An Environmental Evaluation of the Accelerated Mahaweli Development Program:

Lessons Learned And Donor Opportunities For Improved Assistance

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PURPOSE AND OBJECTIVES OF STUDY

The U.S. Agency for International Development (USAID) requested a comprehensive evaluation of three USAID-financed activities that sought to address environmental problems in the Mahaweli river basin. The purpose of this effort has been to assist USAID, the Government of Sri Lanka (GSL), and other donors to determine whether environmental management measures previously recommended in the USAID-financed Tibbetts-Abbett-McCarthy-Stratton Environmental Assessment (TAMS Environmental Assessment) and the Environmental Action Plan for the Accelerated Mahaweli Development Program (AMDP) and subsequent actions carried out through the USAID-financed Mahaweli Environment Project (MEP) and the Forest and Watershed Management Project (FWMP) have effectively mitigated specific environmental problems anticipated in the Mahaweli basin.

The Mahaweli Environmental Evaluation Team included nine professionals in ecology, forest and watershed management, wildlife conservation, project planning and management, environmental economics, agronomy and soil science, and sociology. Team members conducted field work, data collection, and interpretation of results in Sri Lanka from October 15, 1992, through January 29, 1993. Four formal workshops were held during this period with GSL, NGO, other donor representatives, and private sector representatives to provide input on project research activities, strengthen the database used by team members, and present tentative and final findings and recommendations. Two debriefings of findings have been presented to USAID personnel. Numerous informal meetings have been held with GSL, NGO, other donor representatives, and private sector representatives during the course of the study.

THE MAHAWELI RIVER BASIN AND THE AMDP

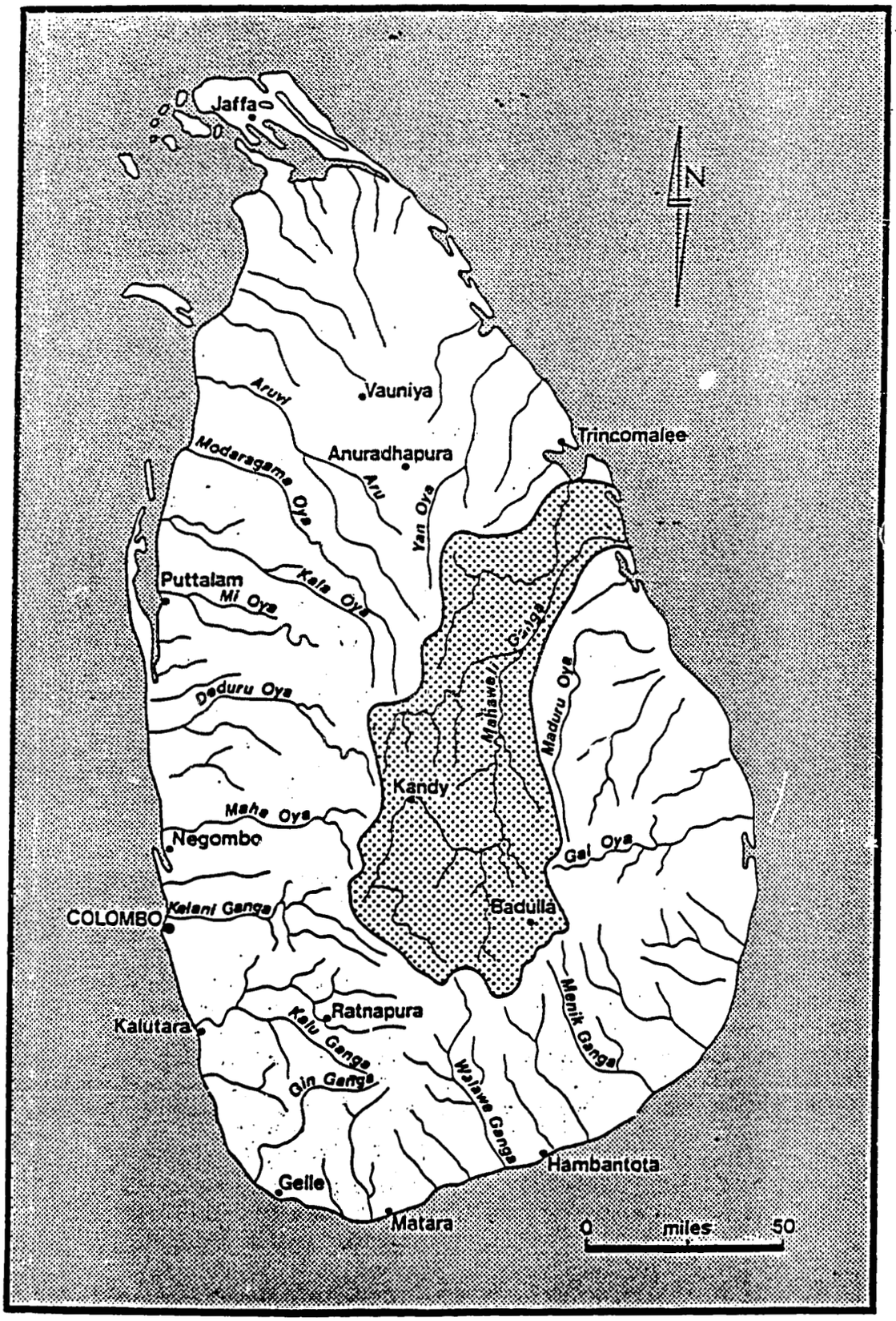
Sri Lanka rises to a central massif in the south central portion of the island. The principal rivers in the country radiate from these highlands and are dominated by the Mahaweli Ganga, which drains more than 16 percent of Sri Lanka's land surface (Figure 1). The Mahaweli carries approximately one-seventh of the total annual runoff and includes a wide variety of biotic communities within its large drainage area.

Prior to the large scale development of the Mahaweli basin for agricultural production, more than 50 percent of the land area was covered with mature tropical humid, subhumid, or dry forests. The steep lands in the upper reaches of the basin were in a mix of closed-canopy tropical montane humid forest cover and developed agricultural lands (mostly tea plantations), and the lower slopes supported dense, but drier, tropical forest cover. All of these lands had been encroached upon to some extent, although habitats were reasonably well connected, with occasional fragmentation.

Biological diversity in these earlier forest and grassland areas in the Mahaweli basin was very high, including most of the 251 resident bird species reported from Sri Lanka, an additional 75 migratory bird species, more than 50 mammal species, more than 20 reptile and amphibian species, and a wide variety of invertebrates. Nine recognized threatened or endangered species resided in the basin. Moreover, 53 endemic plant species and 17 very rare plants had been identified in the basin.

FIGURE 1

SRI LANKA, SHOWING THE MAHAWELI BASIN



The development of agricultural lands in the basin, particularly in the lower areas of Systems A-H, has vastly reduced the total forest cover. The designated forest reserves in the lower basin have been largely cleared. Many of the remaining forest areas have been high-graded, where the more valuable commercial species are removed and less useful trees are left standing. High-grading often results in reduction of species diversity, genetic stock, and populations of plants and animals.

Land use varies from the upper catchment areas to the lower parts of the basin, largely as a result of climatic influences on agricultural options. More than 50 percent of the upper catchment lands are in some form of intensive agricultural production, mostly tea. An additional 20 percent appears to be in fallow or abandoned agricultural land, with the remainder divided between remnant forest cover and smaller-scale agriculture.

Slopes are typically steep, with 75 percent of the upper catchment characterized by gradients of 20-40 percent. The latisol soils are moderately resistant to erosion and have high productive potential for agriculture. Podzolic soils and reddish brown earth, which together constitute almost 85 percent of the upper catchment, are very erodible and are best used for some form of sustainable forestry.

The downstream areas are divided between forest and woodland areas, pasture and anthropogenic grasslands, seasonal (*chena*) cultivation, and permanent crop production. Prior to the large-scale agricultural development of the lower basin, approximately 75 percent of the area was in forest or woodland. This forest area has been significantly reduced, with the majority of land now in crop production, principally paddy rice.

Several large towns are located within the Mahaweli basin, including Nuwara Eliya, Kandy, and Trincomalee. Beyond these towns, most residents live in small communities or villages. Total population within the basin is uncertain, although the area includes some of the lower population densities in Sri Lanka.

Many of the communities in the lower parts of the basin are new, particularly in Systems A-H, having arisen through in-migration during the past 20 years. Some newer villages include residents of government or private company colonization schemes. Other villages comprise migrants who are encroaching illegally on state owned land. Both types of communities are common in the areas affected by the Mahaweli Environment Project. The Reforestation and Watershed Management Project (RWMP) often worked with older, more established communities that have increased in size through in-migration of workers.

Primary income sources are the sale and distribution of cultivated crops, with paddy rice being the principal lowland crop, and potato and other vegetables common in the uplands. Tea plantations occupy much agricultural land in the uplands and provide a source of employment to many residents. Harvest of forest products for timber, fuelwood, and handicraft materials is a common practice in areas where intact forests can still be found, although much of these harvests are often illegal. Service industries have developed in many towns that surround the colonized agricultural communities.

Living conditions in most of the rural communities are very basic, and the overall standard of living is low in comparison with other more established areas of Sri Lanka. Public health conditions can be poor, with many common tropical diseases endemic.

Plans for a comprehensive development of the water resources within the Mahaweli basin were initiated in the 1960s. The objectives were to increase agricultural output by creating more reliable water supplies for downstream irrigation and to increase energy production capabilities. These developments

would also take advantage of the fact that large areas of undeveloped lands could still be found in the northern and eastern dry zones, whereas virtually all agricultural lands in the southwestern wet zone were already in use.

A Master Plan recommended a combination of water storage, hydropower production, improved downstream agricultural facilities, and the clearing and development of new agricultural lands. The development of these downstream agricultural areas proceeded, with land units divided into systems designated by letters A through H. This program was to be implemented over a period of 30 years under the assumption that financial and other constraints would prevent the country from implementing more than one major project at a time (Gunatilaka, 1991).

By 1976, the Polgolla barrage near Kandy and the Bowatenna reservoir and irrigation tunnel southeast of Polonnaruwa had been completed. To expedite resource development in the Mahaweli basin, a consolidated version of the original Master Plan was implemented in 1977 and became known as the Accelerated Mahaweli Development Program. The focus of the AMDP was to provide solutions for acute unemployment problems, loss of foreign exchange for agricultural imports, and a shortage of electrical energy (Hewavisenthi, 1992).

AMDP consisted of the following multipurpose projects: Kotmale Project, Polgalla Diversion, Victoria Project, Randenigala Project, Rantembe Project, Minipe Diversion, Maduru Oya Project, Bowatenna Project, Elahera Diversion, and Angamedilla Diversion.

ENVIRONMENTAL CONDITIONS AND ISSUES IN THE MAHAWELI WATERSHED

The development of the Mahaweli watershed has resulted in some important and extremely valuable social, economic, and technological benefits for Sri Lanka. The project has enabled a large number of poor people to obtain access to land and livelihoods and has significantly increased the country's food production and power resources. However, these advances were not made without some costs, particularly in terms of adverse environmental change.

Over the years, approximately 127,000 hectares of land has been brought under cultivation in the Mahaweli watershed. More than 400,000 people have been settled in the lower catchment area, and these families have participated in the transformation of several hundred thousand hectares of sub-humid tropical rainforest into cultivated fields. Construction of dams and irrigation conveyance networks, roads and related infrastructure has radically altered the way soil and water moves, and biological systems function in the watershed.

An environmental assessment prepared by USAID in 1980 predicted quite accurately many of the major adverse environmental changes that would result from or affect the AMDP, including degradation of watershed conditions, declining water quality, loss of wildlife habitat and populations, and incomplete social infrastructure developments. Many of these environmental problems continue to persist in the Mahaweli basin. The problems generally represent a constraint to some of the original objectives of the AMDP, and contribute to a degradation of the quality of both human and non-human lives in the basin.

The principal adverse environmental impacts within the Mahaweli basin include the following:

- Watershed Systems

  — On-site soil loss rates, particularly in the upper catchment, continue to be greater than soil replacement rates.

  — Downstream water quality in the lower catchment area is being degraded as a result of nutrient loading and pesticides from farm runoff.

  — Natural forest ecosystems are being degraded or eliminated in both the upper and lower catchments because of expanding agriculture and unregulated harvest of forest products.

  — Sediments and agrochemicals in runoff water are resulting in eutrophication of reservoirs.

  — Water management schemes have changed the natural flow regimes of the major rivers, resulting in occasional higher flood flows, lower dry season flows, and degradation of riparian and wetland habitats in the lower catchment.

  — Sediment inflow is beginning to fill some reservoirs and threatens to shorten the useful life of the reservoir network.

- Agricultural Systems

  — Chemical inputs to agricultural systems in the upper and lower catchment areas are degrading local surface and ground water quality.

  — Cropping patterns are often inappropriate for the soil and microclimatic conditions of the site, resulting in reduced productivity and increased reliance on environmentally inappropriate agricultural practices.

  — Poor water management practices, principally in lower catchment irrigated areas, have increased the threat of soil salinization and on-site soil losses.

- Wildlife and Biodiversity Systems

  — The current data on wildlife population characteristics, migration and dispersal patterns, and habitat requirements are not sufficient to guide management decision making.

  — Habitat conditions in many of the designated protected areas have been degraded over time, and restoration or enrichment measures have been inadequate to support existing wildlife populations.

- Social and Economic Systems

  — Land allocation schemes provide too small a land base to support more than one generation through agricultural production, resulting in declining quality of human life and an increase in illegal land uses.

— The social infrastructure in the upper and lower catchment areas cannot yet fully meet the needs for satisfactory health, education, training, or financial well-being of the region over the long term.

It is important to recognize that many of these impacts may not be the result of the construction and infrastructure development of AMDP. In fact, the very limited baseline data that describe pre-existing or even immediate post-project conditions make it extremely difficult to determine the degree to which the AMDP contributed to or represents a direct or indirect cause of any of these impacts. At this point in Sri Lanka's development, blame for the causes of environmental impacts seems of marginal value. The key factor seems that the problems not only persist, but also appear to be increasing in magnitude.

LESSONS LEARNED AND STRATEGIES FOR IMPROVEMENT

There are a variety of opportunities for responding to these mounting adverse environmental impacts in the Mahaweli basin. In many ways, these responses can quickly get to the root causes of overall environmental problems in the watershed and mobilize efforts to sustain and restore the Mahaweli ecosystems. In general, these responses can be summarized:

- Coordinated monitoring of environmental systems is needed in the upper and lower catchment areas to facilitate the development of site or issue-specific management responses. GSL institutions can benefit by improving the technical, financial, or infrastructure capacity to carry out effective monitoring of watershed and environmental management needs.

- Local participation in environmental management should be increased to make implementation of conservation schemes realistic and successful.

- Soil conservation, land use, and environmental management responsibilities can be improved if responsibilities are consolidated and coordinated within a few ministries and agencies and a more coordinated effort is developed for watershed management. Environmental management can also be enhanced through more definitive national policies that are publicized and enforced.

There are no simple answers that will enable Sri Lanka to rapidly overcome these limitations. However, in taking a retrospective view of the environmental history of AMDP and associated development activities in the Mahaweli basin, a few generalized lessons learned may provide valuable guidance to future project efforts. These paradigms can guide actions designed to conserve or restore the essential environmental services that support human endeavors in the watershed. These lessons learned can be summarized within two essential principles, which overlap and are mutually reinforcing:

- Maintenance and restoration of the environmental systems and natural resources base in the Mahaweli watershed should be elevated to a very high priority in management decision making, with adequate personnel and infrastructure to address environmental concerns. This could require some institutional restructuring within the management authority, as well as clarified and empowered policies and mandates. The entire Mahaweli watershed system should become the base operating unit for planning and decision making.

- Future development activities should provide the kind of infrastructure that gives people options and the power to make sustainable decisions: schools, health centers, training, marketing services, and financial resources. These activities should be designed to break the link between poverty and environmental degradation and to provide a strong local input if mitigative actions are to be respected and sustained.

The technical, administrative, institutional, or policy actions that emerge as a response to specific environmental issues should be framed within the context of these principles if they are to be sustainable over the long term and if they are to have the magnitude of impact necessary to influence environmental conditions in an area as large as the Mahaweli drainage basin. The kinds of institutional changes, personnel development, and financial investments required to encourage such a shift need not be exorbitant. Much of the change can be accomplished by elevating and empowering some existing positions within the management structure, decentralizing other responsibilities in tandem with training and educational opportunities in environmental management, establishing policies and mandates that can and will be enforced, and creating an investment environment that acknowledges and respects ecological functions as the key to long-term economic and human well-being.

SECTION ONE

INTRODUCTION

PURPOSE AND OBJECTIVES OF STUDY

The U.S. Agency for International Development has requested a comprehensive evaluation of three USAID-financed activities which sought to address environmental problems in the Mahaweli river basin. The purpose of this effort has been to assist USAID, the Government of Sri Lanka (GSL), and other donors to determine whether environmental management measures previously recommended in the USAID-financed Tibbetts-Abbett-McCarthy-Stratton Environmental Assessment (TAMS Environmental Assessment) and the Environmental Action Plan for the Accelerated Mahaweli Development Program (AMDP) and subsequent actions carried out through the USAID-financed Mahaweli Environment Project and the Forest and Watershed Management Project (FWMP) have effectively mitigated specific environmental problems anticipated in the Mahaweli basin. The objectives of this effort included:

- To describe present conditions and key environmental management issues in the Mahaweli river basin, taking into account technical, social, institutional, or policy factors contributing to or important in the resolution of these issues;

- To determine the extent to which recommendations from the TAMS Environmental Assessment and follow-up TAMS Environmental Action Plan have been completed or accomplished through MEP, FWMP, or other donor or GSL activities;

- To define lessons learned from USAID or other donor-financed activities to guide future environmental management efforts in the Mahaweli river basin;

- To identify strategies or measures that could strengthen or otherwise improve the recommendations made in the TAMS Environmental Assessment and follow-up Environmental Action Plan for the Mahaweli basin;

- To describe actions that can be taken by USAID, GSL, or other donors to build upon the results from the TAMS Environmental Action Plan, MEP, and FWMP and further improve environmental management practices and ecological conditions in the Mahaweli watershed;

- To document the principal results of MEP and FWMP including accomplishments, constraints, and problems encountered;

- To describe the social, economic, and biophysical implications of the results from MEP and FWMP, including identification of physical, biological, social, economic, or institutional constraints that have prevented implementation of recommendations or proposed actions;

- To correlate the results from MEP and FWMP with the recommended mitigative measures in the TAMS Environmental Assessment and follow-up TAMS Environmental Action Plan; and

- To communicate the results and recommendations from this analysis to concerned USAID, GSL, NGO, PVO, private sector, and other donor workers through written reports, seminars, and workshops.

The Mahaweli Environmental Evaluation Team included nine professionals in ecology, forest and watershed management, wildlife conservation, project planning and management, environmental economics, agronomy and soil science, and sociology. Team members conducted field work, data collection, and interpretation of results in Sri Lanka from October 15, 1992, through January 29, 1993. Four formal workshops were held during this period with GSL, NGO, other donor representatives, and private sector representatives to provide input on project research activities, strengthen the database being used by team members, and present tentative and final findings and recommendations. Two debriefings of findings have been presented to USAID personnel. Numerous informal meetings have been held with GSL, NGO, other donor representatives, and private sector representatives during the course of the study.

USAID ENVIRONMENTAL POLICIES AND REGULATIONS

USAID/Sri Lanka must follow a clearly defined set of environmental mandates. These procedures are modeled on the U.S. National Environmental Policy Act (NEPA), authorized by Congress in 1969, and subsequent guidelines developed by the U.S. Council on Environmental Quality (CEQ). The environmental policy for A.I.D. is specified in federal regulations CFR 22, Part 216. In summary, this legislation requires USAID/Sri Lanka to:

- Ensure that environmental consequences of A.I.D.-financed activities are identified and considered by both A.I.D. and the host country prior to a final decision to proceed, and that appropriate environmental safeguards are adopted within the project;

- Assist developing countries in strengthening their capabilities to appreciate and effectively evaluate the potential environmental effects of proposed development strategies and projects, and to select, implement, and manage effective environmental programs;

- Identify all impacts upon the environment resulting from A.I.D.'s actions, including those aspects of the biosphere affecting endangered species (Section 216.5), which are the common and cultural heritage of all humanity; and

- Define environmentally limiting factors that constrain development, and identify and carry out activities that assist in restoring the renewable resources base on which sustained development depends.

Section 533 (c)(3) of the 1991 Foreign Operations Appropriations Act prohibits the use of economic assistance funds for "any program, project or activity which would result in any significant loss of tropical forest; or involve commercial timber extraction in primary tropical forest areas." The act requires the agency to make certain findings or determinations before supporting any activities that could directly or indirectly affect tropical forest conditions. Specifically, Section 533 requires A.I.D. to complete an environmental assessment to accomplish the following:

- Make specific environmental findings and disclose certain environmental impacts on tropical forests;

- Determine whether impacts are of a significant nature;
- Identify whether commercial timber extraction will occur in primary tropical forest areas;
- Identify potential impacts from proposed activities on biological diversity within the affected area;
- Demonstrate that all timber extraction will be conducted according to an environmentally sound management system that maintains the ecological function of the natural forest and minimizes impacts on biological diversity; and
- Demonstrates that the activity will contribute to reducing deforestation.

The environmental evaluation of the AMDP and previously financed A.I.D. project activities related to implementation of the AMDP does not directly relate to any specific A.I.D.-financed activities that would need to comply with these regulations as set in CFR 216 or Section 533. Nevertheless, the evaluation is structured to address each of these concerns and to recommend measures that could be carried out by A.I.D., the GSL, or other donors to minimize any potential adverse environmental impacts.

In addition, the Mahaweli Environmental Evaluation provides an opportunity to review the environmental history of the AMDP and provide a perspective from which more appropriate and sustainable environmental management responses can be applied in the Mahaweli watershed. As such, the Mahaweli Environmental Evaluation is less an assessment of specific impacts and more an evaluation of lessons learned through development of AMDP and identification of opportunities to improve the way development is applied in the watershed.

SECTION TWO

AN ENVIRONMENTAL HISTORY OF THE ACCELERATED MAHAWELI DEVELOPMENT PROGRAM AND USAID-SPONSORED MANAGEMENT ASSISTANCE

THE MAHAWELI RIVER BASIN

Sri Lanka rises to a central massif in the south central portion of the island. The principal rivers in the country radiate from these highlands, and are dominated by the Mahaweli Ganga, which drains more than 16 percent of Sri Lanka's land surface (Figure 2). The Mahaweli carries approximately one-seventh of the total annual runoff and includes a wide variety of biotic communities within its large drainage area.

Climate

The Mahaweli basin is influenced by two annual monsoon seasons. From December to February, the area is usually affected by the northeast monsoon (Maha); a milder, southwest monsoon (Yala) occurs from May to October. In the upper reaches of the drainage basin more than 5,000 millimeters of annual rainfall is usually recorded, whereas precipitation in downstream reaches is typically on the order of 1,600 millimeters. Rainfall in the downstream areas is usually reliable only during the Maha, but precipitation can occur year-round in the upper catchment. Diurnal and annual temperatures vary little, with averages ranging from 25 to 35 degrees centigrade in the lowlands and from 15 to 27 degrees centigrade in the upper catchment. In the lowlands, evapotranspiration rates typically exceed precipitation levels, resulting in a net moisture deficit.

Watershed Systems

The Mahaweli is the largest river in Sri Lanka, and flows northeast to the sea at Koddiyar Bay near Trincomalee. The headwaters of the drainage basin are near the community of Nuwara Eliya in the south central portion of the island. The major tributary flowing from the Mahaweli is the Amban Ganga, and a secondary but important tributary is the Maduru Oya.[1] Flow rates fluctuate significantly from the wet to dry seasons, and tidal influences can be encountered approximately six kilometers from the coast.

Hundreds of large and small irrigation reservoirs, or tanks, have been built throughout the basin, some of which date back more than 2,000 years. Large areas of surface waters also formerly existed as *villus*, which are seasonally inundated wetlands. *Villus* typically occur in association with river floodplains, and occupy depressions between natural river channels and adjacent upland areas. Typically, these wetlands consist of a perennial pool of water and an adjacent floodplain that is inundated only during flood periods. Most of the *villus* have been drained or otherwise eliminated as a result of irrigation development and dam construction, although a few still exist in scattered areas.

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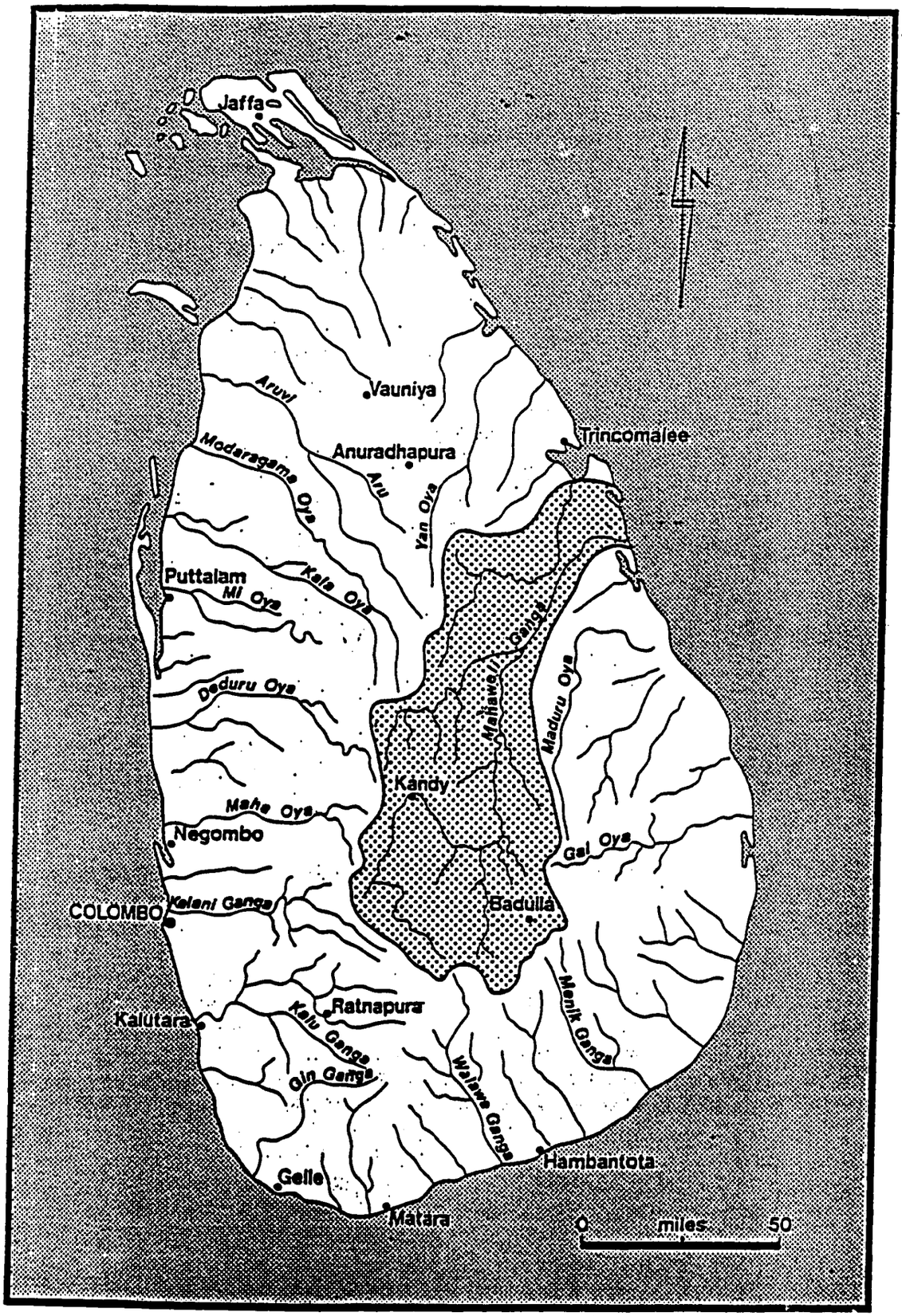
[1] An *oya* indicates a drainage that experiences very low or no flows during the dry seasons. A *ganga* indicates a drainage that maintains perennial flows.

FIGURE 2

SRI LANKA, SHOWING THE MAHAWELI BASIN



Biological Diversity

Prior to the large-scale development of the Mahaweli basin for agricultural production, more than 50 percent of the land area was covered with mature tropical humid, subhumid, or dry forests. The steep lands in the upper reaches of the basin were in a mix of closed canopy tropical montane humid forest cover and developed agricultural lands (mostly tea plantation), while the lower slopes supported dense, but drier, tropical forest cover. All these lands had been encroached upon to some extent, although habitats were reasonably well connected, with occasional fragmentation.

The development of agricultural lands in the basin, particularly in the lower areas of Systems A-H, has vastly reduced the total forest cover. The designated forest reserves in the lower basin have largely been cleared. Many of the remaining forest areas have been high-graded, where the more valuable commercial species are removed and less useful trees are left standing. High-grading often results in reductions of species diversity, genetic stock, and populations of plants and animals.

Biological diversity in the earlier forest and grassland areas in the Mahaweli basin was very high, including most of the 251 resident bird species reported from Sri Lanka, an additional 75 migratory bird species, more than 50 mammal species, more than 20 reptile and amphibian species, and a wide variety of invertebrates. Nine recognized threatened or endangered species resided in the basin. Moreover, 53 endemic plant species and 17 very rare plants had been identified in the basin.

