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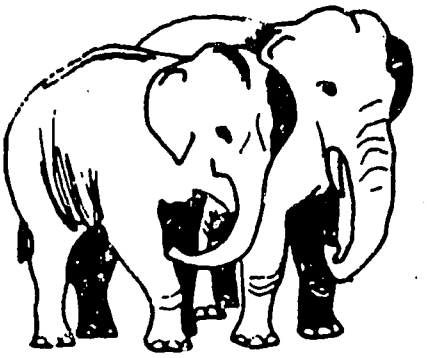

ENVIRONMENTAL ASSESSMENT

ACCELERATED MAHAWELI DEVELOPMENT PROGRAM

Funded by United States Agency for International Development

OCTOBER 1980

VOLUME IV

HUMAN ENVIRONMENT

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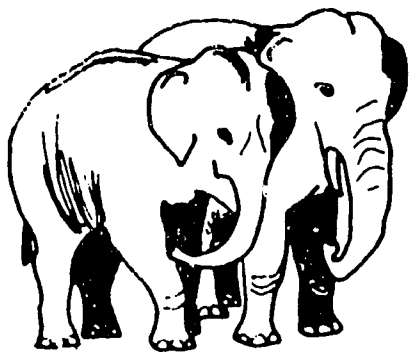

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VOLUME IV
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TAMS TIPPETTS-ABBETT-McCARTHY-STRATTON
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INTRODUCTION

It is possible that any animal or plant can be a pest under some circumstances. The control of a pest is best administered through integrated pest management which may be defined as a combined use of all methods for effective, economical pest suppression with a minimum effect on non-target organisms and the environment. It is based on an understanding of the biology and ecology of the plant or animal to be protected (Kuhr 1979).

Integrated insect pest management, or economic entomology, as it was once called, includes plant breeding (for resistance or tolerance), cultural practices, sanitation (including destruction of crop residues, alternate hosts and volunteer plants), crop rotation, tillage, trap crops, habitat diversification, time of planting, management of fertilizer and water, pest free seed and/or planting stock, biological (natural and/or augmented) control and preservation of natural enemies and diseases. None of these are new methods, but have been brought into focus in recent years with the over dependence on, and use of, chemical insecticides, particularly since some have led to insect resistance and environmental problems (Glass 1975).

Pesticides are, and will remain in many crop protection situations, dependable and strong resources for pest management. Before the use of any pesticide, a careful evaluation of alternatives must be made, after which it can be determined that the economic threshold or treatable pest level has been reached.

The term pesticide is a broad generic term encompassing chemical control of any pest and not just chemicals for insect control. Each group of pests has an individual chemical "cide" term: algacide, nematocide, insecticide, herbicide, fungicide, rodenticide, moluscacide, pesticide, acaricide, etc.

EXISTING CONDITIONS

PRESENT CROPPING PATTERNS

Pest problems are of course closely related to the nature and extent of cropping patterns. Of the approximately 2 million hectares of land presently cultivated in Sri Lanka, about 45% is in paddy (Central Bank of Ceylon 1979). The other major crops under cultivation include coconuts (22% of total cultivated area), tea (12%) and rubber (11%). Areas allocated for the principal crops grown in Sri Lanka over the last 5 to 10 years are listed in Tables J-1 and J-2. Yields for some selected crops are given in Table J-3. Details of available information pertaining to the pest management of the above crops, especially for those proposed for the Accelerated Program, are presented in the following sections.

RESEARCH PROGRAMS

As elsewhere in the world, insects in Sri Lanka have received more attention than other pests such as plant diseases and weeds. Sri Lankan researchers have made some excellent contributions in the protection of food production. For example, the Department of Agriculture (1978) has assembled a "Plant Protection Manual" comprised of a series of very useful articles containing information from surveillance and forecasting (Manickavasagar 1978) to sericulture (Selvarajah 1978). An additional document by the Department of Agriculture (1979) describes for each crop how to prepare for dusting and spraying and when to treat with what materials for specific insect pests. Manikavasagar (1979) has presented specific treatment recommendations for numerous pests including diseases, crabs, rats, snails and birds.

Another source of insect, plant disease, weed and rodent control is the Agricultural Information Division of the Department of Agriculture which has separate publications (leaflets) by crop. However, while these contain detailed information on all phases of growing each crop, some have not been revised for more than ten years.

A program which has been gathering momentum slowly, but which should have a good potential is being conducted under the International Soybean Program (IMTSOY 1977). Thus far, losses have been minimal to such insect pests as bean fly, flea beetle, hairy caterpillar, stem fly and stink bug (Hittle 1979). Particular attention should be directed to the stink bugs, since some species cause considerable dockage in other parts of the world when soybeans are graded for sale. Soybeans offer an excellent opportunity for cooperative efforts between agronomy, entomology, plant pathology and weed science.

In addition, research studies are conducted at several of the 13 Agricultural Research Stations with 22 persons involved in entomology, 20 in plant pathology and four in weed science. The Tea Research Institute at Talawakelle, with 15 researchers involved in entomology and nematology, and eight in plant pathology, is conducting studies on shot hole borer, tea tortrix, termite and blister mite.

The Rubber Research Institute (Agalawatte) has two research officers engaged in plant protection; the Coconut Research Institute (Luniwila) has three entomologists and one pathologist. The Rice Research Station in addition to work on its own, cooperates with the International Rice Research Institute

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Table J-1
Area and Yield of Paddy in Sri Lanka

Year	Season	Asweddumised Area Hectares	Sown Area Hectares	Harvested Area Hectares	Production in 1000 Metric Tonnes	Acreage Yield Kilogrammes per Net Hectare
1968-69	Maha	560,777	478,339	436,470	980	2,641
	Yala		213,331	186,514	394	2,487
1969-70	Maha	570,171	482,172	451,316	1,033	2,692
	Yala		276,839	267,365	583	2,567
1970-71	Maha	574,328	464,360	440,689	867	2,315
	Yala		261,489	253,082	529	2,457
1971-72	Maha	586,148	479,973	419,049	883	2,480
	Yala		246,265	219,922	429	2,296
1972-73	Maha	582,697	477,112	439,134	876	2,348
	Yala		248,126	232,555	436	2,206
1973-74	Maha	606,417	533,303	521,382	1,098	2,460
	Yala		291,471	275,639	504	2,152
1974-75	Maha	620,613	443,475	354,222	719	2,384
	Yala		252,329	243,007	435	2,106
1975-76	Maha	620,972	464,159	425,707	882	2,432
	Yala		259,780	209,764	370	2,078
1976-77	Maha	642,861	537,726	505,863	1,144	2,658
	Yala		290,340	276,422	533	2,268
1977-78	Maha	657,806	574,945	552,731	1,286	2,734
	Yala		300,428	286,694	605	2,403

Source: Dept. of Census and Statistics (1979)

(1) Maha Season - Crop sown from July to November (in Badulla and Moneragala, July to December).

(2) Yala Season - Crop sown from February to June (in Badulla and Moneragala, January to June).

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Table J-2
Area of Land Under Principal Crops (EXCLUDING PADDY) in Sri Lanka

	1972	1973	1974	1975	1976	1977	(Hectares) 1978
Tea	242,046	242,490	242,379	242,065	240,765	242,012	242,903
Rubber	229,636	228,754	228,179	227,810	226,977	226,563	226,328
Coconut	466,733	466,733	466,773	466,733	466,733	451,472	451,472
Kurakkan	21,421	30,212	38,226	43,850	39,540	34,602	31,970
Maize	20,115	29,209	33,823	39,728	38,309	27,468	23,273
Chillies	34,619	44,727	53,330	49,533	54,623	51,707	50,573
Red Onions	8,242	8,666	9,050	9,075	9,676	8,382	8,267
Potatoes	3,542	3,354	3,197	3,124	3,115	3,110	2,861
Manioc	59,446	115,342	182,517	164,899	151,297	95,760	74,320
Sweet Potatoes	14,546	26,979	40,851	48,538	45,581	27,746	20,677

Source: Dept. of Census and Statistics (1979)

Note: The annual extent under other crops except tea, rubber and coconut was arrived at by adding together the area under cultivation during Maha and Yala Seasons.

Table J-3

Yields of Selected Agricultural Crops

Per Acre

Item	Unit	1972	1973	1974	1975	1976*	1977*
Main Agricultural Crops							
Tea	Kg.	367.2	362.3	396.9	414.0	377.7	404.8
Rubber	"	296.1	312.3	285.3	311.0	317.3	319.0
Coconut		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Paddy	Bushels	46.87	44.58	45.65	44.04	44.91	48.92
Other Agricultural Crops							
Manioc	Cwts.	42.8	102.4	74.1	77.1	78.4	56.4
Maize	"	6.5	4.5	4.9	6.9	8.1	9.1
Chillies	"	4.0	4.2	8.0	4.5	6.7	4.5
Red Onions	"	85.8	77.7	87.5	91.7	80.6	59.6
Ground Nuts	"	9.0	11.8	7.6	7.8	7.2	8.7
Green Gram	"	3.5	4.8	4.4	5.4	4.4	5.5
Sorghum	"	3.2	7.4	11.4	13.7	13.3	11.1
Soya Beans	"	7.2	11.5	7.7	8.1	8.2	9.2
Potatoes	"	118.1	151.6	83.2	108.0	183.3	127.0
Bombay Onions	"	57.3	33.4	53.0	75.3	57.0	71.4
Kurakkan	"	n.a.	n.a.	4.3	6.1	6.3	7.0
Gingelly	"	n.a.	n.a.	3.0	3.7	3.6	4.0
Meneri	"	n.a.	n.a.	3.4	3.9	6.2	6.5
Cowpea	"	n.a.	n.a.	5.4	6.9	4.9	5.6
Tanahal	"	n.a.	n.a.	6.1	3.2	5.5	5.1
Black Gram	"	n.a.	n.a.	3.7	4.1	3.7	5.8
Dhal	"	n.a.	n.a.	4.7	6.4	3.5	8.0
Minor Export Crops							
Cocoa	"	11.98	12.46	12.39	11.19	10.79	n.a.
Cinnamon	"	6.37	5.40	6.29	6.13	6.46	n.a.
Cardamoms	"	18.82	9.66	9.84	7.81	7.99	n.a.
Citronella	"	14.38	7.94	8.56	6.53	5.44	n.a.
Pepper	"	18.83	19.93	18.63	16.15	20.20	n.a.

*Provisional Estimates

Source: Central Bank of Ceylon (1979) - Department of Census and Statistics. (1979)

(IRRI) and is responsible for introduction of new as well as disease and insect resistant strains.

INSECT PESTS AND PLANT DISEASES

This section focuses upon the existing Sri Lankan insect pests and diseases in relation to the specific crops they attack. Most of the data compiled here are taken from Department of Agriculture (1978, 1979), Litsinger (1979), Manickavasagar (1979) and interviews with the various research institutes and stations cited above.

Rice

The numerous insect pests affecting rice crops may be categorized as follows:

Major Pests

Rice leaf folder or roller *Cnaphalocrocis medinalis*
Yellow rice stem borer *Tryporyza incertulas*
Pink borer *Sesmamia inferens*
Rice gall midge *Orseolis oryzae*
Rice thrips *Baliothrips biformis*
Rice bug or paddy bug *Leptocorisa acuta*
Brown planthopper *Nilaparvata lugens*
White-backed planthopper *Sogatella furcifera*

Localized Pests

Swarming caterpillar (armywork) *Spodoptera mauritia*
Rice case bearer (caseworm) *Mymphula depunctalis*
Rice stem fly *Atherigona exigria*

Minor Pests

Rice whorl maggot *Hydrellia philippina*
Rice black or pantatomid bug *Scotinophara lurida*
Green leafhopper *Nephotettix apicalis*
Borolia caterpillar *Borolia venalba*
Rice skipper *Parnara gutlata*
Rice leaf butterfly *Melanitis ledaisinene*
Skipper butterfly *Pelopidas mathias*
Green rice bug *Nezara viridula*
Shield bug *Mendia histriol*
White rice leafhopper *Telligella spectra*
A beetle *Dicladispa armigera*
Rice grasshopper *Hieroglyphus banian*
Zig-zag striped leafhopper *Inazuma dorsalis*
Orange colored leafhopper *Erythroneura subrufa*
Mole cricket *Cryllotalpa africana*

These insect pests may cause damage at various life history stages, i.e. larva, nymph and/or adult. Most feed upon the leaves or the stems of the rice plants. However, some cause damage by attacking the spikelets as well (rice thrips) or the grain itself (rice bug). Mole crickets feed on the

roots underground, while caseworms attack the base of the plant. A summary of the effects of some rice insect pests is presented in Table J-4.

Similarly, selected diseases which affect rice crops are listed in Table J-5. The more common diseases are viral or fungal in nature and cause stunting, yellowing, lesions, neck rot, infection of panicles and related damage. Viral infections are usually carried and transmitted to the rice plant by insect pests, especially planthoppers and leafhoppers.

Data from the project area (Polonnaruwa District) indicate that the brown planthopper is considered the number one pest on paddy cultivation. There was only a light infestation this year, and about 200 hectares were affected in 1979. However, in 1974, the brown planthopper reportedly spread to 14,160 hectares, destroying more than 2,800 hectares of rice before being brought under control.

A rice swarming caterpillar (Spodoptera mauritia) caused an epidemic in the Polonnaruwa District in 1953 until it was controlled by Government spraying. Similar epidemics have not recurred.

The stem borer is not believed to be a problem in the region, and paddy bug is only a serious problem on early maturing or early planted rice. A late paddy crop encourages rice thrips to invade here, but the time of planting cannot always be controlled because it is dependent on rain; thus, late plantings require additional surveillance which is apparently often lacking. The green leafhopper is generally not an important paddy pest, but has been increasing in new irrigation schemes.

Sheath blight has caused some damage, but blast is reported as not being a problem anymore.

Stored rice is also damaged by insect pests. The two most prevalent are the angumois grain moth (Sitotrega cerealella) and the lesser grain borer (Rhizopertha dominica). Stored grain pests, including rats, mice, insects and molds, are reported to cause losses of 5-10%, but this figure appears low based upon world loss estimates. Storage losses are believed to be especially high at the farm level.

Sugarcane

Most of the sugarcane varieties used in Sri Lanka mature in 12-14 months. Yields continue to increase even if cutting is delayed until 18-24 months. In Sri Lanka, cane can be ratooned at least twice and sometimes three times. If yields fall below 20 tons per hectare, a field is replanted. Under irrigation, maximum yields are about 50 tons per hectare. Each year of ratoon yield declines. Yields under non-irrigated practices are never more than 35 tons per hectare.

Insect Pests - There are some 55 insect pests recorded on sugarcane in Sri Lanka. These are mostly local species that have adapted to sugarcane after it was introduced to the Island. There are more than 36 beneficial species and 16 indirectly beneficial i.e., one beetle feeds on microfungi smut spores (Rajendra 1976).

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Table J-4
Effects of Some Insect Pests on Rice Production

Insect Pest	Damaging Stage	Feeding Location	Damage	Control
Stem Borers Pink Striped Darkheaded Yellow	Larva	Leaf sheath or culm	Dead heart or white head	Chemical
Rice Gall Midge	Larva	Growing point	Onion leaf or silver shoot	
Rice Whorl Maggot*	Larva	Lower leaf margin	Leaf tissue	Chemical
Rice Hispa	Grub & Adult	Grub mines leaf Adult feeds on upper surface	Leaf tissue white areas	Chemical
Case Worm	Larva	Leaf	Leave only upper epidermis	Chemical
Rice Leaf Roller	Larva	Leaf	White streaks on leaf (roll)	
Rice Leaf Folder	Larva	Leaf	White streaks on leaf (fold)	
Army Worms	Larva	Upper portion of plant	Leaf - Leaves midrib	Chemical
Cutworms	Larva	Base	Cuts off plant	Chemical
Rice Bug	Nymphs & Adults	Grain	Poorly developed grain	
Rice Thrips	Nymphs & Adults	Leaf & spikelet	Unfilled grains or empty heads, leaf roll	
Mole Crickets	Adult	Below ground	Cuts plant at base	Flooding
Rice Black Bugs	Nymphs & Adults	Leaves & sheaths	Brown feeding holes	Chemical
Green leafhopper	Nymphs & Adults	Leaves & stems	Suck juices	Resistant var.
Zig-zag leafhopper	Nymphs & Adults	Leaves & stems	Suck juices	"
White-back Planthopper	Nymphs & Adults	Leaves & stems	Suck juices	"
Brown Planthopper	Nymphs & Adults	Lower leaves & stems	Suck juices (hopper burn)	Chemical

* Greater damage where rice is grown continuously

Source: Mueller (1974)

Table J-5
Effects of Selected Diseases on Rice Production

Disease	Carrier	Damage	Remarks/Control
Yellow Dwarf Virus	Brown Planthopper	Severe stunting & excessive tillering	Yellow-green narrow erect leaves dark spots and blotches
Grassy Stunt Virus	Green Leafhopper	------	Droopy leaves, yel. to yel. white
Tungro Virus	Green Leafhopper	Slight stunting & reduced tillering	Light yellow to orange-yel. leaves
Orange-Leaf Virus	Zig Zag Leafhopper	Similar to borer, kresek or rat	Dark Yel. to Orange Leaves
Bacterial Blight	-------	Pale green lesions from edge of leaf	Resistant varieties low fertility
Kresek	-------	Systemic form of bacterial blight similar to dead heart, iron deficiency, orange-leaf virus, mole cricket or rat	Young plants wilt & die
Bacterial Leaf Streak	--------	Yellowing of leaf blades High rainfall or humidity often associated with leaf rollers, leaf folders & hispa	Resistance or tolerate varieties Use low rates of nitrogen
Rice Blast (Fungus)	--------	Spindle-shaped lesions, larger ones with greyish centers in leaves & stems at nodes - neck rot High nitrogen & non-flooded conditions favor	New races develop quickly to overcome resistance Some fungicides control neck rot
Sheath Blight(Fungus)	--------	Greyish-green lesions on leaf sheath, enlarge & coalesce. Causes poor filling of grain, similar to neck rot	Resistant varieties, reduced nitrogen & wider spacing
False Smut (Fungus)	--------	Infection of panicles	May destroy mature kernels Resistance
Helminthosporium (Fungus)	--------	Germinating seeds, leaves & developing grain. Yellow halo around spot	Collect & burn diseased panicles Zinc or potassium deficiency or salinity problem

(continued)

Table J-5
(continued)

Cerlospora Leaf Spot (Fungus)	------	Short, narrow, brown spots on leaves Long & narrow	Resistant varieties
Stem Rot (Fungus)	------	Dark lesions at water line Causes lodging	Control borers Burn straw

SOURCE: Mueller (1974)

There are three species of insects and one nematode which can be damaging to cane in the specific major cane growing areas near Kantalai, Hingurana and Wellayaya. The pink borer from India, Burma and Malaysia is controlled effectively here by parasites and by keeping weeds a minimum of at least three meters from growing cane. Mealy bugs were a severe problem in the early 1960's, but are now so nearly eliminated by 13 species of parasites and predators that it is difficult to find a single specimen in an entire field (Rajendra 1977). A leafhopper, Pirella, was a problem in 1968 in the Wellawaya area, but a parasite has brought populations back within economic threshold levels. At Hingurana, there is presently a nematode problem in the more sandy soils of the area.

Work has been underway for a number of years in search of resistance in sugarcane island-wide for the shoot borer, Sesamia inferens. Experiments demonstrated that of 19 varieties tested, three were slightly less receptive to shoot borer than the commercially grown variety. The pest spends its early instars on graminaceous weeds (Rajendra 1973). Clean cultivation has reduced the incidence of this pest.

Termites are often a problem in cane land where jungle has been recently cleared. At present, termite damage is occurring to cane in the southern end of System C.

Disease - Smut is the most serious sugarcane disease problem, and variety plots have been designed primiarly to screen out susceptible strains. Some suppression is obtained by a fungus beetle which feeds on smut spores.

During wet weather, damping-off is a problem, and mosaic is present at times. Stunting is a problem which is controlled in the primary nursery by hot water treatment, but sheer logistics make treatment impossible for secondary nursery and field planting.

Other Crops

Common insect pests or diseases which affect vegetables, and other crops which are presently or will be grown in the project area are tabulated below:

Coconut
- Coconut leaf miner Promecotheca cumingi
- Coconut caterpiller Nephantia serinopa
- Black rhinocerus beetle Orgetes rhinocerus
- Termites
- Red Weevil Rhynocophorus furugineus
- Bud rot disease Phytophthorn palmivora and Pnicotinana
- Leaf blight Helminthosporium incurvatum
- Coconut leaf scorch

Tea
- Shot hole borer Xyleboms fornicatus
- Mites of several species
- Livewood termite Postelectrotermes miltaris
- Meadow eelworms Pratylenchus roosi
- Red root disease Poria hypolateritia

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Blister blight disease Exobasidium vexans
Red rust disease Cephaleuros parasitious
Black blight disease Rhizoctonia solani

Rubber
No insect of importance
Oidium leaf disease Oidium heveae

Chillie
Anthracnose Collectotrichum capsici

Tobacco
Brown spot Alternaria longipes

Pumpkin
Mosaic Cucurbita moxima

Onions
Onion caterpillar Spodoptera exigua

Tur Dhal
Pod borer complex

Cabbage
Diamond back moth Xylestella maculipennis

Egg Plant
Shoot borer Leuxinoswa orbonalis
Stored grain and cowpea Calosobruchus maculatus

Potato
Late blight Phytophthera infestana
Mosaic
Leaf curl

Maize and Sorghum
Stem borer Chilo zonellus
Shoot fly Atherigona soccata
Cob borer Helicoverpa armigera

Vegetable Crops
Damping off (nurseries) Pythium sp.
Rhizoctonia sp.
Macrophomina sp.

MAMMALS, BIRDS AND OTHER PESTS

Crop damage from mammals, birds and a few other pests are discussed briefly here; more detailed information for a number of species is presented in TOPIC REPORT E: WILDLIFE and TOPIC REPORT I: AQUATIC VEGETATION.

Mammals

Elephants - Elephants have been reported to cause considerable damage to crops, especially paddy and sugarcane, in and around the project

area. The Kantalai Sugar Corporation has suffered losses valued at about three million rupees due to elephant activity from 1977 to 1979. The Sugar Cane Research Institute at Kantalai reports that a group of six or eight elephants can damage two to five hectares of sugarcane in one night. In the past, the elephant/wild boar watchers have driven the elephants 13-16 kilometers back into the jungle. This keeps that group out for two to six months. Vigilance is maintained on those tracts closest to the jungle. The permanent watch consists of 49 men who also have other duties. The average monthly pay per watcher is Rs. 500.

Elephant damage to paddy can be extensive, especially in agricultural areas adjacent to the jungle. Interviewed farmers from four villages in the same vicinity of the project area reported a total of 4.3 hectares of paddy completely destroyed and another 4.2 hectares partially damaged by elephants in a single evening. Once in the paddy field, an elephant causes as much as or more damage to crops by physically trampling them as it does eating them.

Elephants have caused considerable damage to teak plantations, in one instance destroying areas valued for future revenue at $75 million. Another plantation reportedly has suffered damage amounting to about $2 million for each of the past several years. Elephants have also caused damage to banana plantations and livestock farms.

Wild Boars and Rats - In 1973 at the Kantalai Sugarcane Plantation, 25% of the sugarcane stalks were damaged by wild boars which resulted in a loss of more than five million rupees (Rajendra 1973 b). In 1976, after a rigorous control program, damage from the boars was reduced to less than 3%. However, rats increased in population due to the absence of the boars and, subsequently, rat damage increased from zero to 3%. Also, snakes apparently increased in numbers to such an extent that many plantation workers were bitten. In addition to sugarcane, rats destroy growing rice, pulses, cacao beans, copra, etc., as well as grains, legumes and other seeds in storage. The rice field mole rat (*Bandicota bengalensis*) is particularly damaging to paddy.

Wild boars, like elephants, cause damage to other crops as well; including paddy and various vegetables. Singly, or in combination, these two species have caused the complete destruction of paddy and other crops in some areas, especially in the immediate vicinity of natural habitats.

Birds

Munias are a serious problem in paddy and sugarcane nurseries especially in breeding plots where they feed on tassels. The worst problem is on the edges of paddy and sugarcane. The latter also serves as an excellent roosting site, from which munias descend often in great numbers on paddy fields nearby. It has been suggested (Amaratunga 1980) that munias in the Hingurana sugar area were reduced by insecticides used in nearby paddy. This was not confirmed, and as far as can be determined, no tests have been conducted here.

Parakeets are also an important pest on rice paddy areas and in fact may be a more serious concern than the munias. In the Kantalai area, the loss of rice crops to munias and parakeets is estimated at about 5% per year (Mr. K. P. Pathmantha, personal communication).

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Weeds

In the project area, three aquatic weed species have already infested relatively large areas. These are cattails (Typha), floating fern (Salvinia) and water hyacinth (Eichhornia crassipes) which are discussed in detail in TOPIC REPORT L: AQUATIC VEGETATION.

A particularly effective weed which invades rice paddies in Sri Lanka is Echinochloa crusgalli. Rocheconste (1979) presented a detailed proposal for control of this and other agricultural weed problems. Recommendations were made for a sound research program by crop and/or area, for supporting staff, laboratory facilities and for equipment needed in monitoring.

PEST CONTROL

Control of mammal and bird pests is generally by means of surveillance, often day and night. Elephants and wild boars cause most damage in the evening hours, while birds attack the crops in daylight. When detected, the animals are frightened away by various means, including shooting. Most rural farmers have at least one shot gun or rifle which is kept loaded at all times. Rats, and even wild boars, are poisoned in some areas to reduce their numbers.

For the control of insect pests and diseases, the Agricultural Department and its Experiment Stations have published sound recommendations with clear instructions. Control methods have been varied including the use of resistant crop varieties, parasites, predators, cultural and mechanical practices and water management and manipulation. However, the control of insect pests, plant diseases and weeds is predominantly by means of pesticides, fungicides and herbicides.

Pesticide Usage

Present pesticide application methods in Sri Lanka are summarized in the recommendations provided by Manickavasagar (1979) and other reports from the Agriculture Department. An exhaustive list of nomenclature and formulations of pesticides in Sri Lanka has recently been compiled by Boone and Ramasunderum (1980). The importer-formulating companies in the private sector through various advertising, promotion activities and with trained technical representatives conduct demonstration plots with Extension Officers. This has some educational value. As elsewhere in the world, many farmers depend on the word of the basic supplier and retailer because he is a friend and is available.

The cos· of pesticides in relation to total costs for cultivation are presented for a number of crops in Table J-6. Historical data concerning the use of pesticides and their respective costs with respect to production are variable (Anandasayanam 1969; Izumi and Ranatunge 1972, 1974; Wilerams 1977). However, it is evident that the costs of pesticides for most crop applications have risen significantly in the past ten years, reflecting the increase in petroleum prices. For example, the cost of pesticides (herbicides and insecticides) used on paddy in 1968-1969 was estimated at about 23 dollars per hectare (Amaratunga 1969); this has increased to more than 40 dollars per hectare last year (Manickvasagar 1977). To illustrate further, based upon current prices from local importers, a single application of 3% carbofuran

Table J-6

Cost of Pesticides as percent of Total Farm Costs

(Cost in US $ per hectare)

C r o p	Total Cost	Agro-chemicals (all pesticides)	%
Irrigated rice	324.64	46.48	14.3
Rainfed rice	232.11	40.67	17.5
Irrigated chillies	764.01	206.25	26.99
Rainfed chillies	344.52	37.76	10.96
Irrigated peanut	325.93	0.00	0.00
Rainfed peanut	248.98	0.00	0.00
Rainfed tobacco	600.46	26.14	4.35
Rainfed manioc	275.98	0.00	0.00
Rainfed sweet potato	396.54	0.00	0.00
Irrigated green gram	222.56	14.52	6.52
Rainfed green gram	179.71	11.62	6.47
Irrigated cowpea	207.01	29.05	14.03
Rainfed cowpea	180.86	14.52	8.03
Irrigated black gram	201.93	14.52	7.19
Rainfed black gram	170.99	11.62	6.80
Irrigated soybean	281.84	14.52	5.15
Rainfed soybean	241.88	14.52	6.00
Rainfed maize	158.24	0.00	0.00
Rainfed sorghum	176.84	0.00	0.00
Sugarcane	211.70	38.22	18.05

Sources: Manickavasagar (1979) as derived from Research and Seed Multiplication Station of the Department of Agriculture.

Sugar Cane Research Institute (personal communication)

to control rice brown planthopper, rice gall midge or rice stem borer would cost about 20 dollars alone.

In Table J-7 the pesticides used both past and present in Sri Lanka, for which some toxicological data is available in the literature, and the respective toxicities to rats and rabbits, are listed. Toxicities are shown as acute LD_{50} ($AOLD_{50}$) and acute dermal LD_{50}($ADLD_{50}$) to rats and rabbits (Kenaga and Morgan 1978). The term LD_{50} means that of the number of animals treated at the rate or range indicated in micrograms per kilogram (mg/kg), 50% died. In interpreting the data it should be remembered that the higher the number, the less toxic or more safe the compound is to warm blooded animals. A range in mg/kg indicates that the lowest to the highest are given when data from several sources taken at different times and under different conditions are pooled.

Also shown for the same compounds, where data is available, is the maximum accepted daily intake (adi) for humans and the maximum residue limit (mrl) on foods. In this report it would be too cumbersome to list for each pesticide the residue limit for each food item in the world. As a rule of thumb, the lowest figure is usually for such products as eggs, milk, fish and red meat. The higher limits are usually for products which have a heavy husk or rind or receive extensive processing prior to being used as food or feed. The establishment of adi's and mrl's for pesticides is a slow and careful process and some of the data shown is tentative.

Pesticide Imports

Unfortunately, the last year of complete records for "Agro-chemicals Imported" into Sri Lanka was 1975. An "Approved List of Requirements of Agro-Chemicals 1977", (Ministry of Agriculture and Lands 1976) was obtained as well as "Estimated Requirements of Agro-Chemicals for Paddy and Subsidiary Food Crops Excluding Vegetables in Maha 1968/69 and Yala 1966" (Amaratunga 1970). Comparisons for these three sets of data are shown in Table J-8. This paucity of vital current data places a serious handicap on the evaluation of trends and requirements for nationwide use of agro-chemicals.

External Trade Statistics based on the International Trade Codes were obtained from the Sri Lanka Customs for 1975, 1978 and 1979. These data provide estimates of only the major categories of pesticide imports as follows (in tons):

Category	1975	1978	1979
Disinfectants	---	21	72
Insecticides	449	958	2,419
Fungicides	224	1,095	238
Herbicides	13	541	313
Others	11	1,665	73

These figures demonstrate the significant increase in the importation of pesticides within the past five years. However, the figures are relatively unreliable. In a nation of long established pesticide use, it is difficult to understand how insecticide importation would increase more than 2½ times and that fungicides would drop more than 4½ times in a single year (1978 to 1979).

According to USDA reports (Fowler 1977), no DDT has been exported to Sri Lanka from the USA since 1969. Exports of DDT worldwide from the USA were 498,000 pounds in 1977, down from 25.4 million in 1976 (Fowler 1978).

For the foreseeable future it is expected that most Asian nations will continue to rely on imports of pesticides from makers in Japan, Western Europe and North America. Pesticide consumption is expected to almost double between 1973 and 1985. The largest growth (fourfold) is expected in fungicides (C & E News 1979).

Table J-7

Toxicity of Insecticides, Accepted Daily Intakes and Maximum Residue Limits Guidelines

INSECTICIDES	RAT AO LD_{50} mg/kg	RAT AD LD_{50} mg/kg	RABBIT AD LD_{50} mg/kg	MAX.adi mg/kg Body wgt.	GUIDE LINE or Max.Res.Limi mg/kg
Acetellic	2050	>2000	-	0.01	0.05 - 50
Aldrin	39-60	-65-90	-	0.0001	0.05
Anthion	365-500	>1000-1680	-	0.01	0.1-2.0
Azodrin	18-21	112-126	354	0.0006	0.02-1.0
Baygon	83-104	>1000->2400	-	0.02	0.05-5.0
Bayrusil	62-137	800-1400	-	-	-
Baytex	255-740	300-400	-	0.0005	0.05-2.0
Baythion	1891-2077	1126	-	-	-
BHC	600-1250	-	-	0.01	0.1-2.0
BUX	87-170	-	400	-	-
Chlordane	283-590	580->1600	-	0.001	0.02-0.3
Cygon	28-500	>150-1150	-	0.02	0.3-2.0
Diazinon	66-600	379-1200	4000	0.002	0.1-2.0
Dipterex	450-630	>2000	5000	0.005	0.1-1.0
Dursban	82-245	202	2000	0.0015	0.01-2.0
Endosulfan	18-110	74-130	360	0.0075	0.1-2.0
Etrofolan	178-485	>500	-	-	-
Folimat	50	1400	-	0.0005	0.05-3.0
Furadan	8-14	-	10,200	0.003	0.05-50
Lannate	17-24	-	5,000	None	0.02-10
Malathion	885-2800	>4000-4444	4,100	0.02	8

(continued)

Table J-7
(continued)

INSECTICIDES					
Metasystox-R	47-75	100-250	-	0.005	0.05-10
Papthion	200-2000	>4000	-	-	-
Parathion	3-30	4-200	40-870	0.005	0.5-1.0
Sevin	307-986	>500-4000	-	0.1	0.1-100
Supona	15-56	3-108	420-1140	0.002	0.1-0.4
Tamaron	13-30	110	118	0.002	0.01-5.0
Trithion	6-100	22-66	1250	None	0.02-5.0
FUNGICIDES					
Arasan	375-865	-	-	0.005	-
Benomyl	-	-	-	None	0.1-5.0
Captan	9000	-	-	0.1	5.0-400
Daconil	>10,000	-	-	0.03	0.1-30
Difolatan	2,500-6,200	-	>15,400	0.05	0.05-15
Dithiocarbamate	-	-	-	0.005	-
Lutrol	150-340	-	-	0.003	0.01-0.2
Manzate	6750	-	-	0.005	-
Panagen	-	-	-	0.005	0.05-3.0
Parzate	5200	-	-	0.005	-
Phaltan	>10,000	-	>22,600	0.1	15-20
Cuprous oxide	470	-	-	-	-
Dithane M-45	>8,000	-	-	-	-
Kasumin	22,000	-	-	-	-

(continued)

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Table J-7
(continued)

HERBICIDES					
Alachlor	1800	-	5000	-	-
Benthiocarb	1300	2900	-	-	-
Butachlor	3300	-	>250	-	-
Dalapon	7570-9330	-	-	-	-
Diuron	3400	-	-	-	-
Glyophosate	3925	-	-	-	-
Linuron	1500	-	-	-	-
MCPA	800	-	-	-	-
Metribuzin	1090-1206	-	-	-	-
MSMA	1800	-	-	-	-
Nitralin	>2000	-	>2000	-	-
Paraquat	120	-	> 480	0.002	0.01-2.0
Propanil	1800	7080	-	-	-
Sodium Chlorate	>5000	-	-	-	-
Simazine	5000	-	-	-	-
2,4 - D	300-1000	-	-	0.3	0.02-2.0
2,4,5 - T	300	-	-	-	-
ACARICIDES:					
Dicofol	575-1331	1000-1230	2100	0.025	1-5

SOURCE: FAO/WHO (1973 - 1977)

Table J-8

Agrochemicals - Sri Lanka

INSECTICIDES

Name & Formulation	A Trade Name	Estimated Imports 1968 - 9		Customs Report 1975		Estimated Requirements 1977	
		Metric tons	Liters	Metric tons	Liters	Metric tons	Liters
Aldrin 25 EC	Aldrin	-	1800	-	2,389	-	3,974
Aldrin 2.5 D	"	-	-	12.5	-	25	-
BHC 1.3 D	Gammexane	11.5	-			-	-
BHC 10 D	"	-	-	250	-	58	-
BHC 20 EC	"	-	20,450	-	2,955	-	4,920
BHC 6 G	"	1.6	-	10.5	-	21	-
BPMC 50 EC	Bassa	-	-	-	17,616	-	29,334
Bidrin	Bidrin	-	14	-	-	-	-
Bufencarb 20 EC	Bux	-	-	-	4,660	-	-
Carbaryl 85 WP	Sevin	-	72	10	-	20	-
Carbofuran 3 G	Furaden	-	-	100	-	200	-
Carbophenothion 20 EC	Trithion	-	-	-	5,683	-	9,463
Chlorofenvinphos 24 EC	Supona	-	-	-	2,273	-	3,785
Chlordane 40 EC	Chlordane	-	-	-	568	-	946
Chlorpyriphos 40 EC	Dursban	-	-	-	11,365	-	18,925
DDT 25 EC	DDT	-	30,300	-	-	-	-
Demeton 40 EC	Metasystox R	-	72	-	2,614	-	4,352
Diazinon 10 G	Diazinon	0.4		14	-	28	-
Dimethoate 40EC	Cygon	-	-		8,128	-	13,531

Notes: Numbers in formulations = %
D = dust
EC = emulsifable concentrate
G = granules
WP = wettable powder

(continued)

INSECTICIDES

Table J-8
(continued)

Name & formulation	A Trade Name	Estimated Imports 1968 - 9		Customs Report 1975		Estimated Requirements 1977	
		Metric Tons	Liters	Metric Tons	Liters	Metric Tons	Liters
Endosulfan 35 EC	Thiodan	-	-	-	12,956	-	21,574
Endrin 20 EC	Endrin	-	26,730	-	-	-	-
Fenitrothion	Sumithion	-	2,800	-	-	-	-
Finthion 50 EC	Baytex	-	57	-	-	-	26,495
Formothion 25 EC	Anthio	-	2,800	-	1,705	-	2,839
Isoprocarb 50 WP	Etrofolan	-	-	3.5	-	-	-
Malathion 50 EC	Malathion	-	7,430	-	-	-	-
Methamidophos 60 EC	Tamaron	-	-	-	11,501	-	19,152
Methomyl 90 WP	Lannate	-	-	5	-	5	-
Methomyl 18 EC	"	-	-	-	14,775	-	24,603
Monocrotophos 60 EC	Azodrin	-	-	-	24,094	-	-
MPMC 30 EC	Meobal	-	-	-	1,023	-	1,703
Omethoate 50 EC	Folimat	-	-	-	4,546	-	3,785
Parathion 50 EC	Parathion	-	6,050	-	11,479	-	5,050
Permethrin 25 EC	Ambush	-	-	-	1,137	-	-
Phenthoate 50 EC	Elsan	-	-	-	227	-	379
Phoxim 50 EC	Baythion	-	1,460	-	1,137	-	-
Pirimiphosmethyl 50 EC	Actellic	-	-	-	8,810	-	14,667
" 2D	"	-	-	5	-	5	-
Propoxur 3G	Baygon	-	-	-	-	50	-
" 20 EC	"	-	-	-	-	-	11,355
Quinalphos 20 EC	Bayrusil	-	-	-	3,410	-	6,198
Sulphur 80 WP	Sulphur	-	-	14	-	28	-
Surmiedin	-	-	-	-	227	-	-
Trichlorphon 50 EC	Dipterex	-	2,400	-	5,683	-	2,300

(continued)

Table J-8

(continued)

FUNGICIDES

Name & Formulation	A Trade Name	Estimated 1968 - 69		Customs Report 1975		Estimated Requirements 1977	
		Metric Tons	Liters	Metric Tons	Liters	Metric Tons	Liters
Antimucin	-	-	-	-	455	-	757
Benomyl 50 WP	Benelate	-	-	3	-	3	-
Brunolium Platarium	-	-	-	-	227	-	379
Captafol 80 WP	Difolatan	-	-	4	-	8	-
" 4 EC	"	-	-	-	1,818		3,028
Captan 50 WP	Orthocide	-	-	4.5	-	9	-
Carbendazim	-	-	-	-	227	-	379
Casugemycin	-	-	3,250	-	-	-	-
Chlorothalonil 75 WP	Daconil	-	-	6	-	12	-
Complex Dithiocarbamates	Macozeb	0.5	-	11.5	-	23	-
Copper Oxychloride 50 WP	Cupravit	-	-	19	-	38	-
Cuprous Oxide	Perenox	1	-	33	-	66	-
Edifenphos 50 EC	Hinosan	-	-	-	1,137	-	1,893
FDD	-	5	-	-	-	-	-
Flymac	Flyomac	-	-	-	455	-	755
Folpet	Phaltan	-	-	0.25	-	0.25	-
Fomao	-	-	-	-	455	-	755
Kasugamycin 2D	Kasumin	-	-	-	277	-	189
Mancozeb 75 WP	Dithane	-	-	11.5	-	23	-
Maneb 80 WP	Manzate	0.2	-	11.5	-	23	-
Mema 0.6EC	Panogen	-	-	-	227	-	189

(continued)

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Table J-8
(continued)

FUNGICIDES

Name & Formulation	A Trade Name	Estimated 1968 - 69		Custom Report 1975		Estimated Requirements 1977	
		Metric Tons	Liters	Metric Tons	Liters	Metric Tons	Liters
MEMC 3.5 WP	-	-	-	0.25	-	0.25	-
Mercuric Chloride 3.5 WP	-	0.2	-	-	-	-	-
" " D	-	-	8,600	-	-	-	-
PMA 1D	-	-	-	5	-	0.25	-
Propineb 70 WP	Antracol	-	-	12.5	-	25	-
Quintozene 20D	-	-	-	-	-	5	-
Sulphur 80D	-	0.3	-	100	-	200	-
Thiram 80WP	-	0.5	-	0.25	-	0.25	-
Zineb 80 WP	-	7.75	-	1	-	1	-

(continued)

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Table J-8
(continued)

HERBICIDES

Name & Formulation	Estimated Imports 1968 - 9		Customs Report 1975		Estimated Requirements 1977	
	Metric Tons	Liters	Metric Tons	Liters	Metric Tons	Liters
Alachlor 40 EC	-	-	--	3,410	-	5,678
Benthiocarb 6 G	-	-	12.5	-	25	-
Butachlor 5 G	-	-	12.5	-	25	-
Dalapon 85 WP	-	-	8	-	16	-
Divron 80 WP	-	-	4.5	-	8.5	-
Glyphosate 35 EC	-	-	-	2,273	-	3,785
Linuron 50 WP	-	-	0.25	-	0.25	-
MCPA 3G	-	-	5	-	5	-
MCPA 40 EC	-	335,000	-	116,832	-	194,550
Methabenzthiazuron 70 WP	-	-	3	-	5	-
Metribuzin 70 WP	-	-	3	-	3	-
MSMA 70 EC	-	-	10	-	20	-
Nitralin 75 WP	-	-	3.75	-	7.5	-
Paraquat EC	-	25,500	-	72,963	-	121,500
PCP	2.75	-	-	-	-	-
Piperophos & Dimethametryn	-	-	0.25	-	-	-
Propanil 40 EC	-	-	-	59,098	-	98,410
Simazene 50 WP	-	-	1	-	1	-
Sodium Chlorate 40 WP	-	-	5	-	10	-
2,4 - D 50 EC	-	16,100	-	909	-	1,514
2,4,5 - T 50 EC	-	-	-	68	-	57
2,4 - D 3G	-	-	2.5	-	2.5	-
2,4 - D Sodium Salt	-	-	4.5	-	9	-
3.4 - D PA	-	133,000	-	-	-	-

(continued)

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Table J-8
(continued)

Name & Formulation	Estimated Imports 1968 - 9		Customs Report 1975		Estimated Requirements 1977	
	Metric Tons	Liters	Metric Tons	Liters	Metric Tons	Liters
ACARICIDES						
Dicofol MF 42 EC	-	7,570	-	4,546	-	7,570
Oxyt quinox 50 WP	2	-	-	-	2	-
NEMATICIDES						
Dibromochloropropane 20 G	2	-	-	-	2	-
Pensulfothion 20 G	5	-	-	-	5	-
OTHERS						
Chlorophacinone 0.25%	-		-	205	-	340
Coumarin 1%		-	3.5	-	3.5	-
Coumatetralyl 0.75%		-	2.5	-	2.5	-
Metaldehyde		-	5	-	5	-
Phostoxin (Tablets)					140	
FUMIGANTS						
DD			-	-	-	18,925
Methyl bromide		-	-	-	25	-

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IMPACT ANALYSIS

SPREAD OF EXISTING INSECT PESTS AND DISEASES

Implementation of the proposed Accelerated Program will result in the cultivation of large areas under cropping patterns similar to those existing in other parts of the country. Paddy, the predominant crop nationwide (see Tables J-1 and J-2), will also become the principal crop in the project area. Other crops expected to be grown in the region will include sugarcane, chillies, onions, pulses and vegetables, all of which are also commonly found in the country. Since there are no geographical barriers to prevent the movement of any known insect pest or plant disease, it is anticipated that the crops proposed for the project area will be susceptible to damage from the same pests found in other parts of the island. These were presented in detail, especially for paddy, in the previous section on EXISTING CONDITIONS.

