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Short course on the control of aquatic weeds and an assessment of their economic significance in Thailand

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9. ABSTRACT
This report outlines the findings and progress of a project by the International Plant Protection Center to supply technical assistance for the development of an aquatic weed control program and a training course on aquatic weed control in Thailand. The program was conducted in two phases: a three week short course and a two week assessment of Thailand's aquatic weed problems. It was necessary for the research team to assess several factors. A thorough knowledge of the geography and climate was required as well as consideration of the natural soils, their fertility, and cultural usage. The purpose for which the waterbodies are used was noted. The water quality was assessed. Finally, the assessment focused on the problem weed species itself. The assessment team came to the following conclusions: aquatic weed problems in Thai water systems are manifestations of water quality problems associated with enrichment or eutrophication; and enrichment has resulted from a combination of natural and cultural factors, including those associated with multiple usage. Irrigation systems are infested with both floating and submersed weeds which hinder or block water flow and perpetuate silting in canals. The acceleration of succession in the natural lakes is alarming, and attention should be given to elimination of both floating and submersed weeds. The present weed situation in Thailand is considered moderate but if it became more severe it would have a very detrimental effect on the economy because of the country's dependence on adequate water supplies in all areas of life. The only major water weed species not currently found in Thailand is the notorious water fern Salvinia molesta. It is now flourishing in central Malaysia. The report concludes with recommendations for long and short term weed control programs. The greatest short term priority is the hyacinth problem in the Chao Phraya Irrigation Project. Suggestions are given for long term efforts including: education, economic

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impact, research, monitoring and evaluation, and technical assistance. The appendices include a proposed training course, water quality data for Mae Moh Reservoir in northern Thailand, water quality data for selected irrigation tanks in northwestern Thailand, and an assessment form for water weed problems.

Report On

SHORT COURSE ON THE CONTROL OF AQUATIC WEEDS

And An

ASSESSMENT OF THEIR ECONOMIC SIGNIFICANCE

IN THAILAND

Prepared For

U.S. Agency for International Development

By

George E. Allen, Frank S. Conklin, T. Lloyd Chesnut,

Don E. Henley and Taval Maneewarn

INTERNATIONAL PLANT PROTECTION CENTER

November 1977

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INTRODUCTION

The National Research Council of Thailand requested through USAID channels that the International Plant Protection Center supply technical assistance for the development of an aquatic weed control program and a training course on aquatic weed control (Appendix A). The scope and size of the proposed program were considered excessive without a thorough assessment of the water weed problem in Thailand.

The response to the request consisted of a recommendation for an alternative program including a three week short course and a two week assessment of aquatic weeds in Thailand. The National Research Council of Thailand withdrew their first request and submitted a second one which incorporated these recommendations (Appendix B). Supplemental funds were requested from the Technical Assistance Branch, USAID, Washington, to conduct the training course and assessment trip in November, 1976. Final approval of the additional funds was obtained in March, 1977. Additional funds were provided by the International Plant Protection Center.

The program was conducted in two phases: a three week short course and a two week assessment of Thailand's aquatic weed problems. This report outlines the progress and findings of the Thailand project.

SHORT COURSE ON AQUATIC WEED CONTROL

The training course was organized by the Coordinating Subcommittee on Aquatic Weeds (CSAW) of the National Research Council of Thailand. The course was conducted at the Royal Irrigation Department (RID) during April 4-22, 1977. The course outline and instructors were as follows:

First Week		
April 4-5	General and Aquatic Ecology	Dr. T. L. Chesnut
April 6	Tour of Northeast Thailand	
April 7-8	Ecology and Physiology of Aquatic Weeds	Dr. D. E. Henley
Second Week		
April 11	Taxonomy of Aquatic Weeds	Ms. Umpai Yongboongerd
April 12	Types of Weed Problems	Dr. Thiraphan Bhukasawan
	Socioeconomic Impact	Dr. Santasiri Sornmanee
April 13	Tour of Northwest Thailand	
April 14	Management and Preventative Measures	Mr. Taval Maneewarn
	Mechanical Control	Dr. Larry Bagnall
April 15	Mechanical Control	Dr. Larry Bagnall
Third Week		
April 18-19	Chemical Control	Dr. William Haller
April 20	Utilization	Dr. Larry Bagnall
		Dr. Narong Chomchalow
April 21	Biological Control	Dr. Bill Bailey
April 22	Biological Control	Dr. Banpot Napompet

The following were members of the instructional staff:

<u>United States</u>

- Dr. T.L. Chesnut, Dean of Graduate Studies, Georgia College
- Dr. Don E. Henley, North Texas State University
- Dr. William Haller, University of Florida
- Dr. William Bailey, Arkansas Department of Fisheries
- Dr. Larry Bagnall, University of Florida
- Dr. George E. Allen, University of Florida

<u>Thailand</u>

- Ms. Umpai Yongboongerd, Kasetsart University
- Dr. Thiraphan Bhukasawan, EGAT (Electricity Generating Authority of Thailand)
- Dr. Santasiri Sornamanee, EGAT

Mr. Taval Maneewarn, EGAT
Dr. Narong Chomchalow, Applied Science Research Corporation of Thailand
Dr. Banpot Napompet, Kasetsart University

The training course was coordinated by Ms. Saowanee Thamasara of RID and Dr. T. Lloyd Chesnut. The Thai participants were selected by the CSAW based upon their training and potential involvement in aquatic weed management programs in Thailand. A total of 25 participants attended the course, representing both governmental agencies and universities in Thailand (Table 1).

The course consisted of lectures during the morning and laboratories or demonstrations during the afternoon sessions. Two one-day field trips were conducted to observe various aquatic weed problems in various aquatic systems.

The training course emphasized the "systems ecology" approach and the critical nature of understanding aquatic systems as a whole before considering control measures. Aquatic weed problems are the result of serious alterations in the aquatic ecosystem. Control programs designed for a particular water system must also include methods to correct the alterations responsible for the problem.

The lectures also stressed that the control measures presented were those currently being developed or practiced in the United States, and that these techniques provide a foundation upon which a modified program for use in Thailand could be constructed.

The facilities of RID were adequate for both lecture and laboratory sessions. The support by the Royal Irrigation Department was noteworthy, particularly that of the Deputy Director General, Mr. Charin Atthayodhin. The participants were well selected and all completed the course. The guidance and continuous support of CSAW, particularly Mr. Chobvit Lubairee, contributed greatly to the success of the training course.

Table 1. List of short course participants.

Name	Qualification	Position
Chulalongkorn University		
Pipat Patanaponpaiboon	B.S. Botany	Lecturer
Rajanee Virabalin	M.S. Botany	Lecturer
Laddawan Boonyaratanakornkit	M.S. Pharmacy	Assistant Prof.
Kasetsart University		
Manat Suchavipun	M.S. Botany	Lecturer
Suchada Sripen	M.S. Botany	Assistant Prof.
Vipa Boonnitee	B.S. Botany	Lecturer
Thiemchai Toolayathorn		Assistant Prof.
Khon Kaen University		
Theera Suwanarath	M.S. Weed Science	Lecturer
Prince of Songkla University		
Prasert Chitapong	M.S. Weed Science	Lecturer
Taveesak Saknimit	M.S. Botany	Lecturer
Somsak Boromthanarat	M.S. Biology	Lecturer
Royal Irrigation Department		
Manop Siriworakul	B.S. Entomology	Researcher
Kallaya Boonpuak	B.S. General Science	Researcher
Verasak Vanichsuthirugsa	B.S. Microbiology	Researcher
Aramsri Phatanasophon	B.S. General Science	Researcher
Fisheries Department		
Santana Sangkhakul	M.S. Zoology	Biologist
Wichien Plengchawhee	B.S. Fisheries	Biologist
Department of Communicable Diseases		
Laksami Yisunsri	M.S. Parasitology	Public Health Worker
Electrical Generating Authority of Thailand (EGAT)		
Wiroj Ungarruwittaya	B.S. Agriculture	Scientist
Manu Chanme	B.S. Sanitation	Scientist
Tanad Asakit	B.S. Engineering	Engineer
National Biological Cont. Res. Ctr.		
Kosol Charernsom	M.S. Entomology	Lecturer
Viwat Suasa-ard	M.S. Entomology	Researcher
Applied Scientific Res. Corp. of Thailand		
Supachai Sittilert	B.S. Zoology	Researcher
National Research Council (NRC)		
Phongsri Boonyasirikool	B.S. Agriculture	Research-Coordinator

ASSESSMENT OF AQUATIC WEEDS IN THAILAND:

WATER QUALITY, AQUATIC WEED POPULATIONS, AND ECONOMIC IMPACT

The second phase of the Thailand program consisted of a two week assessment of aquatic weed problems in major water systems in the North, Central and Southern Regions of the country (Table 2). The Northeast Region was not included because this area had been assessed by three of the assessment team members, Dr. George E. Allen, Taval Maneewarn, and Saowanee Thamasara, in 1975. The data from this study is included in this report.

