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MARD PROJECT

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WETLAND DEVELOPMENT, REFORESTATION, PESTICIDE USE AND IPM, and ELEPHANT-HUMAN INTERACTION in SYSTEM B

(Report No. 216)

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TABLE OF CONTENTS

TABLE OF CONTENTS		i
EXECUTIVE SUMMARY		ii
INTRODUCTION		1
WETLAND PROTECTION AND RESTORATION		2
Menik Ela - MARD Road Wetland Development		2
Block 503 Wetland Development		7
Wetland Plant Use and Value		8
REFORESTATION PROJECT		9
WATER QUALITY MONITORING		9
PESTICIDE USE AND INTEGRATED PEST MANAGEMENT		10
ELEPHANT - HUMAN INTERACTIONS		12
RECOMMENDATIONS		14
REFERENCES		17
APPENDIX A	PERSONS INTERVIEWED	18
APPENDIX B	SCOPE OF WORK Kuda Oya Reforestation Project	19
APPENDIX C	MINUTES - Farmer's Meeting Kuda Oya Reforestation Project	31
APPENDIX D	THE CHINESE WATERCHESTNUT USDA Circular 956. 1955.	33
APPENDIX E	CHINESE WATER CHESTNUT OR MATAI - A PADDY CROP OF CHINA Economic Botany 10: 49-55. 1956.	42

EXECUTIVE SUMMARY

The purpose of this consultancy was to follow up on initiatives recommended in this consultant's report a Wetland Assessment carried out during the summer of 1992. The visit covered by this report occurred between May 28 and July 3, 1993 and a total of 18 of these days were in residence at MARD in Pimburattewa. The general Scope of Work for this visit was:

1. Work with the team from the University of Peradeniya to complete the Scope of Work for the reforestation project.
2. Assess progress on wetland development in Block 503 and advise on wetland design.
3. Assess potential for wetland development in the area of the Menik Ela drain in Zone 1 and develop design recommendations for such development,
4. Assess the effectiveness of the water quality monitoring program and make recommendations on its modification if necessary.
5. Provide recommendations on measures to reduce pesticide use through IPM, and
6. Provide recommendations regarding the extent and seriousness of elephant-human contact in System B and measures to reduce such contacts.

To achieve these objectives, meetings were held with Prof. Madduma Bandara and his U. Peradeniya team, local farmers and farmer organizations involved in the reforestation project, IPM specialist from the Plant Protection Department of GOSL, and with various Sri Lankan elephant specialists. Visits were made to all project sites and to village markets and farms. A Scope of Work for the reforestation project was completed, draft drawings were completed for the development of wetlands at Menik Ela drain, preliminary plans were developed with Dr. James Burleigh on implementation of pesticide studies and IPM measures for System B, Dr. Ajantha Perera was recruited to work with MARD on water pollution studies, and preliminary elephant control recommendations were promulgated. Block 503 wetland recommendations were deferred until January 1993.

As a result of these activities, the following recommendations are offered:

1. Wetland restoration on the Menik Ela drain should include the construction of a three-cell wetland south of the new dike and protection of existing wetlands but drainage of stagnant pools north of the dike. Otherwise, the area north of the dike should be maintained in natural state. The small wetland just south of the MARD road should be maintained or even opened to enhance drainage, and the areas adjacent to the drainage canal south and north of the MARD Road bridge should be reforested. MARD should seriously explore potential for water chestnut production in poorly drained areas.

2. Reforestation of the Kuda Oya below the Pimburratewa Reservoir should be protected by installing fences along the inner toes of the dikes and the margins of the passageways through the dikes, and MARD should seek assurances from MECA that diking of the Kuda Oya adjacent to Block 503 will occur before the end of the MARD project and that this diking will adhere to the recommendations made by Davis (1992).

3. All pesticide analyses should be halted immediately. Analyses should be resumed in conjunction with a well designed project as described on page 11. Analyses of NO_3 and PO_4 should continue for the time being, but the laboratory should be asked to reveal its techniques and levels of detection sensitivities. Dr. Ajantha Perera should be contracted by MARD to participate with Drs. James Burleigh and Craig Davis on the design and carrying out of the experimental IPM-water pollution study (page 11)

4. Establish a demonstration study of the impact on crop yields and differential profits of reduced pesticide use through alternative spraying strategies based on monitoring (see page 11). Drainage waters should be monitored throughout the study to quantify pesticide residues. Further, MARD should initiate detailed studies to document pesticide usage, dosage rates commonly used, crop yields, possible development of resistent strains, environmental contamination, safety and health problems, etc. This information should be used to develop IPM guidelines for specific crops, pests, and conditions.

5. MARD should develop and maintain a detailed data base on elephant-human incidents in System B and use this information to determine where resources should be focused and what strategies should be used to reduce such incidents. MARD should install a berm on the right side of the main supply canal that will run adjacent to the Maduru Oya in Block 503. MARD should also explore and test the potential for using living fences of plants such as *Parkinsonia aculenta* L. to keep elephants from entering agricultural areas. Finally, MARD should work with the Department of Wildlife Conservation to create and support an Elephant Control Unit (ECU) for System B and should hire an elephant control

INTRODUCTION

During the summer of 1992 a wetland assessment of Zones 1 and 5 of System B (Davis, 1992) recommended that wetlands in Block 503 be protected and enhanced during infrastructure development, riparian forests along the Kuda Oya be restored in Block 502 and protected and enhanced during development of Block 503, a program be instituted to monitor water quality in drainage water, and consideration be given to retrofitting developed areas in Zone 1 and 5 with wetlands. In April, 1993 a short follow-up visit was made by this consultant to discuss options for involving Sri Lankan Universities in the reforestation and wetland development projects being planned by MARD and MASL in response to the above recommendations. During that meeting a draft Terms of Reference was prepared and discussed with university representatives and cleared with USAID. A team from the University of Peradeniya was contracted by MARD to prepare a Scope of Work for an initial stage reforestation project; the SOW to be used to solicit offerers from among Sri Lankan universities to carry out its objectives.

To follow up on all of these initiatives, MARD contracted with this consultant to provide ongoing advice and technical assistance on a short-term basis for the duration of the project. The visit covered by this report occurred between May 28 and July 3, 1993 and a total of 18 of these days were in residence at MARD in Pimburattewa. The general Scope of Work for this visit was:

1. Work with the team from the University of Peradeniya to complete the Scope of Work for the reforestation project.

2. Assess progress on wetland development in Block 503 and advise on wetland design.

3. Assess potential for wetland development in the area of the Menik Ela drain in Zone 1 and develop design recommendations for such development, and

4. Assess the effectiveness of the water quality monitoring program and make recommendations on its modification if necessary.

Upon arrival in Colombo, USAID requested that two items be added to the scope of work:

5. Provide recommendations on measures to reduce pesticide use through IPM, and

6. Provide recommendations regarding the extent and seriousness of elephant-human contact in System B and measures to reduce such contacts.

To facilitate item 1, a preliminary meeting was held in Colombo on May 31 with Prof. Madduma Bandara, head of the U. Peradeniya team. At that meeting a draft SOW was provided by Bandara for review. A subsequent meeting of the entire team from Peradeniya was held at MARD from 10 to 13 June during which discussions were held with interested farmers and farmer organizations and the final SOW was completed. Wetland assessment involved visits to the sites to be developed and discussions with MARD engineers and local residents.

Meetings with IPM specialists from the Plant Protection Department in Peradeniya and extensive discussions with MARD plant pathologist, Prof. James Burleigh, facilitated the development of recommendations on pesticide reduction strategies and IPM. Similarly, discussions with Mr. L. De Alwis (former Director of the Department of Wildlife Conservation, GOSL), Mr. Jayasinghe (Manager of the Maduru Oya National Park), and Dr. S. W. Kotagama (Zoology Department, OUSL) were helpful in assessing elephant problems and identifying potential solutions.

WETLAND PROTECTION AND RESTORATION

Basin and control structure design for constructed or managed wetlands in Zones 1 and 5 of System B will depend on the topographic and hydrologic conditions specific to each site and on the purpose for which the wetland is being created. Some sites will require virtually no basin contouring and simple control structures will suffice for establishing appropriate hydrologic conditions. Other sites will require extensive excavation and basin contouring and more elaborate control structures to establish and maintain requisite hydrologic conditions. Wetlands being designed for general purposes such as wildlife habitat enhancement or drainage water purification will have less strict design criteria than will wetlands being prepared for more specific purposes such as the cultivation of particular aquatic plants or the purification of animal or human wastes.

Where wetlands are being developed or managed for the production of specific wetland plants, especially when these plant are to be grown essentially in monoculture, basin design and water control must create conditions optimal for growth of the desired species. Criteria should be determined on a crop-by-crop basis from the literature, indigenous experience, or by testing in controlled plots. Engineering designs requiring modest maintenance that can be carried out by farmers are permissible, but self maintaining systems should be designed whenever possible.

Hydrologic conditions in most parts of Zones 1 and 5 are such that only minor modifications can lead to the natural development of wetland conditions and wetland vegetation. Therefore, wetlands that are being created for general purposes will require only minor engineering and should vegetate naturally by invasion of wetland plants from nearby wetlands. Elaborate planting programs should not be required in most situations. Further, such wetlands evolve and change over time as they adapt to changing environmental conditions. Such change is natural and does not usually threaten the existence of or alter permanently the function of the wetland. Therefore, the best strategy to follow in developing general purpose wetlands in System B is to establish basic wetland hydrologic conditions and allow nature to establish the vegetation. Engineered designs requiring ongoing maintenance are to be avoided.

Menik Ela Drain - MARD Road Wetland Development

Drain improvements on the Menik Ela drainage, carried out since August, 1992, channelized the main drain as it approaches and passes under the Dehiattakandiya - Manampitiya (MARD) Road, altered and channelized drainages east of the Mahaulpota - Menik Ela Road, improved that road including the construction of a new bridge over the channelized drain, and installed a long dike cutting off all water flow northward from the channelized drain into the area northeast of the latter road (Fig. 1). The Menik Ela drain was targeted by Davis (1992) as a high priority site for retrofitting constructed wetlands. Current MARD plans call for the establishment of a wetland complex south of the long dike by diverting a portion of the flow from the channelized drain that flows under the new bridge (Site A, Fig. 1), improving conditions in the area to the north of the long dike and northeast of the Mahaulpota - Menik Ela Road (Site B, Fig. 1), and maintaining or enhancing the small wetland occupying the southeast corner of the intersection of the Mahaulpota - Menik Ela and MARD roads (Site C, Fig. 1).

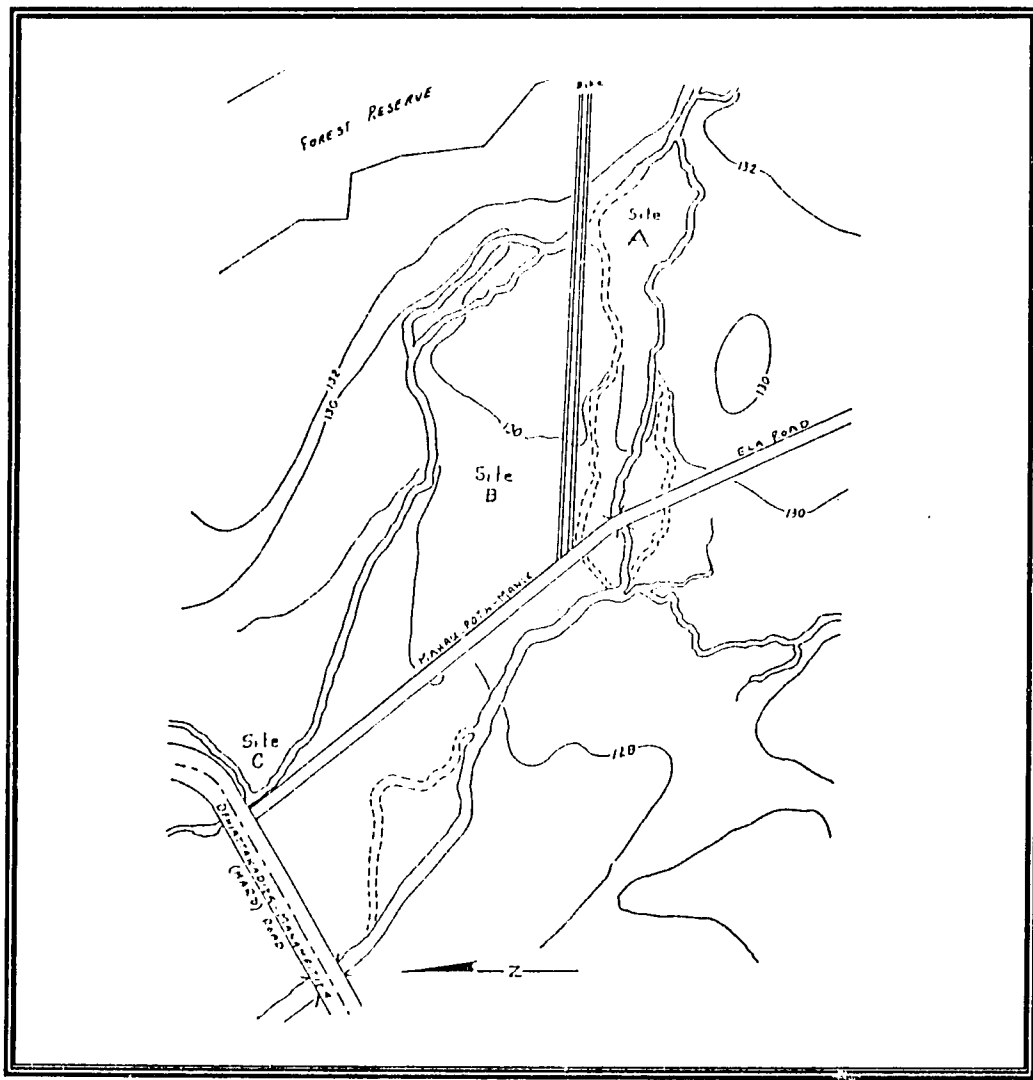

Figure 1. Menik Ela drain. **Site A** - Construction of a one- to three-celled wetland; **Site B** - Area of former drainage channels and grassland to be left alone to succeed naturally to forest; **Site C** - Low quality wetland to be left as is or opened to improve drainage.

Menik Ela Wetland Complex

Sites A and B are largely in natural conditions today, although they have been locally altered by activities associated with road and dike construction. The sites abound with wildlife including abundant waterfowl species, deer, and elephants; the sites abut a forest reserve on their eastern ends. These sites could be developed into natural areas with little effort.

Site A: This site has been excavated on its north side for dike construction, leaving basins that support obligate wetland species (*Cyperus, Scirpus*). A major stream has been cut off by the dike and water flow has been diverted down the newly channelized drainage. A wetland complex could be developed in this Area by minor basin contouring and the installation of simple control structures. A three-basin, step-down complex would enhance wildlife habitat quality, provide riparian water storage during flood periods, and provide purification of waters diverted through it. With concomitant protection of the natural area north of the dike (Sites B), wetland development at Site A would create a high quality natural area that could serve as a study area for researchers, an educational site for school children, and an attraction for tourists from the area and beyond.

A three-cell wetland complex is illustrated in Figure 2. There is a drop of approximately 3 vertical feet from the point of intake into the wetland complex to the point of outflow into the drain at the bridge. The three wetland cells are envisaged as a three-tiered, cascading system with dikes and water depth control structures maintaining flow during non-flood periods at 1-foot intervals. The basin of each cell could be contoured to provide water depths at full capacity of approximately 20 cm over shallow areas and up to 80 cm in channels and the central basins (Figure 3). Banks should be contoured to replicate natural shorelines and bank and dike sides should be vegetated with native bank-holding vegetation.

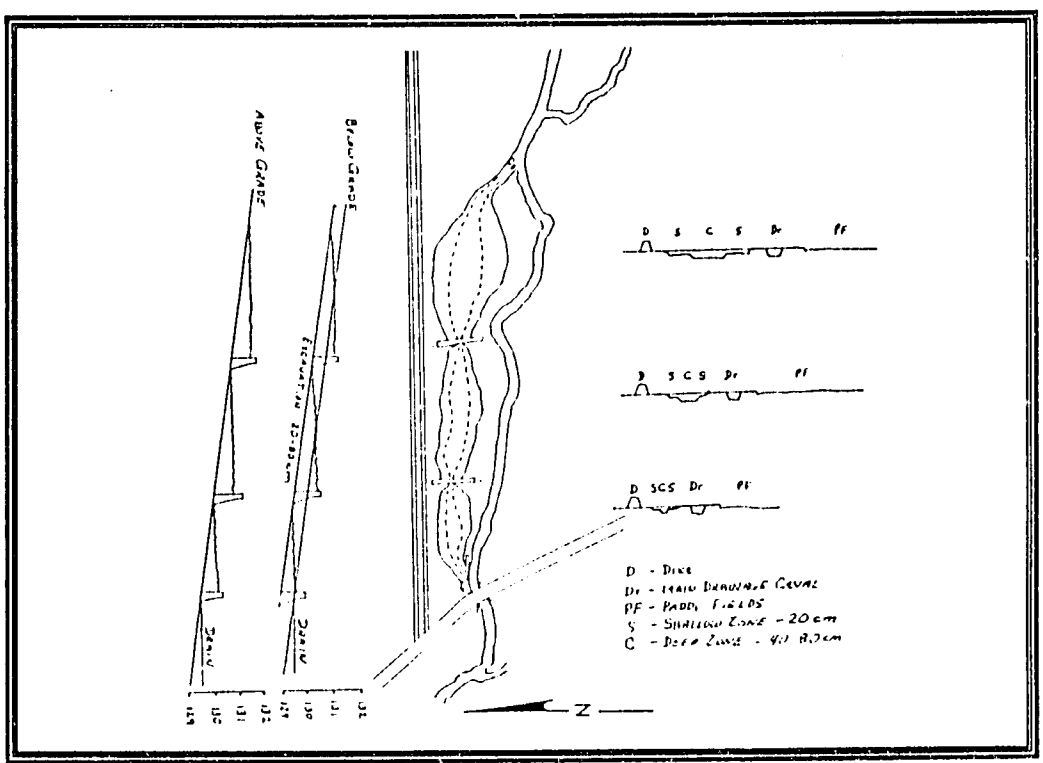

Figure 2. Three-cell wetland complex showing general cross sectional design for graded basins and optional designs for above- and below-grade basin profiles. Shallow zones should be 20 cm deep when the marshes are full, and the channel or open water areas can be up to 80 cm deep, although in this case they will probably be more shallow.

