebe
PELECANIDAE	
Pelicanus philippensis philippensis Gmelin	Grey Pelican
PHALACROCORACIDAE	
Phalacrocorax carbo sinensis (Shaw)	Indian Cormorant
P. fuscicollis Stephens	Indian Shag
P. niger (Vieillot)	Pigmy Cormorant
Anhinga rufa melanosgaster Pennant	Indian Darter
ARDEIDAE	
Ardea cinerea rectirostris Gould	Eastern Grey Heron
A. purpurea manilensis Meyen	Eastern Purple Heron
Ardeola grayii (Sykes)	Pond Heron
Bubulous ibis coromandus (Boddaert)	Cattle Egret
Egretta alba modesta (J. E. Gray)	Eastern Large Egret
E. intermedia intermedia (Wagler)	Median Egret
E. garz etta garzetta (Linnaeus)	Little Egret
Nycticorax nycticorax nycticorax (L)	Night Heron
CICONIIDAE	
Ibis leucocephalus (Pennant)	Painted Stork
Anastomus oscitans (Boddaert)	Open-bill Stork
Ciconia episcopus episcopus (Boddaert)	White-necked Stork
Leptoptiles javanicus (Horsfield)	Lesser Adjutant
THRESKIORNITHIDAE	
Threskiornis melanocephala (Latham)	White Ibis
ANATIDAE	
Dendrocygna javanica (Horsfield)	Lesser Whistling-Teal
Nettapus coromandelianus c. (Gmelin)	Cotton-Teal
ACCIPITRIDAE	
Elanus caeruleus vociferus (Latham)	Black-winged Kite
Haliastur indus indus (Boddaert)	Brahminy Kite

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Accipiter badius badius (Gmelin)	Ceylon Shikra
A. virgatus besra Jerdon	Besra Sparrow-Hawk
Spizaetus cirrhatus cirrhatus (Gmelin)	Crested Hawk-Eagle
Lophotrorchis kienerii kienerii (E. Geo.)	Rufous-bellied Hawk-Eagle
Ictinaetus malayensis perniger (Hodg.)	Black Eagle
Haliaectus leucogaster (Gmelin)	White-bellied Sea-Eagle
Ichthyophaga ichthyaetus plumbeiceps (Baker)	Grey-headed Fishing-Eagle
Spilornis cheela spilogaster (Blyth)	Ceylon Crested Serpent-Eagle
PHASIANIDAE	
Coturnix chinensis chinensis (L)	Blue-breasted Quail
Perdicula asiatica ceylonensis	Ceylon Jungle Bush-Quail
Galloperdix bicalcarata (Forst.)	Ceylon Spurfowl
Gallus lafayetti Lesson	Ceylon Jungle Fowl
Pavo cristatus Linnaeus	Common Peafowl
TURNICIDAE	
Turnix suscitator leggei Baker	Ceylon Bustard-Quail
RALLIDAE	
Amaurornis p. phoenicurus (Pennant)	White-breasted Waterhen
Gallicrex cinerea cinerea (Gmelin)	Water-Cock or Kora
Porphyrio porphyrio poliocephalus	Purple Coot
JACANIDAE	
Hydrophasianus chirurgus (Scopolis)	Pheasant-tailed Jacana
ROSTRATULIDAE	
Rostratus b. bengalensis (L)	Painted Snipe
CHARADRIIDAE	
Vanellus indicus lankae (Koelz)	Ceylon Red-wattled Lapwing
Charadrius alexandrinus seebohmi	Ceylon Kentish Plover
RECURVIROSTRIDAE	
Himantopus himantopus ceylonsis	Ceylon Black-winged Stilt