A previous review of the aquatic weed situation in the Lower Mai Khong River Basin in Laos and Thailand was conducted by a team from the U.S. Corps of Engineers (Nelson et al. 1970). This study gave the current assessment team a good basis to evaluate any significant changes in the development of water weed problems in selected areas.

The assessment team consisted of two American and three Thai scientists, namely:

<u>United States</u>

Dr. George E. Allen
Coordinator, Aquatic Weed Program
International Plant Protection Center
University of Florida

Dr. Frank Conklin
Agricultural Economist
Oregon State University

<u>Thailand</u>

Dr. Banpot Napompet
Director, National Biological Control Center
Kasetsart University

Mr. Taval Maneewarn
Electrical Generating Authority of Thailand

Table 2. Itinerary of Assessment Team

Phase I. North and Central Regions.

Monday, April 25, 1977
Bangkok to Nakornsawarn - visit Borapet Lake

Tuesday, April 26, 1977
Bhumibol Dam to Payao - visit Payao Lake

Wednesday, April 27, 1977
Payao to Chiangmai - Keaw Lom and Doi Saket Irrigation System

Thursday, April 28, 1977
Visit Doi Tao Lake south of Chiang Mai

Friday, April 29, 1977
Chiang Mai to Bangkok

Saturday, April 30, 1977
Rest in Bangkok

Phase II. Southern Region.

Sunday, May 1, 1977
Bangkok to Hat Yai - Hat Yai to Satul - visit southern part of Songkhla Lake and Duson Irrigation Project

Monday, May 2, 1977
Hat Yai to Pattalung - Survey of Upper Songkhla Lake

Tuesday, May 3, 1977
Hat Yai to Songkhla - visit Songkhla Marine Fisheries Experiment Station

Phase III. Hat Yai to Bangkok.

Wednesday, May 4, 1977
Preparation of report (National Research Council)

Thursday, May 5, 1977
Preparation of report (National Biological Control Research Center)

Friday, May 6, 1977
a.m. Preparation of report (NRC)
p.m. Presentation of report to CSAW (NRC)

Ms. Saowanee Thamasara
Royal Irrigation Department
Thailand

The itinerary of the assessment trip is given in Table 2. The first phase of the trip covered the Northern and Central Regions; the second, the Southern Region. The last phase consisted of drafting a final report for the CSAW and National Research Council leaders.

Assessing aquatic weed problems is a complex matter, involving careful examination of a variety of factors. The first requirement is a thorough knowledge of the geography and climate of the affected area, as well as consideration of the natural soils, their fertility, and cultural usage. The purpose for which the water bodies are used must be noted. Next, the water quality must be assessed. This includes determining the physiological cycling dynamics of tropical water systems in general, as well as the particular characteristics of each affected water system and its nutrient sources. Finally, assessment should focus on the problem weed species itself.

In assessing Thailand's water weed problems, the research team followed this regimen, as reported in the remainder of this section.

Background Information

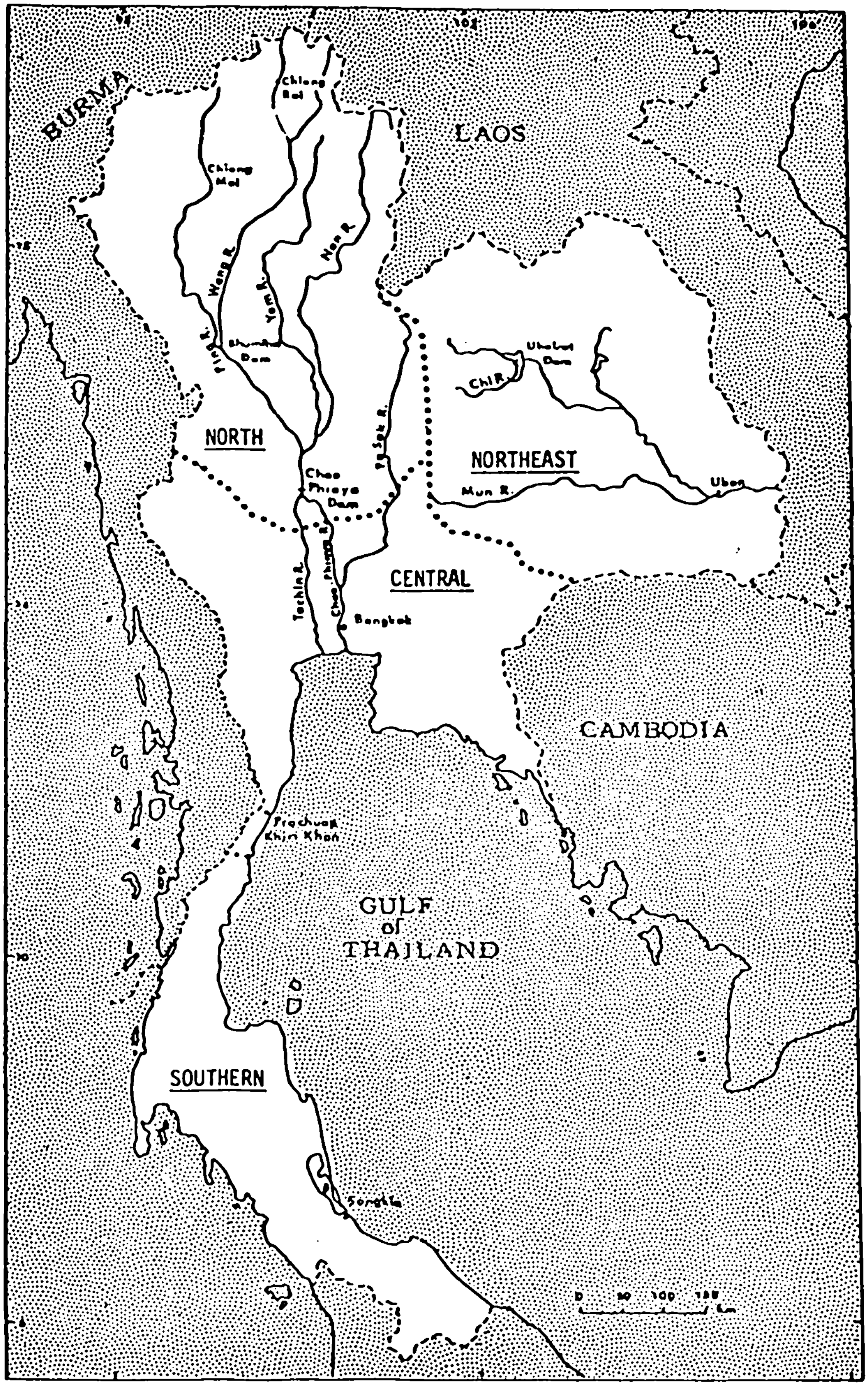
Geography and Climate of Thailand

Thailand is bounded in the east by Laos and Cambodia (across the Mae Khong River), in the west by Burma, and in the south by Malaysia and the Gulf of Siam. Internally, the country's geography is divided by river systems and mountain ranges into four regions: the Northern Region (42,000 square miles), the Central Plain (62,000 square miles), the Northeast Region (66,000 square miles), and the Southern Peninsula (30,000 square miles).