No conclusive census or population studies have been conducted in recent times, although it is apparent that development of reservoirs and associated agricultural lands has significantly reduced the population levels of many species in the Mahaweli. Many habitats have been reduced in total area, degraded in terms of food and cover availability, and fragmented. However, eight new protected areas have been established within the basin, all of which were developed in association with the USAID-financed Mahaweli Environment Project (MEP). These protected areas have enabled many plant and animal species to survive despite the large-scale developments, although these areas have incurred some habitat degradation and fragmentation (Figure 3).

Land Use Characteristics

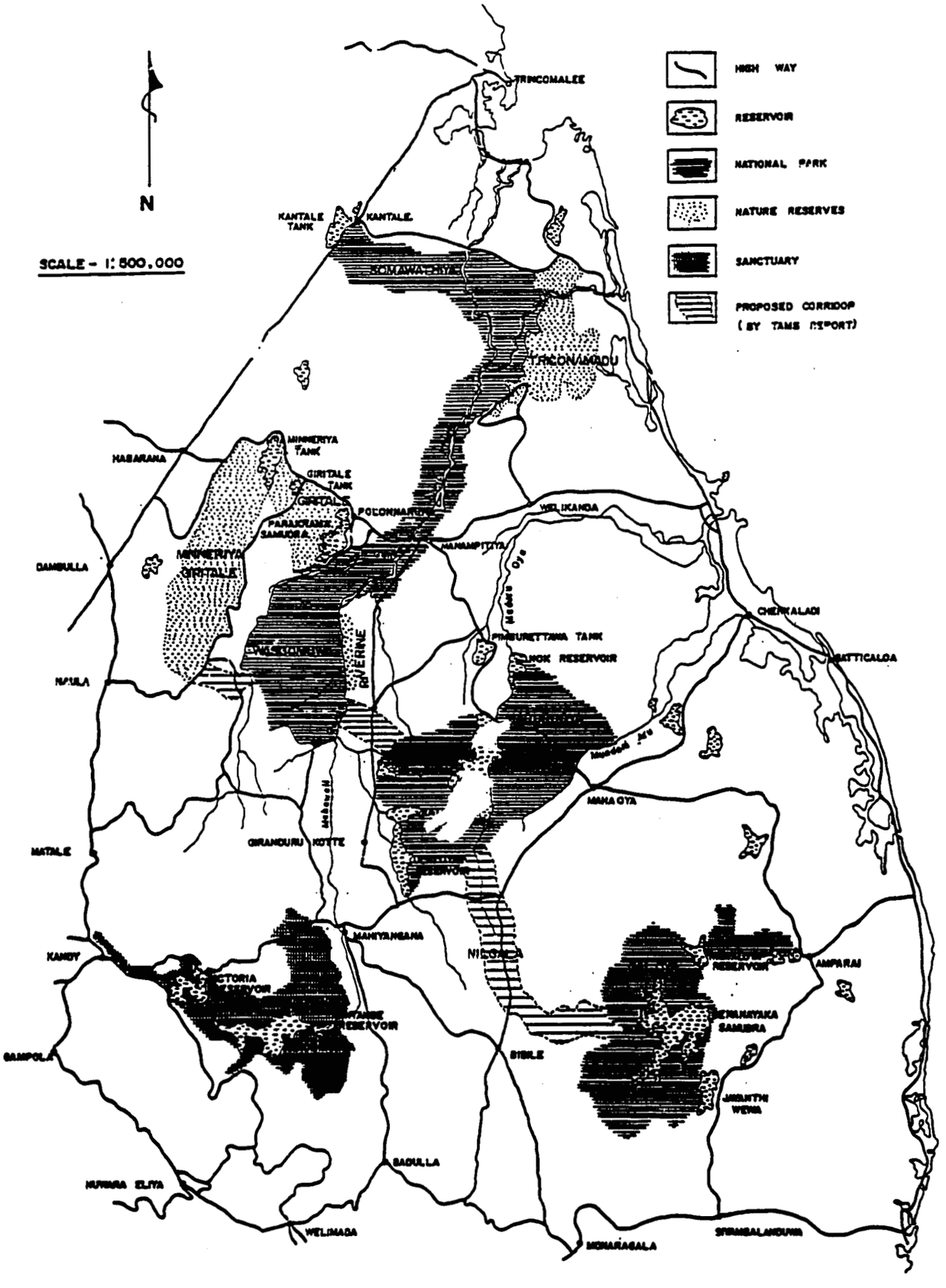
Land use varies from the upper catchment areas to the lower parts of the basin, largely as a result of climatic influences on agricultural options. More than 50 percent of the upper catchment lands are in some form of intensive agricultural production, mostly tea. An additional 20 percent appears to be in fallow or abandoned agricultural land, with the remainder divided between remnant forest cover and smaller scale agriculture.

Slopes are typically steep, with 75 percent of the upper catchment characterized by gradients of 20-40 percent. The latisol soils are moderately resistant to erosion and have high productive potential for agriculture. Podzolic soils and reddish brown earth, which together constitute almost 85 percent of the upper catchment, are very erodible and are best used for some form of sustainable forestry.

The downstream areas are divided among forest and woodland areas, pasture and anthropogenic grasslands, seasonal (*chena*) cultivation, and permanent crop production. Prior to the large-scale agricultural development of the lower basin, approximately 75 percent of the area was in forest or woodland. This forest area has been significantly reduced, with the majority of land now in crop production, principally paddy rice.

FIGURE 3

WILDLIFE RESERVES IN THE MAHAWELI DEVELOPMENT AREA



Slopes are of lower grade, typically less than 5 percent in many areas, and a vast peneplain covers much of the area. The soil mantle on the surface is frequently very thin, in many cases less than one meter in depth. In other areas, deep sandy clay loam or sandy soils have developed but are often underlain by impermeable rock rich in quartz. The majority of the remaining soils include imperfectly drained clays and some better drained alluvials.

During the intensive rains of the Maha, the heavier clay soils and soils with impermeable subsurface layers can become waterlogged. Drainage is necessary to support cultivation. Waterlogging can also occur from irrigation during the drier periods of the year.

Most land in lower areas of the basin has been classified as suitable for rice cultivation, with a smaller percentage of land considered suitable for other crops.

Social Conditions

Several large towns are found within the Mahaweli basin, including Nuwara Eliya, Kandy, and Trincomalee. Beyond these towns, most residents live in small communities or villages. Total population within the basin is uncertain, although the area includes some of the lower population densities in Sri Lanka.

Many of the communities in the lower parts of the basin are new, particularly in Systems A-H, having arisen through in-migration during the past 20 years or so. Some of the newer villages include residents of government or private company colonization schemes. Other villages comprise migrants who are encroaching illegally on state-owned land. Both types of communities are common in the areas affected by the Mahaweli Environment Project. The Reforestation and Watershed Management Project (RWMP) often worked with older, more established communities that have increased in size through in-migration of workers.

Primary income sources are the sale and distribution of cultivated crops, with paddy rice being the principal lowland crop, and potato and other vegetables common in the uplands. Tea plantations occupy much agricultural land in the uplands and provide a source of employment to many residents. Harvest of forest products for timber, fuelwood, and handicraft materials is a common practice in areas where intact forests can still be found, although many of these harvests are illegal. Service industries have developed in many towns that surround the colonized agricultural communities.

Living conditions in most of the rural communities are very basic, and the overall standard of living is low in comparison with other more established areas of Sri Lanka. Public health conditions can be poor, with many common tropical diseases endemic, including malaria, giardiasis and amoeba histolyica, hepatitis, typhoid fever, and related water-borne infestations.

Resource Development in the Mahaweli

Plans for a comprehensive development of the water resources in the Mahaweli basin were initiated in the 1960s. The objectives were to increase agricultural output by creating more reliable water supplies for downstream irrigation and to increase energy production capabilities. These developments would also take advantage of the fact that large areas of undeveloped lands could still be found in the northern and eastern dry zones, whereas virtually all agricultural lands in the southwestern wet zone were already in use.

A Master Plan developed with the assistance of the United Nations Development Programme (UNDP) recommended a combination of water storage, hydropower production, improved downstream agricultural facilities, and the clearing and development of new agricultural lands. The development of these downstream agricultural areas proceeded, with land units divided into systems designated by alphabetic letters (A through H). This program was to be implemented over a period of 30 years under the assumption that financial and other constraints would prevent the country from implementing more than one major project at a time (Gunatilaka, 1991).

The Accelerated Mahaweli Development Program

By 1976, the Polgolla barrage near Kandy and the Bowatenna reservoir and irrigation tunnel southeast of Polonnaruwa had been completed. To expedite resource development in the Mahaweli basin, a consolidated version of the original UNDP Master Plan was implemented in 1977 and became known as the Accelerated Mahaweli Development Program (AMDP). The focus of the AMDP was to provide solutions for acute unemployment problems, loss of foreign exchange for agricultural imports, and a shortage of electrical energy (Hewavisenthi, 1992).

AMDP consisted of the following multipurpose projects:

- **Kotmale Project:** The project consists of a reservoir on the Kotmale Oya, with a system of tunnels conveying water to an underground power station. Primarily designed for energy production, the project also replenishes the Polgalla diversion downstream during dry periods. Commercial power production began in June 1985.

- **Polgalla Diversion:** The project consists of a low-gated barrage across the Mahaweli Ganga near Kandy and a power tunnel diverting water to the Amban Ganga basin through the Ukuwela power station. Two irrigation bypasses provide for irrigation releases when the power station is not functioning.

- **Victoria Project:** Located at the point where the Hulu Ganga joins the Mahaweli, the project includes a large reservoir and a tunnel conveying water to a power station located seven kilometers downstream from the dam. Victoria plays an important role in regulating flows for downstream irrigation, and has an energy generation capacity of 210 megawatts. Actual power production is dependent on the diversion policies followed at Polgalla. The project was completed in April 1985.

- **Randenigala Project:** Situated approximately 20 kilometers downstream from Victoria, this is the largest reservoir in the Mahaweli system, with a gross storage of 860 million cubic meters. A steel conduit diverts water to a power station at the base of the dam. Similar to Victoria, power production and irrigation supplies are dependent on policies at Polgalla. Construction was completed in 1986.

- **Rantembe Project:** Situated approximately 3 kilometers downstream from Randenigala, this is the lowermost reservoir on the Mahaweli Ganga. Principally for energy production, Rantembe also helps regulate water levels at the Minipe weir downstream and irrigation diversions. The project was completed in 1990.

- **Minipe Diversion:** Approximately 2 kilometers downstream from Rantembe, the headworks include a weir across the Mahaweli Ganga, a sluice, and a silt ejector. The weir diverts flow

to the Ulhitiya reservoir, which has a gross storage of 110 million cubic meters. Ulhitiya and Ratkinda reservoirs are linked by a surface canal, and a 5.7 kilometer tunnel conveys water from the Ratkinda to the Maduru Oya reservoir.

- **Maduru Oya Project:** This project includes two power stations structures, and irrigation outlets for downstream farmers in System B.

- **Bowatenna Project:** This project is located on the Amban Ganga below the confluence of the Sudu Ganga and Nalanda Oya. The project includes a reservoir, a power tunnel, a power station, and an irrigation diversion tunnel supplying water to System H.

- **Elahera Diversion:** Releases from Bowatenna are diverted by a weir across the Amban Ganga into the Elahera-Minneriya Yoda Ela. These flows are conveyed, in turn, to the reservoirs that supply irrigation water to System D.

- **Angamedilla Diversion:** Located approximately 31 kilometers downstream from Elahera, this weir on the Amban Ganga diverts flow into a short canal that supplies the Parakrama Samudra serving System D.

Table 1 summarizes the characteristics of the irrigation systems that have resulted from the AMDP.

TABLE 1

IRRIGATION AREAS IN THE AMDP

Irrigation System	Diversion Point	Benefited Tank	Capacity of Tank (mcm)	Extent Under Cultivation (hectares)
H	Bowatenna	Dambulu Oya	11.7	2,100
		Kandalama	33.8	4,900
		Kalawewa	123.3	24,100
		Rajangana	100.7	6,800
IH		Nachchaduwa	55.6	2,400
		Nuwarawewa	44.4	971
		Tissawewa	6.7	600
MH		Huruluwewa	67.8	4,300
G	Elaher	Under EMYE	-	5,100
		Minneriya	135.7	8,900
		Giritale	24.0	3,000
		Kaudulla	128.3	4,500
		Kantalai/ Vendarasan	157.9	9,900
D2	Angammedilla	Parakrama Samudra	134.4	10,100
E	Minipe	(Under LB Canal)	-	6,100
C		Soraborawewa	-	810
		Mapakadawewa	9.3	690
		Dambarawewa	-	610
		Ulhitiya/Ratkinda	146.0	15,000
B	Maduru	Pimburettewa	-	1,800
		Maduru Oya	585.5	7,200
A		Allai	-	7,000
		TOTAL:		126,881

Institutional Arrangements in the Mahaweli

Water and power management in the Mahaweli basin is administered by the Mahaweli Authority of Sri Lanka (MASL). The MASL is under the Ministry of Mahaweli, Lands and Irrigation and is overseen by a Director General. Administration of watershed management, hydroelectric power generation, water diversions and distribution, and environmental management concerns are delegated within various divisions in the management authority.

The MASL is presently made up of a family of organizations. A wide range of settler services are is provided through an integrated matrix management system. At the project level, the resident project manager supervises a team of specialists dealing with irrigation, agriculture, land, marketing, and community development. Beneath the specialists are block managers, who also have a team of specialists in their offices. These people in turn supervise unit managers. Unit managers are intended as the main contact between the settlers and higher agency officials to direct the provision of services.

SECTION THREE

ENVIRONMENTAL CONDITIONS AND PRINCIPAL ISSUES IN THE MAHAWELI WATERSHED

INTRODUCTION

The development of the Mahaweli watershed has resulted in some important and extremely valuable social, economic, and technological benefits for the country of Sri Lanka. The project has enabled many people to obtain access to land and livelihoods previously unavailable and has significantly increased food production and power resources. However, these advances were not made without some costs, particularly in terms of adverse environmental change.

Over the years, approximately 127,000 hectares of land have been brought under cultivation in the Mahaweli watershed. More than 400,000 people have settled in the lower catchment area, and these families have participated in the transformation of several hundred thousand hectares of subhumid tropical rainforest into cultivated fields. Construction of dams and irrigation conveyance networks, roads, and related infrastructure has radically altered the ways soil and water move and biological systems function in the watershed.

A comprehensive environmental assessment for the whole of AMDP was prepared in 1980 (TAMS, 1980), and followed by an Environmental Plan of Action in 1981 (TAMS, 1981). The 1980 environmental assessment identified likely environmental impacts in the area affected by AMDP, and, by and large, most of these impacts have occurred to various degrees. In response to these predicted impacts, the TAMS Environmental Assessment recommended a detailed list of technical and institutional measures to mitigate any adverse environmental problems that could emerge over time. The 1980 Environmental Action Plan was designed to facilitate implementation of these mitigative recommendations.

USAID participated in the implementation of some measures recommended by the Environmental Plan of Action, principally through the Mahaweli Environment Project (MEP) and the Reforestation and Watershed Management Project (RWMP). Both of these projects have reached their completion dates.

This chapter will review the TAMS Environmental Assessment and Environmental Action Plans in light of current conditions. The objective is to estimate the degree to which the predicted environmental impacts have occurred during the dozen years since the TAMS team completed its analysis. On the basis of this information, the MEE Team has attempted to summarize the more significant environmental issues that continue to constrain sustainable development in the Mahaweli watershed. These environmental issues can indicate the corrective actions and components from the original Environmental Action Plans that still need to be accomplished.

This section summarizes principal adverse environmental impacts occurring in the Mahaweli basin. This summary includes a ranking of the environmental and financial costs and benefits of these impacts, including a prioritization of the severity of the impacts. These impacts are categorized by whether they principally affect the watershed, lower basin agricultural, wildlife, or socioeconomic systems. Impacts cutting across all categories also are included. The section also summarizes the limited data available to quantify or qualify the magnitude of these impacts. This information is viewed in the

context of the predicted impacts from the 1980 TAMS Environmental Assessment and the subsequent TAMS recommended mitigative measures.

Section Four consolidates this information into a synthesis of lessons learned in terms of environmental management in the Mahaweli over the years and attempts to point the way toward an updated environmental action strategy for sustainable social, economic, and environmental development in the watershed. We hope the information assembled here can guide future management efforts and project actions in the basin.

AN EMPHASIS ON WHOLE SYSTEMS

In conducting this review, the MEE team has concentrated its analysis on four sectors: watershed systems, agricultural systems, wildlife and biological diversity, and social and economic systems. Although these sectors attempt to encompass the full breadth of physical, biological, and social parameters that define and influence ecological conditions in the Mahaweli, they are also artificial separations.

The Mahaweli basin functions, and is best viewed, as one comprehensive watershed.[1] Within this watershed, the geology, soils, water, climate, vegetation, and diversity of biological organisms constantly interact to define the ecological status of the place. Environmental conditions may vary from site to site, but each site is best viewed in its ecological entirety. Each complete landscape unit affects conditions in adjacent and downstream units to define the ecological status of the watershed as a whole.

This emphasis on viewing whole systems is important, because analysis of problems within a specific sector without consideration of the influence that factors from other sectors have on creating or maintaining those problems is dangerous. For example, if we are concerned with poor market production among residents in a particular Mahaweli system, it may be essential for us to consider soil and water quality conditions, agricultural systems being applied, increased pest problems that have resulted from a simplification of the local invertebrate populations, and so on, as a set of interrelated and mutually reinforcing causative factors. Similarly, our solution to this problem should emerge from an analysis of the influence and impacts that occur within the whole environmental system.

It is convenient and occasionally appropriate to isolate impacts and issues within the context of these separate sectors. However, many of the persistent environmental problems that plague sustainable development within the Mahaweli, despite efforts to mitigate them, appear to be due to the fact that the management institutions have not operated from this whole-system perspective. Applying a watershed perspective to decision making, extension, and development efforts in the Mahaweli represents one of the more important measures that can be taken to improve environmental management in the basin. The MEE team encourages the reader to keep this central tenet in mind when reviewing the sectoral information.

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[1] The watershed herein refers to all the land area draining water in the Mahaweli system, from headwaters above Nuwara Eliya to the outlet at the sea near Trincomalee. When we speak of the Mahaweli watershed, we refer to the 16 percent of Sri Lanka that contributes to this major drainage system.

A SUMMARY OF THE MAJOR ENVIRONMENTAL IMPACTS IN THE MAHAWELI

A variety of environmental problems persist in the Mahaweli basin. These problems generally represent a constraint to many original objectives of AMDP and contribute to a degradation of the quality of both human and non-human lives in the basin. The principal adverse environmental impacts found within the Mahaweli basin include:

- Watershed Systems
  - — On-site soil loss rates, particularly in the upper catchment, continue to be greater than soil replacement rates.
  - — Downstream water quality in the lower catchment area is being degraded as a result of nutrient loading and pesticides from farm runoff.
  - — Natural forest ecosystems are being degraded or eliminated in the upper and lower catchments because of expanding agriculture and unregulated harvest of forest products.
  - — Sediments and agrochemicals in runoff water are resulting in eutrophication of reservoirs.
  - — Water management schemes have changed the natural flow regimes of the major rivers, resulting in sometimes higher flood flows, lower dry-season flows, and degradation of riparian and wetland habitats in the lower catchment.
  - — Sediment inflow is beginning to fill some reservoirs and threatens to shorten the useful life of the reservoir network.
- Agricultural Systems
  - — Chemical inputs to agricultural systems in the upper and lower catchment areas are degrading local surface and ground water quality.
  - — Cropping patterns are often inappropriate for the soil and microclimatic conditions of the site, resulting in reduced productivity and increased reliance on environmentally inappropriate agricultural practices.
  - — Poor water management practices, principally in lower catchment irrigated areas, have increased the threat of soil salinization and on-site soil losses.
- Wildlife and Biodiversity Systems
  - — The existing data on wildlife population characteristics, migration and dispersal patterns, and habitat requirements are not sufficient to guide management decision making.

- Habitat conditions in many of the designated protected areas have been degraded over time, and restoration or enrichment measures have been inadequate to support existing wildlife populations.

- Social and Economic Systems

  - Land allocation schemes provide too small a land base to support more than one generation through agricultural production, resulting in declining quality of human life and an increase in illegal land uses.

  - The social infrastructure in the upper and lower catchment areas cannot yet fully meet the needs for satisfactory health, education, training, or financial well-being of the region over the long term.

It is important to recognize that many of these impacts may not be the result of the construction and infrastructure development that resulted from the development of AMDP. In fact, the very limited baseline data describing pre-existing or even immediate post-project conditions make it extremely difficult to determine the degree to which AMDP contributed to or represents a direct or indirect cause of any of these impacts. At this point in Sri Lanka's development, blame for the causes of environmental impacts seems of marginal value. The key factor seems to be that the problems not only persist but also appear to be increasing in magnitude. It is also essential to remember that GSL and the private sector have demonstrated the technical capacity to respond to and resolve these kinds of problems.

Unfortunately, the magnitude of many of these environmental impacts is difficult to quantify because of the limited available data on environmental conditions. Much of the data available are site-specific and do not offer much opportunity to establish precise basin-wide quantifications. However, the limited data obtained, combined with site-specific field analyses, were used by the MEE Team to estimate the likely environmental costs incurred as a result of uncorrected or incompletely mitigated impacts. Environmental costs reflect a degradation or loss of ecosystem functions, such that the quality of life for human or non-human species is declining.

These principal adverse impacts are summarized in Table 2. The impacts are ranked in terms of the estimated environmental costs that result from inadequate mitigation of present conditions.

TABLE 2

ADVERSE ENVIRONMENTAL IMPACTS IN MAHAWELI

Impacts	Costs[2]
Watershed Systems	
Increase in on-site soil loss rates	8
Degradation of downstream water quality	8
Loss of natural forest cover	7
Eutrophication of reservoirs	5
Change in seasonal flow regimes of rivers	5
Sedimentation of reservoirs	3
Agricultural Systems	
Inadequate monitoring and use of agrochemicals	9
Cropping patterns inappropriate for soil types	8
Inadequate water management practices	6
Wildlife and Biodiversity Systems	
Insufficient data exist to guide management	9
Poor habitat management in reserves	8
Social and Economic Systems	
Land allocation schemes provide insufficient land	8
Incomplete social infrastructure	6

The estimated financial costs required to mitigate or correct these impacts are ranked in Table 3, along with estimated financial and environmental benefits that would accrue from mitigation. The financial and environmental benefits for correcting all impacts are estimated to be equal to or greater than the estimated costs for these actions, which suggests that mitigation of environmental problems could be cost-effective. Examples of the estimated cost-benefit relationship for improved on-site soil conservation are presented in this section.

[2] Reflects a ranking of the estimated environmental costs based on scale of 1-10, where 1 reflects the lowest cost and 10 the highest. Environmental costs refer to estimates of adverse disturbances of ecological systems and do not necessarily reflect financial measurements.

TABLE 3

RANKING OF COSTS AND BENEFITS OF MITIGATIVE ACTIONS

Impacts	Costs[3]	Benefits	
		Rp[4]	E[5]
Watershed Systems			
Increase in on-site soil loss	8	9	9
Degradation of water quality	6	8	9
Loss of natural forest cover	5	8	9
Eutrophication of reservoirs	8	9	8
Change in seasonal flow regimes	6	5	8
Sedimentation of reservoirs	8	8	9
Agricultural Systems			
Inadequate monitoring and use of agrochemicals	4	9	9
Inappropriate cropping patterns	4	8	9
Inadequate water management	5	8	8
Wildlife and Biodiversity Systems			
Insufficient data exist to guide management	5	7	9
Poor habitat management in reserves	6	7	9
Social and Economic Systems			
Land allocation schemes provide insufficient land	9	9	9
Incomplete social infrastructure	8	8	8

WATERSHED SYSTEMS

There are 103 major watersheds recognized in Sri Lanka, with the Mahaweli basin dominating in size (16 percent of the land area, or 10,327 square kilometers). The Mahaweli Ganga has perennial

[3] Represents a ranking of estimated financial costs required to avoid or mitigate adverse environmental impacts, based on scale of 1-10, where 1 represents lowest cost and 10 represents highest.

[4] Represents ranking of estimated financial benefits that would accrue from implementing mitigative or corrective measures, based on scale of 1-10, where 1 represents lowest benefit and 10 represents highest.

[5] Represents a ranking of estimated environmental, though not necessarily financial, benefits that would accrue as a result of implementing mitigative or preventative measures, based on scale of 1-10, where 1 represents lowest benefit and 10 represents highest.

flow — as much as 65 percent of precipitation becomes surface runoff in the wet zone, compared with up to 37 percent in the dry zone. The construction of reservoirs, or tanks, and irrigation distribution systems has resulted in a complex system of water management that has been in place for 2,000 years.

The Upper Mahaweli catchment (UMC) consists of four subcatchments that drain into four major reservoirs: Kotmale, Victoria, Randenigala, and Rantembe (see Figure 4). Areas and major tributary streams include:

Subcatchment	Area (square kilometers)	Major Tributary Streams
Kotmale	562	Nanu Oya
Victoria	1,328	Maha Oya, Kotmale Oya, Atabage Nilambee, Hulu Ganga
Randenigala	440	Kurundu Oya, Ma Oya, Belihul
Rantembe	788	Uma Oya, Maha Oya
TOTAL	3,118	

Watershed conditions describe the physical characteristics of the affected environment as influenced by the underlying geology and soil strata, climatic conditions, topography, and hydrologic systems. Reforestation on channel banks to protect reservoirs from sedimentation has been implemented by MASL through contracts with Nation Builders (a nongovernmental organization). Establishment of fuelwood and timber plantations has also occurred under this activity.

The Upper Mahaweli Watershed Project was initiated by the Mahaweli Authority in 1985 with assistance from the German government (GTZ). The balanced development of water, land, and human resources on a sustainable basis in the UMC area is the primary objective of this integrated rural development project (IRDP). It differs from other broader-based IRDPs because its focus is watershed management, including hydrological studies, soil conservation demonstration plots, pilot land use demonstration areas, social forestry extension activities, and forest nursery trials.

The Food and Agriculture Organization (FAO) has funded a five-year project, begun in 1990, to ensure that environmental safeguards are included in all forest developments, to implement improved practices of forest plantation establishment in the dry zone, and to improve logging and extraction operations. The project is expected to establish an environmental management division in the Forest Department, identify areas crucial for the conservation of natural forest systems and biodiversity, and develop a database to handle environmental information.

Watershed Conditions and Issues

Although these project and program efforts have enabled GSL to realize some of the TAMS mitigative measures, an analysis of current conditions in the Mahaweli indicates impacts on watershed conditions predicted in the 1980 TAMS Environmental Assessment have occurred to various degrees and most continue to be unchecked problems in the Mahaweli river basin. Many environmental problems remain, some of which will require extensive efforts if they are to be fully resolved. A summary of the more prominent watershed management issues is presented in Table 4.

FIGURE 4

UPPER MAHAWELI WATERSHED BOUNDARIES

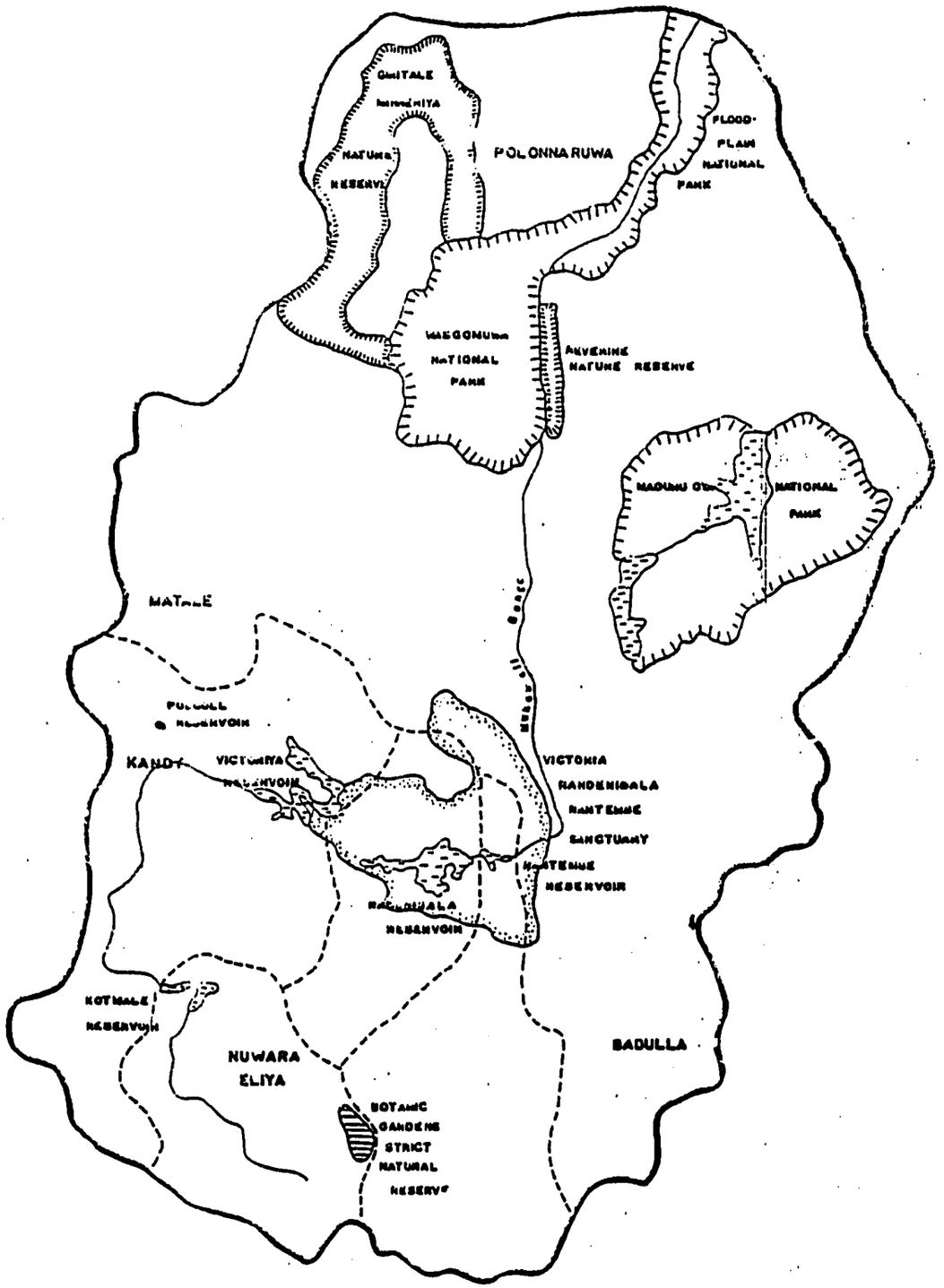


TABLE 4

WATERSHED MANAGEMENT ISSUES

- On-site soil loss rates continue to be greater than soil replacement rates, particularly in the upper catchment.
- Downstream water quality in the lower catchment area is being degraded as a result of nutrient loading and pesticides from farm runoff.
- Natural forest ecosystems are being degraded or eliminated in the upper and lower catchments because of expanding agriculture and unregulated harvest of forest products.
- Sediments and agrochemicals in runoff water are resulting in eutrophication of reservoirs.
- Water management schemes have changed the natural flow regimes of the major rivers, resulting in sometimes higher flood flows, lower dry-season flows, and degradation of riparian and wetland habitats in the lower catchment.
- Sediment inflow is beginning to fill some reservoirs and threatens to shorten the useful life of the reservoir network.