The potential spread of pests to new crops may be increased due to the present cropping within the project area. The fact that some scattered paddy and other crops are presently grown in the area means that some small infestations of insect pests, crop plant diseases and problem weeds are already present. The proximity of these cultivation areas to the proposed cropping sections enhances the possibility of a rapid and extensive spread of insects and diseases to the new crops.

With the present situation, cropped areas for most of the project area are limited and scattered in a mosaic pattern surrounded largely by natural wildlife habitat. This enables natural insect predators including birds, bats and other insects to maintain insect pest levels below economic thresholds. However, development of the Accelerated Program will remove extensive sections of wildlife habitat and thus eliminate a substantial amount of natural predator control. This will in turn, necessitate additional chemical control measures especially in the extensive paddy and sugarcane monoculture areas planned for the future.

MAJOR PEST EFFECTS ON PADDY

Since paddy will be the principal crop in the project area some attention should be paid to at least the major insect pests and diseases which are likely to cause damage to it.

The intensification of rice agriculture throughout Southeast Asia has brought about in most areas some general changes in the importance of specific pest damage on paddy (Glass et al. 1971). The most notable shifts in importance or intensity of pest activity in rice growing regions has been a significant increase in the effects of brown planthoppers and in sheath blight. Correspondingly there has been a reduction in the overall activity of stem borers and rice blast. These changes reflect the resistance and/or effectiveness of chemical control measures as well as the changes in rice varieties, water usage and other factors.

Similarly, this pattern is already evident for the project area. The brown planthopper is considered the number one insect pest of paddy cultivation in the Polonnaruwa area, while stem borers are no longer believed to be a serious problem; also, sheath blight reportedly causes some damage but rice blast has ceased to be a problem. Consequently, in all likelihood

the brown planthopper could become one of the main insect pests to contend with following implementation of the Accelerated Program. Another insect pest which may become significant is the green leafhopper which has recently increased in some new irrigation schemes. A secondary impact of the presence of this species and the brown planthopper should be considered, since both of these insects are also carriers of viruses which are detrimental to rice.

The shift from a single cropping pattern to double or triple cropping in some areas will result in a cumulative increase in pests and will require additional chemical application. In addition, double or triple cropping or the avoidance of floods may require an alteration in the time of planting to meet necessary cropping and water usage schedules. Shifts of this nature usually favor the build-up of particular pest species. For example, it has been demonstrated in Sri Lanka that late plantings encourage the increased infestation of rice thrips, while paddy bugs can be expected to increase on early planted and early maturing paddy. In addition, poor water management has been shown here to cause severe damage to paddy from the rice gall midge.

POTENTIAL SPREAD OF NEW PESTS

Spread from Within the Project Area

Much of the area has not been cropped in the past and there are likely to be many undescribed species of plants and animals in the present jungle. Even so, the odds would appear to be on the side of there being no indigenous pest species which are not presently known. There is always the possibility that a species, especially an insect, when deprived of its natural host will move to a desirable or adaptable alternate crop plant. All insect species are not one host specific - sometimes not even restricted to one family of plants. Insects are probably the most adaptable of all animals - if they can adapt to resist chemical insecticides they can feasibly adapt to a new host plant unless they fit a very restricted ecological niche. But with the many centuries of cultivation in the past history of Sri Lanka it will be surprising if a novel, but potentially major, crop insect pest inhabits the Mahaweli Ganga Basin.

Introduction from Outside Sri Lanka

As far back as 1924, Sri Lanka had a Plant Protection Ordinance which the Legislature revised in 1956 and strengthened further in 1957 (Government of Ceylon 1957, 1960 and 1968). In addition to establishing a basic detection and quarantine system, specific and detailed instructions are given for the destruction of 12 insects, four plant diseases and four weed pests and/or their host material. Among the weeds are water fern (*Salvinia auriculata*) and water hyacinth (*Eichhornia crassipes*). However, present surveillance is inadequate, and if efforts to enforce quarantine regulations continue to lag, coconut, chilli, paddy, plantain, rubber and tea production could be seriously affected in the future.

According to the Department of Agriculture and information reported by Litsinger (1979), the following insect pests of rainfed wetland rice are relatively common in other areas of tropical Asia, but not presently found in Sri Lanka:

Top borer Tryporyza nivella
Rice hairy caterpillar Rivala atimeta
Fijian leaf folder Susima exigua
Rice bug Leptocorisa oratorious
Malayan black rice bug Scotinophora coactata
Bombay locust Patanga succincta
Oriental migratory locust Locusta migratoria manilensio
Small rice grasshopper Oya chinensis
Rice mealy bug Brevennia rehi
Rice root weevil Echinocnemus oryzae

With the exception of the two locust and one grasshopper species, it seems possible that any one of the above pests could be introduced under the present poor quarantine surveillance.

The sudden introduction of a pest previously unknown into a susceptible cultivation scheme could result in extensive crop damage before control measures could be implemented.

IMPACTS OF PESTICIDE USAGE

Increased Imports

With the development of the Accelerated Program, the significant increase in proposed cultivated areas, coupled with the intensification of agriculture practices through double and triple cropping, will necessitate a substantial increase in the use of insecticides, fungicides and herbicides to control potential insect pests. Imports of pesticides will have to be increased accordingly. Based on a straight relation to imports in 1975 (the latest official figures) the additional requirements for all pesticides would be about 115 metric tons of dusts, wettable powders and granules and 66,000 litres of liquid formulations.

Pesticide Accumulation

The increased use in pesticide applications will result in their further accumulation in the environment. Pesticides present in the atmosphere, water and soil have the capability to penetrate living organisms. After entering an animal body, such chemicals as the persistent organochlorine compounds are preferentially absorbed by the fat bodies in animals. These play an important role in the phenomenon of bioaccumulation.

When an animal is placed in a physiological condition which causes it to draw on its reserves of fat, the stored organochlorine compounds are transported to a site where their toxic action takes effect (Hascoet et al. 1978). This is best exemplified by fish, shrimp and other aquatic organisms, many of which undergo seasonal feeding and non-feeding periods. The latter may be due to the onset of spawning of the limited availability of food in the latter part of the dry season. In any event, during a non-feeding or heavy stress period fish utilize all of the energy reserves, eventually mobilizing stored fat. At this time, the toxic pesticides accumulated in the fat are released into the blood stream and can result in mortality or harmful side-effects.

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Pesticide residues usually magnify through the food chain; thus, species at the top of the chain are feeding on other species which have a high pesticide concentration in their fats. For example, many water fowl species which feed upon pesticide-laden aquatic vegetation or fish have eventually accumulated levels high enough to cause mortality and/or reduce fecundity. The latter has often resulted from the production of egg shells which are too thin to support chick embryos.

Similarly, it is generally believed that pesticide residues introduced into the human food chain are less likely to be from those foods of plant origin which have received pesticide applications than from food or animal origin. Animals fed processing wastes have an opportunity to consume plant products containing high residues and thus store large quantities of certain pesticides, i.e. chlorinated hydrocarbons in their body fat which are then assimilated by human consumers (Polen 1971).

Fortunately, the trend in Sri Lanka is directed away from the highly stable chlorinated hydrocarbons to the organo-phosphorous and carbamate insecticides which have lower persistence and lower accumulation in animal tissue and the environment. However, increased accumulation of harmful pesticides in the environment will probably be unavoidable considering the magnitude of the proposed project.

Resistance to Pesticides

The continued use of an insecticide on an insect pest can result eventually in the establishment of resistant strains or sub-populations of the pest. These resistant strains will continue to expand in numbers with further exposure to the same pesticide until the specific pest population will be dominated by the resistant form. Thereafter, continued use of the pesticide originally intended to control the pest will be ineffective. This can then result in an extensive proliferation of the pest with substantial damage incurred until a new control can be found. It is impossible to predict when this might happen or which species would be affected in the project area. However, the possibility of resistant pests developing is a real concern since some of the present pests have been known to produce resistant forms in other areas of the world.

IMPACTS OF WEED, BIRD AND MAMMAL PESTS

As with insect pests, damage from weeds, birds and mammals is likely to occur in a manner similar to that presently observed in other cultivated areas of the country. The spread of aquatic weeds through paddy areas usually occurs as a result of poor water management and inadequate surveillance. Impacts from aquatic weeds are discussed more fully in TOPIC REPORT I: AQUATIC VEGETATION. Bird and mammal damage is covered in detail in TOPIC REPORT E: WILDLIFE, but is summarized here as well.

Potential crop losses due to munias and parakeets are liable to be significant in some areas. A particular concern would be the munia damage which could occur to rice crops which are located near sugarcane fields. The sugarcane serves as an excellent nesting habitat for the munias. Consequently, when sugarcane would be located in the vicinity of rice lands (as variously proposed for Systems D or C), a large munia population would be harbored in

close proximity to a preferred foodstuff. The losses to the rice areas in this case would probably greatly exceed normal bird losses which are attributed at about 5% of total production.

Rat populations in the project area are expected to increase due to the elimination of their natural predators and the provision of suitable rat habitat in and around settlements and cultivated areas. Rats would be expected to cause significant damage without controls to both growing and stored rice. Generally, even with pest management controls, farmers would probably sustain unavoidable crop losses of about 10% due to the combined effects of weeds, insects, diseases and rats.

Invariably, some areas planned for future cultivation will be located adjacent to, or in the vicinity of natural habitats which support large populations of elephants, wild boar, deer and other potential mammal pests to rice or sugarcane. This situation may be more pronounced in "high-quality habitat" areas, i.e. those with a high degree of wildlife activity, which are slated for development and/or in areas where pocketing of animals occurs following land clearance (see TOPIC REPORT E: WILDLIFE). The principal high-quality habitat areas which are planned for cultivation include the northern portion of System C and the northern part of the existing Somawathie Sanctuary. Following clearing, these will be high risk areas which are likely to incur significant crop damage due to wildlife in general, in addition to possible losses of human life because of encounters with elephants in particular. Crop losses in these high risk areas may be total for some individual farmers; however, based upon other damage records, a reasonable estimate of average crop loss in the high risk areas would be about 20% due to physical wildlife damage and feeding. Coupled with additional losses due to weeds, rats, insect pests and diseases, farmers in these areas may suffer actual crop losses of about 30%. This would probably occur for a period of five years or so, until the larger wildlife pests could be killed or effectively driven out of the area. The secondary loss to wild animals, especially elephants, may be significant in the high risk areas. Many will be shot by farmers, although probably after they have caused considerable damage.

RECOMMENDED ACTIONS

INTEGRATED PEST MANAGEMENT

To recommend that an integrated pest management approach be adopted to minimize potential pest problems appears to be obvious. Benefits of integrated pest management are numerous, especially in the areas of crop protection and the proper use of pesticides to limit their spread and accumulation in the environment. Integrated pest management is aimed at maintaining yields at normal levels, decreasing total test management expenditures and reducing risk by distributing information with which to deal with specific insect pest problems.

General recommendations for developing key components of an integrated pest management program would include the following:

- Survey losses due to pest damage and identify pests as they occur;
- Establish economic thresholds for at least the most important pests;
- Establish chemical treatment levels below which growers should not apply chemicals and distribute this information through the mass media;
- Increase applied research in field crop production;
- Limit the importation of potential pests;
- Improve activities and capabilities of extension;
- Prepare and distribute new training materials;
- Monitor pesticide residues in food, water, air, soil, non-target plants, and animals;
- Establish an effective program to reduce post-harvest losses;
- Expand reference collections for identification of insects, plant diseases and weeds at the Peradeniya Central Research Institute and at the National Museum;
- Improve and update resource literature for the extension workers and provide them with exhibits of common pests for demonstration purposes;
- Increase support staff of qualified chemists for the pesticide and soils laboratories; and
- Place an adequate number of trained extension workers in the Accelerated Program area when it is settled.

These recommendations are discussed in varying detail in the following sections. It should be noted that some of these recommendations are being developed to a certain extent by various government agencies.

LIMITING THE SPREAD OF PESTS

While the complete prevention of the spread of existing pests, especially insects and diseases, is not practical, there are some immediate steps which can be taken to minimize the potential proliferation of some pests in the project area. Specific data from cultivated portions of the project area should be

collected and analyzed to determine potential pest species and allow for the preparation of control measures prior to project implementation.

This may require field surveys, especially to identify pest problems in the more remote areas. One simple method of monitoring these presently isolated sections would be by means of inexpensive kerosene lamps to attract insects (IRRI 1979). Foci of pest infestation should be identified and pest populations should be destroyed if possible prior to extensive cultivation. Such an operation would prevent a pest explosion or at least several years or respite for new settlers.

Every effort should be made, by education of the incoming settlers in advance, to prevent the introduction of noxious weeds or seeds into the area. Special emphasis should be placed on keeping out such aquatic weeds as Eichhornia crassipes and Salvinia molesta.

Similarly, quarantine restrictions should be strengthened and more strictly enforced to prevent the introduction of potentially destructive insects, plant diseases or noxious weeds to the country.

GENERAL PEST CONTROL NEEDS

The state of the art of pest insect control in Sri Lanka is quite advanced. There is a good knowledge of methods of management of destructive insect pests on the major crops. The few highly qualified entomologists and other researchers need more support for the provision of a field staff to conduct insect population and other pest studies to determine economic thresholds. Every advantage seems to have been taken of using resistant plant varieties, predators, parasites, cultural and mechanical practices, water management, etc.

Diseases of rice have been met with the use of resistant varieties developed through IRRI. Diseases of most other crops have been met with fungicides. However, the nearly complete lack of budget and staff support for research and extension on crop plant disease studies in Sri Lanka could lead to a disastrous specific crop failure in the future.

Generally, a strong commitment is needed to provide additional trained personnel and funding for pest management research and especially for the expansion of pest monitoring in the project area.

BIOLOGICAL PEST CONTRTOL

As mentioned under other sections, biological control (use of resistant or tolerant plant varieties, parasites, predators and insect pathogens) has been used very successfully in Sri Lanka. The small cadre of professionals who have conducted biological control studies and carried out valuable and successful suppression programs to practical application in the field deserve much credit.

Examples of successful biological control in Sri Lanka by use of parasites are:

- Coconut leaf minu (Promecotheca cumingi)
- Coconut caterpillar (Nephantis serinopa)

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In addition, a study on interplanting of legumes with sugarcane (Rajendra 1977) demonstrated that in addition to promoting a better use of land, substantial additive yields were obtained for cowpeas, green gram and ground nuts while the cane borer was simultaneously suppressed. Sugarcane yields were unaffected, even without additional fertilizers.

These and other biological control research and use programs should be further encouraged with support of personnel and funding. Biological controls are preferential to chemical ones, since costs are usually lower and the harmful effects of pesticides on the environment are reduced.

Special attention should be given to recent IRRI results on the biological control of brown planthoppers for Sri Lanka. In the past seven or eight years much work has been done by IRRI and the Rice Experiment Station in breeding for resistance; parasite studies have been underway for at least five years. Present studies are encouraging on the possible use of several egg parasites (Fujimura and Somasundaram 1978). Since the brown planthopper is likely to be a significant insect pest in the project area, it may soon be advisable to develop a program aimed at adapting biological control methods for it from IRRI for Sri Lanka.

CHEMICAL CONTROL RECOMMENDATIONS

Recommendations for Pesticide Use

The best means of minimizing the potentially adverse impacts of pesticides is to develop sound application procedures to ensure the most effective usage. Economic thresholds above which treatment should be initiated should be developed for each of the specific potential insect pests and for each proposed crop, especially for paddy. Correct chemical applications must be made at the appropriate times without excessive use.

The expertise is available in Sri Lanka to determine the most appropriate method of chemical control. The methodology and application rates, etc. have in fact already been developed in many cases. However, further funding is needed to establish updated programs. Most importantly, adequately trained extension workers are required to properly advise the farmers, who in turn should receive as much education regarding pesticide usage as possible prior to settling in the project area. For example, the use of insecticides on an as needed basis should be emphasized instead of application on a fixed schedule. The latter practice recently resulted in a serious loss to onion growers in Jaffna due to the proliferation of onion caterpillars during a non-application period of a rigid pesticide use schedule. This incident was complicated by inadequate control methods when the pest was inside leaves where pesticides could not make contact.

The present trend toward increased use of organophosphate and carbamate pesticides in place of organochlorine forms should be further encouraged with the passage of the recent regulatory law and public information programs. This will minimize the overall detrimental effects of pesticides on the environment.

Safety and Regulations

The commendable national practice for container recylcing could in some areas lead to disaster. Frequently, in the local markets, attractive used aluminium and plastic pesticide containers may be seen for sale. The end use may be for cooking oil or drinking water by some unsuspecting individual. This, plus the ready availability and careless storage and usage of highly toxic pesticides, are contributing to roughly 100 to 300 pesticide related deaths annually in Sri Lanka. An additional basic problem is that handling precautions and recommendations are not required to be included on labels of pesticide containers. This information is available in leaflets from the distribution in the private sector, but the leaflets rarely reach the farmer's hands.

Policy and guidelines for handling and usage of pesticides need to be emphasized at the farm level in particular. This should be accomplished through increased education of the public especially in relation to the recent enactment of the pesticide use law. This new law regulates imports, restricts the use of chlorinated hydrocarbons and establishes some safety measures.

At an international meeting last year at the U.S. State Department in Washington, D.C. (Smith 1979) it was stated that the United States would begin implementation on export provisions for pesticides including the answering of inquiries from other countries and the preparing of documents based on U.S. Environmental Protection Agency regulations. This proposed action and press coverage may lead to the end of the so-called "Third World dumping ground" syndrome. Fortunately, world production of hard pesticides continues to be reduced, and thus exports will gradually stop (Eichers and Andrilenas 1979).

Monitoring

Background - Of all the environmental contaminants, insecticides are considered the most troublesome; even more so than fertilizers or herbicides, which are also purposefully introduced into the environment. The toxic action of insecticides is in general similar for insects as well as higher and lower animals.

Pesticides are dispersed through the air, water and soil by living organisms. Usually the highest concentrations are found nearest use areas, but traces have been found far from sites of application as well (HEW 1969).

While much progress has been made over the past twenty years, the fate and behavior of many pesticides in living organisms and their effects on metabolites, and most especially those produced by plants and micro-organisms, remain to be determined (Brooks 1971).

Analytical methods now permit the detection of pesticides as well as other chemicals in the environment in minute amounts (Neroza and Bauman 1971). Laboratory exosystems have even been developed to predict possible eco-effects and the biodegradability of pesticides, especially herbicides and insecticides. These systems simulate applications of pesticides to crops and the eventual contamination of the aquatic environment. With the

monitoring of several food chains, metabolic products can be measured in various organisms in the system (Metcalf 1972).

It is recommended that a comprehensive pesticide monitoring program be established for the project area to identify specific chemical control needs, to determine the degree of bioaccumulation and magnification of pesticides throughout ecosystem food chains and to locate improper use sources to enable the implementation of correct application procedures. The basic principle of any monitoring system is to detect faults, but in so doing it should also provide information which will lead to the correction of the faults. This requires as a basis that laws, ordinances and regulations need to be recognized and enforced.

Facilities and Manpower - It is recommended that the pesticide monitoring program be conducted using the facilities at the Chemistry Department of the Agricultural Research Center in Peradeniya. The laboratory there is well equipped in comparison to other laboratories in the country. This laboratory, in conjunction with the one operated by the Irrigation Department in Colombo, is recommended to be an important part of an integrated monitoring program for the project area which would include water quality and soils as well as pesticides. Details of the other aspects of the integrated monitoring are presented in TOPIC REPORTS B AND F for LAND USE AND SOILS and WATER QUALITY, respectively.

The Chemistry Department of the Agricultural Research Center in Peradeniya formerly had one laboratory room, but with increasing needs for pesticide formulation analyses and other monitoring, expansion to eight laboratory rooms has been almost completed. This laboratory is supported by the Government of the Netherlands and is staffed by one foreign advisor, one very capable officer (who will leave in March for two year's study abroad) and two well qualified technicians.

Their chief efforts so far have been to analyze commercial pesticide formulations offered for sale in Sri Lanka to make certain that specifications are met. Some water analyses were made for several chlorinated hydrocarbons in the project area surface waters as reported in TOPIC REPORT F: WATER QUALITY, and a preliminary national survey was completed by Ramasundaram et al. (1979).

Some "market basket" studies have been conducted on more than 150 food items, but this needs to be expanded (Boone and Ramasundaram 1980). In addition, a study on chlorinated hydrocarbon residues in human milk is nearing completion (Dr. N.S.N. Ramasundaram, personal communication). Both of these projects should be continued and expanded to include the Accelerated Program area.

The Peradeniya Pesticide Laboratory has sufficient equipment (three Gas-Liquid Chromatograph Units are to be delivered shortly) to handle all samples generated in the proposed sampling. The following equipment is maintained by a local technician and once or twice each year is checked by a German consultant:

2 - Gas-Liquid Chromatograph electron capture units
1 - N selective P detector
1 - Termion unit
1 - I R spectrophotometer
1 - U V spectrophotometer
1 - Atomic absorption unit

With this amount of equipment in good working order a large volume of samples could be analyzed each year, but not without the chemists to prepare the field samples to be placed in the detection equipment. It is estimated that an additional eight chemists/lab technicians would be needed to perform the analyses required.

With the addition of more chemical technicians the present Officer and Advisor would be released from routine operations to do the job of supervision they are qualified to do. This laboratory should be supplied with a full-time secretary - typist in order to immediately release the two supervisors from doing their own typing.

Other manpower which would be required would include research officers, field assistants, drivers and support staff. Additional equipment to augment the present lab gear would include vehicles, collecting materials, glassware, etc. These requirements have been included in the cost estimate made in TOPIC REPORT F: WATER QUALITY for a monitoring program which would include a pesticide component.

Sampling Program - The monitoring program should establish a base line for existing pesticide residues with sampling commencing as soon as possible. Repeated, seasonal sampling of various components of aquatic and terrestrial ecosystems should be made to determine accumulating efforts. The latter samples should be taken annually, especially during the dry season when water levels are low and agrochemical use is high.

A comprehensive program should include sampling and analysis for pesticide residues in the following:

- Soil
  - Paddy, other field and sediment in tanks and estuaries
- Water
  - Fresh water - reservoirs, canals, tanks, rivers, villus, paddies, tail waters and potable water (wells).
  - Brackish and/or salt water - estuaries and lagoons
- Non-target organisms and food chain species
  - Rice and rice straw
  - Aquatic plants, i.e. water hyacinth
  - Field edge plants and hay
  - Adjacent paddy crops
  - Other non-irrigated and/or irrigated crops, i.e. fruits and vegetables
  - Invertebrates
    - Crabs
    - Shrimp
    - Insects
    - Snails
  - Vertebrates
    - Fish - all water areas
      - Low - medium - top of food chain
    - Birds - brain, fat, liver, breastbone muscle and their eggs at top of food chain
    - Herons, cormorants, terns and gulls
    - Others - Accidental kills, i.e. eagles, small mammals
    - Human milk

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CONTROL OF BIRD AND MAMMAL PESTS

Control of bird and mammal pests is usually very difficult, and often the most effective means is through surveillance and actually chasing the animals away.

Chemical controls can be very effective for some of these pests. Rats can be limited by using poison baits of coumarin or zinc phosphate. About 15 to 30 bait locations should be established per hectare. A combination of poison baits and trapping and fumigation would be recommended for stored grain products (Hope 1976). Centralized storage presently uses some of these control methods.

Wild boar can also be successfully controlled by poison baits of parathion, endrin and potassium cyanide (Rakendran 1972). However, this should only be used to the economic threshold level, since rats will increase significantly if too many boars are eliminated.

Pesticides have also been used with varying results to reduce bird pests. Actual field tests using various organophosphate insecticides to destroy blackbirds in roosting areas have been ineffective. Spraying the target crop with fenthion has met with more success (Pope and Ward 1972). Parathion has also been used, but fenthion is much less toxic to most mammals while very toxic to birds.

Biological controls may be of some use in limiting bird populations by introducing parasites or sterile individuals to the population. However, this is only conjecture and no research has yet been completed in this area for species here. One recommendation which might limit paddy losses to some extent due to munias is not to plant sugarcane adjacent to or near rice fields.

For the larger wildlife, especially elephants, the most effective way of limiting potential crop damage is to remove them from the area prior to cultivation. This will require a wildlife management program which will provide for sustaining the most number of animals in areas not slated for cropping. Related planning in this regard is presented in detail in TOPIC REPORT E: WILDLIFE. However, it is unlikely that many wild animals presently in the project area can be accommodated in regions outside of it; thus, the only means to prevent crop damage would be to cull some of the animals. It should be noted that the government will be reticent to sponsor any program to actively destroy animals, since this is generally considered culturally unacceptable.

EXTENSION SERVICES

An adequate extension service with all trained personnel is the key to successful cultivation programs and integrated pest management. With sufficient extension officers a greater percentage of farmers can be given the benefit of advice on pest management practices along with other crop production information. Use of careful pest management techniques can reduce production costs by reducing pesticide use which in turn reduces possible harmful environmental side effects.

In the training of the agricultural extension officers for the Accelerated Program, it is recommended that the excellent literature which has been developed for Sri Lanka be made available in handbook form. This should include the "Plant Protection Manual" and the document "Major Pests and their Chemical Control" from the Department of Agriculture, among others.

The International Rice Research Institute, in addition to the production breeding program has been a major contributor toward the development of insect and disease resistant varieties and chemical control. While Sri Lanka's agronomists and plant breeders are close cooperators with the International Rice Research Institute, increasing use should be made of IRRI's special and annual reports. Much information is available in the IRRI library in Colombo and excerpts from, or entire, articles could also be reproduced for reference by extension officers (IRRI Annual Reports 1972 - 1979).

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K. PUBLIC HEALTH

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EXISTING CONDITIONS

OVERVIEW

General

Evidence on the pattern of health in Sri Lanka can be characterized as indicating a high incidence of disease attributable to environmental conditions, a situation frequently found in less industrialized tropical countries; but, with heart disease being the leading identified cause of death, mortality statistics are more typical of industrial countries.

Health information is generally compiled by the Ministry of Health in association with the Medical Statistician of the Department of Census and Statistics. Published statistics on health in Sri Lanka have three major sources:

- Patient records from admissions to government hospitals;
- Death certificates; and
- Special surveys.

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

Morbidity

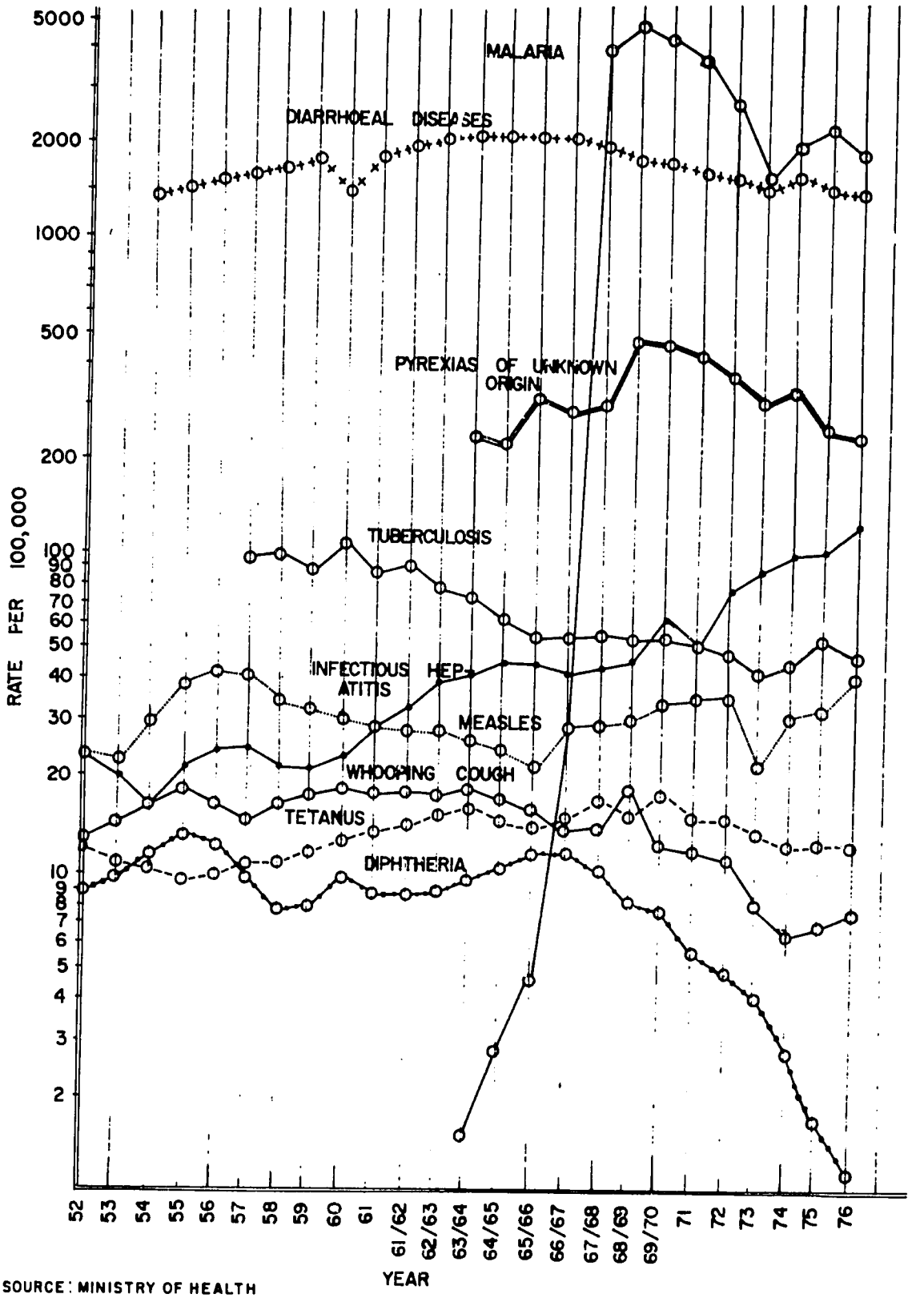
Four classes of infectious diseases dominate admissions to government hospitals: bowel or diarrhoeal diseases, malaria, pyrexias (fevers) of unknown origin, and infectious hepatitis. All are typically linked closely to environmental factors. Trends for the period of 1952-1976 in the reported incidence of common infectious diseases nationwide are presented in Figure K-1. The incidence of some principal water-borne diseases in respective districts is given in Table K-1. The major districts in and around the project area include Badulla, Amparai, Batticaloa, Polonnaruwa and Trincomalee.

Table K - 1

Incidence of Principal Water - Borne Diseases by Districts in 1978

Health Division (District)	Typhoid	Bacillary Dysentary	Amoebia-sis	Enteritis & other Diarrhoeal diseases	Viral Hepatitis	Cholera	Polio	Totals	Rate/100,000
Anuradhapura (& Trincomalee)	122	456	714	5,609	333	1	6	7,241	1,063.3
Badulla (& Moneragala)	1,049	2,491	620	5,161	671	-	5	10,005	1,120.4
Batticaloa (& Amparai)	123	577	477	3,741	284	-	31	5,233	489.5
Colombo	2,242	3,266	3,880	23,031	3,582	19	208	36,228	1,218.9
Galle	160	983	911	4,539	153	-	2	6,748	831.1
Jaffna	232	484	679	3,696	301	8	20	5,420	676.6
Kalutara	99	375	963	7,250	434	1	-	9,122	1,128.9
Kandy (& N'Eliya)	1,654	2,943	1,657	9,694	805	-	14	16,767	956.5
Kegalle	195	1,162	460	4,583	457	-	6	6,863	955.8
Kurunegala	405	991	809	7,316	1,248	-	3	10,772	929.4
Matale (& Polonnaruwa)	92	87	544	4,869	381	-	7	5,980	1,099.3
Matara (& Hambantota)	353	2,419	925	6,327	509	-	17	10,550	1,006.6
Puttalam	67	403	475	1,823	700	10	13	3,491	798.8
Ratnapura	1,158	858	1,482	7,444	676	-	26	11,644	1,575.6
Vavuniya (& Mannar)	33	87	188	1,321	51	4	8	1,692	841.7
	7,984	17,582	14,792	96,404	10,585	43	366	147,756	1,041.7

Source : admissions to Government Hospitals (Ministry of Health)



SOURCE: MINISTRY OF HEALTH

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

FIGURE K-1

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Bowel diseases are believed to consist of bacilliary and amoebic dysenteries, gastroenteritis, colitis, cholera, roundworm and hookworm infections, and they afflict about 40% of all persons seeking treatment at government medical institutions (Ministry of Health 1979). In specific areas, such as in System C, the proportion is believed to be higher.

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

Mortality

Using compilations by the Registrar General from death certificates, life expectancy in Sri Lanka was found to be around 68 years in 1978, about 26 years more than the expectancy in 1946. Two causes of death not directly related to environmental causes, heart disease and accidents/suicides, now rank above diarrhoeal diseases as leading causes (Figure K-2). In 1976, anaemia and malnutrition ranked fourth and malignancies, fifth. Between 20% and 40% of the cancers were of the buccal cavity, and the next most common site was buccal mucosa, indicating a probable relationship between betel chewing and cancer. There is a relative lack of industrially-related cancers.

Priority Diseases

During a Country Health Programming effort in 1978, the Ministry of Health used both objective and subjective criteria to rank 36 diseases and conditions by priority scoring. In a later proposal to provide health services to the Mahaweli Development Program, the ten highest diseases in the priority scoring as warranting primary concern were identified as follows (Ministry of Health 1979):

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

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

WATER-RELATED VECTOR DISEASES

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

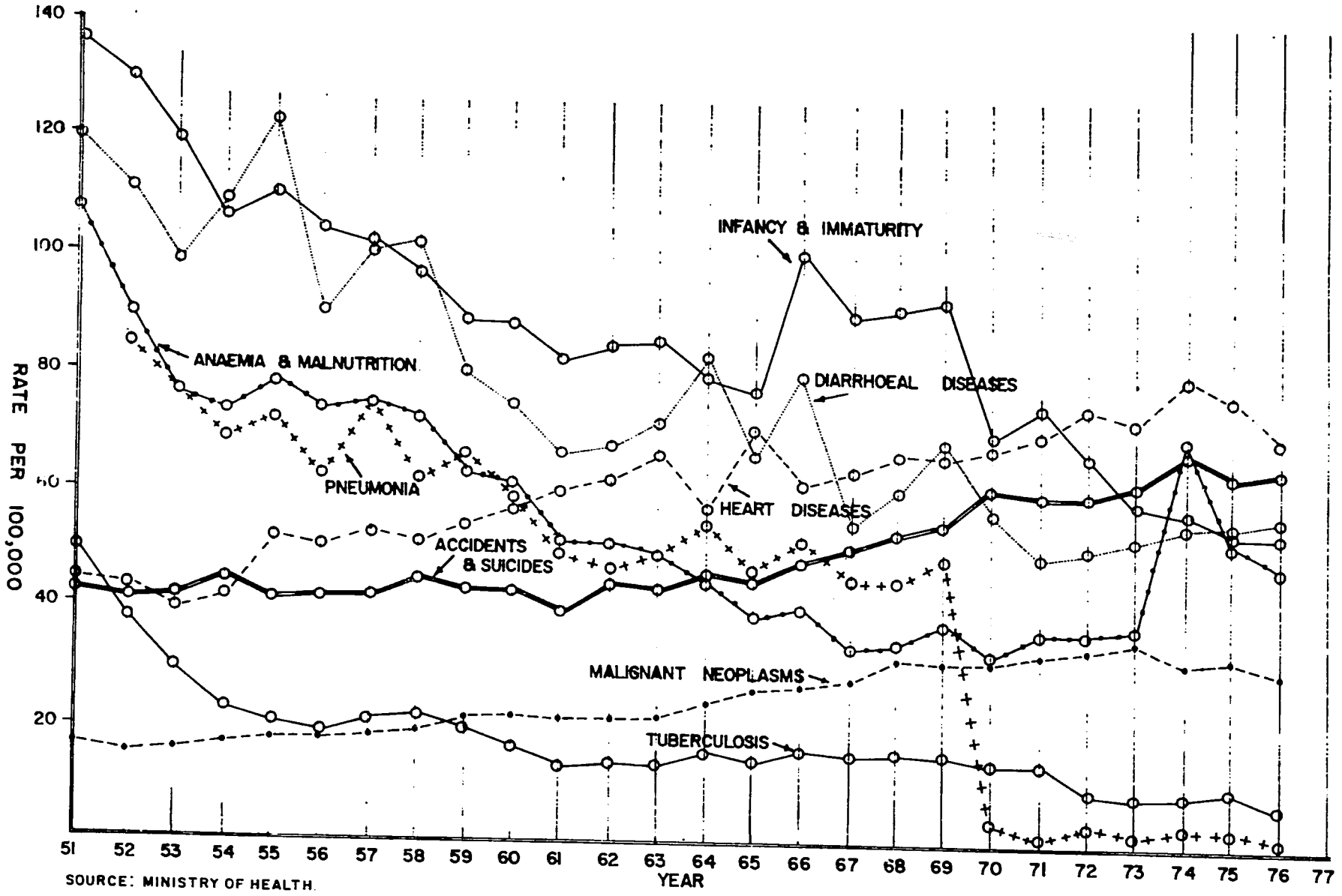
MALARIA

Trends and Incidence Reported

Malaria epidemics have devastated Sri Lanka for centuries, apparently contributing to the collapse of the ancient civilization focusing upon Anuradhapura and Polonnaruwa (Briercliffe 1935). River diversion projects created by these societies may have redistributed water in ways that favored breeding of *Anopheles* mosquitoes. Numerous epidemics have been recorded since 1958, when systematic records began to be maintained. It should be noted that some of these records contain unexplainable discrepancies. For example, 28 malaria-attributed deaths were reported to the Registrar General in 1963 (Table K-2), but other data is recorded showing only 18 cases of malaria diagnosed for the same year (Table K-3). Perhaps some mortality was actually due to other causes which were presumed to be because of malaria.

Outbreaks have been experienced each decade, and for many years malaria was the foremost cause of human mortality in Sri Lanka. The epidemic of 1935 was of such extraordinary magnitude that it elicited international attention. An estimated 59,144 deaths were attributed to malaria during this epidemic (Fredericksen 1962). The episode was attributed to abnormally scanty rainfall which caused the major rivers to cease flowing and to form puddles in their beds.

Attributed malaria deaths continuously declined over the past 20 years and have, until recently, remained at minimal levels. Between 100 and 500 deaths annually have been recorded throughout the present decade (Table K-2). Since nearly 70,000 malaria infections were diagnosed during 1978 (Table K-3), it is remarkable that the apparent case-fatality rate is so low. Indeed, the recorded prevalence of infection was less in 1978 than in any year since 1968. Since three percent of diagnoses in 1978 was ascribed as *Plasmodium falciparum*, the low mortality may be due to convenient and free access to medical institutions and widespread availability of drugs. Fortunately, local strains of malaria appear to remain susceptible to these drugs.