The Northern Region consists of parallel mountain ranges dividing alluvial valleys through which the tributaries of the Chao Phraya flow. Four rivers originate in the north--the Ping, the Wang, the Yom, and the Nan--combining to form the Chao Phraya in the south. In the northern river valleys, rice is cultivated on the alluvial deposits and dark clays. Heavily forested hills provide lumber, including teak, for export.

The Central Plain is the river basin of the Chao Phraya River System. In its 150 mile course from Nakhon Sawan to the Gulf of Siam, the river flows slowly, continually depositing sediment at the mouth, extending the plain 15 or 20 feet a year into the Gulf. Two other important rivers, the Mae Klong and Bang Pakong, flow south into the Gulf of Siam. Annual inundations water and enrich the flat alluvial lands, covering the clay with a sandy and silty soil suitable for fruit trees, sugarcane, vegetables, and jute, as well as the main crop, rice. The Central Plain is the political and economic center of Thailand, and includes the large urban centers of Bangkok (capital), Thon Buri, Ayuthya, Lop Buri, and Rat Buri.

The Northeast Region or Khorat Plateau is a barren region. Except for marshy flats along the Mun and Chi Rivers, the level ground fluctuates between


BURMA
LAOS
Chiang Rai
Chiang Mai
Wang R.
Yom R.
Nan R.
Ping R.
Pa Sak R.
NORTH
NORTHEAST
Chi R.
Mun R.
Ubon
Chao Phraya Dam
CENTRAL
Tachin R.
Bangkok
CAMBODIA
Prachuap Khiri Khan
GULF
of
THAILAND
SOUTHERN
Songkla

swamp land and dry wasteland according to the season. The topsoil is a fine loam low in nutrients and occasionally saline.

The Southern Peninsula, extending down the Malay Peninsula, is dominated by north-south mountain ranges. Tin mining, rubber, and tropical agriculture provide the basis for the economy.

Over half the land in Thailand is forest or pasture; only 21.3% is cultivated. There are evergreen and deciduous forests in the mountains, thorn and bamboo thickets on the plains, and tropical aquatic vegetation along the waterways.

The climate of Thailand is tropical, with an annual mean temperature of $80^{\circ}F$. The rainy season, brought on by the southwest monsoon, lasts from March to October; temperatures range from 80° to $100^{\circ}F$. This wet monsoon is followed by a cool dry season, lasting until February, when the dry monsoon sets in. In the dry season farmers of the Central Plain must depend on the river for water. Dry season temperatures fall to 57° in the Central Plain and $14^{\circ}F$ in the northern and peninsular mountains.

Water Use in Thailand

Water, a vital natural resource in Thailand, is used for irrigation, transportation, energy production, drinking, and other purposes. Master development plans of the country not only require maximum use of existing water resources but the potential of expanding supplies for hydroelectric power and efficient irrigation systems. A major deterrent to maximum utilization of fresh water systems in Thailand is the explosive growth of exotic aquatic weeds. Excessive growth of these weeds has significant implications in many fields: agriculture, irrigation, fisheries, hydroelectric power, wildlife conservation, public health, recreation, flood control, drainage and inland navigation. Aquatic weeds overrun rice paddies and decrease food production.

Significant weed growth in natural water systems is characteristically the result of pollution, whereas in large man-made schemes it is the result of disturbances of the natural hydrological regime.

Developing aquatic weed problems in Thailand are typical of those in other tropical countries. Aquatic weeds are the final product of alterations in the water systems they inhabit. Newly constructed reservoirs, irrigation systems, and other alterations to existing hydrological schemes favor weed population development. In addition, multiple purpose usage supplies increased nutrients. The highly competitive nature of water weeds enables them to develop at uncontrolled rates.

Reservoir construction and associated water resource development projects increased rapidly in Thailand in the 1960s and 1970s, having been initiated under auspices of the Ministry of Agriculture and the Office of the Prime Minister. Departments responsible for these projects include the Royal Irrigation Department (RID) and the Electrical Generating Authority of Thailand (EGAT). In most cases, development projects have been designed for multiple uses, such as:

1. Irrigation water supply
2. Electrical generation (including hydro and thermal)
3. Flood control
4. Fisheries development and management
5. Domestic supplies
6. Transportation
7. Recreation

Water Quality Assessment

Reservoir construction results in certain water quality changes within an impoundment in the tropics. Most water quality changes in a reservoir, and its downstream releases, are associated with the tendency of the reservoir to stratify thermally. Thermal stratification occurs as a result of density differences caused by solar heating of the water column with depth. Effectively, this stratification may divide the reservoir into three layers: an upper layer referred to as the epilimnion; a middle layer, the thermocline; and a bottom layer, the hypolimnion. Based upon the tropical location and upon selected reservoir water quality data from reservoirs in Thailand, these reservoirs may be classified as warm monomictic reservoirs (Hutchinson 1967). A reservoir of this type is characterized by high surface water temperatures, which show little annual variation and never fall below 4°C. Reservoirs of this type may develop a small thermal gradient from one depth to the next. However, the density gradient may be sufficient to impart considerable stability (resistance to circulation). Circulation or mixing of warmer, oxygenated upper waters with colder waters near the bottom generally occurs only during the rainy season (wet monsoon), when colder inflowing waters seek their own density and thereby upset thermal stability. Other factors which act to influence thermal stratification and stability in the tropics include mean depth, volume, surface area, exposure of the reservoir to prevailing winds, and certain physical water quality parameters such as turbidity and color.

Data Collected

Water quality data from selected reservoirs were supplied to the research team by the Royal Irrigation Department and Electrical Generating Authority of Thailand. These data are from both relatively deep basins in the Northern Region and shallow basins in the Northeastern Region. As stated above, these areas drain into two major rivers, the Chao Phraya and the Mae Khong.

Reservoir water quality data selected for discussion in this report is from the Mae Moh Reservoir, located in the Northern Region. These data (Appendix C) graphically illustrate temperature, dissolved oxygen, and free carbon dioxide concentrations versus depth for five stations in the reservoir. The stations are numbered from the dam upstream toward the tributaries as M1 through M5.

Collectively these data illustrate that as tributary water enters the reservoir the following water quality changes occur downstream toward the dam: surface water temperature increases; dissolved oxygen decreases, both downstream and with depth; free carbon dioxide increases, both downstream and with depth; and bicarbonates increase downstream at the surface, but decrease with depth. It is apparent that oxygen-demanding substances and biological respiration reduce dissolved oxygen concentrations rapidly with depth in the reservoir. (High metabolic rates in tropical waters and deoxygenation effects have been discussed by Ruttner 1963.) This creates anoxic conditions (D.O. less than 2 mg/l) throughout a considerable volume of the reservoir. In certain areas anaerobic conditions prevail. Both anoxic and anaerobic conditions (negative E_h potential) foster an increased loss of various nutrients from bottom sediments including phosphate and ammonium (Mortimer 1941 and 1942). As circulation occurs, these nutrients become available to organisms in the photic zone for primary production (although some nutrients may be precipitated once again into the bottom sediments under the oxygenated conditions now prevailing in the photic zone). This release of nutrients, coupled with the effects of poorly buffered waters (King 1970) may result in blooms of algae growth. However, when effective light transmission is limited by color and turbidity of water, blooms of algae may be replaced by explosive growth of floating aquatic plants such as *Eichhornia crassipes* and various species of *Salvinia* or submersed aquatic plants such as *Hydrilla*.