The apparent magnitude of these issues is difficult to determine, given the limited data available on baseline and current environmental conditions in the river basin. However, indications of the severity of the problems, along with an identification of the information needed to more accurately assess problem levels and appropriate solutions, include:

- **On-site soil loss rates, particularly in the upper catchment, continue to be greater than soil replacement rates.**

An important indicator of watershed degradation is soil erosion caused by natural and human-induced processes. While it is difficult to distinguish between the two, it is generally assumed that a tolerable rate (an estimate above natural rates) should not be exceeded. The TAMS Environmental Assessment concluded that a minimum acceptable soil loss of 10 tons per hectare per year should be a target for the development of soil conservation practices. Site-specific conditions should be applied whenever applying tolerable erosion rates.

Erosion rates serve as indicators of significant environmental problems likely to occur on site or downstream in the basin. The most significant on-site problem will be a decline in productivity of the land because of nutrient losses. A study of erosion impacts on Mahaweli patana soils showed that soil loss has decreased soil organic matter by 37 percent, total nitrogen by 29 percent, available phosphorus by 36 percent, and exchangeable bases by 20 percent (Weil, 1982). The study also indicated that

shallowness (50 centimeters) and rockiness were two limiting factors for tree growth and were exacerbated by erosion. Downstream problems can include alteration of stream channels through sediment aggradation and degradation, with subsequent changes in stream velocity, flooding, and dry-season flow rates; eutrophication in ponds and reservoirs because of nutrient build-up; and decrease in the lifespan of reservoirs because of sediment accumulation.

Although definitive information is not fully available, preliminary observations indicate that most soil losses (nearly 90 percent) occur from three land-use types in the UMC: seedling tea (36 percent), chena and tobacco (23 percent), and degraded forest scrub (30 percent). The estimates are consistent with field observations of land use problems in the four subcatchments carried out by the MEE team in November 1992.

The impact of chena cultivation on erosion and siltation rates in the Mahaweli Basin continues to be a major land use issue. The country's oldest form of cultivation, chena involves forest clearing and cultivation for a season or two, abandonment to fallow, which allows the forest to regenerate, and subsequent repetition of the cultivation cycle (NARESA, 1991). When a cultivated plot is abandoned, presumably because of fertility depletion, the seedlings and regrowth from the previous forest quickly form a canopy that reduces soil temperatures and stops erosion. The litter additions decompose rapidly, adding to the soils nutrients that because of the quickly established forest roots are not leached away. A nearly closed nutrient cycle is then formed (Nye and Greenland, 1960). The amounts of nutrients in the cycle increase with added litter fall and eventually reach a plateau in about eight years on typical well-leached tropical soils (Sanchez, 1976). Although chena cultivation can be an appropriate and effective land use where land is abundant and population pressures low, it is becoming a particularly damaging practice in the Mahaweli basin, where fallow lands are rarely allowed to fully regenerate their nutrient base before being subjected to a subsequent cultivation.

Erosion of soil on tea plantations has, on average, greatly exceeded the tolerable loss rates defined by TAMS, with country-wide average estimates of 40 tons per hectare per year over the last century. This is equivalent to a topsoil loss of 30 centimeters in depth (NARESA 1991). Tea plantations are exposed to rainfall erosion from short-duration, high-intensity events during planting and pruning periods when little vegetation cover protects soil.

Erosion rates for other crops grown in the UMC, including forest crops, indicate that these excessive soil-loss problems are primarily due to the lack of soil conservation measures being applied by growers. Erosion rates measured in the field for tea and a variety of additional agricultural crops cultivated in the UMC are summarized in Table 5. Erosion rates measured for land uses in the Nuwara Eliya District of the UMC are summarized in Table 6.

TABLE 5

FIELD MEASUREMENTS OF EROSION RATES

Land Use Type	Location	tons/ha/yr
Tea (mulched)	St. Coombs	0.0
Tea (cover added)	St. Coombs	0.8
Tea (no conservation)	St. Coombs	52.0
Tea (old seedling)	EPeradeniya	40.0
Tea (bare, weeded)	Talawakelle	52.6
Tea (mulched)	Talawakelle	0.1
Mixed home garden	Peradeniya	0.1
Tobacco (no conservation)	Hanguranketa	70.0
Capsicum (no conservation)	Hanguranketa	38.0
Carrots (no conservation)	Hanguranketa	18.0
Sorghum/pea (no conservation)	Maha Illuppalama	21.3
Sorghum/pea (mulched)	Maha Illuppalama	3.9
Cotton (no conservation)	Maha Illuppalama	22.2
Cotton (mulched)	Maha Illuppalama	2.0

TABLE 6

LAND USE IN NUWARA ELIYA DISTRICT

Category of Land Use	Area (%)	Erosion rate (tons/ha/yr)
Dense forest	18	1
Degraded forest and scrub	16	25
Degraded grassland	8	30
Seedling tea (poor mgt)	15	52
Well managed tea (VP)	5	2
Tea (some conservation)	9	15
Paddy	3	3
Mixed home garden	5	1
Chena and tobacco	7	70
Small tea holdings	2	5
Market gardens	2	25
Total	100	

A land use planning study for Nuwara Eliya District concluded that erosion hazard exceeds tolerable limits on 32 percent of the land (Zijlstra, 1989). Soil conservation measures are needed on 59 percent of the land area. On seedling tea lands without conservation practices in place, excessive erosion rates occur on 49 percent of the land classified in the plantation sector. Of land cultivated under the village sector, 56 percent has excessive erosion rates caused by chena and tobacco cultivation (63 percent), small tea holdings (20 percent), and market gardens (15 percent). Degraded forests and

scrubland on steep slopes result in high erosion rates on 10 percent of land classified as woodlands and patanas.

These preliminary data can be used to estimate the apparent magnitude of the soil loss problem in the UMC and to indicate the volume of soil that is gradually moving downslope toward river channels and reservoirs (Table 7). Improved conservation measures designed to reduce the land uses that are more degrading to tolerable soil loss rates could decrease the total volume of soil lost by more than 70 percent.

TABLE 7

ESTIMATED SOIL LOSS FROM LAND USES IN THE UMC

Land Use Category	Area (ha)	Soil Loss (t/yr)	Percent Loss
Dense forest	56,100	56,10	0.8
Degraded forest and scrub	49,900	1,247,500	18.6
Degraded grassland	24,900	747,000	11.2
Seedling tea	46,800	2,432,000	36.4
Well managed tea	15,600	31,200	0.5
Tea (some conservation)	28,100	420,900	6.3
Paddy	9,400	28,200	0.4
Mixed home garden	15,600	15,600	0.2
Chena and tobacco	21,800	1,526,000	22.8
Small tea holding	6,200	31,000	0.5
Market gardens	6,200	155,000	2.3
Totals	311,800	6,690,500	100.0

An effort was made to estimate the economic value of soil losses in the Upper Mahaweli catchment. Two basic methods applied to assess the amount of soil loss included the universal soil loss equation (USLE) and field observations combined with existing data. Both estimates were used in this study to calculate the soil loss and assess the economic value of soil loss for agricultural production. The results from this analysis demonstrate that the financial and environmental benefits from carrying out improved land use practices to reduce on-site soil losses exceed the financial investment costs (see Annex G). This suggests that future investment considerations in environmental management would be well advised to consider soil conservation extension and demonstration programs, particularly in the upper catchment areas.

- **Downstream water quality in the lower catchment area is being degraded by nutrient loading and pesticides from farm runoff.**

Canals and tanks have demonstrated persistent problems with an overabundance of nutrients and aquatic macrophytes (Mahaweli Authority, 1992). Large rooted aquatic plants (Hydrilla and Salvinia) grow quickly and choke flow in irrigation canals within a few months. Costs of physical removal are substantial and have increased over the last several years, from the use of 1,100 laborers and 300 tractor-hours in 1987 to 6,000 laborers and 1,500 tractor-hours in 1988.

Pesticides were identified in the TAMS Environmental Assessment as a problem in the Mahaweli Ganga before construction of the major reservoirs. Sampling in 1979 indicated high concentrations of DDT, aldrin, endosulfan and dieldrin. These chemicals are all on the U.S. EPA restricted list, and represent a significant health hazard for lower catchment residents who rely on canal and tankwaters for drinking, bathing, and other household uses. Recent observations indicate that no sampling for pesticides has been done since 1979, although there are plans to initiate a sampling program in 1993.

Surface water salinity in upstream tributaries indicated very low levels when the TAMS survey was done in 1979 (less than 100 micromhos of conductivity). One tributary to the Amban Ganga had a salinity of 370 micromhos, the highest surface water salinity measured in the TAMS survey. Field measurements conducted by the MEE team in 1992 indicated that salinity is still at very low levels in upstream and downstream waters.

- **Natural forest ecosystems are being degraded or eliminated in both the upper and lower catchments because of expanding agriculture and unregulated harvest of forest products.**

In 1881, forests were estimated to have covered 81 percent of Sri Lanka. By 1900, this forest cover was reduced to about 70 percent (NARESA, 1991). A survey completed in 1961 indicated that about 44 percent of Sri Lanka was forested in 1956. Land use changes in the country between 1956 and 1983 have resulted in the reduction in natural forest from 44 to 27 percent of the country's area; an increase in paddy from 7.9 to 11.6 percent; increase in urban expansion from 8.8 to 15.2 percent; and an increase in shifting cultivation area (chena) from 15.3 to 18.4 percent. The increase in chena cultivation is largely at the expense of natural forest (NARESA, 1991). By 1983, aerial photography showed 27 percent in forest, and extrapolations to 1989 indicate that 24 percent should have been forested (NARESA, 1991).

This declining forest cover trend has been evident in the Mahaweli watershed. A recent land use analysis estimated that the UMC has only 18 percent of the total area of 3,118 square kilometers in dense forest, and an additional 24 percent in degraded forest, scrub, and grassland.

The per capita fuelwood consumption and the percentage of the population using fuelwood show decreasing trends throughout Sri Lanka (Table 8). This may be due to the use of electricity and LP gas in domestic cooking. However, total fuelwood consumption appears to be increasing due to increases in population. Demands for biomass fuel and for logs also appear to be increasing nationally and within the Mahaweli (Tables 9 and 10). This may be due to a pricing structure that does not accurately reflect the financial and environmental costs of the extraction and use of forest products. However, as the population increases in the Mahaweli, the demand for wood resources will likely increase, especially given that approximately 35 percent of the total annual fuelwood consumption in Sri Lanka occurs in the UMC.

Tree planting and public education programs can help balance these wood extractions. However, such programs do not appear to be keeping pace with demands (Tables 11 and 12). It is apparent that there should be an increase in the supply of fuelwood in urban and rural settings in the upper and lower catchment areas of the Mahaweli. It will be important to work with industries and area residents to use wood supplies more efficiently and, in some cases, gradually shift to alternative energy sources.

TABLE 8

ESTIMATED PER CAPITA CONSUMPTION OF FUELWOOD
(million tons per year)

Fuelwood	kg/person for decrease	Percent Using	Rates of Fuelwood Use
1980-1985	525	94	0.3
1986-1990	523	93	0.2
1991-1995	520	93	0.4
1996-2001	507	88	0.8
2010-2020	500	81	1.1

TABLE 9

NATIONAL DEMAND FOR LOGS AND BIOMASS FUEL

	1986-1990	1991-1995	1996-2000	2001-2010	2011-2020
Biomass Fuel (1,000 ton)	9,675	10,359	10,950	11,435	11,714
Logs (M^3 sub)	1,050	1,230	1,390	1,680	2,050

TABLE 10

FUELWOOD DEMAND
(1,000 tons per year)

Period	Households	Industrial	Total
1986-1990	8,315	1,164	9,515
1991-1995	8,969	1,208	10,177
1996-2000	9,473	1,269	10,742
2001-2010	9,909	1,277	11,186
2011-2020	10,158	1,241	11,399

Tree planting and fuelwood plantation efforts also represent only part of the solution to this problem. Field surveys conducted by the MEE team and corroborated with existing data indicate that the primary source for obtaining fuelwood is adjacent forests, shrubs, and home gardens (51 percent) and coconut residue (28 percent). Other fuelwood sources include paddy husk and saw dust. While fuelwood plantations and designated fuelwood gathering areas have been demarcated in several areas, particularly in the lower catchment systems, the MEE team found that few residents had any knowledge of the location of or their rights to these areas. In addition, some local residents indicated that they preferred to use species other than those planted in plantations and thus continue to deplete any remaining natural forest communities. As a result, the benefits of increased fuelwood and timber planting are not being fully realized and, in some cases, may be futile.

TABLE 11

FUELWOOD AVAILABILITY FROM EXISTING SOURCES
(1,000 tons)

Source	1986-1990	1991-1995	1996-2000	2001-2010	2011-2020
Nonforest natural	9,060	8,830	8,465	8,392	9,051
Forest including shrubland	1,916	1,848	1,780	1,683	910
Forestry industry residues	271	319	361	435	533
Existing forest plantations	46	770	393	335	273
Total	11,715	11,767	10,999	10,845	10,767

TABLE 12

FORESTRY PROGRAMS FOR DOWNSTREAM MAHAWELI SYSTEMS

Projects	Afforestation (ha) planted 1986	Afforestation (ha) planted 1987	Avenue plants (kms) planted 1986	Avenue plants (kms) planted 1987	Conservation: Forestry Extent Conserved (ha)
System H	1,615	220	239	64	4,050
System C	785	540	62	32	2,000
System B	600	200	18	32	4,000
System G	20	100	5	32	25
TOTAL	3,020	1,060	324	160	10,075

- **Sediments and agrochemicals in runoff water are resulting in eutrophication of reservoirs.**

The reservoirs in the Mahaweli Basin are traps for the accumulation of sediment and nutrients and, in time, will likely become eutrophic, or rich in aquatic plant and animal life. Although eutrophication is a natural process, it can be accelerated by the cultural impacts of human activities, which can add vast amounts of excess nutrients over a short time span. Fertilizer application is considered the major human-caused source of excess nutrients on agricultural land. Reported chemical fertilizer application rates are 1,500 kilograms per square kilometer per year, in an average nine applications per year (Manthrethileke, 1992).

Although moderate levels of eutrophication (mesotrophy) may be desirable to enhance such values as fish production, advanced levels have severe detrimental effects. Highly eutrophic reservoirs, which tend to be plagued by algal blooms and greatly reduced water quality values, may become anaerobic just below the surface. These waters may develop taste, odor, color, and filter clogging problems that reduce water supply, hydroelectric power production, and recreation values.

Specific potential problems from eutrophication include the proliferation of algae toxic to cattle and fish, masses of filamentous algae with the potential to block the cooling strainers in the turbines that produce hydroelectric power, excess algae resulting in a simplification of the food chain, nuisance algae spreading to downstream reservoirs, and algal blooms and associated conditions that reduce recreation values.

The impact of human activities in the catchment draining into a reservoir is of prime importance in accelerated eutrophication. In the intensively farmed and grazed UMC, it can be presumed that significantly more than half the nutrients washed annually into the major reservoirs are from agricultural practices. If the assumption that nutrients follow soil loss is correct, it can be assumed that the percentage of erosion at greater than tolerable rates would approximate nutrient loss from human-caused activities, or more than 70 percent (the remaining 30 percent would be presumed to come from natural sources).

Surveys of water quality and algal conditions in three major Mahaweli reservoirs have been carried out during the past six years (Piyasiri, 1992). Kotmale Reservoir has been the most intensively studied because of the presence of serious algal blooms. Filamentous, blue-green algae (Microcystis and Anabaena) were found to predominate in much of the lake, resulting in zero dissolved oxygen in deeper hypolimnetic waters and high counts of algal density (over 20,000 cells per liter). Fish kills and bad odors have been reported by villagers near the reservoir. Inflowing nutrients from four critical sub-watersheds (Garandi, Pundala, Kotmale, and Poona) are being monitored. Phosphorus is considered the key nutrient in the overabundance of blue-green algae, and concentrations of orthophosphate reached 26 micrograms per liter in 1992 (total phosphorus would have been significantly higher).

Victoria Reservoir has been monitored since 1987, and, until 1992, there was no evidence of serious eutrophication. However, the reservoir is now regarded as moderately eutrophic (Piyasiri, 1992). A toxic blue-green, filamentous algae (Anabaena) has been discovered for the first time in concentrations high enough to lead to a possible bloom. Because of its toxicity, the presence of Anabaena is much more serious than the previous algal problem with Microcyctis (which is also still in the reservoir). Dissolved oxygen concentrations of less than one milligram per liter have been recorded in deeper hypolimnetic waters.

Randenigala Reservoir is considered mesotrophic, with more than 20 species of algae present in addition to Anabaena and Microcystis. Dissolved oxygen in the hypolimnion is one to two milligrams

per liter (much less than the saturation concentration of 10-12 milligrams per liter). Transparency has been measured as low as 1.9 meters.

- **Water management schemes have changed the natural flow regimes of the major rivers, resulting in sometimes higher flood flows, lower dry-season flows, and degradation of riparian and wetland habitats in the lower catchment.**

An increase in the ratio of surface water runoff to rainfall has been noted in the UMC over the past 30-40 years and has been related to increasing deforestation. This phenomenon is a result of land use changes such as the shift from natural forest to chena cultivation, which reduces evapotranspiration and is accompanied by increased surface flow.

The most recent study analyzes data showing that annual precipitation at Nuwara Eliya in the upper Mahaweli catchment has decreased about 500 millimeters (a decline from 2,500 millimeters to approximately 2,000 millimeters) between 1870 to 1980 (Bandara and Kuruppuarachchi, 1988). Although other precipitation stations in the area have observed similar declines, surface water discharge had increased between 1947 and 1977.

However, it is also apparent that the timing of flows has changed between 1947 and 1977. A significant decline in flow during the dry season appears to be due to an absence of a substantial forest cover. The interception and gradual infiltration of moisture into the soil typically facilitated by forest cover has been lost because of extensive deforestation. As a result, soils become rapidly saturated during wet season precipitation, and more moisture travels overland as runoff to fill streams, ponds, tanks, and reservoirs. This has resulted in some higher flood flows and greater accumulation of water downstream during the wet season. Unfortunately, the moisture formerly held in the soil system by complex forest root systems, released gradually over time, has been reduced by this process. Thus, wet-season flows tend to be higher and dry-season flow rates lower.

In addition, the mean annual flow rate of the Mahaweli Ganga has declined dramatically because of upstream water impoundments and flow regulation. The annual flow rate measured at the downstream Manampitaya gaging station from 1950 to 1977 was 8,289 million cubic meters. Since completion of the Mahaweli project reservoirs in 1988, the annual flow was reduced to 2,851 million cubic meters in the water year 1989-1990 (an average rainfall year). The average long-term precipitation for the watershed is 2,335 millimeters per year, but the amount for 1989-1990 was 2,325 millimeters. Although it is difficult to draw long-term conclusions so soon after completion of the project, analysis of an average year is a useful exercise to demonstrate the magnitude of these impacts (Table 13).

TABLE 13

COMPARISON OF MEAN MONTHLY FLOWS IN THE MAHAWELI
(in millions of cubic meters)

Month	1950-1977	1989-1990	Simulated Post-Project Flows*
January	1,203	725	952
February	709	272	393
March	422	276	150
April	471	158	99
May	508	86	0
June	502	20	0
July	478	44	0
August	442	84	126
September	435	111	108
October	694	65	390
November	966	476	660
December	1,459	535	1,273
Totals	8,289	2,851	4,151

* From the TAMS report.

Several conclusions on water quantity in the lower watershed in the post-project period can be drawn from these data:

- Surface water may be only 34 percent of the natural flow in an average water supply year;
- Monthly low flow can be as small as 20 million cubic meters in an average year;
- Although the TAMS simulation predicted that post-project average flows would be 50 percent of natural flows, actual data from an average year indicate 34 percent of natural flows at Manampitaya.

These conditions can result in an insufficient amount of soil moisture necessary to sustain streamside biotic communities and wetland areas and will likely result, over the long term, in a degradation of these important biological areas.

- **Sediment inflow is beginning to fill some reservoirs and threatens to shorten the useful life of the reservoir network.**

Several studies have estimated the sediment yield of watersheds (not to be confused with on-site erosion rates) by the measurement of suspended and bedload sediment transport or the rate at which reservoirs fill with sediment.

Sediment transport estimates indicate that between 132,000 and 833,000 tons of sediment are washed from the UMC each year, equivalent to a sediment yield of 11.5 tons per hectare per year (Stocking, 1986). A combination of sediment transport and reservoir sedimentation estimates suggests that 15 million tons of sediment are removed from the UMC each year, some of which has led to a loss of 44 percent of the capacity of the Polgolla Reservoir in the first 12 years of its life (NARESA, 1991; Manthritheleke, 1992). If this sedimentation rate continues, the life of the reservoir will be less than 30 years. This high rate is attributed to soil disturbance near the reservoir for urban construction activities in the Kandy area.

A preliminary survey of sediment accumulation in Rantembe Reservoir indicated an unusually high rate of 19 percent sedimentation in two years. However, a review of the data indicates errors in the placement of cross-sections and suggests that recalculations are necessary (J. Weerasekara, 1992). Sediment from land use practices in the Uma Oya watershed appears to be the cause of substantial sedimentation in Rantembe Reservoir, but more accurate information is needed to quantify the rate.

Reservoir surveys of Kotmale and Victoria reservoirs have been made as part of the Forest/Land Use Mapping Project (FORLUMP), a Sri Lankan-British project involving the Environment and Forestry Division of MASL and the Overseas Development Administration (ODA) of the United Kingdom. An initial survey of Kotmale Reservoir done in early 1991 indicated essentially no sediment accumulation during the first eight years of the reservoir's life (Roger White, 1992). A more recent survey of Victoria Reservoir indicated little sediment accumulation. A survey of sediment accumulation in Randenigala Reservoir is planned for 1993.

Little information exists for estimating the sediment delivery ratio of watersheds in Sri Lanka.[6] Because sediment is deposited en route to the base of a watershed, sediment yields are always less than on-site erosion rates (except for extremely small catchments). A recently completed study in the Hapuwela area measured the sediment delivery ratio in four catchments ranging in size from 22 to 216 hectares (Wickramasinghe, 1991). Preliminary results indicate an average sediment delivery ratio of about 35 percent (38 percent for the three smaller watersheds ranging in size from 22-50 hectares, and 31.5 percent for the larger one with an area of 216 hectares). While these rates do not indicate that severe problems exist for reservoir sedimentation, the high on-site soil losses do indicate that a considerable amount of sediment is moving downstream. More thorough data collection and analysis should be encouraged to accurately predict the severity of this problem before it becomes too costly or difficult to manage.

AGRICULTURAL SYSTEMS

TAMS Predicted Impacts and Mitigative Measures

AMDP resulted in many benefits for downstream agricultural development in the Mahaweli. A land area in the dry zone formerly inhospitable for agriculture was made more amenable through provision of irrigation infrastructure, water for agriculture, and land development. The general agricultural productivity of the areas under AMDP has shown an upward trend over the years. Development of infrastructure such as townships, roads, schools, health, and other public amenities necessary for agricultural settlements also have come about within a short time period. The more favorable water regime for cultivation of perennial crops such as coconuts, jack, and mango has improved

[6] Sediment delivery is the percent of on-site erosion that reaches the outlet of a catchment.

homesteads in almost all system and has also provided an additional economic resilience. Efforts of the MASL to carry out reforestation activities has also improved the micro environment and helped to beautify the surroundings, particularly in System H.

However, these benefits were accrued at some cost to the environmental base that sustains this agricultural productivity. The TAMS Environmental Assessment identified only a few adverse environmental impacts likely to affect the agricultural systems and productivity in the Mahaweli watershed, although it did recognize that these impacts could have significant implications for other sectors, principally social and economic conditions (Table 14). The consequences of these environmental changes were also expected to be significant enough to warrant several important mitigate measures.

TABLE 14

TAMS PREDICTED ENVIRONMENTAL IMPACTS
1980

Agriculture and Crop Production Impacts
• Increase in pesticide use, with the subsequent magnification of pesticides throughout natural food chains, including human consumption.
• Crop damage from birds and large mammals in response to a loss of former habitat areas. Potential physical harm to settlers from large mammals, such as elephants and boars.

The TAMS Environmental Assessment recommended mitigative measures that included actions intended to monitor degradation of irrigation water quality, soil salinity, drainage problems, and land use practices. In addition, a strong emphasis was placed on development of aquaculture as a means of taking advantage of available water supplies and increasing economic returns with minimal environmental damage. TAMS also recommended measures to improve the management of irrigation water supplies in the irrigated areas of the lower catchment. The list of mitigative measures the TAMS team felt essential to protect natural systems and stabilize environmental change included:

- Fisheries Development
  - — Much of the woody vegetation should be removed from all of the proposed reservoirs to promote effective fishing.
  - — Stocking of the reservoirs with native or exotic species should be done on a regular basis.
  - — Aquaculture trials should be initiated in participating villages.
  - — Existing tanks should be rehabilitated and stocked.

- Land Use Planning

  — A grazing feasibility study and fuelwood plantation program should be carried out throughout the basin simultaneously.

  — Recommended land use plans developed in the environmental assessment for Systems A, B, C, and D should be implemented.

  — Develop a comprehensive water management program for the lower catchment systems.

  — Monitor salinity content in irrigation waters and agricultural soils.

Many of these recommendations have been partially carried out by GSL, with assistance from other donors, and others are being implemented only now or are still in a formative stage. Specifically, development of fisheries resources and aquaculture systems has been stalled due to GSL restrictions on these activities. Land use plans have been developed for most of the system areas, although they do not seem to be widely applied. Few residents or system management personnel could demonstrate much familiarity with the plans. Salinity has been monitored in isolated locations, and appropriate drainage operations are in place or planned for several areas in the lower catchment.

The USAID-financed Mahaweli Agriculture and Rural Development (MARD) project has made some strides toward meeting some of these needs in System B of the lower catchment. The environmental action plan developed for the MARD project in 1992 is summarized in Appendix D and addresses many of the potential adverse environmental impacts that could result from unmonitored implementation of agricultural technologies in the Mahaweli. Similar action plans would be appropriate for other areas in the lower catchment systems.

Current Agricultural Conditions and Issues

Although these project and program efforts have enabled GSL to realize some of the TAMS mitigative measures, an analysis of conditions in the Mahaweli indicates that all the impacts to agricultural systems conditions predicted in the 1980 TAMS Environmental Assessment have occurred to various degrees and most continue to be unchecked problems in the Mahaweli river basin. Many environmental problems remain, some of which will require efforts beyond the scope of all of these projects if they are to be fully resolved. A summary of the more prominent agricultural issues is presented in Table 15.

TABLE 15

ISSUES AFFECTING AGRICULTURAL SYSTEMS

- Chemical inputs to agricultural systems in the upper and lower catchment areas are degrading local surface and ground water quality.
- Cropping patterns are often inappropriate for the soil and microclimatic conditions of the site, resulting in reduced productivity and increased reliance on environmentally inappropriate agricultural practices.
- Poor water management practices, principally in lower catchment irrigated areas, have increased the threat of soil salinization and on-site soil losses.