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BURHINIDAE	
Esacus magnirostris recurvirostris	Great Stone-Plover
LARIDAE	
Sterna albifrons albifrons Pallas	Little Tern
COLUMBIDAE	
Treron pompadora pompadora (Gmelin)	Ceylon Pompador Tree-Pigeon
T. bicincta leggei Hartert	Ceylon Orange-breasted Pigeon
Ducula aenea pusilla (Blyth)	Green Imperial Pigeon
Streptopelia chinensis ceylonsis	Ceylon Spotted Dove
Chalcophaps indica robinsoni	Ceylon Broze-winged Dove
PSITTACIDAE	
Psittacula eupatria eupatria (L)	Alexandrine Parakeet
P. krameri manillensis	Southern Rose-ringed Parakeet
P. c. cyanocephala (L)	Blossom-headed Parakeet
P. calthropae (Blyth)	Layard's Parakeet
Loriculus beryllinus	Ceylon Lorikeet
CUCULIDAE	
Clamator j jacobinus (Boddaert)	Pied Crested-Cuckoo
Cuculus varius ciceliae (Phillips)	Ceylon Hawk-Cuckoo
Surniculus lugubris stewarti Baker	Ceylon Drongo-Cuckoo
Eudynamys s. scolopacea (Linnaeus)	Indian Koel
Ehopodytes viridirostris (Jerdon)	Blue-faced Malkoha
Phaenicophaeus pyrrohocephalus	Red-faced Malkoha
Centropus sinensis parroti	Southern Coucal
STRIGIDAE	
Otus bakkamoena bakkamoena Pennant	Ceylon Collared Scops Owl
Bubo nipalensis blighi Legge	Ceylon Forest Eagle-Owl
Glaucidium r. radiatum (Tickell)	Indian Jungle Owlet
Bubo z. zeylonensis (Gmelin)	Ceylon Brown Fish-Owl
Ninox scutulata hirsuta (Temm.)	Indian Brown Hawk-Owl

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CAPRIMULGIDAE	
Caprimulgus macrurus aequabilis	Ceylon Jungle Nightjar
C. asiaticus eidos Peters	Ceylon Common Nightjar
APODIDAE	
Collocalia fuciphaga unicolor	Edible-nest Swift
Apus affinus singalensis Mad.	Ceylon White-rumped Swift
Cypsiurus parvus batasiensis Gray	Indian Palm-Swift
HEMIPROCNIDAE	
Hemiprocne longipennis coronata	Indian Crested Tree-Swift
TROGONIDAE	
Harpactes fasciatus fasciatus	Ceylon Trogon
ALCEDINIDAE	
Ceryle rudis leucomelanura Reich.	Ceylon Pied Kingfisher
Alcedo atthis taprobana Klein.	Ceylon Common Kingfisher
Pelargopsis capensis capensis (L)	White-breasted Kingfisher
Halcyon smyrnensis fusca (Boodaert)	White-breasted Kingfisher
MEROPIDAE	
Merops l. leschenaulti Viellot	Chestnut-headed Bee-Eater
M. orientalis ceylonicus Whistler	Ceylon Green Bee-Eater
CORACIIDAE	
Coracias bengalensis indica L.	Indian Roller
UPUPIDAE	
Upupa epops ceylonensis Reichenbach	Hoopoe
BUCEROTIDAE	
Tokus griseus singalensis (Shaw)	Ceylon Grey Hornbill
Anthracoceros c. coronatus (Buddaert)	Malbar Pied Hornbill
CAPITONIDAE	
Megalaima z. zeylanica (Gmelin)	Brown-headed Barbet
M. flavifrons (Cuvier)	Yellow-fronted Barbet
M. haemacephala indica	Crimson-breasted Barbet
M. rubricapilla rubricapilla	Small Ceylon Barbet
PICIDAE	
Micropternus brachyurus jerdoni	Rufous Woodpecker
Dinopium benghalensis psarodes	Ceylon Red-backed Woodpecker