SOURCE: MINISTRY OF HEALTH.
MORTALITY FROM LEADING CAUSES OF DEATH

FIGURE K-2

Table K - 2

Deaths in Sri Lanka Attributed to

Malaria and Reported to the Registrar General

Year	No. Deaths Reported
1954	447
1955	268
1956	144
1957	177
1958	105
1959	82
1960	61
1961	43
1962	31
1963	28
1964	8
1965	10
1966	3
1967	4
1968	171
1969	221
1970	110
1971	82
1972	73
1973	99
1974	145
1975	296
1976	267
1977	501

Table K - 3

Number of Microscopic Diagnoses of
Malaria Recorded in Sri Lanka

Year	No. Slide Examined	No. Slides with Plasmodium				
		vivax	falciparum	malariae	Mixed	Total
1960	542,220	376	39	5	0	420
1961	764,923	75	13	1	0	110
1962	1,028,352	41	16	1	0	31
1963	959,919	9	5	4	0	18
1964	1,180,291	12	69	87	1	169
1965	1,220,584	19	200	97	1	317
1966	1,420,501	25	161	314	1	501
1967	1,379,431	3,194	202	253	1	3,650
1968	1,681,052	439,678	951	9	67	440,644
1969	1,515,087	598,703	2,791	13	626	522,133
1970	1,536,077	527,496	1,310	3	205	530,014
1971	1,451,016	145,994	3,657	0	242	149,893
1972	1,545,700	129,109	3,267	0	228	132,604
1973	1,455,572	218,139	9,378	0	196	227,713
1974	1,423,000	289,241	25,180	0	1,027	315,448
1975	1,492,008	336,924	62,071	0	1,782	400,777
1976	1,408,644	285,696	18,205	0	586	304,487
1977	964,756	251,726	10,431	0	303	262,460
1978	968,327	67,809	1,826	0	50	69,685

The total number of malaria infections decreased further in 1979 (down to about 48,000 cases). The overall reduction of incidence in the last few years is probably due largely to the expanded activities of the country-wide Anti-Malaria Campaign which was initiated in 1977 (see below).

On a regional scale, the Anuradhapura, Trincomalee, Polonnaruwa, Batticaloa and Matale districts historically comprise a notable endemic region for malaria transmission in Sri Lanka. This focus, including basins of the Mahaweli Ganga, Amban Ganga and Madura Oya, of course, encompasses the project area. Portions of this region were considered to be hyperendemic in the past (Briercliffe 1935), a designation indicating nearly maximum transmission. This was particularly evident for communities located near rivers and streams.

The number of malaria cases reported in 1979 from the respective districts of the country is presented in Table K-4. Incidence levels still remain relatively high in the project area districts compared to other regions of the island. A recent evaluation of the Anti-Malaria Campaign indicates that although incidence has decreased throughout the country, the decline in the central eastern regions including the project area is less noticeable (de la Motte *et al*. 1980).

Etiology

In Sri Lanka, malaria consists mainly of two forms: *Plasmodium falciparum* or malignant tertian malaria and *Plasmodium vivax* or benign tertian malaria. The *falciparum* form can produce fever, chills and sweating, headache, coagulation defects, shock, renal failure, and coma. About 10% of the cases among untreated children and non-immune adults are fatal, and death can occur within several days. Fortunately, this form of malaria is less common than *vivax*, which has many of the same symptoms as *falciparum* but to a less severe degree. Death is rare in the latter form, except among young children or in cases complicated by other diseases.

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

Vector Identification

About 20 *Anopheles* species are extant in Sri Lanka. Anecdotal evidence supports the classical concept that *A. culicifacies* is the sole local vector; each outbreak of disease may be explained by the proximity of potential breeding sites. *A. culicifacies* is the main species collected around human habitations, and the *Anopheles* species observed biting man indoors are almost invariably of this species. However, man-biting collections seldom yield more than 10 specimens of this species per night. Generally, biting specimens are collected only once in several nights.

Table K - 4

Number of Blood Films Examined and Positives Recorded for Malaria in 1977 by Districts

District	Number of Blood Films	Positives Recorded
Jaffna	84,490	2,259
Vavuniya	56,827	2,194
Anuradhapura	85,240	3,240
Puttalam	58,022	3,339
Kurunagala	82,099	7,228
Matale	134,456	4,642
Batticaloa	177,686	2,315
Badulla	108,410	6,579
Matara	65,488	986
Galle	48	8
Ratnapura	47,892	2,654
Kegalle	30,716	2,996
Kandy	57,388	1,244
Colombo	55,050	2,943
Kalutara	9,521	318
Totals	1,053,333	42,945

Source : de la Motte *et al*. (1980)

Females of this species seem to be strongly endophillic, resting in houses between blood meals. Two points of evidence support this conjecture:

- Gravid and semi-gravid females are abundant in unsprayed houses (Table K-5); and
- Females that fed out-of-doors on animals are commonly collected indoors (Table K-6). A. subpictus is the only other Anopheles species that is commonly collected in houses, but females of this species rarely contain human blood, and rarely are taken in biting catches. Thus, of potential vectors only A. culicifacies in Sri Lanka appears to have frequent contact with man.

To further evaluate the role of A. culicifacies as a vector of malaria, the monthly prevalence of malaria in one indicator medical institution (Aralangwila) was compared to the abundance of nearby A. culicifacies. Data accumulated over a 10-year period (1969-1979) was summarized by month (Tables K-8 and K-9). Although infection was perennial, P. vivax diagnoses were most numerous during early winter. In general, P. faciparum diagnoses followed this seasonal pattern, but the trend was less clear. Surprisingly, spray catch collections suggested that the presumed vector mosquito was most abundant in later winter. Outdoor human bait collections were more ambiguous. Although infection as well as vectors were present throughout the year, seasonal abundance did not correlate closely.

It should be mentioned that other Anopheles mosquito species occur in Sri Lanka which are confirmed malaria vectors in other surrounding countries. These include A. maculatus, A. aconitus, A. Annularis, A. barbirostris, A. hyracanuns, A. subpictus and A. varuna (UNEP 1980).

In addition, a possible jungle vector of malaria in Sri Lanka is Anopheles elegans, a Leucorphyrus species allied to A. balabacensis. This latter species is a danger vector of chloroquin-resistant malaria in Southeast Asia. Indeed, in one site in a jungle near Kandy, 83 A. elegans were collected. Of these, five contained malaria sporozoites and ten contained oocysts (Nelson et al.1971). These malaria organisms were presumed to be Simian parasites because a monkey, injected with sporozoites from one of these mosquitoes proved to be malarious. Hoever, no evidence was presented that the monkey was previously non-infected. In fact, the monkey was ultimatley diagnosed as having a mixed infection with P. shortti, P. frazile and another unidentified blood parasite. That one mosquito might transmit three parasites is most unusual. This Anopheles species should be reexamined as a vector of human malaria.

Vector Effectiveness

Another form of evidence indicates that in Sri Lanka A. culicifacies is an unusually effective vector of malaria. The incubation period of Plasmodium sp. in the vector is about eight days. Thus, a potential vector must live for at least 10 days before it may transmit. The mean expectation of life of Indian A. culicifacies is estimated at only 3.2 days, requiring huge populations before the species can transmit.

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Table K - 5

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

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

Table K - 6

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

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

Table K - 7

Age and Sex Distribution of Persons Infected with Malaria During 1978

Sex	Years of Age	Number Infected	Percent of Total Infected
Male	-	41635	59.7
Female	-	28050	40.3
-	0-1	646	0.9
-	1-5	7020	10.1
-	6-15	15313	22.0
-	15+	46706	67.0

Table K - 8

Diagnoses of Malaria by Year in Arlangwila Indicator Medical Institution and Abundance of *Anopheles culicifacies* in a Nearby Community

Year	No. of Slides Examined	No. Slides With		Spray Catch		Outdoor Biting	
		P. vivax	P. falciparum	No. houses	No. A. culicifacies /house x 100	No. man hours	No. A. culicifacies /house x 100
1969	72656	23831	462	0	-	0	-
1970	55108	20666	96	70	46	198	28
1971	49517	7894	149	176	16	375	21
1972	56203	7850	21	146	3	195	14
1973	61322	13419	250	250	1	279	8
1974	44072	13482	281	197	33	294	7
1975	69856	28611	2062	220	6	228	7
1976	61293	19365	800	192	6	226	5
1977	19827	5202	131	40	3	241	6
1978*	82490	3931	53	282	0	814	0
1979	38812	659	26	84	8	463	0

* - 5 months

Table K - 9

Diagnoses of Malaria by Month (summarized for the decade 1969-1979) in Aralangwila Indicator Medical Institution and Abundance of *Anopheles culicifacies* in a Nearby Community

Month	No. Slides Examined	No. Slides With		Spray Catch		Outdoor Biting	
		P. vivax	P. falciparum	No. houses	No. A. culicifacies /house x 100	No. man hours	No. A. culicifacies /hour x 100
Jan	58663	17854	550	128	10	261	6
Feb	47768	11424	347	151	19	290	6
Mar	51903	10683	273	143	22	290	11
Apr	38219	7697	216	162	6	283	8
May	51227	10066	476	124	7	271	11
Jun	48804	11283	223	121	7	305	10
Jul	55415	11579	466	154	3	238	5
Aug	48535	9895	229	194	2	238	9
Sep	42918	9278	341	127	12	266	16
Oct	63728	10326	350	160	9	314	16
Nov	57502	14866	488	147	10	341	7
Dec	58187	20396	553	119	2	213	13

In contrast, estimates based upon the parous-rate of Sri Lanka A. culicifacies suggest that the corresponding longevity of certain local populations may approach 18 days. This would suggest that Sri Lanka A. culicifacies is an extraordinary dangerous vector, rivaling the notorious A. gambae of Africa in vectorial capacity.

On the other hand, one factor tends to decrease the capacity of Sri Lankan A. culicifacies as a vector of malaria. Since the species is not highly anthropaphillic, about one-half of the bloodfed specimens collected in human habitations contain non-human blood.

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

Preferred Breeding Habitat

Clemesha (1934) reports the following for Anopheles culicifacies: "The optimum breeding place for this species is a (sandy) stream running over flat country (and which is) almost empty (due to) drought. The water must be clear... (and) there must be a good portion... on which sunlight plays for a good number of hours..... Very small collections of water in the sand are much favored; foot or hoof marks are frequently full of larvae... provided they are in the sun. It is useless to look for A. culicifacies, except in sunny places". This breeding habitat correlates with the riverine distribution of epidemic malaria in Sri Lanka and with maximum transmission following drought periods.

Recently, personnel of the Anti-Malaria Campaign confirmed that in Sri Lanka A. culicifacies do not exploit paddy fields. Of 1,084 larval Anopheles spp. collected in such sites, only 107 were A. culicifacies. Of these, 88 were taken from an exposed pit in one fallow field. This confirms that in Sri Lanka A. culicifacies fails to exploit rice irrigation. Larvae of nine other Anopheles species may be more abundant in such locations. Newly cut trenches and borrow-pits provide additional breeding sites for A. culicifacies (Carter 1930), as does seepage from irrigation structures.

Malaria Control

The 1935 Epidemic - During the 1935 outbreak of malaria, comprehensive control measures were instituted, largely aimed at Anopheles breeding in puddled river beds. At the height of the campaign, oil was applied weekly to 450 kilometers of rivers and streams, including portions of the Mahaweli Ganga and Maha Oya. The value of this treatment was questioned

since "the secondary rise of malaria... was greater near the stretches of the Maha Oya which had been carefully oiled..... than in any part of the epidemic area" (Briercliffe 1935). Massive quantities of quinine were issued, amounting to about 13 million treatment-days supply, but the objective was solely curative.

First National Program - The first national program was planned in 1945; and by the end of 1946, DDT was being applied nationwide to every house in malarious areas every six weeks at a rate of one gram per square meter. By 1950, 585,000 houses were being routinely sprayed with 95% DDT emulsion or lindane suspension every eight weeks. During the next five years, DDT, BHC or dieldrin suspensions were applied at three month intervals.

The program appeared to be a success and, starting in 1951 regular spraying was suspended. By 1954, all routine spraying had ceased; only temporary or new habitations were sprayed. Spray teams were converted in 1955 to surveillance units stationed at 56 of the 256 medical institutions around the country.

A sharp increase in diagnosed malaria infections followed in 1956. The country was then divided into endemic and epidemic zones; and in 1957, DDT spraying was resumed where infection appeared to be endemic. By 1958, only 1,037 malaria infections were diagnosed among 63,866 hospital admissions.

The apparent success encouraged Sri Lanka in 1958 to adopt a formal eradication program. All habitations in the endemic zone were treated with DDT suspensions at the rate of 0.5 - 1 g/m^2 and this continued until May 1963. Malaria seemed to have disappeared, permitting the program to enter a brief period of consolidation.

Again, local outbreaks were soon recognized; and, by the end of June, the country had reverted to a modified attack phase of eradication. The problem appeared to focus in jungle regions, and the strategy was to protect human communities in contact with jungle (Rao et al. 1964). Houses within jungle clearings and those within one-half mile of the jungle were sprayed. Houses in demonstrated foci received two grams DDT/m^2. Passive case detection, based on fever patients attending hospitals, provided the main surveillance mechanism.

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

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

The 1967 Epidemic - By late 1967, the existence of a new *P. vivax* epidemic had become evident, and by January 1968, there was little doubt that the epidemic had major proportions. The main focus of the infection centered in the North-Central region of Sri Lanka in the Matale, Polonnaruwa and Anuradhapura districts. A second focus lay in the South-East, in Moneragala and Hambantota districts. These were the loci of the 1906, 1912 and 1935 epidemics, and maximum prevalence of all four episodes occurred in the months of January and February. The 1967 epidemic was unique in Sri Lanka, and in the tropics generally, because of the predominant role of *P. vivax.* The relative scarcity of *P. falciparum* has not been explained. In any case, attributed deaths were rare due to widespread availability of drugs.

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

Sri Lanka returned to an intensified attack phase of eradication following a WHO evaluation in 1968. More than ten times the amount of DDT was applied during each of the years 1968 through 1970 than was applied in the year before the epidemic. Surveillance by passive case detection was intensified after the program was implemented in November of 1968. This program failed. Prevalence of malaria seasonally attained higher levels in 1968-1969 than in 1967-1968, and peaked to even higher levels in 1969-70. Resistance had destroyed the usefulness of DDT against *A. culicifacies*. Limited quantities of malathion were sprayed beginning in 1970.

Introduction of Malathion - During the period 1973-1975, the country suffered another massive increase in malaria transmission, and the eradication program resumed. Massive applications of DDT continued until 1976 in spite of increasing evidence of the ineffectiveness of this pesticide. Malathion, which had been applied in limited quantities since 1970, was adopted as the principal insecticide in March of 1975. Satisfactory results stimulated additional coverage by September of 1975 and further extension in November of 1976.

This pattern of progressively increased malathion coverage continues to this day, and the recorded prevalence of malaria has correspondingly declined.

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

Current Control Program - By November of 1976 the government of Sri Lanka, WHO, USAID and the British and Netherlands governments had each signified basic agreement for launching an intensive malaria control program based on the above precepts. A new operational plan was drafted, and then implemented in August, 1977. In July 1979, USAID approved an extension of the plan to cover new Mahaweli settlements by providing an additional $4 million per year.

The basic objective of the new "Intensive Malaria Control Program" is to eradicate P. falciparum and to reduce the prevalence of P. vivax to an acceptably low level which would, thereafter, be sustained. This objective is to be accomplished in five years and would require that all houses in malarious parts of Sri Lanka be sprayed with malathion four times during each of the first two years. It is anticipated that spraying during 1979 would be reduced to two cycles in certain regions and progressively eliminated by 1981.

The control program is being administered through the Anti-Malaria Campaign. The latter includes four epidemiologists, two entomologists, and establishment, finance and assessment branches plus a central laboratory and training center. There are 16 regional offices headed by Medical Officers and 17 subregional offices under experienced sanitarians. In addition, there are 42 public Health Inspectors' Vigilance Units which supervise spraying activities, surveillance and treatment. About 4,000 total employees are involved (de la Motte et al. 1980). The criteria for withdrawal of the program would depend mainly upon parasitological assessment including both passive (PCD) and active (ACD) case detection. Passive case detection involves all fever patients reporting to each of 235 clinics or hospitals. Active detection focuses on malarious regions isolated from these "indicatory institutions". One ACD agent becomes assigned to each 4,000 to 10,000 people and each house is visited monthly. In order to make their services acceptable to the population, ACD agents now distribute anti-malarial drugs.

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

Susceptibility of Vector Mosquitoes to Insecticides

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

In the first recorded test, two of the five localities sampled contained a few A. culicifacies that did not die, and similar results were recorded in 1966 (Table K-10). DDT continued in use throughout the 1960's, and resistance problems began to be evident by 1968. The effectiveness of DDT had declined markedly by the time of the epidemic of 1967-1968; and, by the next year, high levels of resistance were widespread.

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

Discriminating dose techniques of insecticide testing were applied to A. culicifacies using other potential public health insecticides. These included malathion, fenitrothion, and dieldrin (Table K-11). Each of these toxicants in 1978 killed all mosquitoes tested at the time, and dose schedules were adopted. By 1979, malathion had been used in Sri Lanka for eight years, the last three years involving extensive applications of more than a million pounds (Table K-12). Malathion, thus, appears to remain useful in the Anti-Malaria Campaign.

If malathion is applied four times a year, treated walls should remain highly toxic to mosquitoes for at least three months. However, malathion spray does not render walls sufficiently toxic (Table K-13). Even within the first 30 days after application, about one-quarter of such biossay mosquitoes escape death.

In the event that malthion resistant A. culicifacies are discovered in a particular portion of Sri Lanka, the malaria control program hopes to locally eliminate the resistant population using fenitrothion intensively applied to all human habitations. Experience with other Anopheles species in Brazil and Sardinia provide optimism that such an eradication

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Table K - 10

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

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

Table K - 11

Insecticides that Killed all
A. culcifacies Tested in 1978
Within 1 Day After Exposure

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

Table K - 12

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

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

* Pounds of malathion anticipated in Anti-Malaria Campaign

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Table K - 13

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

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

campaign is practical. However, all authorities do not share this optimism. At enormous expense, a DDT susceptible species was almost eradicated from a sharply demarcated region in Sardinia. However, a different species population was highly domestic and had only recently become established. Furthermore, experience with malathion-resistant A. culicifacies in India indicates cross-resistance with fenitrothion. If the two insecticides are "positively correlated" in Sri Lankan A. culicifacies, fenithrothion would be ineffective for control purposes.

FILARIASIS

Bancroftian Filariasis

Bancroftian filariasis, caused by the worm Wuchereria bancrofti, is endemic in the south-western coastal strip of Sri Lanka between Negumbo and Matara. This is the most densely populated part of the country, containing Colombo and its suburbs. The present population of this region numbers about 2.5 million people with a 10% microfilaria rate. Of 680 filariasis patients in Dehiwela Clinic in 1975, more than 500 had swollen arms or legs and 21 had frank elephantiasis. Fever and lymphangitis were common. Transmission of the W. bancrofti worm has also been reported away from the coastal belt on the Peradeniya University campus near Kandy. The worms are all transmitted through mosquitoe bites of Culex pipiens quinquefasciatus.

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

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

Brugian Filariasis

Brugian filariasis was once scattered in discrete foci over much of Sri Lanka. The worm, Brugia malayi was transmitted mainly by Mansonia sp. mosquitoes closely associated with tanks containing water lettuce,

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

DENGUE FEVER AND HEMORRHAGIC FEVER

Dengue virus of at least two serotypes is prevalent throughout Sri Lanka. Anti-body to Group B togavirus, which includes dengue, was present in almost half of the general population during 1966 and 1976 (T. Vitarana, MRI, unpublished data). While residents of Colombo appeared to be most at risk, the disease is generally distributed throughout the northern dry, wet, and intermediate zones.

Dengue fever is rarely fatal, and infection by each of the four serotypes confers life-long immunity against that strain of virus. An episode of dengue fever is highly debilitating; but the patient usually recovers within one or two weeks. Thus, uncomplicated dengue fever does not greatly effect the economy of an indigenous population. Transient persons, on the other hand may suffer greatly during their visit, and this concerns the tourist industry.

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

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

ENCEPHALITIS

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

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

OTHER MOSQUITO-BORNE VIRUSES

Chikungunya virus is a Group A togavirus that produces a dengue-like disease in man. Like dengue, it is transmitted by A. aegypti, and is known to cause epidemics mainly in a south-western coastal belt of Sri Lanka. Epidemics have been recorded in 1965 and 1966 (Mendis 1967; Munasinghe et al. 1966). At about this time, 10.6% of the general population circulated antibody against Group A viruses (Vesenjak - Hirjan et al. 1969). Interestingly, the highest rates were reported from Trincomalee (35%) and this suggests that other Group B viruses may be present in the Mahaweli delta. The list of zoonotic togaviruses that may affect residents of newly cleared jungle is extensive.

SCHISTOSOMIASIS (BILHARZIASIS)

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

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

NON WATER-RELATED VECTOR DISEASES

Scrub Typhus

Scrub typhus (tsutugamushi) is a rickettsial disease transmitted by larval chigger mites. It is zoonotic in small rodents and typically affects

persons in newly cleared jungle or residing in the jungle edge. One notable Sri Lanka epidemic affected number of a British army division manoeuvering, in 1943, in the southern part of the island (Kalra and Radford 1947). After four days in the jungle, 756 persons became ill with 85% having primary lesions. The disease had not been previously recognized in Sri Lanka. Leptotrobidium deliense is considered to be the local vector but a recent list of ectoparasitic arthropods of Sri Lanka fails to list any chiggers taken from man (Senadhira 1969).

At present, Sri Lanka lacks ability to diagnose rickettsial diseases (including Q fever). Considering the magnitude of the morbidity category "pyrexia of unknown origin", local rickettsial expertise should be encouraged. Scrub typhus, as well as one or another of the tickborne typhus infections, may well pose an important health hazard to man in the region now being cleared of jungle by the proposed project.

Sandfly-Borne Disease

Kala azar (visceral leishmaniasis) a severe chronic disease of man, is enzootic in dogs in India. Infection is transmitted in southern and eastern India by sandflies, mainly Phlebotomus argentipes, and this vector species has been reported from Sri Lanka. However, no leishmanial infection has definitely been recognized in Sri Lanka. One case report of kala azar in an English girl who had lived in Sri Lanka suggests that the disease may be present in the country. However, the girl may have acquired infection while travelling elsewhere. In any case, Asian leishmaniasis differs from that of African or the Americas in that it is zoonotic in the village rather than in some sylvan or other feral focus.

Bed-Bugs

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

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

Several villages in both affected regions were visited in order to evaluate this complaint. Houses in both localities apparently well sprayed were heavily infested with bed-bugs. Living bugs were abundant in cracks in walls that were heavily coated by spray applied one month earlier. This

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apparent problem was widespread, and people had begun to effectively remove malathion spray from walls of houses as soon as it was applied. In reply to questions as to their motives in removing this spray, they cited (1) possible toxic effects of the spray on small children; (2) the unsightly and odorous nature of the spray, and (3) an apparent increase in bed-bug annoyance beginning about two weeks after each house had been sprayed. They believed that the spray aggravated the problem. This evidence of resistance is conjectural and must be confirmed by laboratory study.

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

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

WATER-BORNE AND WATER-WASHED INFECTIONS

These diseases are closely associated with the presence or absence of adequate human waste sanitation and the provision of safe drinking water supplies. Where these facilities are insufficient, water-borne diseases are capable of spreading very rapidly. The incidence of some of the more important water-borne diseases by district is presented in Table K-1.

CHOLERA

In 1974, 4,556 cases and 333 deaths were attributed to cholera in Sri Lanka with a focus of the disease in the lower Mahaweli Valley, Anuradhapura, and slightly northward (Table K-14). Reported cases declined to 726 including 16 deaths in 1976, but the disease remains endemic. Only 43 cases were reported in 1978.

Cholera is a serious intestinal disease characterized by sudden and acute diarrhea, vomiting, rapid dehydration, and circulatory collapse. Death may occur within a few hours of onset, and the fatality rate in untreated cases may be 50%; but appropriate treatment can lower the fatality rate to below 1%.

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

Table K - 14

Number of Cases and Deaths from Cholera in 1973-1976

Health Division (District)	1973			1974			1975			1976		
	c	r	d	c	r	d	c	r	d	c	r	d
Anuradhapura (incl.Trincomalee)	-	-	-	855	132.1	57	157	23.4	N.A	3	0.4	-
Badulla (incl.Monaragala)	-	-	-	494	56.0	41	32	3.5	N.A	34	3.8	4
Batticaloa (incl.Amparai)	-	-	-	210	36.3	14	220	36.9	N.A	-	-	-
Colombo (incl. Municipalty)	23	0.5	1	736	25.9	37	253	8.7	N.A	603	20.3	5
Galle	-	-	-	12	1.6	-	15	1.9	N.A	4	0.5	-
Jaffna	172	23.9	9	671	91.0	25	418	55.7	N.A	52	6.8	-
Kalutara	-	-	-	46	6.0	7	30	3.8	N.A	10	1.3	5
Kandy (incl. Nuwara Eliya)	1	0.1	1	101	5.9	12	13	0.7	N.A	-	-	-
Kegalle	-	-	-	34	5.3	1	3	0.4	N.A	-	-	-
Kurunegala	-	-	-	132	12.1	18	44	3.9	N.A	1	0.1	-
Matale (incl.Polonnaruwa)	-	-	-	205	38.9	22	12	2.2	N.A	1	0.2	-
Matara (incl. Hambantota)	1	0.1	1	301	30.6	21	74	7.4	N.A	18	1.8	2
Puttalam	-	-	-	253	61.9	26	21	5.0	N.A	-	-	-
Ratnapura	-	-	-	156	22.6	14	112	15.6	N.A	-	-	-
Vavuniya (incl. Mannar)	3	1.6	1	350	183.3	38	49	24.7	N.A	-	-	-
Total	190	1.4	13	4556	33.7	333	1453	10.5	N.A	726	5.1	16

Note : c = number of cases; r = morbidity rate per 100,000 population; d = number of deaths.

Source : Admissions to Government Hospitals (Ministry of Health)

TYPHOID FEVER

In 1975, hospital records registered 10,656 cases of typhoid fever in Sri Lanka, and a significant proportion of "pyrexias of unknown origin" are assumed to be undiagnosed typhoid fever. The largest number of cases was reported from Colombo, followed by the Kandy area. The Badulla Health Division, which is in the project area, also reported a large number of cases. Similar reports were found in 1978 (Table K-1).

Typhoid fever is an infectious disease characterized by continued fever, headaches, either constipation or diarrhea, lymphoid swelling, and other systemic symptoms. The fatality rate of about 10% can be reduced to 2 or 3% or less by appropriate treatment.

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

BACILLARY DYSENTERY

In 1975, hospital records registered 2,125 cases of bacillary dysentery which is assumed to be a small proportion of actual cases. More than 17,000 cases were reported in 1978. In an earlier survey of 333 children in Sri Lanka, 211 were found to be dehydrated; and about 12% of these were found to have the shigellae enteropathogen of bacillary dysentery (van Zul 1966).

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

GASTROENTERITIS

Gastroenteritis is a broad medical term that can encompass a wide variety of intestinal diseases, and thus the designation can include undiagnosed cases of diseases discussed earlier. In any case, the use of a "gastroenteritis" diagnosis is very widespread in Sri Lanka, indicating an estimated rate of 948.4 cases/100,000 population and ranking second (after malaria) in the priority list of major health problems (see Figure K-1 and Table K-1).

One of about five gastrointestinal diseases are assumed involved when the diagnosis of gastroenteritis is used in Sri Lanka:

- Epidemic Viral Gastroenteritis: Generally mild and characterized by one or more symptoms, including nausea, vomiting, diarrhea, abdominal pain and malaise. Symptoms usually last from 24 to 48 hours.

- Sporadic Viral Gastroenteritis: A more severe disease of infants and young children characterized by diarrhea, and sometimes, vomiting.

- Giardiasis: A protozoal infection characterized by a wide variety of symptoms, including chronic diarrhea, cramps, bloating, fatigue, and weight loss.

- Vibrio parahaemolyticus (food poisoning): Usually diarrhea and cramps but can be accompanied by nausea, vomiting, fever, and headaches. Duration is generally between one and seven days.

- Enteropathogenic Escherichia coli: Similar to bacillary dysentery with fever and occasionally severe diarrhea.

The exact modes of transmission of the viral diseases are unclear, but the other diseases are known to be transmitted by contaminated water and food.

INFECTIOUS HEPATITIS

About 15,000 cases of hepatitis were treated in government hospitals in 1977 and more than 10,000 in 1978. The number of unrecorded cases is assumed to be considerably larger. Infectious hepatitus is usually characterized by an abrupt fever, malaise, nausea and abdominal discomfort, followed by jaundice. The disease can be seriously disabling with a duration from a few weeks to several months.

Being viral, the agent is difficult to identify and trace, but evidence exists that it is transmitted by water or food that has been contaminated by human urine or feces.

HELMINTHS

According to data assembled by the Ministry of Health, helminths were the cause of hospitalization for 258.3 cases per 10,000 population, and the death rate from helminthiasis infections was 6.2 per 100,000. Numerous surveys, however, idicate that a majority of the rural Sri Lanka population is infected. For example, an extensive survey by Fernando and Balasuriya (1976) in 1966-7 of 5,201 persons living in a district bordering on Mahaweli

Ganga near Kandy indicated that 83.5% were infected with one or more helminths. The most common helminth species was Ascaris lumbricoides (64.4%) followed by Necator americanus and Ancylostoma brazilianum (45.2%) and Trichuris trichiura (19.5%). Ascaris infections were most common in children between 10 and 14 years of age, but hookworm infection became increasingly prevalent with age, rising from about 11% for persons under five years of age to 83% for persons 60 years of age and over.

Ascariasis infections can be characterized by irregular respiration, spasms of coughing, fever, and changes in blood color. Heavy infections can cause digestive and nutritional difficulties, pain, vomiting, and bowel obstruction. Death occurs from migration of adult worms into the liver, the gall bladder, and other organs.

The blood-letting characteristic of Necator infections leads to severe anemia, and infected children can become retarded in mental and physical development. The Trichurus (whipworm) infections typically involve abdominal pain, bloody stools, diarrhea, and loss of weight.

Transmission is from person-to-person, but indirectly, the eggs being deposited in feces on the ground where, if moisture and other conditions are appropriate, they hatch or become infective.

LEPTOSPIROSIS

Leptospirosis is a widespread environmental disease which is found in the Mahaweli Accelerated Program area and will be exceptionally difficult to prevent or control under current conditions. Leptospirosis is actually a group of diseases caused by various leptospira parasites that infect both domestic and wild animals, including cattle, dogs, horses, rats, deer, squirrels, foxes, raccoons, and even snakes and frogs. Infections of humans can occur through abraded skin, mucous membranes, and the ingestion of food contaminated with infected urine. Anyone working in water that is animal habitat will be exposed to the disease, so it will be important in an irrigation program.

The symptoms of leptospirosis include fever, headaches, chills, malaise, vomiting, muscular aches, and - occasionally - jaundice, anemia, meningitis, renal (kidney) insufficiency and hemorrhaging in skin and mucous membranes. Death is infrequent except in older persons where the rate may be 20% or more due to jaundice and kidney failure.

In Sri Lanka, the disease is believed very widespread, and a significant proportion of the "pyrexias of unknown origin" may be cases of leptospirosis (Nityananda and Harvey 1971). For example, 1,583 blood samples collected from many areas of Sri Lanka for typhoid tests in 1962-64 were also tested for leptospirosis, and 520 (33%) were found to be positive (Nityananda 1976). Of 18 sewer rats (Rattus norvegicus) tested, seven were found to be infected;

and, out of 154 paddyfield rats (*Gunomys gracilis*) tested, 49 were infected. Ten of 351 dogs tested were also found infected.

OTHER DISEASES AND HEALTH HAZARDS

Rabies

Rabies in Sri Lanka kills over 300 people each year. Most cases can be traced to rabid stray dogs. All Sri Lankan cities and towns appear to have large populations of ownerless dogs, and the sentiment among the general citizenry is strongly against catching and destroying dogs. Dog catchers are reportedly attacked occasionally by spectators, and the government was openly but unsuccessfully trying to recruit more dog catchers when this study was being conducted.

Tetanus

Tetanus is another disease afflicting a small number of persons each year in Sri Lanka, and it may be a special problem in the Mahaweli Systems A-D, because the tetanus bacillus is reportedly particularly prevalent in the soils there. Tetanus spores are introduced into the body during any injury that punctures the skin. The wound can seem trivial. The disease, which is characterized by painful muscular contractions, can have a fatality rate of 35% to 70% if effective immunization is not administered.

Accidents

Accidents also exact a high health cost in both morbidity and mortality among all residents of Sri Lanka, and the unsettled conditions in Systems A-D will undoubtedly elevate the accident rate there. Besides adaptation requirements for the area, people will be experimenting with new equipment and procedures for many daily functions.

Snake Bites

In System H, snake bite incidents have alarmed farmers. During one year in a small area, 14 deaths reportedly occurred, four in one day. As the jungle is cleared in System A-D, snakes will probably retreat to drainage areas and then return to paddy fields and residential areas. Most of the bites reportedly happen during harvesting.

AVAILABLE HEALTH FACILITIES

Government Hospitals

As in any developed health-care system, Sri Lanka has a hierachical hospital structure, including 351 dispensaries, 84 rural hospitals, 110 district hospitals, nine provincial hospitals, and a network of specialized

institutions, such as tuberculosis, leprosy, and mental hospitals.

In the project area, the following health care institutions with their respective available hospital beds are presently operating (Ministry of Health 1979):

Institution	Beds
Base Hospital, Polunnaruwa	184
District Hospital, Muttur	59
Peripheral Unit, Valaichchenai	52
Peripheral Unit, Vakaneri	24
Rural Hospital, Manampitiya	24
District Hospital, Mahiyangana	88
Peripheral Unit, Minipe	49

Nationwide, the number of general hospital beds was 2.63 per 1000 people in 1977 (Ministry of Health 1979). The health districts comprising the project area are all below this national average.

Health Care and Staff

Health care, including drugs, is free; and personnel standards are comparatively high for the economic status of the country. The system, however, has become increasingly overextended as facilities have expanded to meet demand while, simultaneously, health-care personnel -- especially physicians -- have migrated abroad to countries offering higher salaries. The movement to the Middle East has become particularly widespread, and the exodus of physicians over the past five years has reported equalled or exceeded the number of new physicians being graduated from the educational institutions in Sri Lanka.

In addition to limiting the quality of available health care, this situation has reportedly reduced the patience of remaining physicians with the completion of forms used in the compilation of statistics. Free drugs, on the other hand, have meant that drugs can be prescribed without the constraint of cost so patients can accumulate drugs for use when illness reoccurs, thus reducing visits to hospitals and the need to report the more frequently occurring diseases.

In 1977, Sri Lanka had 1.14 Doctors, 0.15 Public Health Nurses and 1.3 Midwives for 10,000 people (Ministry of Health 1979). In the Accelerated Program area, the present availability of these types of staff is lower than throughout the rest of the country. In general, rural health care services including those presently in the project area suffer from low staff morale and efficiency, lack of equipment, vehicles and supplies and poor communication, coordination and education programs (Ministry of Health 1979).

Private Health Services

Throughout the island, persons with varying medical and pharmaceutical training have opened offices to provide primary health care. Their "dispensary and surgery" shingles can be seen in front of mud huts on jungle roads as well as on modern buildings in urban centers. Offices for private practitioners appear to vastly outnumber government facilities, and their charges are adjusted to the market, the cost for a consultation in a village for -- for example -- being on the order of Rs.10 or less. These private practitioners are distinct from ayurvedic practitioners, who are tradition-oriented and dispense mainly herbs. Numbering at least 10,000 (official registrations), ayurvedic practitioners have a significant following and seem to have a near monopoly on some health problems, particularly treatment of simple bone fractures and snake bites in rural areas.

CURRENT WATER SUPPLY AND SANITATION

Based upon census data collected in 1971 and a recent report by the Ministry of Local Government, Housing and Construction (1980), more than 40% of rural housing units in Sri Lanka do not have a latrine of any kind, while about 45% have simple pit latrines (Table K-15). Urban and estate housing has a much higher percentage of suitable sanitary excreta disposal systems.

Similarly, about half of the urban population has access to a piped water supply. In rural areas, more than 90% of the people obtain drinking water from streams, tanks and mostly dug wells. In addition, most of the rural village water supplies are poorly maintained and contaminated with fecal (mammal) wastes. Generally, most rural residents share a community well using it simultaneously for drinking, bathing and other domestic purposes. The number of community wells recorded by districts for the country is listed in Table K-16.

Socio-cultural Considerations

The rural populace, including that of the project area, are accustomed to regard water supply both as free and as a given right. This is generally from open dug wells usually where a bucket is used for drawing water.

Table K - 15

Latrine Facilities in Urban,

Estate and Rural Areas

(% of Total Housing Units

Type of Latrine	Urban	Estate	Rural
1. Flush Toilet			
Inside Housing Unit			
- Exclusive	11.9	3.5	1.1
- Shared	1.0	0.2	0.1
Sub-total	12.9	3.7	1.2
Outside Housing Unit			
- Exclusive	3.0	1.4	0.8
- Shared	6.8	3.1	0.2
Sub-total	9.8	4.5	1.0
Sub-total (I)	22.7	8.2	2.2
II. Water-Seal Toilet			
- Exclusive	13.5	8.5	8.5
- Shared	5.7	25.4	1.4
Sub-total (II)	19.2	33.9	9.9
III. Bucket Type Latrine			
- Exclusive	8.9	0.5	0.6
- Shared	10.5	3.6	0.4
Sub-total (III)	19.4	4.1	1.0
IV. Pit Latrine			
- Exclusive	11.6	6.6	37.5
- Shared	6.7	31.6	6.9
Sub-total (IV)	18.3	38.2	44.4
V. None	19.1	13.4	41.5
VI. Unspecified	1.3	2.2	1.0
TOTAL	100.0	100.0	100.0

SOURCE : Census 1971
Ministry of Local Government, Housing and Construction (1980)

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Table K - 16

District Community Wells

District	Community Wells			Total
	For Bathing	For Drinking	For Bathing & Drinking	
Colombo, Gampaha	63	689	47	799
Kalutara	136	109	16	261
Galle	477	98	16	591
Matara	601	69	90	760
Hambantota	9	197	221	427
Kurunegala	517	824	1253	2594
Puttalam	129	361	130	620
Kegalle	841	570	228	1639
Ratnapura	846	1295	142	2283
Kandy	1036	1002	746	2784
Nuwara Eliya	135	254	87	476
Badulla	203	527	95	825
Monaragala	81	176	313	570
Matale	311	272	521	1104
Anuradhapura	3	723	301	1027
Polonnaruwa	20	231	20	271
Trincomalee	57	159	276	492
Amparai	72	78	131	281
Batticaloa	13	13	444	470
Jaffna	112	262	399	773
Vavuniya, Mullativu	9	29	249	287
Mannar	60	73	187	320
	5731	8011	5912	18,654

Sources : Ministry of Local Government, Housing and Construction (1980)

These wells are normally used for both bathing and drinking by many people, which of course increases the risk of spreading a number of communicable diseases. Many wells are open and unlined, permitting run-off of human and other wastes to contaminate them easily. People tend to believe that wells should be open to the sun and air.

Further, people will not boil water which may be understandable concerning the expense of fuel sources. Most people express more interest in having clean bathing and drinking supplies than in sanitation facilities.

A government subsidy program exists which can provide Rs.150 to convert a pit latrine into a water-seal latrine. However, the program has not generated widespread interest and much of the budget is unspent (Ministry of Local Government, Housing and Reconstruction 1980).

Administration

A coordinating committee on Water Supply and Sanitation has been established in the Ministry of Local Government, Housing and Construction to integrate the various activities of a number of governmental agencies involved in this sector. The latter include the National Water Supply and Drainage Board, Water Resources Board, Ministry of Finance and Planning, Ministry of Plan Implementation, Irrigation Department and local governments. Each of these has various responsibilities. However the Ministry of Mahaweli Development is responsible for the provision of water supply and sanitation in the new settlements.

IMPACT ANALYSIS

HEALTH PERSPECTIVE

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

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

SPREAD OF WATER-BORNE DISEASES

General Effects

With the substantial increase in population which is anticipated in the project area, there will be an inevitable spread of a number of viral and parasitic water-borne communicable diseases. This will be exacerbated by the lack of basic health education and the cultural practices of the people. They would be expected to continue their present health related activities, such as utilizing the same water supply for drinking, bathing and waste disposal, which would be very conducive to the spread of gastroenteritis, hepatitis, dysentery and other water-borne diseases. This condition will be worsened if suitable water supply and sanitation facilities are not provided, or perhaps more importantly, not maintained.

However, most of the water-borne diseases can be controlled with proper usage of these facilities. Leptospirosis may be more difficult to control than others since many people will have repeated exposure to irrigation water and thus be continually susceptible. Even with proper health facilities installed, it is likely that gastroenteritis and "pyrexias (fevers) of unkown origin" will continue to be a major percentage of the diseases incurred in the region. The existing facilities will, of course, be too

limited to accommodate the health needs of the additional population. Many of the above problems are reflected by an analysis of the existing System H.

Projections from System H for Water-Borne Diseases

Only one irrigated settlement area, System H, has been developed and settled under the direction of the Mahaweli Development Board. For this study, evidence of the health status of settlers in this area was obtained from two sources: personal observations and interviews by the study team and the analysis of statistical reports compiled by Silva, Perera and Wilson (1978).

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

Diarrhea was not among the diseases registered by socio-economic surveys, but fevers constituted by far the largest category of registered illnesses. This was followed by pains in the bone joints, stomach ailments, and chest pains.

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

While limited extension and credit services have been provided to the settlers, no advice, assistance or regulation of any type to assure the new village communities a supply of disease-free water was reported. The quantity of the water supply is, however, expected to improve. Presently, wells exist for every 20 families. This has been found to be far too few; a program is underway to construct enough new wells to provide one for every five families. The wells are concrete lined, but are open and water is retrieved by buckets or comparable containers.

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

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and a government dispensary is operating.

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

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

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

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

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

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

IMPACTS RELATED TO MALARIA

Potential Spread of Malaria in the Project Area

Increase of Mosquito Breeding Habitat - The proposed development program provides the potential for diverting water from the major river basins, thereby reducing flow in the river beds. If used insensitively, this could increase potential breeding sites for *A. culicifacies*, with of course an overall population increase of this vector. Seepage from irrigation channels will increase breeding still more, especially on a full year cycle compared to present seasonal breeding which is limited by water availability.