Mae Moh Reservoir presently has a serious problem with *Hydrilla verticillata*. Similar conditions occur at other reservoirs in the Northern Region, including Bhumibol Reservoir (EGAT, Report No. 154-40-1901, 1976).

The research team also visited two reservoirs, Lam Takong and Huang Sub Pradoo, in the Northeastern Region of Thailand. Water quality data for these reservoirs could not be secured but were similar in most respects to those given for Mae Moh. Representative data for a number of other irrigation tanks located in the Northeast were obtained from the RID (Appendix D). In contrast with the data obtained from the Mae Moh Reservoir, these data show lower concentrations of bicarbonates (HCO_3^-), associated cations of Ca^{++}, Mg^{++}, Na^+, K^+, and other nutrients. Thus, waters of the Northeast appear to be generally softer and even less buffered than natural waters of the Northern Region. This condition causes even more explosive growth of aquatic weeds following increases in nutrient input.

Nutrient Sources

Sources of nutrients to surface waters were not investigated by the research team in detail. However, observations, discussion with Thai scientists and study of reports indicate that the following are major contributors:

1. Cultural non-point sources associated with farming activity. In certain instances, it was observed that forested areas are cleared for farming in the area of the reservoir immediately adjacent to the shoreline.

2. Point sources from municipal dischargers.

3. Large and shallow backwater areas in reservoirs. These forested and swampy areas deposit a considerable amount of organic litter during the dry season. During floods, these areas become inundated. Receding flood waters then transport the litter and nutrients into the reservoir.

Aquatic Weed Assessment

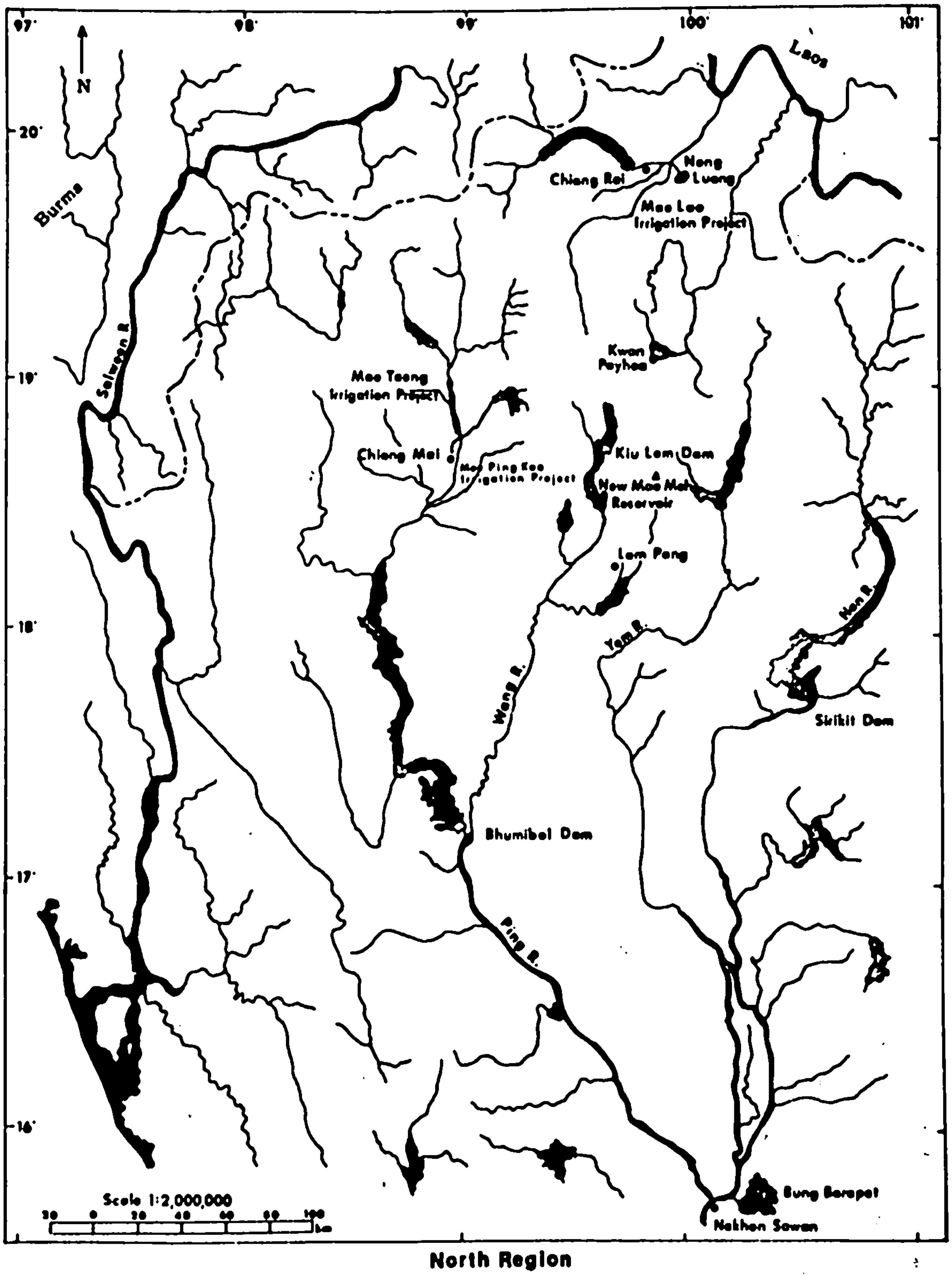
Water weeds are well established in all types of water systems in Thailand, including canals or klongs, reservoirs, irrigation systems, natural lakes and rivers. Three of the major world wide aquatic weed pests, *Eichhornia crassipes* (water hyacinth), *Pistia stratiotes* (water lettuce), and *Hydrilla verticillata* inhabit most systems. In addition, several potential pest species are present, including *Alternanthera philoxeroides* (alligatorweed) *Potamogeton* spp. (pond weed), *Ceratophyllum demersum* (coontail) and *Najas graminea* (grassy naiad). A list of the aquatic plants observed in Thailand is presented in Table 3. Data used for water weed assessment was collected and recorded on a standard form (Appendix E).

Northern Region

The northern region of Thailand contains major reservoirs, natural lakes, man-made lakes, rivers and irrigation systems. Because of the fertile soils and availability of water the area sustains rich cultivated crops, including rice, vegetables, tobacco, and fruits. Four relatively flat basins are drained by the tributaries of the Chao Phraya, Thailand's major river. These are the Ping, the Wang, the Yom and the Nan Rivers. Extensive irrigation systems are supplied by the Ping, Wang and Nan. The Nan River irrigation system is currently under development.

Major reservoirs associated with hydroelectric power, the Bhumibol and the Sirikit, are located on the Ping and Nan Rivers, respectively. Bhumibol Reservoir, 300 square kilometers in size, supplies water to the Greater Chao Phraya Irrigation Project in the Central Region and to the Bhumibol Dam for generation of an electrical power output of 1,600 million kilowatt hours.