- **Chemical inputs to agricultural systems in the upper and lower catchment areas are degrading local surface and ground water quality.**

The TAMS Environmental Assessment predicted and recommended monitoring the effects of increased use of fertilizer and pesticides by strengthening capabilities and facilities of the Central Agricultural Research Station at Gannoruwa, Peradeniya. An additional recommendation was to improve the extension services to reduce the hazard of pesticide misuse. Unfortunately, this institutional development has not occurred, and no significant monitoring of pesticide use has been conducted. There are few data available to quantify the magnitude of pesticide and major fertilizer nutrient concentrations in irrigation or drainage waters in the lower catchment other than that published by TAMS.

Studies within specific systems do indicate a very high use of agrochemicals, with little, if any, monitoring and regulatory enforcement (Tolisano, 1992). Fertilizers and pesticides are routinely used by most farmers in the lower catchment area, including some pesticides that are listed as Restricted Use Pesticides (RUPs) by both the U.S. Environmental Protection Agency (EPA) and GSL. Farmer use of agrochemicals is not routinely monitored by trained professionals, and most advice on chemical selections and use rates is obtained from chemical sales agents.

Fertilizers are typically applied during four stages of crop production. Approximately 185 kilograms per hectare of Triple Superphosphate NPK is usually applied at the time of planting.[7] Roughly two weeks later, the farmer applies approximately 60 kilograms per hectare of urea, with an equal amount of urea again added about five weeks after planting. Finally, a top dressing of NPK fertilizer is added approximately eight weeks after planting. Farmers receive extension advice on fertilizer use from MEA agents, MARD staff, and retailers.

Fertilizer use has probably contributed to the very evident algae blooms in drainage canals, as well as extensive *Salvinia* growth on the edges of the numerous reservoirs. This eutrophication is partly responsible for many blocked drainage canals and probably results in some loss of habitat for fish.

Chemical control is a preferred method of weed control for many farmers, especially those who have limited available labor or machinery. Herbicides used for weed control in paddy areas can be

[7] Triple Superphosphate NPK is a mix of synthetic nitrogen, phosphorus, and potassium.

classified as selective and non-selective herbicides, pre-emergent and post-emergent herbicides, systemics, contact killers, and soil sterilants. Where weed growth is dense, farmers frequently use a total herbicide such as gramaxone (Paraquet). It is estimated that less than one percent of farmers ever resort to use of gramaxone. Systemics such as Round-Up are used only on experimental plots because of the high cost of the product.

Farmers report insect problems in paddy rice and other crop production. The usual response by farmers is repeated applications of a variety of chemicals throughout the growing period. The persistence of some of these chemicals in water supplies is uncertain, given the lack of monitoring, although the health implications of some chemicals used are severe. The problem may be intensified by the fact that the agrochemical industries represent the only sources of extension information to most farmers on agrochemical use and management.

These agrochemicals can result in a significant degradation of water quality, threatening the longevity of reservoirs and power production schemes through eutrophication and health conditions for humans and wildlife. A significant reduction in chemical use could be achieved through improved cultural practices, including transplanting, row transplanting, manual hand weeding, and use of pure, registered weed-free seeds. On-farm demonstration trials of appropriate chemical use would also help reduce agrochemical problems.

- **Cropping patterns are often inappropriate for the soil and microclimatic conditions of the site, resulting in reduced productivity and increased reliance on environmentally inappropriate agricultural practices.**

There is wide variation in the data found in different sources on soil classification and productivity levels in the Mahaweli systems. The available information is also not clear about the location of the well-drained areas under homesteads; area cultivated with other field crops (OFCs); lands abandoned, under scrub jungle, and so forth; and the extent of poorly drained soils suitable for lowland rice and other drainage tolerant crops. This has led to poor land use planning in the system areas and little regard for crop diversification under different systems.

If recent data are accurate, then about 30 percent, 8 percent, 10 percent, and 9 percent of the soils in Systems H, C, B, and A, respectively, are well drained and therefore suitable for OFCs. Also, the data seem to indicate that greater potential for crop diversification lies in systems H and G (Acres, 1985). However, these data are not being applied through effective land use strategies. They should also be confirmed through more detailed field measurements. It will be important to identify soil drainage classes throughout these system areas and map the soil types accurately in different systems for correct agricultural use to sustain the productivity of these soils. Although this was a recommended measure in TAMS, the discrepancies of various sources show that a systematic approach has yet to be initiated.

A further limitation to agricultural development in the Mahaweli arises from the intensive labor and input required by OFCs in comparison to lowland rice. This is a direct consequence of inappropriately sited cropping schemes. Ideally, however, the irrigation techniques adopted for OFCs should reduce the labor required in irrigation water management. Unfortunately, conventional gravity irrigation techniques such as graded terraces and furrowed basins recommended for Mahaweli areas were never practiced by the farmers due to the increased labor requirement and costs in land preparation.

In addition, farm power availability is inadequate to support agricultural mechanization needs. A study conducted in Block 302 of the Mahaweli System H indicates that inadequate farm power

constrains irrigation scheduling, particularly during land preparation. This has resulted in delayed land preparation and poor resource use for the cultivation of rice. In addition, poor land preparation results in lower yields due to weed-infested fields (Goonasekera, 1990). Cultivation of highland crops has been mechanized to a very limited extent in comparison with rice. As a consequence, the timeliness of cultivation operations, which is a crucial issue for effective irrigation management, has become a limitation. This is particularly true for small holdings where individual farmers are unable to afford power sources or farm machinery on their own.

An appropriate program of agricultural mechanization or simply improved on-farm management practices can help overcome this limitation for better farm and system irrigation management. As an indication of the ways the actions can facilitate greater environmental management, improved irrigation management can reduce water requirements for farmers, minimize the raising of water tables, lessen the need for drainage facilities and wetland disturbances, and enable higher instream flows to be maintained in the natural river courses. These kinds of management improvements can result from strengthened extension programs, including better training opportunities for extension workers.

- **Poor water management practices, principally in lower catchment irrigated areas, have increased the threat of soil salinization and on-site soil losses.**

Electrical conductivity (EC) measurements were done in Systems H, B, and C in December 1992 as a part of the MEE field assessment work. Drainage water of System H showed very low conductivity values ranging from 200 to 700 micromhos per centimeter and salinity levels of 0-0.3 percent. These values do not indicate any significant water quality degradation, since poor quality water values would more likely approach 4,000 micromhos per centimeter. However, since the sampling was done during the middle of Maha season, the seasonal rainfall had effectively flushed the excess salt accumulated during the dry spell and, thereby, lowered the salinity incidence. As a result, salinity in system H appears to be more common in localized patches, particularly affecting abandoned small irrigation tanks and waterlogged areas. Thus, salinity levels are likely to be aggravated during dry spells and reduced during rainy seasons.

In System B, electrical conductivity measurements in irrigation water and main drains showed a variation of 90 to 375 micromhos per centimeter with very low salinity (0-0.5 percent). Thus, the situation again is similar to System H. The soils are shallow and coarse-textured in System B and have rapid filtration action. Main drainage improvements accomplished with USAID assistance through the MARD project has very effectively removed excess water from the system. In System B, salinity problems exist only in some low-lying areas where drainage is impeded. Soil solutions showed electrical conductivities ranging from 300 to 15,000 micromhos per centimeter with salinity levels ranging from 0 to 20 percent.

In System C, water quality investigations were confined to areas specifically reported to have salinity problems, including Weheragala and Mahawanewala. However, field measurements showed that these were not really due to salinity (EC of 30 micromhos per centimeter and salinity of 0 percent), but were due instead to problems of land leveling and exposure of subsoils.

Although the salinity problem does not appear to have reached serious proportions at present, it may increase in severity over time, particularly in Systems H, B, and C, where landholdings are smaller and there is second-generation pressure for land. This is due to the tendency of farmers to cultivate rice in the main drainage pathways. Construction of temporary stick dams in main drainage channels are already causing problems in System D, which is an older system with larger land holding sizes per

farmer. Measures can be taken to clear drainage pathways arising from such cultivation to mitigate water logging problems in all AMDP systems. Also, it is recommended that water quality monitoring be done regularly at low intensities to identify potential problem areas and implement appropriate remedial measures. Although these are measures that were already recommended in the TAMS Environmental Assessment, effective action has fallen short of recommendations because of insufficient funding.

The TAMS Environmental Assessment also suggested that soil erosion would have a negligible impact in the lower catchment because of lower slopes on the downstream irrigated areas. Although the very limited data available do not indicate any areas with significant soil loss problems in the lower catchment, this situation does warrant more detailed monitoring. Rainfall erosivity can increase with decreasing elevation. In many downstream areas, high-intensity rainfall combined with intensive land cultivation may cause erosion to assume serious proportions (Wickramasinghe and Premalal, 1989). This is especially true in locations where diversified agricultural schemes result in minimal groundcover during intense rainfall periods. As a consequence, there is a need to implement soil conservation measures to mitigate future soil productivity problems that may arise due to erosion.

Wildlife and Biodiversity

The TAMS Environmental Assessment identified several highly significant adverse environmental impacts likely to affect wildlife and biological diversity in the Mahaweli watershed (Table 16). The consequences of these environmental changes were also expected to be significant enough to warrant several important mitigative measures.

TAMS Predicted Impacts and Mitigative Measures

The TAMS Environmental Assessment recommended a few very ambitious mitigative measures that included actions intended to increase the area of protected habitat available to remaining wildife in the watershed and to strengthen the institutional capacity of GSL to manage and maintain these protected areas. A strong emphasis was placed on building staff capabilities in park planning, environmental monitoring, research, and education, as well as on increasing economic returns through conservation actions. The list of mitigative measures for wildlife conservation and management the TAMS team felt essential for protecting natural systems and stabilizing environmental change included:

- Large, contiguous reserves should be established in and around the project area. Recommended areas for reserves include the Somawathie Sanctuary, Mahaweli Ganga riverine forest, Wasgomuwa, Hurulu National Park and Kaudulla Reserve, Maduru Oya National Park, Nelugala Corridor, and all major riverine forests. Reserves should include designated core zones, habitat enrichment within the core zones, and connecting corridors to prevent habitat fragmentation.

- The administrative and management capacity of the Wildlife Conservation Department (DWLC) should be expanded and strengthened through additional staff, increased infrastructure, and training.

- A National Wildlife Management and Park Planning Team should be assembled to plan and coordinate the development of the proposed reserve system.

TABLE 16

TAMS PREDICTED ENVIRONMENTAL IMPACTS
1980

Wildlife Impacts

- Elimination of essential habitat for nine threatened, endangered, or sensitive species listed by the U.S. Fish and Wildlife Service and GSL and the more than 90 endemic species found in the basin. Habitat losses were anticipated as a result of clearing tropical dry forests and floodplain wetlands to provide area for agricultural developments.
- Population reductions and reduced ecosystem carrying capacities for most wildlife species.
- Loss of breeding and feeding grounds for some fish species (particularly floodplain species), waterfowl, and migratory birds.
- Blocked migratory routes for river fish.
- Altered biomass productivity and energy cycles in estuarine systems, with a detrimental effect on aquatic life.
- Proliferation of species that adapt readily to agricultural development (such as rats, parakeets, and munias) and become pests for crop production.

All these recommendations have been carried out to some degree by GSL, primarily with assistance from the USAID-financed Mahaweli Environment Project (MEP). The purpose of MEP was to minimize the environmental damage likely to result from the irrigated agricultural developments being constructed in the watershed and from human settlements in the AMDP area by providing alternative protected habitats for displaced wildlife in a manner that is ecologically sound and socially acceptable. MEP consisted of development of national park infrastructure, strengthening of the DWLC planning and management system, and development of DWLC research and training capability.

The project successfully facilitated the delineation and gazetting of eight new protected areas in the Mahaweli watershed totaling more than 177,000 hectares of natural wildlands. Infrastructure, commodities, and other goods and services have been provided to DWLC and are still actively used. Training programs have advanced the capacity of department personnel to take on the complex planning and management requirements of the new protected areas. The project was completed in 1988. An evaluation of MEP project purpose-level accomplishments is provided in Annex A.

Present Biodiversity Conditions and Issues

Although these project and program efforts have enabled the GSL to realize some of the TAMS mitigative measures, an analysis of conditions in the Mahaweli indicates that all the impacts to wildlife and biodiversity conditions predicted in the 1980 TAMS Environmental Assessment have occurred to

various degrees, and many continue to be unchecked problems in the Mahaweli river basin. The persistence of these problems largely seems to reflect that the solutions applied were incomplete and did not adequately address the root causes of many of the problems. A summary of the more prominent biodiversity issues is presented in Table 17.

TABLE 17

ISSUES AFFECTING WILDLIFE AND BIODIVERSITY

- The data on wildlife population characteristics, migration and dispersal patterns, and habitat requirements are not sufficient to guide management decision making.
- Habitat conditions in many of the designated protected areas have been degraded over time, and restoration or enrichment measures have been inadequate to support existing wildlife populations.

- **The data on wildlife population characteristics, migration and dispersal patterns, and habitat requirements are not sufficient to guide management decision making.**

The primary objective of MEP and associated protected areas and conservation strategy in the Mahaweli basin was to sustain wildlife populations and the habitats they require. Ideally, this objective would be met by correlating known information about the reproductive, feeding, and movement patterns of keystone species in order to ensure that appropriate habitats of sufficient size are protected to maintain minimum viable populations.[8] Unfortunately, incomplete data exist to define the life histories of many species in Sri Lanka, much less the survival patterns of the specific subpopulations, or demes, that live in the Mahaweli basin. It is also not apparent that data have been used to determine the area or spatial requirements of protected areas (Eisenberg et al., 1990). As a result, there is no certainty that the protected areas as now delineated will actually guarantee the survival of many wildlife populations over the long term.

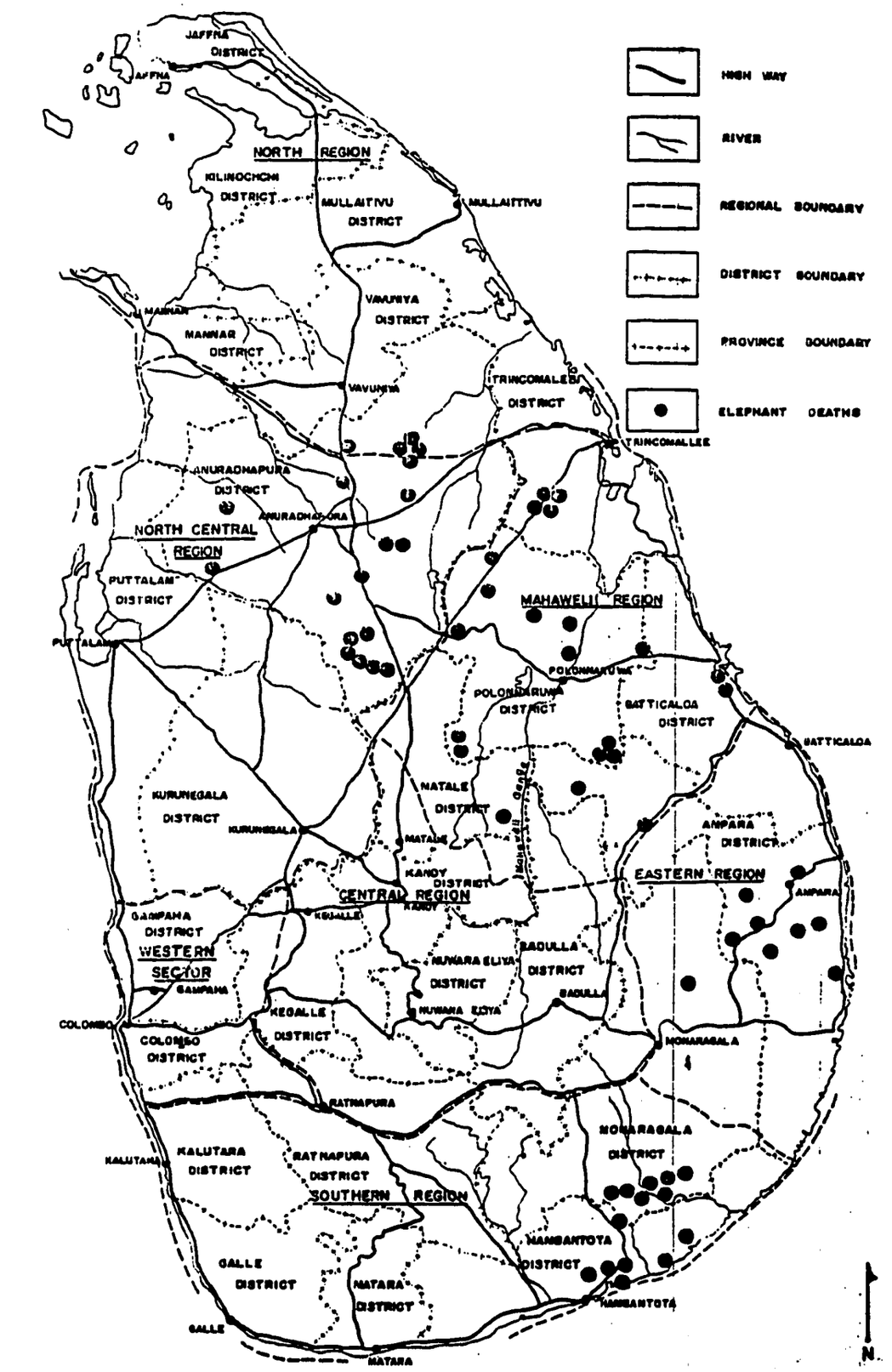
Information on the sex and age ratios of keystone species is particularly important if the species are to be provided an opportunity for long-term survival. For example, although the total population of elephants in the Mahaweli basin may exceed 500, perhaps only 75 are actively breeding females. More than 60 elephant kills were recorded in 1992, with approximately half of these occurring in the Mahaweli basin. Factoring in natural mortality, along with an additional percentage of unrecorded elephant kills, could indicate that natural reproduction may not be equal to mortality. Over the long term, the population will decline in numbers. Inbreeding and sterility can occur among some of the demes within the basin if the populations become small enough. Figure 5 shows elephant deaths in 1992.

Unfortunately, there is no way to technically define the minimum population size that will still allow a species to survive over the long term. Some biologists suggest minimum viable population sizes

[8] Keystone species are those plants or animal species whose presence determines or influences the survival of a large number of species in a biological community. Minimum viable populations represent the smallest isolated population of a species having a 99 percent chance of surviving the next 1,000 years despite foreseeable effects of demographic, environmental, and genetic stochasticity, as well as natural catastrophes (Fielder and Jain, 1992).

FIGURE 5

ELEPHANT DEATHS IN 1992



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ranging from 50 to 500, but these numbers are meaningless on their own. Minimum population sizes are dependent on the genetic diversity within a particular deme, proximity and ability for the species to move among other demes, habitat conditions, and natural pressures on the species, among other factors. It is precisely for this reason that more accurate data need to be generated on identified keystone species.

There is no doubt that previous efforts and intentions to collect reliable data on species and habitats have been severely constrained by ongoing civil disturbances, particularly in the lower catchment areas. However, random sampling can now be safely conducted in all representative habitat types in the Mahaweli basin, and these data can be extrapolated to guide management decisions throughout the rest of the basin.

An initial task will involve identifying the appropriate species that represent keystone linkages in the ecosystem or can otherwise provide strong indications of ecosystem health. Some of the larger fauna would serve well here, including elephant, leopard, and bear. However, the diversity of soil and water flora and fauna also represents a strong indication of the resilience within an ecosystem.[9] Periodic tests of soil and water microbiology can be a simple and effective method of monitoring watershed biodiversity (see Annex F). Once keystone or indicator species have been identified, then regular monitoring of population dynamics, habitat conditions, and external threats must be maintained. Without this information, all conservation efforts are merely a shot in the dark.

- **Habitat conditions in many of the designated protected areas have been degraded over time, and restoration or enrichment measures have been inadequate to support existing wildlife populations.**

Conservation biologists have recognized that species extinction rates are affected by the kind, quality, and diversity of available habitats. The patterns of plant succession and natural disturbance that occur within these habitats also play an important role (Grumbine, 1992). Unfortunately, few conclusive studies of habitat conditions within or adjacent to the protected areas in the Mahaweli basin have been conducted. Visual observations made by the MEE Team indicate that the habitat conditions in the protected areas are far from optimal for most species. The poor quality habitat in many of the protected areas encourages wildlife to use these parks and reserves primarily as sources of water and cover — food supplies are much more appealing outside the reserves. Hence, elephants, boar, buffalo, sambar, and other grazing or rooting ungulate species tend to invade cultivated fields on the perimeters of the protected areas, and conflicts between farmers and wildlife become a daily occurrence. These conflicts are not a small matter, in terms of both human and elephant lives lost. From 1986 to 1991, an estimated 16 people were killed as a result of confrontations with elephants.

Most of the protected areas are in the lower catchment area and include relic forest lands in varying stages of vegetation succession, along with extensive grasslands. The forest lands have been selectively harvested in recent times, and very few intact undisturbed forests are evident in the parks. The grassland communities appear to be largely anthropogenic (that is, created by human actions), and

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[9] Resilience represents the degree to which an ecosystem's structure and long-standing composition can be disturbed and yet retain or rapidly return to its original features.

are probably the result of past slash-and-burn (chena) cultivation.[10] The dominant species in most of these grassland areas appears to be *Imperata cylindrica* (Illuk), which is of low nutritional value and largely palatable only in its early growth stages. The grass is consumed by herbivores, including elephants, wild buffalo, and deer, although all these species would select more palatable and nutritious grasses if available.

The grassland areas have created an extensive network of "edges" in the park. These edges represent boundaries between the dense forest vegetation and the more open, park-like grasslands. A high degree of edge is generally supportive of more diverse and abundant wildlife populations, and elephant populations are particularly attracted to areas of plentiful edge (Eisenberg et al., 1990). However, too much edge eliminates important habitat needs (Janzen, 1986). Also, not all species are fond of this edge effect. Edges can also represent pathways for invader plant species to infiltrate and dominate an ecosystem. The Illuk grasses are an example of this kind of invasion, and many other such invasions are already evident in the parks. Several small tanks and wetland areas exist in the parks and reserves, although many of these are in poor condition because of overuse by wildlife and establishment of invader plant species, particularly aquatic weeds.

Some preliminary survey and analysis has been done to define the life histories and habitat requirements of some of the major vertebrate species in the Mahaweli authority (Eisenberg et al., 1990).[11] However, more detailed analyses of the habitat requirements for specific Mahaweli demes of defined keystone or indicator species are needed. These analyses will fulfill a database that planners and managers desperately need if their long-term goal of biodiversity conservation is to be realized. Suggestions for activities to initiate these analyses are included in Annex B.

Social and Economic Systems

AMDP has positively contributed to national development more than any other development program implemented in Sri Lanka. It has contributed not only in terms of agricultural development, but also in supplying electricity, addressing difficult unemployment problems, working with problems caused by the high population in the wet zone, improving road networks, and in many other important social development aspects. However, the social engineering instigated by AMDP has also resulted in changes to the family and household environment in which Mahaweli residents live and the overall socioeconomic and cultural conditions in which they interact. In reviewing the AMDP development programs, families were relocated from their original socioeconomic and cultural environment to a new settlement area in order to solve national problems. In this process, the Mahaweli planners significantly changed the social and economic conditions within which people function, as well as the physical engineering aspects that affect their livelihoods. These impacts to social and economic conditions in the basin significantly influence the decision-making capabilities and options available to residents. The personal and social choices made by residents in the Mahaweli can, in turn, have a strong impact on the natural systems around them as they decide how landscapes will be used and changed over time.

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[10] Repeated fires can change the productivity, species composition, and cover type in plant communities. The impacts of fire on grassland are very dependent on the intensity (heat) of the burn. Slow-moving hot fires tend to kill much of the later, successional vegetation and provide opportunities for more fire-tolerant species, such as Illuk, to invade and maintain some kind of equilibrium.

[11] See John Eisenberg and Melvyn Lockhart, "An Ecological Reconnaissance of Wilpattu National Park, Ceylon," pp. 10-77, in Eisenberg et al., 1990, for a good summary of population characteristics, social behavior, and habitat utilization by 10 major vertebrate species.

TAMS Predicted Impacts and Mitigative Measures

The TAMS Environmental Assessment predicted a number of adverse environmental impacts likely to result from the social engineering inherent in the implementation of the complete AMDP scheme (Table 18). Although the data to estimate the magnitude of these predicted impacts were incomplete or non-existent at the time, the consequences of these environmental changes were expected to be significant enough to warrant a lengthy list of mitigate measures.

TABLE 18

TAMS PREDICTED ENVIRONMENTAL IMPACTS
1980

Social and Economic Impacts
• Local unemployment problems for second-generation offspring of settlers.
• A spread of water-borne and vector diseases as a result of water developments in the project area.

The TAMS Environmental Assessment recommended mitigative measures that included actions intended to address unemployment problems and declining health conditions that could result from the development of the irrigation infrastructure in the Mahaweli. The list of mitigative measures that the TAMs team felt essential to protect natural systems and stabilize environmental change included:

- Health Care and Sanitation Planning
  - — A survey of groundwater availability should be conducted for all proposed settlement schemes.
  - — Standpipes should be developed to supply domestic use water in commercial or government centers, and protected wells should be constructed in rural hamlets and villages. Every village house and commercial establishment should be provided with sanitary facilities for human waste disposal.
  - — Minimum flow depths should be maintained in river channels to flush breeding populations of mosquito vectors.
  - — Immunizations, particularly against tetanus and polio, should be expanded.
- Social Considerations
  - — A strengthened staff for the Regional Planning and Socioeconomic Studies Unit of the Mahaweli Economic Agency (MEA) should design an orientation program for all

new settlers and critically review all facilities and infrastructure development plans for proposed settlements.

— Special studies should be conducted of urban-rural relationships, fishing conditions and opportunities, agricultural laborer conditions and opportunities, and alternative development schemes for the Kotmale and Victoria reservoir areas.

— Monitoring programs should be initiated to evaluate the successes and problems inherent in the settlement schemes.

— Administrative and support staff for agricultural extension services should be strengthened and expanded through new personnel, infrastructure, and training.

These recommendations have been carried out to some degree by GSL, with assistance from several donors, while others are being implemented only now or are still in a formative stage. However, none of these measures has been fully accomplished, and much work remains to meet the needs of local residents in the Mahaweli for adequate health care, education and training opportunities, and income-generating strategies. These facilities will create opportunities for residents to improve their lives, and such options can provide the impetus for more locally enacted environmental management actions.

Environmental Conditions and Issues

Although the efforts taken to improve social and economic conditions, particularly in the lower catchment area, have enabled GSL to realize some of the TAMS mitigative measures, an analysis of current conditions in the Mahaweli indicates that many issues remain. These problems will require a greater emphasis on social and economic needs, particularly of the second- and third-generation settlers, if they are to be fully resolved. A summary of the more prominent social and economic issues is presented in Table 19.

TABLE 19

ISSUES AFFECTING SOCIAL AND ECONOMIC CONDITIONS

- Land allocation schemes provide too small a land base to support more than one generation through agricultural production, resulting in declining quality of human life and an increase in illegal land uses.
- The social infrastructure in the upper and lower catchment areas cannot yet fully meet the needs for satisfactory health, education, training, or financial well-being of the region over the long term.

The apparent magnitude of these issues is difficult to determine, given the limited data available on baseline and existing environmental conditions in the river basin. However, indications of the severity of the problems, along with an identification of the information needed to more accurately assess problem levels and appropriate solutions, include:

- **Land allocation schemes provide too small a land base to support more than one generation through agricultural production, resulting in a declining quality of human life and an increase in illegal land uses.**

In the settlement schemes, the land belongs to the state and the original settlers are given temporary permits for use of one hectare of land (2.5 acres). In a system designed to encourage paddy cultivation, this area of land is adequate to supply the subsistence and income needs of approximately one single-family unit. Land cannot be sold by the permit holder, but can be passed on to one member of the family by the original settler. This can frustrate and isolate all the other sons and daughters in the family since they are offered no other means of making a living. In some cases this leads to a breakdown in the family unit.[12]

As a response to this situation, most parents allow all their sons (in some cases including their sons-in-law) to cultivate the small family plot of land once they get married. This tends to result in depletion of soil productivity and inadequate economic returns to sustain the entire family unit. Ultimately, the result is a continuation of a subsistence agricultural system and acute poverty.

Impacts on Women

The situation may be more acute for women in the settlement areas. The traditional Sri Lankan practice is for the female members of the family to leave the family unit once they marry. As a result, they do not usually obtain any rights to land. Poor education, combined with a lack of income-generating opportunities for women in the area, especially for the female school-leavers of the second generation, often encourages women to pursue marriage at a young age. Statistically, this appears to contribute to several increasing social problems that particularly affect women:

- Malnutrition is comparatively higher among women than men.
- Suicide rates are high and are increasing among women; a considerable amount of the rate has been directly attributed to the lack of options women find available in their lives.
- Women spend a large percentage of their time collecting subsistence resources, such as fuelwood.
- Female participation in resource management and decision-making tasks is virtually absent.
- Family planning services are largely unavailable to women who might want to limit family size and increase their own contribution to land and resource management.

At the present time, few programs address or correct these problems, and an entire sector of the population that plays an intrinsic part in resource use has little role in its ultimate management.

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[12] The situation is exacerbated by large state-holdings of potentially productive land, much of which has fallen into a condition of poor or declining productivity and is minimally used. Lands previously in productive forest cover have been degraded to scrub or are largely barren due to poor management, monitoring, and enforcement measures. Local people often use these lands for illegal cultivation or resource collection, although they tend to apply poor land use and management practices since they have no legal rights to the property.