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

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

Socioeconomic Impacts of Malaria

In addition to the effects of malaria caused mortality, morbidity due to malaria is an important impediment to economic progress in Sri Lanka. Each time a person suffers a malarial attack, he is incapacitated for about three or four days, and this may occur three or four times each year. Since at least 70,000 people seem to suffer this pattern of disease (in 1978), the general population is burdened by about one million person-days lost to malaria each year. If half of the general population is gainfully employed, then about five million person-days of work would be lost each year. Agricultural workers are a particular risk of economic loss since episodes of illness may coincide with some critical period of planting or harvest.

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

In the surveys conducted among new settlers by Silva, Perera and Wilson (1978), farmers were questioned each week about the health status of their households and, specifically, regarding self-diagnosed malaria. These people considered malaria to be the most common disease of their families with an average of about five episodes of attack per family per year (Table K-17). Only about 4% of the persons considered to have malaria reported to the clinic in Kekirawa or to government malaria control representatives. During 46 of these episodes of malaria, the patient sought curative care and, of these, two-thirds (travelling on foot or by bicycle), went further than five miles from home.

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

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

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

Effects of the Present Malaria Control Program

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

Table K - 17

Frequency of Self-Diagnosed Malaria in Several Rural Communities Near Kekirawa and Frequency of Reporting to Government Institutions

	No. Families			No. Malaria Episodes	
Harvest Period	Total Questioned	Reporting Illness	Reporting Malaria	Total Recorded by Families	Reported to Government Institutions
Yala 1977	218	204	175	788	26
Maha 1977-78	128	118	35	47	7
Total	346	322	210	835	33

Source : Silva, Perera and Wilson (1978)

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The present intensive campaign involves a calculated risk. Malathion-resistant A. culicifacies and chloroquin-resistant P. falciparum might become established in Sri Lanka before P. falciparum could be eliminated from the area or P. vivax permanently reduced to acceptable levels. The original malathion-based control plan called for a time-limited campaign of intensive insecticide and drug administration, followed within five years by complete withdrawal of residual spraying and routine drug administration. Withdrawal was to have begun during 1979, but this goal has not been reached. Withdrawal, in fact, has not been recommended except for one small area throughout 1980 and 1981 by the recent annual evaluation of the campaign (de la Motte et al. 1980).

Malathion and fenitrothion resistant A. culicifacies are already present in India, and drug resistant P. falciparum is common in Southeast Asia and present in Eastern India. These circumstances indicate that resistence problems may spread to Sri Lanka, especially in view of the massive quantities of agrochemicals now being used. In addition, since the present vector has already demonstrated resistance to DDT, a similar potential for adaptation to malathion or against other pesticides may be anticipated in the future.

IMPACTS OF OTHER VECTOR DISEASES

Filariasis

At present, due to the unavailability of suitable breeding habitats, there seems little opportunity for mosquito-carrying filariasis to exploit the Mahaweli Accelerated Program region. In the event that such a population developed, easinophilic lung would be an early manifestation of the presence of active transmission. Stable foci of patient infection would take decades to develop.

However, the Bancroftian filariasis could someday be a problem with the increase of urbanization to the eastern part of the country. Also, the Brugian form could possibly return if suitable aquatic vegetation (Pistia) breeding habitats appear for the Mansonia vector.

Dengue Fever

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

Chinkungunya Virus, Scrub Typhus and Bed-Bugs

All of these diseases may spread with the development of the project area. Chinkungunya virus is prevalent in nearby Trincomalee and scrub typhus often occurs in newly cleared areas. The latter may be a problem for construction workers and early settlers. Similarly, a spread of bed-bugs would be anticipated with the large number of settlements planned.

Schistosomiasis

Schistosomiasis is not presently found in Sri Lanka. However, widespread concern exists among authorities here that an infected Sri Lankan migrant to the Middle East could return to the Mahaweli irrigation systems and contaminate the water. It is not clear that a suitable snail host for either S. mansoni or S. haematobium exists in Sri Lanka. There is further concern that suitable snails may possibly be imported, for example, on a shipment of fish products, etc. However, even if snails suitable for S. japonicum were brought from elsewhere in Asia, it is likely they would be of the genus Oncomelania; but S. mansoni requires the genus Biomphalaria and S. haematobium, the genus Bulinus. Consequently, the spread of schistosomiasis is not expected to occur as a result of project implementation.

Encephalitis and Leishmaniasis

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

IMPACTS OF OTHER DISEASES AND HEALTH HAZARDS

Rabies and Tetanus

Although these diseases can be controlled and prevented, localized incidence will inevitably occur in the project area. Rabies presently is reportedly increasing significantly throughout the island, with a high potential of danger for small children.

The tetanus bacillus is prevalent in project area soils. The disease may be a particular problem during construction when the number of punture wounds which would be susceptible to tetanus infection will probably occur most frequently.

Industrial Cancers

Except for malignancies related to betel chewing, environmental cancers are now rare in Sri Lanka although the occurrence will undoubtedly increase in the future. In the Mahaweli areas, two practices may result in some future cancer incidence: (1) contamination of water supplies with agricultural chemicals and (2) the method of preparing tars for road construction

and repair. Chemical pesticides tend to become ubiquitous in any modern agricultural area, but the problem in Sri Lanka appears enhanced by carelessness of handling the pesticides and the spraying equipment and the indiscriminate use of water drained from agricultural land.

In addition, the practice of road construction assures that workers will receive severe exposures to vaporizing tars. Some of the fractions, such as benz(a)pyrene, released by heated tars are highly carcinogenic. The method of liquifying road tars in Sri Lanka involves workers breaking open a drum of tar and burning the contents until the entire mass is melted. Dense clouds of smoke are released, and workers are constantly working in the area where gases and particulates are rising.

Accidents and Snake Bites

Due to the generally unsettled conditions, particularly during the initial development period, accident rates would be expected to increase in the project area. Injuries during construction must also be anticipated.

Similarly, the occurrence of snake bites may rise considerably in the project area, especially during the clearing operations of presently forested areas.

POTENTIAL NEW DISEASES

A jungle clearing project in a tropical area, requiring immigration and concentration of large numbers of people, expose those people to a real risk of acquiring novel zoonotic infections.

A new disease that could result may be devastating and may involve may persons. Monkeys, which are numerous in the Mahaweli Ganga basin, are particularly prone to share disease with man. For example, *Entopolypoides sp.* is a tick-borne (probably malaria-like) parasite of monkeys and may infect man. Similarly, *Babesia* parasites of rodents produce human disease that has been confused with malaria. Even immunological tests may confuse *B. microti* and *P. falciparum*. This complicates malaria control as well as clinical care. In any case, novel diseases, by definition, are not anticipated, although it is essential that public health authorities of the country be alert to the possible occurrence of previously unidentified hazards.

NUTRITION

Overall, dietary patterns and nutritional quality should improve for the incoming settlers due principally to increased food availability and an increased standard of living. However, the Ministry of Health (1979) has indicated that a future problem for the Accelerated Program is that there is no effective nutrition strategy planned.

In this regard, one potential serious problem may be an insufficient supply of animal protein to meet nutritional requirements for the general maintenance of good health. The supply of dairy products to the project area may be limited since it appears that grazing land will be reduced throughout the region. In any event, an excellent protein source which should be capitalized upon is through the development of inland fisheries resources. Increased fish production could contribute significantly to the need for animal protein which will arise in the project area. Means of improving and developing fisheries for the Accelerated Program are discussed in detail in TOPIC REPORT G : FISHERIES.

IMPACTS DURING CONSTRUCTION

As mentioned above, construction workers may be particularly vulnerable to certain diseases or hazards such as tetanus and snake bites. Malaria, dengue fever and other vector diseases may also be a problem.

In addition, large numbers of construction workers (as many as 130,000 during peak periods) will be necessarily housed in the close quarters of construction camps and thus continually exposed to various communicable diseases through a number of transmission modes. Deficient sanitary and water supply facilities in the camps could result in a rapid and repeated spread of enteric and other water-borne diseases. For the phases of the program under international sponsorship, health problems are expected to be minimal if, as reported, foreign contractors are required to construct and equip a camp hospital for providing health care to workers. Contractors will also be responsible for providing adequate water supplies and sanitary facilities. These requirements should be extended to Sri Lankan contractors as well.

RECOMMENDED ACTIONS

COMPREHENSIVE HEALTH PLANNING

Background

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

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

The Comprehensive Approach

At present, sufficient priority regarding the provision of health care services, especially potable water supplies, suitable waste disposal systems and adequate housing, are needed in the overall planning for the Accelerated Program. Without a specific preventive program, incidence of certain diseases can be expected to increase in the project area because of (1) contaminated water supplies, (2) inadequate sanitation and housing, and (3) increases in disease vectors, especially for malaria.

A comprehensive planning approach is necessary for the provision of suitable health care for the Accelerated Program. This would involve an integration of a well balanced program planned in an order of priority with a selection of a combination of control and preventative methods based upon their respective efficiency, feasibility of application, cost and adaptation to local conditions.

Presently, health programs regarding the Accelerated Program are coordinated by a health officer seconded to the Mahaweli Authority from the Ministry of Health. This approach has brought good results, although more personnel will probably be required in the future. Actual implementation of health programs under the Ministry of Health appears to be very practical since the organization of personnel and equipment is more easily accomplished than through any other agency.

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Ministry of Health Proposal

A basis for comprehensive health planning was established for the Accelerated Program when in March 1979, the Ministry of Health submitted A Proposal for Health Services in the Operational and Accelerated Mahaweli Development Areas to the Mahaweli Development Board.

The Ministry of Health identified six "Priority Health Interventions and Targets" considered the most necessary for the Mahaweli Accelerated Program:

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

Special attention was given to the potential problems related to malaria as the development proceeds.

In addition, a number of recommendations, both general and specific were made. General recommendations included:

- Priority attention to the possibility of settling the farmers in permanent houses on the allocated settlement areas;
- Provision of safe and adequate water supplies;
- Promotion of environmental sanitation and environmental protection;
- Pre-settlement medical screening of settlers;
- Setting up of a Health Monitoring System at the hamlet level;
- Setting up a very sensitive Malaria Surveillance System;
- Priority assignment of health staff to the development areas and the provision of non-monetary incentives;
- Utilization of volunteer health workers;
- Performance of specified curative functions by field staff;
- Improvement of the health management system;

- Improved contact between preventive and curative staff; and

- Adoption of a simplified reporting system.

Specific recommendations concentrated on the provision of health care services and facilities as follows:

- A Midwife and two or three volunteer health workers recruited from among the settlers serving every five hamlets or 3,000 population;

- A Central Dispensary serving every five villages or 15,000 population;

- A Peripheral Unit with 48 beds, clinic room, and ambulance to serve 60 to 70,000;

- A District Hospital with 90 beds, ambulance and jeep for every block of 100,000 to 150,000 people;

- Referral facilities; and

- Special facilities, including six Ayurvedic Dispensaries and one Ayurvedic Hospital.

The development phasing for these specific facilities was projected for the next five years, and general locations were identified for the installation of the facilities. Details at this level were provided for systems A, B and C. Comparable planning for System D is still required.

In general, the Ministry of Health's proposal provides an initial framework from which comprehensive health planning can be evolved for future implementation. The proposal is endorsed here with the recognition that a number of aspects need expanded study and consideration. While the proposal provides specifications for health care facilities, most of the general recommendations require comparable detail before they can be incorporated into a comprehensive plan. Many of these aspects plus some additional recommendations are addressed in the following sections.

SURVEILLANCE

UNEP Proposal

Adequate surveillance is an essential feature of a successful comprehensive health program. In this regard, UNEP (1980) has recently proposed that a Health Effects Monitoring System be instituted for the Accelerated Program. This would be comprised of surveillance, monitoring, quarantines and related data information collection and reporting services which would include the following health aspects:

- Identification of new breeding habitats for vectors;

- Water quality of surface and drinking water supplies;

- Air quality;
- Construction related health problems;
- Screening of new settlers;
- Nutritional status of pre-school children;
- Sanitary and hygienic conditions in various settlements;
- Soils analysis for the presence of parasites and toxic chemicals;
- Survey for potential new vectors including snails, insects, small rodents and plants; and
- Recording morbidity and mortality incidences by age groups and sex for malaria, water-borne diseases, accidents, nutritional deficiency, respiratory diseases and venereal diseases.

UNEP recommend the immediate initiation of this program under an inter-agency committee composed of the MDB, Ministry of Health and the National Science Council. UNEP also recommends that an entirely new system of data management analysis be implemented to supplant the existing health information system.

While the majority of UNEP's surveillance program is consistent with the needs of a comprehensive health plan, it does not take into consideration the interests of a number of other governmental agencies concerned with health problems, especially those involved in the provision of water supply and sanitation. These agencies should be included on the coordinating inter-agency committee to develop monitoring as part of the overall planning effort. Further, the proposal to establish a completely new data collection and dispensing service should perhaps be reviewed in the light of manpower and equipment needs. It may be more feasible instead to upgrade the existing system and integrate it with other monitoring and data retrieval services, especially the one operated by the Anti-Malaria Campaign.

Anti-Malaria Campaign Monitoring

The extensive Anti-Malaria Campaign monitoring program was described previously, and updated details are provided in de la Motte *et al*. (1980).

Effective epidemiological surveillance is a prerequisite to controlling and, especially, withdrawing spraying. If knowledge of the prevalence of malaria is flawed, spraying cannot logically be withdrawn and the Intensified Control Program will fail to meet its time limited objectives. Some recommendations concerning the present surveillance program are discussed below.

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Present utilization of active case detection by trained workers might appear as a useful substitute for a more passive technique. However, the method seems to work poorly in Sri Lanka, except in regions remote from medical institutions. Sri Lankans prefer to be examined and treated by physicians rather than by ACD workers. Active-detection agents generally distribute drugs when a patient with malaria is discovered, but this service seems redundant in present day Sri Lanka. Abundant anti-malarials can be obtained cheaply and as soon as needed. Unavoidable delay in treatment renders the active detection process unsuitable as a clinical service.

In spite of these difficulties, active detection remains the most promising surveillance mechanism. However, the present profligate supply of drugs confounds parasitological epidemiological intelligence. People self-medicate until clinical signs are reduced, while infection may remain. Thus, drugs permit malaria cases to escape surveillance while reducing disease. In order to minimize this confounding element, it is suggested that parasitological surveillance be based on blood-samples taken from infants between two months and three years of age. This nonconventional age category is most easily located and probably fewer people of this age would refuse to be bled than do older people. In addition, infants may not consume sufficient anti-malarials to mask malaria as frequently as do older people. A blood sampling program of infants has just been initiated by the Anti-Malaria Campaign (de la Motte et al. 1980). This may eventually provide a basis for controlling spraying.

Another suggested departure from established practice involves the method for studying blood samples. Derived samples of blood might be collected on filter paper and the eluate subjected to IHI serological testing. At present, the Anti-Malarial Campaign is experimenting with IFA test, but this may not be optimal for sera collected on filter paper. Dirt, which is unavoidable under field conditions, masks flourescence microscopy, but does not interfere with hemagglutination inhibition.

A regular system for collecting sera from project area residents should be instituted. These samples would serve as a basic surveillance system for various viral and rickettsial diseases in addition to malaria. In particular, the screen should include Japanese encephalitis virus, dengue, scrub typhus and epidemic typhus. This type of integrated surveillance would be very beneficial in conserving manpower and increasing the efficient use of equipment. It plus the existing Anti-Malaria Campaign surveillance system and the UNEP (1980) Health Effects Monitoring Program should be combined as a single health monitoring program for the comprehensive health plan. One of the major objectives of this surveillance system should be to significantly increase the speed of both reporting and distributing survey results.

WATER SUPPLY AND SANITARY WASTE DISPOSAL

Rationale

The provision of an adequate supply of safe, potable water is a major precondition for achieving a healthy community. Statistics and field surveys indicate that diseases attributable to contaminated water supplies are excessively straining the health-care delivery system, suppressing productivity, and decreasing human morale. Access to safe drinking water and the use of basic sanitary facilities are the simplest and most effective means of controlling the incidence and spread of the principal water-borne viral and parasitic diseases including gastro-enteritis and diarrhoeal diseases, cholera, typhoid, dysentery and hepatitis.

Recommended Water Supply Systems

Every settler, including those in commercial-government centers, should be assured a reliable and safe water supply in place prior to settlement. Since most settlements will be dispersed over 0.4 hectare lots the cost of piped water outside of towns is assumed to be prohibitive. Numerous small water treatment plants maximize operational costs and risks. Thus, wells appear to be a logical solution for most situations. When wells are not practical, small protected reservoirs can provide an alternative, although some rudimentary treatment may be desirable.

Well Type and Location - The traditional design of shallow, open wells should be changed slightly to assure sanitary conditions. Present wells have a concrete lining which limits surface and some groundwater contamination. However, the wells are open, and retrieval procedures are conducive to the transfer of disease.

It is recommended that wells be constructed with the following features:

- An impervious apron with drains which exclude surface water from entering the well;
- Concrete watertight seal for 3 meters below ground level;
- Provision of pumps or rope and bucket that limit user accessibility and contact with actual well water; and
- Provision of chlorination when necessary when disease focus is identified locally.

Typical well construction which limits contamination and indicates the above features is depicted in Figure K-3.

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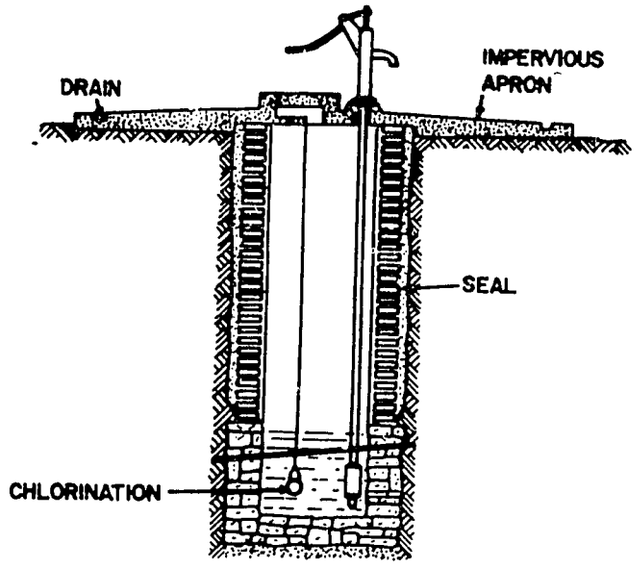
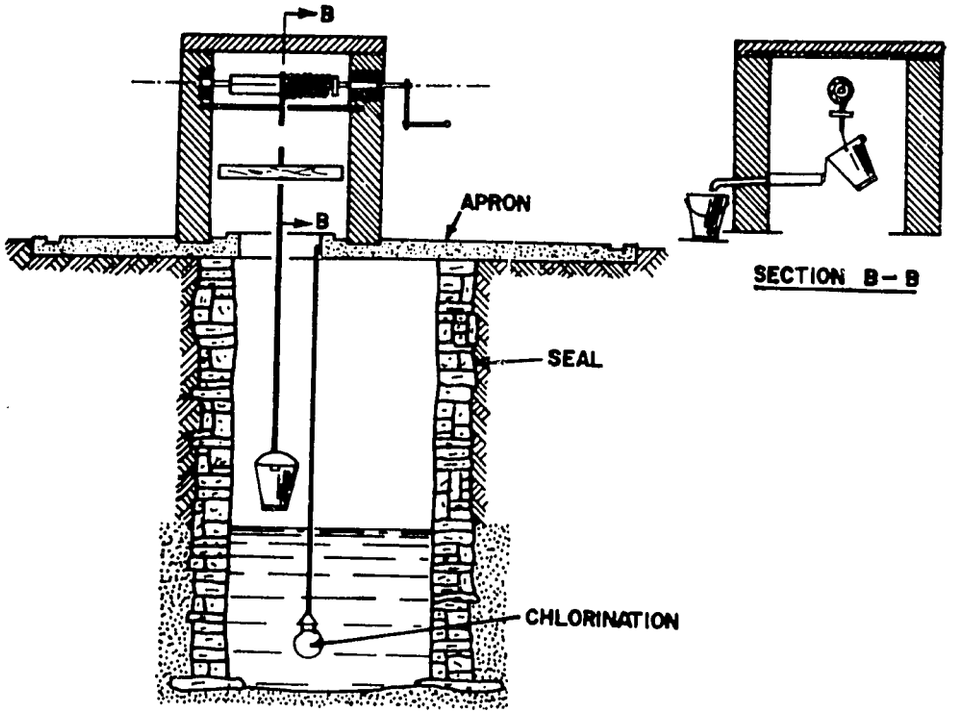
A· DUG WELL WITH PUMP



B· DUG WELL WITH WINDLASS



SOURCE: RAJAGOPALAN AND SHIFFMAN (1974)

TYPICAL WELL TYPES WITH SAFETY FEATURES

FIGURE K-3

Wells should be located in areas which would prevent potential drainage from liquid wastes and privies. In addition, in areas where bed rock is close to the surface, shallow wells may become dry in the peak of the dry season. The Water Resources Board apparently is considering deep wells penetrating the rock zone, an enormously costly solution, instead of a mixed solution of a few deep wells (low risk, high cost) and many shallow wells (high risk, low cost). In areas with relatively homogeneous, stable clay soils, for example, communities could easily be provided with inexpensive hand augers for bored shallow wells. Thus, the only capital cost would be the well pipe and strainer point, the hand pump unit, and some type of base plate or well cover. It should be noted that due to maintenance problems, pumps may not be as feasible as a windlass type of water retrieval system.

Requirements and Costs - In System H, wells were provided for every 20 families. This was found inadequate and attempts now are underway to dig wells for every 5 families. This should be the minimum provision for the Accelerated Program; in fact a single well for each family would be preferable.

An immediate survey is required to determine ground water availability in the project area and its proximity to proposed settlement schemes. At present, there has been no water demand forecast made in relation to potential yields from aquifers.

As a guideline, a consumption level for rural areas should be approximately 75 liters per day per capita. Estimates for planning rural centers should be based upon a level of about 200 liters per person daily. Based on these estimates, the domestic water requirements for the project area will be as follows:

Rural Area	75 x 500,000 =	37,500,000 liters/day
Urban Area	200 x 500.000 =	100,000,000 liters/day
Total	=	137.5 million liters/day

This would require an annual water supply from all sources of about 50.2 million cubic meters. The study recommended above will need to determine whether this amount is available and from what potential sources (see MAIN REPORT for details).

The capital costs of providing water supplies for the Accelerated Program can be roughly approximated on the basis of figures presented by the Ministry of Local Government, Housing and Construction (1980) with a slight increase as follows:

Rural Areas (wells) at Rs.60/person	=	30 million
Rural Centers (standpipes) Rs.550/person	=	275 million
Total	=	Rs.305 million

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Recurrent operations and maintenance costs plus contingencies would be about 10 to 20% of the total capital cost.

Recommended Waste Disposal

Every village house and commercial facility should be provided with sanitary facilities for disposal of human wastes. The Ministry of Local Government, Housing and Construction (1980) has proposed a program to convert existing pit latrines into water-seal pit latrines or comparable facilities for rural areas which should be extended to the Accelerated Program area.

Latrine Type and Location - In hamlets, a general latrine type which would be recommended would include the following features:

- A housing structure;
- A concrete floor slab;
- Tamped earth mounded around the privey for drainage and fly seal;
- Impervious floor base to prevent larvae emergence;
- A pit lined with cut limbs and soil-content base; and
- A pit volume sufficient to last four or five years.

Assuring a sanitary facility requires more than simply providing a villager, who has probably never used a latrine, with a floor plate. There must be some action to assure that the latrine pit is dug and the plate is installed with a water seal prior to occupancy.

The latrines should be located preferably below water supply drainage catchments. They should be more than six meters from dwellings and more than 30 from wells. Also, they should be constructed in soils which will not collapse into the pit.

Requirements and Costs - It is recommended that latrines of the above type be provided for each family in the project area. This includes existing families as well as future settlers. Disease prevention will not be effective unless all individuals receive access to sanitary facilities. The major cost for the latrine is the concrete slab. Roughly, each latrine would have a capital cost of about Rs.1000; total capital cost for the project area would consequently be around Rs.175 million.

Administration

The implementation of water supply and sanitation facilities should be conducted as part of the overall comprehensive health plan for the project area. The present Coordinating Committee on Water Supply and Sanitation can make valuable inputs into this sector.

In addition, participation of the local community will be very important in the success of installing, maintaining and effectively utilizing sanitary facilities of all kinds. Early involvement of the community should be encouraged for the selection of sites, the provision of information on water availability, the transfer of health education programs and the establishment of requisite operation and maintenance procedures. A community self-help program for the actual construction is recommended.

HOUSING

Every settler should be provided with the basis for a clean, properly located house that would reduce vermin infestations and would encourage more healthy life styles. A house is more than a shelter from the elements. By its design, certain life styles are encouraged and others are inhibited. Location affects the provision of services and the ambiance of the community. Many of the health and economic problems of the settlers in System H can be attributed to unhealthy habits, which constitute life styles. Thus, by encouraging improved housing, perhaps also with guided self-help, some immediate gain can be made in health. Perhaps, more importantly, a mechanism would be provided for encouraging practices that will improve the living standards of the people and the community.

Quality housing does not have to be provided at government expense. Aided self-help housing has proven successful in numerous areas of the world. Possible approaches include providing (1) a concrete floor slab, (2) subsidized materials and technical advice, (3) credit, or (4) some combination of these. A concrete floor slab and limited credit for materials stockpiled by the government may be an optimum solution.

RECOMMENDATIONS CONCERNING PRESENT MALARIA CONTROL PROGRAM

Goal Orientation

Effective control of malaria is essential to the success for the Mahaweli Accelerated Program. Failure of control would impose unacceptable malaria mortality in Sri Lanka as well as a heavy burden of morbidity. The dispersed nature of the proposed development, as well as other considerations, require that malaria control remain integrated with the national campaign. This disease-control effort deserves a special separate public health unit within the comprehensive health plan. The present Sri Lankan Anti-Malaria Campaign is a highly effective organization. It appears to be well administered, and the technical staff are competent and engergetic. Operational spray units appear to attain the prescribed insecticide coverage. Useful records are compiled and are well maintained. Financial support seems adequate for present needs. The organization of the present Sri Lankan Anti-Malaria Campaign is well suited to the needs of the Accelerated Program.

However, the stated goals of the campaign are impractical. It is unlikely that P. falciparum will be eliminated within the foreseeable future, or that prevalence of P. vivax can be reduced below some threshold that permits maintenance by reduced spraying schedules. A formal demonstration that such a threshold may exist is unknown. The concept of an intensified, time-limited control program seems to be a contradiction in terms. Indeed, any disease control program should be designed for indefinite continuance. Thus, new malaria-control goals should be formulated for Sri Lanka. A continuance of the program has been discussed recently in the 1980 evaluation of the Anti-Malaria Campaign (de la Motte et al. 1980).

Spraying, Resistance and Withdrawal

The methodology of the present intensified program is nearly identical to that of a classical eradication program. Indeed, the doctrine of complete spray coverage is now applied more rigorously than during the eradication campaign of 1958-1963. This doctrine appears to have resulted in the loss of usefulness of DDT, and malathion is similarly threatened. In order to conserve the effectiveness of malathion, its use in Sri Lanka should be greatly restricted. For example, a new spray strategy should be devised that focuses upon threatened outbreaks of malaria and upon regions where transmission is readily broken. Regular spraying should be withdrawn from centers of intense, stable transmission. Withdrawal is being evaluated annually, although recommended withdrawals for 1980 and 1981 will be in very few regions (de la Motte et al. 1980).

There may be an alternative to the time limited, intensive near-eradication program now being conducted in Sri Lanka. This would require that the government identify certain tolerable levels of malaria disease in particular regions of the country. Spraying should be partially withdrawn so that the absolute minimum amount of malathion is used. This would be analagous to the "dirty field concept" now widely employed by agriculturalists. Farmers now appreciate that pesticides are costly, conducive to selection and potentially harmful to non-target organisms; and they optimize spray use in terms of the minimum necessary. Thus, agricultural goals are adjusted to reality just as public health goals might be adjusted. Costs of the program should not exceed long-term capabilities and should be discussed and organized in terms of an indeterminate series of five-year programs aimed at reducing diseases (rather than infection).

One resistance-related issue complicates such planning while presenting interesting novel opportunities. This derives from the well-established principle that the effectiveness of selection for resistance, within limits, is a direct function of the number of vectors treated with the insecticide (Spielman and Kitzmiller 1967). For this reason, regions in which the vectors are dense should require maximally conservative spray criteria. Those where the vector is scarce, might be sprayed more frequently.

A policy of concentrating spray on regions where vectors are least dense is consistent with the goal of economically reducing disease. Regions of low vector density would most economically be rendered almost malaria free. These would be areas of seasonal transmission, unstable epidemiologically, where the personal impact of each malaria episode would be greatest. Regions of greater vector density might be sprayed in a more selective manner, aimed at preventing epidemics. In regions of intense transmission, the immune status of the population would help residents better tolerate infection. Transient people should have access to drugs. Clearly, in the short run, humane considerations dictate that "problem areas" should get the most attention. But, this constitutes a danger to the entire country. On the contrary, problem areas might better be withdrawn from spray coverage or subject to less frequent or deliberately incomplete spraying. In any event, effective withdrawal planning is based upon an adequate, detailed surveillance system which was discussed in the preceding section on SURVEILLANCE.

Logistic Needs

Logistic needs of the Anti-Malaria Campaign are presented in detail in the recent annual evaluation of the program (de la Motte *et al*. 1980). Major logistic problems which should be solved as soon as possible to meet demands for the Accelerated Program include:

- Provision of additional vehicles and motor cycles;
- Improvement of transport repair facilities and procurement of spare parts;
- Reorganization of storage facilities;
- Proper disposal of malathion containers; and
- Improvement of sprayer nozzles and provision of proper hose extensions for sprayers.

Research Needs

An in-depth malaria research program linked to a new surveillance effort should be organized, adequately equipped, and given the institutional support to undertake long-term, problem-oriented projects. The lack of even basic knowledge of malaria ecology, including transmission, has handicapped the development of balanced, long-term control strategies. The correlation between seasonal water levels in major streams and *A. culicifacies* populations needs to be determined. The natural parasites and predators of *A. culicifacies* and their relative effectiveness under different conditions should be investigated.

The identity of Sri Lankan vector anopheline(s) should be rigorously defined. The matter now rests mainly on the results of salivary gland dissections, and this is insufficient evidence. Failure to discover naturally infected mosquitoes does not demonstrate non-vector status for a species. Instead, longevity, man-biting habits and rate as well as

vector competence of all abundant Anopheles should be compared, with special attention given to exophagic, exophillic species. The possibility of a jungle cycle should be explored thoroughly. If another vector, such as A. elegans, is identified, a control technique based on breeding patterns must be designed.

The longevity, therefore the transmission effectiveness, of A. culicifacies and the long-term response pattern genetically with exposure to different chemical insecticides also needs study. Research of this nature has been initiated in 1978 by the Anti-Malaria Campaign in conjunction with the London School of Hygiene and Tropical Medicine and the U.K. Medical Research Council (de la Motte et al. 1980). This work effort includes investigations concerning insecticide selection regarding male mosquitoes and the determination of the proportion of adult A. culicifacies which originate more than one kilometer from the collection site.

Insecticide susceptibility of A. culicifacies (and other possible vectors) should be thoroughly understood. This requires that an A. culicifacies laboratory colony be established in a room distant from stored insecticide. Colony material would be used as malathion susceptible standards for bioassy of various sprayed surfaces and for insecticide selection studies. Specifically, Anti-Malaria Campaign personnel should define the spectrum of resistance resulting from selection with various insecticide. It is suggested that "discriminating dose" measures be re-evaluated. Dose-time criteria should be adjusted to Sri Lankan A. culicifacies, rather than the "international standard" now in use. Dose response regression lines against adults as well as larvae are periodically required.

Three residual insecticides remain as potential alternatives for malathion in the event that the usefulness of this organophosphate is lost. These include another organophosphate, fenitrothion; the organochlorine, lindane, and the carbamate, propoxur. Each has drawbacks and each is much more expensive than malathion. For example, a cost ratio between DDT, malathion and propoxur has been calculated at 1 to 3.1 to 8.5. Thus, the present campaign would expend only $5.8 million if DDT could be used, but $49 million if propoxur were required. Present Indian experience suggests that malathion-selected A. culicifacies may be resistant to fenitrothion, and that lindane (BHC) resistance appears rapidly. Field trials have been initiated by the Anti-Malaria Campaign for fenitrothion use, but results are not yet available (de la Motte et al. 1980). Only one additional category of potentially useful insecticide appears as a promising future development. This is the category of synthetic pyrethroids including such products as decamethrin and resmethrin. None have been fully evaluated, but WHO malariological screening is well advanced. Some concern has been raised since these compounds seem repellant to insects. If vector Anopheles are irritated by a residual, they may not remain in contact long enough to be killed. These considerations indicated that malathion is a uniquely anti-malarial chemical that should be conserved.

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The public health impact of agricultural insecticides in Sri Lanka should be evaluated. Because local A. culicifacies breed mainly in stream beds and away from paddy fields, it seems unlikely that agricultural insecticides would select resistant A. culicifacies. At present, Sri Lankan law precludes agricultural use of malaria control insecticides, but this is based on results of work with American anophelines that breed close to sprayed cotton fields. It may be that this law places an undue burden on Sri Lankan farmers. The degree of involvement of agricultural insecticides in resistance selection is one of the objectives of the collective research study mentioned above.

In the event that agricultural use of insecticide proves to select A. culicifacies, the present "use" law should be converted to a "distribution law". It seems futile to attempt to apply sanctions against individual users of insecticide. Instead, larger distributors could be identified and compelled to refrain from selling malathion or fenitrothion.

CONTROL OF MOSQUITO VECTORS

Biological Control

The Anti-Malaria Campaign has conducted trials which indicate that the fish species Aplocheilus dayi is very effective in preying upon anopheline larvae (de la Motte et. al. 1980). Use of this species or others could limit breeding effectiveness for any mosquito species. Other fish species which may be considered would include Panchax panchax, a native species, or Gambusia affinis.

Water Level Management

Monitoring Discharge Rates - In the face of a threatened loss of anti-malaria chemicals, it is imperative that water management policies be formulated as to minimize river-bed breeding of A. culicifacies. Drought periods, when agricultural needs are greatest will be the time of greatest malaria risk.

The Anti-Malaria Campaign is presently conducting trials whereby weekly hydrological monitoring of stream discharges is used to determine potential pool formation in the steam beds (de la Motte et al. 1980). The pools are then investigated for mosquito larva production and treated with larvacides when necessary. This system should be expanded throughout the Accelerated Program area.

River Flow Regulation - In future years when the Mahaweli Development Program is operating, water control in river beds may be the logical technique to prevent the recurrence of malaria due to rapid increases in A. culcifacies populations.

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A periodic sudden discharge of water down a river channel has been shown to be an effective measure to prevent pool formation and limit mosquito vectors (WHO 1973). Flushing of the river bed physically damages eggs and larvae and/or strands them in dry areas, effectively destroying them.

In order to flush out the larvae in the puddles, a minimum flow depth of 0.2 meter should be maintained in the river channel. The average slope of the Mahaweli Ganga downstream of the Minipe Anicut is approximately 0.0007 and the average width is about 200 meters. The discharge required to maintain a depth of 0.2 meter would be approximately 6 cumecs. If the process of flushing is conducted once a week with a duration of two hours each time, the total volume of flow required for river-bed flushing would be equal to 172,800 cubic meters per month. There should be more than sufficient reservoir storage to provide this amount.

There may, in fact, be sufficient water storage to permit a conservation flow of about 10 cumecs in the lower Mahaweli through the dry season (Hydrology Division, Irrigation Department, personal communication). Maintenance of this flow level would be highly recommended to not only prevent intermittent pool formation, but also to conserve aquatic habitats for fish and other organisms.

Another means of flow regulation could be based upon a stabilization of water levels. This is likely to naturally occur in the Maduru Oya river basin due to increased flows due to irrigation return flows. It would probably not be feasible in the Mahaweli Ganga, especially with full development of the transbasin diversion areas. In any event, river-beds should be canalized where possible near towns to maintain flows there.

Reservoir Preparation - For all of the proposed reservoirs, preparations should be made to limit pool formation in the drawdown zone which will be exposed annually for an extended period. This preparation would involve measures to clear, drain and modify the basin so that all marginal ponds, sloughs, depressions, marsh areas and swamps will drain into the main lake even as drawdown proceeds. Planning for this type of operation would be conducted for each reservoir on an individual basis.

Design and Operation of Irrigation Systems - An excess amount of water delivered to the irrigation system can be a major cause of health problems. Overflowing canals that inundate the adjacent lands and excessive seepage that saturates the soil form pools favourable to mosquito breeding. Surplus water may also overtax the capacity of the drainage system, with subsequent flooding and formation of pools. Consequently, proper water use and management are essential to the limitation of mosquito proliferation.

Canals and drains should be designed to facilitate high flow velocities. Usually velocities of 0.3 m to 0.9 m.sec are sufficient to prevent pooling. These velocities will naturally develop with canals placed on a gradient of 0.1 to 0.3%. Faster velocities are of course not a problem, provided no

overflowing occurs (WHO 1973). The design of main canals, laterals and sub-laterals should follow straight lines to the degree possible. The lining of canals also limits mosquito breeding habitats. Intermittent flushing of canals and drains may be necessary to interrupt mosquito breeding in localized areas.

Settlement Location - Village and other rural centers should be located away from potential mosquito habitats, i.e. reservoirs, canals, rivers and lakes, and on the leeward side of prevailing winds. This will limit areas of mosquito to human contacts. A distance of 1.5 kilometers, where possible, from potential breeding areas is recommended (WHO 1978).

Filling - A simple means of limiting mosquito breeding habitats is to fill and grade unused holes or excavations, especially those near community centers. Included in this category would be:

- Borrow pits, especially along canals and roads;
- Abandoned ditches;
- Gem pits;
- Abandoned wells;
- Unused irrigation channels;
- Holes where trees have fallen; and
- Areas of seepage collection.

Fills should be graded in the direction of the land slope to permit natural drainage which will not re-excavate the hole.

CONTROL OF OTHER DISEASES AND HAZARDS

Informal discussions suggest that plans are underway to extend the Anti-Filariasis Campaign to include the Accelerated Program area. This should be re-evaluated taking into consideration the effectiveness of the program and the need for filariasis control in the project area.

The present Anti-Filariasis Campaign is not successful in reducing the transmission of W. bancrofti nationwide. At best, the program can detect and treat no more than an insignificant fraction of microfilaria carriers, and treatment of this fraction is entirely inadequate to interrupt transmission. A recent effort using the nucleopore filter technique revealed positive rates of 15-17% in regions where the program recorded rates are less than 1%. This program should not be extended to Mahaweli settlements because there is negligible risk of transmission in these areas, while even in endemic regions, the program seems futile.

The effect of residual insecticides upon bed bug populations should be assessed. Does biting activity by resistant bugs actually increase 1-2 weeks after spraying as residents claim? If so this would discourage insecticide use and would interfere with antimalaria activities. The factors that normally limit bug populations should be studied. Concern for the bed-bug resistance problem has also been raised by the recent review of the Anti-Malaria Campaign (de la Motte et al. 1980).

The effective control of the spread of leptospirosis will be very difficult. For the early stages of the Mahaweli Accelerated Program, the appropriate control approach would probably be periodic rat-control campaigns accompanied by an educational program and the availability of antibiotic therapies.

It is recommended that at least all construction workers be immunized against tetanus prior to the commencement of work. Polio immunization should also be given. Rabies immunization vaccine should be kept in stock. In addition, anti-venom for cobras, kraits and Russell's vipers should be made locally available.

CONSTRUCTION CAMP SANITATION

Camp sites which will be used regularly should be supplied with a permanent water supply by means of stand pipes, tube-wells or at least a covered dug well.

Shallow trench latrines should be avoided since they invite the spread of enteric diseases. Deep trench latrines at least three meters deep are preferable. Straddle trench latrines with wooden borders are even more suitable. The straddle trench is 0.25 meters wide and about one meter deep. Two trenches each five meters long can serve 10 people for a few days. The latrine should be closed when it is filled within 0.5 meters of the ground surface. Hand washing facilities should be provided separately. Each individual should cover his excreta with a shovelful of earth to limit flies and odors. At permanent camps, more substantial water-sealed pit latrines are advisable.

HEALTH EDUCATION

An intensified health education and public information program is needed to break down cultural habits which are presently conducive to poor health conditions. A nationwide self-help program of training and education has been instituted by the Anti-Malaria Campaign including some areas of the Accelerated Program. These of course are aimed primarily at malaria control. It may be possible to expand this program to other areas of health needs.

It is recommended that a health education unit be established as part of the comprehensive health plan for the project area. This unit would prepare and circulate literature and conduct training programs for all aspects of health education. The unit would explore the possibilities of extending present education programs to encompass other health disciplines. Also, it would be responsible for encouraging health education in schools and promoting the involvement of community level non-governmental agencies which have public health objectives.

Health education must be an integral part of the comprehensive health plan and may, in fact, be a major limiting factor to its success.

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L. SOCIAL SCIENCE

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EXISTING CONDITIONS

SOCIAL STRUCTURE

The current residents of the Accelerated Program area live in settlements of three major types: traditional villages, colonization schemes and new villages.

Traditional Villages

At an earlier period in history the dry zone of Sri Lanka was the home of major civilizations based upon centrally organized irrigation systems. Large tanks or reservoirs stored water for cultivation and domestic purposes during the dry season and supplemented the rainfall which fell during the wet season.

With the collapse of the political kingdom supporting this system, and with the movement of political power to the wet zone in the southwest, the form of human culture and habitation contracted in size and sophistication. The predominant means of survival in the dry zone continued, on a smaller scale. The unit of survival contracted to the village, and the size of the village was that which could be maintained by the village tank.