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Dendrocopus maharattensis maharattensis	Yellow-fronted Pied Woodpecker
D. nanus gymnopthalmus (Blyth)	Ceylon Pygmy Woodpecker
ALAUDIDAE	
Mirafra assamica affinis Blyth	Indian Bushlark
Eremopterix grisea (Scopoli)	Ceylon Finch-Lark
HIRUNDINIDAE	
Hirundo daurica hyperythra Blyth	Ceylon Swallow
ORIOLIDAE	
Oriolus xanthornus ceylonensis Bonap.	Black-headed Oriole
DICRURIDAE	
Dicrurus caerulescens insularis	White-bellied Drongo
D. paradiseus ceylonicus	Racquet-tailed Drongo
ARTAMIDAE	
Artamus fuscus Vieillot	Ashy Swallow-Shrike
STURNIDAE	
Acridotheres tristis melanosternus	Common Myrah
Gracula religosa indica (Cuvier)	Common Grackle
CORVIDAE	
Corvus splendens protegatus Madrasz	Ceylon House Crow
C. macrorhynchos culminatus Sykes	Black Crow
CAMPEPHAGIDAE	
Hemipus pictus leggei Whistler	Ceylon Pied Cuckoo-Shrike
Tephrodornis pondicerianus affinis	Ceylon Wood-Shrike
Coracina melanoptera sykesi	Black-headed Cuckoo-Shrike
Pericrocotus flammeus flammeus	Ceylon Little Minivet
P. c. cinnamomeus	Ceylon Little Minivet
IRENIDAE	
Aegithina tiphia multicolor (Gmelin)	Common Iora
Chloropsis aurifrons insularis	Gold-fronted Chloropsis
C. cochinchinensis jerdoni	Jerdon's Chloropsis
PYCNONOTIDAE	
Pycnonotus m. melanicterus (Gmelin)	Black-capped Bulbul
P. cafer haemorrhousus (Gmelin)	Red-vented Bulbul
P. luteolus insulae (Whist & Kin.)	White-browed Bulbul
Hypsipetes indicus indicus (Jerdon)	Yellow-browed Bulbul
H. madagascariensis himii	Ceylon Black Bulbul

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TIMALIDAE	
Pellorneum fuscoeapillum babaulti (Wells)	Brown-Capped Babbler
Pomatorhinus schisticeps holdsworthi	Ceylon Scimiter-Babler
Dumetia hyperythra phillipsi	Ceylon White-throated Babbler
Rhopocichla atriceps siccatus	Ceylon Black-fronted Babbler
Chrysomma sinensis nasalis (Legge)	Yellow-eyed Babbler
Turdoides affinis taprobanus Ripley	Common Ceylon Babbler
MUSCICAPIDAE	
Muscicapa tickelliae jerdoni (Hold.)	Tickell's Blue Flycatcher
Rhipidura aureola compressirostris	White-browed Fantail-Flycatcher
Monarcha asurea ceylonensis (Sharpe)	Ceylon Azure Flycatcher
SYLVIIDAE	
Cisticola juncidis cursitans (Franklin)	Fantail Warbler
Prinia hodgsonii pectoralis Legge	Franklin's Prinia
P. subflava insularis (Legge)	White-browed Prinia
P. sylvatica valida (Blyth)	Ceylon Large Prinia
P. socialis brevicauda Legge	Ceylon Ashy Prinia
Orthotomus s. sutorius (Pennant)	Ceylon Tailor-Bird
TURDIDAE	
Copsychus saularis ceylonensis	Southern Magpie-Robin
C. malabaricus leggei	Ceylon Shama
Saxicolodies fulicata leucoptera	Ceylon Black Robin
PARIDAE	
Parus major mahrattarum Hartet	Ceylon Grey Tit
SITTIDAE	
Sitta frontalis frontalis Swainson	Velvet-fronted Nuthatch
MOTACILLIDAE	
Anthus novaeseelandiae malayensis	Indian Pipit
DICAEIDAE	
Dicaeum agile zeylonense (Whistler)	Thick-billed Flowerpecker
NECTARINIIDAE	
Nectarina zeylonica zeylonica (L)	Purple-rumped Sunbird
N. lotenia lotenia (L)	Loten's Sunbird
N. asiatica asiatica (L)	Purple Sunbird

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ZOSTEROPIDAE	
Zosterops palpebrosa palpebrosa (Temm.)	Small White-Eye
PLOCEIDAE	
Passer domesticus indicus	House-Sparrow
Ploceus philippinus philippinus (L.)	Bays Weaver
P. manyar flaviceps Lesson	Striated Weaver-Bird
ESTRILDIDAE	
Lonchura striata striata (L.)	White-backed Munia
L. punctulata punctulata (L.)	Spotted Munia
L. malacca malacca (L.)	Black-headed Munia

Appendix 9 - IV

Financial, Technical, And Infrastructure Capabilities Of The Department of Wildlife Conservation, Sri Lanka