Problems with suicide are not, however, limited to the female sector of society. Research conducted in System C of the lower catchment indicates that most suicide victims appear to have been influenced by economic factors. Approximately 90 percent of the suicide victims belong to the lowest economic class. 40 percent of the victims were unemployed, and a majority were illiterate or only marginally literate. Approximately 80 percent of the victims had no immediate relatives in the immediate area in which they were living. In addition, approximately 90 percent of these victims used induced agrochemical poisoning as the suicide method, which further emphasizes the relations between inadequate social resources (for example, lack of educational opportunities) and environmental abuses.

The limitations of the land area they are given to work, combined with the weak community and family network in the systems, often taxes settlers beyond their means. Accrued debts, combined with inadequate incomes, often force some residents to become hired laborers on their own lands. Interviews conducted with system officers and local farmers suggest that as many as 40 percent of farmers in some areas of the lower catchment may be leasing their lands to others and hiring themselves back onto the land as a laborer (Table 20). This further stimulates a system of poverty and lowered productivity on the land.

TABLE 20

LAND TENURE IN SYSTEM C
1988 (PADDY LAND)

Tenure	No.	%
Land owner cultivates the entire land	146	70.8
Land owner cultivates part of the land (part is given in *Ande*, leased out, mortgaged, etc.)	11	5.3
Entire land is not cultivated by the owner	49	23.9
Entire land is given on *Ande*	16	7.8
Entire land is leased out	14	6.8
Entire land is mortgaged	17	8.2
Entire land is given on *asvaddumaiz*ation	2	1.1
Total allotments	206	100.0

This poverty cycle is further illustrated by an assessment of typical income and expenditures incurred by an average settler in the lower catchment (Table 21). A consequence of this self-reinforcing poverty cycle is that residents can identify few options for improving their well-being. People with limited opportunities for maintaining their livelihood will rarely count sustainable environmental management among their priorities.

TABLE 21

MONTHLY INCOME AND EXPENDITURE OF THE SETTLERS

Income/Expenditure	Average Income Range (Rs)
Income - from	
Agriculture	3000-3500
Other employment	500-600
Other sources	300-500
Total	3800-4600
Expenditure - for	
education	200-400
agriculture	1600-2000
food items	1200-1400
transport & fuel	150-200
health	100-200
recreation	50-100
other needs	50-100
Total	3350-4400
percent from total spent on food	44-48

Unfortunately, current population projections indicate that these problems may worsen before they improve, unless dramatic actions are taken to increase options and provide alternative income-generating opportunities, particularly for second- and third-generation residents. In certain areas of the lower catchment, population growth rates are estimated to be greater than four percent, which would indicate a potential doubling of population in less than 20 years. Even assuming a more conservation growth rate of 1.2 percent (the approximate national average), the land availability for future generations appears inadequate to meet even subsistence needs (Table 22).

TABLE 22

PERSON-LAND RATIO IN LOWER CATCHMENT
1990-2000

System	Acres	Total per capita Land (acres)*		
		1990	1995	2000
System B	120000	1.47	1.38	1.30
System C	60000	0.72	0.68	0.64
System G	10000	0.54	0.51	0.48
System H	70000	0.41	0.38	0.36

* The irrigable land is actually much less than this. the land ratio calculated is based on the land area proposed for development in the future.

USAID and GSL have combined efforts to address some of these problems through the Mahaweli Enterprise Development Project. MED has been designed to promote investment and business development in agribusiness, manufacturing, tourism, minerals, and services. MED assists small-, medium-, and large-scale investors with technical assistance, marketing support, training, business advisory services, and credit. A summary of 1991-1992 MED results and 1993 target objectives is included in Table 23.

Although the MED Project represents an excellent opportunity to address many of the financial and infrastructure development needs faced by new settlers in the Mahaweli region, it has not yet embraced all the important environmental concerns inevitably associated with these socioeconomic developments. Without a strong environmental perspective, there is some risk that the enterprise and policy developments promoted through MED will contribute to undesirable environmental consequences.

For example, the MED Project has been actively involved in investment programs for many of the select commercial growers in the lower catchment areas. These few commercial growers receive access to larger land holdings (20 hectares) than other settlers. However, many of the commercial lands visited by the MEE team are in a process of clearing and development that shows little regard for environmental concerns. Forest cover has been cleared and burned on many commercial properties in a way that appears likely to reduce the overall productivity of the site, and without consideration of opportunities to retain important soil, water, and biodiversity characteristics. The MED Project efforts could be enhanced over the longer term by incorporating an environmental review process in the planning of activities such as these commercial farm developments.

TABLE 23

SUMMARY OF 1991-1992 MED/EIED RESULTS AND 1993 TARGETS

	Results		Target
	1991	1992	1993
Outgrower jobs created	1,450	2,806	1,500
New jobs generated in enterprises with more than 25 employees (non-garments)	400	20	1,500
Jobs created in enterprises with 1 to 25 employees	400	900	800
New self-employment jobs generated	700	500	500
Total MED jobs created	2,950	4,220	4,300
Jobs created in garment factories	0	4,700	0
Total jobs generated	2,950	8,920	4,300
Outgrower net incomes (not including CTC)	Rs 35.5 million	Rs 44.3 million	Rs 68 million
Hectares cultivated directly by agribusinesses (not including outgrower cultivations)	385	415	600
Loans arranged for self-employed and micro and small businesses	Rs 6.1 million	Rs 8.1 million	Rs 12.0 million
Number of agribusiness investments approved*	12	17	25
Value of agribusiness investments approved	Rs 35.6 million	Rs 284.2 million	Rs 300 million
Number of non-agribusiness investments approved*	16	23	25

* An investment is classified as approved after approval by relevant body (MASL Board, Minister, Cabinet) and signing of Memorandum of Understanding by investor and MASL.

- **The social infrastructure in the upper and lower catchment areas cannot yet fully meet the needs for satisfactory health, education, training, or financial well-being of the region over the long term.**

For millennia, humans existed as collections of more or less related individuals, living by traditions generated by their surroundings and previous traditions. Life had a relatively sustainable management recipe for the manageable resources and disaster plans for the unmanageable. Sustainable agroecosystems were the dominant nonwild vegetation type (Goodland et al., 1990). However, the water resources and social engineering in the Mahaweli watershed, combined with increasing human population growth and new economic goals, has introduced significant changes into these traditional relationships

of humans to land. Residents in the upper and lower catchments need to evolve new traditions that will allow them once again to generate income and subsistence in a way that can sustain ecosystem functions.

Important tools that can enable people to achieve this more balanced relationship to the land and resources around them include improved educational, health, and financial facilities. These facilities provide the foundation for personal and social well-being. As the health and financial status of Mahaweli residents improves, people will have more opportunities to address issues such as conservation of soil and water resources, biological diversity, and forest ecosystems. However, as long as people's lives are affected by poverty and its associated debilitating drains, then environmental management will likely remain a secondary concern and ecosystem degradation will continue. The degree of infrastructure provided to help settlers in the lower catchment has been extensive, although apparently not entirely sufficient (Table 24).

The level of education of the children in the Mahaweli settlement schemes is relatively very poor. This is due to a variety of factors, including the need for youth to work with their families to develop and maintain farm operations. However, the facilities and resources available to improve educational conditions in the basin do not appear to be fully adequate, particularly in the lower catchment settlement areas. Education can create options for people to improve their health, social, and financial well-being. Without these educational opportunities, the goal of improved environmental responsibility, especially among watershed residents, will be consistently constrained.

At the time of the settlement, people were not provided with adequate potable water supplies, and most people obtain water for household uses and consumption from irrigation canals. This water is not potable and contributes to a variety of water-borne health disorders. The hand-pump wells and other means of safe drinking water supply provided at later dates in the settlement schemes have been inadequate to meet the target number of water supplies (wells and tube wells), even at the end of settlement of families. Sanitation facilities are lacking throughout the lower settlement areas and are inadequately addressed in the watershed in general. Most settlers use either open areas for sanitary needs or construct a primary latrine. These poor sanitation conditions are contributing directly to the spread of water-borne diseases.

An Increase in the Incidence of Malaria

AMDP has been cited as a leading cause of the increase in the occurrence of malaria in Sri Lanka in general and the Mahaweli watershed in particular. Data clearly show that the spread of malaria re-activated during the commencement of AMDP, and the districts under the Mahaweli program have recorded the highest rates of malaria. This is mainly the result of:

- Standing water in newly developed reservoirs, irrigation canals, and on-farm fields provides an excellent habitat for breeding mosquito vectors; and

- Infected Mahaweli settlers moving in the country on family visits or other visits provide a mechanism for the parasite to spread throughout the island.

TABLE 24

TARGETED AND ACTUAL CONSTRUCTION OF BASIC INFRASTRUCTURE FACILITIES

Infrastructure	System B	C	G	H
Total Houses				
Targeted	18,161	19,074	3,395	25,292
Actual	11,882	16,093	2,242	25,292
Target vs actual %	65	84	66	100
Total Latrines				
Targeted	16,381	19,054	3,395	25,292
Actual	8,419	12,300	1,634	20,798
Target vs actual %	51	64	48	82
Total Wells				
Targeted	18,509	19,054	2,015	8,746
Actual	5,716	8,079	109	8,627
Target vs actual %	31	42	5	99
Total Tube Wells				
Targeted	459	25	163	152
Actual	325	23	163	152
Target vs actual %	71	92	100	100
Total Schools				
Targeted	161	85	24	88
Actual	67	61	24	88
Target vs actual %	42	72	100	100
Total Health Establishments				
Targeted	89	70	15	54
Actual	68	43	15	76
Target vs actual %	76	61	100	141
Total Co-operative Establishments				
Targeted	61	76	18	59
Actual	43	31	18	64
Target vs actual %	70	41	100	108
Total Bank Establishments				
Targeted	11	11	5	26
Actual	4	5	4	25
Target vs actual %	36	45	80	96

Available records indicate that from 1935 to 1960, the incidence of malaria was declining in Sri Lanka (Table 25). However, beginning in 1983, the disease has demonstrated a rapid increase, particularly in the Mahaweli watershed (Table 26). Although the general water resource development

infrastructure is in part the cause of this increase, a significant factor is also the lack of experience and education among settlers in avoiding or mitigating the disease. According to some officials of System C, abandoned rock and soil excavation sites, canals, and water holes are the main sources for mosquito breeding. The poor and inadequate health facilities available to settlers further aggravates the problem. Once again, the missing infrastructure in the Mahaweli basin directly contributes to an increase in environmental degradation, in this case in the form of poor environmental health conditions.

TABLE 25

TOTAL RECORDED MALARIA PATIENTS AND DEATHS

Year	Patients	Deaths
1935	5,459,539	47,326
1940	3,413,618	9,169
1945	2,539,949	8,539
1950	610,781	1,903
1955	23,370	268
1960	422	0
1962	31	0
1965	308	1
1967	3,466	1
1968	440,644	64
1970	468,202	12
1975	400,777	5
1976	304,487	2
1977	262,460	2
1978	69,685	0
1979	48,004	0
1980	47,949	ni
1981	47,383	ni
1982	38,566	ni
1983	127,264	ni
1984	ni	ni
1985	117,816	ni
1986	412,521	ni
1987	687,599	ni
1988	383,294	26
1989	258,727	9
1990	ni	ni
1991	400,263	19

TABLE 26

INCIDENCE OF MALARIA IN MAHAWELI WATERSHED

District	1985	1986	1987	1988	1989	1991
Anuradapura	21,771	124,223	172,830	77,133	43,037	47,857
Polonnaruwa	--	--	--	--	19,887	20,462
Badulla	1,430	28,272	20,736	25,819	9,100	3,715
Matale	19,642	81,004	90,650	64,001	19,121	38,142
Kandy	3,455	8,072	12,942	6,436	2,558	4,011
Nuwaraeliya	495	1,375	1,498	792	463	421

The principal issues emerging from these social and economic constraints can be summarized:

- Residents in the upper and lower catchment areas can identify or act on few options for improving their livelihoods or communities.

- The limited social infrastructure and economic options are encouraging increased environmental degradation in the river basin through inappropriate land use and poor management of resources.

The importance of these issues for effective environmental management actions, along with suggestions for measures that can be taken to improve these social conditions, are discussed in Section Four.

Principal Responses for Improving Conditions in All Sectors

There are several opportunities to respond to these mounting adverse environmental impacts in the Mahaweli basin. In many ways, these responses can get to the root causes of overall environmental problems in the watershed and can mobilize efforts to reverse the environmental degradation occurring. In general, these responses can be summarized:

- **Coordinated monitoring of environmental systems is needed in the upper and lower catchment areas to facilitate the development of site- or issue-specific management responses. GSL institutions need the technical, financial, or infrastructure capacity to carry out effective monitoring of watershed and environmental management needs.**

Routine monitoring of basic soil and water parameters provides the baseline from which we can measure the status and severity of potential or existing problems in the watershed. In the absence of these data, decision making becomes less certain, and responses to specific problems carry with them an

increased risk of success. While monitoring is being carried out for many parameters, the consistency and application of these results do not appear to have much useful impact.

For example, water quality monitoring in the three major upstream reservoirs is scheduled to be done regularly (every two weeks) by the Headworks Division of the MASL at Digana. Sixteen parameters are monitored in the reservoirs, including phosphorus, nitrogen, algal biomass, dissolved oxygen, sulfate, conductivity, alkalinity, and transparency. Five tributary streams to Kotmale Reservoir are also monitored for nutrients and sulfate.

Unfortunately, very few of the data that should result from these monitoring efforts are readily available. There is also some uncertainty about the consistency and accuracy of the overall monitoring effort. In addition, the data produced through monitoring efforts do not appear to be used in any meaningful effort to guide planning and decision-making efforts in the tributary watersheds or the reservoir operations.

This trend appears to be consistent with monitoring and data compilation for all other sectors. A significantly increased portion of resources should be shifted to make certain that agencies have the capabilities and the commitment to do required monitoring of soil, water, productivity, biodiversity, social, and economic conditions. This information is essential if planning and management of environmental systems are to achieve the long-term goal of improved sustainability.

- **Local participation in environmental management needs to be increased to make implementation of conservation schemes realistic and successful.**

Experience obtained in other countries in Asia has demonstrated that interactive village planning in microwatershed management has produced more successful conservation and environmental management results than the traditional top-down approach, which reflects the management pattern in the Mahaweli (Fleming, 1991). Incorporating local perspectives and ongoing participation in the identification of problems and planning and implementation of solutions has demonstrated responses with much greater social, economic, and technical success.

Several emerging projects in the Mahaweli watershed are attempting to apply this increased local participation to soil and water management concerns, including the new USAID-financed SCORE project, the Forest Department's Participatory Forest program, and an increased delegation of management responsibilities to farm organizations in the lower catchment area. Improved policy measures that can enhance these kinds of efforts are outlined in Section Four and Annex C. It will be important to monitor and build on these efforts if future watershed management and conservation efforts are to achieve their full benefits.

- **Soil conservation, land use, and environmental management responsibilities can be improved if responsibilities are consolidated and coordinated in a few ministries and agencies and a more coordinated effort is developed for watershed management. Environmental management can also be enhanced through more definitive national policies that are publicized and enforced.**

The TAMS Environmental Assessment identified 25 institutions involved in watershed management in the Mahaweli basin, few of whom were involved in any form of collaborative planning or management activities. A more recent study identified 12 ministries and 38 agencies with

responsibility or interest in participating in soil conservation and land use planning in the upper catchment area (Stocking, 1986). The uncoordinated distribution of environmental and natural resources management responsibilities throughout numerous agencies continues to be an obstacle to the development of coherent policies and management actions toward watershed conservation.

At the present time, it is not entirely clear which agencies hold the authority or responsibility for carrying out specific environmental and watershed management tasks. As a consequence, many important management tasks are not carried out. Even when management tasks are carried out, the results from these efforts are often not shared among agencies with overlapping authority or interests. Monitoring of environmental changes represents the most obvious example. The monitoring of water quality conditions should be of equal interest to agencies charged with protection of human health, soil management, crop productivity, and wildlife conservation. Yet the results from the occasional water quality monitoring conducted in reservoirs or downstream river systems is rarely shared among the diverse audience responsible for these issues.

The TAMS Environmental Assessment and subsequent GSL studies have recommended the establishment of a national authority on watershed management. Such an authority could avoid interministerial and interdepartmental rivalry. The implementation of watershed management activities can be decentralized to a subwatershed basis, with the watershed area serving as the management unit. Local representation and participation should be a significant component of this subwatershed management. However, even with the development of a national authority, it will still be important to restructure and reorient existing institutions to ensure that they collaborate with and support this authority (Stocking, 1992).

Overlapping institutional authorities and a lack of coordinated agency efforts are exacerbated by the unclear and incomplete laws and policies available to guide management actions. Although Sri Lanka does have a strong assortment of environmental laws in place, there are few agencies that have effectively applied the mandates inherent in these laws.

The TAMS Environmental Assessment recommended a comprehensive law that would effectively define integrated watershed management policies for the Mahaweli. Unfortunately, this recommendation has not been addressed in any subsequent actions taken over the years. Policy guidelines and mandates continue to be spread as partial solutions to integrated problems throughout many diverse agencies. Again, a consequence of this weak policy setting is inaction toward environmental management needs by the responsible agencies.

A promising strategy to improve these policy conditions is outlined in Section Four. Annex C identifies specific policy studies and actions that may improve environmental management actions in the Mahaweli watershed.

SECTION FOUR

LESSONS LEARNED IN THE MAHAWELI

The environmental issues identified in Section Three are expanded versions of the environmental problems identified by the TAMS Environmental Assessment team in 1980 and observed by other analysts of the Mahaweli river basin in years since. Mitigative efforts designed to control, minimize, or eliminate these problems have not yet fully accomplished their overall objective of balancing economic and technical development of the Mahaweli river basin with a stable and rich environmental system.

There are no simple answers that will enable Sri Lanka to overcome these limitations rapidly. However, in taking a retrospective view of the environmental history of AMDP and associated development activities in the Mahaweli basin, a few generalized lessons learned may provide valuable guidance to future project efforts. We hope these paradigms can guide actions designed to conserve or restore the essential environmental services that support human endeavors in the watershed. These lessons learned can be summarized in two essential principles, which overlap and are mutually reinforcing:

- Maintenance and restoration of the environmental systems and natural resources base in the Mahaweli watershed should be elevated to a very high priority in management decision making, with adequate personnel and infrastructure to address environmental concerns. This would likely require some institutional restructuring in the existing management authority, as well as clarified and empowered policies and mandates. The entire Mahaweli watershed system should become the base operating unit for planning and decision making.

- Future development activities should provide the kind of infrastructure that gives people options and the power to make sustainable decisions: schools, health centers, training, marketing services, and financial resources. These activities should be designed to break the link between poverty and environmental degradation and to provide a strong local input, if mitigative actions are to be respected and sustained.

The technical, administrative, institutional, or policy actions that emerge in response to specific environmental issues are best viewed in the context of these principles if they are to be sustainable over the long term and if they are to have the magnitude of impact necessary to influence environmental conditions in an area as large as the Mahaweli drainage basin. The kinds of institutional changes, personnel development, and financial investments required to encourage such a shift need not be exorbitant. Much of the change can be accomplished by elevating and empowering some existing positions within the management structure, decentralizing other responsibilities in tandem with training and educational opportunities in environmental management, establishing policies and mandates that can and will be enforced, and creating an investment environment that acknowledges and respects ecological functions as the key to long-term economic and human well-being.

FROM INFRASTRUCTURE CONSTRUCTION TO ECOSYSTEM MANAGEMENT: A NEW PURPOSE FOR MAHAWELI INSTITUTIONS

Sustainable development in the Mahaweli watershed is dependent upon maintenance of the entire ecological system in all its complexity. This concept should become a central guiding purpose of the GSL institutions operating and directing management decisions in the Mahaweli system. Environmental management in the watershed can be enhanced if these institutions establish sufficient authority and enforcement power within their structure to allow decision makers to respond quickly and appropriately whenever maintenance and the long-term sustainability of the Mahaweli watershed are threatened or constrained.

The original purpose of AMDP included development of agricultural resources, increased power production, and providing resettlement opportunities for the landless poor. These objectives were achieved through the construction of a vast and intricate network of hydropower and irrigation infrastructure. Most of this infrastructure is now in place and represents an essential technological resource for the future of Sri Lanka. However, any significant degradation of the natural systems that support these technological resources could severely limit the usefulness or value of this infrastructure in the future.

Problems such as declines in soil productivity, changes in the timing and volume of downstream runoff, eutrophication in reservoirs, or hazardous health conditions for lower catchment residents could certainly reduce the services provided through this infrastructure. In the long term, this could severely limit the potential returns on the investment expended to build this infrastructure. Building thorough and meaningful environmental management capabilities into the Mahaweli management institutions represents an inexpensive, simple, and highly cost-effective means of ensuring the long-term viability of this infrastructure.

It is apparent that the watershed functions as a complex mosaic of landscape units with differing attributes: such factors as soil types, fertility, vegetation communities, wildlife populations, elevation, aspect, and precipitation levels vary from location to location. Although land use decisions should attempt to make the most suitable use of each landscape unit according to its characteristics, it is equally important for decision makers to operate from a perspective that enables them to understand the impacts of these unit decisions on the functions of the entire watershed. For example, perennially saturated soils in middle or lower elevations might best be used for natural wetlands or for such specialized crops as water chestnuts (*Eleocharis*), taking advantage of the natural filtration actions provided by wetlands to mitigate nutrient-laden sediments transported from upland agricultural areas. On the other hand, steep upland landscapes might best be used for biodiversity restoration, patina grassland, or some perennial soil-holding crops (as at Kandy Gardens). Paddy should be encouraged on poorly drained lowland soils, leaving better drained soils for crop diversification.

This kind of development attempts to work with the dynamics of the ecological system, using our understanding of ecological processes to plan human activities that cause the least damage. Such an approach will require fewer subsidies and less maintenance than will development activities that attempt to work against the natural processes in the watershed. Conservation of the biophysical resources in the river basin through careful and thorough environmental management efforts is much more cost-effective than trying to restore these systems after they are degraded.

The classic example is the effort in areas, such as System B, where extraordinary measures are often employed to maintain drainage on sites that by nature tend to be wet. Changing these ecological systems

is technically feasible, but we may seriously regret the loss of ecological services they provide. And, although easily destroyed, these systems can be difficult and costly to replace. Further, the restoration or even partial restoration of biodiversity in an altered landscape can take many years or even decades to accomplish; in many cases, it is impossible. Therefore, protection of vital ecosystems and biodiversity should be a requisite of all development activities within the watershed.

Elevating environmental management to serve as a higher priority in the management of the Mahaweli is principally a conceptual and ideological shift which can easily be taken by current management authorities and translated throughout the public and private sectors working in the watershed. If done with conviction, this ideological change should lead immediately to more environmentally appropriate construction and infrastructure development carried out in the future. Management institutions and decision-making processes — and policies voiced to maintain these efforts — should rapidly follow along these same sustainable lines.

THE MISSING INFRASTRUCTURE: BREAKING THE LINK BETWEEN POVERTY AND ENVIRONMENTAL DEGRADATION

Section Three describes the need to significantly increase infrastructure development in the Mahaweli to meet the social and economic needs of resettled residents: schools, health centers, extension agents, market advisors, credit unions. Without this social infrastructure, the people living in the Mahaweli basin will have inadequate opportunities to better their living status. This becomes increasingly true for second- and third-generation residents, who will also lack access to arable land.

Development cannot be sustained when possession of land is the base required to meet human needs. A landholding of one hectare is appropriate only to supply the subsistence and income-generating needs of one generation, even when applying the best of existing agricultural technologies. Alternative livelihood strategies should be found to support second-, third-, and maybe fourth-generation settlers. Failure to find off-land employment opportunities could easily force a subdivision of landholdings or encroachment onto reserves and undeveloped land. More likely, both impacts will occur simultaneously. The former leads to more and more people struggling to survive on a fixed land base, and the latter results in destruction of vital ecosystems and preserves.

Water resource development and the conversion of land for agricultural production have already eliminated or caused damage to some natural ecosystems, such as forests and wetlands, particularly in the lower Mahaweli catchment. This, in turn, has eliminated or reduced vital services that these ecosystems provide for human communities in some locations, including water storage and release, water purification, microclimate moderation, water and bathing sites for people and domesticated animals, animal and plant products for domestic or commercial use, wildlife habitat, and places of natural beauty and peacefulness in an otherwise monotonous agricultural landscape. However, this environmental degradation can be minimized and the development of the Mahaweli watershed can become a sustainable process when the focus of development expands beyond water resource and energy construction to include environmentally sustainable income-generating opportunities for Mahaweli residents.

Sustainable development is fundamentally an evolutionary social process that is driven by the needs of people and is defined by their ability to create institutions and enterprises that provide for those needs while protecting the natural resource and ecological systems that are the foundation for economic and social well-being. Sustainable development strives to create sustainable communities where people are

self-reliant. People are self-reliant to the extent that they take responsibility for and are able to control their lives.

As a goal, then, further infrastructure development in the Mahaweli watershed should measure success to the extent it increases options for the people living in or benefiting from the developed areas in the watershed and increases options for the nation. People — or nations — that have options have freedom. Environmental degradation eliminates options, and the elimination of options can destabilize economic and political systems.

PROJECTS WITH IMPACTS AND RESULTS: THE IMPORTANCE OF LOCAL PARTICIPATION IN MANAGING THE MAHAWELI SYSTEM

At present, most management decisions in the Mahaweli are made at levels above the reach of most farmers and local residents. This severely limits the level of commitment that farmers and local residents are willing to make to support and maintain infrastructure or other development activities. It also constrains the personal and financial investment that residents will want to make in sustaining the environmental base over the long term. In order to increase local dedication to environmental management needs in the watershed, it will be important to incorporate people's views and efforts in planning, implementing, managing, and evaluating site-specific environmental projects.

This emphasis on local participation will represent some change from past policies in the Mahaweli. As described in Section Two, MASL is presently made up of a family of organizations with many different specializations. Many services for settlers are provided through an integrated matrix management system. At the project level, the resident project manager supervises a team of specialists dealing with irrigation, agriculture, land, marketing, and community development. Beneath this manager are block managers, who also have a team of specialists in their offices. These people in turn supervise unit managers. Unit managers are intended as the main contact between the settlers and higher agency officials to direct the provision of services.

The organizations within MASL have generally assumed that settlers are not united and require a great deal of guidance and training from officials (Merrey, 1992). As a result, there is an emphasis on developing a somewhat unequal partnership with settlers, in which the agencies tend to direct actions and settlers implement them. Still, this arrangement has resulted in significant local participation in irrigation and water resource management. However, there has been little effort to include local people in the broader-based environmental and watershed management needs in the Mahaweli, particularly at the project level. There is a need to establish local institutions at the farm organization level in order to bring this participatory approach to environmental management needs.

TECHNICAL ACTIONS NEEDED TO SUSTAIN THE MAHAWELI WATERSHEDS

There is no shortage of actions that can be taken to improve environmental management and enhance ecological conditions in the Mahaweli watershed. When these actions are designed, implemented, maintained, and evaluated from a watershed context and with the intent of increasing local participation and opportunities for local residents, then the likelihood of success and long-term sustainability dramatically increases.

A range of technical actions appropriate for consideration in future project developments in the Mahaweli is outlined in Annex B.

ADMINISTRATIVE OR INSTITUTIONAL ACTIONS TO APPLY AND COORDINATE RECOMMENDATIONS

Given the limited success to date in fulfilling the environmental management needs in the Mahaweli watershed, there are definite needs to enact administrative or institutional actions that apply a more comprehensive watershed perspective. These administrative changes could be accomplished within the existing institutional framework operating in the Mahaweli, although the priority assigned to environmental and watershed concerns should be enhanced. In general, these institutional changes can be enhanced by addressing the following:

- Forest, watershed, and environmental management that is elevated to the level of other agencies and consolidated under a Watershed Management Agency (WMA);
- This WMA should be provided with trained and adequate staff and funds;
- WMA should also hold sufficient authority to enable proper coordination at the national level; and
- A Steering Committee under the Secretary of the Ministry of Lands, Irrigation and Mahaweli Development can be established and empowered to:
  - — Initiate and coordinate policy on watershed management,
  - — Facilitate long-term planning and monitoring programs, and
  - — Promote coordination among various institutions.

Environmental management activities would be most effectively linked into one coordinated management system. This coordinated management system should delegate responsibilities at the project level to environmental coordinators at the system level. Each project should be merged into a single unified project focused on a particular watershed, each with a consolidated budget, with downstream command areas included. The field staff of concerned line departments at the district level and below should be brought under the unified control of a watershed manager selected for managerial rather than technical skills. These few administrative modifications could encourage significant changes in the perspective from which decisions are made in the Mahaweli basin and provide an important incentive for stronger environmental decision making.

POLICIES THAT CAN BE APPLIED AND ENFORCED

Sri Lanka already has in place strong policies favoring protection of its environment. Environmental laws have established a Central Environmental Authority, numerous national parks and wildlife sanctuaries, soil and forest conservation, land use and urban planning, and assessment of environmental impacts for new development proposals. The government, universities, and NGOs have focused public

attention on important environmental issues, especially those in the Mahaweli watershed, and the media have brought environmental awareness to the forefront.