The dry zone today is dotted with abandoned tanks and with traditional or purana villages. Physically, the purana village is identified by three parts: the village tank itself, the paddy land below the tank which produces rice, and the gangoda or highland area usually near the tank on which are found homesteads and home gardens. In addition to the cultivation of paddy, villagers supplement their income with crops grown on plots of cleared jungle following the practice of chena agriculture.

Socially, the predominant characteristic of purana villages has been their isolation and self sufficiency. They are characterized by a strong sense of their own isolation from the outside world, intermarriage within the village itself, and distrust of outside officials and government agents.

Inhabitants of a purana village belong to a single family. They resist the intrusion of outsiders into their communities, and they have been reluctant to move to new locations and new ways of life. In one case, when the government tried to expand production and alleviate over-crowding by making new lands available under a village expansion program, few of the eligible villagers were willing to move (Perera 1979). Their lives and security have until now been dependent upon their cohesion as a village unit.

The subsistence of the village depends upon the production of paddy. The amount of paddy which can be produced depends upon the amount of irrigation water stored in the village tank. When the rainfall has been great, all of the paddy fields below the tank can be irrigated. When the tank is not full, only the fields nearest the tank will be cultivated. The management of water from the village tank requires the coordination of the farmer and the joint decision making of influential farmers of the community. Historically, paddy land was owned in common by the villagers. The cultivation was carried

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out by more capable and prestigious farmers; but through an intricate system of familial obligations, the poorer farmers were able to exist. However, communal ownership is now rare. Private ownership of paddy lands has been the norm in purana villages since about the turn of the century.

The authority in charge of managing the water distribution in the village, was throughout most of the last century, the Vel Vidane. Typically, the Vel Vidane was a respected and larger landowner. He also was a link between the village and the regional or national authorities. With recent governmental efforts to modernize village agriculture and extend the national political arena to the village level, the post of Vel Vidane was abolished and was replaced first by a Village Cultivation Committee and later by the Agricultural Production Committee.

During periods of harvest and planting, cooperative forms of labor permitted the villagers to combine their resources more effectively. Through the custom of kaiya, a villager who needed help would call upon neighbors and relations to assist in a demanding task such as roof thatching, harvest and land preparation. Reciprocal forms of labor exchange, or attan, permitted farmers working as a group to harvest each of the farmer's lands in a rotation.

Farmers who did not own land would appeal to larger owners to be permitted to cultivate as tennants. In this type of labor, called ande, normally the landowner provides the seed paddy and buffaloes and receives 50% of the crop. While at an earlier period these relationships might become permanent in a steady patron-client form, the current pattern is for landowners to rotate tenants. In this way they avoid the penalty of the Paddy Land Act and the Agricultural Lands Law, by which a tenant who cultivates for two consecutive seasons becomes eligible to claim the right to till (Perera 1979).

In today's purana villages the number of landless farmers can be as high as 40% of the farmers. This may be a recent phenomenon resulting from population pressure. It is probably one of the causes of the current practice of wage labor. While wage labor is not viewed very highly by villagers it is quite prevalent. In some cases the labor is paid in kind. Otherwise the current rates are eight rupees per female laborer and ten for male laborers (except in areas of great demand such as the Mahaweli Accelerated Program).

While basic subsistence in purana villages is provided by paddy cultivation, this type of agriculture has always been supplemented by chena cultivation. Chenas are cultivated by groups of farmers on an attan basis. A circular area is cleared in the jungle, and portions are marked off to correspond to the shares of the number of cultivators. The shares are cultivated and the members of the chena take turns guarding the land at night. Originally the shifting cultivation returned to the same spot only once in every ten years. In more recent years the chena cycle has been shortened to three to five years. In some cases it is stabilized to the same plot of ground.

While chenas produced crops necessary for subsistence, they have become a major source of cash crops for purana villagers today. A survey of System H prior to colonization showed that 40% of cash farm earnings were derived from chena (Ranatunga et al. 1979).

Settlement and Irrigation Schemes

Since the early 1920's, and particularly since the 1930's, policies and programs have been initiated by various Sri Lanka governments to provide land to landless peasants by sponsoring colonization of uninhabited regions of the dry zone.

Under these programs, the government provided irrigation channels, rehabilitation or construction of irrigation systems, schools and medical facilities. These irrigation schemes provided irrigation for existing purana paddy fields which depended mainly on rain fed cultivation besides providing irrigation to new lands. Settlers were assisted with an allowance for housing, sometimes housing itself, a subsistence allowance, assistance with land clearing and ridging. They were given an allotment, which for a number of schemes consisted of five acres of paddy and three acres of highland. In other cases, allotments were one to three acres which were cultivated by farmers while they continued to reside in their traditional villages.

During the 1950's some reductions were made in government expenditures. Settlers were given land up to two years prior to the availability of irrigation and did their own house construction and preparation of land. In addition, the size of allotments were altered to three acres of paddy and two acres of highland.

During the 1960's it was recognized that the production on major colonization schemes was not as high as anticipated. Special projects were initiated to enhance the productive capabilities of existing schemes. Under these programs efforts were made to improve methods of cultivation, strengthen arrangements for credit and marketing and to encourage community development.

A wide range of settlement programs were attempted. These included both major schemes (usually including major irrigated works) and minor schemes such as the rehabilitation of tanks fed from their own catchment areas. Some programs offered additional crown lands to existing purana villages; others were totally settled from outside. A number of schemes offered land to unemployed or landless youth. Some offered land to estates to be managed as plantations. The success and failure of these schemes varied. In some cases under advance alienation settlers became discouraged and returned before irrigation water was made available. Other colonization schemes have progressed. The scheme at Minneriya in System D has been identified as one of the most successful settlements of its kind in the world (Scudder 1979).

While there are differences among the various settlements, the communities resulting from them are all different from the original purana villages. In some of the schemes families or villagers were able to move as a unit, but in many cases the settlements were made up of immigrants who were unaccustomed to each other. Because of their immigrant status, the kinship ties based on generation of intermarriage are lacking in settlement communities. In many settlements in the initial stages, lack of community cohesion manifests itself in distrust, higher rates of theft, and lack of cooperation in water management.

Settlements were planned to permit immigrant families to cultivate their own three to five acre plots. In fact, it appears that this idealized plan was departed from almost from the inception of most schemes. Studies

of the Minipe scheme show that a large proportion of the original three acre plots were leased or mortgaged by farmers who were unable to maintain their financial solvency. These farmers, according to the study, mortgaged out varying proportions of their allotments. They were still, according to the legal rules of the colonization scheme, able to apply for agricultural credit. Most of this credit was used to pay back the principal of the mortgage. The rest was used for subsistence items. Through this process many of the original holders became increasingly indebted and eventually disenfranchised.

The resulting social stratification in colonization schemes reveals a large proportion of poor and indebted settlers, and a few de facto larger landowners who may also have occupations as traders, wholesalers, and contractors.

A distinctive feature of colonization schemes from the social point of view is the regulation on land inheritance. According to the inheritance law within settlement schemes, land cannot be fragmented below the size of the original allotment. Thus, each settler family must name a single inheritor. In practice this regulation is often evaded since although one inheritor is named, it is understood that more than one child will be supported by the land. Legally, however, this regulation poses a problem for a large proportion of second generation settlers who are disinherited and therefore are legally landless.

Typically the kinds of social relations which characterize colonization schemes are those which accompany the modernization process. The close communal, familial relationships of the purana village lose their binding power. Attan labor gives way to wage labor. Ande relationships lose some of the sentiments of patron-client and become more contractual.

Patterns and forms of leadership also are different. The leader in a traditional village is typically a larger landowner, organizer of reciprocal forms of labor, patron to a number of tenant farmers and benefactor of the landless. He participates in the resolution of communal differences and problems. He organizes the repair of tanks and irrigation canals.

In a colonization scheme, many of these functions are taken over by project management. Irrigation management becomes the responsibility of government bureaucracy.

The colonization settlers typically do not recognize communal leadership in the same way. They are titularly of equal landholding. The more wealthy traders, on whom they may come to rely, are not necessarily viewed as communal leaders. One of the major complaints of government throughout the history of colonization schemes, is the lack of community leadership or its extremely slow evolution.

New Villages

Almost all of the purana villages in the Accelerated Program area have lost the exact physical characteristics of the ideal type. In place of a cluster settlement directly below the traditional tank, the physical layout of purana villages now has two parts: the remnants of the cluster settlement, and the new settlement, usually at a short distance from the original village, and typically along the road. These new settlements are the result of village

expansion schemes which have permitted landless inhabitants of the old village to acquire title to homestead land, highland plots, and sometimes to expanded paddy land under rehabilitated or enlarged tanks.

Land hunger in other parts of the island and among second generation settlers combined with the expectation of land colonization and eventual legitimization have brought large numbers of encroachers into the area. Encroachers typically practice cultivation of highland plots, or chena cultivation which may or may not be shifting. They frequently settle near existing roadways, either in isolation or in a form of scattered settlement.

National Ethnic Groups and Castes

The three major ethnic groups in Sri Lanka are the Sinhalese, the Tamils and the Moors. There are about nine million Sinhalese (around 72% of the population) who are predominantly Buddhists and speak Sinhala, a language of Sanskritic derivation. Most Tamils are Hindus and speak a Dravidian language common with that of Tamils living in South India. The two and one-half million Tamils in Sri Lanka (20% of the population) are divided into two groups. Ceylon Tamils are descendants of settlers who arrived from South India more than a thousand years ago. Indian Tamils are descended from emigrants who have been coming from South India since the mid - 19th century, principally for employment in the tea and rubber estates. The Moors currently comprise a total population of about 850,000 (5.9% of the total population). Moors are of Arabic and Indian Muslim descent. The remainder of the country's populace are Burghers, Malays and others.

Sri Lanka society has not yet achieved an integration among its various ethnic, religious and language groups. These groups maintain distinctly separate social customs and cultural traditions. Similarly, each group is very sensitive to potential colonization schemes in terms of the proportion of representation it will have in the development of new settlements.

In the project area, the minority group question is further complicated by the existence of villages which trace their descendants to the Veddah peoples who are presumed to be the original inhabitants of the island. While the language of these people has now become Sinhalese, this does not imply that they have been absorbed culturally into the dominant Sinhalese Buddhist society, by whom they are considered a lower caste.

Tamil Hindu society,focussed in the north of the country,supported a caste system which was until this century rigidly maintained. Sinhalese Buddhist also evolved a caste system despite the contradiction with Buddhist philosophy. The predominant caste focussed in the dry zone is the cultivator caste or goigama which is at the top of the social caste among Sinhalese. Other castes include fishermen and cinnamon peelers. The cultivator caste among the Ceylon Tamils is the vellalai caste. Classical purana villagers were supported by attached settlements of service castes who performed service for the cultivators in exchange for a portion of the harvest. These castes, including tom-tom beaters, musicians, washermen, etc. still exist in some villages although they also have become cultivators. No specific surveys have been done of existing caste structures in the project area.

THE PROJECT AREA - POPULATION AND SETTLEMENTS

Population surveys were carried out for Systems B and C in 1979 by the Mahaweli Development Board. A partial survey was carried out for System A in 1980. No enumeration has yet been made for System D. Presently, there are probably about 200,000 people residing in the project area, with about one-half of this population in the settled areas of System D, another 15% in the settled areas of System C and the remaining 70,000 people distributed throughout the four systems.

System A

An estimate of the total population of System A based on the partial survey is about 22,000. There is reason to believe that the actual number of people is higher and that a more accurate estimate is about 30,000.

The area to the north of the Somawathie Sanctuary is the most developed and contains the one colonization scheme in the system, the Allai Tank scheme. The Allai Tank was colonized in 1941, with uniform allotments of three acres of paddy and one acre of highland. It is divided into left and right bank channels with eight sections on the left bank and six sections on the right bank. A total area of 8,874 acres has been developed here, of which 3,618 acres were given to 1,206 Sinhalese families from outside areas. The balance was alienated under village expansion schemes to local inhabitants who are mainly of Tamil and Muslim origin.

There are a number of traditional purana villages remaining in the northern area, such as Mallikatheve and Kangavelli. Both of these villages are comprised of Tamil people of a single caste group.

More typically, the indigenous villages in the area conform to the characteristics of extended or disintegrating traditional villages. Population pressure was accommodated by "village expansion schemes" which gave title to villagers from Crown Land. The village tank was expanded and paddy fields extended. The extended areas are inhabited by descendants of the original village, and by some Purana villages from the vicinity. They depend upon the original village for temple activities and for cooperative societies. Examples of such villages are Manachenai, Vachchenai and Jubalanagar.

"New villages" in the area have been founded by second generation population from the settlement scheme. They live on encroached highland plots on which they engage in highland farming. They also work as laborers on a familial basis for the colonization scheme. These villages are found along the Allai-Kantalai road, and between tracts of the schemes. Other encroachers live in isolated patterns of chena homesteads. The earliest of these settlements dates back to the 1940's, the latest in 1979. Examples are Sri Mangalapura, Walawalawa, Wali Wala, Mandalapura, Samagipura and Dehiwatte. The new villages are unplanned and legally without title. are dependent socially and economically on the colonization scheme. They lack infrastructure and social cohesion and are viewed within the area as characterized by anti-social behavior. During peak labor periods they assist their kin groups on the colonization schemes.

There is one new town in the area which is not an off-shoot of the Allai scheme. Pullivedicholai is an encroached village made up of second generation Indian Tamil estate laborers. They work as wage laborers for the well-to-do settlers in the Allai scheme.

Two semi-urban centers have grown up as service centers to the colonization schemes. These are the Serun awasa bazaar and the Killiveddi bazaar.

The settled areas of System A to the west of the Mahaweli Ganga are made up of some purana villages. The east includes a livestock farm at Trikonamadu and several purana villages on the western edge of the Somawathie Reserve.

System B

According to the results of the 1979 survey, the number of people currently inhabiting System B is 25,515. The Sinhala population accounts for 64.5% of the total, followed by 25.5% Tamil and 8% Muslims. According to reported income, over 51% of the families in System B earn less than Rs. 3,000 per year. Another 25.8% earn between Rs. 3,000 and 6,000 per year. The average family size is 4.8.

There are two major colonization schemes in System B. The largest is the Pimburettawa Tank in the southeastern part of the area. It was begun in 1969 and completed in 1976 and covers 4,380 acres. It has been settled by 1,460 Sinhalese families, each of whom received 3 acres of paddy and 2 acres of highland.

The Wadumanai scheme in the Batticaloa district was begun in 1952. About 126 families from the surrounding area have been settled. Allottees were provided with houses, but finding them unsatisfactory have returned to their original homes in neighboring villages while cultivating the new allotments in the scheme.

The largest irrigation scheme is Vakaneri which irrigates 8,090 acres of paddy land. This scheme provides regular irrigation facilities to existing purana lands as well as new lands which have been alienated under the Land Development Ordinance to only landless peasants in the Batticoloa District who are mainly Tamils and Muslims. Holdings here vary from three to ten acres.

In addition to the major irrigation schemes, System B also contains cooperative farms. Two livestock farms are located in the north of System B, at Kadakadu and Welikanda. These are administered by the Department of Agriculture and the National Livestock Board. Two Kenaff farms have been opened at Welikanda and Punani by the Sri Lanka Cashew Corporation and the National Paper Mill Corporation.

A distinctive feature of settlement in the eastern part of System B is the large number of absentee owners. Many of the agricultural lands within this area are cultivated and/or owned by residents of the towns along the coast. This includes lands under cultivation in the Vakaneri irrigation scheme, and a number of other allotments. The owners prefer the coastal climate. Also, their cultivated lands are presently subject to floods of the Maduru Oya. According to official sources, while only 126 families in System B

own allotments of more than five acres, the number of absentee owners with over five acres is 2,285. The number of encroachers was enumerated in the 1979 survey at 2,736, of which 26% arrived since 1976.

The purana villages in the system represent four different ethnic groups, Tamil, Muslim, Sinhala and Veddah. Some purana villages are Karapola, Mutugala, Katuwanwila, Alichipotana, Soruwila, Alavakumbura, Manampitiya, Damminna. Alinchipatana and Katawanwila are Muslim villages. Millana, Dalukana and Ellewewa have been identified as Veddah villages.

New villages for which there is no legal title have grown up along the major roads in the area, and as part of the colonization schemes. Most of those in the Pimburettawa scheme are inhabited either by relatives of the settlers or by farm laborers attached to the scheme. There are a number of new towns along the Polonnaruwa-Batticaloa highway including Kumarapura, Suayodi and Pulleyaradi.

In the Tamil area of the Batticaloa District there are a number of new towns. The inhabitants are former workers on the tea and rubber plantations from Kegalle, Matale, Moneragala, Ratnapura, Avissawella, Rambukkana and Gampola. One of the reasons for their emigration was communal disturbance in 1977. Some other settlers to this area were brought and installed by the Batticaloa Rotary Club.

Under the food production campaign of 1973-1977 lands under small tanks were alienated in Polonnaruwa District to settlers from inside the district and from outside. Most of these lands are currently abandoned, but some new villages remain.

There are three centers which can be considered potential towns in the system. These are Manampitiya, Welikanda and Aralayanwila.

System C

The southern portion of System C is settled and developed by a number of colonization schemes. The population of this southern part was enumerated at 23,340 in 1979. Three irrigation schemes in this area are Nagadeepa, Baduluoya and Batmedilla. Portions of the large irrigation schemes of Mapakada, Dambarawa and Sorabora are also included.

North of this zone, in Badulla District, there is sparce population totalling 5,197. This population includes some purana villages, remnants of the Department of Agriculture and Land Commissioner's Department Youth Colonization scheme, and the Ceylon Tobacco Company colony. The total population of the remainder of System C was enumerated at 1,239 most of which scattered through the northern area.

A number of purana villages are remaining in the area north of the settled area. The major ones are Hebarawa, Aluththarama and Pagaragamana in the south and Kaludelewa, Ellewewa and Yakkure in the north. Pagaragamana is a Muslim village. There is some evidence that Yakkure was once a Veddah village, although its current language is Sinhala. The majority of purana villages in System C are Sinhalese. There are a large number of new villages in the area. These are primarily made up of encroachers from the colonization schemes.

The extent of encroached lands in the system is larger than that of private and Land Development Ordinance lands (excluding the colonization schemes). Most of the encroachers come from the colonization schemes. Some are from the Minipe major colonization scheme located at the southern tip of System C. Most of the encroachers make their home on highland plots which they cultivate in upland crops. Encroaching has increased rapidly with the announcement of the Accelerated Mahaweli Program.

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

System D

The southern part of System D which borders around the highway from Polonnaruwa to Valaichchenai is settled. The town of Polonnaruwa is included in this area. Major colonization schemes include Minneriya stages 2 and 3, Kantalai, Kaudulla, Giritale, and Parakrama Samudra.

To the north east of the colonization schemes are a number of purana villages. They include Migaswewa and Wadiyawewa. No systematic socio-economic survey has yet been conducted in System D. However, a rough estimate of the present population including that of the major irrigation schemes is more than 100,000.

SETTLEMENTS IN PROPOSED RESERVOIR AREAS

Reservoirs for the Accelerated Program area will inundate four river valleys, forcing the relocation and resettlement of the current inhabitants. The Maduru Oya reservoir area is relatively unpopulated. An initial estimate of the number of families to be relocated from the Randenigala reservoir is 271 (Mahaweli Development Board, Settlement Planning, personal communication).

The numbers of people to be affected by the Victoria and Kotmale reservoirs are substantial. The communities living in these areas are more highly developed than those in the project area. The temperature of the mountains is cooler permitting spice, coffee and tea cultivation. The river valleys contain some of the best paddy lands in the area. The communities are old and established, and fairly well developed.

Victoria Reservoir Site

The Victoria Reservoir will flood approximately 7,000 acres along the Mahaweli and the Huluganga rivers. The area to be inundated includes Teldeniya town and two smaller towns, Nattarampota and Tennekubura. A number of traditional villages, nine village expansion schemes, and three estate worker settlements will be inundated. The total population affected is estimated at 13,840 (Mahaweli Development Board 1980b).

The traditional villages are organized in a similar fashion to those in the project area. While they do not depend on a tank for irrigation water, most of the villagers cultivate paddy in terraced plots along the river bottoms. Land is considerably fragmented and paddy plots are small. In addition to the paddy land, most villagers farm a highland plot on which their home is also located. The highland plots produce cocoa, coffee, spices, coconuts and frequently timber

of high quality. The social structure of these villages are based on kinship ties and attan labor is practised. There has been little intermarriage among different villages.

While most of the villagers are Sinhalese, some are Muslims and a number are Tamil. The Tamil population has come from the estate sector. Different ethnic groups are rarely found in the same villages, and within villages, different castes are spacially located.

There are nine village expansion schemes which will be flooded. Some of these were early schemes which have large units of alienation; although presently the married children of the original allottees have resulted in overcrowding of these colonization schemes. The inhabitants were drawn from the region itself.

Teldeniya town has a sizable population of government employees and businessmen. It includes the administrative center of the Medadumbara A.G.A. Division, and important infrastructural facilities for the region including a secondary school, the Teldeniya district hospital, and the post office. A number of industrial facilities will be flooded including the National Milk Board factory and Pallekele industrial town.

There are three large estate worker settlements which will lose most of their productive land. These are Mahaberiyattena, Haragama and Pallekele.

Kotmale Reservoir Site

The Kotmale area to be flooded will affect an estimated population of 12,000. The settlements in this valley consist of a series of cluster settlements. They are less fully developed than those in Victoria and contain no major towns. The most developed areas are located on the left bank of the river, due to townships like Sangilipalama. Land holding for most farmers in the area is divided between terraced paddy lands which extend the steep river valley and highland plots which produce income crops of coffee, arecanut, pepper and cloves. Jak, Tuna and Sapu trees are also important commercially from the highland plots (See Bulankulame 1979).

Until the 1920's the area was relatively isolated and maintained a traditional social structure. The large landowners in the area traced their inheritance to historical relationships with the king. In the 1920's tea estates were opened on the hills above the paddy fields. These brought roads into the area. Some of the villagers cultivate tea on highland plots, but for the most part the tea estates are higher up the mountains while the settlements are close to the bottom paddy land. Tea estates are traditionally cultivated by Indian Tamil labor.

The character of the settlements includes a strong sense of history and their family roots. There exist in the Kotmale region villages which are still dominated by traditional castes. The villages of Navagama, Pusulpitiya, Konsingammedda belong to the Navandanna caste and produce agricultural implements and domestic knives. Bouiwagama is inhabited by traditional ceremonial performers drummers and dancers. The chandala caste at Wataddara now make brooms and small drums. Thispane is a traditional village inhabited by the Goigama cultivator caste. Of the approximately 3,000 families affected, 98% are Sinhalese. The remaining families are Tamil and Muslims.

Traditional land holding is based on ancestral rights. It is corporately owned. Gradually this form of ownership has given way to Sinnakkara or individual outright ownership. There also exists controlled state ownership due to land reform, land development ordinance or encroached land. In the Kotmale region, 25% of the land is still in ancestral forms of ownership. Land holding is fragmented. Twenty-six percent of the families own less than one-fourth acre, and 50% own less than one-half acre. A sizable number (33%) of the family heads are engaged in agricultural wage labor.

There are a number of large landowners in the area, whose landholding is traced to their geneology. The area as a whole is better educated than the rest of Sri Lanka, indicating a prosperous traditional social setting.

IMPACT ANALYSIS

SETTLEMENT PROGRAM

The Mahaweli Accelerated Program is the largest and most ambitious of the planned colonization schemes in Sri Lanka. Under this program the areas in A, B, C and D which are not now under a colonization program will be developed. Water will be provided for both Maha and Yala seasons. Settlers will receive 2½ acres of irrigated paddy lands and 0.5 acre of highland for a homestead plot.

The people who are currently residents of the project area will be the first to be resettled under the program. They will qualify as settlers if they are over 18 years of age and have an agricultural background. Settlers from outside the area will be selected according to a set of criteria established by the Mahaweli Authority. Once applicants conform to these criteria, final selection will be made by the Member of Parliament from the electorates from which allottees are taken.

Current settlement plans are similar to those which have been instituted in the System H area. Highland plots will be allocated on non-irrigable lands within walking distance of the corresponding irrigable plots. The homestead areas will be grouped in hamlets consisting of about 200-250 homestead units. Five hamlets will be laid out around a town center which will include a branch cooperative society, a primary school, a community center and a dispensary. Settler services will include agricultural extension, water management classes and a range of community development programs.

Where possible, the existing village tanks will be preserved, the paddy land below the tank rebunded and reallocated to members of the village whose home plots will be maintained. Land holding will be equalized, as no one will be allotted more than 2½ acres of paddy.

The number of new settler families who will participate in the Accelerated Program is estimated at 80,000. This figure is based upon the number of new available hectares of irrigable land in the Accelerated Program area.

Those who must be relocated from Kotmale and Victoria Reservoir sites will be given opportunities to relocate in the Mahaweli Accelerated Program area. This is an attractive alternative to those without land in the area, although it is less attractive than alternative land in the areas of Victoria and Kotmale. To those who own more than 2½ acres of land, the move to the Mahaweli Program area represents a change in climate and landholding which is considered inferior to their present condition.

The major social impact of the project involves the transition from small isolated village societies to production oriented large scale colonization schemes. Implicit in the model of transition is the modernization of rural society with the attendant loss of traditional values and factors of social cohesion of small, kinship based villages. This social transition is both desired by planners and participants at the same time that its dislocations are regretted.

MAJOR SOCIAL BENEFITS

The principal social benefits of the project will accrue to the settler families who stand to gain land and water. This is a major benefit

and is perceived as such by those living in the project area and those applying for allotments in the project. The people living in the project area currently rely on tank water for one crop a year. In addition, most of those in the area own small plots which are shared by several family members. Even large landholders residing in traditional villages share their several acres with enough adult family members that the allocation of 2½ acres of paddy plus an acre of highland looks to them as a major gain in resources. It might be noted that size of land cultivated has been controlled both by the capacity of village tanks and by the control of Crown Land by the state. Only under village expansion schemes has it been possible for traditional villagers to increase their landholdings in response to population pressure in their own villages.

The applicants for land from outside the project area also stand to benefit appreciably from the allocation of 2½ acre plots since those chosen will be without land and without other employment. When applications for selection were taken from the System H area from Matale, Kotmale and Nuwara Eliya, 32,000 applications were received for 1,600 allotments, which indicates a strong demand for land within the villages of Sri Lanka.

THE SECOND GENERATION

Colonization schemes in Sri Lanka have quickly faced a problem of employment for the second generation. In the effort to prevent fragmentation of land, allocations are not to be divided among the children of colonists. On the other hand, it is expected that colonists will have sufficient family labor to farm their plots without the necessity of employing labor from outside the scheme. By tradition, supported by the need for family labor, settlers tend to have reasonably large families.

In other colonization schemes this has led to fragmentation of paddy land and home plots on an illegal basis, encroaching on lands located within or between irrigation blocks, and encroaching on yet undeveloped chena lands. Many of the encroachers in the Accelerated Program area are second generation settlers from other schemes who have encroached land in order to be in a position for acceptance in the program. Many of those in the colonization schemes within or near the program area expect their children to receive allocations in the Mahaweli Development Program.

There exists, therefore, an attitude among colonists and their offspring which is strongly in favor of more colonization schemes, and which is in conflict with the goals of preserving national forests. There is little appreciation among this group of the limitations of resources or the needs for population control. Settlement planners and program management personnel recognize the problem of limited land availability for indefinite expansion and hope to develop other economic sectors to meet resource and employment needs in the future.

One of the avenues for this is the encouragement in the area of small shopkeepers and service industries for the settler population. Another is the attraction by planning and financial incentives of larger industries and agribusiness. The Mahaweli Program is planning to reserve homestead allocations for small business applicants. This procedure is currently being utilized in System H. It is hoped that larger industrial growth will be stimulated by the activities of the Mahaweli Economic Agency. Division Three, Investment and Business Development.

ADAPTATION OF TRADITIONAL COMMUNITIES

Traditional villages within the project area will face the disintegration and restructing of their current economics and corresponding set of social relations. While efforts will be made to maintain the integrity of the village unit by keeping the relatives and family together in settlement hamlets, the basis of the village economy will change.

There will be an equalization of landholding which may have detrimental effects upon the social standing and self esteem of the current elite, especially if these present landholders have fewer children who qualify for land in the settlement scheme. This has occurred with some families in the resettlement within System H (K. Wimaladharma, personal communication).

The mechanisms for landholding and its acquisition will shift. Landholding in traditional villages is maintained by inheritance and kinship ties. In the new scheme, inheritance will not play its traditional role in passing on control of land resources.

Traditional villages have maintained a large degree of autonomy from the central government and from development programs and bureaucracy. The villagers will now find themselves a part of a bureaucratically organized planning effort. This will include the systematization of agricultural inputs, use and understanding of credit and agricultural production loans and the organization of water management.

To appreciate the changes which will be undergone by the traditional communities, one can consider;

- Traditional pastureland will be lost;
- Attan labor will be replaced by wage labor;
- The isolated village will be incorporated in a large irrigation system;
- Villagers will be surrounded by newcomers to the project area;
- Chena agriculture will be lost (Chena represents a considerable source of income and a cultivation strategy which minimizes the risks of paddy production.); and
- Villagers will become dependent on bureaucracies for marketing of paddy, provision of irrigation water and provision of agricultural inputs.

The meaning of this adaption is that whatever the overall improvements in standards of living brought about by the Mahaweli Project, the changes will involve considerable stress and reorientation for individuals as they seek to reconstruct their communities. The qualitative changes in viewpoint and style of life which accompany these adaptations involve losses which cannot be quantified.

SOCIAL STRATIFICATION

A great deal is known about the forms of social stratification which emerge in colonization schemes. Specifically it is known that while the original colonization model supposes an egalitarian society based upon owner-operator farms of 2½ acres of paddy, in actual practice, social differentiation occurs

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quite rapidly. Wealth is accumulated by contracting with the development authority, money lending, wholesaling and various business activities which serve as a liaison between settlers and their external needs.

Land is also surreptitiously leased and mortgaged, resulting in an actual land distribution pattern which is highly unequal. In the Minipe colonization scheme it was discovered that most allottees cultivated one to two of their original five acre allotments, leasing or mortgaging the remainder to outside entrepreneurs, richer colonists or to mudalalis residing in the scheme. Under these mortgage conditions the full benefits of production are given to the mortgagee as interest on the principal until the principal is paid off. Agricultural production credit, it was discovered, was being taken by the original permit holders and used to repay the principal on the original loan. Under this system, large landlords emerged, relying on sharecropping forms of labor. One such landlord, a mudalali, operated 100 acres of land (Wanigaratne 1979).

Preliminary studies and monitoring from System H indicate that land is being leased, mortgaged and given in ande to relatives within the first years of cultivation (Mahaweli Development Board and NEDECO, 1979). To some extent, this represents a strategy of labor allocation among family members. It also indicates the beginnings of a process of social differentiation, similar to that which has resulted from earlier colonization schemes.

While it is widely recognized that processes operate which violate the ideals of the scheme and which are frequently illegal, attitudes about what should be done vary. The predominant attitude is that this merely reflects what is a natural process and the greater ability of some settlers to capitalize on resources than others.

Others would recommend that a means be provided for buying and selling land within the scheme which will regularize the process and make it amenable to legal regulation. This would also permit farmers who can and wish to cultivate larger acreages to do so. The argument against this is that it permits those who enter the system with larger possessions simply to capitalize on their relative position more quickly. The example is given of Nachchaduwa colonization scheme, where middle class owners were permitted to buy larger allotments. The result was that the original small holders did not survive the scheme (Bulankulame 1975).

In a recent proposal, it has been suggested that middle class farmers be settled in the area from its inception. One of the justifications for this idea is that larger holders will emerge from the scheme in any case. Some argue that 2½ acre plots are not economically viable units, as evidenced by the emergence of larger de facto landholding units. It is also suggested that since small holders become indebted, they are unable to manage their plots. The middle class farmers may have greater resources available which may be needed to grow unfamiliar crops.

However, such an alternative seems to forego some of the original social objectives of the project which include the creation from landless peasants a class of independent small but commercially viable farmers. Land which is allocated to the middle class will not be available for allocation to the landless.

Various means of strengthening the independent small farmer concept seem preferable. One can acknowledge the credit needs of the small farmers from the beginning, by providing banking services from their arrival and making provisions for initial five year loans.

In addition, considerable research suggests that farmers' problems with credit are related to assignment of inferior quality of plots and to the unavailability of water. These are issues which can reasonably be considered the responsibility of the project management (Silva 1978; Tilakasiri 1979).

A monitoring program can identify these problems as they arise and permit reallocation of better plots and the extension of loans for farmers who have experienced failure of the irrigation system.

SOCIAL INTEGRATION

The problems of initial adaptation to a new environment are thought to be eased by settling village and family units together. An attempt was made in System H to select new settlers from areas of similar geo-cultural origins to the indigenous inhabitants. By selecting people of similar backgrounds and by respecting cohesive family units as much as possible in the actual spatial settlements, early difficulties of integration are lessened.

In an overall sense, however, the problems of social integration remain to be resolved. These include the integration of various castes, the integration of linguistic and ethnic groups and the integration of new settlers with existing villagers.

Experience in past settlement schemes shows that when members of a single caste are settled primarily together, they initially form bonds of friendship and exclusivity. These bonds translate into local political factions. In the Nachchaduwa colonization scheme, a large number of the Padu caste were settled in one irrigation block. The few settlers who were not of this caste in the scheme were excluded from the close ties established by the majority group (Bulandulame 1975). It is reasonable to suppose that this same pattern could repeat itself in the Accelerated Program.

There is also evidence that these bonds of exclusivity break down over the period of a generation. Thus, in the second generation and among older settlers, friendship and labor help groups cut across caste lines.

A major issue needs to be resolved within the Accelerated Program concerning the location and settlement of Muslims, Tamils and Sinhalese.

One approach is to accept a principle of maintaining existing ethnic group balance in existing areas. If this principle is adopted, then a quota system for selectees must be applied. This can be applied at the individual level without respect to the region or electorate of origin. Alternatively, large blocks of a homogeneous ethnic group could be settled which would essentially be an extension of the present local distribution of the respective groups.

With the goal of national integration in mind, an additional policy might be considered to integrate the communities within the villages. The combination of group cohesiveness and integration can be promoted by keeping hamlets homogeneous, while villages are integrated. In order to maintain the current rights of existing minorities a quota system could still be applied to the overall numbers of selectees.

DEVELOPMENT PERSONNEL

The current settlement pattern provides for housing for project personnel within the town centers of the project area. What this creates, at least at the beginning of the project, is a situation in which project personnel live in permanent housing in centrally located spaces, while settlers must make their own temporary homes away from the central areas. The discrepancy between the living conditions of the project staff and the settlers is thus visually and spacially accentuated.

The objective of this pattern is to attract development personnel to live in the project area and to interact with the settlers in their jobs. This has not always been the result. Permanent housing in the middle of a farming community is not sufficient to induce highly trained and educated professionals to live in the project area. In System H, project personnel have developed a pattern of residence which essentially involves commuting from Colombo to the project area. It appears that the social needs of the professional management staff have not been met by this pattern.

One alternative to this model would be to develop urban cultural facilities within a few centers within the project area. It may not be necessary for project personnel to actually live with their families in the villages themselves, if they can easily commute to their offices from nearby urban areas.

AGRICULTURAL LABOR

Labor is organized in colonization schemes in a number of ways. Settlers may give out allotments on ande basis to relatives or they may rely on family labor entirely. They may rent tractors or buy tractors and rent them out. During peak seasons, all farmers must find ways of increasing the labor intensity. They mobilize relatives from their home villages to assist them after the home village harvest is in. They hire on a daily wage basis teams of migrant laborers who move from one field to the next. During transplanting, teams of women travel from nearby villages into the colonization scheme to serve this function. Among groups who know each other, attan labor is practiced. Even among relatives, however, there is a tendency for reciprocal labor to become wage labor.

The concept of the one hectare family farm, cultivated by family labor, whatever its theoretical justification is not the way in which colonization farms actually are cultivated. There is reason to believe that the colonization scheme will encourage a class of rural wage laborers.

One of the major effects of the Mahaweli Accelerated Program will be the increased demand for agricultural labor. There is some expressed concern that there will be insufficient labor within the project area. In the Pimburettewa scheme in System B, an agricultural labor shortage has resulted in not transplanting on some farms and a reversion to broadcast. The price for agricultural

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wage labor has risen in the last few years from nine rupees a day to Rs. 15. In System H, a further reason for the rise in wages is the increased demand for unskilled labor for construction of the irrigation system itself.

An indication of the dependence of colonization scheme farmers on outside wage labor is provided by the data from System H. During the Yala season, only 6.6% of the farmers were able to cultivate their farms relying only on themselves and their own families. The rest relied on additional labor, most of it from outside the scheme (See Table L-1).

Table L-1

Types of Labor Used, Yala Season, System H in 1977

Only Family Labor	6.6%
Family and Hired Labor	53.9%
Family and Exchange Labor	13.77%
Family, Hired and Exchange	24.7%
Hired and Exchange Labor	1.1%
	100%

n = 182

SOURCE : Silva, Perera and Wilson (1978).

The increased demand for agricultural labor is beneficial in that it absorbs the unemployed or underemployed agricultural work force. However, it poses some important problems for the Mahaweli Program. The major questions are : Where are the laborers to live, and what is the responsibility of the Mahaweli Program to their welfare?

One of the proposed solutions is to provide small highland allotments in areas near the edge of the scheme, on lands which cannot be irrigated. This will provide living area without providing enough income to inhibit work as wage laborers.

In its efforts to reach the small farmer, the program is providing considerable original capital and continuing investment in the program beneficiaries. What is often forgotten is that these efforts often do not include the poorest heads of households even within the project area. Nor do they necessarily reach the actual cultivators who may be hired laborers.

ATTITUDES TOWARDS PROPOSED LAND USE CHANGES

The terms of reference calls for an assessment of attitudes and behaviors of inhabitants toward the proposed land use. In order to assess attitudes directly, a number of in-depth interviews were made with selected households. The households were located in traditional villages in Systems B, C and D, new villages in B and C and colonization schemes in A and C. Some interviews were also conducted among Kotmale residents and new settlers selected for settlement in System H in the Kandy electorate. The results of these interviews are described below.

Size of the Allotment

The important attitude which came through all the interviews was that 2½ acres of paddy land, irrigated for two full seasons would represent an

improvement in landholding for families in the area. This was true even for a respondent whose extended family in a traditional village owned twenty acres of paddy land. The twenty acres was divided among as many adult family members.

However, although some of the respondents said that 2½ acres of paddy land was sufficient, over half believed the allotments should be larger. Several respondents replied that while 2½ acres might be sufficient for a small family, it would not be sufficient for a family of for example nine children, especially when the children were grown and wanted to farm. One respondent said that the people in his village were not educated to find other avenues of employment.

A response from a traditional village in System D was somewhat different. The respondent pointed out that previous colonization schemes had offered "outsiders" five acres of land. Under these schemes, the residents of the area had not been offered land. Now the government was offering land to them, but only 2½ acres. This did not seem just, and he believed five acres to be more appropriate.

Chena Cultivation

The respondents in traditional villages were aware that the government forbids chena cultivation. They therefore stated that they did not practice chena, and it is quite likely that a number of them have given it up. Some had recently been fined for practicing it. An encroacher in System C on the other hand had been engaged in chena cultivation for fifteen years. He is now planting an acre of chena with maize and manioc. He is aware that the government has forbidden chena, but it is his inability to clear more jungle which prevents him from cultivating more chena. He expects to benefit from the Mahaweli Program and thinks two acres of paddy will be sufficient.

Household Plots

One of the issues discussed by planners is the distance of household plots from each other. The cluster pattern of settlement in System H was designed to replicate the kind of settlements traditionally found in the dry zone. Most of the respondents, when asked about the layout of homestead plots, emphasized that they would like enough distance between them to assure privacy. One respondent pointed out that the reason for cluster settlement was fear of wild animals; without the threat it was not necessary to live so close together. Living too close encouraged disputes over cattle, and among family members. (The only dissenting opinion was a woman who felt that closer homesteads encouraged families to resolve their disputes.) On the other hand, respondents felt that homes should be close enough together to permit visiting and mutual help when people were sick.

Social Integration

Although it is a sensitive question, to which there are problems of response reliability, respondents were asked how they would react to neighbors of different ethnic groups or caste. The answer differed by type of village. Those in traditional villages all expressed preference for being settled with people they knew. They felt that it was important to know the character of people and whether they could be trusted. But they almost all stated that other ethnic groups or castes would not be a problem. This statement may reveal a sentiment of goodwill; it may not be based upon any actual experience.

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One respondent, from a Veddah village, stated that while she had no objections to mixing with other people, others might object to mixing with her family. Her children had difficulty in school for this reason.

Those in colonization schemes answered from more experience, and there was more awareness of what the problems might be among those in future colonization schemes. However, various responses were given; some individuals felt that problems of inter-racial strife could arise, while others believed there would be no major problems.

Pastureland

There are a large number of cattle and buffaloes visible in Systems A, B and D. The ownership of these cattle is not entirely within the area. Many are herds owned by businessmen living on the coast, while a person from in the area is hired to watch them. Not all are owned by outsiders. A similar system is used by villagers who keep cattle. Villages seem to vary according to how many cattle and buffaloes are owned, some villages being without animals, others possessing large numbers.

One village on the border of System D had a large number of buffaloes which were used as draught power. Almost all families owned a pair of animals and some owned as many as twenty. The animals were taken for grazing to one of the villus along the Mahaweli Ganga. The villagers here had no perception that the Mahaweli Accelerated Program would cause problems for pastureland. When asked what they would do when the villus dried up, they said they would take their animals elsewhere.

A respondent in System C explained that cattle currently graze on uncultivated lands near the village. He was well aware of the problem facing him and was perplexed about what to do. If he sold the buffaloes he could not use them for cultivation. If he kept them, where would they graze?

Wild Animals

Traditional villagers in most of the project area live near jungle areas where wild animals constitute a problem with respect to crop damage. Respondents complained about wild boar and elephants in certain areas. In one village a member of the respondent's family had recently been killed by a wild elephant.