1) Budget 1979	Salaries	Rs. 2,844,000 =	45.6%
	Travel	300,000	
	Supplies	305,000	
	Maintenance	150,000	
	Utilities	90,000	
	IUCN Membership	3,000	
	Capital Equipment	764,990 =	12.3%
	Permanent Structures	1,784,000 =	28.6%
	Total Budget	Rs. 6,240,990 =	$390,061

2) Wildlife Reserves

Status	No.	Area (Sq. miles)
National Parks	5	1,175.45
Intermediate Zones	2	139.29
Strict Natural Reserves	4	234.47
Nature Reserves	1	12.20
Jungle Corridor	1	40.00
Sanctuaries	45	799.63
Total	58	2,401.04 Sq. miles

3) Field Personnel

Job Description	No.	Minimum Education Qualifications
Park Wardens	5	10th Grade
Deputy Park Wardens	4	10th Grade
Rangers	34	10th Grade
Range Assistants	81	8th Grade
Wildlife Guards	288	7th Grade
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No. of field personnel stationed in National Parks = 266
No. of field personnel stationed in other wildlife preserves = 156

4) Vehicle Pool

Description	No.	
4-Wheel drive jeeps	29	
Tractors	8	
Motor bicycles	3	
2-Wheel tractors	2	
Bus	1	
Saloon car	1	loaned by the Ministry of State

Source: Dept. of Wildlife Conservation

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CHAPTER 10

ECONOMICS

INTRODUCTION

The economic analysis seeks to evaluate the environmental impacts on the area within the accelerated Mahaweli Development Program (MDP) as a result of the various proposed projects. Where negative impacts are identified (and wherever possible quantified) alternative cost effective approaches will be recommended to mitigate the effects.

The basic tenent of this report is develop the planning tools necessary to help optimize the efficiency of land use through identification and quantification of environmental impacts representing opportunity costs to society.

Other areas open to analysis while technically outside the parameters of strict environmental impacts, but nevertheless of importance are income distributions, and marginal efficiency of applied capital.

It must be emphasized that this is a particularly arduous undertaking in that a great deal of the realm of this analysis lies within that which has traditionally been relegated to indirect costs and benefits generally passed over in project appraisal because of the extreme difficulty of prediction and quantification.

Traditional analysis relegates itself to input; output relationships and subsequent economic and financial profitabilities according to project goals. Environmental impact analysis however concerns itself with the repercussions to the resource base itself as a result of project development. This resource base includes the physical as well as animal and human environment and the costs and benefits to society as a whole. Some of these impacts are directly related to the resource base (erosion, water quality) and

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are quantifiable, others are indirect impacts which are associated with society values (clear air, open vistas) and are extremely difficult to value.

It should be pointed out at this stage that it is not the purpose of this report to critique the various feasibility studies on the systems within the MDP, nor to determine whether or not they are viable. However, whenever a negative impact to the environment is ascertained it will be treated first in the context as a cost to society (opportunity cost of development), this cost then can be handled in a number of different ways according to planning goals; a line item cost to development of a project, cost of mitigation or, finally, a cost significant enough to warrant an alternative plan.

In general this report will treat the environment as a productive system with the basic production unit being soils. Environmental values will be established according to various yields. To equate this concept to traditional input, output relationships, the yields will be expressed on an annual basis and (wherever possible) given a present net value following the same quantitative assumptions developed for each system feasibility study. Unfortunately there was no standardization between the various consultant studies resulting in varying discount rates and opportunity costs of capital, thus emphasizing various I. R. R. cutoffs.

Analysis of Topic Areas

The various topic areas have been introduced previously in this report along with the technical analysis to date. Some of these topics represent factors of production (soils, water quality, labor) and some represent production systems (wildlife, fisheries, wet lands). Many of the topics will lend themselves to quantifiable interpretation with measurable data, others will surely stretch the imagination and ingenuity to attempt assigning values. Nevertheless are all components of the environment and are assumed in some measure to effect or be affected by the proposed projects.

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In the final report the economic analysis will be incorporated into each topic, however for the purpose of this mid term report the economic section is separated to show the types of analyses undertaken on data available to date. Where data is lacking a scenario will be developed to show how the various impacts will be analyzed. It must be emphasized that data used in this report is provisional and subject to change in entirety by the time of the final report due to updates and corrections.