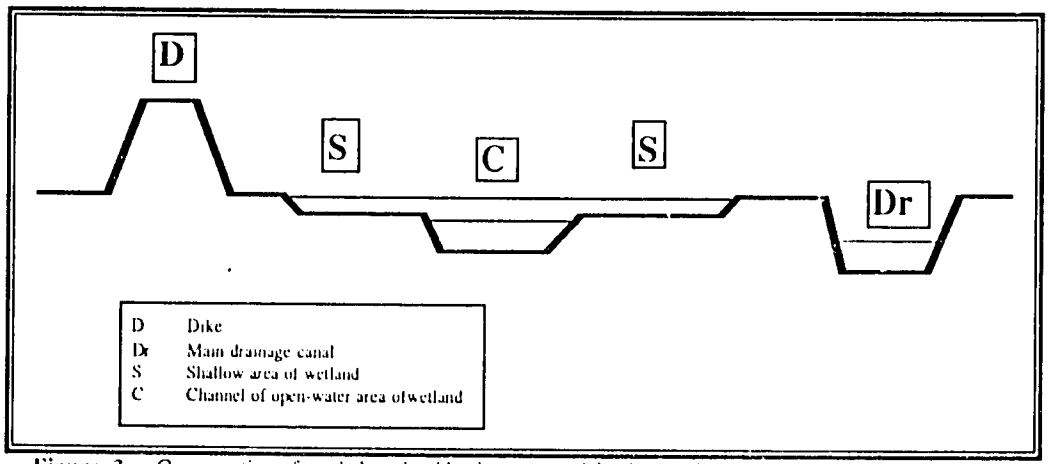

Figure 3. Cross section of graded wetland basin suggested for the Menik Ela. The design provides for one or more deep channels in the marsh to provide for open water areas attractive to waterfowl. These areas can be up to 80 cm deep. The shallow areas are designed to carry approximately 20 cm of water when the wetland is full. These areas should be saturated to soil surface during the vegetation development period to allow for germination and establishment of wetland species. Once these plants reach heights greater than 20 cm, the wetland can be filled. Control structures (inlets and weirs) should be designed to hold approximately 20 cm of water on the shallow zone when full and to maintain residence time of at least one day except during flood periods. Therefore, only a fraction of the normal drain flow can pass through the wetland. All dams and control structures must be designed and constructed to withstand Maha floods.

After initial contouring and control structure installation, openings should be cut at the east end of the wetland complex to connect it with the channelized drain. Openings should be of such size and shape to allow for appropriate flows to maintain average depths of 20 cm on the shallow areas during non flood periods. Input structures should restrict flows during floods so most of the flood flow is diverted down the channelized drain. All structures in the wetland complex will have to be designed to withstand the maximum flooding conditions expected.

Initial flooding of the cells must be carefully controlled to hold water levels a 0 ± 1 cm on the shallow areas. This will provide suitable conditions for the establishment of wetland species that invade the new wetlands. Once wetland vegetation is more than 20 cm tall, full flooding to 20 cm can be allowed. [After initial inspection of the wetland cells in January of the first year, consideration might be given to doing some planting of desirable species if these have not self established at the site. Just what species might be most beneficial can be determined at that time.]

A one-cell plan is illustrated in Fig. 4. This plan would save on construction costs. Further savings could be realized by leaving the basins in natural contour, allowing the wetland to mold to the existing topography. If the basin is not contoured, vegetation will develop around the fringe of the open water zone. Manipulation of water depth during vegetation establishment to maintain a broad band of saturated soil below the maximum fill line would stimulate germination. This would require management during the first months of filling.

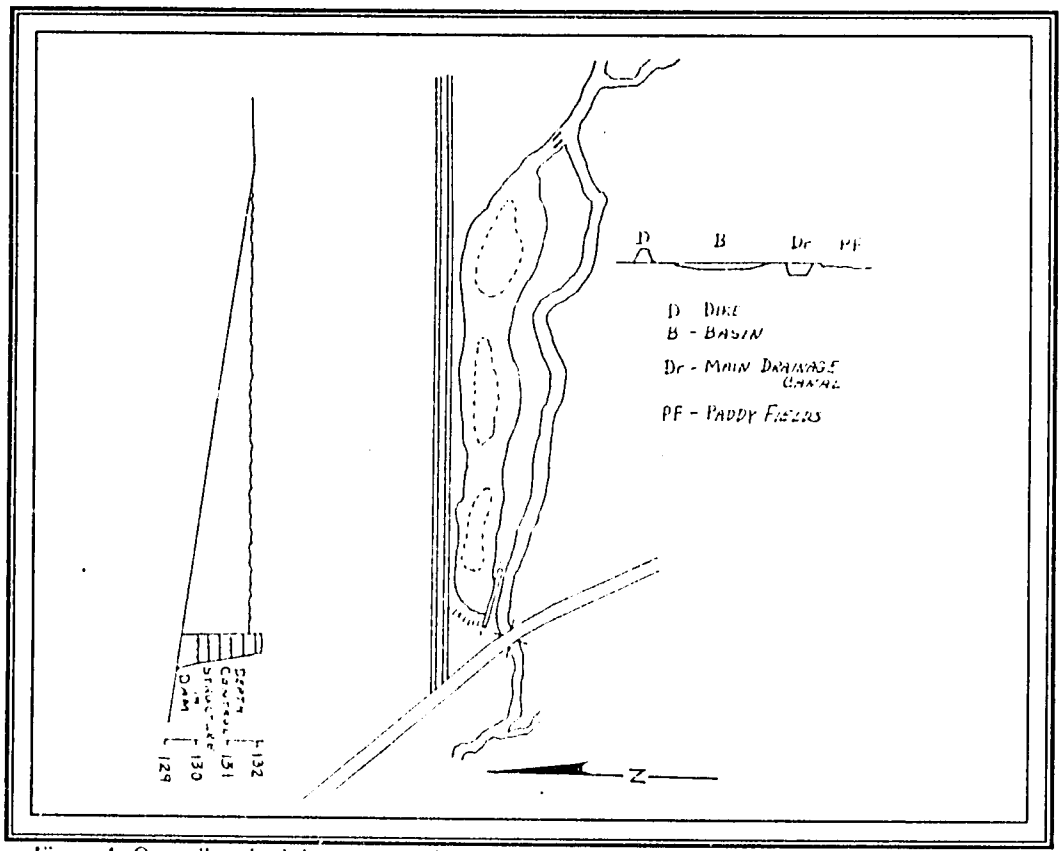

Figure 4. One-cell wetland showing general cross section of a nongraded basin and a longitudinal profile of the cell gradient and control structure with log weir.

Thus, four options are given: (1) three cells with full grading as in Figs. 2 and 3, (2) three cells with no grading as in Figure 2, (3) one cell with grading as in Figs. 3 and 4, and (4) one cell with no grading as in Fig. 4. Option (1) is preferred in terms of establishing ideal wetland conditions, but it might be too expensive and require too much ongoing maintenance. Option (4) would be the least expensive to install and would require the least maintenance, but it would back up approximately 1 m of water at its lower end, and this would probably affect the dike. The best choice might be a three-cell system with one graded and two nongraded cell. This would allow us to gain information on construction and maintenance of graded and ungraded basins and on the ecological dynamics of both types.

Site B: This Site is a complex of old stream channels and pools dissecting a degraded grassland with scattered trees. Its northern end, between the old stream channel and the Mahaulpota - Menik Ela Road is occupied by wetlands. Rice paddy cultivation extends right up to the old stream channel on its northern side, and there is some threat of encroachment by farmers into the area of Site B. This Area should be maintained in as natural a state as possible as a mixed upland-wetland complement to the new wetland complex at Site A. This would establish a diverse natural area extending from the forest preserve to the Mahaulpota-Menik Ela Road. Some minor drainage will

be required on the site to eliminate stagnant pools, and consideration should be given to planting native trees on some of the upland areas in the site. The current mixed vegetation could, if somewhat enhanced with native species, be the best choice for the site. No extensive wetland development is recommended at this site, because the new dike cuts off most water flow that would maintain flows in wetland basins. The wetlands that already exist at the northern end of the Site, should, however, be retained and protected from encroachment.

Site C: This site is essentially a pair of ditches, remnants of the northern extension of the old stream channel that flows along the northern side of Site B and a ditch that runs along the south side of the MARD Road. These converge at a two-culvert drain that carries flow under the MARD Road. Rice paddy cultivation extends to the edge of this drain already, so there is no room for expansion of the wetland area. The drain is vegetated by typical wetland plants, most notably at this time by an extensive growth of kang kung (*Ipomoea aquatica*) which is collected by local farmers for use as a vegetable in their households but is apparently not marketed. This is a low-quality wetland that should be left as it is or opened up as necessary to maintain water flow under the MARD Road.

MARD Road Channelization Site

South of Road: The area south of the MARD Road, between the Mahaulpota-Menik Ela Road and the main drainage channel is poorly drained and contains some basins in which small wetlands have developed. There is potential for developing a wetland complex similar to that proposed for Site A at this site. Similar design criteria would be appropriate here. Alternatively, this area could be drained and returned to forest.

North of Road: No wetland development of the area north of the MARD Road adjacent to the right bank of the channelized drain is recommended. This area is occasionally flooded during Maha floods but is probably suitable for agricultural development. If this proves to be not true, the area should be reforested. At the very least, riparian forests should be planted to a distance of forty meters on each side, except where existing paddies make this impossible. A forest stretch along the right bank here, combined with wetland or forest development south of the MARD Road and development of Sites A and B as suggested above, would establish a corridor for wildlife movement from the Mahaweli floodplain forest to the forest preserve east of Sites A and B.

Block 503 Wetland Development

Wetland systems have been included in the design of irrigation infrastructure for Block 503 as recommended by Davis (1992). At this time, infrastructure development has started in the southern end of Block 503. Plans for this year call for installing supply canals on the west side of the block, establish the drainage gradients and begin installing wetlands planned for the central and Kuda Oya braid drains, and close the connection of the Narana Ela at the Maduru Oya and divert Narana Ela flow down the central drain in Block 503. Infrastructure installation on the east side of the Block will be delayed for one year for security reasons.

No detailed inspection of Block 503 wetlands was carried out on this visit, because work on these sites will not begin until winter. This consultant will return to MARD in January to oversee that work. A doctoral graduate student in wetland ecology may be attached to MARD for several months during the winter and spring of 1993 to oversee ongoing construction and vegetation of Block 503 and other wetlands.

Cultivation of Wetland Plants for Home and Commercial Use

Zones 1 and 5 of System B include vast areas of low, poorly drained areas that are ideally suited for growing crops that require or can tolerate saturated soils or inundation, e.g. rice. Indeed, some areas are even too wet for rice. In these areas, we have three choices, drain them, abandon them, or find something useful and productive to grow on them. In my assessment of the wetlands of this area last summer (Davis, 1992), I noted that several plants found in natural and impounded wetlands are eaten by local residents, e.g. Kang Kung (*Ipomeae aquatica*), or used for other purposes, e.g. making bed mats (*Cyperus corymbosus* and *Scirpus grossus*). As a result of visits to village markets and homesteads near Aralagonwila this month, I add another to that list -- Kohilla (*Lasia*). Kohilla is a very popular rhizomatous macrophyte that thrives on saturated soils and is touted to have beneficial effects for those suffering from hemorrhoids. It grows in dense patches and is tolerant of shade, therefore it can be grown in home gardens. Both rhizomes and leaves are eaten, the former mainly to add bulk or fiber to the diet (good for the digestion). In the market at Dimbulagala, leaves were selling for Rs 3 per bundle of 12, and rhizomes sold for Rs 7 per half kilo.

Kang Kung, Kohilla, and reeds should be explored because of their potential use in making areas of saturated soils more productive. There are, however, other wetland plants that have potential as cash crops that could compete favorably with the best of the alternative crops being produced in System B today. Probably the most promising is the Chinese water chestnut (*Eleocharis dulcis*). MARD should initiate field tests and explore domestic and export market potentials for this crop. It should also explore possibilities for establishing bottling facilities in the Mahaweli as a source of

Chinese Water Chestnuts

(Maddox and Kingsley, 1990)

The Chinese water chestnut (*Eleocharis dulcis*) is an anchor-rooted, grass-like plant that grows to a height of 1.0 to 1.5 m (3.5 to 5.0 ft). It requires 150-220 days to mature, needs 250-300 kg/ha of nitrogen, and produces a high starch, sweet corm (chestnut) with a retail value of $5-7/kg ($2-3/lb) in the United States. Corm sizes vary with the variety or plant selection but are marketable when 2.5 cm (1 in.) or greater in diameter. Corm yields of 4 - 8 mt/ha can be expected under good conditions. Research has shown that water chestnut hay is a good forage for ruminant animals and the corms have as much available starch for ethanol fuel production as corn. See also Hodge (1956), Hodge and Bisset (1955), Maddox *et al* (1982), Kingsley *et al*, (1990), and Tayer (1981).

employment for second generation settlers in this area. Such processing will be necessary if export markets are to be tapped. Chinese water chestnuts could be cultivated in converted rice paddies or in shallow ponds in which fish culture could also be carried out. There are no apparent reasons why Chinese water chestnuts couldn't be grown successfully and very profitably in System B.

Information on water chestnut production is provided in APPENDICES D and E.

REFORESTATION PROJECT

A meeting with the Scope of Work team from the University of Peradeniya was held on June 10-13. The primary purposes of this meeting were to complete the Scope of Work and to hold a third meeting with Farmer Organization leaders and riparian farmers. The scope of work was completed and edited (APPENDIX B). Some version of this will accompany the call for proposals that is scheduled to be mailed to universities on or about July 5.

The meeting with farmers and farm organizations was very successful. While the farmers and their organizations have some minor concerns about the reforestation project, they are overwhelmingly supportive and want to be involved. They took initial steps to organize an action group to work with MARD and the subcontractor on project planning, implementation, and monitoring. Minutes of the meeting are in APPENDIX C.

A major concern about this project is how to protect the young trees. Several strategies were discussed including fencing with barbed wire, the use of living fences, enclosing each seedling in a cage or barrel, zoning the area to exclude buffalo from critical areas, etc. Zoning to exclude buffalo is unrealistic, because the entire eight kilometers will be planted. Living fences are also unrealistic in the short run, because they take three or more years to grow to an effective size and density. Enclosing individual trees has been successful here and in other countries but can be very expensive. The costs should be explored, however

Fencing would provide the best protection but is also very expensive. Costs could be reduced by using wood posts and only two or three strands of wire - perhaps only the top strand would have to be barbed. Further, the critical areas of protection are the inner toes of the dikes and the sides of the dike breaks through which buffalo will move into the grazing area between the dikes. Fencing could be done along the inner toes and the sides of the passages, essentially halving the footage of fencing needed. Outer margins of the reforestation areas would mostly abut on paddy and upland fields. These areas are scheduled to be planted in crops of value to the farmers. Therefore, farmers will be motivated to keep cattle and buffalo from entering the forest from this side of the dikes. Fencing should belong to the Mahaweli and should be taken down and used for other sites when it is no longer needed at this site. There is concern that the wire for the fences would be stolen at night. Consideration might be given to hiring farmers to patrol the fence on irregular bases and to keep an eye open for suspicious activity.

Another major concern that arose during this visit was the possibility that diking of the Kuda Oya adjacent to Block 503 would not take place. This would be a serious mistake. The dikes demarcate the reserve lands, leaving no doubt about how far farmers can extend their paddy and fields. It is essential that the lower Kuda Oya be diked, even if these dikes are not of great stature. Further, these dikes should be established (as recommended by Davis, 1992) outside the existing riparian vegetation in this stretch of the river.

WATER QUALITY MONITORING

Water quality (NO_3, PO_4, and pesticides) has been monitored at drains entering the Narana Ela wetland and at the outlet of the wetland. To date analyses have detected no pollutants in any of the samples (the lone exception being a one-time detection of malathion, a pesticide restricted to use in malaria control -- probably resulting from poor handling techniques on the part of applicators).

The ND (not detected) findings for all samples are suspect. One of four things is happening:

1) We are sampling at times when no chemicals are coming off the land. It is conceivable that our monthly samples have occurred when farmers are not spraying or applying fertilizer, but I find it hard to believe that this would be a consistent sampling error over several months.

2) Sampling techniques and transport of samples to the laboratory are faulty, and pollutants are degrading to undetectable levels before the samples reach the lab.

3) Analytical techniques are inadequate. If the laboratory is incapable of detecting substances in parts per million at least, they may be missing these contaminants.

4) There are indeed no detectable quantities of these chemicals in the drainage water. This is possible, but highly unlikely.

My guess is that our problem results from a combination of one, two or three. We need to design a scheme that will enable us to sample at times when we know what spraying activities are occurring on the land. Sampling techniques and transport should be examined to reduce the chances for degradation, and we need to find out exactly what analytical techniques are being used and what their detection sensitivities are.

To accomplish these things, sampling of effluent water should be incorporated in a larger project designed to examine the use of chemicals on various crops (see IPM project on page 11). If this were done, sampling sites and frequencies would be determined by activities on the land, e.g. spraying, fertilizing, etc. We would know exactly what was being applied, what concentration and quantity it was being applied, the nature of the crops and soils involved, and the quantity of effluent leaving the study area. Water samples could then be timed to sample runoff events and results could be linked back to application strategies.

MARD should contract with Dr. Ajantha Perera, environmental toxicologist at the University of Colombo, to work on this project with Drs. James Burleigh and Craig Davis. Dr. Perera is an expert on water pollution and has particular experience with pesticide pollution.

PESTICIDE USE AND INTEGRATED PEST MANAGEMENT

> ***"Last year, two shops in this area grossed Rs 9.3 million in pesticide sales."***
>
> **Dr. Jinasiri Fernando**

The overuse of pesticides appears to be a serious problem is System B, unnecessarily increasing production costs for farmers and polluting effluent waters. Further, careless application practices are endangering the health and safety of those spraying these chemicals. In his assessments of pesticide use on high value crops in System B, Ikram Mohyuddin (1990, 92) found that pesticides were sprayed on a prophylactic basis without knowing whether pests are there, that farmers were spraying five to ten times per crop when not needed, that insect pest numbers in sprayed and unsprayed plots were often not significantly different, that crop damage from such pests was often kept below economic injury levels by predators, and that such predators may be threatened by high use of pesticides. Further, Mohyuddin observed that farmers often failed to take appropriate precautions to protect their health and safety and the environment when using pesticides, e.g. not wearing proper clothes and washing spray cans in canal waters. I have observed similar actions on several occasions in Zones 1 and 5 of system B. Mohyuddin recommended that alternative pest control measures be adopted to reduce costs and protect the environment.

An argument could be made that few data are available on actual pesticide application rates, on the biological and economic impact of either overuse or reduced use of pesticides of particular crops, and on the impact of pesticide residues on the environment and that studies should be undertaken to document such impacts before IPM strategies can be recommended. It is true that this type of information is not available and that such information would enable pest control specialists to devise IPM strategies to target specific crops or conditions. Studies to obtain this information should be designed and implemented immediately. It would, however, be a mistake to wait for such data before implementing measures to reduce the use of pesticides in System B. The qualitative evidence of extreme overuse of pesticides is clear and sufficient. We are dealing with a problem that is out of control -- a runaway horse so to speak. We must stop the horse quickly before severe or fatal damage is done. Then we can set the horse in the right direction. Pesticide use must be brought under control quickly, then we can fine tune IPM practices to fit specific crops, pests, and conditions. Both short- and long-term strategies are needed.

Short-term Strategy: To halt the rampant misuse of pesticides, MARD must convince farmers that the reduced use of these chemical is in their best interest. An experiment/demonstration is needed to determine the impact that major reductions in pesticide use would have on major crops in System B, demonstrate options open to farmers for reducing dependence on pesticides, and train farmers in techniques of IPM, e.g. monitoring, mechanical controls, etc.

Test-Demonstration of Reduced Used of Pesticides on Major Crop Species in System B

For each crop selected for testing, a series of experimental fields should be established on similar sites. These plots should be planted and cultivated in similar ways so as to limit variability as much as possible to differences in pesticide application regimes. Experimental fields should be divided into (1) Controls - pesticide applications follow traditional regimes, (2) no pesticides used, and (3) a series of intermediate application regimes. Fields receiving different treatments should be sufficiently separated to minimize the chances of pesticide drift or pest movement contaminating treatments. Farmers invited to participate in the trials should be assured a minimum profit level; everyone should be guaranteed the income that is generated on the control - spray as usual - fields. Participating farmers should also be fully informed about the reasons for the experiment and for the various spraying strategies assigned. Farmers are more apt to cooperate if they are informed.