When asked what should be done about the wild animals, the predominant attitude was that government should do something about them. Respondents said it was not right to kill animals, but if someone could put them some place or keep them away from crops, that would be a very good thing. All liked the idea of parks, although few had previously heard of them. In fact, many villagers do have guns and shoot at elephants to scare them away. This behavior is not necessarily viewed as inconsistent with not killing animals although in the long run it has the same effect.

One respondent suggested that government would solve the problem by issuing permits to those in the area to capture elephants. Captured elephants could be used for work or sold.

Forests

Some were enthusiastic about the idea of clearing forests, since it seemed a way of eradicating the wild animal problem. Few had thought about the problems of obtaining firewood, since at the moment wood is so abundant. When asked what they will do for firewood after the Mahaweli Project some replied that they would have to buy firewood like urban people. One said he would obtain a permit to cut in the forest reserves. One man said that he believed with the branches from the coconut tree on his homestead plot, he could obtain the firewood for his family's needs.

Public Health Facilities

The respondents looked forward to the arrival of the Mahaweli Program for a year round source of water. Current sources of water for domestic use are considered inadequate and not as safe as residents would like. Village tanks are used for bathing, but these are considered not clean, especially when water is low. On the other hand there is no appreciation currently in the project area for the need for latrines. When asked if they would use latrines if they were provided, several respondents said they would not.

The Accelerated Mahaweli Development Program

The overall perception of the people interviewed of the Mahaweli Program was positive. They thought it would bring them land and water and raise their standards of living. They also looked forward to better educational and health facilities, including safe water supplies. Roads will make it possible to go to shops and to see a doctor.

On the other hand, the level of actual knowledge about the program was quite low, especially in Systems A and B. Two respondents stated that they wished someone would inform them about the program. In System C, there was more general knowledge available and two of the respondents who were also village leaders had clearly thought through some of the issues quite carefully. One suggested that grazing lands should be left for cattle, and that there should be a tractor unit where tractors can be rented. Another discussed the problems of indebtedness. Most people fail to repay government loans, because water is unavailable and the crop fails. The respondent felt that this situation should not prevent the farmer from taking out a loan the next year.

The level of knowledge about the program was also low among the selected settlers for System H. They were unaware of when they would be contacted to move to the area. When asked what services they expected to find in the program area their reaction typically was that they had not considered the question.

Inheritance

The attitude of most respondents toward the inheritance law indicated that while they understood the law, they assumed that practices would continue to be traditional. One person said that the law was not good because it depended on the named inheritor being a good person and sharing land with his or her siblings. One respondent from a traditional village supported the old land tenure policy; that plots should be rotated among siblings so that each has an opportunity to farm the good plots of land.

The inevitable fact about relocation as opposed to settlement is that people who are forced to move for the good of "the nation" resent it. While the residents of Kotmale have had some 20 years to become accustomed to the idea of a forced relocation, and while many have now accepted its inevitability, there remains a sense of grievance.

The main attitude which is expressed concerns giving up the planted homesteads with jack fruit, coconuts, cocoa, coffee. In addition they give up paddy lands which provide rice for subsistence. Their fear in moving to tea estates is that while on their current homes they have what is necessary to earn a living and to eat, it will take 10 years to replace this investment on the new lands. In the meantime they must buy many things which currently they grow. What money will they live on during these years, they ask?

There is also a feeling of loss of ancestral homes which has a personal meaning to people who have experienced little geographic mobility, over many generations. This is a loss for which new lands cannot compensate. Simply from an aesthetic point of view, the terraced paddy fields of the low lands and the lush growth of the homestead areas are in stark contrast to the barren, wind swept tea fields.

While the rehabilitation of tea lands appears an added benefit from the national point of view, from the perspective of those to be relocated, it looks like an added penalty. Not only are they being asked to relocate for the good of others, they are given the poorest land of the tea estates.

The issue involved is that people who are forced to relocate are in fact being asked to pay a penalty, and therefore should not be treated as other settlers. In Kotmale, settlement is currently being carried out without reference to an overall plan for the region. This planning of the overall reservoir area needs to be done including plans for urban centers, and for social infrastructure.

VICTORIA RESERVOIR AREA

The reservoir area for Victoria involves similar problems to those of Kotmale, since people in the area are being forced to relocate. However, because the level of income and development is higher than in Kotmale the opposition to the dam has been more organized. A delegation protesting the Victoria Reservoir was organized early in 1980. The protest was rejected, and there have been no further demonstrations.

Planning for the reconstruction of the Victoria area has received more serious attention than planning for Kotmale. The Mahaweli Development Board decided to construct housing for construction personnel in Digana, a town five miles from Kandy. Later it was suggested that this housing development could serve as a nucleus for a new town, which could absorb the people to be relocated from Teldeniya. The Urban Development Authority was asked to prepare such a town plan. The town plan for Digana is currently with the Mahaweli Authority for implementation. There has been some dissatisfaction with the choice of Digana from an administrative point of view since it will result in the movement of inhabitants from Teldeniya to another electoral district. There is current interest in the relocation of administrative facilities to Udispattu.

Fishing Communities

A survey has not yet been done to establish the number of families currently relying on fishing as a primary means of livelihood in the Accelerated Project Area. The communities along the Mahaweli Ganga in System B currently rely on fishing as well as farming as a means of livelihood. Much of the fishing is done by migrant fishermen from the coastal areas who move into the project area fishing the tanks on a seasonal basis.

The Accelerated Program will create opportunities in inland fisheries for a number of families. This may include traditional fishing families, usually defined by religion and caste. But it will also open up possibilities for other families to enter the occupation.

Interviews in System C revealed that a new group of Sinhalese fishermen have taken up the occupation on the Horabora Wewa Reservoir. They entered the profession largely for lack of other opportunities and because they had no paddy land. Associated on a single fishing boat, a group of seven had formed a business partnership. From the Mahaweli Program, these men expect to benefit by having constant water in the reservoir. One of their current problems is that when the reservoir is low, not only professional fishermen, but other farmers can easily catch fish. Sometimes the supply of fish is therefore depleted. They would benefit from some orderly government regulation of the situation as well as from certain loans for nets, boats, etc.

So far, little planning has been done to organize the settlement of fishing families or to encourage farmers to enter this profession. The Mahaweli Economic Agency will be responsible for the small investment loans in the area.

KOTMALE RESERVOIR AREA

Plans for relocating the residents from the Kotmale Reservoir area are currently underway. A first group from the area of the dam site have been relocated. Some 100 have been moved up the mountain, on the Rothschild tea estates. A previous government housing project on the estates made it possible for these settlers to be given houses as well as two acres of tea land. Another group of 400 have been moved to System H, Block 404.

The residents are being given a choice they may elect to go into the Mahaweli settlement area, probably System C, or they may remain in the area of Kotmale to be resettled on lands higher than the reservoir. These are currently mostly in tea estates. Of the 1,417 families to be resettled, 14% agreed to go to the Mahaweli area and 86% to tea lands. The Central Engineering Consultancy Bureau (CECB) which is now in charge of resettlement of the Kotmale area is seeking to purchase tea lands from the following estates : Harangala, South Medakumbura, Sanguhar, Glenlock, Riverside, Ramboda, Kolapatana, Orwell and Moragolla. One of the secondary benefits of this resettlement will be the reclaiming of tea lands which have not been properly maintained. The people who have elected to move to the Mahaweli area are primarily those who are now landless. For the other residents, the change in climate and locality is not as attractive as staying in the Kotmale area. So far, the CECB has not taken on the responsibility of resettling middle class residents. They will simply be compensated according to the value of the assets lost. However, there is now some consideration that lands should be acquired from government tea estates which can be resold to the middle class.

A major concept behind the development of Digana was to create a town to absorb the population growth of Kandy. Kandy's value as a tourist center is being undermined by excessive growth. The area around the Victoria reservoir could be planned to absorb the tourist trade. If this objective is to be met, then an overall structural plan must be developed, based upon socio-economic mapping of the entire reservoir area.

RECOMMENDED ACTIONS

NEEDS FOR SOCIAL PLANNING

Much of the planning which is currently being carried out by the Mahaweli Development Board is based upon engineering requirements and considerations. This is understandable given the importance, urgency and priority of the irrigation works to the project. For different reasons, the donor agencies also place emphasis on engineering design and planning. The justification for this among donor agencies is that settlement planning is the business of those in the country and cannot knowledgeably be assisted by outsiders. This decision, while based upon sound reasoning, has an unfortuante consequence: it allocates an overwhelming proportion of the financial and manpower resources to the physical planning from an engineering point of view. This must be the result if resources are not allocated for the human side of planning.

The decision to shift settlement issues to the Mahaweli Economic Agency (M.E.A.) has been viewed as a positive step toward separating settlement issues from the priority of engineering considerations. However, the major concerns of the Mahaweli Economic Agency are and must be agricultural production. These are not always coincident with the needs of the settlers or people living in the project area. In addition, there is reason to believe that the M.E.A. will rapidly become too involved in day to day settlement issues to carry out long range planning.

The specifically social areas of planning to which more effort could be profitably directed include the following:

- Incorporating human needs into the physical settlement plans;
- Planning for social integration in the project area;
- Regional and urban planning;
- Monitoring the social evolution of the program;
- Planning for settler orientation; and
- Regional plans for Kotmale and Victoria Reservoir areas.

SOCIAL OBJECTIVES OF THE MAHAWELI PROGRAM

One of the major objectives of the Mahaweli Program is a social one. It seeks to reduce unemployment, and to create from the unemployed and landless, a class of small holders who are financially viable and commercially oriented. These social objectives need to be protected and supported. This means reserving most of the irrigable land for small holders, which will permit them to cultivate at a financial gain to themselves and their families.

A monitoring system needs to be set up which will accurately determine:

- The indebtedness of the settler families;
- The proportions who lease out their land; and
- The reasons for indebtedness.

This monitoring program should allow feedback to project management so that solutions can be devised as the project develops. The monitoring program in System H suggests that problems can be alleviated by providing

banking services when settlers arrive, and by extending the period of the initial agricultural loans to a period of five years.

It is also important in a monitoring system to include the non-beneficiaries of the project. The important group to be monitored in this case are agricultural laborers.

SOCIAL ISSUES WHICH NEED TO BE ADDRESSED

Social Integration

The problems of social integration in any country are extremely sensitive. It is sometimes felt to be in the interests of social integration not to address the issues or, not to address them publicly. However, there is also a danger in this approach that the result will be an unjust allocation of resources which will lead to renewed sense of grievance and impede long range efforts at national integration.

This is obviously an area where decisions must be made at the political level and the level of program management. While not precluding any solution to the problem, a few basic principles are suggested.

In some specific areas, settlement of homogeneous groups may be warranted to extend present ethnic distributions. In other areas, a mixture of the groups may be more feasible to prevent an imbalance of the existing ethnic group proportions.

In order to promote eventual integration within the society, it is suggested that consideration be given to settling different ethnic groups at the village level. The principle of settling family members together at the hamlet level can still be maintained to ease the initial problems of adaptation.

The overall development of the region needs to be considered. The settlement of Systems A, B, C and D will have an effect upon growth of the urban centers of Batticaloa, Trincomalee, Polonnaruwa and others. The principle of balanced growth between Tamil and Sinhalese within these urban centers needs to be treated in the context of an integrated regional plan.

Regional Approach

There are a number of issues which cannot be addressed except within the regional context. The chief among these is the problem of the second generation. The second generation has traditionally been accommodated by division of original allotments, encroacher settlements and new colonization schemes.

These three solutions will no longer suffice in the Mahaweli Accelerated Program, primarily because: the allotments are smaller than in older colonization schemes; there will be no free land left for encroacher towns and; after the Mahaweli Accelerated Program, there will be less land for new colonization schemes.

The issue, then is to provide non-farm employment to the second generation within the region, by the stimulation of growth of the urban areas,

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industrial development and agri-business. The second division of the Mahaweli Economic Agency will deal specifically with this aspect of growth in the Mahaweli Program. However, this aspect particularly cannot be treated in isolation from neighboring urban areas. There is therefore an urgent need for a serious study of the regional implications of the Mahaweli Accelerated Program.

The regional plan should also address the problems of creating urban environments to serve the Mahaweli area. Until real urban centers exist in the area, it will be difficult to attract and to keep the professionals needed to run the program itself.

Rather extensive plans for the provision of social infrastructure (schools, medical facilities, banks, cooperative stores) have been made by the Mahaweli Development Board. There is reason to believe, however, that difficulties will be met in the implementation, and especially in the timing of implementation to meet the demands of the settlers upon their arrival. These difficulties will be exacerbated by the proposed speed of implementation of the Accelerated Program. These problems can be addressed as part of a regional planning unit.

Social Needs and Physical Planning

The clearing of the project area for development will deprive existing communities of current supplies of firewood and land for cattle and buffaloes to graze. While this has been recognized by the Mahaweli Development Board, the needs have not yet been reinstated in the physical plans.

There is a need to take community aspects such as these into consideration at the stage of physical planning and preparation of settlement maps. The required effort is not great, but action is required to translate an accepted idea onto the physical plans.

Need for Socio-economic Studies as Part of Regional Planning Unit

With the movement of the settlement planning unit to the Mahaweli Authority, the socio-economic unit of the Mahaweli Development Board became divorced from the planning unit. This is unfortunate because this study unit was an innovative measure which incorporated social studies as an integral part of the planning process.

There is a continued place for socio-economic studies as part of the planning process. Specific topics which need to be addressed are:

- Detailed actual land use maps including existing settlement and encroacher towns, with current population estimates;
- Land use maps for proposed settlements, parks, and urban areas;
- Population growth estimates for the colonization schemes and urban areas in ten to twenty years;
- Growth of urban centers near and in the Mahaweli Program;
- Areas zoned for business and industrial development; and Tourist potential for the area, both for the national expanding middle class and for international tourism.

Needs for Social Monitoring and Evaluation

While a number of studies have been carried out for other colonization schemes, including System H, the same level of social research is not currently being planned for the Accelerated Program area. Given the complexity of the issues described in the social impact analysis, more research needs to be addressed to the issues of social change which will be experienced by those in the project area. The studies to be carried out will each require its own methodology. No single baseline study can adequately cover all of the topics.

A list of formulated topics put out by the Mahaweli Development Board in 1980 includes the following:

- A study of the stages of growth of a colonization scheme; This study will help to establish a knowledgeable estimate of the ratio of farm families to non-farm families;
- A study of the comparative adaptation of settlers from Kotmale who moved to the tea estates and those who moved to System H;
- A study of changes in "quality of life" in System H, using cross cultural indicators laid down by the United Nations Research Institute for Social Development;
- A study of the applicants and those selected for settlement in the Mahaweli Program;
- A study of social and economic conditions of settlers in System H; and
- A study of resource utilization and farm income.

It is recommended that this kind of research program be established as part of a monitoring and evaluation program for social change within the Accelerated Program Area. In addition to the topics already outlined and currently underway by Sri Lankan researchers, it is recommended that actual land holding and leasing arrangements be monitored. In this way, the proportion of settlers who become in effect tenants on their own land can be determined.

Settler Orientation

All of the interviews with selectees and with villagers in the Program Area suggested that they had little preparation for what to expect for the Mahaweli Program. It is recommended that the settler orientation program be expanded for settler training and to help them prepare for the experience of settlement in the Mahaweli Program area.

The orientation programs are currently being planned by the M.E.A. One way that this project could be handled is to assign a community development worker to work with a selected group of families for a number of months previous to the resettlement, and for a period after settlement. It is believed that a great deal of stress of adaptation might be resolved by an adequate information program previous to the move. It was noticeable in the interviews with selectees and with people in the project area that they did not know what to expect. Even selectees who had applied to the program had not thought through what they would want to take with them to the new area.

The content of the orientation course should answer all the basic and immediate questions about how the program is structured, what will be allocated, what services will be available and where services can be found. In addition, an overview of the course planned for community development should be presented. While details can wait for the actual course, the settler should be aware of the basic concepts of the courses to be taught. Particularly important would be some instruction on the implication of settler crowding on public health and the need for latrines. Other topics which need to be taught previous to settlement include basics about water management, pest management, credit, fuelwood control, and community grazing lands.

It is recommended that a complete orientation program be developed including the formulation of an appropriate curricula, scheduling for initial and subsequent programs, the training of suitable teaching staffs, and the preparation of specific materials such as visual aids for presentation as well as the preparation of specific pamphlets, leaflets, etc. in appropriate languages for distribution to the settlers. The development of this program would require specific expertise in orientation and educational training and would probably take about one year or more to properly complete. However, initial training and orientation for the settlers could begin as soon as specific modules of the program are developed. The cost of developing the program would probably be on the order of Rs. 3.2 million.

Agricultural Credit

The investigations undertaken as part of this study lead to some suggestions to be incorporated into our agricultural credit program. In order to make it possible for settlers to avoid initial high indebtedness, it is suggested that loans be extended for a period of up to five years. Another possible subsidy which might be necessary will be to farmers in areas of high crop damage by elephants. It should not be necessary for these farmers to bear the total cost of the damage since the damage can be predicted for certain areas.

Need to Plan for the Overall Development of Kotmale and Victoria Reservoir Areas

Current plans for relocation of Kotmale residents have not been integrated with plans for relocation of service centers or urban areas. There is an immediate need to plan the region of Kotmale. A similar need exists to draw up an overall structural plan for the Victoria region. This is particularly important given the tourist potential of the Victoria area after the reservoir is full.

INSTITUTIONAL RECOMMENDATIONS

In order to incorporate social concerns and human needs into the ongoing Mahaweli Program, the following institutional mechanisms are recommended.

Regional Planning Unit

The unit which must be responsible for a regional approach to the Mahaweli Program should appropriately be located as an advisory group within the Mahaweli Authority. It would be made up of a number of highly qualified

specialists in the fields of economic, regional and urban planning. It should include a socio-economic studies group as part of its staff. The arrangements for such a unit need to be carefully formulated by a working committee of qualified professionals, working on these issues in Sri Lanka.

Institute for Socio-economic Studies and Monitoring

In order to assure the long term continued evaluation and monitoring of social considerations, research needs to be devoted specifically to that purpose. These studies should not be tied specifically to the day to day needs of the program, nor to the immediate needs of planners to demonstrate progress. Therefore, the concept of a research institute devoted to studies of social change in the Accelerated Program area is supported.

This institute should be associated with the program, but should include a board of directors made up of qualified social scientists. Research should include but not be limited to monitoring of the social evolution of the project. The institute would initiate and carry out research on topics proposed by professionals on its staff. Present agencies including the Agrarian Research Institute and the university staffs should be funded and encouraged through such a socio-economic institute to conduct relevant monitoring and research programs for the Mahaweli Accelerated Program. This approach had been used successfully in prior years and could be revived to meet future research needs.

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M. ECONOMICS

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ECONOMICS OF ENVIRONMENTAL ANALYSIS

METHODOLOGY

The economics associated with environmental analysis have generally been relegated to analysis of secondary or indirect benefits and costs associated with proposed actions. The reasoning behind this is that intuition assumes a non productive resource altered to give society a desired product is beneficial. This certainly may hold true where resources are plentiful, and impacts to development are easily absorbed. However, society is now moving into an era of environmental consciousness, as resources become more scarce due to depletion and population increases. Development impacts are being felt more intensively to society as measured through the resource itself.

The result of this environmental awareness is that the development of natural resources is now looked upon in a more objective manner with a greater emphasis toward preservation of critical areas and minimization of negative impacts incurred directly on the developed resource or indirectly on neighbouring areas.

What this means as pertains to economic analysis is that new emphasis should be placed on assessing and quantifying total productivities of an ecosystem. Present analysis is constrained to measuring the value of an ecosystem through a production indicator. Thus, a resource which produces commercial timber is considered a forest resource and valued accordingly. Surely this resource produces more than forest cover alone. There are in fact other production dynamics taking place which have a value to that resource whether measured by a marketable commodity or not. This leads now to a philosophical consideration associated with the assigning of values. In short, values are determined by a consuming or utilizing public. A product not assigned a value is such, not intrinsically because it has no value, but because, at a point in time, it has no public utility. It is entirely likely, however, that over time this presently non-valued entity, through changes in supply and demand patterns, can become highly valued. History is full of examples of this, of which, the most glaring today is oil. The challenge therefore is to develop the methodology and expertise to value resources in their true prospective so that future generations may enjoy them. The outgrowth of this is not to curtail development but to properly understand what the opportunity cost of development is in real economic terms. For example, is it fair to assume the economic value of an aquatic resource is the tilapia it produces, which relates to the harvest of one trophic niche, as opposed to say agricultural cropping should the aquatic resource be drained? What has not been analyzed in the aquatic resource under discussion is the other trophic niches not presently utilized, which might be highly valued by future generations. The point in fact is that a multi-benefit reource could be lost simply because the analytical tools have not been developed to analyze beyond present utility values.

The analysis put forward in this report will be of a traditional nature with quantified benefits used to sum up totals. However, as long as benefits are subject to qualifying values rather than discrete quantification

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there will always be a problem ranking them against desired benefits from market oriented development. It is hoped that through projects and reports such as this, environmental planning will devise more sophisticated and concise methods of valuing ecosystems.

ECONOMIC CRITERIA

INTRODUCTION

This report seeks to evaluate in economic terms proposed recommendations that would mitigate negative environmental impacts caused by the proposed actions to develop the Accelerated Mahaweli Program.

Some of the proposed recommendations call for specific programs with which to mitigate negative impacts to the environment itself, e.g. Watershed Management; other recommendations mitigate negative impacts to the human environment, e.g. Forestry, and yet some recommendations are to enhance productivity to help offset irretrievable losses, e.g. Seasonal Tank Program for Fisheries Development.

Not all recommendations indicated in the various topic reports call for or need an economic analysis. Some do not lend themselves to quantifiable values from which to develop an analysis. The analyses developed in this topic report are directed toward those programs, recommended project options or requirements for human needs that by concensus among the TAMS staff represented priority importance.

The basic tenet of this report is to develop the planning tools necessary to help optimize the efficiency of land use through identification and quantification of major environmental impacts representing costs or benefits to society.

It must be emphasized that this is a particularly arduous undertaking in that a great deal of the realm of this analysis lies within that which traditionally has been relegated to indirect costs and benefits generally passed over in project appraisal because of the extreme difficulty of prediction and quantification.

Traditonal analysis relegates itself to input/output relationships and subsequent economic and financial profitabilities according to project goals. Environmental impact analysis, however, concerns itself with the repercussions to the resource base itself as a result of project management. This resource base includes the physical as well as animal and human environment and the costs and benefits to society as a whole. Some of these impacts are directly related to the resource base (erosion, water quality) and are quantifiable, others are indirect impacts which are associated with society values (clean air, open vistas) and are extremely difficult to value.

Since this report deals with economic rather than financial analysis, distinction must be made of those commodities and items whose economic prices differ from the financial or market price. The following sections in this chapter develop the economic prices along with various criteria and assumptions used throughout the report.

In establishing the analytic methods and economic process, consideration has been taken of the NEDECO Implementation Strategy Study, Acres Feasibility Study of System B and Hunting's Feasibility Study of System C. In addition, discussions have been held with representatives of the Ministry

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of Finance and Planning, the Bank of Ceylon, the Ministry of Agriculture and Joint Venture Randenigala Consultants.

FOREIGN EXCHANGE RATE

Until 1977, the Sri Lankan currency was substantially over-valued in relation to other world currencies, and rigorous measures were necessary to offset severe foreign exchange shortages. In November of 1977 the dual exchange rate system in effect was abolished, the Rupee was devalued and many foreign trade controls were lifted. Since that time the Rupee has floated at a level between Rs.15 and Rs.16 to the U.S. dollar, with the present official exchange rate of 16:1.

Different consultants involved in proposal and feasibility reports concerning the Accelerated Mahaweli Program have used varying shadow exchange rates to try to approximate the real economic value to the Rupee in relation to world currencies and to ameliorate short term effects. The NEDECO Implementation Strategy Study adopted an exchange rate of Rs.18 = $1. U.S. - a rate approximately 15% higher than the prevailing mid 1978 rates. The World Bank used a rate of Rs.20 = $1.U.S. in their recent project appraisal of System C. Other consultants for System B, C, and D have used the prevailing exchange rate under the assumption that the Rupee is not overvalued at its present level.

It is highly likely however that the Accelerated Mahaweli Program will have an effect on the economy of the country and may in fact have an inflationary effect. This in itself would call for using a shadow-exchange rate higher than the prevailing exchange rate, but, as NEDECO has indicated, "macroeconomic models are insufficiently detailed to enable a correct estimation of the shadow rate of exchange to be applied in economic analysis" (NEDECO 1979).

In view of the varying opinions and because of the lack of macro-modeling, the Consultants have decided to use the exchange rates approximating the official rates, thus eliminating the necessity of shadow pricing the foreign exchange cost component in the economic analysis. In order to convert foreign cost componenets in the economic analysis, the exchange rates used throughout this study are therefore:

$1 U.S. = Rs.16.00

This approach is in general agreement with the present project evaluation guidelines of both the Ministry of Finance and Planning and the Central Bank of Ceylon.

ACCOUNTING RATE OF INTEREST (ARI)

The accounting rate of interest reflects the opportunity cost of capital and establishes the discount rate used to compare various streams of costs and benefits over time for project evaluation.

The determination of the accounting rate of interest is a complex undertaking in that it is based on a number of macro-economic relationships. In principle, it should represent the opportunity cost of capital or the return on the last project, given a limited stock of capital, which can be implemented. Since Sri Lanka has scarce capital, a high discount rate would be justified in maximizing expectations on project returns.

Two papers published by Dr. Deepak Lal in 1978 supported this by recommending an accounting rate of 13% be used in project evaluation. NEDECO has indicated that due to the long term characteristics of the Mahaweli Program and the relative scarcity for additonal suitable arable land, a lower accounting rate could be used. NEDECO therefore opted for 12% as the overall discount rate used in their analysis.

Other consultants working on studies related to the Mahaweli Program have used a discount rate of 10%. This was consistent with the rate used by the Ministry of Finance and Planning and Central Bank of Ceylon through late 1979. However, the Ministry of Finance and Planning has, the first quarter of 1980, revised the discount rate upwards to 13.5%. This reflects a policy tending to accept projects returning a high rate in view of capital scarcity.

The discount rate that will be used in this report will be 10%. This may seem inconsistent with the present indicated rates; however, the very nature of environmental projects indicates a set of judgement criteria unique to those found in projects with traditional input/ouput relationships. For one thing, most environmental projects are concerned with resource protection for future generations. Thus, effects may last far beyond the time frame of other types of projects. Next, many important benefits accruing to resource optimization and environmental protection cannot be measured in quantifiable terms.

In effect, the rationale and justification of using a discount rate lower than that in current analysis is to offset the project life and, most important, to allow for fair competition in cut off rates where social and environmental benefits cannot be measured.

EVALUATION TECHNIQUES

In traditional project evaluation a number of methodologies are used to compare cost and benefit streams. The three most frequently used are:cost/benefit ratio, net present value and the internal rate of return (I.R.R.). The latter is that rate which reduces the present net value to zero, while the present net worth uses a chosen discount rate to bring future cash flow, to a present value and, the cost/benefit ratio compares the present worth of benefits to the present worth of costs.

This report will utilize two of the techniques, i.e. present net worth and I.R.R. wherever applicable. However, as was previously expressed, the analysis of natural productive systems will present certain variables which cannot be quantified given present levels of knowledge. Wherever this occurs an attempt will be made to identify as many values within the system as possible and apply either a gross value or present a value with a qualifying indication of non-measurable values.

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PRICING THEORY

In order to properly assess the real value of inputs and outputs of the Mahaweli Development Program it is necessary to use economic prices and values rather than prevailing market prices. Market values (financial values) can be distorted by subsidies, taxation, tariffs, support prices, interest, or maladjustment in reflecting the true scarcity of both renewable and non-renewable resources. Thus, the economic values will measure costs and returns to society as a whole, whereas financial values are used to evaluate returns or losses to a particular entity.

Set values and prices used in this report are expressed in mid 1980 constant prices in order to eliminate the impact of inflation. Project inputs and outputs which are traded on world markets are valued at long-term projected prices which are expected to continue throughout the life of the identified project periods thus ameliorating short term fluctuations. Thus long term pricing forecasts will be based on 1980 World Bank projections expressed in mid 1980 prices.

Commercial forest timber will be valued as an import substitution good as it is felt this accurately represents the true cost to society of a diminishing resource. Major production commodities will also be treated on an import substitution basis. Their prices have been worked back to farm-gate prices in the Accelerated Program area by allowing for local transport, marketing and handling costs.

Important items such as diesel oil, kerosene, fertilizers and building materials are calculated on an import parity basis, again based on World Bank projects to 1990 in constant 1980 prices.

For commodities not traded internationally, present price levels are considered indicative of future prices when expressed in terms of mid 1980 prices. Inflation indicators used to bring prices up to current levels are shown in Table M-1.

OPPORTUNITY COST OF LABOR

Determining the value of skilled labor is rather straight forward and is generally accepted to be the financial wage offered. The reasons for this are that skilled labor is scarce and the marginal value product is fairly easy to access. However, the same does not hold true for unskilled labor and in particular farm labor. Because of a prevailing high unemployment and under-employment rate, the economic cost of employing additional labor may be lower than actual wages paid. This circumstance requires that a shadow wage rate (economic rate) be determined to express the real value of labor.

The International Bank for Reconstruction and Development (IBRD 1978) shadow priced unskilled labor at Rs.5/ per day based on 1978 values. However, there have been major changes in labor and employment since that time. In its recent project appraisal in System C the IBRD suggested an updated shadow wage rate of Rs.10/day. Hunting (1980) recently updated its shadow wage rate to Rs.9.62/day and the Ministry of Planning and Finance is using the conversion of 0.62, developed by Deepak Lal (1978), of the

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Table M-1

Inflation Indicators, Sri Lanka and World Economy

	Sri Lanka (1)		World (2)	
	Index	Increase over previous year	Index	Increase over previous year
1974	65.8	25.[illegible]	67.5	25.1
1975	71.3	8.3	77.9	15.4
1976	75.9	6.4	79.2	1.7
1977	87.8	15.6	86.8	9.6
1978	100.0	14.0	100.0	15.2
1979	110.0	10.0	108.6	8.6
1980+	-	10.0	-	6.0

Sources: Central Bank of Ceylon
World Bank, Commodity Price Forecast, May 1979

(1) 1974 to 1978 implicit GDP deflator used by the Central Bank of Ceylon, adjusted to 1978 base. Consultants' estimates for later years.

(2) World Bank estimates based on developed countries "CIF" index of US dollar prices on manufactured exports to developing countries.

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current financial wage rate to indicate the economic rate. Current financial rates for unskilled and farm labor in the project area vary from Rs.15 to 20/day with Rs.16/day being the most quoted value. Thus, the Ministry of Finance and Planning would support an indicated economic price of Rs.9.92/day.

The economic wage rate used in this report for unskilled rural labor is Rs.10/day. This is supported by cited current analyses and reflects a prevailing assumption that rural labor and in particular farm labor will in fact be in short supply during peak seasonal periods, i.e. cultivating and harvesting due to the accelerated project. In addition, the large amount of construction and development activities undertaken in Sri Lanka may very well reduce surplus unskilled labor to the point where there is price competition between industrial and farm labor.

FUEL PRICES

Fuel prices in Sri Lanka have been heavily subsidized in the past and there appears to be no forthcoming change in this policy. The Ceylon Petroleum Corporation (CPC) operated a refinery with a present capacity of 1.8 million tons. Plans are to expand this capacity to 2.4 million tons in the near future. The refinery produces large surpluses of heavy distillates which are exported. However, there are no surpluses produced for diesel oil and import is needed to cover shortfalls. Since diesel oil is a traded commodity, it will be economically priced on world prices.

The particular difficulty involved with fuel prices is the rapid inflation of world prices which have made quantum leaps in the last few years, 1979 being a particular glaring example with over 2 1/2-fold increase. The World Bank report on Price Prospectus for Major Primary Commodities, (Washington, June 1978) expressed the opinion that long-term price fluctuations of petroleum will go up in line with general inflation. However, it has been seen that petroleum prices have advanced faster and higher than inflation. Whether or not this will be a continuing situation or whether in fact prices will level off to an inflation pull rather than a price push situation remains to be seen. For the purpose of this report, present world mid-1980 financial prices will be used and an assumption that petroleum prices will rise in line with general inflation. The economic price of diesel oil is figured on 1990 projections with mid 1980 constant dollars as shown in Table M-2.

PRICE OF PADDY

It is necessary to determine the economic price of paddy in order to assess possible impacts to the "with project" cropping patterns as a result of environmental influences. An example of this is the crop damage that will be sustained by farming in areas of high wildlife concentration. In Table M-3, the price is projected out to 1990 to establish a parity base and also that full project production levels are assumed by then.

Table M-2

Long Term Financial and Economic Fuel Prices
(Constant 1980 Prices)

	Diesel		Kerosene	
	US$ tonne	Rs/gal	US$ tonne	Rs/gal
Present Import Prices (1) CIF Colombo	390		400	
Projected World Price Increase 1980 to 1990 of 36% (2)	140		144	
Add: Handling, storage, overheads of CPC (1)	25		25	
Economic price at Colombo (Official exchange rate Rs.16 = $US 260 gallons per tonne)	555	34.16	569	35.02
Rail and road transport to project areas (3)		0.60		0.60
Economic price to Accelerated Program area		34.76(7.64/1)		35.62(7.83/1)
Financial Prices Accelerated Program area (3)				
Present				12.50(2.75/L)
Future				16.76(3.68/L)

Sources:

(1) Ceylon Petroleum Corporation, May 1980.

(2) Commodities and Export Projections Division, IBRD, Jan. 1980.

(3) Hunting Technical Services Limited. Monaragala Sugar Sub-Sector Study May 1980.

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Table M-3

Derivation of Long Term Economic Price for Paddy
(In Constant 1980 Prices) (Based on Import Substitution)

	$ U.S. ton
Projected world market price 1990 (1)	386
Freight and insurance, Bangkok-Colombo (2)	26
CIF Colombo price	
	Rs/ton
Conversion to local currency (US$ = Rs.16.00)	6592
Shore handling, harbor dues etc. (2)	75
Economic price	6667
Conversion to Paddy basis (3)	5434
Less: milling and storage (4)	499
transport from farm gate to mill	25
Economic farm gate price	4010
Rs/bushel	85

Sources:

(1) World Bank Commodity Projections Jan. 1980, FOB Bangkok adjusted to 25.35% brokens

(2) Food Department

(3) 68% conversion ratio

(4) Paddy Marketing Board 1980 estimates

TRANSPORTATION

The recent import increase of diesel oil has made it necessary to update the economic price of road transport. These updated costs are based on an average of local contractor's current freight rates to the Accelerated Program area and adjusted for the subsidized cost of diesel duties on new vehicles, and expected increase on new vehicles due to increased freight demand from expanding construction and development activities.

The increased fuel price has had a significant impact on total annual vehicle running costs. NEDECO estimated that fuel(diesel oil) comprised approximately 16.7% of total annual economic running costs for 5 and 15 ton trucks. This was based on an economic price of Rs.2.12/liter. Since the NEDECO report (1979) diesel oil has increased in price to Rs.6.29/liter or 197%. The future economic price for diesel oil derived for this report is Rs.7.64/liter or 260% over NEDECO's figure. With this percentage increase incorporated into the total annual vehicle running cost, assuming all other variables have remained within 10% inflation rate, diesel oil now comprises 42% of the total bill.

Table M-4 shows adjustments made to arrive at the transport rate per tonne per km used in the economic analysis.

FUELWOOD

The economic price of fuelwood is figured on an equivalent caloric basis to kerosene. The reasoning behind this is that currently the only substitute for fuelwood is kerosene, and, that with the present reduction of national supplies fuelwood, e.g. the dry zone forests, this substitution will become more and more predominant. The USAID environmental assessment of Stage II of the MDP calculated that 11-15 gallons of kerosene are needed to provide an equivalent calorific heat for boiling water or cooking as one cubic meter of firewood. By using a substitute price of kerosene equivalents for fuelwood an economic value can be derived. Table M-5 shows the economic price of fuelwood calculated to be Rs427.44 or 6.8 times higher than the financial price. Background data for these estimates is provided in Tables M-6 and M-7.

Table M-4

Road Transport Rates

	Rs/Ton/Km
Current Average Market Freight Rates (1)	1.20
Add: Increase expected due to increased demand and new capital equipment, 30%	.36
Projected market freight rates	1.56
Economic prices	
Less: Import duties of 5% on capital costs (60% of total) (2)	.05
Add: Economic diesel price 213% above financial diesel price on 42% of costs	1.35
Projected Economic Freight Rate	2.86

Source:

(1) Represents a market survey averaging costs for 5 and 15 ton trucks

(2) Capital costs account for about 60% of total running costs.

Table M-5

Economic Price of Fuelwood

	Economic (Rs/M^3)	Financial (Rs/M^3)
Economic price of Kerosene: Rs.35.62/gal		
Conversion factor : 12 gallons Kerosene to 1 cubic meter fuelwood		
Price of Fuelwood prevailing in the Accelerated Program area	427.44	63

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Table M-6

Financial Price of Fuelwood

	Rs/M^3
Rs.12/cwt. depot Polonnaruwa	= Rs.268.8/mt
less 36.0 transport (30 km x Rs.1.20/tonne Km)	
232.8	
Uncut fuelwood takes up 50% more volume then cut	
Rs.116/Mt uncut fuelwood	
	= Rs.63/M^3 uncut at source

Table M-7

Commercial Value of Timber based on Import Substitution Prices: Logs

	Rs/cu.ft
Current Import Price of Sawn Commercial Grade Timber CIF Singapore	98
Add: Shore handling and harbor dues	1.15
Subtract: Log conversion rate @ 50%	49
Add: Transport cost to production site 220 Km @ 2.84 per tonne Km	9.60
Economic Price of commercial grade logs	59.75

ENERGY REQUIREMENTS

The basic fuel sources presently used in rural areas are kerosene for lighting and some cooking and fuelwood predominantly for cooking. Substitute and supplementary energy sources are charcoal and paddy husk.

Electricity is not considered as an energy alternative in this report as no development strategy has been included in the Mahaweli scheme. Hydro-electric power will essentially be used for the towns and villages rather than transmitted to settlers' houses. New energy sources which should be researched and implemented are biogas, solar and wind power.

It is assumed that cooking in the Accelerated Program area will be done with fuelwood only. ACRES (1979) estimated that a family will use 124 cu. ft. of fuelwood annually for cooking. Weatherly and Arnold (1979) estimated fuelwood requirements per family at 132 cu. ft. per year. These estimates represent usage under present population and conditions in which there is virtually an inexhaustable supply within relatively easy access. However, under full development the picture changes dramatically. Crops and settlements will replace forests. Population is expected to increase to one million above the present level, creating a greatly increased energy demand. With this sequence of events the supply of fuelwood will be considerably reduced from natural sources, and proposed plantations which are planned to mitigate this loss will in all likelihood be less proximal to the homestead. The result will be a more conservative usage of a new scarce or costly resource (costly in terms of cash outlay at time spent in gathering) with an overall reduction in requirement. This change in consumer attitude is expected to give a new estimate requirement of approximately 100 cu. ft. per family.

Approximately 98% of the families in the rural sector of Sri Lanka use kerosene as the only energy source for lighting (USAID 1979). This condition is not expected to change in the future unless new technologies are developed.

Household requirements for lighting are estimated at two lamps per house utilized for 2.5 hours each night. Kerosene consumption is figured to be 21.5 gallons assuming each lamp burns one gallon every 85 hours.

Table M-8 shows the energy requirements per fuel source for the total projected one million additional people representing 200,000 families anticipated in the Accelerated Program area by 1990 with population increases of 2% through to the year 2020.

ECONOMIC ANALYSIS OF ENERGY REQUIREMENTS

The economic price of fuelwood based on kerosene substitution derived from Table M-5 is 6.8 times higher than its financial price. This pricing serves to emphasize the importance of perpetuating this energy resource for domestic consumption through forest conservation and fuelwood plantation programs. The only current acceptable energy substitute for fuelwood is kerosene, an import dependent product subject to external pricing fluctuations

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and requiring foreign exchange capital to procure. Table M-9 shows the annual fuel costs associated with energy requirements for the settlers in the Accelerated Program area.

Per family fuelwood costs are estimated to be approximately Rs. 1,210 economic per annum and Rs. 178 financial.

It is apparent that on substitution basis of kerosene for firewood the total fuel bill becomes excessively high; probably beyond the settlers ability to obtain full requirements without subsidization and at the same time putting additional pressure on scarce foreign exchange capital to import the commodity. However, by ensuring the perpetuation of fuelwood in adequate supplies to meet demand the domestic marketplace will set the price which will reflect both economic and financial prices at quite a bit lower (estimated Rs. 63/Rs/m^3) than the substitution price indicated at Rs. 427.44/m^3.

In addition, as alternative energy sources are developed to a degree of social acceptance by the settlers, further dependence on kerosene for lighting will be reduced. Alternative energy sources that should be considered are: charcoal, alcohol, wind and solar power and biogas.

FUELWOOD

Sri Lanka is in the precarious position in that as demand for energy sources increases its most cost effective supply is decreasing. The previous discussion on pricing shows the true cost to society that is incurred as each additional cubic meter of fuelwood is foregone and replaced with kerosene. This high opportunity cost of forest production demands that planners take an accurate look at the repercussions inherent to environmental alterations in terms of production benefits foregone, costs of substitution and program costs to perpetuate this resource.

TOPIC REPORT D: FORESTRY goes into detail concerning the forest area in the project area and the impacts due to development. The main conclusion from that report as pertains to fuelwood is that most of the resource will be destroyed through clearing and that which is left will have to be managed to ensure any sustained harvest. Concurrently, fuelwood plantations will be needed to meet additional demand created by farm settlers and non-farm families. Table M-10 shows demand for fuelwood based on population increases of 2% and the area of plantings needed to meet this demand. The plantations will be planted to quick growing varieties such as ipil ipil or eucalyptus and are expected to yield 141.48 m^3 per annum per hectare based on a five year rotation.