Mae Ping River Basin. The Mae Ping River basin, in Chiang Mai Province,



North Region

Table 3. Aquatic plants present in Thailand

Scientific Name	Common Name	Type
Azolla pinnata	Water velvet	Floating
Eichhornia crassipes	Water hyacinth	Floating
Lemna spp.	Duckweed	Floating
Nelumbo spp.	Water lotus	Floating
Nymphoides indica	Water snowflake	Floating
Pistia stratiotes	Water lettuce	Floating
Salvinia cucullata	Floating water fern	Floating
Blyxa echinosperma	Blyxa	Submersed
Ceratophyllum demersum	Coontail	Submersed
Ceratopteris thalictroides	Water fern	
Chara spp.	Chara	Submersed
Hydrilla verticillata	Florida elodea	Submersed
Limnophila heterophylla	Limnophila	Submersed
Najas graminea	Grassy naiad	Submersed
Ottelia alismoides	Ottelia	Submersed
Potamogeton spp.	Pond weed	Submersed
Utricularia flexuosa	Bladderwort	Submersed
Alternanthera philoxeroides	Alligatorweed	Marginal
Arundo donax	Arundo	Marginal
Coix aquatica	Coix	Marginal
Cyperus difformis	Sedge	Marginal
Cyperus procerus	Sedge	Marginal
Cyperus rotundus	Sedge	Marginal
Echinochloa colonum	Junglegrass	Marginal
Eleocharis dulcis	Spikerush	Marginal
Fimbristylis miliacea	Fimbristylis	Marginal
Imperata cylindrica	Lalang	Marginal
Isachne globosa	Rounded Isachne	Marginal
Ischaemum rugosum	Reedgrass	Marginal
Jussiaea repens	Water primrose	Marginal
Marsilea crenata	Pepperwort	Marginal
Mimosa pigra	Catclaw	Marginal
Monochoria vaginalis	Monochoria	Marginal
Panicum repens	Torpedograss	Marginal
Paspalum scrobiculatum	Water paspalum	Marginal
Phragmites communis	Giantreed	Marginal
Phragmites karka	Phragmites	Marginal
Polygonum tomentosum	Water smartweed	Marginal
Sachharum spontaneum	Wild sugarcane	Marginal
Scirpus grossus	Bulrush	Marginal
Typha angustifolia	Cattail	Marginal

includes the Mae Taeng and Mae Ping Kao Irrigation Projects. The Mae Taeng Irrigation Project is relatively free of aquatic weeds at present. *Mimosa pigra*, a marginal species, is a serious problem along natural canals and ditches and is expected to continue spreading. Submersed aquatic weeds (hydrilla, coontail) are present and are potential problems in the old natural tributary of the system.

The Mae Ping Kao ..igation Project, devised from the Old Ping River, was completed in 1941. The Mai Dang Canal, the primary drainage system, is heavily infested with hydrilla. The principle method of control is manual labor supplied by volunteer farmers.

Mae Khong River Basin. The primary irrigation project in the Mae Khong River basin, the Mae Lao, is located in Chiang Rai Province. *Mimosa pigra* is a serious problem along the margins of most natural canals of the system.

Nong Luang, a natural lake used primarily for fish production, is heavily infested with floating (hyacinth, *Salvinia cucullata*) and submersed weeds (*Najas graminea, Ceratophyllum demersum, Utricularia flexuosa, Hydrilla verticillata*). The situation is serious and greatly limits fishing activities. The lake is currently being developed for fisheries, irrigation and recreation by the Chiang Rai Provincial Authority. The present and potential effect of aquatic weeds must be controlled to ensure adequate availability of the resource for these activities.

Kwan Payhao Lake supplies water for the city of Payhao, irrigation and a major fisheries activity. Infestations of submersed weeds (*Najas graminea, Ceratophyllum demersum,* and hydrilla) and floating water hyacinths are serious. Both manual removal and herbicide spraying are used to suppress hyacinth populations. Local citizens harvest, dry, and bag *Najas* and *Ceratophyllum* for sale as pig feed. This practice serves as a source of income to numerous people and any major effort to control these weeds would have a minor socio-economic impact.

Following the monsoon rains and subsequent flooding, mats of water hyacinth are manually forced over the dam into the Mae In River, which flows into the larger Mae Khong River system. The grass carp, *Ctenopharyngodon idella*, has been released in yearly lots of 10,000 fingerlings, but they have not prospered. This failure can be attributed to the large number of native carnivorous fish species, such as the snakehead, *Ophicephalus* sp. In order to utilize the grass carp as a control agent of the submersed weed species, they must be released in large numbers when they are 8 to 10 inches long. Having attained this size, the grass carp is capable of escaping predatory fish and eluding fisherman's nets.

Wang River Basin. The major water system in the Wang River basin is Kiu Lom Irrigation Project. Recently completed, this system exhibits high potential for future floating and submersed water weed species. *Mimosa pigra, Panicum repens* and *Saccarum* spp. (reeds) are well established and expected to cause severe problems.

The New Mae Moh Project was completed in 1975 to furnish a water supply for a lignite power plant. *Hydrilla verticillata* has already reached a serious level, inhabiting approximately one half of the water body.

Bhumibol Reservoir. The Bhumibol Multipurpose Project was constructed for the development of the Mae Ping River Basin. The catchment area totals 26,386 kilometers with a maximum water surface area of about 318 square kilometers. The hydroelectric plant is a major supplier of energy for Thailand.

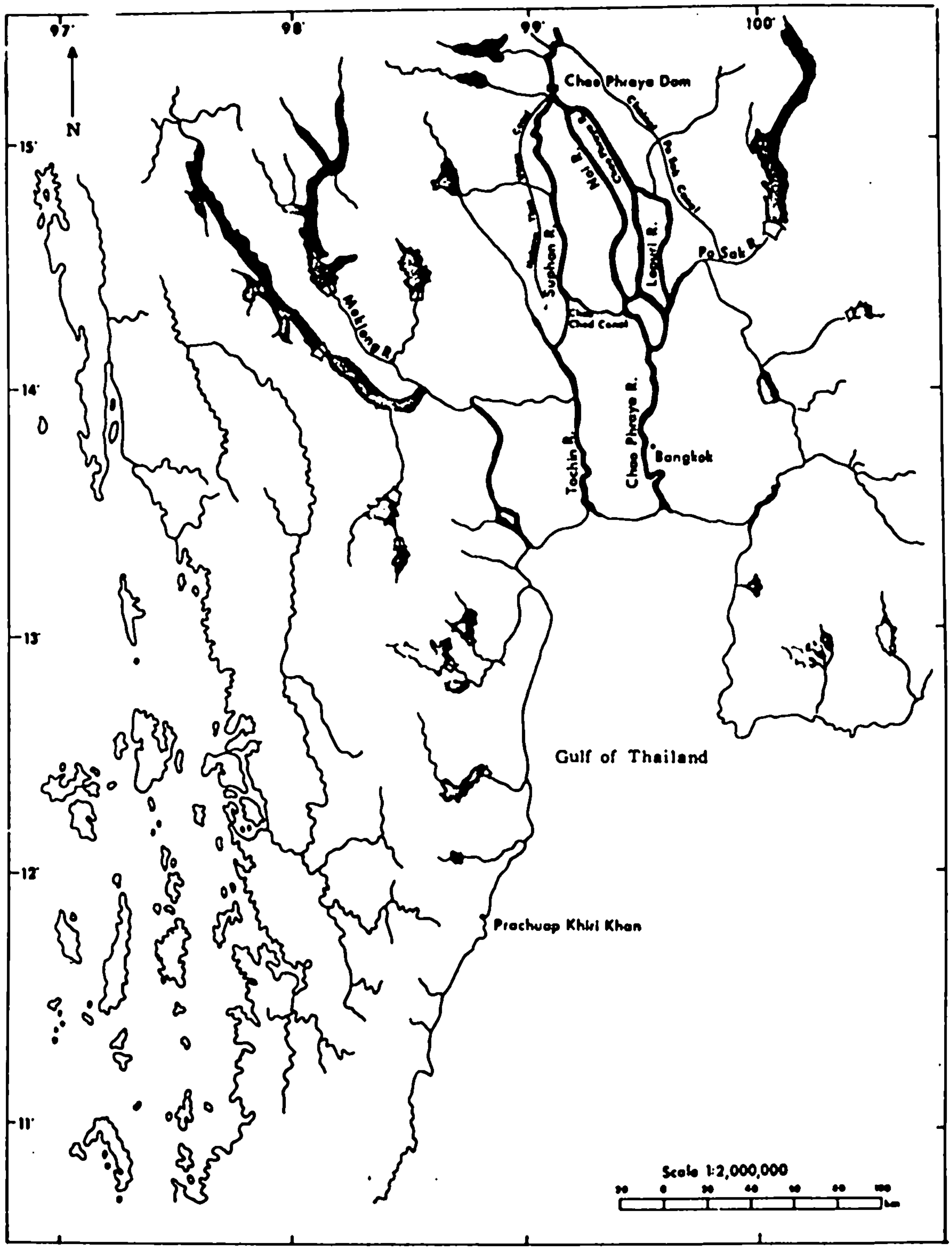
Water hyacinth invaded the first impoundment of the reservoir soon after it was completed in 1964, interfering with navigation and fishing activities In addition to hyacinth, water lettuce and *Salvinia* are present. An intensive program of 2,4-D spraying, water level fluctuation, physical removal and blocking was conducted. Since that time, hyacinths have been maintained at an acceptable level; however, large log booms are still required to prevent interference with electrical generating turbines. The potential of explosive populations is constantly present and routine monitoring continues to be necessary. Because of the immense size of the reservoir, wave action limits weed populations to the perimeters and wind-protected enclaves.