Data should be collected on crop yields, profit from sale of crop, degree and timing of pest infestation, pest damage to plants (visible damage may not affect crop yields), amount of pesticides applied and when it was applied, cost to farmer of pesticides applied, and water quality of effluent waters leaving the fields.

The study should be set up to run for a minimum of three years (preferably five years) to level temporal variability.

The study should be used as a demonstration for farmers in System B and elsewhere. Extension programs and brochures should be developed to explain the results and implications of these studies for pesticide use on these crops.

Long-term Strategy: Detailed studies and experiments are needed to provide baseline data on pesticide use, dosage, etc. to enable GOSL to develop pesticide restrictions and guidelines for long-term solution of this problem. Detailed, crop-by-crop, pest-by-pest IPM strategies can be developed once these data are available. This will take time.

ELEPHANT - HUMAN INTERACTION

Settlement patterns that have accompanied development of System B have severed paths used by local elephant herds as they moved among watering and grazing areas within their ranges. System B is virtually surrounded by active elephant herds, and human-elephant contact has been occurring around this entire periphery. These interaction have involved damage to crops and structures, including buildings. Such incursions seem to be limited to the margins of cultivated areas and also seem to be concentrated in certain locations around the periphery of System B, but detailed information on incursion sites has not been compiled for this area. Areas of particular concern include the Dimbulagala area where elephants have even invaded the orchards at the Buddhist Temple, areas adjacent to the Handipan Villu,areas in Block 504 adjacent to the Kuda Oya, and new settlement areas between the Pimburratewa Reservoir and the Maduru Oya dam. The first three of these areas are fully developed and elephants are encroaching from adjacent forested areas along the flood plain of the Mahaweli Ganga in the first two and the right bank of the Maduru Oya in the third. In the latter case, the elephants are moving across Block 503 from the Maduru Oya to reach these farms. Once Block 503 is developed, these sites may be free from elephant damage, but new farms along the Maduru Oya in Block 503 will be susceptible unless MARD installs elephant barriers along the Maduru Oya. The newly settled areas between the Pimburratewa Reservoir and the Maduru Oya dam are still being carved out of the jungle. Elephant herds still move fairly freely in this area, and control will require different measure than those applicable in more developed areas.

Some factors to be considered when devising control strategies are[1]:

- Elephant incursion incidents seem to be restricted to the very periphery of settled areas with damage limited largely to those fields and paddies adjacent to the forests. If this indeed a pattern, a buffer zone sown with palatable forage might be an answer.

- A wounded elephant can travel for many days and many miles before succumbing to his or her wounds. Therefore, it is very difficult to link the location of elephant carcasses and the sites of their shooting.

- The traditional means of dealing with encroaching elephants has been to frighten them off with loud noise - fire crackers, beating on pans, etc. Two factors may be causing a replacement of this strategy with one of killing the intruders. First, elephants that have frequent contact with human settlements lose their fear of people and structures. For instance, wild elephants will normally avoid stepping on unfamiliar surfaces such as concrete, but in areas where they encounter human structures regularly they have no such fears and have been known to enter compounds and even houses. Second, the presence in System B of large numbers of men

[1] Based on discussions with Mr. L. Alwis, former director of the Department of Wildlife Conservation (DWC); Mr. A. D. U. S. Vattala (DWC); and Dr. S W. Kotagama, Open University of Sri Lanka and from personnal observations and discussions with farmers.

under arms, home guards and LTTE, increases the likelihood of elephants encountering humans with rifles.

- The Wildlife Department used to employ Elephant Control Units to work with farmers and villagers in reducing adverse human-elephant interactions. These units were a "presence " in agricultural areas adjacent to large elephant populations. They provided emergency crop protection services and ran educational programs on elephant repellant measures. Such a unit in System B might reduce elephant deaths by providing farmers with alternative repellant measures and rapid assistance in time of need.

Before MARD can design measures to reduce human-elephant contacts, it needs more detailed information on the nature and extent of the problem. Detailed maps of incident locations and information on such matters as (1) distance form undeveloped areas, (2) number of elephants involved, (3) exact nature of the damage, and (4) estimated cost of damage are needed. Only after such information is available can appropriate strategies be devised and implemented. Many elephant control measures are very expensive, and action should target those areas of critical concern. The characteristics of such areas willbear on the choice of strategies.

The best strategies for this area willbe those that require little or no maintenance. For this reason, ditches should be favored over electric fences, habitat protection and enhancement should be favored over ditches, etc. Another strategy used by farmers at various places on the island is the planting of living fences of plants such as Parkinsonia aculenta [Jerusalem thorn (English), bath karal gus (sinhala), bachchi (local). P. aculenta, native to Central America, is a densely growing woody plant with sharp thorns on the stem. Farmers often clip excess branches and pile them on the ground outside the fence. Elephants are hesitant to walk on these branches or try to pass through the living hedge. Young twigs are used for fodder for goats. It is also used to reforest saline and arid areas. In the United States it is cultivated as a residential ornamental. There appears to be no commercial seed source in Sri Lanka and seeds from the U.S. would be expensive. Seeds may be collected in the Hambantota area. They were mature in late June when I was there, so immediate collection should be successful. Seeds could then be started in the MARD/MEA nursery.

While elephant-human contact can have severe local impact on crops and structures and may occasionally result in human injury or even death, and while such incidents certainly cause considerable hardship and despair for the human victims, ultimately it is the elephant that is endangered by such contacts. Whoever said that when elephant meets man it is bad for the man was correct in the specific but wrong in the general. In ongoing interaction of wild elephants with human settlements, the elephant must ultimately lose. Ultimately, elephant-human conflict willresult in the elimination of wild elephants from all but the most remote and isolated locations in Sri Lanka. This is a scenario that has been repeated over and over throughout the world with large wildlife species. It willhappen with the Sri Lankan wild elephant unless steps are taken soon to protect this animal that is so much identified with this island and the human culture that has developed here.

RECOMMENDATIONS

1.0 WETLAND PROTECTION AND RESTORATION

1.1 At Menik Ela Site A, a three-cell wetland system with one graded and two ungraded cells is recommended. This would allow us to gain information on construction, maintenance, and ecological dynamics of graded and ungraded basins.

1.2 Site B should be maintained in as natural a state as possible as a mixed upland-wetland complement to the new wetland complex at Site A. Some minor drainage will be required on the site to eliminate stagnant pools, and consideration should be given to planting native trees on some of the upland areas in the site.

1.3 Site C is a low-quality wetland that should be left as it is or opened up as necessary to maintain water flow under the MARD Road.

1.4 The area south of the MARD road between the Mahaulpota-Menik Ela Road and the main drainage channel should either be improved as a wetland complex or drained and reforested. The right bank of the drain north of the MARD road should be reforested to a distance of 40 m. The left bank should be planted to bank holding species.

1.5 MARD should initiate field tests and explore domestic and export market potentials for water chestnut (Eleocharis dulcis). It should also explore possibilities for establishing bottling facilities for water chestnuts and other items in the Mahaweli to enhance export capabilities and provide a source of employment for second generation settlers in this area.

2.0 REFORESTATION PROJECT

2.1 To protect plantings, fencing should be installed along the inner toes of the dikes and the margins of the passageways through the dikes. Wood posts should be used and only two or three strands of wire. Perhaps only the top wire need be barbed. Farmers should be hired to patrol the fence on irregular schedules to minimize theft.

2.2 MARD should seek assurances from MECA that diking of the Kuda Oya adjacent to Block 503 will occur before the end of the MARD project and that this diking will adhere to the recommendations made by Davis (1992) that these dikes be established outside extant riparian forests.

3.0 WATER QUALITY MONITORING

3.1 All pesticide analyses should be halted immediately. Analyses should be resumed in conjunction with a well designed project as described on page 11. Analyses of NO_3 and PO_4 should continue for the time being, but the laboratory should be asked to reveal its techniques and levels of detection sensitivities. If they are not able to detect parts per million for nitrate and phosphate, another analytical laboratory will have to be found. Dr. Perera (see below) can assist with these determinations.

3.2 Dr. Ajantha Perera should be contracted by MARD to participate with Drs. James Burleigh and Craig Davis on the design and carrying out of an experimental IPM-water pollution study (page 11). Dr. Perera should visit MARD with Dr. Davis while he is there in September, should examine sampling and analytical procedures currently being used and recommend on modifications to improve detection, and assist Dr. Burleigh in the design of the IPM-water quality project. She should continue on the monitoring team for this study for its duration and serve as a consultant to MARD(with Dr. Davis) on the wetland project.

4.0 PESTICIDE USE AND INTEGRATED PEST MANAGEMENT

4.1 **Short-term actions:** MARD should establish a demonstration study of the impact on crop yields and differential profits of reduced pesticide use through alternative spraying strategies based on monitoring (see page 11). Drainage waters should be monitored throughout the study to quantify pesticide residues. Funds should be provided to guarantee participating farmers profits equal to farmers using normal spraying regimes (control plot farmers). Participating farmers should be fully informed about the goals of the project and the reasons they are being asked to follow a certain spraying strategy in the study. An extension education and training program should be developed to train farmers in alternative (IPM) strategies for pesticide use and in the proper precautions to use while spraying, in cleaning sprayers, and in the proper storage and disposal of pesticides. The study should be used as a demonstration in these extension programs.

4.2 **Long-term actions:** MARD should initiate detailed studies to document pesticide usage, dosage rates commonly used, crop yields, possible development of resistent strains, environmental contamination, safety and health problems, etc. This information should be used to develop IPM guidelines for specific crops, pests, and conditions.

5.0 Elephant-Human Contact[2]

5.1 MARD should develop and maintain a detailed data base on elephant-human incidents in System B, including a map showing precise locations of incidents and information on (1) the direction from which the elephants came and went, (2) distance of elephant incursion into developed area, (3) number of elephants involved, (4) exact nature of damage, (5) nature of efforts used to repel the elephants, if any, and (6) estimated cost of he damage in rupees. This information should be used to determine where resources should be focused and what strategies should be used to reduce such incidents. MARD may have to employ someone strictly for this effort at least in the beginning.

5.2 While developing irrigation supply infrastructure in Block 503, especially the supply canal that will run along the left bank of the Maduru Oya, MARD should consider installing appropriate elephant control structures. The best structure might be a berm along the right side of the canal. Elephants will not attempt to cross a ditch the bottom of which they cannot feel with their trunks (L. Alwis). A steep bank on the right

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[2]see footnote #1.

side of the canal will make the elephants think the canal is deeper than it is. Such a berm should be constructed even if the canal is too wide for elephants to step over; they may enter the canal assuming that they can climb out the other side and get stuck.

5.3 MARD should explore and test the potential for using living fences of plants such as Parkinsonia aculenta L. to keep elephants from entering agricultural areas.

5.4 MARD should explore with the Department of Wildlife the creation and support an Elephant Control Unit (ECU) for System B. Personnel for this ECU could be recruited from second generation farm residents of System B, trained by the Department of Wildlife Conservation, and report to the local Wildlife Department Officer. MARD and USAID should identify protocols enabling MARD or other USAID funds to be used to support the ECU for the duration of the MARD project. Such support should include salaries for ECU members, cost of training for ECU members, an appropriate vehicle, such other equipment and supplies that the ECU would require to carry out its duties, and facilities for a dispatching station (office, telephone, radio, etc.). Further, MARD and USAID should work with the Department of Wildlife and other GOSL agencies to insure the continuation of the ECU after the MARD project concludes.

ECU responsibilities should include:

- Providing emergency assistance for farmers in dealing with elephant incursions,
- Monitor elephant movements in and adjacent to System B,
- Provide educational programs to teach farmers about elephant habits and needs and train farmers in strategies for repelling elephants without hurting them.

5.4 MARD should contract the services of an expert in controlling elephant incursion into agricultural and other settled areas to advise on strategies and techniques appropriate for the problems in System B. This should be done as soon as possible but not before a data base is compiled as recommended in 1.1.

5.5 All things being equal, low- or no-maintenance strategies and techniques should be adopted, e.g. ditches instead of electric fences, habitat protection rather than ditches, etc..

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APPENDIX A

PERSONS INTERVIEWED

Mr. Alex. Area Wildlife Officer, Pimburattewa. Department of Wildlife Conservation.

Mr. L. De Alwis. Former Director, Department of Wildlife Conservation, Government of Sri Lanka.

Professor C. M. Madduma Bandara. Geography Department, University of Peradeniya, Peradeniya.

Mr. J. Bandara. Assistant Director, Plant Protection Department, P.O. Box 49, Getembe, Peradeniya.

Dr. James Burleigh. Professor of Plant Pathology, Chico State University, Chico, California. Consultant, DAI/MARD.

Dr. Jinasiri Fernando. Deputy Director; Seed, Seed Certification, and Quarantine, Plant Protection Department, P.O. Box 49, Getembe, Peradeniya.

Dr. Shantha Hannayake. Geography Department, University of Peradeniya, Peradeniya.

Mr. Jayasingha. Manager, Maduru Oya National Park. Department of Wildlife Conservation.

Lisa Krynen. Aquaculture Specialist, Mahaweli Regional Training Center, Hansayapalama.

Dr. S. W. Kotagama. Chairman, Wildlife Programme, Zoology Department, Faculty of Science, The Open University of Sri Lanka.

Dr. K. Manuweera, Assistant Registrar of Pesticides, Plant Protection Department, P.O. Box 49, Getembe, Peradeniya.

Dr. Ajantha Perera. Zoology Department, University of Colombo, Colombo.

Mr. Sampson. Assistant Director (Wildlife), Randenigale. Department of Wildlife Conservation,

Mr. Hector Senerath. Assistant Director and Head, Plant Protection Department, P.O. Box 49, Getembe, Peradeniya.

Mr. A.D. U. S. Vattala. Department of Wildlife Conservation, GOSL.

Mr. Wilson. Assistant Director (Wildlife), Polonnaruwa. Department of Wildlife Conservation.

Dr. Hemanthi Ranasinghe. Forestry Department, University of Sri Jayawardhenapura.

APPENDIX B

MAHAWELI AGRICULTURE AND RURAL DEVELOPMENT PROJECT

KUDA OYA REFORESTATION PROJECT

Project Description and Specifications

TABLE OF CONTENTS

1. SUMMARY OF PROPOSAL REQUIREMENTS
2. PROJECT OBJECTIVE AND CONCEPT
3. PROJECT CONCERNS
4. PROJECT AREA
5. REFORESTATION STRATEGIES
6. COMMUNITY PARTICIPATION
7. POST-GRADUATE TRAINING AND RESEARCH
8. MANAGEMENT PLAN
9. WORK SCHEDULE
10. BUDGET
11. PERSONNEL SCHEDULE

SUMMARY OF PROPOSAL REQUIREMENTS

Offerer must include the following items in the proposal. Failure to address any required topic may disqualify the proposal.

1. Detailed planting plans forthe three river segments, including species to be used, where they will be procurred, how they will be planted and by whom, where they will be planted.

2. Detailed maintenance plans, including fertilization, watering, protection from buffalo and other threats, etc. Offerer should include a detailed incentive plan to encourage farmers to maintain plantings. etc.)

3. A plan for monitoring the growth of the new forest during the project period and beyond.

4. A detailed plan for bringing farmers and Farmer Organizations into the planning process and including them in the planting and maintenance of the forest.

5. A plan for working with farmers and Farmer Organizations on allocation of fruits, medicinal substances and other forest products among the farmers in the area. The primary assumption is that such products are the property and responsibility of the Farmer Organizations, but special consideration should also be given to riparian farmers who will bear most of the adverse impact of forest development at this site.

6. A concrete plan on how to handle the problem of existing encroachments on reserve land and how to discourage encroachments in the future.

7. Plans for developing and carrying out educational and training programs.

8. A specific plan for carrying out a preliminary baseline survey and mapping of current vegetation and land use in the project area. Such a study could involve university post-graduate students.

9. A detailed management plan as outline under 7.0 below.

10. A detailed work schedule showing tasks and targets on a monthly basis.

11. A detailed budget and separate budget explanation in which offerer justifies all budget items.

12. A detailed manning schedule, including job descriptions for each professional and management position and a general job description for each catagory of non-professional staff. Estimations of manning needs presented in the project description (page) should be used as guides. Divergence from these estimates is permissable but must be explained and justified.

13. A description of university facilities and capabilities that can be brought to this project.

14. A description of university experience in manageing and carrying out interdisciplinary, problem-focus research and contracts.

1.0. PROJECT OBJECTIVE AND CONCEPT

1.1. The objective of this project is to reforest approximately 10 km of riparian land on either side of the Kuda Oya immediately downstream from the Pimburattewa dam in Zone 5 of System B

(Figs. 1 and 2).

1.2 The project was conceived to enhance natural biodiversity in this largely agricultural landscape by restoring native, dry-zone riparian forest vegetation in bands up to 40 meters wide on either side of the Kuda Oya. The outer fringes of this forest area adjacent to fields and paddy, fruit and medicinal trees will be planted to provide non-destructive products of value to local residents. The primary purpose of the new forest, however, will be conservation rather than product production. Th+wreforested area will be treated as a conservation forest rather than a production.

1.3. The concept of this project also includes a strong emphasis on participation of local residents, especially the farmers adjacent to the reforestation areas. In this context, the cooperation and participation of farmer organizations and NGOs is essential for project success and sustainability.

2.0. PROJECT CONCERNS

2.1. Ecological Concerns

Restoration and maintenance of Dry Zone riparian forest ecosystems is a major goal of the project. This is based on the need for sustainability and preservation of bio-diversity.

2.2 Utilitarian Concerns

Although it is not the primary objective of the project to develop production forests, it is desirable to incorporate in the planting program, useful plant species such as those used in indigenous medicines or for human and animal consumption.

2.3. Engineering Concerns

There is a need to introduce bank-stabilizing species that would help in checking erosion of the stream banks and dykes.

2.4. Environmental concerns

The riparian forest will enhance wildlife habitat and improve the quality of life for local residents by providing accessable natural areas. There is some concern, however, that the forest will increase bird damage to nearby crops. attraction of birds and wildlife into the reforested area.

2.5. Training and Education Concerns

Newly forested areas can serve as educational sites for local schools and as laboratories for university students and researchers. They can also serve as demonstration sites for extension education for local residents.

2.6. Sustainability Concerns

The project should be designed in such a way as to maximize the sustainability of the new forests and of the local human community. Care must be taken to ensure that local residents see the forest as theirs and that they will want to protect and maintain it after this project ends in two years. It is for this reason that involvement and participation of local residents in all phases of the project is mandatory.

3.0. PROJECT AREA

3.1 Background

The Kuda Oya is a left bank tributary of the Maduru Oya (Figs. 1 and 2). With the construction of the Pimburattewa reservoir in the 1950s, the Kuda Oya was dammed in its upper reaches. The present channel of the Kuda Oya beginning from the Pimburettewa dam site collects water from the spill-way and drainage waters from the paddy fields on its either side. The terrain of the Kuda Oya Basin and the surrounding area is low-lying with marshy conditions. The streams tend to braid and meander and change their courses periodically. The project area generally falls within the Dry Zone and has characteristic land forms, soils and vegetation. With the progress of the Mahaweli Development Program, Pimburettawa irrigation scheme had also been integrated into the Mahaweli Project.