However, the gap widens between these stated environmental policies and their implementation (Baldwin, 1988). The well-stated policies and legislation are not consistently translated into environmentally sound planning processes, monitoring programs, and enforcement practices. Policies also cutting across many diverse GSL agencies, which leaves most professionals uncertain of the actual role and responsibilities they are expected to fulfill. There is considerable opportunity to improve coordination among agencies.

Thus, a first priority for any central managerial authority in the Mahaweli is to define precise policy statements that will guide agency directors and personnel in carrying out practical environmental management actions on a routine basis. To ensure the integrity and long-term sustainability of the Mahaweli system, the watershed must be the operational unit.[1] Policy, planning, and enforcement efforts should be carried out at the watershed level, with full recognition of the integrated nature of the ecological systems within the watershed in all institutional or on-the-ground responses.

Decision making that focuses only on site-specific initiatives is decision making without context. In terms of watershed development, it makes no sense to focus decision making on specific projects such as hotels or industries unless we first know what the overall goals are for the watershed, what the carrying capacity of the watershed is for that type of activity project, and to what extent that capacity is already being filled.

It is at the policy level that Sri Lanka lays out its values and stipulates how those values are to be enforced and protected. It is at the regional level (watershed) that these values are achieved. Ideally, individual projects should be evaluated on the basis of how they serve the overall goals of watershed management and conservation. With adequate policies in place, including enforcement provisions, and with implementation of watershed planning and information systems, then site-specific project proposals can be evaluated in terms of ecological or social values. Ultimately, Sri Lanka will need to decide what it wants to have happen in the Mahaweli watershed and what the watershed should look like over the course of the next one or two hundred years. Specific policy studies and actions that may improve environmental management actions in the Mahaweli watershed are outlined in Annex C.

THE NEED FOR AN UPDATED ENVIRONMENTAL ACTION PLAN

The mitigative measures defined in the 1980 TAMS Environmental Assessment were formulated into an Environmental Plan of Action (TAMS, 1981), with a follow-on Environmental Update prepared to assess the success of the recommendations (TAMS, 1987). GSL was to be the responsible agency for financing and carrying out these activities, with principal authority delegated to an Environmental Division within the Mahaweli Authority of Sri Lanka/Mahaweli Economic Authority (MASL/MEA).

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[1] For management purposes, decisions will need to be made at both a watershed and subwatershed level. The watershed level includes all the lands draining the entire Mahaweli river basin, from the headwaters to the outlet at the sea. The subwatershed level includes all the lands draining specific tributary basins, or isolated segments of the main-stem Mahaweli river that can be hydrologically or biologically distinguished from one another.

The GSL response to environmental concerns was very strong, and many of these measures were subsequently carried out. A follow-up Mahaweli Environmental Update then identified new recommendations to revise the 1981 Plan of Action. These new recommendations included:

- General
  - — All environmental reports and data pertaining to the Mahaweli should be inventoried and catalogued by MASL; and
  - — The proposed Forestry and Environmental Units within MASL should be implemented as soon as possible.
- Wildlife Conservation
  - — All necessary measures should be taken to remove encroachments and limit development in the Flood Plains National Park, and in other parks as warranted;
  - — A review should be made of existing and future equipment and vehicle needs within the Department of Wildlife Conservation (DWLC). Proposals should be prepared to procure the necessary items;
  - — An Elephant Management Unit should be established in DWLC; and
  - — A National Master Wildlife Management Plan should be prepared by DWLC and interested agencies.
- Watershed Management
  - — A Master Plan for redevelopment of the Upper Mahaweli catchment area should be prepared; and
  - — A survey of total land rehabilitated to date should be carried out and used to propose alternative strategies for conservation of upper catchment areas.
- Forestry
  - — A survey of total fuelwood plantation areas established should be conducted and used to guide alternatives for increasing available fuelwood supplies.
- Water Resources Research and Monitoring
  - — A review of water quality monitoring programs should be conducted to determine whether information gaps exist or whether additional equipment and vehicles should be purchased. Special attention should be given to equipment for testing pesticides;
  - — *Villu* conservation studies should be undertaken to test the use of regulatory structures at *villu* outlets as a conservation measure; and

- A hydraulic/sediment transport study should be done for the lower basin below Rantambe Reservoir to evaluate changes in flows, sediment transport and deposition, alterations of riverbed geometry, and the extent of salinity intrusions.

- Health Care and Sanitation

  - Further survey work should be done to identify problem stagnant water areas and promote mosquito vector controls around irrigation systems; and

  - Measures to increase the construction and use of pit latrines in the settlement areas, including incentives, stricter monitoring, and more intensive education programs, should be implemented.

Many of the elements of these original Environmental Action Plans (EAPs) are still relevant today. However, the 1987 update of the original EAP now deserves its own modernization in light of the social, economic, and ecological changes that have occurred in Sri Lanka and the Mahaweli system during the past six years. Specifically, an updated EAP should be structured to incorporate the general lessons learned outlined in Section Four and apply them as practical actions.

Proposed efforts to modify the institutional structure and responsibilities of MASL, and ongoing or proposed projects and programs working to measure and mitigate environmental changes occurring in the Mahaweli watershed, could benefit from a strengthened and elevated environmental focus within the GSL. Again, the watershed, either in its entirety or as subwatershed units, should become the minimum operating unit for management decision making and action.

Such an empowered environmental purpose needs to be translated into policies and mandates that are appropriate and specific to the agencies they will serve and that carry enough weight to ensure that they can and will be applied. With a strengthened and more straightforward policy structure in place, an institutional structure that emphasizes the elevated environmental purpose in Mahaweli decision making can be refined and enacted; diverse projects responding to specific technical needs and issues in the watershed can be coordinated, supported, and enhanced; and the people living in and from the Mahaweli's resources can be given the options that will allow them to sustain the technological and natural systems for generations to come.

The Government of Sri Lanka would do well to reassess the importance it intends to place on sustaining the environmental systems and natural resource base supporting the Mahaweli infrastructure. If the role of environmental management is indeed to be elevated in stature and power, then a call for a new Environmental Action Plan for the Mahaweli, one with strength and authority to act, is certainly in order.

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ANNEX A

EVALUATION OF PREVIOUS USAID ACTIONS: MEP AND RWMP

ANNEX A

EVALUATION OF PREVIOUS USAID ACTIONS: MEP AND RWMP

USAID MAHAWELI ENVIRONMENT PROJECT

Purpose of Activity Evaluated

The USAID financed Mahaweli Environment Project (MEP) was initiated in 1982 and continued through 1987. Project funding included US$ 5.0 million in bilateral funding (grant), plus an additional $1.9 million in host country counterpart funds. The project was implemented through the Sri Lankan Ministry of State, Department of Wildlife Conservation.

The purpose of the MEP was to ensure the stability of irrigated agricultural development and human settlements in the AMDP area by providing alternative protected habitats for displaced wildlife in a manner that is ecologically sound and socially acceptable.

The MEP consisted of the following components:

1. **National Park Infrastructure Development:** Four protected National Park areas were to be legally established and developed, consisting of Somawathiya Sanctuary (52,000 hectares), Wasgomuwa Strict Natural Reserve (76,000 hectares), Maduru Oya National Park (40,000 hectares), and Flood Plain Reserve (15,000 hectares). Infrastructure development activities were to include:

   - Survey and establish 500 miles of boundaries;
   - Develop 700 acres of buffer zones and rehabilitated habitat;
   - Develop 95 miles of new roads and upgrade 150 miles of existing roads;
   - Construct 90,000 square feet of personnel housing and administrative buildings; and
   - Establish 380 signboards along the park perimeters.

2. **Strengthening the DWLC Planning and Management System:** The project was to expand the then existing DWLC cadre of personnel by approximately 225 employees, resulting in a total staff of 850 by the end of the project period. Planning and management, research, training, education, and maintenance programs were to be established within the DWLC with the assistance of short to medium-term consultancies totaling 37 person-months spread over five years. The technical assistance was to enable the DWLC to prepare a comprehensive systems plan for the development of parks and protected areas and to initiate a detailed management plan for each national park. A regional headquarters was to be established at Welikanda near Somawathiya National Park to decentralize park administration.

3. **Develop DWLC Research and Training Capability:** A Wildlife Conservation Unit was to be established at the Welikanda regional headquarters to undertake surveys and related research studies on elephants and other wildlife populations. These studies were to include baseline data collection and monitoring designed to guide park management decisions. Sociological studies were to provide information on activities and perceptions of settlers in relationship to the parks. A Wildlife Training Center was to be established at Kegalle to provide training facilities for DWLC personnel, and to offer conservation education programs to the public. These conservation education programs were to contribute to the development of materials and media for a national public awareness campaign to develop support for national parks and related conservation activities.

   Identified indicators of achievement of the project purpose in the Project Paper included:

   - Crop records collected by the MEA will show that crop losses caused by wildlife will be reduced by 70-80 percent of the (then) current level of losses.
   - No loss in water quality will be traced to illegal timber cutting or watershed deterioration taking place within the four national parks.
   - None of the seven (then) current endangered species of animals will become eliminated.
   - None of the two current threatened species of animals will become endangered or eliminated.
   - Park buffer zones will be productively utilized by people in the area.
   - Off-farm employment opportunities will become available for 2,000 people by 1987 in maintenance and park-related tourism, and for 3,000 people during construction phases of the project (1983-1987).

Purpose of Evaluation and Methodology Used

A Project Evaluation of the MEP was conducted in March 1987. However, MEP project activities were continued through project extensions, and some component activities have only recently been completed. A final evaluation of the project was authorized in the original Project Paper, and this assessment will serve as a summary of project impacts, accomplishments, and limitations. In addition, the comprehensive evaluation of environmental conditions and issues in the Mahaweli watershed represents an ideal opportunity to identify the impact the MEP has had on environmental management needs and accomplishments in the Mahaweli. The evaluation was designed to furnish the USAID/Sri Lanka Mission with insights and lessons learned to guide future GSL and other donor measures in environmental conservation.

The Mahaweli Environmental Evaluation (MEE) team reviewed available documentation of project accomplishments, conducted field assessments of construction and infrastructure development activities, and interviewed GSL and other professionals directly or indirectly involved in the MEP during its lifespan.

Findings and Conclusions

The MEP represents one of the more important conservation efforts undertaken in Sri Lanka, and has helped place more land under protective status than any other single project in recent history. Approximately 12 percent of the total land area of Sri Lanka is now designated as a protected reserve. A total of 225,660 hectares of land was put into protected area status as part of the MEE in the following reserves:

Flood Plains National Park	17,350 ha
Maduru Oya National Park	58,850 ha
Somawathiya Chaitiya National Park	37,762 ha
Wasgomuwa National Park	37,063 ha
Tirikonamadu Nature Reserve	25,019 ha
Minneriya Giratale Nature Reserve	7,529 ha
Victoria Randenigala Rantambe Sanctuary	42,087 ha

Although precise data on activity completions were not obtained by the MEE Team, the related national park development activities, including boundary surveys, road construction and rehabilitation, and building construction, appear to have been largely been completed. However, institutional strengthening measures have only met a portion of the original target objectives.

The MEP originally set out to increase the Wildlife Conservation Department by 225 personnel. However, only 68 personnel were ultimately added to park staff. In terms of training, 25 officers had received international training opportunities under the MEP. Of this number, only 15 officers remain with the department. Others have retired, vacated posts, or resigned or have been killed by terrorists.

A Research Committee was appointed through the project to guide research policy and activities. While a considerable amount of research was ultimately commissioned and financed, no results were obtained during the life of the project. Other measures originally proposed for implementation by the GSL through the MEP include the following:

- Development of buffer zones, including some strip planting of trees, ditch construction, one-mile strips of grazing land in specific wildlife conflict areas, and guard posts situated where the boundaries of parks and wildlife reserves border agricultural lands;
- Protection of all riverine forests for a distance of at least one to three chains (approximately 66-200 feet) from either bank, depending upon the width of the channel;
- Training opportunities to improve management and operational capabilities of Department of Wildlife Conservation (DWLC) staff;
- World Wildlife Fund assistance to the Zoology Department, University of Peradeniya, to conduct wildlife surveys; and
- Detailed land use plans that delineate wildlife reserves, fisheries projects, health care facilities, and fuelwood plantations in relation to other agricultural developments.

Conditions indicate that, while many of these measures were in fact carried out, some work remains to be done. Some of the issues remaining include:

- Wildlife-farmer interactions continue to be a problem, and measures taken to reduce the problem do not appear to have met with much success. More than 50 percent of the elephant deaths recorded in Sri Lanka in 1992 occurred in the Mahaweli basin. Buffer zone development and habitat enrichment measures that could have reduced these conflicts have not been carried out adequately to date.

- Continued farmer encroachment has prevented protection of *villus*, floodplains, and riverine forests. Specifically, encroachment has occurred within the Floodplains National Park, where illegal brickmaking activities are degrading wildlife habitat, disrupting wildlife movement, and impairing the hydrologic functions of the riverine ecosystem.

- Available data on wildlife populations and habitat conditions are insufficient to facilitate management needs.

- Habitat enrichment has not occurred within or outside protected areas, and the available habitat for wildlife is of inferior quality to areas in planted crops. Wildlife predation on agricultural crops has likely increased over the years.

- Off-farm employment, especially in park-related jobs, has not materialized for any significant number of local people.

In addition, Department of Wildlife Conservation accountability for project activities and accomplishments is poor, and actual data to measure results are limited. However, it is important to recognize the constraints under which the MEP functioned, and which certainly contributed to any limitations in project accomplishments:

- Security problems related to civil disturbances limited or prevented field work related to construction, research, public education, and park demarcation through the middle and later stages of project implementation;

- During this time, the Department of Wildlife Conservation experienced considerable turnover among management staff. Department inexperience, combined with constraints imposed by other participating GSL agencies, led to consistent delays in approving and carrying out many of the project development efforts;

It may also be useful to consider potential impacts that may have resulted under a no-action scenario — that is, if the MEP had never been carried out in the Mahaweli. While these assumptions are largely speculative, it is reasonable to predict the following developments in the absence of MEP:

- Land development and encroachment on remaining undeveloped lands in the Mahaweli basin would have eventually included many lands now under protected status. This would have resulted in a considerable loss of important wildlife habitat and dramatic decline in species populations, specifically to include nine threatened, endangered, or sensitive (TES) species in the basin. While it is unlikely that any of these TES species would have been exterminated, the long-term genetic viability of the remaining populations could have been severely impaired through this loss of habitat. For example, given present understanding of habitat requirements, it is likely that this loss of habitat could have eliminated more than 500 elephants from Sri Lanka, including large breeding populations.

- Habitat alteration, combined with declines in wildlife population levels and dispersal patterns, would have significantly degraded the species richness and abundance in the watershed. Simplification of the ecosystem could reduce or eliminate many important ecosystem functions, such as the breakdown and recycling of human and natural wastes, climate stabilization, and control over potential pest problems.

- Department of Wildlife Conservation staff would not have obtained valuable training and experience in park planning, management, conflict resolution, environmental education, and research and monitoring techniques. It is likely that department staff would be at a formative stage, with limited capacities to carry out complex management tasks.

- Available infrastructure to support ongoing department training, research, education, and planning efforts would be minimal, and would be limiting the long-term accomplishments in park establishment and management.

Conclusions and Recommendations

Despite functioning under difficult social and institutional conditions, the MEP accomplished a great deal and contributed greatly to the development of the national park program in Sri Lanka. Training and work facilities have been constructed, agency personnel have received important training and educational opportunities, and more than 177,000 hectares of valuable wildlife habitat and intact natural communities are now held as protected reserves.

There are opportunities to build upon these successes, however, including actions designed to accomplish the following:

- Increase public awareness of park boundaries and facilities through improved park delineations, additional sign board installations, and greatly increased community education programs for school children and adults;

- Habitat enrichment and buffer zone development activities should be carried out in all of the designated protected areas, encouraging local participation in the design and construction of these measures;

- Agency personnel should continue to receive professional training, with particular emphasis on environmental education, interpretive skills, and park administration;

- Monitoring and research activities should be implemented where security conditions permit, with particular emphasis on measuring population dynamics and habitat conditions for keystone species, such as elephant; and

- Wildlife-settler conflicts should continue to receive high priority in agency management, with increased research and emphasis placed on non-aggressive actions such as habitat enrichment in the protected areas as a management measure.

USAID REFORESTATION AND WATERSHED MANAGEMENT PROJECT

Purpose of Activity Evaluated

The USAID-financed Reforestation and Watershed Management Project (RWMP) was initiated in 1980 and continued through 1988. Project included U.S. dollars and was implemented through the Forest Department in the Ministry of Lands and Land Development (FD/MLLD).

The purpose of the RWMP was to conserve and stabilize watershed areas in the highlands of Sri Lanka and provide a natural renewable energy and commercial resource for Sri Lanka. The project indicators to measure the achievement of this purpose were to increase the amount of stabilized ground cover in the Upper Mahaweli Catchment Area (UMCA) to 20 percent by 1987 through tree planting on 24,000 hectares, and increase total area under permanent forests from approximately 265,000 acres in 1980 to 355,000 acres in 1990.

The project included an institutional development component, and five specific end-product activities. The institutional development component consisted of the following:

(A) Expanding forestry training at all levels

- Strengthen the syllabus and increase the capacity at the Forest Department's Forest College at China Bay;
- Develop and implement an in-country short course on forest management, protection and utilization for 45 forestry personnel per year;
- Institute a six-month specialized traineeship program for 19 outstanding nonprofessionals (forest guards and beat officers) to be conducted in foreign countries; and
- Provide a program of international seminars or specialized short courses for 20 outstanding non-professional staff.

(B) Strengthening forestry research and development

- Develop long- and short-term research objectives and priorities with special emphasis on tropical forest plan selection, propagation, establishment techniques, and methods for improving growth rates. Conduct a full review and analysis of native forest species, to develop more efficient planting and species recommendations.
- Institute a program of six-month specialized coursework for 19 professional research staff members abroad in subject areas which will strengthen the national research effort.
- Provide college-level training (advanced level degree) for two selected Forest Department and one State Timber Corporation staff in order to upgrade skills and broaden the technical base of these two institutions.

(C) Establishing a Forest Extension Service

- Develop the objectives, priorities, and operation of a National Forest Extension Service.

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- Provide assistance to equip and train seven mobile extension units to contact villages and disseminate forest information through an audio-visual program.

- Train 18 nonprofessional and professional personnel of the Forest Department in specialized extension skills.

- Upgrade two Forest Department professionals to MS level in extension skills.

- Provide assistance to Forest College to train nonprofessionals and selected village leaders in extension and conservation methodology.

Purpose of Evaluation and Methodology Used

A Project Evaluation was conducted of the RWMP. A final evaluation of the project was authorized in the original Project Paper, and this assessment will serve as a summary of project impacts, accomplishments, and limitations. In addition, the comprehensive evaluation of environmental conditions and issues in the Mahaweli watershed represents an ideal opportunity to identify the impact the RWMP has had on environmental management needs and accomplishments in the Mahaweli. The evaluation was designed to furnish the USAID/Sri Lanka Mission with insights and lessons learned to guide future GSL and other donor measures in environmental conservation.

The Mahaweli Environmental Evaluation (MEE) team reviewed available documentation of project accomplishments, conducted field assessments of construction and infrastructure development activities, and interviewed GSL and other professionals directly or indirectly involved in the RWMP during its lifespan.

Findings and Conclusions

Specific end-product activities included:

- Reforest and stabilize 15,000 acres of denuded watershed areas in the UMCA;

- Establish and maintain 35,000 acres of fuelwood plantations;

- Develop a national forestry baseline map;

- Establish village-run fuelwood plots on a pilot basis in 50 villages; and

- Establish a village charcoal production program.

A Project Paper Amendment dropped some of these original elements and added or expanded others. In the amendment, two hostels and other support buildings were added as part of improved training capacities; seven divisional field offices and equipment were added to the Forest Extension Service component; two field laboratories and equipment were added to the Research component; reforestation of the UMCA was increased to a goal of 24,000 acres; village fuelwood plots were reduced from 50 to 15 plots; two fire control centers and radio networks were added; and the baseline mapping and charcoal production programs were dropped when other donors financed similar measures. The amendment also

modified the magnitude of USAID-financed inputs as a result of the project design changes and insufficient GSL funds.

Existing conditions indicate that the project was very successful in accomplishing most of the original objectives. More than 20,000 hectares of UMC lands have been planted with trees, primarily steeply sloping lands in critical catchment areas. This USAID effort in many ways initiated and represented an important impetus to replanting of these upper catchment lands. Further, the extensive infrastructure developed through the RWMP, including training facilities, laboratories, supplies, and vehicles, are still being used on a regular basis, and are in fact supporting the efforts of other donor efforts in watershed conservation.

Some of the original objectives could not be accomplished due to social or institutional constraints. For example, the support buildings constructed in the original China Bay training center are no longer accessible due to civil disturbances in that area. The effort to construct fire control information and communication centers was eliminated on the basis of a government request.

TABLE A.1

COMPLETED PROJECT OUTPUTS FROM THE RWMP

Activity	Output	Result
Institutional		
Training Centers	support buildings	done, unused
Forest Extension	7 field offices, staffed, equipped	partially done
Research	2 field labs, staffed, equipped	completed
Reforestation		
Fuelwood plantations	10,250 hectares	14,000 ha
UMC reforestation	10,000 hectares	6,000 ha
Village fuelwood	15 plots	12 plots
Fire control	2 control centers, communication center	GSL ban on activity
Training		
Long-term (U.S.)	219 person-months,	100 percent
Short-term	8 participants	100 percent
Workshops	350 person-months,	89 percent
	164 participants	95 percent
	21 person-months,	49 percent
	85 participants	85 percent
Technical Assistance	113.5 person months	100 percent
Commodities		
Vehicles	52 vehicles	completed
Other	Miscellaneous	completed
Construction	1 training, 7 extension, 2 research centers	partially done

In addition, while many of the original project objectives have been carried out, some work remains to be done. Some of the issues remaining include the following:

- The lack of a participatory element for local residents limited project acceptance and success. The RWMP provided no real mechanisms for local residents to advise or participate in site and species selection, and long-term management strategies for reforested lands. As a result, many of the treated lands have subsequently been burned, cut, or otherwise damaged by local residents.

- The species selected for reforestation, and the use of a plantation system for tree planting, were inappropriate for some of the project objectives, particularly the objective of soil and water conservation. Recent studies demonstrate that pine species in particular, and plantation planting in general, can often result in greater soil loss and hydrologic disturbance than untreated grasslands or even agricultural cropping.

- The lack of coordination with other agencies involved or concerned with reforestation and watershed management limited the magnitude of success of the RWMP. The project concentrated its training and institutional development efforts in the Forestry Department, although recent surveys indicate that approximately 40 GSL and NGO entities are working in various aspects of soil conservation (Stocking, 1986). By coordinating efforts with other agencies, the RWMP could have strengthened and expanded the potential on-the-ground and institutional impact of the project.

However, it is important to recognize the constraints under which the RWMP functioned, and which certainly contributed to any limitations in project accomplishments. Specifically, security problems related to civil disturbances limited or prevented field work related to construction, research, and training through the middle and later stages of project implementation.

Conclusions and Recommendations

Despite functioning under difficult social and institutional conditions, the RWMP accomplished a great deal and contributed greatly to the implementation of tree planting and watershed restoration efforts in Sri Lanka. Training and work facilities have been constructed and are being used, agency personnel have received important training and educational opportunities, and more than 20,000 hectares of upper catchment lands are now in tree cover. There are opportunities to build upon these successes, however, including actions designed to accomplish the following:

- Research and demonstrate economically viable uses for the pine and other species now established in upland plantations;

- Increase local community participation in the maintenance and use of existing plantations, and in future forestry programs, in exchange for legal rights to forests lands;

- Continue policy for reforestation in high-altitude sites;

- Natural forest management — Horton Plains, Knuckles;

- Provide adequate expenditures to allow farmers to install and maintain appropriate on-farm soil and water conservation measures; and

- Better use of patana grasslands — range management, buffer zones for wildlife, and so forth.

ANNEX B

RECOMMENDATIONS FOR TECHNICAL ACTIONS TO IMPROVE ENVIRONMENTAL MANAGEMENT IN THE MAHAWELI SYSTEM

ANNEX B

RECOMMENDATIONS FOR TECHNICAL ACTIONS TO IMPROVE ENVIRONMENTAL MANAGEMENT IN THE MAHAWELI SYSTEM

There are a variety of on-the-ground actions that can be taken to improve and strengthen environmental management actions in the Mahaweli watershed. A selection of some of the more important opportunities would include technical, economic, and social studies that can demonstrate the extent of upstream-downstream linkages in watershed management projects. These studies should attempt to provide the following:

- Technical information on the impacts on agricultural productivity of soil loss, sedimentation rates in reservoirs and tanks, damages to canals and intake structures, and water quality impacts. .

- Economic analyses of the costs and benefits of upland watershed conservation, along with practical strategies for financing and implementing these conservation practices.

- Social studies on the acceptability of watershed conservation measures and incentives for local participation (including land tenure arrangements).

- Hydrological modeling of water and sediment yields from ungauged watersheds, particularly regarding downstream water quality and quantity trade-offs with upstream watershed conservation.

- Wildlife inventories and habitat assessments to determine the quality and management needs of existing protected areas. Inventories should emphasize population characteristics of keystone or indicator species and external threats to species and habitats. Habitat assessments should primarily define opportunities to enrich or otherwise improve habitat conditions to support keystone populations and reduce farmer-wildlife conflicts.[1]

Information obtained from studies or ongoing monitoring efforts should be applied by managers and decision makers at the watershed or microwatershed (system) level. Efforts should be made to share information across agencies and to ensure that information results in action, not just dialogue. Specifically, actions should be taken to accomplish the following:

1. A comprehensive environmental information center should be established which includes a compilation of all relevant studies, data, and mapping efforts conducted within the

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[1] These analyses can be completed by conducting random transects in representative habitat types. The technical capacity to design and complete these analyses does exist in the Department of Wildlife Conservation and the universities. Transects can be conducted in areas without civil threats. The output from such studies will enable planners and managers within the basin to determine if present protected areas are of sufficient size and shape to support species movement and reproduction; provide adequate food, water, and cover to representative populations; and experience any external threats through invader plant or animal species or adverse human interventions. The output will also enable planners and managers to design habitat enrichment measures and buffer zone management in and adjacent to the protected areas.

Mahaweli watershed. This information center should include water quality, soil mapping, and land use analyses, preferably computer-based in a geographic information system (GIS).

2. Output from this information system can be used to identify field sites for environmental rehabilitation and maintenance activities. Specific restoration actions should address the following:

   a) Revegetation of dikes and berms:

      - Dikes and berms can be reforested without destabilizing the structure of the dike or berm. The problem of destabilization is caused mainly by the decay of roots of dead trees. The solution is to plant trees that will live for a long time. The reforestation of irrigation infrastructure is an opportunity to restore the native biodiversity of the watershed. There is ample evidence for this within the Mahaweli. Many of the old or even ancient dikes are heavily forested, many appearing to be riparian forests along streams or rivers instead of forested dikes along irrigation supply canals. One need only compare the human habitat along these old canals to that along the concrete-lined canals and channelized river channels of newer irrigation systems within the Mahaweli to see the value of reforestation of dikes.

   b) Enrichment planting in degraded forest areas;

   c) Reforestation with multi-purpose tree species on denuded lands;

   d) Tree plantations:

      - Reforestation to restore native biodiversity could be accomplished at many sites throughout the Mahaweli, and such efforts will be enhanced if residents are provided with an inexpensive and reliable source of fuelwood. Fuelwood often becomes scarce long before food production falls below levels needed to sustain the local human population. Once the demand for fuelwood forces people to harvest in excess of the sustainable yield, the forests become depleted, then eliminated; soils degrade, regional water tables drop, and land productivity, including agricultural productivity, declines. Thus, fuelwood shortages lead ultimately to food shortages. Planting efforts should focus primarily on meeting these fuelwood needs, but should also include efforts to accelerate natural succession of native forest communities, particularly on upland slopes. These efforts should include the use of native tree and shrub species that have been documented to represent a distinct successional stage in forest recovery.

   e) Habitat enrichment and buffer zone development for selected wildlife species:

      - Measures can include such activities as enrichment planting of native tree, shrub, and grass species; cultivating food crops exclusively to attract wildlife; or restoration plantings to stimulate rapid succession of

native plant communities. Most of the protected areas would benefit from restoration of a greater diversity of native grass species, and a reduction of the well-established opportunistic plants such as Illuk (*Imperata cylindrica*). Many of the forested areas in the parks and reserves have also been degraded over time, and enrichment planting with native tree species could accelerate natural succession of these forest ecosystems. Experimentation should also be done with planting food crops attractive to wildlife within the protected areas as a means of luring the animals away from cultivated lands.