Bung Barapet. Bung Barapet, a natural lake, is used exclusively for fisheries. A wide variety of both floating and submersed weeds are well established. Major submersed species include *Potamogeton* spp., *Hydrilla verticillata, Coix aquatica*, and *Najas graminea*. The primary floating weed pest is water hyacinth, large mats of which are forced over the dams into the Chao Phraya River during monsoon flooding. This practice contributes to more serious problems in the catchment areas in the Central Region. The grass carp has been released in Bung Barapet, but, as in the Mae Khong River System, fingerlings cannot compete with the carnivorous fish species.

Central Region

The Central Plain is commonly referred to as the "rice bowl" of Thailand. Water for this rich agricultural area is furnished by the Greater Chao Phraya Project, which is the largest water control project in the country, covering 910,000 hectares. The greatest source of the Chao Phraya River is the Nan River, followed by the Ping, Yom, Pasak and Wang Rivers.

As stated above, the Bhumibol Dam on the Ping River (Northern Region) was constructed to generate hydroelectric power, and to aid irrigation, navigation, and flood control. In 1972, Sirikit Dam (Northern Region) was completed on the Nan River to store water for dry-season irrigation. The Bhumibol and Sirikit



Central Region

Dams feed the Chao Phraya Irrigation Project in the Central Region. The massive system of canals composing this project with their retainer and diversion dams encourage explosive populations of aquatic weeds. Water hyacinth is well established throughout the system, causing serious problems. The practice of forcing massive amounts of hyacinths in the North into the rivers feeding the Chao Phraya Project in the Central Region during the flooding season concentrates the hyacinth problem.

Water hyacinth is an acute problem in the Chao Phraya Project and a concentrated control program must be initiated soon to prevent serious water blockage and loss. The weed is present throughout the year in the canals, the Suphan and Noi Rivers, as well as the Song Phi Canal, and canals in the Chanasut Project. During the rainy season (July-November) hyacinths also infest the canals down to the North Rangsit Canal. Approximately 50% of the RID aquatic weed control budget is devoted to the Chao Phraya Project. Because of the direct effect of hyacinth populations on agricultural productivity in the Chao Phraya Project, the Central Region should receive the emphasis of any future major effort to control aquatic weeds.

Northeastern Region

A major survey of the Northeast was conducted in 1974 by Dr. George E. Allen and two members of this assessment team, Ms. Saowanee Thamasara of RID and Mr. Taval Maneewarn of EGAT (Table 4). Both RID and EGAT projects were reviewed.

Lam Takong Irrigation Project. The Lam Takong Irrigation Project reservoir is infested with two major water weed species, hydrilla and *Potamogeton* sp. However, at present they are restricted to the shallow margins. Both are aggressive species and should be monitored periodically. Water

Table 4. Aquatic Weed Infestations in Tank Irrigation Systems in the Northeastern Region of Thailand.

Province	Irrigation Tank	Surface Area (rai)* Design	Survey	Area of Aquatic Weed (rai)*	
Nakornratchsima	13	48,696	17,349		2,132
				S.W.	1,000
				F.W.	725
Khon Kaen October 27, 1974	9	2,104	824		485
				S.W.	200
				F.W.	75
Maha Sarakham July 8, 1975	10	9,773	6,000		2,150
				S.W.	1,750
Surin	9	31,500	4,912		2,188
				M.W.	1,133
				S.W.	895
Buriram Sept. 6, 1974	8	19,206	7,969		6,379
				E.W.	1,300
				S.W.	4,773
Sakon Nakhon	5	16,692	13,022		6,255

*1 rai equals 1,600 square meter

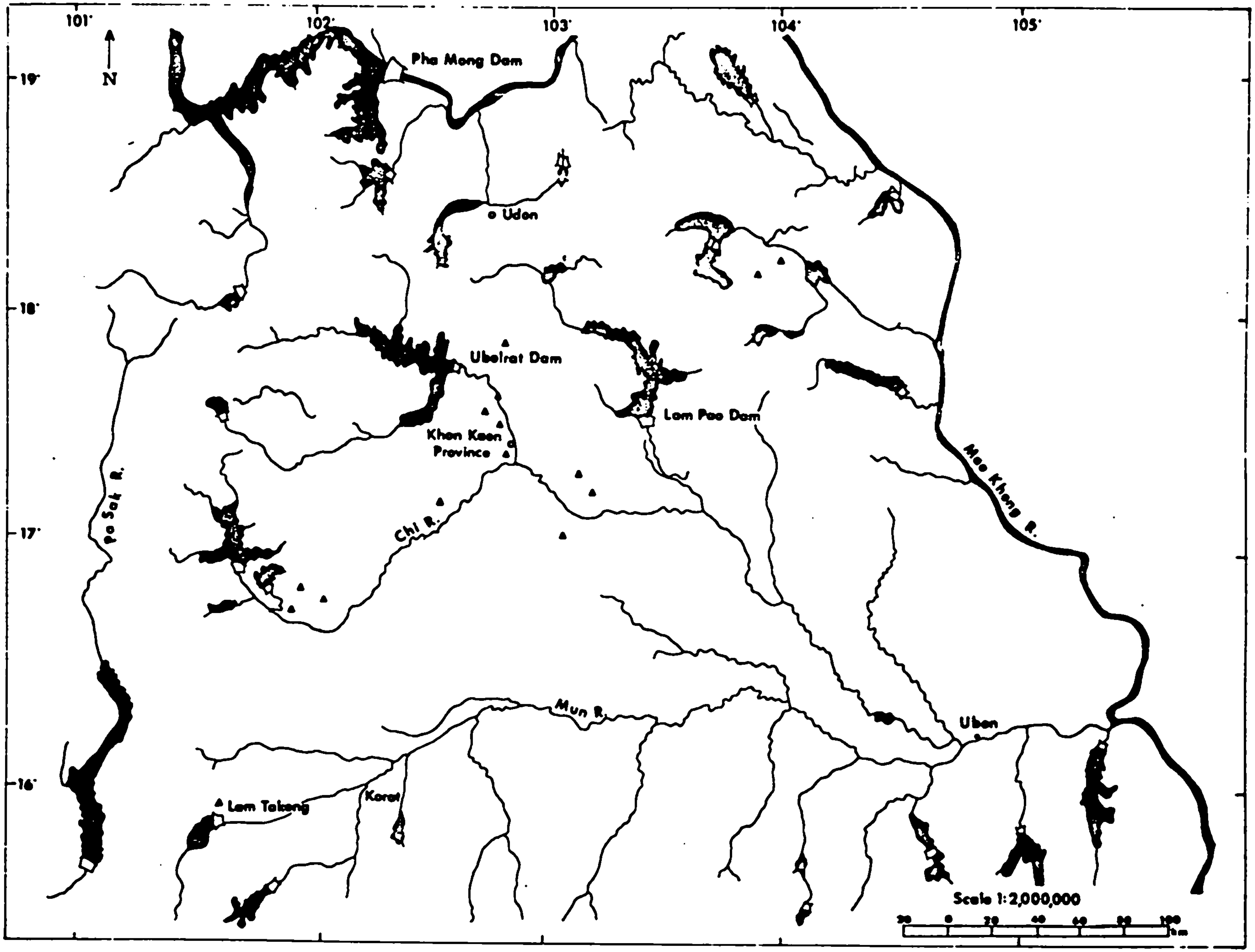
Note: S.W. = Submersed Weed, i.e., *Ceratophyllum demersum, Hydrilla verticillata, Chara* sp., *Nitella* sp.