Under the Pimburattewa irrigation settlement scheme, settlers were brought to the area from different geocultural backgrounds. Some of them originated from this district while others have come from wet zone areas. Some of the settlers' paddy lands extend right up to the banks of Kuda Oya. At present farmers are organized into Farmer Organizations under the Agrarian Services Act.

The anticipated reforestation program covers about 10 Kilometers of riparian lands on either side of the Kuda Oya from the Pimburattewa spillway. This 10 Kilometer stretch has three distinct segments.

3.2. The Undeveloped Segment (UDS)

This covers the first two kilometers from the Pimburattawa spill way. Little of the original riparian forest remains in this stretch but parts of the riparian lands in this area have been replanted by the MEA with acacia and eucalyptus. There are hardly any farmlands in this stretch except for a small settlement at Damminna.

3.3. The Channelized Segment (CHS)

The next six kilometers of the river were channelized during

the development of block 502. In this area all the trees were removed and dykes were constructed on either side to prevent flooding. In some places the natural meanders of the river were cut off, leaving oxbows outside the dykes. In several places dykes are breached to let drainage waters from the paddy fields flow into the Kuda Oya. The distance between the dykes is approximately 60 meters and is occupied by the meandering channel of the Kuda Oya. In some places the meanders are beginning to undercut the toe of the dykes.

3.4. The Non-Channelized Segment (NCS)

The next two kilometers downstream were not dyked during the earlier period of development and the river has cut a deep and erosive channel with wide meanders. Flood waters emerging from the upstream channelized section inundate the low lying areas threatening adjacent agricultural lands. This segment is earmarked for improvement in conjunction with irrigation and drainage infrastructural development planned for block 503. However, it is anticipated that these improvements will be designed so as to conserve existing riparian zone trees by placing dykes as far from the river as possible.

4.0. REFORESTATION STRATEGIES

Reforestation strategies must address the particular needs of each segment of the river as follows:

4.1. CHANNELIZED SEGMENT (CHS)

4.1.1 Site conditions

The stream which meanders within the dykes in this zone carries a heavy load of water (up to 2 meters deep) during the rainy season when the Pimburattewa reservoir spills. The area within the dykes remains submerged during those periods and is used by farmers for buffalo grazing during other times. The planting program for this section should be designed in such a way that water flow in the rainy season is not impeded and farmers do not lose their grazing grounds. Figure 3 depicts a diagrammatic model for planting in this area. The following major zones in the CHS have to be treated separately.

4.1.2. Grazing area (A zone)

The area between the inner toes of the dykes should be left in grass for grazing. No planting should be done in this area.

4.1.3. Bank stabilization and flood control area (B Zone)

In the B zone a double row of bank stabilizing species can be planted at intervals of 2 m X 2 m alternatively. The following species are recommended for this purpose.

1. Bambusa vulgaris, kaha una (S), yellow bamboo (E)
2. Dendrocalamus strictus, una (S)
3. Pandanus thwaitesii, wetake (S), screw pine (E)
4. Saccharum arundinaceum, rambuk (S)

4.1.4. Inner slope of the dyke (C Zone)

The planting distance may be 5 m X 5 m. Trees should be planted in this area before the onset of Maha rains (before the stream begins to carry high volumes of discharge). The following are some of the species recommended.

1. Terminalis arjuna, kumbuk (S)
2. Aglaia roxburghiana, puwangu (S)
3. Madhuca longifolia, mee (S)
4. Polyalthia longifolia, owila (S)
5. Syzygium cumini, ma dan (S)

It is expected that these trees will eventually restore the original riverine setting.

4.1.5. Dyke area-(D Zone)

The trees in this area should be drought tolerant, medium size and shallow-rooted. A belt 4 m wide should be left out from tree planting on the summit of the dyke to facilitate the movement of agricultural vehicles, people and animals. The planting distance should be 4 m x 4 m. The following are some of the species recommended for this section.

1. Azadirachta indica, kohomba (S), neem (E)
2. Feronia acidissima, divul (S), wood apple (E)
3. Cassia fistula, ehela (S), Indian laburnum (E)
4. Dimocarpus longan, mora (S)
5. Siyambala (S) Tamarind (E)

4.1.6. Utilitarian (Gan goda) area (Zone E)

It is recommended to plant the area on the outer slope of the dykes with home garden plants that are widely used by the farmers in the Dry Zone. Already there are isolated patches of this type along the dykes. It is expected that these areas will eventually be developed into dry zone forest gardens. Some of the species recommended are,

1. Artocarpus heterophyllus, kos (S), jak (E)
2. Artocarpus altilis, del (E), bread fruit (E)
3. Mangifera indica, amba (S), mango (E)
4. Cocos nucifera, pol (S), coconut (E)
5. Areca catechu, puwak (S), areca nut (E)

4.1.7. Peripheral area (Zone F)

The area outside the dykes and the boundaries of paddy fields

is limited in many places. In others, low-lying lands display wetland conditions particularly where the old meander channels still exist. In such situations it is not possible to establish home garden trees. However, economically important plants such as banana, Pandanus (wetake), Sedges (pan), Colocacia (gahala), Lassia (kohila), etc. may be introduced into these areas.

4.1.8. Establishment of fire barriers

It is necessary to protect the planted species from fire and vandalism. This may be partly achieved by planting fire resistant species in strategic locations. It may also be necessary to introduce thorny species into these areas to discourage trespassing. It is also useful to persuade farmers not to burn hay and if they do, to prevent it spreading into the tree planting zone.

4.1.9. Buffalo Entry Points

The grazing area should be accessible from various places. These entry points may not be obstructed. Existing inlets in through the dykes may be used for this purpose.

4.2. UNDEVELOPED SEGMENT (UDS)

In this area the stream banks (B zone) and the barren lands (C Zone) on either side have to be planted. The planting model recommended for this section (Figure 4) is similar to that of CHS, differing only in the absence of the E zone.

Prevention of fire is very important in this area. At the peripheral areas fire resistent species should be planted. Species with economic value such as Aloe can be used for this purpose.

Trees recommended for the C zone of this segment are drought tolerant, fast growing and shallow rooted species generally found in the dry zone of Sri Lanka. The B zone plants are same as those recommended for CHS.

Trees recommended for the B zone of UDS are given below.

1. Berrya cordifolia, halmilla (S), Trincomalee wood (E)
2. Cassia fistula, ehela(S)
3. Chloroxylon swietenia, burutha (S)
4. Dimocarpus longan, mora (S)
5. Feronia acidissima, divul (S)

4.3 NON CHANNELIZED SEGMENT (NCS)

Remnants of original riparian forest are present in some areas of this segment. However, much of this area is disturbed. In

such places a 40 m wide belt on the right bank may be used for enrichment planting with trees recommended for the B nd C Zones. On the left bank only the bank stabilizing plants may be planted due to lack of space resulting from the spread of paddy fields up to stream banks. Figure 5 gives a model for planting in this zone.

4.4. PROCUREMENT OF PLANTING MATERIALS

The contractor shall be responsible for supplying seeds and planting materials to the MEA/MARD nursery in a timely manner to insure that adequate planting materials are available according to the planting schedule. Because the first planting period occurs at the beginning of the rainy season in 1993, plant will have to utilize whatever planting material readily available at the time. The plants available in the MEA/MARD nursery are given in Appendix 1. When possible, seedlings should be allowed to grow to 50 cm before transplanting, so they will have a greater chance of survival. Saplings of dry zone climax forest species may be collected from dry zone riparian lands if that is desirable.

4.5. GROUND PREPARATION

On sites where a dry grass cover prevails it will be necessary to clear weed the ground where necessary by manual scraping. However, the medicinal plants already in the areas should not be removed.

4.6. GENERAL GUIDELINES FOR PLANTING

1. Planting should be done to maximize the species diversity.

2. Trees should not be planted in rows.

3. The planting hole should be 1.5 ft X 1.5 ft X 1.5 ft. (= 0.5m)

4. Cow dung/compost should be added to the planting hole. (one basket per hole = 1 cubic foot)

5. A basal application of inorganic fertilizer is required. (30 grams per hole)

6. Tree guards or other protective means will be necessary at critical locations for protection of planted trees during the initial growth periods.

7. Farmers may be contracted to carry out planting in the CHS and NCS.

8. NGOs, school children and university students should be involved in planting in UDS.

9. Planting should be properly supervised.

10. All personnel involved in planting should be given adequate training under expert guidance.

4.7. TENDING OPERATIONS

1. Three major areas of tending are identified.

   a. weeding and casualty replacement.
   b. watering plants specially during the dry periods,
   c. maintenance and protection.

To motivate farmers for protecting plants an incentive program should be implemented.

4.8. MONITORING

Growth and development of the forest must be monitored closely; this may be carried out by university students as part of projects.

4.9. FIRE PROTECTION

Apart from establishing fire resistant species like Agave and Aloe, fire lines should be created between the paddy fields/open ground and reforested area. Care should be taken to maintain fire lines throughout the year.

5.0. COMMUNITY PARTICIPATION

Community participation is essential for the success and sustainability of the reforestation project. It is expected that the sub-contractor will seek active community participation throughout the project. The offerer must provides the following plans.

5.1. A PLAN FOR BRINGING FARMERS AND THEIR ORGANIZATIONS INTO THE PLANNING PROCESS IN ORDER TO MAKE THE FARMERS FEEL THAT THE REFORESTATION PROJECT IS FOR THEIR BENEFIT

Meet with riparian farmers and their organizations along with MEA/MARD officials to conduct open discussions on the need for and the usefulness of the project and to ensure their participation in the choice of species, planting, maintenance and protection of the reforested area.

5.2. A PLAN FOR PARTICIPATION IN PERIODIC LOCAL MEETINGS WITH FARMER REPRESENTATIVES TO KEEP THEM UP TO DATE ON PROJECT PROGRESS AND TO SOLICIT THEIR VIEWS.

It is advisable to organize frequent formal meetings with the representatives of the riparian farmers and existing farmer organizations. This should be arranged by the Resident Manager and Community Liaison Officer.

5.3. DESCRIPTION OF HOW THE LOCAL COMMUNITY WILL MANAGE THE FOREST, ESPECIALLY THE PLANTS OF ECONOMIC VALUE.

Sub-contractor should facilitate the process of sharing benefits from the reforestation project among the local communities. MEA/MARD policy is that such products belong to the Farmer Organizations. Special consideration should be given, however, to riparian farmers who will bear the major burden of forest development adjacent to their lands.

5.4. DESCRIPTION OF HOW TO HANDLE THE PROBLEM OF FARMERS HAVING ENCROACHED ON STREAM RESERVATIONS

An initial survey should be conducted to compile a detailed map of all riparian lands indicating encroachments. Through educational programs and institutional means encroachments into the area may be discouraged. The encroached land may be planted with suitable species with the concurrence and cooperation of farmers.

5.5. A PLAN FOR DEVELOPING AND CARRYING OUT EDUCATIONAL AND TRAINING PROGRAMS MAY BE PROPOSED.

6.0 <u>BASELINE SURVEYS AND LAND-USE MAPPING</u>

One of the first task will be the production of baseline maps of vegetation, land uses, and property boundaries in the project area.

7.0. <u>MANAGEMENT PLAN</u>

The offerer must provide a detailed management plan indicating the following.

1. Project Leader who will bare overall responsibility for the project and communicate with COP of MARD.
2. The project should have a Resident Manager (RM) who will be responsible for all day-to-day operations.
3. A Community Liaison Officer (CLO) working with the farmers and their organizations.
4. Adequate personnel to accomplish the project objectives.
5. Statement on how the University will manage the project and coordinate with MARD/MEA.
6. Detailed plan for project monitoring and evaluation.

8.0. <u>WORK SCHEDULE</u>

The offerer must provide a detailed time-chart indicating the planned activities of the project on a monthly basis for the entire project period.

9.0. BUDGET

The offerer must provide a detailed budget with necessary justifications including the following items.

1. Pre-project expenses
   a. planning and modelling

2. Capital costs
   a. planting materials
   b. planting and maintenance
   c. protection of trees
   d. Field office
   e. Office equipment and computers
   f. Audio-visuals
   g. other equipment

3. Recurrent costs
   a. Office maintenance
   b. Transport (vehicle hire)
   c. Audio-visual production
   d. Salaries and wages as listed in the manning schedule
   e. Workshops and Seminars
   f. communication (Telephone and fax)

4. Miscellaneous costs (including media and
   a. media and publicity
   b. University overheads
   c. Contingencies

10. PERSONNEL SCHEDULE

Provide a detailed statement of man-power requirements as given below. Task assignments, remunerations of each person must be explained and justified.

1. Management Staff

a.	Project leader	130 days
b.	Deputy Leader	45 days
c.	Resident Manager	approximately 23 months
d.	Community Liaison Officer	approximately 23 months
e.	Field supervisors	approximately 46 man months

2. Scientific Staff

a.	Reforestation Specialists	45 days
b.	Botanist	30 days

c.	Forest Ecologist	20 days
d.	Natural Landscape Architect	20 days
e.	Social Scientist	20 days
f.	Resource Economist	20 daus
g.	Land Surveyor	20 days

3. Support Staff

a.	Secretary (field office)	12 months
b.	Secretary/accounts clerk (campus office)	12 months
c.	Data Entry Person	3 months
d.	Environmental Artists	24 days
e.	Research Assistants	24 man months
f.	Labourers	approximately 46 man months
g.	Part-time support staff	offerer estimate

APPENDIX C

KUDA OYA REFORESTATION PROJECT

Farmer's Meeting
June 12, 1993, 4:30 - 6:00 pm

House of Farmer Somadasa near Kuda Oya Causeway, Wijayabapura Block
Meeting was held in a home garden under the shade of coconut trees.

Attendance
55 farmers
including 23 riparian farmers and 15 Farmer Organization leaders

Meeting was convened by Mr. Mahinda Panapitiya at 4:30 pm

Agenda

Introduction of Farm Leaders, Officials, and Visitors by Block Manager Mr.P. I. Chandrabose.

Welcome in Sinhala by MARD Chief of Party, Mr. Bruce Spake

"I wish to welcome everybody cordially on behalf of MARD. MARD project has always been working in close cooperation with farmers. Today's meeting is also for the same purpose. I wish all success for the deliberations of the meeting."

Meeting Objectives: Professor C. M. Madduma Bandara, University of Peradeniya

Explained the value and need of having farmers involved in programme and the importance of having MARD/MEA, the University, and the farmers working together. Explained the propose reforestation project and said that from the planning stage on the participation of the farmers is essential. Noted the need for concrete action at this, the third farmer meeting. Explained that Farmer Organization leaders and farmers adjacent to the Kuda Oya (riparian farmers) are essential participants and this is why they were invited. This group should get together to plan the next step.

Open Discussion - led by Mr. Abeygunawardena, MARD Farmer Organization Specialist.

Discussion

Mr. Abeygunawardena noted that this project is the farmer's project and that we are only facilitating it. The floor was opened for discussion

K. M. B. Gunarathana, Chairman, Pimburattewa Farm Organization -- Explained what happened in earlier meetings and noted that just planting a plant is not enough and that fencing is necessary on both sides of the dikes is necessary. He also noted that the riparian farmers are important in this project and they should be given the responsibility for looking after the forest.

Further, he noted that the farmers should be made to understand that there is an economic return from the project, that the farm organizations can shoulder part of the responsibility, and that this is a good program and it can be useful even for the next generation.

G. M. J. Bandara from Arunapura said that about 600 meters of his paddy field is adjoining the stream and that he has already started planting trees on his land and has requested assistance from the MASL in support his efforts. He said that "avenue planting program" was not successful, because it lacked community participation. He noted that he hailed from Galaewela village where there had been a very successful teak plantation where land had been leased for five years to farmers who w;ere expected to plant and look after teak trees in exchange for being allowed to interplant their own crops. He said that the plant species chosen for the Kuda Oya should fit into the environment. When the canal is closed the plants may die of dryness. Plants can also be destroyed by buffalo, therefore, barbed wire fencing is necessary. He suggested giving trees to farmers who would plant them on their land. He referred to an environmental cartoon that he has seen: A politician comes and plants a tree and goes away, then a goat turns up and eats the tree. Then finally a dog comes and waters it. And the dog says 'now we are the people who are looking after it'. He said we should not let this happen on this project.

Other farmers noted that there are no dikes in some areas and that dikes should be extended into those (unchannelized) areas. One farmers said that after the dikes are made floods decrease, but there are a lot of anicuts downstream that should be removed. Another farmer, suggested that riparian lands should be divided among and made the responsibility of the farm organizations.

After some discussion, the farmers resolved that a riparian farmer organization should be established. Names of proposer and seconder have been recorded by the interim secretary, Mr. G. M. J. Bandara. They also resolved that the membership of the organization should comprise all riparian farmers and representatives of Farm Organizations. They appointed an advisory group (including leaders of Farmer Organizations, Mahaweli and MARD representative, District Forest Officer, the A.G.A., and Buddhist clergy and school principals in the area) and an action committee (see notes of G. M. J. Bandara, Interim Secretary). The Action Committee shall comprised two riparian farmers nominated by each Farmer Organization in the Kuda Oya. Further, it was resolved that a meeting of the full membership should be held in the near future to adopt a constitution and elect office bearers.

It was agreed that Mr. G. M. J. Bandara should serve as contact person for the farmers on this project until formal office bearers are elected.

Participants were thanked for their participation and the meeting was adjourned at about 6:00 pm.

APPENDIX D

The Chinese Waterchestnut

By W. H. Hodge, *principal botanist*, and David A. Bisset, *scientific aid, Horticultural Crops Research Branch, Agricultural Research Service*

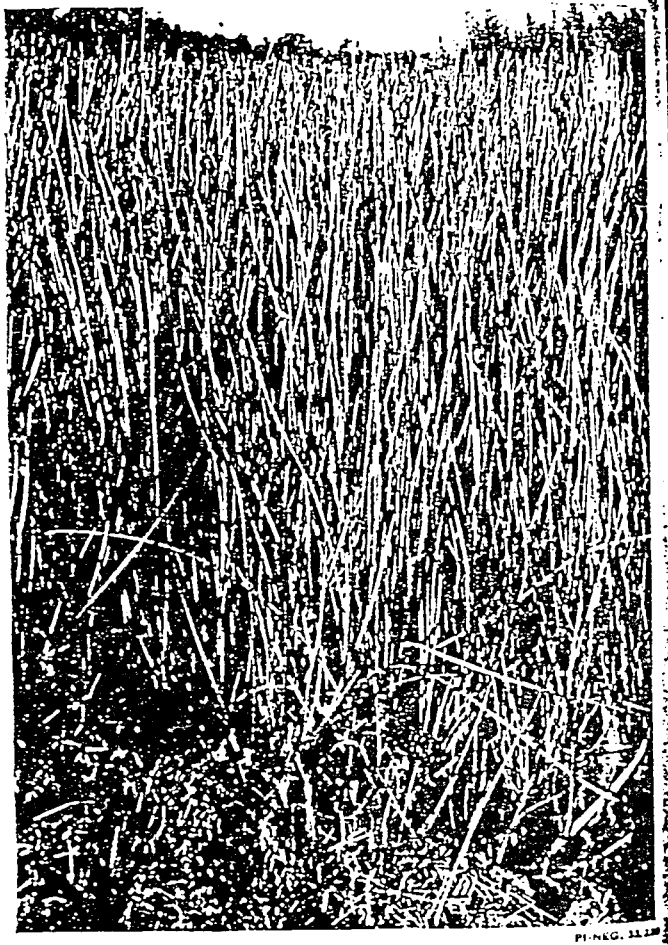
"Chinese waterchestnut" and "waternut" are English common names for a tropical sedge, *Eleocharis dulcis* (Burm. f.) Trin. (synonym: *E. tuberosa* Schult.) which is widespread in the tropics of the Old World. In the warm temperate parts of China, this species has long been cultivated for its corms, or so-called tubers. These are esteemed as a nutritious delicacy in Chinese cookery and are extensively eaten raw.