- Buffer zone management should include increasing the available grazing areas for herbivorous mammals. Buffer zone management will also require the development of environmentally benign income-generating activities among people living on the perimeters of the protected areas. Activities could include fuelwood cropping or biomass fuel technologies (such as stoves); sustainable timber or non-timber forest product materials; or a variety of services to support nature tourism ventures. These kinds of habitat enrichments may offer the most promising strategies to reduce farmer-wildlife conflicts, while enhancing native wildlife populations.

f) Protection and restoration of natural wetland communities:

- Wetlands serve as important water storage areas, absorbing precipitation and flood waters like a sponge and releasing them gradually to effluent streams. Wetlands also serve as filters removing minerals, nutrients, and pollutants from waters passing through them. An accurate analogy would be to view wetlands as the "kidneys of the landscape." Natural and constructed wetlands are used for treating municipal sewage, acid mine drainage, industrial effluent, effluent from animal confinement operations, and agricultural fields. Wetlands show particular promise as a means of treating non-point sources of pollution such as runoff from timber harvest operations or agricultural fields. Wetlands usually provide t' important ecological functions at a fraction of the cost of traditiona. vage and water treatment technologies. Wetlands also serve as vital wildlife habitat and nurseries for fish and shrimp. There seems to be considerable opportunity in the Mahaweli watershed for the development of a productive aquaculture industry, largely tank based, but also utilizing villus, wetlands, and artificial ponds. Strategies for promoting improved wetland conservation and restoration have been well-defined in earlier studies (Davis, 1992).

3. An improved water management program should be developed on a sub-watershed scale. This water management program should emphasize on-farm water conservation to protect instream flows and minimize waterlogging concerns; protection of water quality; and farmer education to mitigate or avoid farm runoff non-point source pollution.

4. Extension programs need to be enriched and expanded on the sub-watershed (system) level to include a variety of environmental management needs. These programs should emphasize on-farm soil and water conservation practices; health and sanitation programs; sustainable uses of

native or planted forests; and alternative income-generating opportunities for small farmers and rural residents. As divergent as these topics appear, they all are aiming toward the same goal: improving the living conditions and decision-making options of people who live in the watershed. From this base, environmental management becomes an achievable task. For example, components of this extension effort could include the following:

a) Expansion and development of craft industries:

- Opportunities exist for the development of reed-based crafts industries utilizing reed species native to wetlands and villus in the watershed. Further, reeds can be cultivated in low-lying fields where soils are difficult or too expensive to drain.

b) Expansion and enrichment of formal and non-formal environmental education programs:

- Environmental education is a critical need if development in the Mahaweli is to be sustainable. The success of environmental education in raising the awareness of children is already being witnessed in Sri Lanka. Extension education is a related effort that has had success in the Mahaweli in terms of showing farmers how to enhance crop productivity and profitability. Unfortunately, agricultural extension has yet to recognize and include care for environmental quality in its message in Sri Lanka. Extension education should be expanded but also broadened to include environmental quality. Unless this is done, development will degrade the environment, at least in places, and will not be sustainable. Finally, university education can make a major contribution to sustainable development by developing courses in environmental studies, environmental science and management, and environmental impact assessment.

ANNEX C

RECOMMENDATIONS FOR FUTURE POLICY STUDIES TO GUIDE ENVIRONMENTAL MANAGEMENT IN THE MAHAWELI WATERSHED

ANNEX C

RECOMMENDATIONS FOR FUTURE POLICY STUDIES TO GUIDE ENVIRONMENTAL MANAGEMENT IN THE MAHAWELI WATERSHED

A variety of policy studies and actions can be conducted to strengthen and clarify existing or new environmental management policies in the Mahaweli basin. While the list of environmental policy actions needed could be very extensive, it is most important at this time to accomplish two objectives:

- Develop an administrative and institutional structure that uses the watershed and sub-watershed as the basis for planning and decision-making, and
- Increase and improve local, on-site responses to environmental management needs.

Immediate actions that could further these two objectives include the following:

- Integrated watershed planning and management would be most effectively implemented from one centralized agency in the GSL, with clear mandates and policies to guide soil and water management needs, agricultural productivity, social and economic equality and stability, and biodiversity conservation throughout the entire watershed. These mandates and policies should then be adapted to the sub-watersheds throughout the basin. National and localized agencies can become responsive to these sub-watershed policies and standards with annual target goals defined for each entity. Sub-watershed agencies and committees, including significant representation from local people, should also be assigned annual target goals, and should assume a considerable proportion of responsibility for on-the-ground environmental rehabilitation, management, and enforcement.

- Land tenure should be evaluated in the planning phase of watershed management. Project areas should be chosen in which land tenure is, or is likely to be, predominantly in private ownership to increase incentives for participation. The 20 percent of the country in private ownership is more likely to support a successful watershed management project with a high degree of local participation than the remainder which is in state ownership. Land use mapping information should include classifications of land tenure. Also important is the evaluation of communal land as an important resource for increased productivity and watershed conservation.

- Land allocation schemes in the lower catchment areas should emphasize technologies that can maximize productivity and income-earning opportunities without disrupting ecological sustainability. This may result in greater crop diversification and greater emphasis on non-traditional crops, including perennial tree cropping. Commercial land allocations (land areas greater than 10 hectares in total area) should include strict environmental standards to ensure that these lands are used wisely. Initial Environmental Examinations (IEE) should be required for all commercial farm developments, and commercial operators should be required to prepare an Environmental Action Plan for the property. This plan should ensure that forest clearing and land cultivation will be carried out in a

manner that results in minimal disruption to soil and water systems or biological diversity in the surrounding areas.

- Appropriate industry should be encouraged and stimulated within the watershed. This industrial development should, ideally, evolve from and be controlled by local residents so that profits are returned to the local communities where they will increase economic opportunities, enhance well-being, and conserve natural resources and environmental quality. Industrial development could provide inputs to the agricultural sector, including fertilizers, seeds, equipment and tools, and consultative services. It could also service the output side of agricultural production, processing and adding value to products, marketing, shipping, etc. Industrial development based on non-agricultural amenities should also be encouraged and stimulated.

  Another promising opportunity for economic development is the area of ecotourism. Few places on Earth are better situated to capitalize on this new, profitable, and environmentally friendly enterprise than the upper and lower catchment areas of the Mahaweli watershed. Local residents in the watershed can realize significant personal and financial enrichment by providing others with an opportunity to experience and appreciate the Mahaweli environment. While security problems may limit (though they do not entirely eliminate) ecotourism opportunities at the moment, the long-term perspective for the watershed should definitely include consideration of tourism development which emphasizes conservation and appreciation of the tremendous physical and biological diversity in the basin. However, for ecotourism to truly enhance the social and ecological well-being of the Mahaweli watershed, it should be locally based.

  Policies should be developed to ensure that profits from enterprise remain largely in the watershed, and under the control of Mahaweli residents where they can be used to enhance local well-being. To the extent that the profits from enterprise leave the watershed, residents of the watershed are relegated to a subservient position with reduced and limited self reliance.

- In moving people toward self-reliance, the role of subsidies should also be carefully considered. Subsidies are needed to enable Mahaweli residents to become players in the larger economy, including enabling them to function in entrepreneurial enterprise. Subsidies are also helpful in assisting people install infrastructure to maintain productivity (for example, soil retention). There is a danger, however, that unconstrained and unlimited subsidization of the means of production often leads to inefficiency in the use of those resources, leading to waste and pollution. The excess use and waste of water with concomitant soil saturation problems is an example. Means should be sought to wean users from subsidies over time, and ultimately make them self sufficient.

- There are substantial on-site benefits to farmers who participate in watershed management programs. Research and demonstration plots to show farmers the profitability of reducing erosion losses (particularly nutrients) are needed to increase incentives to participate. Subsidy schemes should be carefully considered before implementing because they can lead to overemphasis on construction of structural measures and neglect of maintenance, serving as a disincentive to less expensive measures that would otherwise be adopted by farmers on their own (World Bank, 1990).

- An approach that involves villages from the beginning planning stages of a potential project is recommended over a top-down method with emphasis on structural measures built by the government without local participation. Rather than telling villagers what their problems are and what they must do to correct them, rapid rural appraisal methods should be employed to enable residents to define their problems and acceptable solutions that can be both profitable and sustainable.

- After comprehensive watershed planning is completed, implementation should take place at the village level. Demonstration areas for education and training should be set up as minicatchment centers. Lessons learned in the centers should radiate to other minicatchments as successful implementation schemes are demonstrated by extension staff.

- Training at the extension agent and farmer level should be given more emphasis in planning and implementation phases of watershed projects. Because of the social orientation of many NGO groups, a larger role is recommended for them in raising environmental awareness and training at the village level. International aid organizations should consider projects focusing on conservation training, both at the extension agent and village level.

- Monitoring and evaluation budgets and methodologies should be built into projects at the planning level. Trained staff need to be available and there needs to be an institutional commitment to monitoring on a regular basis. External reporting requirements need to be clearly understood and responsibilities clarified. Independent verification of progress should be planned for in the initial budget. It should be understood that well managed monitoring and evaluation, along with efficient dissemination of success stories to the public and decision makers, have significant public relations value.

ANNEX D

MAHAWELI AGRICULTURE AND RURAL DEVELOPMENT PROJECT ENVIRONMENTAL ACTION PLAN

ANNEX D

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To protect biological diversity and remaining tropical forests and to avoid any potential loss of wetland areas, streamside vegetation, and soils from borrow pits, the following mitigative measures are being carried out by the Mahaweli Agriculture and Rural Development Project (MARD) in System B:

- The MARD Project will inventory, protect, or restore some remaining wetlands which may be lost through infrastructure developments. These wetlands can serve as important wastewater filters for farm and homestead runoff, and as habitat for aquatic species and other wildlife. The MARD Project has contracted the short-term services of an ecologist for two months specializing in the conservation of wetlands, with experience in the construction of artificial wetlands.

- Improved drainage construction, or land development measures, particularly those to occur in Block 503, will not result in the removal of streamside vegetation. Wherever possible, given available funds, land allocation, and security concerns, efforts will be extended to restore streamside vegetation, particularly along the Maduru Oya and Kudu Oya drainages. GSL regulations stipulate that streamside vegetation should be protected for a distance of two chains (approximately 40 meters) on both sides of the Maduru Oya river bank, and one chain (approximately 20 meters) on both sides of the Kudu Oya. It may be possible to establish tree crops along stream bank areas using species which yield important non-timber products.

- The proposed MARD amendment will continue and expand Integrated Pest Management (IPM) demonstrations and training courses. Training activities in IPM will include information on safe and appropriate methods for pesticide application, including correct storage and disposal of chemicals.

- The proposed MARD amendment will include measures that will increase the project extension efforts to promote tree cropping, especially for the establishment of fuelwood, timber, and fruit trees, as well as an increased emphasis on the cultivation of non-timber forest products: fibers, medicinals, and dyes. Project staff will facilitate the promotion of tree cropping as a homestead or commercial activity.

- The MARD project will contract the services of a Wildlife Management specialist with experience in the mitigation of elephant-farmer conflicts. This specialist will be contracted for one month or longer, as finances provide, to (a) interview local farmers; (b) develop non-harmful strategies for reducing or eliminating elephant-farmer conflicts; (c) present seminars or informal dialogues with area farmers and extension workers to describe these strategies; and (d) instruct and assist MARD Project staff on means for implementing these strategies.

- Drainage and flood control measures constructed as part of the proposed MARD amendment will be designed to facilitate the passage of flows from a 100-year storm

event. Reinforcement of earth dam embankments has also been designed to withstand a 100-year storm event.

- Borrow pits for road construction and embankment improvements will be monitored by MARD staff or other contracted services to ensure that no significant loss of agricultural lands or soil erosion results from the activities.

- Any road construction contracted by MARD will include adequate drainage to ensure that roadways can pass flows from a minimum of a 25-year storm. Road drains will also be designed to minimize sedimentation or contamination of intact wetland areas, forest areas, or farm fields.

ANNEX E

INCOME GENERATION AND WATERSHED CONSERVATION: CONFLICTS IN THE KNUCKLES RANGE, UPPER MAHAWELI CATCHMENT AREA

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INCOME GENERATION AND WATERSHED CONSERVATION: CONFLICTS IN THE KNUCKLES RANGE, UPPER MAHAWELI CATCHMENT AREA

There are four major natural forest areas in the upper Mahaweli Catchment Area (UMC), including the Knuckles range, Pedro Frotoft, Mahakundugala-Nildandahinna, and Kikiliyamana-Pattipola-Bobat. The major land uses in the UMC emphasize intensive agriculture or tea cultivation and cover approximately 47 percent of the watershed (Table E.1). Only about 10 percent of the area is intact natural forest. No detailed watershed analyses have been conducted to assess soil and water conditions in this watershed. However, it is apparent that the present land use pattern does not reflect the objectives of the MASL in terms of soil and water management under the present land use patterns.

TABLE E.1

LAND USE PATTERNS IN THE UPPER MAHAWELI

Land use	Area %
Intensive agriculture/tea	47
Misused/abandoned	14
Low intensity agriculture	14
Marginal/unused	12
Forest	10
Others	3

The Knuckles region is located in the districts of Matale and Kandy, within the Mahaweli watershed. The total area is approximately 155 square kilometers (60 square miles). The mountain range runs from northwest to southeast, with an undulating crest of the central hilly areas of the country. The average height is approximately 1,500 meters, with highest elevations of 1,900 meters.

Streams and Rivers

The Knuckles range represents a watershed with a complex tributary system feeding the Mahaweli river at various points. The water collected from the western slopes of the range flow down to the Hulu Ganga. The Hulu Ganga finally joins with the Mahaweli river at a point south of Teldeniya, above the Victoria reservoir. This is the catchment area most affected by human activities at the present time. Some of the tea estates located in this catchment cultivate steep slopes above 1,350 meters.

Major tributaries on the eastern slopes of the Knuckles are the Heen Ganga and the Kalu Ganga. The former collects its waters from rapidly flowing streams such as Mimure Oya, Kaikawala Oya, and Maha Oya. These streams drop rapidly from the steep hills, and finally join with the Mahaweli river a little above Hembarawa. Kalu Ganga, on the other hand, drains off the entire northern sector of the

eastern slopes into Amban Ganga, which eventually meets the Mahaweli above Manampitiya. The northeast monsoonal rains affect both the eastern and the western slopes of the Knuckles range of forest. The southwest monsoonal rains affect mainly the western slopes. Thus, the distinction from the Wet Zone to the Dry Zone is quite noticeable on the ridge areas of the mountain range (Edussuriya).

Vegetation

In this region the dominant types of vegetation include ory (pre-montane humid tropical) evergreen forest and wet evergreen mountain (rain) forest. Within these two distinct vegetation types five specific forest communities can be identified, including:

- Lowland tropical wet semi-evergreen forest;
- Submontane tropical wet semi-evergreen forest;
- Montane tropical wet evergreen forest;
- Montane grassland; and
- Montane pygmy forests.

Wildlife

Animal diversity within the Knuckles range is severely limited due to habitat disturbance and agricultural developments. The introduction of cardamom to the upper slopes eliminated important habitat, as has ongoing predator controls in defense of crops.

Problems in Forest Management

According to the Knuckles conservation and management plan, the 18,290 hectares of land above 1,050 meters represents reserved forests. However there are some agricultural activities in both government and private lands above the 1,050 meters. In 1986, Sri Lanka earned about 65 million rupees exporting 272 metric tons of cardamom, which was equivalent to 6.25 percent of total earnings of all minor export crops. Enforcement of the cultivation restrictions in the forest reserve lands above 1,050 meters would result in economic losses of approximately 10 million rupees per year in terms of foreign exchange earnings. Other related costs have not been assessed with proper alternative plans to examine whether it is possible to compensate such losses under potential benefits.

Average annual income of small-scale cultivators illegally farming in the upland reserve lands was estimated to be 27,356 rupees in certain villages around the Knuckles (Gunatilake et al., 1992). All of these developments represent a major threat for the long-term viability of the remaining natural forest communities in the region.

TABLE E.2

ECONOMIC IMPACTS OF THE Cardamom INDUSTRY
ON UPLAND SLOPES IN THE KNUCKLES RANGE

Category	Extent ha	Yield kg/ha	Price kg	Revenue Loss Rs.
1. SPC Estates	745	11	180	1,475,100
2. Private Estates	100	100	180	1,800,000
3. Encroachment (Registered)	300	80	180	4,320,000
4. Encroachment (Unregistered)	270	50	180	2,430,000
Total				10,025,100

The 1988 status of cardamom cultivation in the Knuckles area was reported as follows:

1. One hectare of cardamom requires 0.74 labor days per day for cultivation and maintenance, according to the State Plantation Corporation (SPC) records. Elimination of cardamom cultivation in the reserved upper slopes could result in a loss of approximately 553 labor days per year, which would be a significant loss of local employment.

2. The Forest Department was directed in the 1960s to lease out land for cardamom cultivation in several existing forest reserves, resulting in 20-year leases being established for 621 hectares.

3. In addition to these leased cardamom growers, 298 encroachers are reported as cultivating an extent of 702 hectares. Approximately 160 hectares of this encroachment are more than 100 years old, and an additional 465 hectares are around 50 years of age.

4. An extent of 170 hectares have been leased by the Land Reform Commission, Matale, for cardamom cultivation in some of the estates (Lebonon and Knuckles).

5. 90 hectares of land under the control of the Divisional Forest Officer, Matale are being illicitly cultivated by cardamom growers. In addition, the following encroachments are reported by the Assistant Government Agents in these areas:

   a) Laggala: 271 encroachers and estimated 140 hectares.

   b) Udadumbara: 250 encroachers and estimated 120 hectares.

   c) Ukuwals: estimated 60 hectares.

6. The Land Commissioner issued leases for cardamom cultivation from the Knuckles area for 32 hectares over a period of 30 years from 1984. An additional 40 hectares were issued in 1967 on a special lease.

Obviously, the area has now been developed to represent an important economic resource for the region, if not the country. However, the important watershed functions of the Knuckles Range have indicated the value of maintaining upper slope lands above 1,050 meters in natural forest cover. Even below these slopes, the cultivation of cardamom needs to be strictly controlled. For example, an optimal canopy density for cardamom is approximately 75 percent, although canopy cover is frequently less due to fuelwood harvests by plantations for drying purposes. Controls on these canopy harvests, along with measures to reduce depletion of the native forests for fuelwood needs, should emphasize relocation of processing facilities to more appropriate lower elevation sites.

The trade-offs between the short-term economic benefits of continued cardamom cultivation and the long-term watershed conservation needs represent the kinds of policy choices facing watershed managers in the Mahaweli basin. Development of buffer zone management actions providing alternative economic opportunities, especially for the illicit cultivators in the area, will also be essential if this important watershed region is to be conserved and restored.