F.W. = Floating Weed, i.e., *Eichhornia crassipes, Pistia stratiotes, Lemna minor, Salvinia auricullata*

M.W. = Marginal Weed, i.e., *Leesia hexandra, Brachiaria jubata, Hymenachne pseudointerrupta, Coix aquatics, Phragmites communis*

E.W. = Emergent Weed, i.e., *Scirpus articulatus, Eleocharis dulcis, Cyperus rotundus,*

These data were collected during a weed survey from June to November, 1974.



Northeast Region

hyacinth is present and is a potential problem in the reservoir; however, it has already reached serious levels in the 45 km main canal and its lateral canals below the restraining dams.

Huang Sub Pradoo Tank Irrigation Project. The Huang Sub Pradoo Tank Irrigation Project is infested with water hyacinth and the submersed weed *Najas graminea*. Attempts have been made to maintain hyacinth populations with the application of 2,4-D. No attempt has been made to arrest the development of *Najas*. A major concern is the contribution of heavy biomasses of aquatic weeds to the tank sediments, which will reduce its depth in a few years. As this phenomenon continues, the nutrient load will increase, resulting in more favorable conditions for greater production of aquatic weeds.

Nong Wai Irrigation Project. The area of the Nong Wai Project for Irrigated Agriculture is located on the right bank of the Nam Pong River, extending for more than 30 km in the area of Khon Kaen. The total area covers some 15,000 ha of which approximately 13,500 ha can be irrigated.

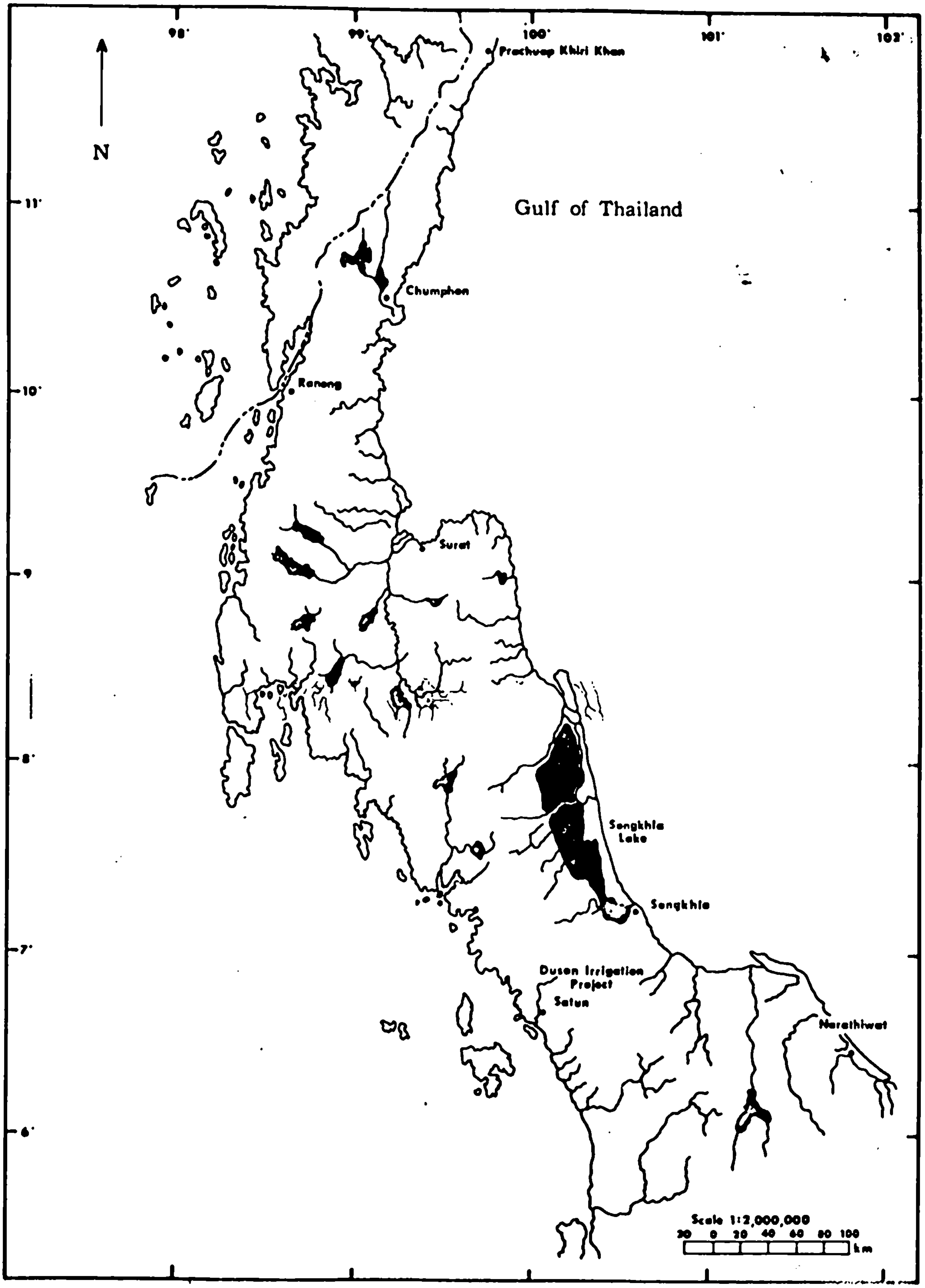
The Nam Pong River is the primary source of water of the Nong Wai Project. The portion of the Nam Pong River extending from Ubolrat Dam to the Chi River is heavily infested with water hyacinth, *Pistia stratiotes, Salvinia cucullata, Ceratophyllum demersum, Najas graminea,* and hydrilla. Hyacinths often collect and block irrigation gates in the irrigation systems. Submersed species, *Najas, Ceratophyllum* and hydrilla, are serious problems in secondary canals where the rate of water flow is slow. A common practice is to block these canals and permit them to dry up for 2 to 3 weeks. After the submersed weeds have dehydrated they are removed by manual labor and mechanical equipment such as drag-lines. This practice is costly, not only in terms of labor and equipment, but in the loss of needed water supplies by area farmers.

Tank Irrigation Project Near Khon Kaen. The tank irrigation project near Khon Kaen is a small but typical system on the road to Chum Pal. Practically every important aquatic weed present in Thailand is represented there. The concentration of weeds has been so heavy that they block the pump intakes. This system will be rapidly filled with plant biomass within a few years.

Nam Pong Reservoir--Ubolrat Dam. The Nam Pong is one of the largest completed reservoirs in the Northeast Region and serves irrigation, hydro-electric power and flood control activities. Because of the morphology of the reservoir it is highly conducive to water weed infestations. The gradually sloping sides provide excellent sites for submersed weed growth. Started in 1965 and completed in 1976, the Nam Pong Reservoir is infested with a wide range of aquatic weeds, including floating water hyacinth, *Salvinia cucullata, Pistia stratiotes,* and submersed *Hydrilla verticillata, Potamogeton* spp. *Najas graminea* and *Ceratophyllum demersum.* There seems little doubt that aquatic weeds will present a major problem in the Nam Pong.