The plant is grasslike in general habit, growing to a height of 5 feet, and is cultivated somewhat like paddy rice (fig. 1). It is an important crop of southern China, and is also grown throughout the eastern part of that country as far north as Peiping.

Fairly large quantities have been imported into the United States in previous years. In 1947, the imports totaled about 2,500,000 pounds. By 1952, however, because of the embargo on shipments from China, this importation had practically ceased. The result was a shortage of this commodity, coupled with an increasing interest in establishing this type of waterchestnut as a specialty crop in the United States.

The Chinese waterchestnut is commonly known as "matai" (horse hoof) in the Canton district and throughout the provinces of Kwangsi and Kwangtung, but elsewhere in China the Mandarin name "pi chi" (pronounced *pee chee* or *bee chee*) is used. Perhaps the chestnut-brown color of the skin, together with the chestnutty flavor and texture of the white flesh, gave rise to the English name "waterchestnut" which has supplanted the Cantonese name "matai" in Chinese restaurants catering to occidental patrons. The name "waterchestnut" is also used extensively by both American and Chinese processors of this vegetable.

Unfortunately, the same English common names, "waterchestnut" and "waternut," are also used for quite a different floating aquatic plant, the waterchestnut (*Trapa natans* L.) often called "water caltrop." This Eurasian species has become naturalized to the extent of being considered a pest in some streams in the Eastern United States (fig. 2). The leaves of this plant form floating rosettes



PI-NEG. 33 239

FIGURE 1.—Mature Chinese waterchestnut plants, 5 feet tall, growing at the United States Barbour Lathrop Plant Introduction Garden, Savannah, Ga.

PI-NEG. 90 229

FIGURE 2.—*A*, Mature floating rosette, 18 inches in diameter, of the waterchestnut, *Trapa natans* L. (also called "water caltrop"), an aquatic pest often confused in name with the Chinese waterchestnut; *B*, the four-horned, nutlike fruit

which can hardly be confused with the upright leafless green stems of *Eleocharis dulcis*. Although the seeds of *Trapa* can be eaten, the characteristic four-horned fruits in which they are borne are quite distinct from the highly edible corms of *Eleocharis*. In view of this apparent confusion between plants, the Cantonese name "matai" has been recommended for use in the United States; however, the name "waterchestnut" is so firmly established that it seems impossible to supplant it. Under the circumstances, it seems best to distinguish between these two distinct plants by calling the economically valuable *E. dulcis* the "Chinese waterchestnut."

Botanical Description

In its general habit, *Eleocharis dulcis* resembles other species in this large genus of the sedge family (*Cyperaceae*). Characteristic of the genus is its lack of leaves, their photosynthetic function having been transferred to the numerous upright tubular septate stems. Under cultivation these run from 3 to 5 feet tall.

Insignificant flowers are produced among tiny imbricated scales located at the tip of the stems (fig. 3). Male and female flowers are produced but not concurrently. The female (pistillate) flowers appear first when the stem tips are 5 or 6 inches above the water level. Considerably later, after the stems have attained a height of about 24 inches, male (staminate) flowers appear in the same inflorescences. Tiny "seeds" (actually achenes) are produced, but these are of no importance in the culture of the plant as a crop.

Even in the wild state, *E. dulcis* apparently reproduces mainly through the vegetative production of subterranean rhizomes and corms. Rhizomes are of two types and are easily distinguishable. One, appearing early in the growth cycle (usually from 6 to 8 weeks after planting) serves to multiply the individual during the current

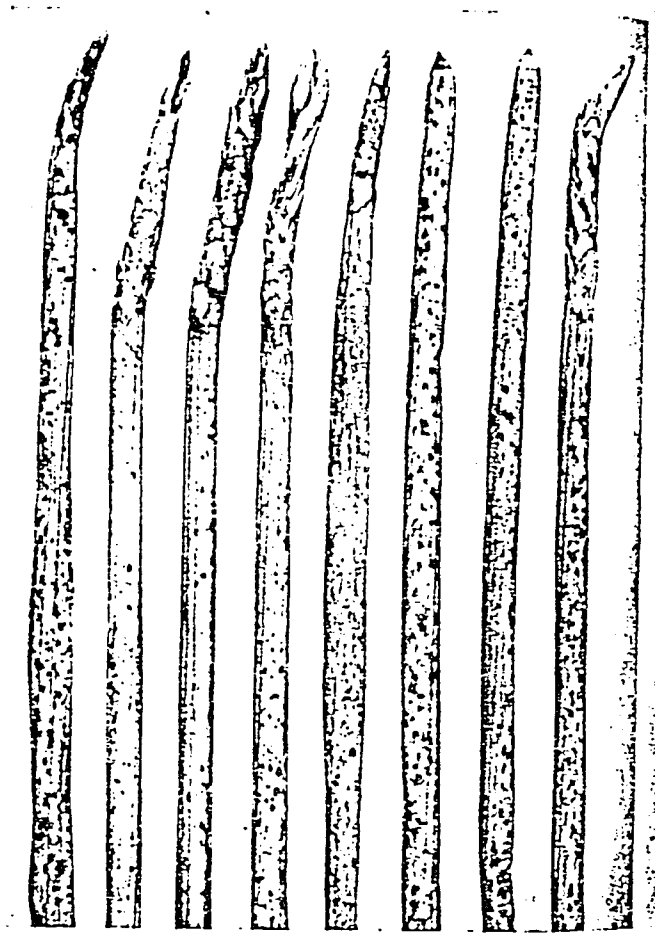


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FIGURE 3.—Dried Chinese waterchestnut stems, showing inconspicuous flowering structures at tips. (The spotting of the stems is caused by saprophytic fungi not present on the living plants.)

growing season through the lateral production of a number of daughter plants (fig. 4). Another rhizome type appears much later in the season, shortly after flowering. This type is produced by the mother as well as by all the daughter plants and is the important producer of corms which develop at their tips (fig. 5).

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FIGURE 4.—A Chinese waterchestnut plant (center) and the secondary plants produced by it early in the season through the growth of underground rhizomes.

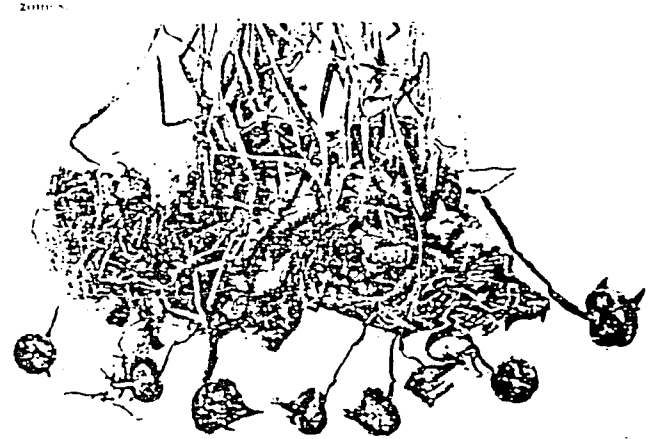

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FIGURE 5.—Corms and corm-producing rhizomes as they appear on a Chinese waterchestnut plant at the end of the growing season.

Waterchestnut corms usually are abundantly produced. In size and form, they bear a superficial resemblance to the corms of the garden gladiolus, being brown-skinned, subglobose, and vertically compressed, but the firm, white flesh inside is unusually crispy, like that of an apple (fig. 6).

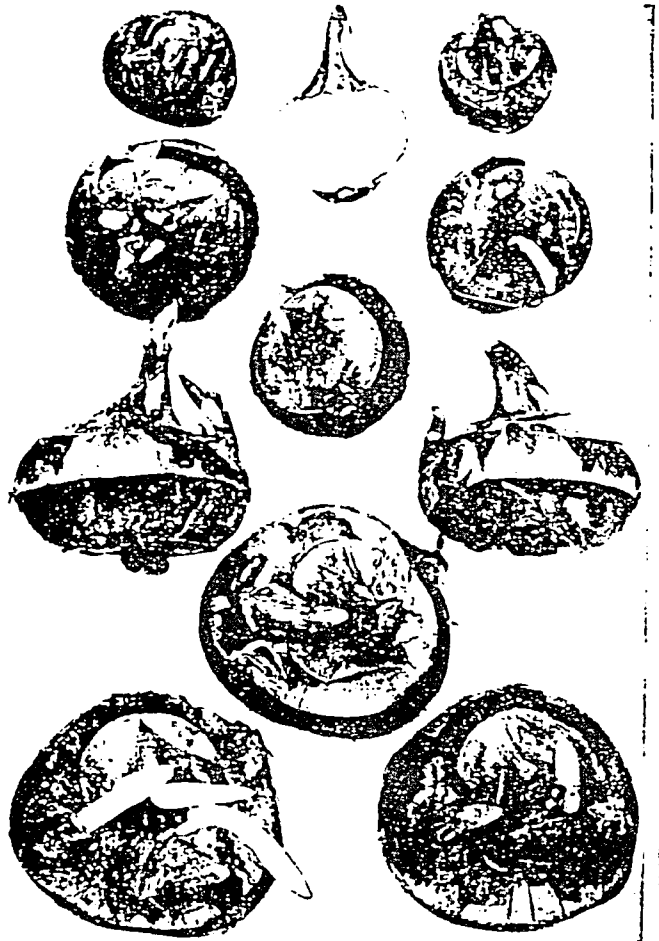

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FIGURE 6.—First-class Chinese waterchestnut corms (life-size); the top-center corm is shown in section. All are marketable except the smaller corms in the top row.

Introduction Into the United States

A superior variety known in southern China as "hon matai" was introduced by the Plant Introduction Section of the United States Department of Agriculture from Canton in 1934. This is the only type of Chinese waterchestnut now planted in the United States. This introduction (P. I.[1] No. 106274) was first grown at the United States Barbour Lathrop Plant Introduction Garden, Savannah, Ga., where, over a period of years, plantings have been made to determine cultural requirements, and also to make propagation material available for evaluation in other areas (fig. 7). "Hon Matai" has since

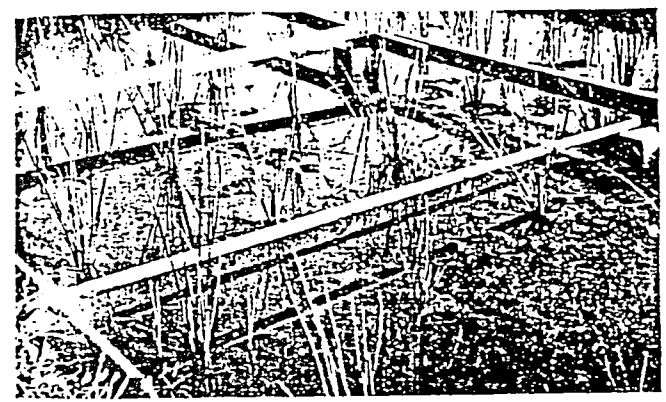

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FIGURE 7.—Test plots of Chinese waterchestnuts at the United States Barbour Lathrop Plant Introduction Garden, Savannah, Ga. Several of the plants have already produced laterals through the growth of rhizomes.

been tested in a number of localities in the South and on the Pacific Coast. These tests show that the plant can be successfully grown in the country. To date the best results have been obtained in the southern areas of the Atlantic Coastal Plain. Plantings in northern areas have been unsuccessful because of the lack of a long, frost-free season. The coastal section around Norfolk, Va., seems to be about the northern limit for the successful commercial culture of Chinese waterchestnuts.

Cultivation

Chinese waterchestnuts may be grown as an annual crop, under controlled irrigation, in warm temperate regions where there is a lengthy frost-free growing season of approximately 220 days. They are not a crop for swamplands or marshlands, unless such lands are fitted with banks and ditches to control water levels and facilitate

[1] P. I. refers to accession number of Plant Introduction Section.

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drainage for harvesting and preparation of the land. Complete details of culture have not been fully determined, but tests made at Savannah, Ga., indicate that the best planting time in the South is in March or April. In general, plantings should be made 2 to 3 weeks before the date of the last killing frost. In the spring, young plants are seriously injured by freezing temperatures.

Planting should be made in level, fertile soil with the plot surrounded by low banks or dams, making possible the retention of 4 to 6 inches of water over the entire field (fig. 8). Such soils as muck soils, which

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FIGURE 8.—A ¼-acre plot of recently planted Chinese waterchestnuts at the United States Barbour Lathrop Plant Introduction Garden, Savannah, Ga. Water was maintained at a depth of approximately 5 to 10 inches by the overflow from an artesian well.

are rich in organic material, are favored, but they should be tested to determine their acidity. Chinese waterchestnuts do not seem to do well in acid soils, and such difficulties as have been encountered to date with this new crop have been associated with overacid conditions. The pH should run between 6.9 and 7.3. Ground limestone may be added to or broadcast over the soil as an aid in correcting acidity.

Corms used for seed purposes should be selected to insure soundness, freedom from injury, and intact terminal bud, and they should be of good form. Observations at Savannah indicate that, although a crop can be produced from small seed corms, superior growth and production may be expected if large corms are planted. To counteract drying out or sprouting prior to planting, propagation stock should be kept cool and moist. Storage temperatures ranging between 30° and 40° F. will keep the corms reasonably dormant.

Depending on the latitude, one of two methods of planting may be used. In northern plantings, at about the latitude of Norfolk, Va., where the growing season is shorter, corms may be started early in protected seedbeds or nursery plots where the necessary growing temperature of approximately 66° F. can be maintained. Such beds should be well prepared. The corms are planted about 2 inches deep and are spaced 4 to 6 inches apart in each row, while the rows are spaced 6 to 8 inches apart. Following planting, the bed is flooded to settle the soil, after which the water is withdrawn. The grasslike stems will appear following a germination period of about 10 days.

When the plants are about 8 to 12 inches high, they should be transplanted to the permanent field beds or plots. This is a hand operation, requiring the careful moving of each young plant to its final field position. If the soil of the seedbed is first softened by flooding, the young plants can be removed much more easily. By carefully placing a hand under the seed corm and raising the corm and plant vertically, the entire plant and its root system can be lifted with little injury. Such started plants should be set 30 inches apart, in triangular arrangement, in prepared plots that are kept flooded thereafter with 4 to 5 inches of water (see fig. 7). Careful handling of plants of this type should insure the establishment of 95 percent or more of the young transplants.

In southern plantings, at about the latitude of Savannah, Ga., and points south, the seedbed and transplanting procedure described above may be followed, or corms may be planted directly in permanent field plots. For permanent planting, corms should be planted 4 to 5 inches deep and 30 inches apart in rows that are similarly spaced. In small plantings, seed corms may be set by hand in holes dug with a hand trowel. The corm is placed in the bottom of the hole and covered with loose soil, which need not be firmed or packed. In large plantings, furrows may be opened with an opening plow or colter, and the corms dropped in the furrows at 30-inch intervals. They can then be buried with a covering plow or hiller.

After planting, the entire plot or field should be flooded and kept submerged for a day, after which the water supply should be shut off and the water in the plot or field allowed to settle and drain naturally. This initial flooding settles the soil around the newly planted corms and facilitates the establishment of the young plants. As soon as they are 8 to 12 inches high, the planting should again be flooded and kept flooded with 4 to 5 inches of water throughout the remainder of the growing season.

Weeds have not proven to be a problem in the culture of Chinese waterchestnuts, especially if the soil is tilled a day or so before plantings are made. If weeds become established in the plots after the corms are planted, they should be removed before the plots are flooded permanently. Any subsequent weeding should be done in such a manner as to avoid unnecessary trampling or packing of the prepared soil.

Under favorable conditions, plants develop rapidly, and in 6 to 8 weeks' time, rhizomes will be growing out from the base of the original plant, giving rise at their tips to secondary plants which appear at varying distances from the parent.

Chinese waterchestnut plants continue to grow throughout the summer season, the many lateral rhizomes producing secondary plants in such numbers as to hide or cover the soil and floodwater completely with a dense mass of tubular, leaflike stems (see fig. 1). The tips of the stems often die back a bit, becoming brown during the growing season, but this is a normal decline and is to be expected. Following the completion of the flowering period in late summer, all the plants form corm-producing rhizomes. The crop of corms usually reaches maximum size between early fall and the first heavy frost. At the close of the growing season, there will be corms in all stages of development. Fully mature corms are chestnut brown in color, whereas immature corms are whitish. Corms should be left in the ground as long as possible so that the immature ones can mature properly.

At the latitude represented by Savannah, Ga., the first killing frost usually comes in the last half of November. Water should be drained from the planting approximately 30 days before this killing frost or at the time when the plants have attained maximum maturity. Removal of the water serves to hasten maturity of the corms and also aids in the harvest by providing a drier, more easily handled soil.

As soon as the stems are dry, they should be removed either by burning or cutting, for if left on the plot they serve as a protected retreat for rodents which may dig down and cause serious havoc with the crop.

The dry stems, when harvested, have proven useful in several ways. They are eaten readily by cattle; they make an excellent mulch or a superior compost; and they can be utilized as packing material for the shipment of plants.

Fertilizing

Chinese waterchestnuts require large amounts of plant food; and on average soils, heavy applications of high-grade, complete fertilizer, such as would be used for other vegetable crops, should be added. Applications at the total rate of 1 ton per acre have promoted maximum production. Approximately one-third or one-half of this total should be applied to the soil during the preparation for planting. Fertilizer can be broadcast and stirred into the soil with tillage operations. Organic manures can also be applied to the soil before preparation; however, such fertilizer should be well rotted before application and should be applied 2 to 3 weeks in advance of the planting date.

Another application of fertilizer (one-third or one-fourth of the total application) should be made about 8 to 10 weeks after planting, or at the time that the first of the secondary plants, produced by the parent, are appearing. For this application the beds should be drained and the fertilizer broadcast over the plot when the plant stems are dry, to prevent "burning" or similar injury.

The balance of the fertilizer should be applied during the last half of August, prior to the initial development of the young corms. Inasmuch as the developing rhizomes are tender and easily broken, no walking or moving of equipment should be attempted in the plot after plantings are established, for such traffic would injure considerable numbers of the developing young rhizomes.

Harvesting

Approximately 20 to 30 days after the first killing frost, or after the plants have attained maximum maturity, harvest of the crop may be started. At such time, practically all the corms are full grown and have assumed the chestnut-brown color typical of mature corms of the variety "hon matai." If desirable, some corms may be dug as soon as the plants attain maturity, but at such an early harvest date there will be a considerable number of immature white or light-colored corms. These young corms are not so sweet and palatable or so suitable for cooking as those which have fully matured underground, nor are they so acceptable to the trade. Where winters are mild, as at Savannah, Ga., the crop may be left in the ground, to be dug as needed.

Because of the heavy and compacted nature of the soil in which they are grown, Chinese waterchestnuts are not easy to harvest. In small plantings, corms are dug most easily with handtools. A spading fork is well suited for this purpose, and when such a tool is used, the soil is turned carefully and the corms are picked out by hand. Care should be taken to avoid bruising the corms with the digging tool.