Table M-8

Energy Requirements for Settlers by Fuel Source 1990 to 2020 with a 2.0% Annual Population Increase

Fuel Source	Year	Population	Demand
FUEL	1990	200,000[1]	566,300 M^3
	2020	362,272	1,025,800 M^3
KEROSENE	1990	200,000	4,300,000 gals
	2020	362,272	7,788,848 gals

Note: FAMILIES - 5 PEOPLE PER FAMILY

Table M-9

Annual Fuel Costs for Accelerated Program Settlers - 1990 to 2020 with a 2% Annual Population Increase

Fuel Source	Year	Demand	Economic (Rs)	Financial(Rs)
Fuelwood:	1990	566,300 m^3	242,059,272	35,676,900
	2020	1,025,774 m^3	438,456,839	64,623,762
Kerosene (1)	1990	4,300,00 gals.	153,166,000	72,068,000
	2020	7,788,848 gals	277,438,766	130,541,093

Note: (1) Conversion of 12 gallons of Kerosene per m^3 fuelwood

Table M-10

Fuelwood Demand for the Accelerated Program Areas

Demand on 2.0% Population growth

Year	Population	Demand (m^3)	Plantings (ha)
1990	1,000,000	566,300	20,000
2000	1,218,000	690,316	4,383
2010	1,485,947	941,540	5,344
2020	1,811,361	1,025,774	6,511
			36,238 ha
			1083 ha planted each year after 1990

Note: Assuming that by 1990 population is 1,000,000 and demand is .566 m^3/ family/annum.

ECONOMIC ANALYSIS: WATERSHED MANAGEMENT

TOPIC REPORT C: WATERSHED MANAGEMENT presents a detailed analysis of the upper catchment for the Mahaweli Ganga and its tributaries. Included in the topic report are analyses of soils and present land use, which concluded that there is extensive soil erosion caused by past and present cultural practices. Reasons cited which lead to high soil erosion are: planting on extreme slopes, forest cutting at over 1,524 meters, and chena farming. Ninety two thousand seven hundred hectares, or 38.7% of the area in the upper catchment, are suffering extreme erosion. The aggregated annual soil loss from this erosion is calculated to be 11,292,000 tonnes, representing a 5,900 hectare equivalent of productivity lost, calculated on the basis of 10 cm of top soil per hectare, or 1.85 cm depth of soil over the mapped area of the catchment. This obviously represents a high value foregone, and if left unchecked will eventually not only leave the upper catchment without a productive base, but will have a heavy repercussion on the downstream environment.

Recommended mitigative actions to offset erosion and stabilize it to acceptable levels fall into two categories: first, there is the physical development program of fuelwood and timber plantations and agricultural diversification programs to establish ground cover and stabilize exposed slopes and crowns; second, is the development of a master plan which not only includes the physical activities but develops the governmental infrastructure, legal basis, financing and authority to plan, operate and coordinate soil conservation in the upper catchment under a single organized body.

The economic analysis will be directed towards the costs and benefits of the recommended physical programs of plantations and agricultural diversification. Costs and returns are based on USAID programs undergoing implementation in the upper catchment for plantations, and the National Agricultural Diversification and Settlement Authority figures as developed by the U.N.F.A.O. for agricultural diversification.

FUELWOOD PLANTATIONS

In order to meet the objectives of fuelwood requirements and soil conservation, 2,000 hectares will have to be planted annually, in addition to present plantings, starting in 1981 and totalling 18,000 hectares by 1990. The projected captial costs are Rs.2,514 per hectare with recurrent costs averaging Rs. 260 annually up to the 11th year when they reduce to Rs. 135. Yields are expected to be 140 m^3 per hectare on a 10 year rotation. The cost of harvesting is not considered as the fuelwood will be harvested by villagers living within the vicinity of the plantations. Since the development costs are to be borne by either the government or donor agencies as a sunk cost with neither a payback nor maintenance charge assessed to the users, it is therefore assumed that the labor cost for harvesting can be absorbed by the villager himself. Since the task of gathering firewood is relegated to children or elder people, the marginal value product of this labor may very well approach zero. For these reasons, no labor cost is used for the economic analysis.

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Table M-11 shows capital and recurrent costs to both the fuelwood and commercial timber plantations. The economic price of fuelwood used in this analysis is Rs. 49.72 per m^3. This price is lower than the derived financial price of Rs. 63 m^3 due to the economic cost of unsubsidized diesel fuel (Rs. 2.84/tonne/km vs. Rs. 1.20/tonne/km) used to determine transport cost from market depot to source. The economic price of fuelwood based on kerosene substitution (derived earlier in this report) was used as a sensitivity in this analysis rather than the base case price, as the plantation program itself is designed to mitigate future dependence on kerosene as a substitute for fuelwood.

The first fuelwood harvest takes place ten years after initial planting showing a net profit of Rs. 6,825 in that year. The recurrent costs decrease after the 10th year as the full 18,000 hectares have been planted and the activities of the nursery cease. Further reduction in recurrent costs occur in year 11 as vehicles and most of the employees are withdrawn. The plantation at this point is expected to be maintained by villagers with the help of a government extension officer.

Present net worth of the plantation is Rs. (324)/ha based on a 41 year life and discount rate of 10% (Table M-12), with an I.R.R. of 8.2%.

A sensitivity (Table M-13) was run using the kerosene equivalent substitution price of fuelwood at Rs. 427 m^3. The present net worth was Rs. 29,097/ha based on a 10% discount rate with a 41 year project life with an I.R.R. of 36.2%. This sensitivity was run to show the opportunity cost to society in terms of kerosene equivalent substitution pricing, the presently accepted energy alternative. By assuming this the net benefit of fuelwood plantations is Rs. 28,773/ha over the life of the project, i.e. the opportunity cost of kerosene equivalents (represented by the present net worth of Rs. 29,097/ha) plus the value of fuelwood plantations (present worth of (324/ha).

COMMERCIAL TIMBER PLANTATIONS

Approximately the same infrastructure development is needed for the timber plantations as the fuelwood plantations. The difference lies in a one-third cost increase for the seed bed in the nursery and planting for the timber plots. In addition, Rs. 60/ha road development and Rs. 39/ha maintenance cost must be added along with twice the number of staff and support requirements. The timber plantation will incur periodic returns and harvest costs at years 10 and 15 from thinning; the harvest of commercial grade timber will be at 20 years instead of 10 as in the fuelwood plantation.

Returns from the timber plots are from fuelwood, poles and commercial timber. The economic price of harvested commercial logs is based on the import substitution price of construction grade logs, Rs. 2,110/m^3. This economic price is expected to prevail until 2,020 at which time it is envisioned the domestic timber production from plantation and reserves (See TOPIC REPORT D: FORESTRY) will assure sufficient supply to eliminate dependence on imports. The price of fuelwood is Rs. 49.72/m^3 and that for poles (based on current STC prices adjusted for economic cost of transport) is Rs. 65.22/m^3.

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Table M-11

Plantation Development Costs (Rs/ha spread over 18,000 ha and 27,000 ha respectively)

Source: Forest Department 1980

Nursery	Fuelwood	Timber
Cost of seeds	26	33
Polyethylene Tubes	35	46
Land Preparation	5	7
Formation of seed beds	1	2
Collection of soil, sand and Microcrizzal soil	75	98
Mixing and filling tube beds	13	16
	155	202
Plantation		
Survey and Demarcation	75	75
Cultivation	563	563
Aligning and marking 8'x8' plots	75	75
Patchweeding 2x2	263	263
Holing 0" diameter by 18" deep	375	375
Head load transport	225	225
Planting	300	300
Application of fertilizer	38	38
Roads	50	60
Firelines	75	90
	2039	2064
Buildings		
Nursery Buildings	8	9
Buildings, Lab	8	9
Temporary Quarters	97	154
	113	172

Table M-11
(Continued)

	Fuelwood	Timber
Vehicles	97	81
Equipment	10	15
Contingencies	100	150
Recurrent Costs		
Nursery: Weeding, Watering & Maintenance & Seeds	63	82
Plantation : 1st yr 601		
2nd yr 221		
3rd yr 100		
Salaries	100	150
O & M Roads	20	39
Buildings	16	40
Vehicles and running costs	11	17
Equipment	25	20
	2	2

(Continued on following page)

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Table M-11
(Continued)

STAFF REQUIRED

	ANNUAL SALARY (Rs.)	
	FUELWOOD	TIMBER
Assistant Conservator	15,000	15,000
Forester	36,000	45,000
Forest Rangers	48,000	72,000
Forest Guards	96,000	400,000
Plantation Laborers	72,000	405,000
Drivers: Tractor	24,000	36,000
Lorry	12,000	18,000
Jeep	12,000	12,000
Lorry Cleaner	10,000	10,000
Clerks	15,000	15,000
Steno Typist	8,000	8,000
Office Laborer	5,000	5,000
Watcher	5,000	5,000
	358,000	1,046,000
Quarters for Field Staff	1,750,000	4,150,000
Vehicles		
Jeep with Trailer	300,000	300,000
Lorry	450,000	450,000
Tractor with Trailer	400,000	600,000
Motor Cycles	600,000	750,000
Bicycles	-	80,000
	1,750,000	2,180,000

Table M-12

Economic Returns Fuelwood, Plantations
(Rs/ha)

Year	Capital Cost	Recurrent Cost	Returns	Net	Present Net value at 10%
1981	391	45	-	(436)	(396)
82	2123	96	-	(2219)	(1833)
83	-	738	-	(738)	(554)
84	-	358	-	(358)	(245)
85	-	237	-	(237)	(147)
86	-	237	-	(237)	(134)
87	-	237	-	(237)	(122)
88	-	237	-	(237)	(111)
89	-	237	-	(237)	(100)
90	-	174	-	(174)	(67)
91	-	135	6960	6825	2389
1992 to 2000	-	1215	-	(1215)	(272)
2001	-	135	6960	6825	921
2002 to 2010	-	1215	-	(1215)	(105)
2011	-	135	6960	6825	355
2012 to 2020	-	1215	-	(1215)	(40)
2021	-	135	6960	6825	137
	2514	6781	27,840	18,545	(324)

Table M-13

Economic Returns Using the Economic Price of Fuelwood

Based on Kerosene Equivalents

(Rs./ha)

Year	Capital Cost	Recurrent Cost	Returns	Net Returns	Present Net Value at 10%
1981	391	45	-	(436)	(396)
82	2123	96	-	(2219)	(1833)
83	-	738	-	(738)	(554)
84	-	358	-	(338)	(245)
85	-	237	-	(237)	(147)
86	-	237	-	(237)	(134)
87	-	237	-	(237)	(122)
88	-	237	-	(237)	(111)
89	-	237	-	(237)	(100)
90	-	174	-	(174)	(67)
91	-	135	59,780	59,645	20,876
1992 to 2000	-	135	-	(1215)	(272)
2001	-	135	59,780	59,645	8,052
2002 to 2010	-	135	-	(1215)	(105)
2011	-	135	59,780	59,645	3,102
2012 to 2020	-	135	-	(1215)	(40)
2021	-	135	59,780	59,645	1,193
	2514	6,781	239,120	229,825	29,097

Thinning costs at years 10 and 15 are estimated to be Rs. 24.46/m^3 (labor intensive operations) with total costs per hectare figured as:

Fuelwood: 20% of production at 10 year thinnings = 56 m^3/ha
cost of thinning = Rs. 1,369/ha.

Poles : 20% of production at 15 year thinning = 44.80 m^3/ha
cost of thinning = Rs. 1,096/ha.

The harvest cost for the commercial timber to be extracted from the plantation on a contractual basis is: (Source: STC 1-29-80).

	Rs.
Felling, converting and hauling first km	2.15
Transport/haul additional forest track per cubic meter per km	6.13
Transport gravel road per cubic meter per km	3.28
Transport Highway per cubic meter per km	2.19
Loading and unloading per cubic meter	18.34

Average distances for hauling and transport in the plantations to sawmills and costs are:

Felling and one km haul	= Rs. 384.85
Transport forest track	= Rs. 2194.54
Transport gravel road 4 km	= Rs. 2348.48
Highway Transport 30 km	= Rs. 11760.30
Loading and unloading	= Rs. 3286.44
TOTAL	Rs. 19974.61

The economic cash flow for the project is shown in Table M-14. Present net worth is Rs. 50,984 based on a 41 year life of project with a 10% discount rate and the I.R.R. is 25.51%. The life of the nursery is 10 years at which time the plantations are fully planted. However, unlike the fuelwood plantation, the commercial timber plantation will retain full complement of vehicles and staff throughout its 40 year life. These plantations will be developed, managed and maintained by the Forestry Authority with commercial sales both to public agencies and private dealers through designated depots.

Fuelwood from the first thinning will most likely be sold locally as pricing will not allow transport costs beyond 20 km and remain cost competitive.

Table M-14

Economic Analysis, Timber Plantations (Rs/ha)

Year	Capital Cost	Recurrent Cost	Harvest Cost	Returns	Net	Present Net Worth
1981	517	59	-	-	(576)	(524)
82	2167	195	-	-	(2362)	(1951)
83	-	801	-	-	(801)	(402)
84	-	421	-	-	(421)	(288)
85	-	350	-	-	(350)	(217)
86	-	350	-	-	(350)	(183)
87	-	350	-	-	(350)	(180)
88	-	350	-	-	(350)	(163)
89	-	350	-	-	(350)	(148)
90	81	350	-	-	(431)	(166)
91	-	350	1369	2784	1065	373
92	-	350	-	-	(350)	(112)
93	-	350	-	-	(350)	(102)
94	-	350	-	-	(350)	(92)
95	-	350	-	-	(350)	(84)
96	-	350	1096	2923	1477	322
97	-	350	-	-	(350)	(69)
98	-	350	-	-	(350)	(63)
99	-	350	-	-	(350)	(57)
2000	81	350	-	-	(431)	(64)
01	-	350	19975	377,690	357,365	48,244
02	-	350	-	-	(350)	(43)
03	-	350	-	-	(350)	(39)
04	-	350	-	-	(350)	(36)
05	-	350	-	-	(350)	(32)
06	-	350	-	-	(350)	(29)

(Continued)

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Table M-14
(Continued)

Year	Capital Cost	Recurrent Cost	Harvest Cost	Returns	Net	Present Net Worth
2007	-	350	-	-	(350)	(27)
08	-	350	-	-	(350)	(24)
09	-	350	-	-	(350)	(22)
10	81	350	-	-	(431)	(24)
11	-	350	1369	2784	1065	55
12	-	350	-	-	(350)	(17)
13	-	350	-	-	(350)	(15)
14	-	350	-	-	(350)	(14)
15	-	350	-	-	(350)	(12)
16	-	350	1096	2923	1477	48
17	-	350	-	-	(350)	(10)
18	-	350	-	-	(350)	(9)
19	-	350	-	-	(350)	(9)
20	81	350	-	-	(431)	(9)
21	-	350	19,975	377,690	357,365	7,178
	3,008	14,426	44,880	766,794	704,480	50,984

AGRICULTURAL DIVERSIFICATION PROGRAMS

In conjunction with the development activities of the Agricultural Diversification Division (ADD) of the Ministry of Agriculture and the National Diversification and Settlement Authority (NADSA) which is already involved with rejuvenation and development in the upper catchment, recommendation has been made to plant in various crops an additional 2,000 hectares annually for the next nine years to control erosion.

It was estimated that the project (ADD/NADSA) would return a net Rs. 9,861 annually at full production from production of spice crops and homestead commodities based on 1978 prices. With capital investment costs figured on updated mid-1980 prices of Rs. 13,600/ha and net returns of Rs. 11,850/ha the net present worth from production returns per hectare based on a 41 year cash flow at 10% discount rate is Rs. 92,466.

ECONOMIC BENEFITS FROM EROSION CONTROL

Current soil loss from erosion suffered in the upper catchment is 11,292,000 tonnes per year representing 5,900 hectares over the mapped 239,000 hectares. The greater extent of this loss comes from 92,700 hectares of poorly managed crop land, abandoned tea, chena cultivation, scrubland and degraded forest.

This loss represents 100 tonnes per hectare if averaged over the total 92,700 hectares of highly eroded lands. The minimum acceptable soil loss due to erosion before negative impacts are felt is estimated at 10 tonnes per hectare. Control measures must therefore be aimed at reduction of present loss by 90 tonnes per hectare in order to mitigate negative environmental and productive impacts. It is assumed that the recommended program of 45,000 ha of tree plantations plus the 18,000 ha of agricultural diversified crops planted over a nine year period in addition to the development already undergoing, or planned for implementation (pilot project of 20,000 ha) will effectively meet this goal of soil conservation.

What this means in terms of measurable values and benefits is explained in the following analysis:

Current annual soil loss due to erosion on 92,700 ha : 9,270,000 tonnes

(82% of erosion takes place on 39% of the analyzed land)

= 4838 ha x 10 cm

= .0522 ha x 10 cm loss per ha

Acceptable annual soil loss due to erosion : 927,000 tonnes

= 484 ha x 10 cm

= .0052 ha x 10 cm loss per ha.

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Soil Conservation Goal : 8,343,000 tonnes

= 4,354 ha x 10 cm

= .047 ha x 10 cm loss per ha.

The recommended program thus will be effective in reducing an annual loss of .0522 ha for each hectare in the high erosion area of the upper catchment to an acceptable loss of .0052 ha. The net benefit of the program therefore is a net savings of .047 ha top soil per hectare per year.

In order to place a value on this soil, an assumption is made that this soil represents a factor of production since its loss would represent productivity foregone. A recent analysis made on the protective value of a watershed (ISTI 1979) developed a methodology to quantify the value of soil loss attributed to erosion resulting from the deforestation of the upper catchment and the decrease in watershed protection. An interpreted amount of soil loss was equated to economic loss measured due to changes in agricultural production resulting from land changes using three categories of extent:

1) loss of 1 foot of soil = Rs. 37,500/ha
2) loss of 6" of soil = Rs. 30,000/ha
3) loss of 1" of soil = Rs. 1,875/ha

The value arrived at in each of these categories was derived from the extent of agricultural foregone (e.g. tea cultivation changing to chena) which was a function of soil depth lost per hectare.

While the ISTI report was admittedly based on several assumptions, it nonetheless, made an attempt to assess the economic loss of erosion in realistic terms. The values derived were used in this report.

Since the extent of annual soil loss 5900 ha x 10 cm (4") lies between categories 2 and 3 an average value of Rs. 15, 938 was used as the value for soil loss in this report. Thus, the value of soil loss per hectare per year is Rs. 15, 938 (.047) = Rs. 749. Recommended mitigation measures are expected to be 100% effective such that the net benefit to soil conservation will be a saving of .047 ha per year valued at Rs. 749 following the fully implemented program.

In order to equate this soil conservation savings to the mitigative program, a cash flow was run on 41 years at 10% which gave a present net worth of Rs. 4,907. No costs were attributed to this savings as all costs were previously covered in the mitigative programs.

The total net benefits to the recommended program for watershed management in the upper catchment expressed in present net values per hectare for each project is Rs. 148,013. Table M-15 summarizes the benefits per recommended program.

Table M-15

Net Benefits from Recommended Watershed Management Programs (Rs.)

Without Programs		With Programs		Net Benefits
Soil Loss	Fuelwood	Timber	Ag. Diversification	
(4907)	(324)	50,984	92,446	148,013

SOURCE : TAMS (1980)

ECONOMIC ANALYSIS: FORESTRY

The fuelwood requirements for the expected 200,000 settler families in the project area will amount to 567,000 m^3 yearly. Since most of the available fuelwood sources will have been either cut down as a result of land development or not within an accessible distance to planned settlements, provision must be made in the initial scope of planning to ensure an adequate supply proximal to settlements.

Recommendation (see TOPIC REPORT D: FORESTRY) has been made that fuelwood plantations be developed within a short distance from planned settlements, planted in fast growing trees able to produce 140m^3 on a five year rotation. Ipil-Ipil and eucalyptus have been suggested, but any species would suffice providing it could meet supply requirements and the requisites of good fuelwood. The total initial plantings needed to meet demand by 1990, at which time the project area should be fully implemented, are 20,000 ha. The hectarage needed per settlement would be derived according to the settlement's size and the requirement formula of 2.8m^3 per family per year.

The recommended plan of development is that the government will provide seedlings and initial land clearing for the plantations. This will be an integrated development coordinated with settlement and irrigation planners to assure proper siting proximal to settlements and out of cropping areas. The actual planting, roads, firebreaks, guarding, and maintenance and harvesting are to be borne by the villagers with extension personnel supervising. The costs to the program (Table M-16) are therefore the nursery, vehicles, infrastructure and personnel needed over a five year period to provide seedlings to the plantations. The seedlings are to be given gratis to the villagers, under the auspices that they are responsible for production and harvesting. Returns to the program are figured on the mid-1980 economic price of fuelwood at Rs.49.72 m^3. The present net worth of the program given a 41 year life at 10% discount rate is Rs.136,457 (Table M-17), with an I.R.R. of 41.93%.

Indirect benefits such as home use of building timber obtained through selective harvesting, surplus fuelwood that could be sold or charcoaled and grazing are not included as returns because their likelihood is dependent on proper forestry management and conservative measures of utilization which are intangibles at present.

Failure to ensure adequate fuelwood supplies will result in settlers being dependent on the next accepted energy source given present technology i.e., kerosene. The section on energy requirements has shown the economic pricing of fuelwood based on kerosene equivalents. This pricing was developed to show the opportunity cost of foregoing fuelwood supplies which in effect would be the true cost borne by society for the substitution of kerosene for fuelwood. The opportunity cost, therefore, of not developing fuelwood plantations (given the assumption most fuelwood sources are cut down or not within acess) with an annual energy demand equivalent to 567,000 m^3 of fuelwood is Rs.242,059,272. The net annual returns to fuelwood plantations

under the same demand is Rs.27,680,000. Thus the net annual benefit from fuelwood plantations under full implemenation by the year 1990 is the cost savings in not having to use kerosene as a substitute plus the additional net annual returns from the plantations, totalling Rs.269,739,272.

Table M-16

Fuelwood Nursery and Plantation Costs
for 20,000 ha

Nursery	Rs/ha
Cost of seeds	55
Polyethene Tubes	74
Land Preparation	11
Formation of seed beds	2
Collection of soil, sands and Microcrizzal soil	158
Mixing and filling tube beds	27
	354
Plantations	
Survey and demarcation	158
Aligning and Marking 8' x 8' plots	158
Head load transport	473
Application of fertilizer	80
	869
Buildings	
Nursery Buildings	8
Buildings, Laboratory	8
Temporary Quarters	28
	44
Vehicles	58
Equipment	10
Contingencies	66
Recurrent Costs	
Nursery: weeding, watering, maintenance and seeds	132
SALARIES:	
O & M	10
Buildings	5
Vehicle repairs and running costs	25
Equipment	2

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Table M-17

Economic Returns Fuelwood Nursery and Plantations
(Rs.1000)

Year	Capital Cost	Recurrent Cost	Returns	Net	Present Net worth @ 10%
1981	1996	140	-	(2136)	(1942)
82	5604	836	-	(6440)	(5319)
83	5604	1532	-	(7136)	(5359)
84	5604	2228	-	(7832)	(5349)
85	5604	2924	-	(8528)	(6309)
86	3608	2816	27,840	21,416	12,079
87	-	2152	27,840	25,688	13,178
88	-	1488	27,840	26,352	12,306
89	-	824	27,840	27,016	11,455
90	-	160	27,840	27,680	10,684
91	-	160	27,840	27,680	9,688
92	-	160	27,840	27,680	8,830
93	-	160	27,840	27,680	8,027
94	-	160	27,840	27,680	7,280
95	-	160	27,840	27,680	6,616
96	-	160	27,840	27,680	6,034
97	-	160	27,840	27,680	5,481
98	-	160	27,840	27,680	4,982
99	-	160	27,840	27,680	4,540
2000	-	160	27,840	27,680	4,124
01	-	160	27,840	27,680	3,737
02	-	160	27,840	27,680	3,405
03	-	160	27,840	27,680	3,100
04	-	160	27,840	27,680	2,823
05	-	160	27,840	27,680	2,547
06	-	160	27,840	27,680	2,325
07	-	160	27,840	27,680	2,104
08	-	160	27,840	27,680	1,910
09	-	160	27,840	27,680	1,800
10	-	160	27,840	27,680	1,578
11	-	160	27,840	27,680	1,439
12	-	160	27,840	27,680	1,301
13	-	160	27,840	27,680	1,190
14	-	160	27,840	27,680	1,080
15	-	160	27,840	27,680	996
16	-	160	27,840	27,680	803
17	-	160	27,840	27,680	747
18	-	160	27,840	27,680	692
19	-	160	27,840	27,680	664
20	-	160	27,840	27,680	609
21	-	160	27,840	27,680	581
TOTALS	28,020	20,060	1,002,240	954,160	136,457

ECONOMIC ANALYSIS : WILDLIFE

There are two ways of viewing wildlife habitat when a project is proposed which will alter that habitat. From the project viewpoint, wildlife are a secondary consideration which in terms of say, agricultural development. are generally considered a nuisance which will go away over time. This nuisance may be absorbed as a cost item and, if not considered high enough to indicate project failure, may very well be ignored. If the cost is high enough to warrant failure then an active measure or measures will be developed to mitigate this cost. From the environmental viewpoint, however, an entirely different perspective must be taken. The habitat itself will be exploited to the detriment of the entire ecosystem, and as such an ecovalue is foregone. Whether this ecovalue is equal to, greater than, or less than the proposed project is certainly a matter of analysis and debate. Unfortunately, debate is the greater part of the analysis as quantification of ecovalues is seldom attempted beyond indicator species (mono-benefit analysis).

This analysis will deal with both viewpoints and will give costs and returns whenever possible. Mitigation measures will be considered and various proposals evaluated where applicable to the proposed action itself. It must be emphasized that what is really being analyzed here is land usage, and that there is competition between man and wildlife for the land i.e., they cannot both occupy and utilize the same area at the same time. In order to maximize cropland, the wildlife habitat will have to be reduced and vice versa. The economist's role is to measure the opportunity costs to both to determine highest and best land usage. However, there are social values along with development goals in Sri Lanka which must also be taken into consideration.

WILDLIFE CONFLICTS ON THE PROPOSED ACTION

TOPIC REPORT E : WILDLIFE presents a detailed analysis of the wildlife situation in terms not only of habitat under existing conditions, but also the conflicts which will arise as a result of the proposed action. This section of the report will estimate the cost to the proposed action due to this conflict which is assessed in net crop production returns lost through wildlife encroachment. The methodology used consisted of identification of high quality wildlife habitat areas, that is, areas of high wildlife concentrations with the assumption that new croplands developed in these areas are subject to higher crop loss than in other areas. Crop loss estimates for these high quality habitat areas are on an average of 30% in the first year of production, diminishing each subsequent year down to the normal loss of 10% generally attributed to pests regardless of control measures. It should be mentioned that these loss figures are with control measures; without them, losses could well be up to 100%. The 20% loss over and above the normal 10% is attributed to wildlife namely elephant, wild boar, deer, monkeys and birds. Crop destruction will decrease over time as control measures and habitat reduction diminish wildlife populations. However, one primary pest concern not measured in this analysis due to lack of data is the impact on biological control of pests. Studies (Rajenda 1973) have shown, for instance, that a decrease in wild boar numbers may cause an ensuing

increase in rats, since rats are a natural food source for boar. Whether or not the potential crop destruction due to proliferation of rats is higher than that sustained by wild boar needs to be researched.

Since crop loss due to wildlife is a function of settlement scheduling and duration of established crops, a detailed analysis of numbers of new settlers, placement, crop patterns and scheduling was needed for each system. However, this data was not available with the exceptions of System C in which Hunting had made an update on their feasibility draft (Hunting 1979) giving a rice/rice crop pattern; and the ACRES (1979) feasibility draft which was indicated to represent a semblance of settlement scheduling based on land classification. Determination was made to analyze both Systems B (Scenario A) and C based on available data looking only at rice holdings as particular upland crops were not identified. The agronomics used in the analyses are: cropping area under full development is one hectare, with a buildup to this taking two years; cropping intensity is .96 for each Maha and Yala season; target yields are 4.2 tonnes per hectare per season with production returns figured on the 1990 economic value of paddy at Rs.4,010 per tonne and production costs at Rs.7,391 per hectare. Returns to production are Rs.8,777 per hectare per crop at full production. The crop yields and cropping intensities used in this analysis represent a weighted average of figures used by the various consultants for each irrigation system.

Table M-18 shows settler scheduling per sector in System C and potential yield per harvested area for a six year period. It was assumed this was a long enough period for a) complete implementation and b) the diminution of the wildlife problem. The total crop loss is estimated at Rs.99,750,000 or 15.3% of loss from gross potential returns. However, it should be mentioned that System C has a large high-quality habitat area and that 52% of the planned settlement families will be moved into this area. This suggests that System C will have a higher percentage of crop loss per planted hectare than Systems B and D. System A will most likely suffer a similar rate of crop loss per planted area since approximately 5,600 ha. of the total 14,000 or 40% are planned to be planted in the Somawathie Game Sanctuary. Since no exact date was available on settlement, a projection was made using a 40% settlement schedule over a six year period. The same cropping intensities, buildups and yields were used as in the System C analysis. Total crop losses were estimated to be Rs.128,810,000 or 14.4% of loss from gross potential returns.

Systems B and D were expected to have less wildlife problems than the other systems. Using land class data and tentative sector development descriptions, an analysis (Table M-19) was run of System B which estimated crop loss at Rs.175,970,000, or 13.3% of gross potential returns. Since Systems B and D were figured to have similar crop losses, due to wildlife concentrations, an approximate scheduling to System B was used to calculate losses to System D. These losses were estimated to be Rs.81,970,000.

Table M-20 summarizes total estimated crop loss suffered over a six year crop production build up. Crop losses from all types of pests amounted to Rs. 486,500,000. Crop losses due to wildlife alone amounted to Rs.113,430,000. It must be emphasized that these figures are merely estimates, to show orders of magnitude, based on a number of conventions:

Table M-18

Estimated Cost of Pest and Wildlife Damage in System C
Rice Holdings : 19550 ha New Paddy

Year of Harvest	Zone	Settlers	Area Harvested (Ha)	% of Yield	Potential Production (Tonnes)	Value of Production (Rs.M)	% Pest and Wildlife Loss	Net Value of Production (Rs M)
1	2	1500	2M[2].4Y[3]	60	1.51	4.93	10	4.44
2	2	1500	.6M .96Y	70	4.58	14.96	10	13.46
	2	2200	.2M. 4Y	60	1.51	7.23	10	6.51
	3	700	.2M.4Y	60	1.51	2.30	20	1.84
3	2	1500	.96M.96Y	80	6.45	21.06	10	18.95
	2	2200	.6M.96Y	70	4.58	21.94	10	19.76
	3	700	.6M.96Y	70	4.58	6.98	20	5.58
	3	1650	.2M.4Y	60	1.51	5.42	20	4.34
	4	3350	.2M.4Y	60	1.51	11.01	30	7.71
4	2	1500	.96M.96Y	90	7.26	23.71	10	21.34
	2	2200	.96M.96Y	80	6.45	30.89	10	27.80
	3	700	.96M.96Y	80	6.45	9.83	10	8.85
	3	1650	.6M.96Y	70	4.58	16.45	10	14.81
	4	3350	.6M.96Y	70	4.58	33.40	30	23.38
	4	5100	.2M.4Y	60	1.51	16.77	30	11.74
5	2	1500	.96M.96Y	100	8.06	26.32	10	23.69
	2	2200	.96M.96Y	90	7.26	34.77	10	31.29
	3	700	.96M.96Y	90	7.26	11.06	10	9.95
	3	1650	.96M.96Y	80	6.45	23.17	10	20.85
	4	3350	.96M.96Y	80	6.45	47.04	20	37.63
	4	5100	.6M.96Y	70	4.58	50.85	30	35.60
	5	2500	.2M.4Y	60	1.51	8.22	30	5.75
	6	2300	.2M.4Y	60	1.51	7.56	20	6.05
6	2	1500	.96M.96Y	100	8.06	26.32	10	23.69
	2	2200	.96M.96Y	100	8.06	38.60	10	34.74
	3	700	.96M.96Y	100	8.06	12.28	10	11.05
	3	1650	.96M.96Y	90	7.26	26.08	10	23.47
	4	3350	.96M.96Y	90	7.26	52.95	10	47.66
	4	5100	.96M.96Y	80	6.45	11.10	20	8.88
	5	2500	.6M.96Y	70	4.58	24.93	20	19.94
	6	2300	.6M.96Y	70	4.58	22.93	10	20.64
	1	250	.2M.4Y	60	1.51	.82	10	.74
						651.88		552.13

Loss: Rs. 99.75M or 15.37% of gross potential value.

Source : 1. Consultants from HTS : revision 6-80
2. Maha
3. Yala
4. Cropping intensity of .96 of a hectare

Estimated Cost of Pest and Wildlife Damage in System B
Rice holding : 25,800 ha New Paddy

Year of Harvest	Sector	Settlers	Area Harvested	% of Yield	Potential Production (tonnes)	Potential value of Production (Rs M)	% Pest and Wild-life damage	Net Value of Productior (Rs M)
1	1	3870	.4Y	60	1.01	8.51	10	7.66
2	1	3870	.6M.96Y	70	4.58	38.59	10	34.73
	1	3870	.2M. 4Y	60	1.51	12.72	10	11.45
	2	4820	.4Y	60	1.01	10.60	20	8.48
3	1	3870	.96M.96Y	80	6.45	54.34	10	48.91
	1	3870	.96M.96Y	70	4.58	38.59	10	34.73
	2	4820	.6M.96Y	70	4.58	48.05	20	38.44
	2	4820	.2M.4Y	60	1.51	15.84	20	12.67
	3	4210	.4Y	60	1.01	9.26	20	7.41
4	1	3870	.96M.96Y	90	7.26	61.17	10	55.05
	1	3870	.96M.96Y	80	6.45	54.34	10	48.91
	2	4820	.96M.96Y	80	6.45	67.67	20	54.14
	2	4820	.6M.96Y	70	4.58	48.05	20	38.44
	3	4210	.6M.96Y	70	4.58	41.98	20	33.58
	3	4210	.2M.96Y	60	1.51	13.84	20	11.07
5	1	3870	.96M.96Y	100	8.06	67.91	10	61.12
	1	3870	.96M.96Y	90	7.26	61.17	10	55.05
	2	4820	.96M.96Y	90	7.26	76.18	15	64.75
	2	4820	.96Y.96Y	80	6.45	67.68	15	57.53
	3	4210	.96M.96Y	80	6.45	59.12	15	50.25
	3	4210	.6M.96Y	70	4.58	41.98	15	35.68
6	1	3870	.96M.96Y	100	8.06	67.91	10	61.12
	1	3870	.96M.96Y	100	8.06	67.91	10	55.05
	2	4820	.96M.96Y	100	8.06	84.57	10	76.11
	2	4820	.96M.96Y	90	7.26	76.18	10	68.42
	3	4210	.96M.96Y	90	7.26	66.54	10	59.89
	3	4210	.96M.96Y	80	6.45	59.11	10	53.20
						1,319.81		1,143.84

Loss: Rs. 175,970,000 or 13.3% of gross potential value.

Source : Developed by Consultants from Acres Personal Communication (6.14.80)

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- Updated and revised data on new paddy lands to be brought into production as a result of the proposed action;

- Analysis on new paddy land only. Existing paddy land, even if improved, was considered to have already mitigated the wildlife problem. Upland crop losses were not figured due to lack of specific data;

- Average crop yields and cropping intensities derived from the various consultants were used rather than those used by the consultant groups for the specific system they were working on. This convention was established to give an equitable value base to each system; and

- Reports on crop devastation by pests and wildlife. See TOPIC REPORTS E and J. The amount of crop loss per system was seen to be a function of the rate of settlement scheduling, concentration and placement. Those systems that had a faster schedule showed greater losses in the initial years regardless of actual settlement concentration in high quality habitat areas. Table M-20 illustrates this aspect. System B had a quicker settlement schedule than System C (as evidenced by the fact that at the end of the 6th year, 49% of full production potential was attained while System C had 34% which had a greater high quality habitat area with heavy settlement concentration; yet, the losses per hectare were close in amounts for the two systems.

CONCLUSION

The analysis of crop losses due to wildlife encroachment supports the obvious i.e., settlement schedules placed in areas of wildlife concentration will suffer greater crop damage than those placed elsewhere. Thus, Systems A and C which represent the greatest settlement concentration in identified high quality habitat areas show the greatest costs per hectare over the initial six years period used for the analysis. On a ranking basis, System A suffers a cost of Rs.2,811/ha and is number one followed by System C at Rs.1,767/ha; System B at Rs.1,692/ha and; System D at Rs. 1,448/ha. Total losses for the Accelerated Program due to wildlife alone come to Rs.133,430,000. On an aggregate basis, these are crop losses due to wildlife which represent maximum averages, for instance of 5.3% in System C, of potential paddy yields over the production buildup phase. The net effect would be a reduction in the net agricultural benefits developed by Hunting (Hunting 1979 revised) for say year four of production buildup by 3%(3.395/106.3). This percentage will decrease in succeeding years as the wildlife populations diminish. Thus, it would seem on an intuitive basis that the wildlife problems if projected across the board at a maximum of 5% loss to the net benefits developed for the whole Accelerated Program in the initial stages of development, with a reduction in this loss over time, would most likely withstand the rigors of sensitivity testing against a base case I.R.R. and not prove disruptive to the project.

However, the above assumption was based on aggregate analysis. What in fact needs to be taken into account is the reaction of the farmers who are settled into the high quality habitat area and, who as individuals

Table M-20

Summary of Estimated Crop Losses Due to Pests and Wildlife

System	6 Year Build up % of Potential Production under full development	Crop Loss (Rs.M)	% of Crop loss due to Wildlife	Value of crop loss Due to Wild-life (Rs. M)	Loss per hectare (Rs)
A	60.94	128.81	30.56	39.36	2811
B	48.59	175.97	24.81	43.66	1692
C	35.56	99.75	34.64	34.55	1767
D	57.42	81.97	19.35	15.86	1448
TOTAL		486.50		133.43	

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proximal to the problem, will incur high crop damage. How much damage will they be able to sustain financially and how long before they leave? It is the individual failure rate that could have the greatest impact on the project regardless what the aggregate analysis indicates.

RECOMMENDED MITIGATION TO THE PROPOSED ACTION

All recommended mitigation measures referring to wildlife are fully explained in TOPIC REPORT E : WILDLIFE. Considerations pertaining to the human environment are discussed in TOPIC REPORT L : SOCIAL SCIENCE. This report will address itself only to the costs and benefits associated with these mitigations and related alternatives and not their technological aspects.

As previously mentioned, estimation of potential crop losses to new paddy lands over a critical six year production buildup for all of the systems is Rs.133,430,000. This amount is not figured to be detrimental to the project as a whole, but may prove hazardous to the individual settler's success. The greatest impact, however, will be felt on wildlife. Habitat will be reduced, animal populations will decline and endangered species will be forced more quickly towards extinction. With this in mind, various proposed mitigative actions to these negative impacts caused by the proposed action are calculated in the following sections on a system by system basis. The evaluations presented below concern only those mitigative actions which would cause land use conflicts with proposed developments and/or those for which sufficient economic data could be generated.

System A

The mid-project draft feasibility study for System A was not completed by the time of this report, so the data developed for analysis has come from personal communication with the Joint Venture Randenigala. To date, the plan is for 14,000 ha to be developed in System A. Approximately 5,600 ha of this lies within the northern boundary of the Somawathie Sanctuary and is slated for paddy. This area is considered to be a high quality wildlife habitat, one that is especially important as a wet season grazing area.

The economic ramifications of retaining the 5,600 ha area of the Somawathie Sanctuary as wildlife habit while developing the remainder of System A for agriculture, is evaluated here to the extent possible. It is likely that retention of this area for wildlife conservation would necessitate a significant change of scope in the proposed action to the extent that a new feasibility analysis would be required to develop the entire system. However, since the Joint Venture report is still in formulation, data is not available in which to complete an economic analysis, nor is it within the scope or capability of this study to analyze the engineering aspects of an option to the proposed action which would certainly alter planned infrastructure development. However, (as with the following analysis of System C), certain costs and returns can be identified from data generated in this report.

The land classification summary for the 5,600 ha in the north of the Somawathie slated for development as paddy is:

1 R soils	4,430 ha
2 R soils	1,160 ha
	5,590 ha

Cropping intensities and yields were developed earlier in this report along with net returns from production of Rs. 17,540 based on double cropping. Consequently, the annual costs associated with foregoing development of this 5,600 ha and estimated settlement of 5,600 homesteads are:

Potential crop returns foregone (paddy) 5,590 ha x Rs.17,540 =	Rs.98,048,600
Potential homestead income foregone (Rs.1580x5590 homesteads)	Rs. 8,832,200
	Rs.106,880,800

Returns attributable to not developing the 5,600 ha section would include some infrastucture cost savings and the not-quantifiable benefit due to the social value of wildlife and its habitat. A return due to crop loss from wildlife foregone is estimated at about Rs.27,552,000. However, due to the high annual potential crop returns, the maintenance of the 5,600 ha area as a wildlife habitat would not be justifiable on a strictly economic basis.

This, however, does not represent the non-quantifiable social value to wildlife which nontheless represents a return, nor does it include the potential financial returns from elephants. This elephant value can be determined on a surplus of 1% from a breeding herd on 450 (entire project area)which could be considered as an annual offtake under a managed herd concept. As a point in fact, the elephants remaining after development could be managed as they will no longer have free and expanded home ranges. This 1% offtake or five animals would have an economic value as domesticated work animals of an annual net return of Rs.18,000 (Rs.1500 a month x 6 months) per year over a 30 year work life or Rs.540,000. Present market value for a prime elephant is Rs.100,000 which represents a capitalization rate of 18% on expected returns.

The value of potential work animals was not included in the economic analysis because neither the number of elephants in the project area nor the reality of an animal offtake for domestic use has been determined. The above figures were developed merely to illustrate a potential value associated with a wildlife resource and to suggest further studies be made along these lines.