LAND USE AND SOILS

As previously mentioned, the basic resource unit or factor of production under consideration in this report is the soils component of the environment. The soils will be analyzed in terms of productive compacity under present usage and as to potential capacity given altered factor inputs - technology, annual controlled water, fertilization etc. Soil analysis is the basic requisite toward development of proper land use planning with the subsequent goal of highest and best usage given certain factor constraints inherent to a developing country. For instance proper land use planning will identify those soils giving high returns under labor rather than capital intensive cultivation. It will also allow for analysis necessary to determine reallocations where diminishing marginal returns are pushed toward irrational production.

Data developed in this topic area will be used throughout the report and incorporated in other topic areas. Negative impacts to be analyzed will be on the order of environmental degradation due to land misuse (erosion, loss of water shed, loss of nutrients resulting in reduced production), project oriented impacts (raised water levels due to inadequate surface runoff and subsoil drainage) and inefficiencies due to planning policies (land use allocations, cropping patterns).

FORESTRY

While there are forests or remnants of forests in all the systems initial concentration to date has been made on the forest area

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in System C north of the Kuda Oya. This area has received primary attention because of its high environmental and economic value as an area of timber production, vegetative zone, wild life habitat and important water table and soil quality effects.

The data analysis developed on this initial look at System C will be refined and upgraded to eventually be incorporated in the forestry/soils/land use planning analysis throughout the entire accelerated project.

Primary data used to date is based on the Hunting Survey Corporation Forest Inventory, Ceylon 1961 (Andrews) with updates from Hunting Technical Services Limited, Feasibility Study 1979.

Table 11-1 shows the volume by percent composition of commercial timber in the northern Block for group size and class. The percentage is a weighted average based on original data from the Hunting survey in 1961. An attempt will be to update this through both photo interpretation and ground survey.

Table 11-2 shows potential annual timber production based on a harvest rotation of 100 years with a 20 year cutting cycle (2% of growing stock annually concentrated on 5% of total area).

At the time of this report the financial price and gross value for an annual harvest has been determined based on updated price lists from the State Timber Corporation (STC), Hunting Surveys 1979 (wira and poles) and interpolation based on the fact that the State Timber Corporation supplies 50% of timber demanded, the remainder is supplied by import, private contractors and illict felling. This incremental supply price was determined through local market surveys of manufacturers, sawmills and suppliers to be abot 50% higher than STC listed prices.

Economic prices have not yet been developed due to lack of data on import substitution for building grades or export substitution

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for luxury grade woods. For example the value of ebony is commonly quoted locally as being "inestimatible" meaning that a piece of ebony large enough to manufacture into a piece of furniture could command presumably "any" asking price. Since there is no set world price for the luxury grades found in System C then an economic value has to be determined on a value added or finished product basis less factor inputs.

The annual harvest of commercial logs represented in this analysis is 84.42 Mcuft. representing a gross value of 5,013,400 Rs. Production costs are figured on use of labor intensive operations, elephant power and road transport by truck. This cost of production is figured at 5.477 Rs./cu ft. giving a net financial return of 4,551,623 Rs. annually to forest production. It should be emphasised that this concept of forest production is developed entirely on a management concept with sustained yield production applied to the growth characteristics of each harvested species.

The present worth estimate presented shows only a part of the value associated with the forest. In addition to the timber production e.g. grazing for livestock, wildlife habitat and medicinal herbs. These are readily identifiable and to some extent can be quantified. However in addition there are other components which, while not readily quantifiable, still represent very real values; water shed, soil quality and retention and finally the social value inherent in a natural resource and national heritage.

Attempts will be made as the report progresses to quantify as much of the resource as possible to give an accurate picture of present value.