A ½-inch mesh screen, laid horizontally on supports, is useful in harvesting small plots (fig. 9). The soil is carefully lifted onto the screen and worked over with rubber pads or paddles. Approximately

PI-NEG. 50 219

FIGURE 9.—Harvesting a small Chinese waterchestnut planting at the United States Barbour Lathrop Plant Introduction Garden, Savannah, Ga. Soil is screened as dug, the corms being dropped into water in the large container.

98 percent of the corms will remain on the screen as the soil is worked through. These are picked up and dropped into a bucket or other container filled with water. This method not only prevents the bruising that would occur from dropping corm upon corm, but it also helps remove excess soil. Although such harvesting methods may seem laborious, the labor cost involved is not excessive providing there is a good production of corms.

In larger field plantings, corms may be harvested advantageously by use of a small plow that turns a furrow to a depth of approximately 6 inches. Each furrow should be raked with a potato rake, the tines of which have been covered with soft rubber tubing; the ends of the tines should preferably be sealed with the rubber. As the corms are picked up, they are carefully placed in containers and then carried to a suitable washing device for the removal of excess soil and debris.

After careful washing, the corms are placed in shallow trays to dry. Slow drying in shade is preferred to sun-drying. When no moisture remains on the surface of the corms, they can be packed for shipment or prepared for storage.

For special harvesting and handling precautions for corms that are to be stored, see section on storage (p. 13).

Diseases and Pests

Chinese waterchestnuts are still too new a crop in this country to have provided much information regarding potential diseases or pests.

Already mentioned under "Cultivation" (p. 8) is the apparent necessity for a proper pH level in soil in which the waterchestnuts are to be grown. The only difficulties so far reported in the culture of this specialty crop seem to be associated with acid soils. Sometimes plants grown under such conditions undergo gradual deterioration about the time of flowering. In this weakened state, they may be more subject to attack by disease. The only pathogen reported for this crop is a stem fungus (*Cylindrosporium* sp.) found attacking plants growing on a soil of high acidity (pH 5.5).

At present the most serious insect pest is the billbug, *Calendra cariosa* (Oliv.), a species that generally feeds on native sedges. It has damaged test plantings of the waterchestnut in central Florida.

In one planting in Florida, Chinese waterchestnuts have been observed being attacked by a stem nematode, *Ditylenchus* sp., and by the awl nematode, *Dolichodorus heterocephalus* Cobb. However, the pathogenic significance has not been determined, and control procedures are unknown.

Rodents, especially rats and muskrats, relish waterchestnut corms and thus are a potential threat to the crop, especially if the plantings are near the natural haunts of these animals. The cutting-off or burning of the stems, once the mature waterchestnut plot has been drained and dried off in the fall, makes the crop less inviting to such pests by destroying their shelter from natural enemies. It is conceivable that if allowed to burrow in the retaining banks, such rodents, as well as crayfish, might also interfere with the maintenance of the water level required for this crop by honeycombing these banks. Regular patrolling of the banks of the plots is usually sufficient to drive off such pests.

Yield and Marketing

In suitable locations and with liberal applications of organic or other fertilizers, good yields should be expected from this crop. In southern China, yields are reported ranging from 2,700 to 5,000 pounds of corms, mainly of good size, from ¼-acre plots. The maximum production on trial plots at Savannah, Ga., has been approximately 1 1/16 pounds per square foot, or about 47,000 pounds per acre. Under good growing conditions, 1 plant (representing the mother and all daughter plants produced in a season from a single planted corm) has produced 20¾ pounds of corms. Such a plant occupies an area of about 25 square feet at harvesttime.

Marketability

Corms vary considerably in size and, under good conditions of growth, may measure as much as 45 mm. in diameter. In general, only corms 30 mm. (1 3/16 inches) or more in diameter are acceptable to the trade. About 60 percent of the yield is usually marketable. Smaller corms (20 to 30 mm. in diameter) can be saved for seeding purposes; but any surplus can be used for special purposes suggested in the section on utilization (p. 14). Corms damaged or bruised during digging may be salvaged and canned.

Market Prices

Around 1952, following the embargo on imports from the Chinese mainland, increasingly attractive prices were offered for homegrown Chinese waterchestnuts. By 1954, the prices paid to small domestic growers in the United States ranged from 35 to 80 cents per pound, as compared with prices of 30 to 40 cents received for corms still being imported from Formosa.

Storage

Although fresh corms of Chinese waterchestnuts are preferred by the trade, corms can be satisfactorily stored for market purposes if containers are used that are reasonably tight but not airtight.

Before storage, the corms should be graded to remove all broken or damaged individuals and then washed in clear water to remove soil and foreign matter. They should then be air-dried until all surface moisture is removed. After drying, the corms should be carefully packed in moistureproof containers, but *not sealed airtight*. Containers holding approximately 16 gallons are convenient and easily handled. The commercial storage temperatures should be between 30° and 40° F., the range commonly used for storage of apples, celery, and lettuce. Corms packed and stored in this manner have been kept successfully for 6 months.

For home purposes, Chinese waterchestnuts can be washed, dried, and placed in mason jars, with lids applied *but not sealed*, and the filled jars kept in the home refrigerator. If storage temperatures are too high, sprouting of the waterchestnuts may occur. Some experiments have been made with storage in plastic bags, which seem suitable for holding corms for short periods in the home refrigerator *Provided the bags are not sealed tight.*

Chinese waterchestnuts cannot be kept successfully in open storage, for they soon begin to shrivel and in a few days become worthless for home use.

It should be emphasized that the most careful harvesting and handling methods and procedures should be used, to avoid bruising or injuring the corms that are to be stored. When the corms are mature, they are turgid and are thus susceptible to injury by bruising, dropping, knocking, and other kinds of rough handling. Sound, unbruised corms can be stored for much longer periods than corms that have not received careful handling during digging and harvesting.

Experiments at the Barbour Lathrop Plant Introduction Garden have shown that mature corms can be left in the soil for several months after maturity, that is, during the winter months of December, January, and February. Under such natural storage conditions, the temperature of the soil should be observed; and if the soil temperature rises above 56° F., the corms should be examined to determine whether sprouting has begun. If sprouting is detected, the crop should be dug and disposed of, or stored under refrigeration to retard sprouting.

Processing

Although Chinese waterchestnuts are in greatest demand in the fresh form, interest is developing in standardizing procedures for processing them by canning and freezing. Corms to be processed are first peeled. Hand peeling is done in the canning plants of the Orient where labor is cheap. The flattened shape of the corms makes them difficult to peel by standard mechanical means, and no completely satisfactory new method of peeling has been devised. A plate of hand-peeled corms is shown (fig. 10).

The National Canners Association recommends processing periods for Chinese waterchestnuts similar to those for white potatoes. The recommended commercial-canning temperature would be 240° F. after an initial temperature of at least 140° F., with the following processing periods for the can sizes designated:

Size of can:	Minutes
No. 2	30
No. 2½	35
No. 10	45

For home canning in glass jars, waterchestnuts should be processed, 30 minutes for pints and 40 minutes for quarts, in a steam canner at 10 pounds pressure and a temperature of 240° F.

Corms to be frozen are held at standard freezer temperatures. In general, canned waterchestnuts lose much of their flavor but retain their crispness, whereas frozen waterchestnuts retain the flavor but are less crisp than the canned product.

Utilization

The corm of the Chinese waterchestnut has a crisp, white, applelike flesh that is both sweet and starchy. Some users find the flavor and texture of the uncooked corm similar to that of fresh coconut rather than the true chestnut. The total solids approximate 22 percent, of

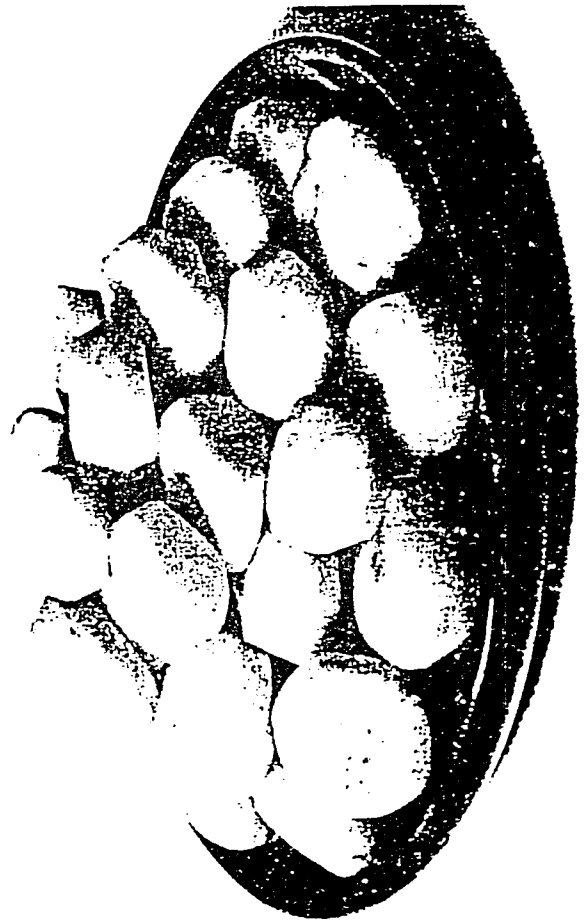

FIGURE 10.—Pared and canned Chinese waterchestnuts, ready for use.

which about 1.4 percent is protein, 19 percent carbohydrate, and the fiber less than 1 percent.[2]

The vegetable is used best in combinations and seems to blend well with almost any food. It has been used satisfactorily in a number of American dishes, such as omelets, gravies, all kinds of meat and vegetable stews, soups, macaroni-and-cheese en casserole, and mixed salads. In contrast to the behavior of most common vegetables, which soften under cooking, the corms fully retain their crisp texture when cooked—a texture that adds an excellent quality to the dish in which they are used.

Chinese waterchestnuts, especially the smaller corms which are not marketable, can also be used for various types of unusual, high-quality pickles. The crisp texture enhances the tastiness of such preparations.

Surplus small corms (see p. 13) are suitable for use, not only as pickles, but also as feed for livestock—especially fowl, which relish these corms greatly.

Waterchestnuts are standard ingredients of most Chinese dishes, and in the Chinese restaurant trade they are much in demand. The growing popularity of Chinese foods and their increasing use by the canning and frozen-food industries in the United States suggests even greater demand for this unusual Chinese vegetable.

When prepared for the home table, the corms are pared and usually sliced about ¼ inch thick before being cooked. Paring is facilitated if a slice is taken from the bottom and from the top of the corm, after which the epidermis can be removed from the sides (see fig. 10). When cooked separately from other foods, Chinese waterchestnuts are boiled in slightly salted water. The cooking time required for the sliced corms is rather short—not over 15 minutes—and even partial cooking is often entirely satisfactory.

For omelets and other dishes requiring a very short cooking period, corms are best shredded; if sliced, however, they should be sliced very thin, then cut up into small pieces.

[2] LEUNG, WOOT-TSUEN WU, PECOT, R. K., and WATT, B. K. COMPOSITION OF FOODS USED IN FAR EASTERN COUNTRIES. U. S. Dept. Agr. Handb. 34, 62 pp. 1952. [Processed.]

APPENDIX E

Chinese Water Chestnut or Matai—*A Paddy Crop of China*

This edible corm of a sedge has long been valued throughout the Orient as a vegetable delicacy and as a source of medicine and starch. Imposition of an embargo in 1950 on commercial shipments from Communist China has promoted interest and experimentation in cultivating it in the climatically milder regions of the New World.

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Introduction

The family of the sedges, Cyperaceae, is an important contributor to the world's vegetation and flora, but, unlike the closely related family of grasses, the sedges are not noted as producers of important economic plants. Scarcely a half-dozen species from its ranks have entered into the service of man and then only to a very minor extent. One of the best known of these is papyrus, *Cyperus papyrus* L., formerly important as the paper plant of the ancient Egyptians but now grown solely as an ornamental aquatic along with its sister species, *Cyperus alternifolius* L., the umbrella-plant. At least two sedges have been used by man as minor sources of food. One of these is the Old World chufa, *Cyperus esculentus* L. The other is the Chinese water chestnut [1], or matai, *Eleocharis dulcis* (Burm. f.) Trin., whose unusually crisp edible corms have made it the most important, economically speaking, of this insignificant group of sedges. During the last decade there has been interest in the establishment of this plant as a new crop in the United States. The federal Department of Agriculture has investigated the possible domestic culture of the Chinese water chestnut and has published the results in a recent circular (3). A discussion of this plant and its culture in the Orient was not included in the publication and so is being summarized here.

[1] Unfortunately, species of the weedy aquatic genus *Trapa* are also known commonly as "water chestnut", but they should not be confused with *Eleocharis dulcis*. *Trapa bicornis* is also grown in China, under the name Ling Ko, for its two-horned edible nuts (10).

History

Eleocharis dulcis is a widespread variable species native to fresh-water or brackish marshes of the Old World tropics from Madagascar to India, southeastern Asia, the Philippines, Malaya, Indonesia, Melanesia and Fiji. According to Merrill (quoted in 2), the plant is never cultivated in most of this vast range. This is substantiated by others. For example, though the plant is common in the Fiji Islands, its potentiality as a food is apparently unknown to the natives. There, as elsewhere throughout its range, other plants superior for food are apparently abundant or easier to get. The water chestnut could not compete with those for the favor of man.

Apparently it was in Indo-China or in southeastern China that the species was first cultivated and developed into a

strain yielding corms far superior in size and sweetness to those normally produced in the wild. The Chinese have been able horticulturists since early times, and population pressure has forced them to utilize and develop most wild plants having food value. Thus *Eleocharis dulcis* was brought into cultivation and today has become known as one of China's unusual vegetable crops.

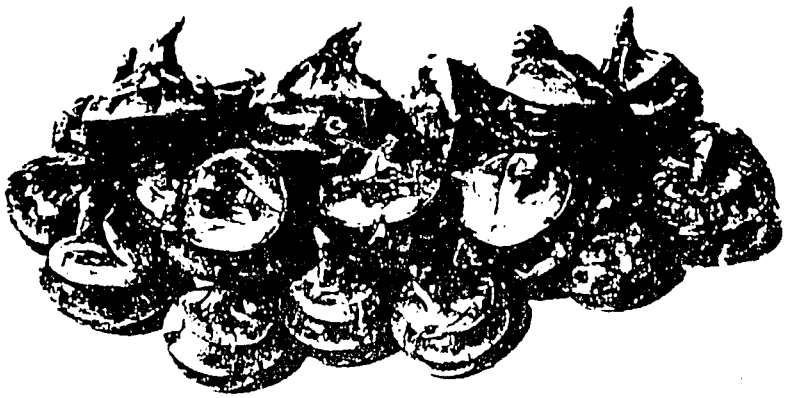
Like that elsewhere in southeastern Asia, China's food economy is based primarily on rice, the native staple cereal. In the domestication of cultivated plants, cereal species, if available, are generally believed to have been selected first. This would include the domestication of rice. In the Orient, rice is grown widely as a water crop in paddies. Special techniques have had to be learned in the culture of such a crop, and, because of this, agriculturists in that region probably looked with favor on any other edible aquatic plants which could be grown along with paddy rice. Actually, certain of these may have first appeared as weeds among the rice or along the margins of the paddies. Among such esculent species would be included the Old World arrowhead (*Sagittaria sagittifolia* L.), Oriental lotus (*Nelumbium nucifera* Gaertn.), sweet flag (*Acorus calamus* L.) and water chestnut (*Eleocharis dulcis*). The last-named species, under the synonym *Heleocharis plantaginea* R. Br., is reported even today as spontaneous in the rice plantations of the Tonkin delta (4). Whatever the case may be, these and other aquatic species of humid monsoon Asia are now valued food plants in that part of the world, and certain of them enter regularly into crop rotation as practiced with paddy rice in southern China. The remark has been made that the rest of the world has developed few cultivated hydrophytes compared to this region. As a possible explanation, one can add that of the major cereals rice is the only one that is an aquatic. In the development of rice culture it would be logical to expect man to discover satellite plants that could be similarly grown as sources of food.

Although it is evident that *Eleocharis dulcis* has been cultivated in China for many centuries, it was not until the XVII century that this unusual vegetable became known to western civilization through the reports of European missionaries. Martini (7) and Le Comte (5) are among those who prior to 1700 published brief but unmistakable descriptions of this crop under the Chinese name "peci". Of a city in the province of Che Kiang, Martini wrote, "*Nascitur per totam hanc regionem in stagnantibus aquis fructus figura rotundus, Peci Sinae vocant, cujus magnitudo castaneam nucem haud multum excedit, pellis subtilissima pulli coloris nucleum vestit, cujus intus candidissima caro est plena succo gratique saporis, durior est quam pomorum vulgarium, ac parumper acida*".

Edible Corms

The esculent portions of *Eleocharis dulcis* which have made this species interesting to man are the corms, or tubers, the so-called "water chestnuts". These are produced in large quantities on numerous subterranean rhizomes toward the end of the growing season. In size and shape the corms resemble those of the garden gladiolus. But in the Chinese water chestnut the plump corm is firm and white, and possesses an unusually crispy apple-like texture that is sweet to the taste. It is the crispness of texture which has endeared this vegetable to the Chinese, who find that this quality adds something very distinctive when incorporated in their many delightful dishes. Even after cooking, which softens the flesh of most other vegetables, the flesh of water chestnuts, whether sliced, diced or chopped-up, still remains crisp. Because of this characteristic they are easily detected among the numerous other components of a dish in which they are included.

FIG. 1 (*Upper*). Plants of hon matai (*Eleocharis dulcis*) at time of flowering.
FIG. 2 (*Lower*). The inconspicuous (pistillate) flowering spikes of *Eleocharis dulcis*.



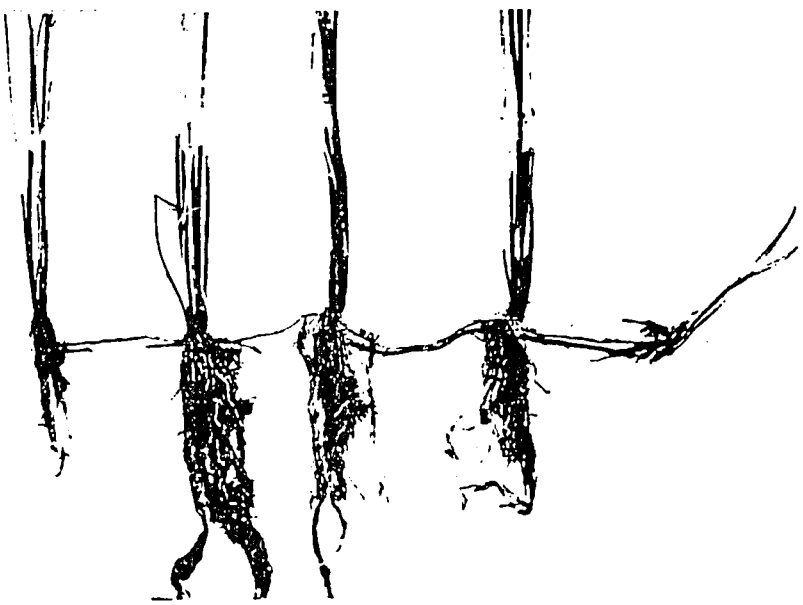


FIG. 3 (*Upper*). Typical edible corms of hon matai, the socalled Chinese water chestnuts. ×¾.