System B

The feasibility of maintaining and extending the Nelugala corridor is evaluated here from an economic standpoint. The engineering costs associated with this corridor along with the opportunity cost of crops foregone are presently being developed by ACRES and will appear in their final report. Riverine forests are to left along the Maduru Oya and along

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the Mahaweli Ganga up to the Somawathie which will also act as wildlife habitats. Returns from these actions can be measured in crop loss foregone by creating corridors and buffer zones between crops and wildlife, commercial timber from the agroforest buffer, grazing, supply of elephant for the domestic labor force and the social value of wildlife.

The proposed corridor would be 35 km in length and five in width. It would be composed of a central part three km wide which would be the actual corridor. This corridor would be enhanced through clearing and seeding and water points. A buffer zone of one-half km of agroforest and one-half km of grazing land on either side of the corridor would be established to keep wildlife out of crops and humans out of the corridor. Jeep tracks would be run on both sides of the corridor outside of the grazing buffer zone to be patrolled by game scouts.

The costs of developing and maintaining the Nelugala Corridor (including the extension) are as follows:

Dimensions:	Approximately 5 km x 35 km	
Corridor:	3 km x 35 km	Rs.
Capital Cost:	- thinning and burning @ Rs.2,000/ha for 10% of area	2,100,000
	- Seeding desired grasses @ Rs.100/ha	1,050,000
	- Water points consisting of a small seasonal tank every 10 km @ Rs.12,000 ea.	24,000
	- Chief Game Warden's House	30,000
	- Staff housing every 12 km each side	108,000
	- Roads/firebreak outside of corridor @ Rs.16,000 - per km	1,120,000
	- 1 Four-wheel drive jeep	120,000
	- Bicycles @ Rs.800 for each game scout	4,800
		4,557,000
Recurrent Cost:	Salaries: Game Warden	9,000
	Game Scouts x 6 @ Rs.7,200	43,200
	Maintenance of Corridor @ 5% of capital cost	228,000
	Maintenance, repairs and running of vehicles	42,000
	Road maintenance	60,000
	Maintenance and repair of housing	14,000
		396,000

Buffer Zone

Agro Forest

Capital Cost:	Clearing, cultivating, planting @ Rs.3,170/ha x 3,500 ha	11,095,000

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	Rs.
Grazing	
Capital Cost: Clearing and seeding @ Rs.100/ha x 3,500 ha	350,000
TOTAL CORRIDOR PLUS BUFFER ZONE COSTS	
CAPITAL COST	16,002,000
RECURRENT COST	396,000

A conservative estimate of 35% reduction in crop losses due to wildlife can be expected as a result of integrated planned development with a properly developed and expanded Nelugala Corridor. This represents Rs.15,281,000 of crop loss foregone (see Table M-19). In order to realize this an initial capital investment of Rs.16,000,000 is required. In addition, gross returns from grazing of Rs.969,938 to be realized in two years and commercial timber of Rs.1,073,600 in 20 years can be expected as described below:

Gross returns from grazing are figured as:

Area	3500 ha
Accessibility of forage	70%
Carrying Capacity	0.75 A.U./ha
Numbers of Animals	1838
Gains	30 kg
Value: 1838 x 30 kg x Rs.5 kg	Rs.275,200
Milk	
Value: 1838 x .5+6 x 280 liters x 2.04 =	Rs.572.603
Total	Rs.848,303

Gross returns for Agro-forest:

Yields 20 m^3/ha based on a 40 year rotation (3500/40) 88 ha per year harvested. Current financial price (STC 6-80) is Rs.610 per M^3 for class III commercial logs.
20 M^3 x 88 ha x Rs.610/ha = Rs.1,073,600 gross annual returns expected after 20 years.

No recurrent costs are associated with this agro-forest as it is not planted for commercial purposes. Returns which could be obtained are considered windfall gains. Returns would be higher under a managed basis.

A cost/benefit analysis was not run on the Nelugala Corridor since sufficient data was not available as to the assessment of the corridor on the Maduru Oya Project. This assessment is being developed by ACRES following the format presented in Appendix M-I of this report.

System C

The northern sector, or Zone 4, of System C is considered a high quality wildlife habitat area. Settlement and crop development in this zone are expected to cause severe disruption of present wildlife habitat on the one hand and suffer heavy encroachment by wildlife into proposed crops on the other. Mitigative actions recommended to reduce negative impacts are:

- Enhancement of the Wasgomuwa Natural Reserve and proposed Maduru Oya National Park prior to development of System C; and then to drive wildlife into these areas by slow and orderly development. Animals which are pocketed will either be physically moved to alternative accommodation or eventually culled; and

- Development of a wildlife corridor as suggested by the Department of Wildlife Conservation between Wasgomuwa and Maduru Oya National Park in Zone 3 along the Kuda Oya.

Returns from the proposed Kuda Oya Corridor and slowed development are figured as:

	Rs.
Initial (Net)	
Crop losses foregone: 40% of estimated crop loss from Zones 4 and 5 and 80% from Zone 3.	33,870,000
Annual (Gross)	
Commercial harvest (financial value): $20\ m^3 \times 25\ ha \times Rs.610/m^3$	305,000
Grazing: neat cattle (see following economic analysis)	290,981
Eco values: Preservation of wildlife	X

The proposed Kuda Oya Corridor lies 2.5 km on either side of the Kuda Oya in Zone 3 of System C. It runs from the Mahaweli Ganga up to and around the Hengala Kandiya Tank. It is approximately 12 km in length by 5 km in width. Physically, this corridor will correspond to the Nelugala Corridor in System B i.e., three km of central corridor bordered on either side by one-half km of agro-forest and one-half km of grazing land. Jeep tracks are to run on both sides of the corridor outside of the grazing buffer to be patrolled by games scouts.

The costs of developing this corridor are as follows:

Captial Costs:	Rs.
- Game Warden's House	30,000
- Staff housing @ 12,000 ea.	48,000
- Roads/fire break outside of corridor @ Rs.16,000 per km	384,000
- Jeep	120,000
- Bicycles @ Rs.800 ea.	1,600
Sub-Total	583,600

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	Rs.
- Agro-forest buffer: clearing, cultivating, planting @ Rs.3,170/ha x 1,000 ha	3,170,000
- Grazing buffer: clearing and seeding @ Rs.100/ha x 1,200 ha	120,000
Sub-Total	3,290,000
Recurrent Costs	
- Salaries	
Game Warden	9,000
Game Scouts x 4 @ Rs.7,200	14,400
Maintenance, repair and running of vehicle	30,000
Road Maintenance	38,400
Maintenance and repair of buildings	5,400
TOTAL	97,200
TOTAL CORRIDOR PLUS BUFFER ZONE COSTS:	
CAPITAL	3,873,600
RECURRENT	97,200

Opportunity cost of agricultural production foregone:

Approximately 300 ha of paddy production will be foregone along with returns from 1200 acres of homesteads.

3000 ha x Rs.17,540 Net economic production returns from paddy	Rs. 52,200,000
1200 ha x Rs.1,580 Net homestead return (HTS: 1980 revised)	Rs. 1,896,000

Returns from the Kuda Oya Corridor are based on crop loss foregone (40% of the crop loss from Zones 4 and 5 will be prevented and 90% from Zone 3. The high percentage from Zone 3 is explained as a great deal of Zone 3 will be enclosed by the corridor). Not figured into the returns to the project are cost savings in branch canals not having to serve within the corridor. This could prove a considerable amount. Sufficient data, time and personnel are not available to develop these cost savings.

Returns from commercial timber are based on harvest yield potentials of 20 m^3 per hectare on a 40 year rotation. Since 1000 ha are to be planted in eucalyptus, this means that 25 ha can be commercially harvested annually 20 years after initial planting. The agro-forest buffer is not given a recurrent cost as it is not established as a managed forest. However, proper management will give better returns with an anticipated low annual cost.

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Grazing returns are based on the following assumptions:

Area	1200 ha
Accessibility of forage	70%
Carrying capacity	0.75 A.U.
Numbers of animals	630
Gains	30 Kg
Value: 630 A.U. x 30 Kg x Rs.5/Kg =	Rs.94,500
Milk	
Value: 630 A.U. x .546 x 280 liters x Rs.2.04 =	Rs.196,481

There is no apparent economic justification in quantifiable values for developing the Kuda Oya Corridor. Total returns amount to the value of crop loss foregone of Rs.33,870,000 for the six year buildup period developed in Table M-19; Rs.305,000 gross annually after 20 years from potential commercial timber harvest of the agro-forest buffer and; Rs.290,981 gross annually from grazing of the outermost buffer zone. The returns due to wildlife preservation are (as in the case with System B) non-quantifiable. Costs on the other hand are (on the basis of crop production foregone) Rs.52,200,000 and foregone returns from homestead of Rs.1,986,000; totalling Rs.54,096,000.

A cost/benefit analysis will not be presentated in this report. An initial trial run was made using gross returns from grazing and timber together with net returns from crop loss foregone for a 30 year period at 10%. This run showed a negative present net benefit of Rs.27,000,000. No attempt was made to refine the analysis as the indication was clear that no net economic benefit could be derived from quantifiable data.

Since the northern sector of Zone 4 of System C is a high quality wildlife habitat an analysis was made of the possibility of excluding this area from proposed agricultural development.

Zone 4 has a total of 15,300 ha of which 5,560 ha are in class 1R soils, 7,640 in 2R and 2,100 ha in class 6 (see TOPIC REPORT B : LAND USE AND SOILS for definitions of land classification).

The decision not to develop must be analyzed in terms of the opportunity cost of potential crops and homestead production foregone versus the returns associated with the social value of protected habitat, potential crop loss foregone from wildlife encroachment and the irrigation and drainage infrastructure cost savings in not having to serve Zone 4.

As in the analysis of the project option for System A it is beyond the capability and scope of this report to carry out a feasibility study for this option. However certain costs and returns can be identified from data and analyses already collected and developed in this topic report.

Total returns over a six year period are estimated as follows:

- Crop loss from wildlife foregone:	100% of Zone 4	Rs.30,710,000
	40% of Zone 5	1,660,000
	40% of Zone 3	590,000
		Rs.32,960,000
- Infrastructure cost savings (as a point in fact this may turn out to be an actual cost rather than savings dependent upon the cost allocation of the main branch canal serving Zones 4, 5 and 6)		x
- Social value of wildlife and habitat		x

Crop production figures and returns were developed earlier in this report. The average yield of 4.2 tonnes per hectare per cropping season is considered to be well within the yield capabilities for System C which has a ratio of .72 1R to 2R class soils. There are approximately 8,450 ha of 1R and 2R soils within command in Zone 4 with a planned settlement of 8,450 farm families. Thus, the costs of not developing this area are:

Potential crop returns foregone (paddy) (8,455 ha x Rs.17,540)	Rs.148,213,000
Potential homestead income foregone (8,450 ha x Rs.1580)	Rs.13,351,000
TOTAL -	Rs.161,564,000

A sensitivity analysis conducted by Hunting indicated that with a one-third decrease of agricultural land, the IRR for the entire development of System C would drop from 10% to 7%. A comparable decrease would then be expected if the development of Zone 4 was foregone. It is likely that this would preclude the development of System C on an economic ground. In addition, the development of System B would also be affected, since the two systems share some of the infrastructure costs necessary for implementation.

System D

System D is considered to be one of the most highly productive for paddy and sugar cane. There are no defined high quality wildlife habitats within System D with the result that wildlife and crops are not in major conflict. In addition, System D is the most densely settled of the irrigation systems and has dispelled most of the wildlife population through development. Established areas such as the Kantalai Sugar Estate which had crop losses from elephant and wild boar of over 20% annually(Rajenda 1973) in the early years of production have had a significant reduction in loss both because of wildlife population decline and through active control measures.

The major problem foreseen within System D due to wildlife is the loss to rice production from birds. When sugar cane and paddy are within proximity it is found that munia and the rose-ringed parakeet proliferate, using the cane as a nesting area and feeding on the rice. Alleviation of this problem lies primarily in management of cropping patterns as cost effective measures rather than large applications of pesticides.

ECONOMIC ANALYSIS: FISHERIES

GENERAL

The impacts to the existing fish stock and potential yields as a result of the Accelerated Program are detailed in TOPIC REPORT G: FISHERIES. The proposed projects including new reservoirs, and the diversion and irrigation schemes will initially impact existing water bodies dependent on river flow and flood stages in a negative manner. The greatest impact will occur to villus which will lose up to 50% of mean annual surface area. Major irrigation tanks will also suffer a reduction in mean surface area. On the positive side over 14,470 hectares of new reservoirs will be constructed.

The impacts to fish production due to these changes in the water resource are summarized in Table M-21. The initial impacts on capture fishing potential yields are a loss of 433 tonnes from the river, villus and major tanks. However, the loss is more than offset by the potential yields of 2,570 tonnes from the new reservoirs.

In order to offset any negative impacts to fishery production due to the proposed action and to maximize the aquatic resource potential, proposed development projects have been recommended by the various consultants. These range from stocking programs of the reservoirs and tanks to an aquaculture program for seasonal tank rejuvenation and stocking. With the implementation of these actions the potential yields from the estimated 37,000 ha of water bodies within the project area would be on the order of 9,400 tonnes (See Table M-22). This amount of fish represents 1,505 tonnes of protein which could supply 28% of the animal protein requirement for the one million people in the project area by the year 1990. In addition, this fishery would employ approximately 2,215 fishermen.

FISHERY BENEFITS

Table M-21, shows impacts to the existing potential fishery production as a result of the Accelerated Program to be a positive increase of 2,137 tonnes. This increase is due totally to potential production from the new reservoirs. Production decreased from all other existing water resources with the exception of medium tanks which were not affected. However, it is a general consensus among fishery experts that most negative production impacts can be mitigated through development projects. These projects are explained in TOPIC REPORT G: FISHERIES which emphasizes stocking of seasonal and medium tanks and the necessity of fishing effort to optimally utilize production potential from all water resources.

Additional development aspects of clearing and initial stocking is recommended for new reservoirs. It should be mentioned that there has been no cost effective method envisioned for the mitigation of fishery loss from villus. Weirs have been suggested and should be looked into on a feasibility basis.

The additional benefits accruing to the fisheries potential in the Accelerated Program depend entirely on the amount of development undertaken for improvement, upgrading and stocking of the aquatic resource; and the

Table M-21

Potential Fishery Yield Impacts (tonnes)

Water Source	Existing Condition	Proposed Action	Change	Total Area After project (ha)
Proposed Reservoirs	0	2570	2570	16,470
Major Tanks	1000	(98)	902	5,430
Medium Tanks	160	0	160	4,250
Villus	640	(320)	320	6,400
River/Irrigation	50	(15)	35	500
Seasonal Tank	0	0	0	4,000
Total	1850	2137	3987	37,050

Table M-22

Potential Yield Benefits from Proposed Fishery Projects (tonnes)

	With Accelerated Project Implementation	Proposed Fishery Projects	Gross Benefits
Reservoirs	2570	2570	0
Major Tanks	840	1340	520
Medium Tanks	160	1060	900
Villus	320	320	0
Rivers/Irrigation	35	100	65
Seasonal Tanks	0	4000	4000
Total	3925	9390	5485

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maximum sustainable utilization of the fish harvest. Benefits in terms of additional potential production are shown in Table M-22. Again it must be emphasized that these yields are obtained through a comprehensive development program.

In order to translate this gross production benefit into a net benefit, costs and returns for various fishing enterprises were developed. The cost of the stocking is detailed in the following section under the seasonal tank program. The capital costs associated with the proposed hatchery and stocking program have been economically justified through net returns from the seasonal tank harvest. It is envisioned that this be the only annual stocking aspect of the proposed projects; the other systems (major and medium tanks and reservoirs) will be initially stocked either through collection of tilapia and carp from other water sources or hatcheries or supplied through a surplus production from the seasonal tank hatchery. Thus, no cost associated with stocking is attributed to these water resources. The government is planning a tree clearing program for reservoirs estimated to cost Rs. 200 per hectare (Hunting: 1979). This cost will be absorbed by the government and is not included as a cost in figuring net returns to reservoir, major and medium tank fishing enterprises.

NET RETURN: RESERVOIR AND TANK FISHERIES (INITIAL STOCKING ONLY)

The following analysis is based on several assumptions derived to estimate economic costs and returns per hectare for various water bodies. The cost of boats and gear are assumed to be constant and were obtained from the Ministry of Fisheries. Catch effort however will vary according to potential yields in order to assume equitable returns to each fisherman.

Reservoirs	30 hectares per boat			
	Year			
	1	2	3	4 onwards
Yield kg/ha	75	100	150	150
Gross return @ Rs. 4/kg	300	400	600	600
Capital Cost[1)]	51	51	51	
Recurrent Cost[2)]	-	15	15	15
Labor [3)]	167	167	167	167
Net Return of Fishermen	82	131	367	418

Large and Medium Tanks	20 hectares per boat			
	Year			
	1	2	3	4 onwards
Yield kg/ha	75	150	250	250
Gross Returns @ Rs. 4/kg	300	600	1000	1000
Capital Cost	76	76	76	
Recurrent Cost		23	23	23

Large and Medium Tanks	20 hectares per boat Year			
	1	2	3	4 onwards
Labor[4] 200 days x 2 x Rs. 10/day	200	200	200	200
Net Return of Fishermen	24	301	701	777

1) Capital cost pay back on 3 year basis

2) Recurrent cost 10% of boat and 20% of gear

3) Economic labor wage of Rs. 10/day x 250 days x 2 family members

4) Economic labor wage of Rs. 10/day x 200 days x 2 family members

NET RETURNS FROM THE RECOMMENDED SEASONAL TANK PROGRAM (AQUACULTURE)

General

In order to maximize the water resource potential in the project area, a hatchery/seasonal tank renovation program has been recommended. The background and estimates of the program are stated in TOPIC REPORT G: FISHERIES. The benefits of the program are related to the concept of stocking fingerlings in a concentrated area at high water level and harvesting at the minimum draw down level during the dry season. This program differs from the other stocking programs in reservoirs and other tanks in that those represent capture fisheries with relatively low yields of 150 to 250 kg/ha, while this concept is really a form of aquaculture with high yields of 1000 kg/ha. Correspondingly, input costs are higher.

Hatchery

The hatchery is planned to produce up to 20,000,000 fingerlings of carp annually and is related to approximately 4000 hectares of seasonal irrigation tanks. The maximum size tank will probably not exceed 30 hectares and the minimum fall below 4 hectares. The capital costs are estimated at Rs. 10,214,000 (excluding contingency) or Rs. 2555/per ha; the recurrent costs will amount to Rs. 1,096,000 per year, or Rs. 274/ha. Details of these costs are presented in Table M-23.

Seasonal Tanks

The government initiated a program for small tank renovation throughout the dry zone. These tanks are used primarily for minor irrigation schemes, but have a high potential for seasonal fish stocking programs.

The seasonal tank renovation will include 4,000 hectares at a total capital cost of Rs. 16,400/ or Rs. 4,100/ha. In addition, a 35% subsidy on boats and gear for fishermen is included. Therefore, the total capital cost for tank renovation, boats and gear is Rs. 20,385,670 or Rs. 5,096/ha. Recurrent costs which include maintenance, repairs and labor are Rs. 1,640,000 or Rs. 410/ha. Capital costs and recurrent costs are shown in Table M-23.

The economic cost figures differ from financial costs wherever unskilled labor and fuel are concerned; all other costs are considered to represent both financial and economic costs.

Fishing Operation

Assumptions:

- Each fisherman will own a canoe costing Rs. 1,000, plus gear (gill nets) totalling Rs. 3,000, plus a hand net shared between a pair of fishermen at Rs. 600 each;
- Capital costs are subsidized 35% by government and balance is paid back in three years at 15%;
- Recurrent costs include repair, maintenance and replacement of nets at 25% and canoe at 20%; and
- Yields are 1,000 kg/ha at Rs. 4/kg landed, wholesale price.

In order to assume an equitable financial viability to other rural industries each fisherman will need to fish three hectares of a tank. The financial cash flow represented in Table M-24 shows a net financial return to investment of Rs. 5,034 realized in the first year of harvest with harvest at 75% of potential. Maximum net returns of Rs. 8,100 occur in the 4th year of harvest. The yields expressed here are conservative and could be 50 to 100% higher depending on the tank environment and control of predators.

ECONOMIC ANALYSIS

Table M-25 indicates the assumed economic returns per hectare. The yields are based on a buildup of fishermen as the seasonal tanks are renovated and stocked. The yields expressed in the table represent the harvest buildup per year spread over the entire 4,000 hectares of the program in order to show a return per hectare to cost per hectare.

Table M-26 shows the economic cash flow to the program based on total costs and gross revenues.

Table M-27 is the final economic analysis for the seasonal tank program. Total investment expenditure over a six year implementation period (Hatchery-two years, Tanks-five years, Fisheries-four years) comes to Rs. 32,746,000. Of this amount Rs. 6,131,800 is borne by the fishermen for boats and gear. The program achieves a positive cash flow (net benefit) in the 4th year which is the second year of harvest. The present net worth for the 25 year program is Rs. 67,885,000, with an internal rate of return of 25%.

In addition, 1,333 fishermen are employed, not including those in the hatchery and stocking project; and 4,000 tons of fish are produced for the project area settlers.

NET BENEFITS FROM FISHERIES

Without the proposed project, the potential fishery yields within the project area are estimated to have a net benefit of Rs. 2.3 million annually. This is computed by using the morphoedáphic index (MEI) (see TOPIC REPORT G: FISHERIES) which estimates potential yields for the existing water resources assuming total harvest and subtracting out the cost of harvest to arrive at a net figure. The potential yield per hectare for existing water resources averages 50 kg; a wholesale value of Rs. 4/kg gives a gross figure of Rs. 200 per hectare. Cost of harvest is figured at roughly Rs. 100 per hectare, leaving a net return of Rs. 100 per hectare. This net return multiplied by the 23,000 hectares of water resources gives the total existing fishing benefit. It must be explained that the estimates for fishing returns used in this analysis are based on potential harvest. Whether or not these potentials are obtained is not assumed to have bearing on the economic potential benefit.

The net benefits resulting from the proposed action and fishing development projects (initial stocking of reservoirs and tanks, seasonal tank program) are shown in Table M-28. The net benefits accruing to the entire system after 1988 are Rs. 22.8 million Rupees. This does not take into account the nutritional value of increased protein intake, nor the created employment effect.

There is strong economic justification for a concerted fisheries development program. The potential yields estimated in this analysis are conservative and with increased technological and extension input, a 25% increase in projected yields could be fully expected with very low cost increments.

Table M-23

Capital And Recurrent Costs of Hatchery, Seasonal Tanks and Gear

HATCHERY

CAPITAL COSTS		RS
1.	Water Supply & Filter System	1,000,000
2.	1 Km Access Road	500,000
3.	Land Fill & Levelling	100,000
4.	Hatchery Building w/equip (15x10m)	210,000
5.	Staff Qtrs	500,000
6.	Lab, Garage, Office	100,000
7.	Cement Breeding Tanks (5x2.5x2x1m)	54,000
8.	Lab Apparatus Installation	375,000
9.	Fencing & Poles Rs.50/m	220,000
10.	Ponds & Runways 16ha x 2.4ha	3,000,000
11.	Culverts. Screens, Drainage	1,062,000
12.	Walkways	75,000
13.	Generator & Engine	160,000
14.	Workshop Tools	50,000
15.	Refrigerator	18,000
16.	Spare Parts	270,000
17.	Vehicles 11, 4WHL DR @ $7500 & 4, 2WHL DR P.U. @ $6.000	2,520,000
		10,214,000
	(20% contingency)	2,042,800
	TOTAL	12,256,800

(continued)

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Table M-23
(Continued)

SEASONAL TANK 4000 hectares

CAPITAL COST

1.	Gear & Nets @ Rs.1533/ha with 35% subsidy	2,146,150
2.	Upgrade Tanks @ Rs.4100/ha including screens	16,400,000
	TOTAL	18,546,130

RECURRENT COSTS

HATCHERY - (000 Rs)

		Financial
LABOR :		
Hatchery Manager		9,500
2 Aquaculturalists	@ 7500	15,000
2 Asst Aquaculturalists	@ 6000	12,000
4 Field Laboratory Assts	@ 5000	20,000
5 Drivers	@ 4500	22,500
2 Watchmen	@ 45000	9,000
2 Secretaries/Clerk	@ 4500	9,000
4 Maintenance Workers	@ 4500	18,000
SUPPLEMENTAL FEED @ Rs. 1000/T(1)		
16 ha Runways		16,000
2.4 ha Brood Stock Pon		14,400
FERTILIZER (500 kg/ha)(1)		
16 ha Runways		8,500
2.4 ha Brood Stock Pond		1,700

(continued)

Table M-23
(Continued)

	Financial	Economic
OPERATION AND MAINTENANCE		
Vehicles(2)	150,000	195,000
Depreciation	100,000	
Runways and Ponds	300,000	300,000
Buildings	81,000	81,000
Equipment	123,000	123,000
Roads & Walkways & Fence	80,000	80,000
Culverts, Screens, Drainage	106,000	106,000
TOTAL	1,096,000	885,000
SEASONAL TANK		
Maintenance @ 10% of Capital Cost		1640,000

(1.) Fertilizer & Feed not subsidized to Govt. Project

(2.) Rs.1.15/km @ 10,000 km per vehicle, Repairs at Rs.18,000 per vehicle, lubricants 5% of fuel cost. Economic cost Rs.2/km @ 10,000 km per vehicle, repairs @ Rs.18,000/per vehicle, lubricants 5% of fuel cost.

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Table M-24

Financial Cash Flow (Fishing Operation)

	Years					
	1	2	3	4	5	6
1. REVENUES						
Gross sale of carp(1)	9,000	12,000	12,000	12,000		
2. COSTS						
Investment costs (2)	997	997	997			
Interest	449	299	149			
Operating cost (3) labor	2,520	2,520	2,520	2,520		
Maintenance and depreciation of fishing craft		380	380	380		
Gill nets annual replacement & maintenance		900	900	900		
Handnet depreciation & maintenance		100	100	100		
TOTAL COSTS	3,966	5,196	5,046	3,900		
3. NET CASH FLOW	5,034	6,804	6,954	8,100		

(1) Yield 1000 kg/ha @ Rs.4/kg.

(2) Boats and equipment subsidized @ 35% with a 3 year pay back at 15%.

(3) Labor costs are for fisherman and his family assuming 1.5 full time fisherman per family at Rs.14 per day and 120 working days per year. Financial labor value is same as current rural unskilled labor at Rs.14 per day.

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Table M-25

Assumed Economic Returns from

Seasonal Tank Program (Rs per ha)

	Yr.1	Yr. 2	Yr. 3	Yr. 4	Yr. 5	Yr. 6.	Yr.7 onwards
Yield (kg/ha)(1)	-		300	550	750	950	1000
Gross return @ Rs.4/Kg	-		1199	2200	3001	3800	4000
Capital cost	-		398	199	199	199	-
Production costs	-		-	184	276	368	460
Labor costs	-		240	360	480	600	600
Net return to fisherman	-		561	1457	2046	2633	2940
Cost of Hatchery, Stocking & Tanks	1848	2019	1420	1395	1476	739	631
Net Economic Return	(1848)	(2019)	(859)	62	570	1894	2309

(1) Represents build up of fisherman per year divided by 4000 ha.

Table M-25

Economic Cash Flow (Rs1000)

CAPITAL INPUTS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23-25
HATCHERY	4110	4088					504					504					504					504	
TANKS	3280	3280	3280	3280	3280																		
BOATS & GEAR			2452	1228	1228	1224																	
TOTAL	7390	7368	5732	4508	4508	1224	504					504					504					504	
OPERATION & MAINTENANCE COSTS																							
HATCHERY		443	885	885	885	885	885	885	885	885	885	885	885	885	885	885	885	885	885	885	885	885	885
TANKS		328	656	984	1312	1640	1640	1640	1640	1640	1640	1640	1640	1640	1640	1640	1640	1640	1640	1640	1640	1640	1640
PRODUCTION COSTS																							
MAINTENANCE & REPLACEMENT				736	1103	1471	1839	1839	1839	1839	1839	1839	1839	1839	1839	1839	1839	1839	1839	1839	1839	1839	1839
LABOR @ Rs10/DAY			960	1440	1920	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
TOTAL		771	2501	4045	5220	6396	6764	6764	6764	6764	6764	6764	6764	6764	6764	6764	6764	6764	6764	6764	6764	6764	6764
TOTAL COSTS	7390	8079	8233	8553	9728	7620	7268	6764	6764	6764	6764	7268	6764	6764	6764	6764	7268	6764	6764	6764	6764	7268	6764
GROSS RETURNS	-	-	4797	8799	12003	15198	15996	15996	15996	15996	15996	15996	15996	15996	15996	15996	15996	15996	15996	15996	15996	15996	15996
NET CASH FLOW	(7390)	(8079)	(3436)	246	2275	7578	8728	9232	9232	9232	9232	8728	9232	9232	9232	9232	8728	9232	9232	9232	9232	8728	9232

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Table M-27
Seasonal Tank Program
Economic Analysis
(Rs. 1000)

Program Year	Investment Cost	O & M Cost	Production Cost	Total Cost	Gross Value (Gross Benefits)	Net Economic Benefits
1	7390	-	-	7390	-	(7390)
2	7368	771	-	8079	-	(8079)
3	5732	1541	960	8233	4797	(3436)
4	4508	1869	2176	8533	8799	246
5	4508	2197	3023	9728	12003	2275
6	1224	2525	3871	7620	15198	7578
7	504	2525	4239	7268	15996	8728
8	-	2525	4239	6764	15996	9239
9	-	2525	4239	6764	15996	9232
10	-	2525	4239	6764	15996	9232
11	-	2525	4239	6764	15996	9232
12	504	2525	4239	7268	15996	8728
13	-	2525	4239	7268	15996	9232
14	-	2525	4239	7268	15996	9232
15	-	2525	4239	7268	15996	9232
16	-	2525	4239	7268	15996	9232
17	504	2525	4239	7268	15996	8728
18	-	2525	4239	7268	15996	9232
19	-	2525	4239	7268	15996	9232
20	-	2525	4239	7268	15996	9232
21	-	2525	4239	7268	15996	9232
22	504	2525	4239	7268	15996	8728
23-25	-	2525	4239	7268	15996	27696
TOTAL	32,746					164,586

NET PRESENT WORTH @ 10% = Rs 64,885,000
I. R. R.= 25%

Table M-28

Accelerated Mahaweli Program with Proposed Action Net Potential Fisheries Benefits (Rs.Million)

Year	Net Benefits with Project and Proposed actions					Net Benefits without project(2)	Net Benefits due to project
	Seasonal Tank	Villus	Res-ervoirs(1)	Other tanks			
1981	(7.390)	.83			(6.560)	2.3	(8.860)
1982	(8.079)	.83		.232	(7.017)	2.3	(9.317)
1983	(3.436)	.83		2.914	.308	2.3	(1.992)
1984	.246	.83		6.786	7.862	2.3	5.562
1985	2.275	.83	1.351	7.521	11 977	2.3	9.677
1986	7.578	.83	2.158	7.521	18.087	2.3	15.787
1987	8.728	.83	6.044	7.521	23.123	2.3	20.823
1988	9.836	.83	6.884	7.521	25.071	2.3	22.771

(1) Assuming Reservoirs are not operational until 1985.

(2) Assume Rs.100 Net return per hectare on 22,980 ha.

ECONOMIC ANALYSIS: WETLANDS (VILLUS)

EXISTING CONDITIONS

Villus can be considered to be one of the most higly productive zones of the biosphere as concluded by Whitaker and Likens (1977) in their survey of primary productivity of world ecosystems. They found that such wetlands can have up to a mean net primary production of 3,000 kg of organic matter (dry weight) per m^2 per year. This high net primary production sustains numerous organisms, including human beings, by complex food web relationships.

Due to this high productivity it would logically follow that villus have a high net resource or eco-value. Not only does the villu provide a primary food source for terrestrial and aquatic organisms, but it also provides for wildlife habitat and migration routes.

In order to measure the worth of a villu, a rigorous undertaking is needed to assign various eco-values to total input/output relationships and a determination must be made as to an end product. For this report, a methodology will be developed to delineate the value of a villu in terms of what can be quantified and what cannot.

Quantifiable values used will be represented by:

- Carrying capacities (a function of vegetation) and measured in milk and meat production for domesticated stock; and

- Fish production.

Qualifiable values will be represented by:

- Potential biogas and fertilizer production from aquatic vegetation; and

- Eco-values (X) which, while not quantified at this time are nonetheless realized to have worth and are included in the equation as an unknown. These include: wildlife (mammals, amphibians, reptiles, birds, insects), watershed and habitats.

Therefore, the equation used for villu value is:

Value = Grazing + Fish + Aquatic vegetation + X

where:

grazing = value of grain + milk; and

X = non quantified eco-values.

VALUE OF GRAZING

The value of grazing is derived from the values of meat production, measured as gain, and the value of milk production. Carrying capacity of villus is figured in TOPIC REPORT H : WETLANDS and is used here to analyze

the productive value of villus. The figures developed from estimated villu vegetation are:

Carrying capacity	:	1 animal unit per hectare (1 A.U./ha)
Forage Accessibility	:	80%
Gain	:	51 kg
Species Composition	:	60% Buffalo
		40% Neat Cattle

Value of Gain

The value of grazing is figured on estimated net weight gain of an animal unit per grazing period plus the amount of milk produced times the current respective economic value.

Using a young bull as a model for conversion of villu grazing, the gains could be estimated as follows (Joint Venture Randenigala 1980):

1st & 2nd months average daily gain	500 grams
3rd & 4th months average daily gain	400 grams
5th & 6th months maintenance level	0
7th & 8th months average daily loss	(100 grams)
TOTAL	51 grams

The average net weight gain therefore is 51 Kg per grazing season. Current producer price for cull cows and bulls is Rs.5/Kg. Therefore, the value of weight gain per animal unit of villu is Rs.225, and total value for grazing from villus is Rs.2,088,960,

Value of Milk Production

Assuming herd composition as below, lactation period and milk yields are estimated to be (ACRES 1979):

	Neat Cattle	Buffalo
Bulls	.40	.20
Cows	.60	.80
Lactating cows	.70	.70
Lactation	280 days	300 days
In mind yield/H.d./ lactation	280 liters	400 liters

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Further, assuming that with a subspecies composition of 40% neat cattle and 60% Buffalo found on the villus, milk production based on animal units converted to cow equivalents would be:

8192 ha x 1 A.U. x .689/2.185 x 60 x 400 liters milk (Buffalo) = 1,773,071 liters

8192 ha z 1 A.U. x .1.746/2.235 x .40 x 280 liters milk (Neat Cattle) = 501,733 liters

Gross value ;	1,773,071 1 x 2.59 Rs/1 liter (Buffalo)	= Rs.4,592,254
	501,733 1 x 2.04 Rs/1 liter (Neat Cattle)	= Rs.1,023,535
Total Milk Production		= Rs.5,615,789
TOTAL (value of gain plus value of milk production)		= Rs.7,704,749

FISHERIES

Production levels from villus are 50 kg/ha. (See TOPIC REPORT G : FISHERIES).

Villu area is 12,800 ha x 50 kg =	640,000 kg
Current market price is:	Rs.4/kg
Gross value:	Rs.2,560,000

AQUATIC VEGETATION

Biogas can be produced from aquatic vegetation found in the villus. Current experiments show that approximately one kilogram can be converted into .0448 cu. ft. of biogas through low level technology. An average of 15 cu. ft. of biogas would be required daily for cooking requirements for a family of five. This means approximately 300 kg of aquatic vegetation per day would be required. Since there is no data yields of aquatic vegetation from villus available, and since there is no indication that the effort of collecting 300 kg of vegetation per day would justify the returns, no economic analysis is carried out. However, the fact remains that aquatic vegetation does represent an energy source that should be explored.

WILDLIFE

In terms of eco-values there is undoubtedly a high economic value that can be place on wildlife associated with villus. However, this has to remain an intuitive statement until such time as these values can be quantified. No data is presently available on species nutritional requirements, the food web or on migrations to and from the villus.

TOTAL GROSS VILLU VALUE:

Rs.10,264,749

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ECONOMIC IMPACT ANALYSIS

TOPIC REPORT A : CLIMATE AND HYDROLOGY has described the hydrological impacts to the villus as a result of reduced river flood peaks. The indication is that under full Program development, the inundated flood plain area of the villus could be reduced up to 50%. In addition, the duration of inundation will be shortened. The implications of this are that the productive value of the villu will be greatly reduced. The following analysis will attempt to estimate by what amount this value is reduced.

IMPACTS TO VALUE OF VILLU GRAZING

The total villu surface area will be reduced to 6,400 ha. It is assumed that drawdown will still leave 20% in pools, and that grazing accessibility will be reduced to 75%. Thus, the reduced area available for grazing is 3,840 ha. The extended grazing regime from seven to nine months will reduce the carrying capacity from 1 A.U. to .75 A.U. allowing the new villu to support 2,880 A.U.

Value of Gain

The amount of gain is expected to remain approximately the same as in the before project analysis, assuming decreased carrying capacity is observed. The value of weight gain per animal unit of villu is Rs.255. The total value for villu grazing is Rs.734,400.

Value of Milk Production

The same herd and species composition as in the before project analysis is assumed.

3840 ha x .75 A.U. x .5411 (lactating cows) x .60 x 400 liters milk
= 374,008 liters (Buffalo)

3840 ha x .75 A.U. x .546 (lactating cows) x .40 x 280 liters milk
= 176,118 liters (neat cattle)

GROSS VALUE : 374,008 liters x Rs.2.59/liter (buffalo) = Rs.968,681

176,118 liters x Rs.2.04/liter (neat cattle) = Rs.359,281

Total Milk Production = Rs.1,327,962

TOTAL (value of gain plus value of milk production) = Rs.2,062,362

IMPACTS TO FISHERIES

A reduction in value of fisheries is directly proportional to the reduction of villu size; thus a 50% reduction of villu area gives a 50% reduction in fish production levels.

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Villu area : 6400 ha x 50 kg	= 320,000 kg	
Current market value:	= Rs.4/kg	
Gross value:		= Rs.1,280,000

IMPACTS TO WILDLIFE

While these losses cannot be quantified, there is going to be considerable reduction in habitat as a result of villu reduction. In addition to the direct impact to wildlife other areas will be repercussed due to surplus wildlife seeking alternative grazing and habitat areas. TOPIC REPORT E : WILDLIFE expands on these impacts.

IMPACTS TO AQUATIC VEGETATION

Should an economic basis be determined for the manufacture of biogas or composted manure from aquatic vegetation, the reduction of villu size would have a direct effect on production thus having a negative effect on the value of this alternative energy source. More investigations into both the economic feasibility and social acceptability of aquatic vegetation transformation need to be done before any conclusions can be drawn.

ECONOMIC IMPACTS TO INTERMEDIATE DAMANA LANDS FORMED FROM VILLUS

The value of lands foregone from the villu grazing regime will be transformed into value of intermediate damana. While this land has an estimated lower grazing value than the villu proper, it nevertheless will be able to support a fair number of animal units. Thus, it is necessary to assign a grazing value to this land to determine net resource loss from reduction of villus.

Values given in TOPIC REPORT H for these new lands are:

Carrying capacity	0.6 A.U.
Accessibility	0.65
Gain	20 Kg
Species Composition	0.35 buffalo
	0.65 neat cattle

Value of Grazing

Gain

6400 ha @ .65 accessibility	= 4160 ha	
Carrying Capacity = .6 x 4160 ha	= 2496 A.U.	
Gain per A.U. - 20 kg x Rs.5/kg	= Rs.100	
Value of Graze		= Rs.249,600

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Milk Production

4160 ha x .6 A.U. x .5411 (lactating cows) .35 x 400 liters
= 189,082 liters (buffalo)

4160 ha x .6 A.U. x .5460 (lactating cows) .65 x 280i
= 248,033 liters (neat cattle)

Value of Milk: 189,082 liters x Rs.2.59/liter (buffalo)
= Rs.489,722

248,033 liters x Rs.2.04/liter (neat cattle)
= Rs.505,987

Total Milk Production = Rs.995,709

TOTAL (gain and milk production) = Rs.1,245,309

The sum total loss in benefits derived is shown in Table M-29 to be Rs.5,677,078. There is no cost effective mitigation action proposed to offset this loss. However, losses in production can be offset by enhancing other land resources such as: clearing, seeding and range management of damana lands; enhancement of tanks and reservoirs; and development of a seasonal tank aquaculture program (see TOPIC REPORT G : FISHERIES).

Table M-29

Total Impacts to Villus Resulting from the Proposed Action

Without Proposed Action (Rs)		With Proposed Action (Rs)	Net Benefits (Rs)
Grazing	: 2,088,960	984,000	(1,104,960)
Milk	: 5,615,789	2,323,671	(3,292,118)
Fisheries	: 2,560,000	1,280,000	(1,280,000)

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APPENDIX M-I

ELEPHANT CORRIDOR - SYSTEM B

The assessment of the elephant corridor for the Maduru Oya Project will be handled on a "with corridor" and "without corridor" basis. The key steps in this analysis are as follows:

(a) determine the area of paddy land and upland crop areas that will be lost to agriculture production as a result of the designation of a corridor through System B. From this estimate and a breakdown of the various soil types, the agriculture benefits foregone can be calculated.

(b) determine the cost-savings in branch canal costs resulting from not having to serve certain areas. For example, cost savings will result for the following branch canals:

1. Part of BRC . LB . 17
2. Part of BRC . LB . L7B
3. Part of BRC . LB . L8
4. All of BRC . RB . L4

(c) determine the additional costs associated with providing elephant crossings at certain points on the main canal system. The crossings will be 50 m wide for wading-type crossings and 20 m wide where bridges over deep cuts must be used. Crossings will be incorporated at the following points:

1. Left Bank Main Canal - two crossings north of Kadawathamadu.
2. Left Bank Branch Canal LBR6 - two crossings north of Kadawathamadu.
3. Right Bank Main Canal - two crossings north of Nelugala.
4. Right Bank Branch Canal RBR1 - two crossings south of Nelugala.

(d) Project IRR's will be calculated "with corridor" and "without corridor" based on the above costs and benefit parameters. No other costs or benefits will be considered for purposes of economic analysis.