ANNEX F

FIGURES

FIGURE 6

PLACES OF ORIGIN OF THE SETTLERS IN MAHAWELI SYSTEM C

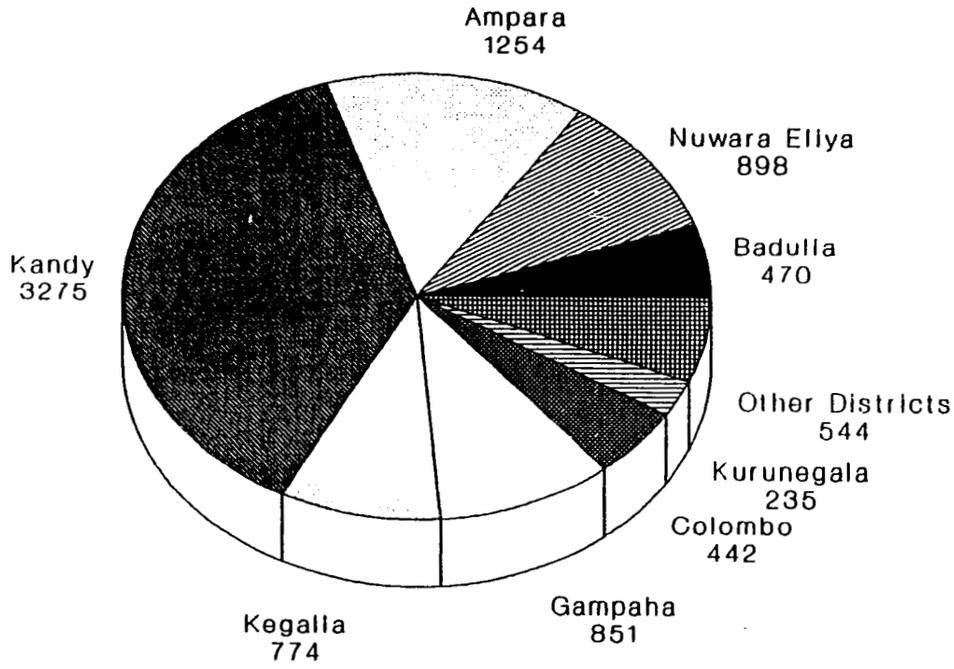

FIGURE 7

INFRASTRUCTURAL FACILITIES IN SYSTEM B

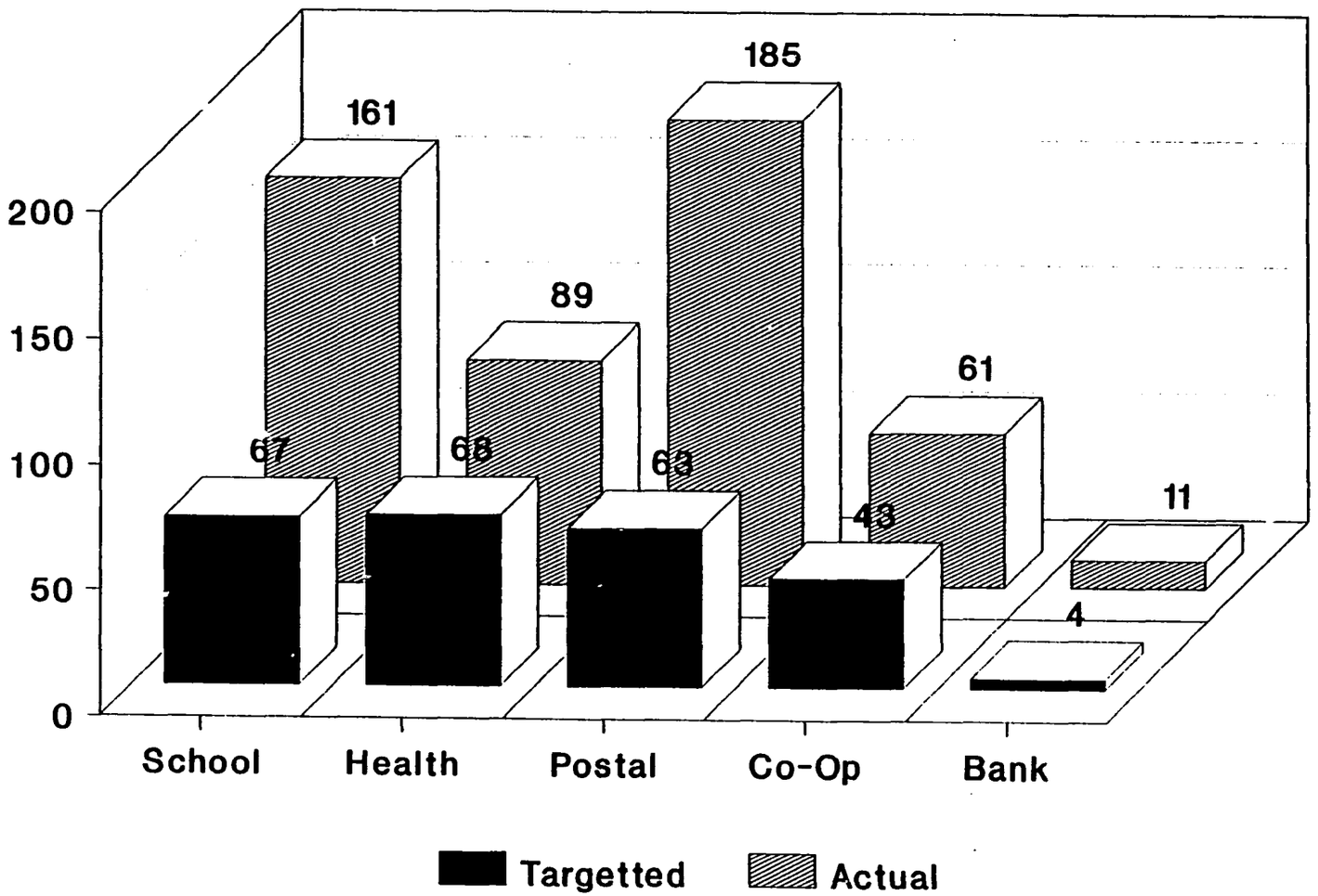

FIGURE 8

BASIC NEED FACILITIES IN SYSTEM B

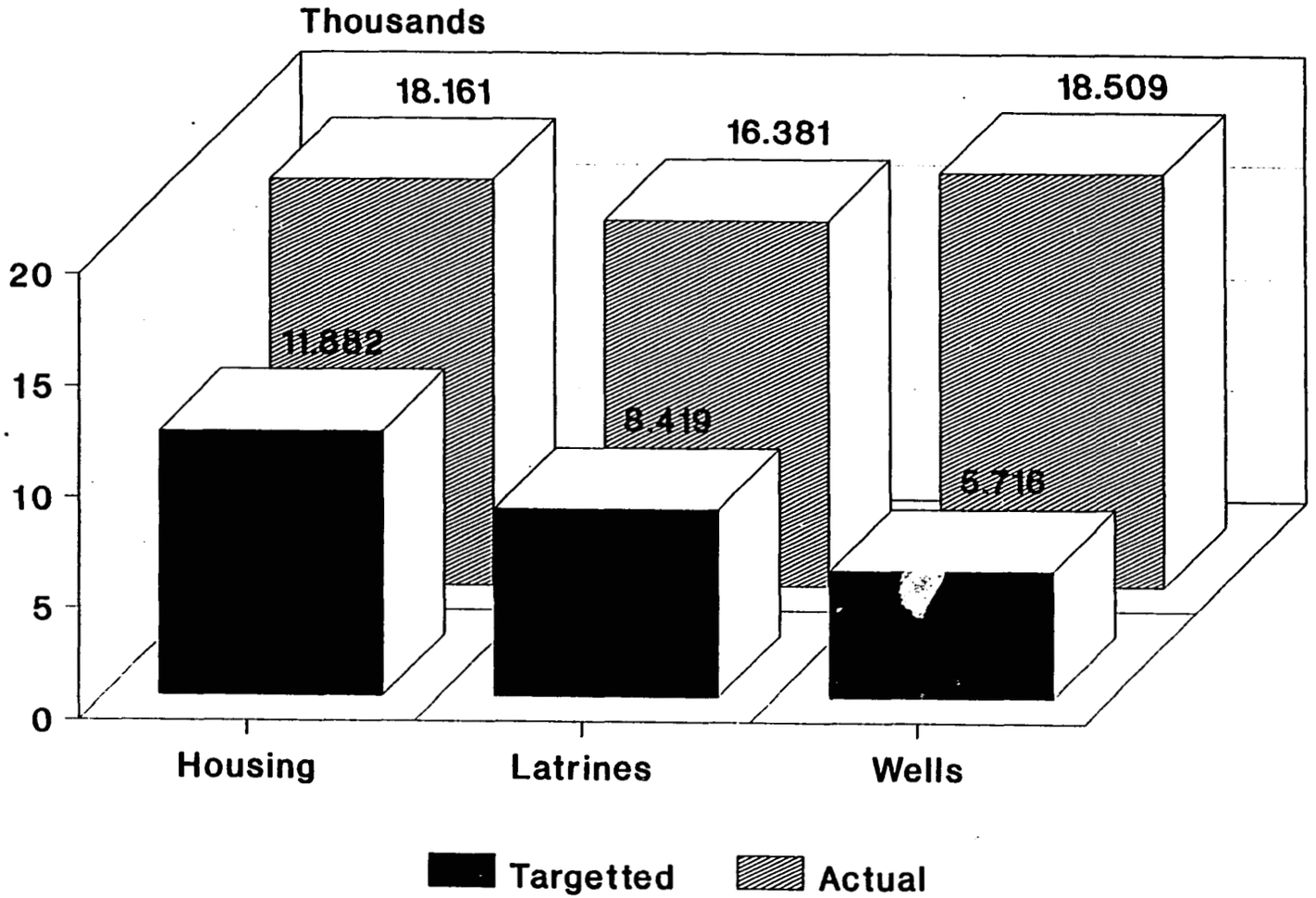

FIGURE 9

INFRASTRUCTURAL FACILITIES IN SYSTEM C

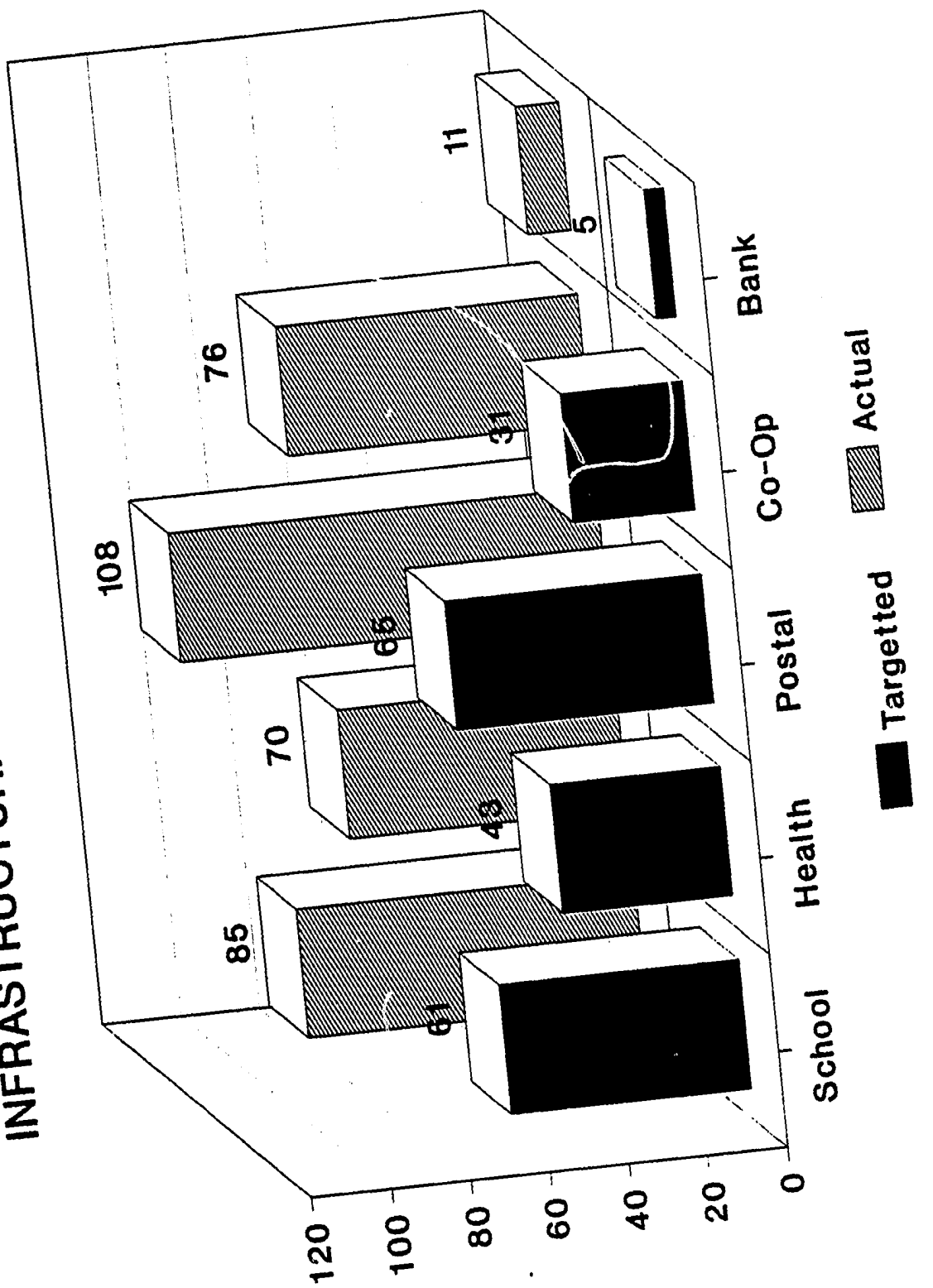

FIGURE 10

BASIC NEED FACILITIES IN SYSTEM C

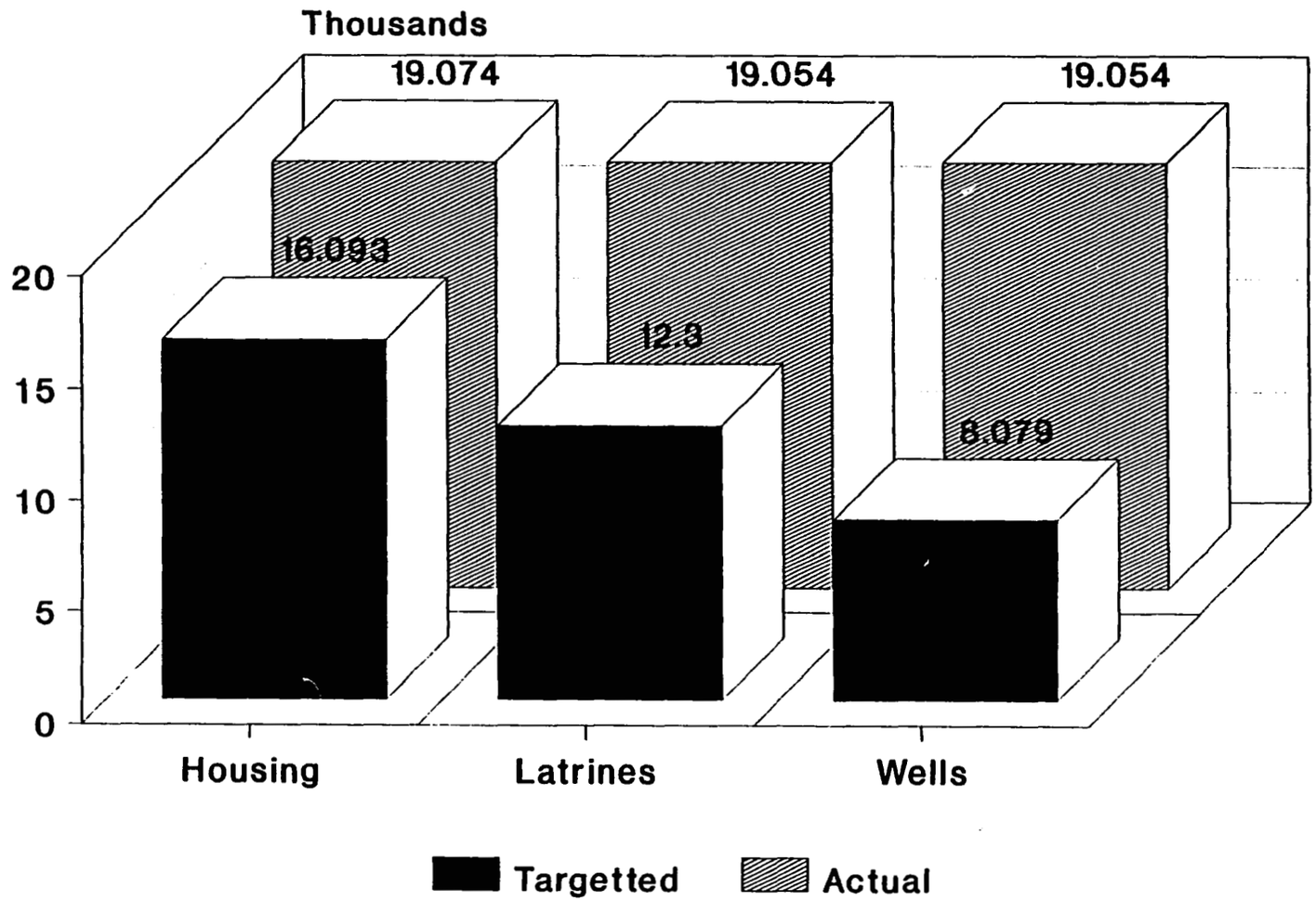

FIGURE 11

INFRASTRUCTURAL FACILITIES IN SYSTEM G

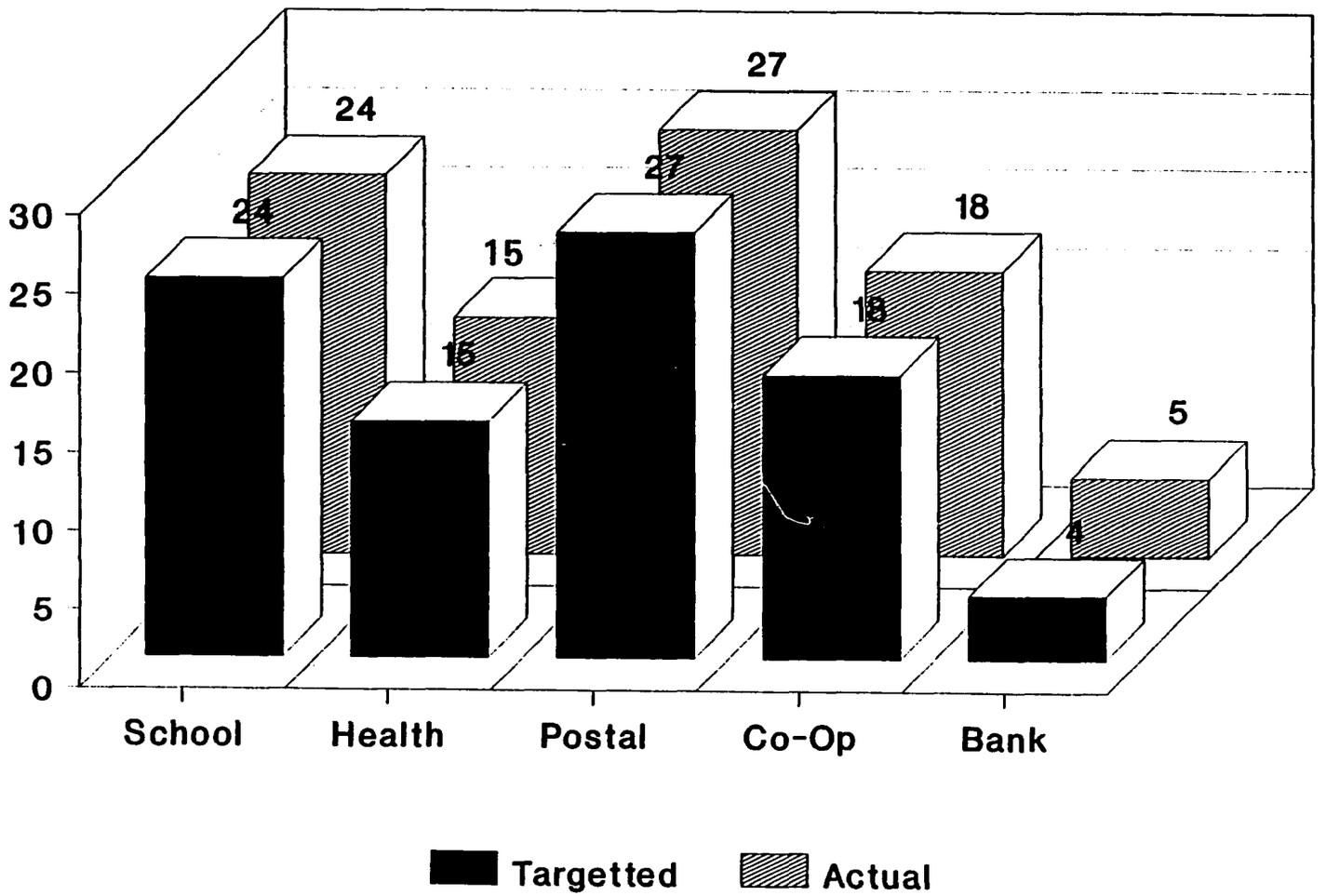

FIGURE 12

BASIC NEED FACILITIES IN SYSTEM G

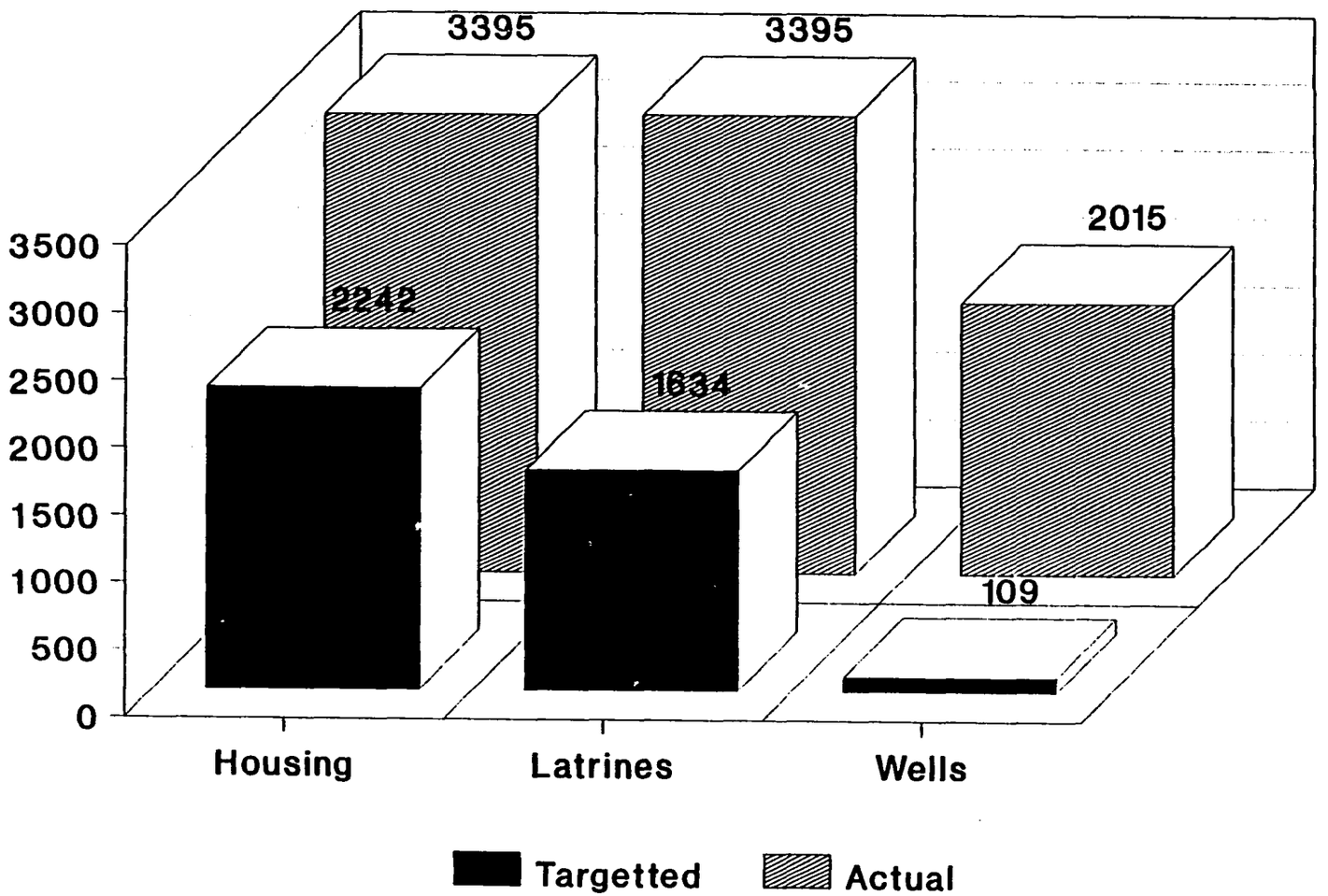

FIGURE 13

INFRASTRUCTURAL FACILITIES IN SYSTEM H

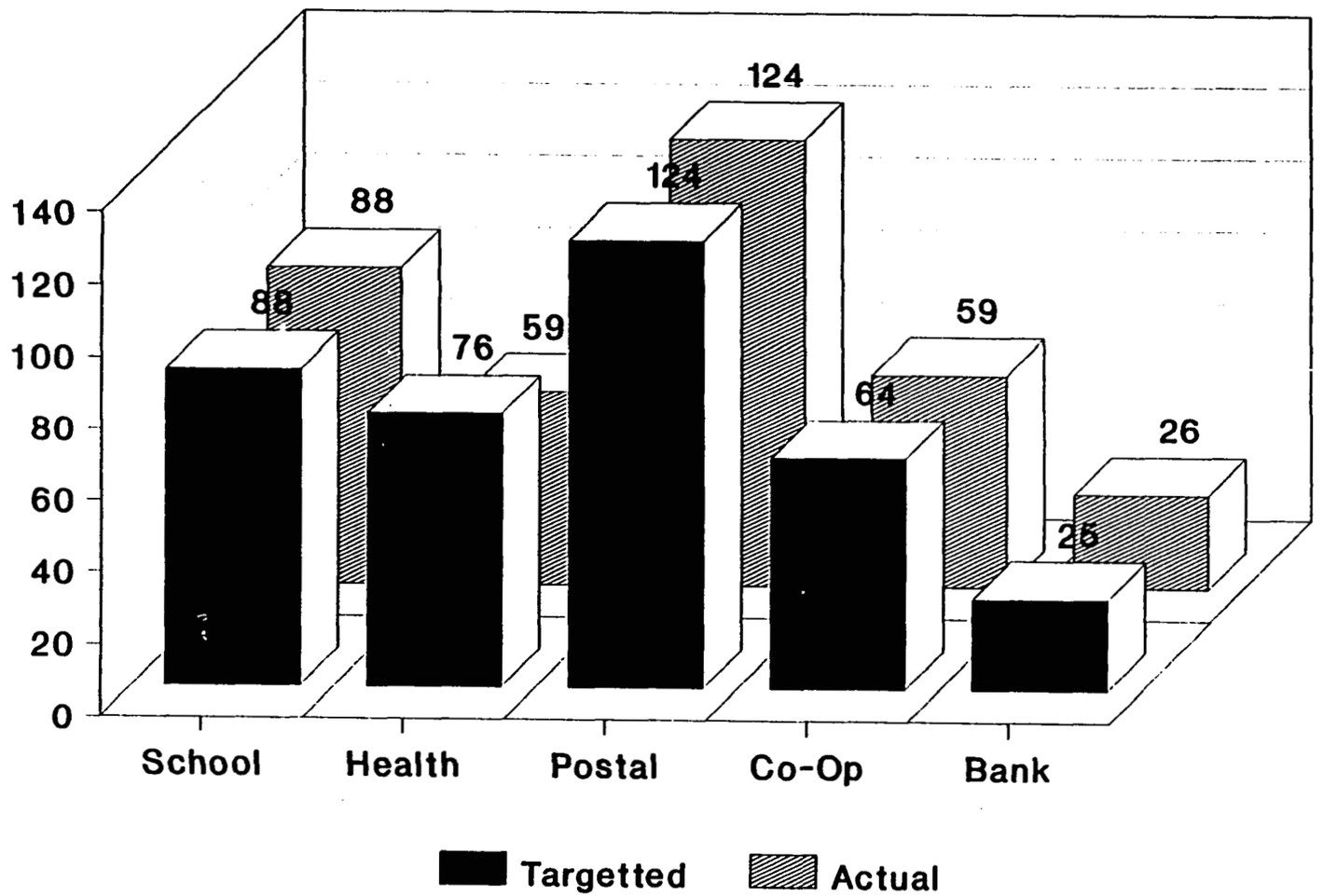

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FIGURE 14

INCIDENCE OF MALARIA IN MAHAWELI SYSTEMS AND IN SRI LANKA

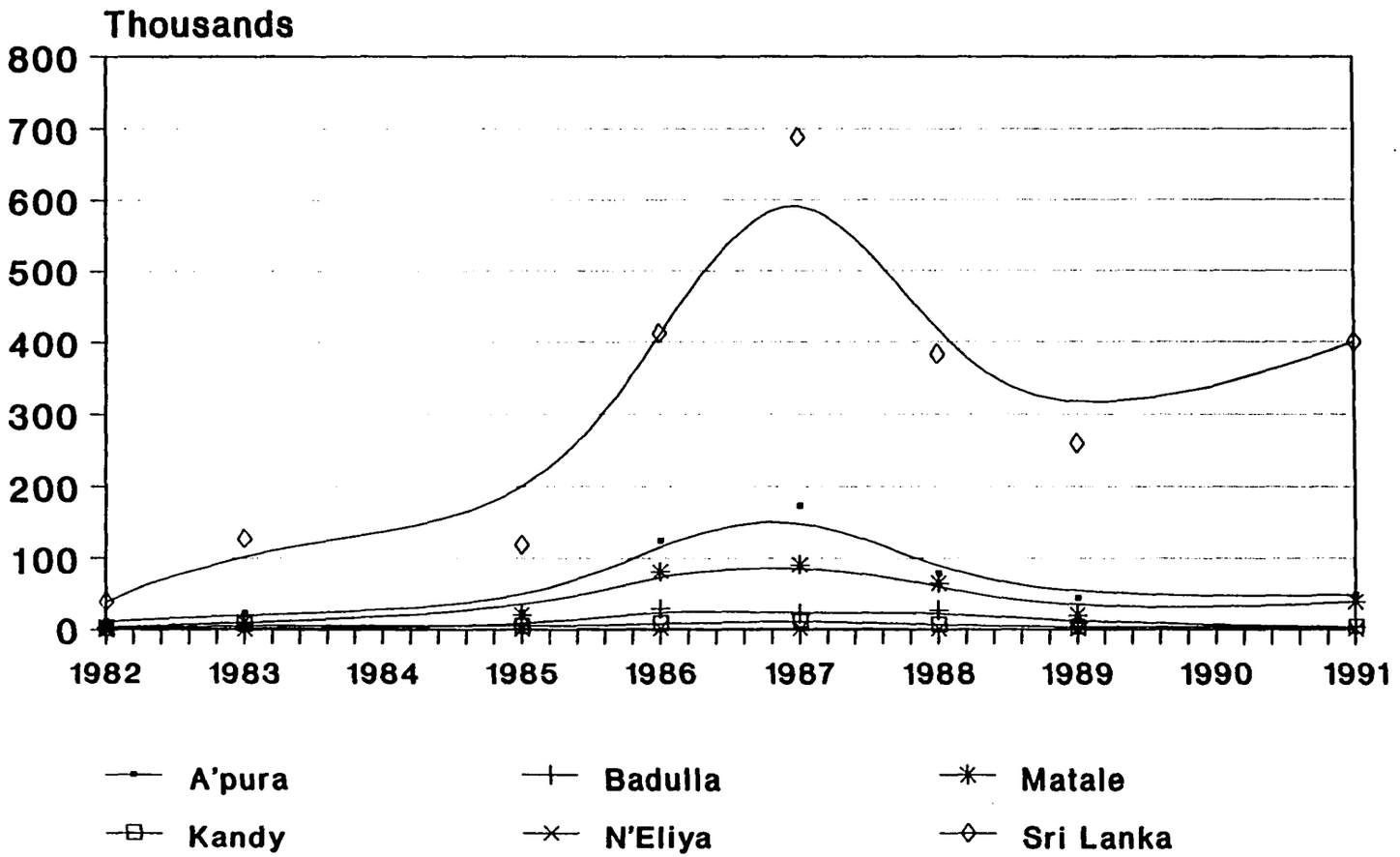

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FIGURE 15

INCIDENCE OF MALARIA IN SRI LANKA

CUMULATIVE, 1950-1991

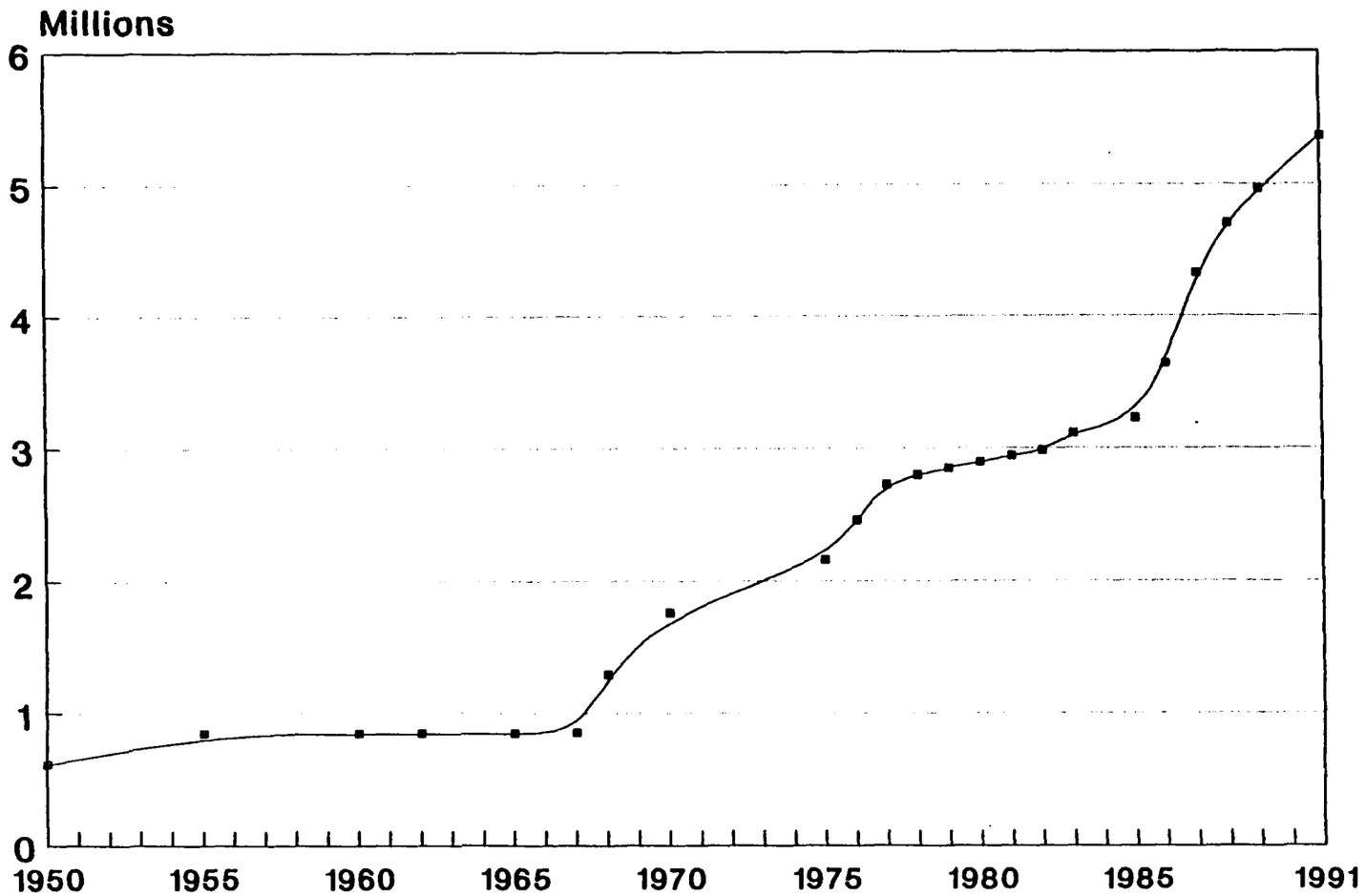

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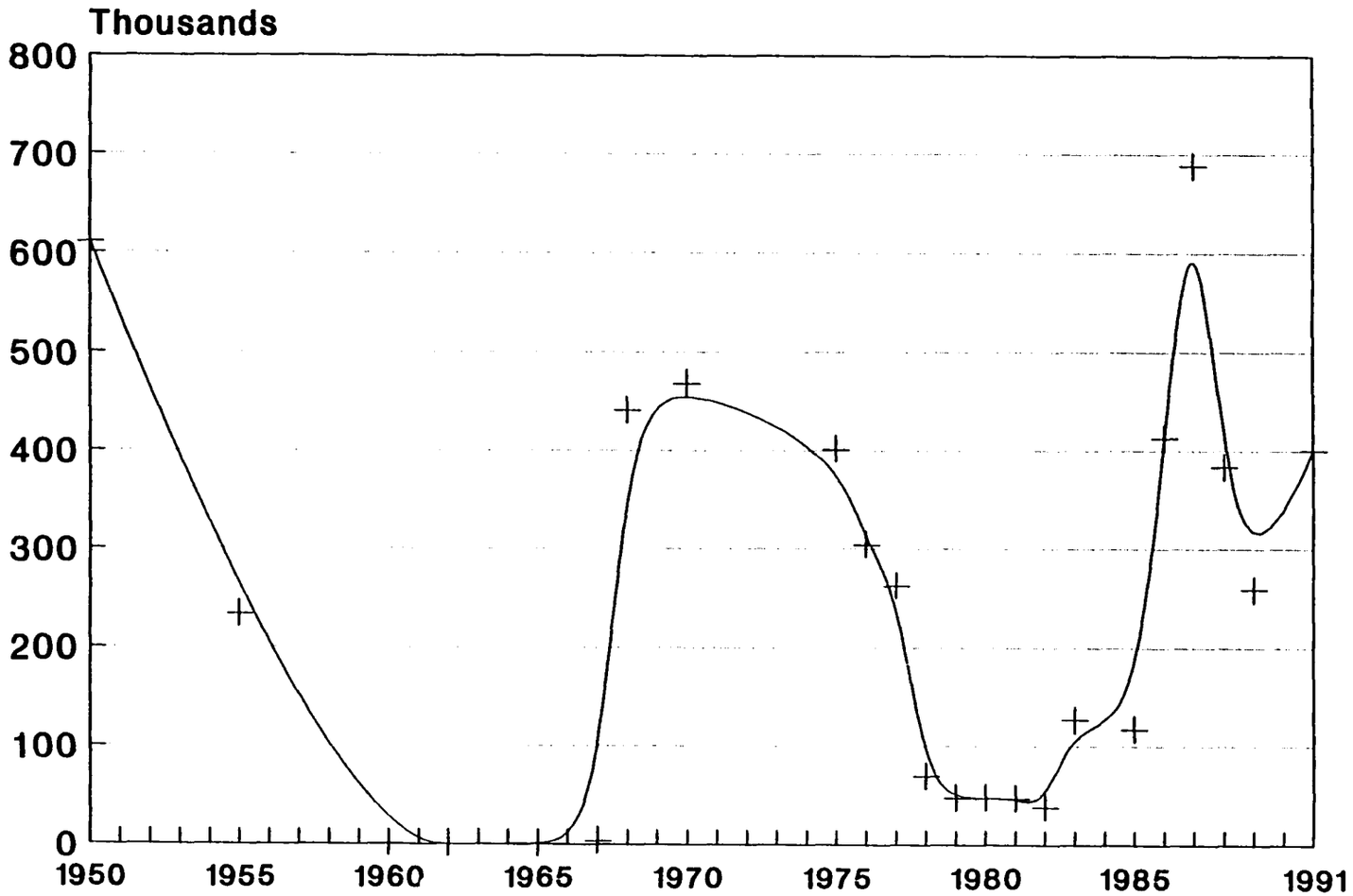
FIGURE 16

INCIDENCE OF MALARIA IN SRI LANKA

DISTRIBUTION, 1950-1991



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