FIG. 4 (*Lower*). Young matai plants uprooted to show vegetative reproduction by means of rhizomes.

As might be expected with a species which is essentially tropical, the center of cultivation of *Eleocharis dulcis* in China lies in the warmer southern provinces. According to the Chinese, the finest water chestnuts (e.g., the largest and the sweetest) are produced in the vicinity of Kweilin in Kwangsi Province. Nevertheless, *Eleocharis dulcis* is grown commonly throughout southeastern China as far north as the Yangtze River (2). However, it has been observed by agricultural explorers of the United States Department of Agriculture near Peiping (40° north latitude). The range of its cultivation in China is thus extensive, running for some 2500 miles north of the Indo-China frontier. It is not surprising therefore to learn that *Eleocharis dulcis* has several Chinese names. Throughout southern China, especially in the provinces of Kwangtung and Kwangsi, the common name used is the Cantonese "matai" (pronounced mah-tie), meaning "horse's hoof", in evident reference to the shape of the edible corm. Elsewhere in China, especially in the north, a Mandarin name, "pi chi" (pronounced pee chee or bee chee), is used. This also appears in the forms "pi tsi" and "peci", the latter spelling being the form originally given in 1655 by Martini. The appellation "wu-yü" is also recorded (9). Since the great majority of Chinese-Americans are of Cantonese extraction, the Chinese name "matai" is more frequently met with in this country and has been recommended as a substitute for the English name, water chestnut.

Two apparently distinct types, differing mainly in size and texture of the corms, are grown in southern China. One of these varieties is known by the Cantonese names "hon matai" and "Kweilin matai"; the other passes in the Cantonese vernacular as "sui matai". Hon matai prefers sandy soils and produces large corms with a sweet and juicy flesh enclosed by a brownish skin. The Chinese word "hon" may be translated as "dry" and possibly refers to the fact that this variety is harvested under dry soil conditions after the paddy water is drawn off. This is the variety of matai which has made the region around Kweilin noted as a source of choice corms, a fact reflected in the use of the alternative name "Kweilin matai". Hon matai has a sweet flesh and for this reason is frequently eaten raw, out-of-hand; because of its crispness, it is also the variety which appears sliced in Chinese foods. The variety sui matai produces smaller black-skinned corms possessing a dry flesh. It is said to grow better in fields underlain with clay. Because of its drier flesh, sui matai is not palatable as a fresh vegetable and it finds its chief use in the manufacture of starch.

Notes on nutrients found in corms of hon matai, based on 100 grams of pared corms as compared with an equivalent weight of unprepared corms, have been compiled by the United States Department of Agriculture (6), as shown in Table I.

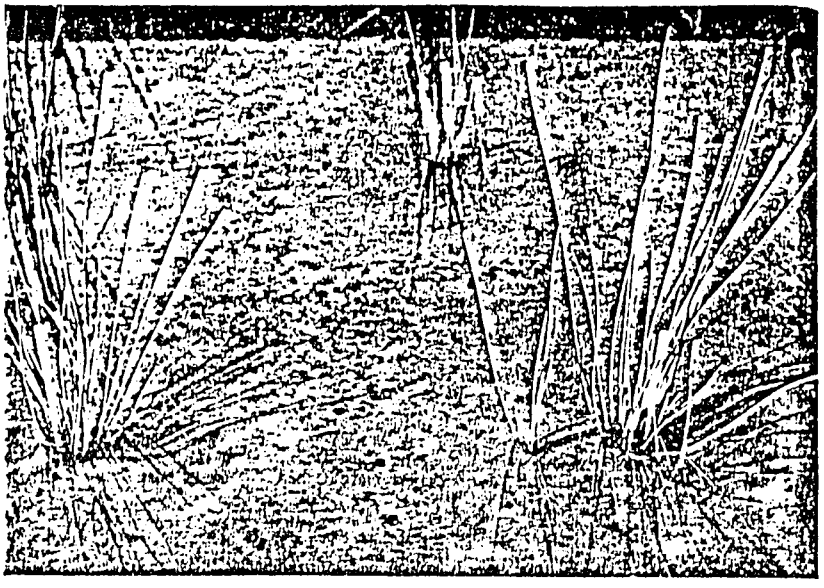
Botanical Description

Taxonomy. The existence of the two types of matai mentioned previously has undoubtedly been one reason for the

TABLE I

COMPOSITION OF MATAI CORMS

	Edible portion, pared	As purchased, before paring
Refuse (pct.)	0.0	23.0
Water (pct.)	78.3	60.3
Food Energy (cal.)	78.0	61.0
Protein (gm.)	1.4	1.1
Fat (gm.)	0.2	0.2
Carbohydrate (total) (gm.)	19.0	14.6
Carbohydrate (fiber) (gm.)	0.8	0.6
Ash (gm.)	1.1	0.8
Calcium (mg.)	4.0	3.0
Phosphorus (mg.)	65.0	50.0
Iron (mg.)	0.6	0.5
Ascorbic acid (mg.)	4.0	3.0



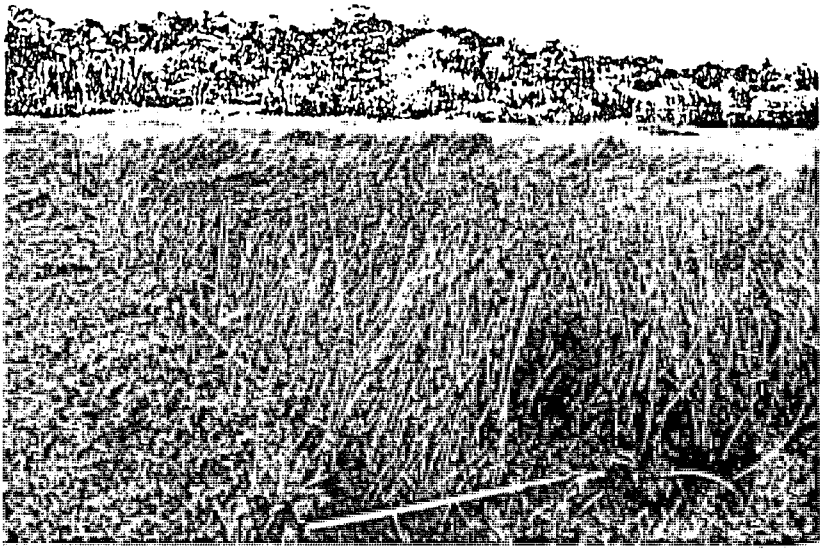


FIG. 5 (*Upper*). Young plants of hon matai in a paddy as they appear early in the growing season. Each plant is beginning to produce daughter plants through the growth of subterranean rhizomes. Later in the season all available paddy space will be completely filled with plants.

FIG. 6 (*Lower*). A quarter-acre paddy of mature hon matai plants as they appear in late summer at the time when corm-producing rhizomes are forming. The stems are four to five feet tall.

numerous binomials applied by botanists down through the years. At present the binomial *Eleocharis dulcis* is generally accepted as including all these forms of matai and especially entities previously described under such names as *Eleocharis plantaginea* R. & S., *E. plantaginoides* W. F. Wight, and *E. tuberosa* R. & S. The details of synonymy were discussed by Merrill [2] in 1917 and more recently by Svenson [3].

Variability in *Eleocharis dulcis*, although shown in the culms, is concerned primarily with the general morphology of the corms. In their strictest sense the binomials *Eleocharis dulcis*, *E. plantaginea* and *E. plantaginoides* have referred to the wide-ranging, wild form(s) producing small, starchy, dark-skinned corms (or none at all); this form generally grows in stagnant water recorded as either fresh or brackish. Although occasionally used as a wild source of food, particularly in Java and in the Philippines, this form has not been cultivated except in China (and possibly Japan), where it is apparently represented by sui matai. Opposed to this wild progenitor form is the one originally described as *Eleocharis tuberosa*, the plant producing the large, discoid, sweet-fleshed, brown-skinned corms, typified by the hon matai of China. This form is known only in cultivation, and this seems to indicate what several botanists have suggested, that hon matai is a cultigen. Observations made in Indo-China (4), where hon matai ("Ma-thay") was grown together with the wild form ("Conan" or "Cây-nan"), show that, aside from corm differences, the general habit of the two forms is similar except that the culms of the cultigen are more robust, being taller and thicker. A cytological study might be of interest in indicating whether polyploidy is involved.

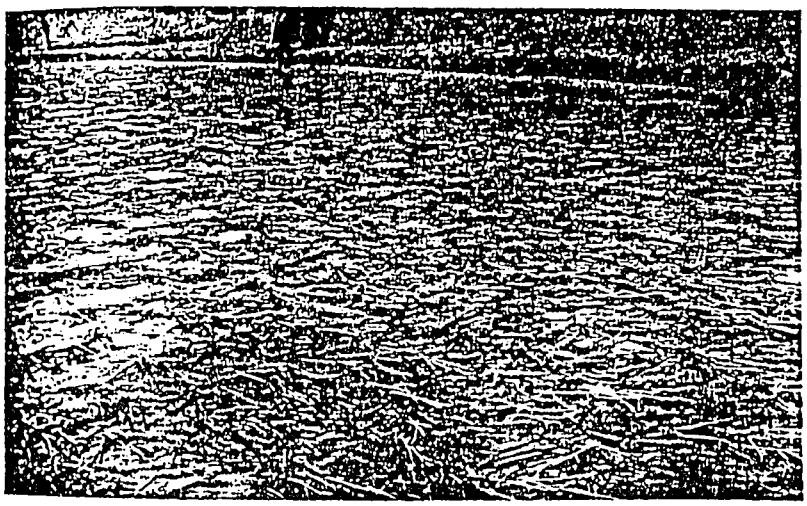


FIG. 7. A paddy of *Eleocharis dulcis* near Peiping, China, in mid-December. The stems are frozen in ice but no injury will occur to the edible corms below as long as the mud does not freeze.

[2] Merrill, E. D. Interpret. Herb. Amb.: 104. 1917.

[3] Svenson, H. K. Rhodora 31: 158–159. 1937.

FIG. 8 (*Upper*). Harvesting hon matai in China. The paddy is drained and allowed to dry before the corms are dug by hand.

FIG. 9 (*Lower*). Harvesting sui matai. The corms are dug out of the mud by hand without draining off all the paddy water.

Morphology. In general habit *Eleocharis dulcis* resembles other species of this genus of the Cyperaceae. A characteristic of these plants is the lack of leaves, whose photosynthetic function has been transferred to the numerous terete, septate culms (stems). Under wild conditions these are recorded up to three feet tall, but in the cultivated hon matai they may average as much as five feet tall. Flowers are produced in inconspicuous spikelets which appear at the tips of the culms before maximum vegetative growth has been attained. Plants grown in the United States develop inflorescences in early August. The pistillate flowers mature first, and after the culms have attained more height the staminate flowers appear. Within the scales of the spikelet the diagnostic tiny lenticular achenes are produced.

Actually plants of *Eleocharis dulcis* reproduce much more rapidly and efficiently vegetatively by underground rhizomes of two types. One type appears early in the annual vegetative cycle, usually the sixth to the eighth week after initiation of growth by a corm; such rhizomes run roughly at right angles to the axis of the parent plant and serve to multiply the individual during the growing season through the production at their tips of many satellite plantlets. Another type of rhizome appears in late August or early September after all aerial vegetative growth has been attained and following the appearance of the flowers. The second type of rhizome, or corm-producer, develops usually at an angle (approximately 45°) to the surface of the soil. Its function is evident as soon as the rhizome appears, for its growing apex is characterized by a noticeable swelling, representing an incipient corm. As the rhizome elongates its tip increases in size until finally it has enlarged into a mature corm. Young corms are whitish, but with maturity their scaly epidermis becomes chestnut-brown or blackish. The corms are produced at varying depths below the soil surface, but the average depth is about five inches. The sprout on a planted corm must thus elongate considerably to form the aerial parts of a new plant. Consequently a new adventitious root system is formed not from the corm but from the shoot at the crown just below the surface of the soil.

A matai plant growing under optimum conditions produces corms abundantly. There is a record of a single plant and its offshoots which yielded slightly over 20 pounds of corms in a season with 60% of them marketable, but the average is considerably below that. Under field conditions the yield lies somewhere between one-half pound and three-fourth pound per square foot of the producing area. The corms vary considerably in size and at the same location they have ranged up to one and three-fourth inches in diameter. Generally speaking, only corms one and one-fourth inches or more in diameter are acceptable in the trade, but smaller corms may be used as seed, for home use, or as food for domestic stock or wildfowl.

Matai Culture in China

The following description of matai culture and utilization in China is based on the observations of federal plant explorers, especially P. H. Dorsett, F. A. McClure and Frank N. Meyer, as recorded in the files of the Plant Introduction Section. In southeastern China matai is grown as a paddy crop in rotation with other aquatics. As mentioned above, some of the other water crops involved in the rotation are rice, Old World arrowhead and Oriental lotus (2).

Planting. During late March or early April, after all danger of frost is passed, the land to be planted to matai is thoroughly ploughed, harrowed and fertilized. Parts of this land, about 60 square feet per mow [4], are set aside as nursery

[4] One mow equals 0.166 acre.

beds, and the day before planting, night soil is applied to them. The following day about 20 catties[5] of matai corms are planted about one inch apart. Thereafter the nursery soil is kept moist. When the young plants are about an inch high they are transplanted to rows three inches apart, and then diluted night soil is applied. When the seedlings attain a height of seven to eight inches they are ready for permanent planting in the field, where a triangular spacing of one and one-half to two and one-half feet between plants is used. Up to the time of permanent planting, the plots have been kept only moist; once the plants are in the field, the plots must be kept permanently flooded in paddy form.

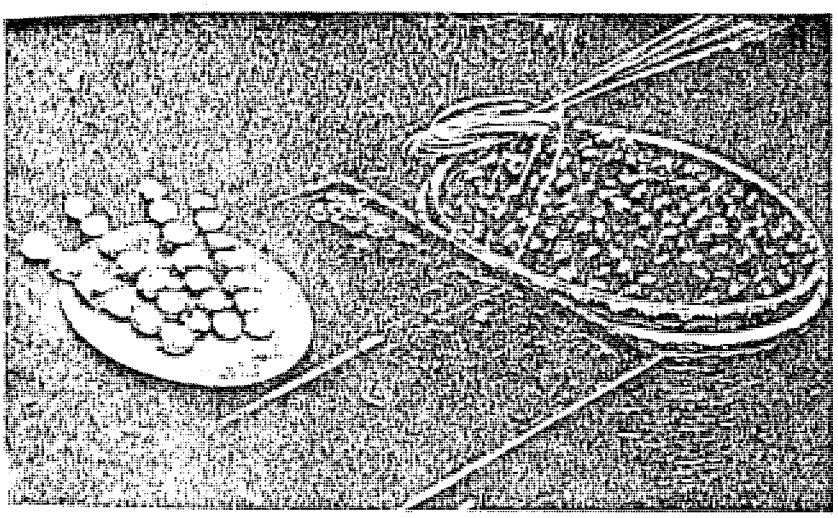


FIG. 11. Hon matai as commonly offered for sale in a Chinese market place. At the right is a basket of fresh corms; at the left, corms on bamboo splints prepared for eating out of hand.

Fertilizing. Heavy applications of fertilizer are necessary for the best growth of matai. For each mow, two or three piculs[6] of peanut cake, one or two piculs of lime, three piculs of plant ash, six or eight piculs of hog manure, 20 piculs of cow manure, and five piculs of night soil are required. Fertilizers are applied as follows. The cow manure and half the lime are spread during preparation of the field. Two weeks after permanent planting, all the night soil is used, while two weeks later, when the plants are beginning to produce lateral rhizomes with secondary plantlets, half the peanut cake is applied and the field is covered with hog manure and plant ash. About two months after this, when the crop of new corms begins to form, the remainder of the fertilizer and lime is added.

Harvesting. Matai requires a long, warm, growing season, and corms of hon matai are not fully mature until frost has killed the green culms. Thus the

[5] One catty (Old Chinese System) equals 1.33 pounds.

[6] One picul (Old Chinese System) equals 100 catties or 133.33 pounds.

FIG. 10. A farmer harvesting hon matai with a rake in southern China.

FIG. 12. Chinese water chestnuts as canned in Hong Kong for export.

harvest usually does not take place until late fall, though it is said that in certain parts of China it may occur in late summer. Since the corms keep well underground in regions where the ground does not freeze deeply, the harvest may be delayed until as late as March or April of the following year. In the case of hon matai the water is drained off before harvest time to permit the field to dry. At times it is again flooded and then allowed to dry a second time. This procedure is believed to sweeten the corms by promoting the transformation of starch to sugar. The dried chunks of soil are then broken up and the corms removed. Sui matai is harvested without any preliminary draining off of the paddy water. It should be recalled that this variety is used almost entirely for starch production and that transformation of the starch to sugar is not desired. To harvest sui matai, workers must wade in knee-deep mud, stooping over to claw out the corms with their hands.

The harvesting of hon matai is a much cleaner though still laborious hand operation. Simple spades or rakes are used to break the dried earth into clods from which the corms are extracted. Corms are then placed in coarse sacks or bamboo baskets and shipped to market. The yield runs between 2000 and 4000 catties (2,660 and 5,320 pounds) per mow, depending upon the variety grown. This is roughly equal to 16,000 to 32,000 pounds per acre. In the case of sui matai the total yield of corms in a field is estimated, a price is set, and the whole is then sold as a lot—usually to a matai-starch producer who arranges for the harvesting of the crop. Corms used for home or local consumption are often stored in a cool place in stone crocks for several months. At regular intervals they are taken out and sorted, and any showing signs of decay are discarded. The season during which corms are available can be extended by holding them in the ground over winter

Utilization in China

Use as a Vegetable. Depending upon the variety, matai may be either used as a vegetable (hon matai) or in starch manufacture (sui matai). Because of its crisp, sweet, apple-like flesh, hon matai is widely eaten out-of-hand in China as a substitute for fresh fruits. This is particularly true during the winter and spring when corms are available and when fruits are scarce or absent. It is common practice for a Chinese host or hostess to serve a dish of freshly peeled matai corms to guests. Peeled matai, skewered on bamboo splints, also is a familiar commodity offered for sale on the street or in trains, where it is eaten by young or old, rich or poor. To some the sweet flesh, sampled in this way, is reminiscent of fresh coconut meat.

Matai attains maximum popularity in China as a common ingredient of local food dishes. Generally it is sliced, diced or grated with other vegetables in omelets, soups, chop sueys, salads and the like. When shredded it appears commonly in meat and fish dishes (9). Minced matai is made into puddings and fritters, including matai ko, a kind of cake which can be bought from the "portable kitchens" on the street corners or in tea houses. Matai is often served boiled or steamed as a winter vegetable, sometimes in a sauce of sugar, butter and flour. Prepared this way the vegetable is said to resemble sweet corn in both looks and taste.

Use as a Source of Starch. Sui matai, as indicated previously, is used principally for the making of matai starch, which is processed in a characteristic though crude peasant fashion. Simple thatched shacks are usually set up near the matai-producing paddies or by a

ample. Shipments still come to this country from the British port of Hong Kong, but more frequently these days the imports originate in Formosa. Fresh corms are simply packed in large slatted crates permitting good ventilation in transit. Matai for the New York market comes by sea either by way of Panama or overland after transshipment at the port of San Francisco. Even with the 30 and 45 days required in transit, fresh corms from the Orient, if kept cool, keep for a number of weeks after arrival, provided they are looked over periodically to remove any corms that may be rotting. Canned Chinese water chestnuts also are being exported from the Orient, but are less desirable to the trade than the fresh product.