WILDLIFE

While intentively it would seem likely that all forms of wildlife have value whether as eco-value inherent to the biological dynamics of an ecosystem, market value or esthetic value, seldom is

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this value quantified or even considered in project analysis. The reason for this is obvious in that quantification of these values is extremely difficult. A value may sometimes be assigned to an ecosystem as a whole representative of a major production component of that system e.g. forests. However, to analyze each component of an ecosystem, their interactions and possible repercussions due to environmental alteration is a tremendous undertaking bordering on the impossible and outside the time frame of this report. With this in mind, determination has been made to look at key species considered to have the most significant impact on altered environment or to be most affected by habitat reduction. Before progressing further in this discussion the basic premise from which subsequent analysis will take place is this : under natural conditions wildlife tend to exist in dynamic equilibrium with their environment. Biological control keeps the numbers of producers and consumers in check with existing conditions. Alteration of the natural environment through human technology will tend to cause a disequilibrium. This disequilibrium will be felt in the wildlife community through habitat reduction and a complete cyclic chain of events affecting species composition. In turn feeding pressures forced upon the wildlife will be felt in encroachment into areas of human settlement at which point the term pests comes into play with its attendant costs to development and production.

It is obvious from the above that a complex set of cause and effect relationships will take place as a result of the proposed projects. It is also apparent that two cost aspects will have to be analyzed i.e. the cost of disequilibrium to the environment which can be termed the opportunity cost of development and the subsequent cost to the projects as a result of the created pest problem.

In all likelihood it will probably prove too ambitious an undertaking to quantify the true opportunity cost of development in terms of wildlife, however the technological input in this report will develop the data base not only necessary to assess the costs to the project due to wildlife encroachment, but to prepare cost effective mitigation.

The key species which are being analyzed to date are :

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ELEPHANT

Lyn de Alwis, Director of Wildlife Conservation estimates there are approximately 800 elephant inhabiting the accelerated project area. Of these elephant approximately ¼ are located in areas which planners have allocated for development, thus increasing the potential for conflict. Reports to date have shown sustained crop losses of up to 20% in some settlement and estate areas (Kantalai Sugar Estate, Village reports). In addition elephant encroachment has started to occur in Teak plantations in the last few years. Losses in Teak alone amounted to over 75 million U.S.$ in 1975 (Administration Report, Forest Dept. 1975).

It is quite apparent that elephant are a major source of potential crop loss in the project area as evidenced by previous development schemes. However elephant cannot be treated simply as a pest representing a decreasing nuisance cost over time (assuming humans win the war). Due to the high social value (placed on elephants through both religious context and conservation - Sri Lanka's elephants are on the endangered species list) and, market value associated with the wild herd as a source for the domestic animal work force, it is insufficient to look at mitigation of crop losses as an end point. A comprehensive conservation program must be developed with the view that elephant be removed from areas of conflict and kept in preserves that are adequately enhanced and maintained to ensure containment and/or absorbed into the domestic herd.

The economics of such a venture can be analyzed from a number of ways. One is that the benefits outweigh the costs simply because the high social value based on religious grounds and preservation negates all else. However this scenario would seem to indicate that a laissez faire attitude might also exist which would tend to ignore the true conflict cost. Another method is to value the elephant as an economic unit in terms of supply for domesic stock, a value presently established at 60,000 Rs (age and sex dependent), and as potential source of revenue from a tourist industry. Finally the

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elephants can be analyzed in relation to negative impacts to development. These impacts can be measured as crops destroyed, farm settlement failures and production land ignored.

In all likelihood all three methods mentioned should be used for economic justification. The social value to show the need for conservation of elephant and preserved habitat, the economic value to show an intrinsic worth, and the nuisance cost to show not only the cost to the project but the cost effective approaches needed to mitigate.

Wild Boar

A somewhat different approach will be incorporated into the analysis of the wild boar. Social value and market value will probably not apply here, leaving a straight forward analysis as to the pest or nuisance cost to production.

Wild Boar have proven a great nuisance to production in that they are prolific, adaptable to human pressures, can cause great crop damage through both feeding and rooting and are very resistant to control measures. While current data is scant concerning Wild Boar encroachment on crops, estimates on the Kantalai sugar estate show consistent losses of 20% (A. Rajendra, 1973). Further data will be analyzed including a mixture of technical and biological control.

Fisheries/Wetlands

Both of these topics will be combined in this report as the data to date links them in terms of quantifiable production impacts.