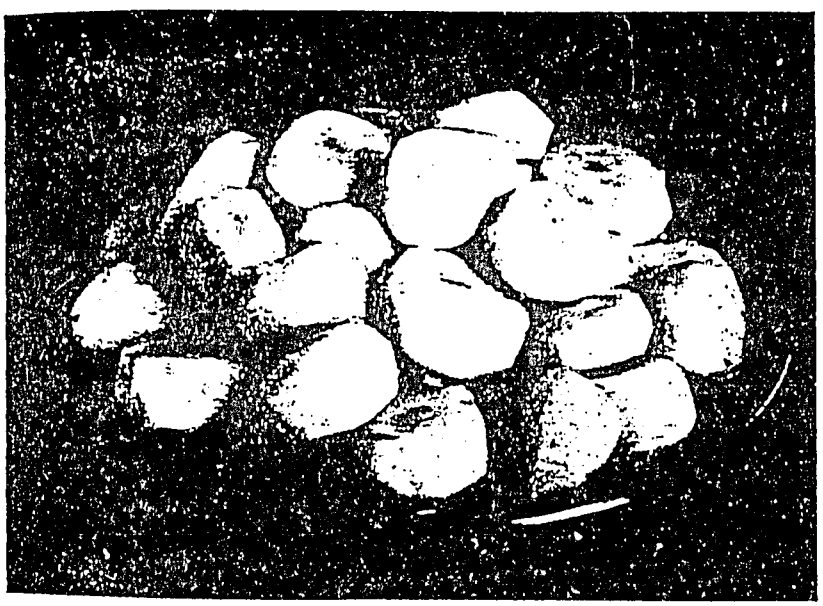


FIG. 13. Pared whole corms from the tin shown in Fig. 12.

Utilization in the Orient outside China

Although the two types of *Eleocharis dulcis* have been important as cultivated plants only in China, the wild species, in one form or another, has been utilized to a small degree as a food plant elsewhere in the Orient. In those other areas where it enters into the local diet, it is not as the cultigen, matai, with its large, sweet, crispy-fleshed corms, but rather as a wild plant with small, starchy corms. Java is one center of such use. Ochse (8) reported the species (under the name, *Heleocharis dulcis*) as occurring as a native from sea-level up to about 3000 feet elevation, growing in both salt and fresh water but preferring brackish water. The small tubers are said to be collected particularly in the marshes bordering the sea near Djakarta (Batavia) and appear plentifully in the markets from August to December (1). According to Ochse, the corms are usually cooked, being "made into Kreepik, the so-called ĕmping tĕkee". Following cooking the

stream, and these serve to house the primitive hand "mill" used to reduce the corms to starch. Corms are first washed in a stream in rough bamboo baskets by men or women. The washer stands in the water, using one foot to stir the contents of the basket. After washing, the corms are transferred to small bamboo baskets and then turned over to women laborers. Specially designed earthenware bowls with vertically corrugated inside walls are used for grinding. The corms, held by the apical buds, are rubbed forcibly against the inner corrugations of the bowls. As a protection the women wrap their thumbs and first fingers in strong cloth.

Once grated, the resulting mass is placed in a fine bamboo basket which is then set in a cloth filter hung over an earthenware pot above a wood fire. Water is then poured into the basket, and its contents are stirred thoroughly for about 15 minutes. Three pans of the resultant milky mixture, each with a different dilution, are then collected. The first one taken contains a great proportion of starch and consequently is set aside so that the starch may settle out; the other pans are used again for washing the macerated material. The settling process requires four or five hours. The clear water is decanted and the starch-bearing portion poured through a fine cloth filter, on which the starch is collected. The latter is then spread on shallow round bamboo trays to dry in the sun. Matai starch is used in China in the same way that cornstarch is in this country. It is also reputed to have medicinal properties. A brief description of the microscopy of matai starch has been published (13).

Use in Medicine. There are two interesting records of therapeutic use of matai corms. The oldest is that of Martini who in 1655 indicated that if a copper coin was put into the mouth along with the "fruit" (e.g., corm) of this species it would be sufficiently softened thereby as to be chewed very easily (7). Later Roxburgh (quoted in 9) indicated the reputed medicinal value of this observation by quoting a correspondent who sent matai corms from Canton to the East India Company's Garden at Calcutta—"The children here often play with cash in their mouths, which at times slip down into the stomach and bring on alarming symptoms. The nut (matai) is immediately given in quantities, either raw or boiled, and they say it never fails to give relief, and is always considered as specific; they allege it decomposes the metal?". This appears to be but another instance of the application of the old Doctrine of Signatures, in this case a roughly coin-shaped corm being used to relieve the bad effects of coin-swallowing.

In 1945 a brief report (14) was published, stating that Chinese workers of Tsing Hua University at Kunming had obtained a new antibiotic, puchin, resembling penicillin in its action, from matai corms. Puchin, unlike penicillin, is not soluble in organic solvents, such as ether and benzene, and is destroyed by moderate heating; it is yet to be produced in a purified form.

Export Trade. The large succulent corms of hon matai, produced in South China, are exported in the fresh form in considerable numbers for use primarily by Chinese populations in other countries. Fair quantities have been imported by Indo-China (4), Thailand and Malaya. In Calcutta the corms are sold under the misnomer "Singapuri Kysur" which incorrectly indicates Singapore, a port of transshipment, as the place of production (1).

Until the recent embargo on trade with Communist China, sizeable shipments of matai were imported by Chinese-Americans in the larger cities of the United States. Imports totalled about 2,500,000 pounds in 1947, for ex-

scales are removed and the corms are then mashed with a small hammer and dried in the sun to produce a meal called "emping". Emping is produced in sufficient supply to appear in the native markets, especially in Djakarta as well as in various localities in Central Java. Emping is prepared as a delicacy by simply frying it in coconut oil.

In the Philippines the name given the wild strain of *Eleocharis dulcis* is "apulid". As in Java, its corms are small, three-eighth to five-eighth inch in diameter. They are collected in the wild and are simply boiled and eaten as a vegetable (12).

In more recent years hon matai of China has also been introduced for trial in other areas in the Far East, though there is no indication that its culture has become important anywhere outside of China, including Formosa. Test plots have been grown in Australia, Java, Indo-China and the Philippines, but as far as is known, only in the last two countries have cultural tests resulted in detailed published reports (4, 11). As indicated earlier, China does supply some of these countries with matai through export.

Introduction and Utilization in the United States

There are several recorded introductions of the Chinese cultigen, hon matai, into the United States. Most success has been obtained with propagation material of a strain (P.I.[7] 106274) obtained by the United States Department of Agriculture through the cooperation of Lingnan University, Canton, China (2). Practically all Chinese water chestnuts at present being grown experimentally or otherwise in this country, owe their origin to this introduction which was initially increased and made available at the Department's Barbour Lathrop Plant Introduction Garden, Savannah, Georgia. Horticultural studies undertaken at Savannah are the basis of the information recently published on the culture of this specialty crop in the United States (3).

In 1950 the United States imposed an embargo on all commercial shipments from Communist China. Imports of Chinese water chestnuts practically stopped, with the result that there has been increasing interest in the possible production of this specialty crop in the United States to meet the domestic demand. This interest has been associated with the high prices offered for this commodity by American importers.

Chinese water chestnuts may be grown with success in this country as an annual crop, under controlled irrigation, in warm temperate regions where there is a lengthy frost-free growing season of about 220 days. Thus they appear best-fitted for the Atlantic and Gulf coastal plain (as far north as Norfolk, Virginia), milder parts of the Pacific coast states, Puerto Rico and Hawaii. Although southern Florida approximates the same latitude as China's Kwangsi Province, where the choicest matai is claimed to grow, there are indications that sweeter (hence more desirable in the trade) corms are produced farther north. Corms harvested at the latitude of Savannah are said by American-Chinese to equal "Kweilein-grown matai".

[7] P.I. refers to the published inventory number of the Plant Introduction Section.

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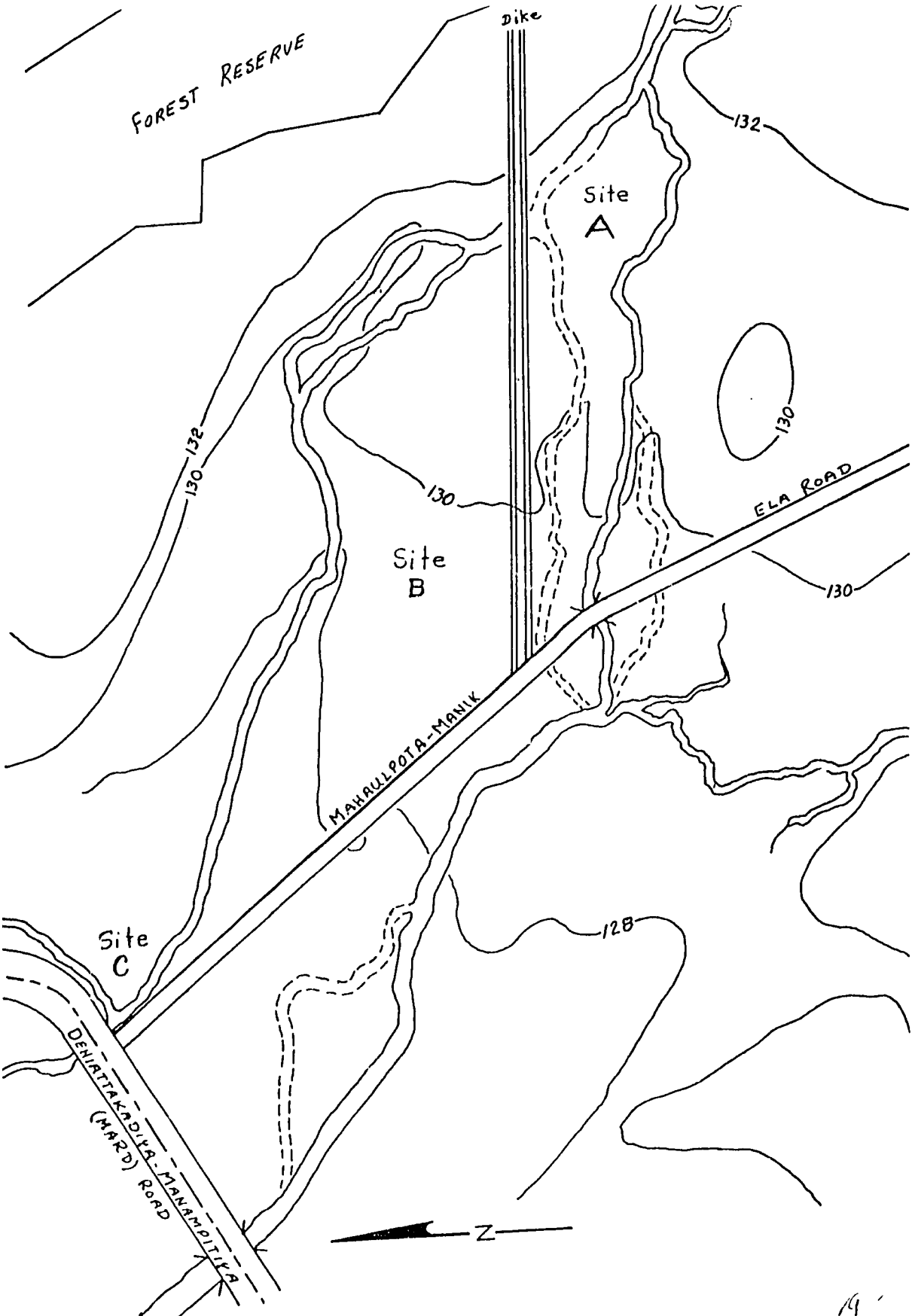
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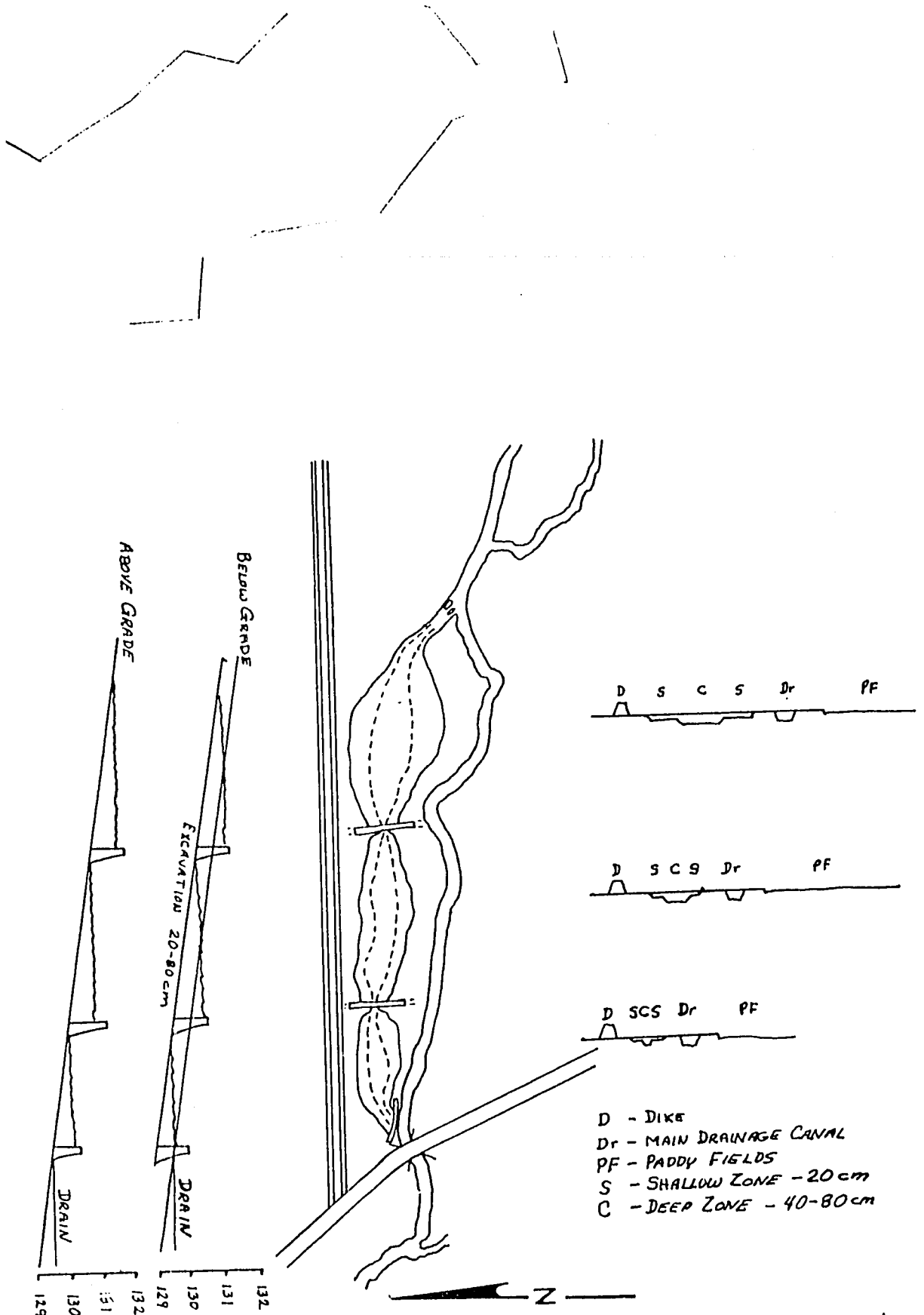
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PF - PADDY FIELDS
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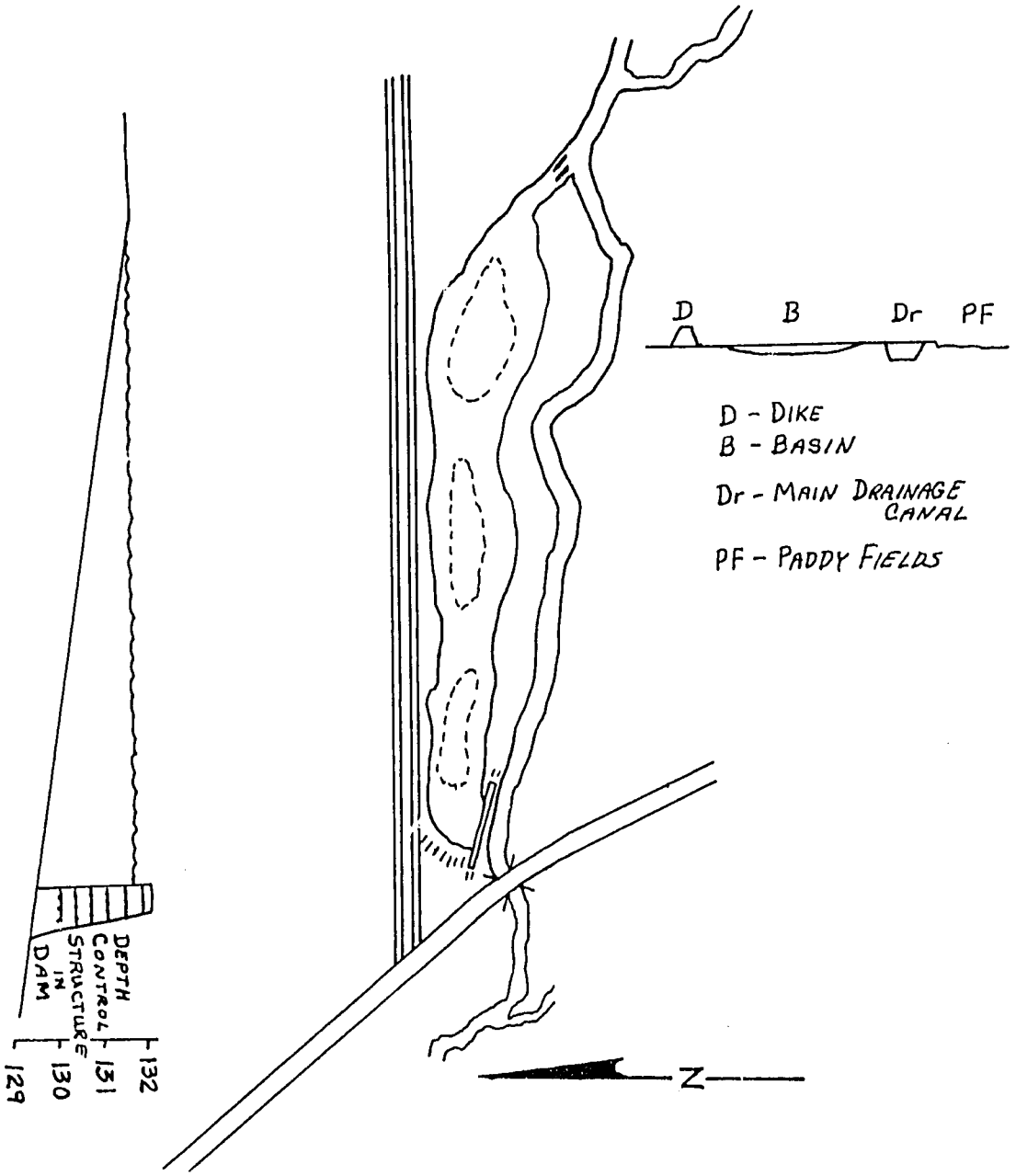
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