The proposed reservoirs in the accelerated area will have a direct benefit on production of fresh water fish. Table 3-4 shows estimated fish yields from the reservoirs to be 2570 tonnes annually. Since little input cost is attributed to this production it can be considered almost as a windfall. The gross financial value of this benefit is 11,297,880 rupees based on a present average price of fresh water fish at 4.4 Rs/Kg. This production potential of 4770 tonnes annually (see Section 3 Fisheries) with a total gross value of 20,988,000 Rupees.

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The importance of fish production cannot be over emphasized not only in terms of employment generation but also as a food source that ranks very high in meeting basic human needs for animal protein. Very few animal protein sources are as cost effective to produce in terms of protein equivalents as fish.

Illustration of this point will be made using the net fish protein production potential from the figures presented above, given that the minimum per capita daily requirement of animal protein is 30 grams (Altshul: 1965). If the entire fish product from the reservoirs is marketed to the settlement families (estimated population of 1,000,000) this amount would supply 359,800 kg net protein (14% of total fish weight) or about 3.3% of the total daily animal protein requirement. With the additional production from other water sources taken into account, the ensuing 4770 tonnes would supply 667,800 kg net kg protein or 6.1% of total daily animal protein requirement.

The economic analysis of inland fisheries and its value as a food source relating to proper nutrition and employment effects are still in the formative stages. What needs to be undertaken from this point on is:

A) identify the dietary animal protein gap, if any, present in the rural sectors of Sri Lanka
B) determine the most cost effective means of closing this gap
C) propose programs to obtain this goal

It is likely that there is a substantial animal protein gap and that increased fish production will be a high candidate to help fill this gap as evidenced in other countries with similar religious and cultural bias associated with animal production and slaughter.

Sensitivity analysis will be conducted to determine what production levels will supply daily requirements from 100% down to 10% along with cost data to justify a chosen optimum level of production given technological, market and cultural constraints.

While development of reservoirs will increase fish production, at the same time there are going to be downstream effects as a result of the projects. Dams and water diversion will result in lower river levels and reduced wetlands area.

The subsequent impact on the wetlands (Villus) is ected to be significant. Villus are considered to be the ighest resource producers of biomass. This includes not only aquatic production but peripheral vegetative production utilized for grazing by both wildlife and domestic stock. This reduction on Villu size will negatively affect a highly productive food chain complex.

Presently the total Villu surface area associated with the Mahaweli Ganga and its tributaries totals 10,400 hectares, representing a mean annual surface area of some 8,200 hectares. (Sobezak). Combined fisheries production from these Villus is 50 Kg/ha or 410,000 Kg. Assuming that the total surface area was reduced by 40% due to diversion schemes and that fish production was directly proportional to surface area then a 40% drop in fish production or a loss of 246,000 Kg could be expected (this proportionality is a fair assumption due to the shallowness of the Villus). In terms of value at 4.4 Rs./Kg. this represents a 721,000 Rs. loss per annum. Other value loss from other organisms and grazing will be considered as more data becomes available. For instance, grazing potential alone, based on a 40% area reduction could be reduced by 4100 ha annually - the value of this needs to be worked out.

Measures such as weirs to prevent return drainage will be investigated as cost effective means of negative impact mitigation, as well as the opportunity cost of foregoing wetlands production in favor of cropping.

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Table 11 - 1

Size Group	(1) Class	(2) %	Vol (Mcuft)
4"-60"	1	3.32	138
	2	16.27	678
	3	60.00	2500
	1	1.38	57
	2	6.00	251
	3	14.00	584
		Total	4208

(1) Species Classes

1. Hamilla
2. Satin
   Hulanbik
   Ebony
   Milla
3. All others (except wira)

(2) Percentage weighted average of species by class and size from Hunting Survey Corporation. Forest Inventory, Ceylon 1961 (Andrews).

Table 11 - 2

Potential Annual Timber Production

Size Group	Class	Vol (Mcuft)	Sales Price	(Value 000 Rs)
4" - 60"	1	2.76	51.60	142.42
	2	13.56	66.60	903.1
	3	50.00	33.15	1,657.5
60"	1	1.14	308.70	351.92
	2	5.02	308.70	1,549.67
	3	11.68	34.80	406.46
WIRA		.255	9.13	2.33
		84.42		5,011.7

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