Chi and Mun River Basins. Both the Chi and Mun, two of the major rivers in the Northeast, are infested with water hyacinth. As these two basins continue to undergo development, the hyacinth problem can be expected to worsen. The construction of diversion dams and irrigation systems will encourage water hyacinth population increases.

Lam Pao Basin and Dam. This project, scheduled to be completed in 1979, will eventually irrigate approximate 54,000 ha. The upper portion of the reservoir has already developed a serious water hyacinth population, greatly curtailing potential use of the system. Control programs are currently restricted in the upper areas of the reservoir because of a highly sensitive political atmosphere. Any control program developed for the dam area would



Southern Region

be quickly undermined by re-infestations from the upper area of the reservoir.

Southern Region

The Southern Region consists of the Thai Peninsula, an area of about 30,000 square miles. The area assessed for aquatic weed problems was the lower portion, which is divided by a central mountain range.

Duson Irrigation Project. Located in Satun Province, the Duson Project supplies water for approximately 5,200 ha. The irrigation canals are seriously infested with hydrilla. According to the administrator of the project, six employees devote full time, year round, to the manual removal of this species; little or no assistance is obtained from farmers and villagers. A considerable amount of manpower is being devoted to hydrilla removal, a practice which will be required continuously. A well designed control program is needed and certainly warranted for this small but important irrigation system.

Songkhla Lake. One of the largest natural lakes in Thailand is Songkhla Lake, located in Songkhla and Phatthalung Provinces. The mouth of the lower Songkhla is brackish, where fresh and salt waters meet. The water body itself, which is fresh water, is relatively free of water weeds except around the more shallow periphery. The high cross winds and wave action should continue to keep the open waters weed-free.

The upper Songkhla, in contrast, is extremely shallow (2 to 3 meters) and heavily infested with hydrilla. There is concern by the local people that this body of water is undergoing rapid succession. The dominance of hydrilla could greatly accelerate this process. Several other serious water weed species are also present, including: *Alternanthera philoxeroides, Ceratophyllum demersum, Blyxa* sp., *Cyperus rotundus, Eichhornia crassipes, Jussiaea repens,* *Najas indica, Phragmites karka, Potamogeton malayanus, Salvinia cucullata,* and *Utricularia flexuosa*.

Water hyacinth is the dominant floating aquatic weed and is used extensively by village fishermen to compose fish traps. Large mats of the weed are staked with bamboo and traps placed beneath them. This practice could have a strong influence in the development of a weed control program on the Songkhla.

Economic Assessment

General Overview

The economy of Thailand is operating at a high level as evidenced by a number of economic indicators. The gross national product has been increasing since 1970 and inflation is rising. Population growth has stabilized at a rate of slightly over 3% per year. Visual observations of economic activity throughout Thailand support these data and may even suggest an acceleration of activity.

Thailand's infrastructure is extensive and well developed relative to many LDC's. Intensively used facilities include highways, roads, schools, hydroelectrical power plants, irrigation projects, telephone and telegraph lines. Vehicles of all types--ox carts, bicycles, pickups, motorcycles, trucks, and buses--ply the highways from dawn to dusk. Longboats are used extensively in canals and lakes. A high percentage of highway vehicles are filled with agricultural commodities, evidence of strong local and regional demand for food products.

Greater economic activity occurs in irrigated agricultural areas which permit two rice crops per year on agricultural land instead of one. Here, water buffalo are the dominant power source. Some tractors with land equipment are hired on a custom basis for short periods during planting or harvesting when timing is crucial to crop yield or loss. In these areas the trucks and pickups are widely used, while motorcycles dominate in the drier regions. Less productive and lower valued zebu cattle are the major farm power source in the drier areas.

Evidence of increased consumer income and savings is commonplace. Many of the homes, even those in small rural areas, have glass windows, painted or stained wood exteriors, televisions, and portable radios. Modern clothing is worn by people of all ages in the countryside, as well as in the villages and larger cities.

Secondary roads are extensive and generally all-weather with a gravel base rather than dirt, making them passable even during monsoons. Many of the more inaccessible mountainous roads are being paved using local labor for all but the most difficult earth moving and grading tasks, which are done with Japanese equipment.

More dams and irrigation systems are in various stages of planning and construction for hydroelectric power and irrigation of rice and vegetable crops near the larger cities. Also, aquaculture for fish production is being expanded both in freshwater ponds and canals and in brackish water lakes and marshes near the ocean. In the upland areas, rubber production is on the increase due, in part, to the oil crisis.

The Thai government has contributed strongly to economic growth. This monarchy is well respected throughout the country and is noted for its stability and strong social reforms. The government has been nearly free from external political forces for several hundred years, which has contributed to its stability. Income distribution is uniform over most of the population with widespread evidence of women in the work force, including the public sector.

Influence of Aquatic Weeds

Aquatic weeds are evident in canals, lakes, and irrigation channels throughout Thailand. Water hyacinth (a floating weed) and hydrilla (a rooted weed) are the most common. These plants are somewhat regionalized in terms of their commercial utilization and their threat as a serious economic problem. In the Northern Region, near Chiang Mai, the second largest city in Thailand, hyacinth and hydrilla are found in irrigation canals and waterways. Each spring, usually in April, the farmers of the area rake the weeds out of the canals and stack them on the banks to dry, after water in the canals is shut off. Because domestic water supplies come from shallow wells, the draining of canals creates no water shortage for domestic purposes. After drying, the weeds are ground up and used as feed supplement for pigs. Farmers give freely of their time, partly because work in the fields is light and partly because they fully comprehend their dependency upon an adequate and continuous water supply for crop production.

In many of the numerous lakes, including Songkhla Lake, which flows into the Gulf of Thailand, the natural silting and eutrophication process provides a natural environment for increased weed infestation. The receding shorelines, shallow lake depths, and increased weed growth are a natural consequence, encouraged by local farmers who gain more income from rice on the increased shoreline than from lake fishing. Farming of private plots is more easily controlled and stable than fishing from a common property resource.

Perception of Future Problems and Control Measures

Development brings about negative as well as positive dimensions in a dynamic society such as Thailand. Increased air and water pollution are examples of negative factors. Water pollution provides an ideal medium for increased aquatic weeds which in turn partially offsets the benefits from free sewage disposal which waterways now provide.

Socioeconomic analysis is required to appraise both the negative and positive effects of reduced crop production, weed cleanup by physical, biological, and chemical means, and benefits from commercial utilization of aquatic weeds.

Historically, natural flushing actions within river systems by annual monsoons force weeds down to the ocean each year. This natural cleansing effect is being diminished by increased irrigation and flood control projects which impede natural water flow. The consequences are most pronounced in the Chao Phraya River Basin just north of Bangkok, which includes the country's largest irrigation system. Removal of hyacinths by natural flushing is being seriously impaired by the large number of diversion dams and gates. This development is further aggravated by greater use of waterways for sewage disposal and greater leaching of soil nutrients into the waterways from large areas of irrigated land on which commerical fertilizers are used. The economic effects of such current changes take several forms:

(1) Increased capital investment and operating costs at power generating sites for external heat exchanger systems to prevent weed clogging of the generator and permit periodic cleansing without system shutdown.

(2) Economic cost for farmers and/or irrigation district personnel to clean the canals annually of aquatic weeds. A secondary social

cost involves development of shallow wells to provide domestic water in areas requiring canal cleaning and which relied historically upon canals for potable water.

(3) Economic loss from reduced fishing and/or rice production due to clogging of irrigation channels from aquatic weeds.

(4) Economic loss of water transportation and further public investment in that sector.

(5) Transfer of economic activity from one region to another. As some regions gain, others lose because aquatic weed growth and its economic consequence varies between regions.

(6) Development of capital-intensive primary and secondary sewage treatment plants for the larger cities to substitute for waterways now used for sewage disposal and as natural flooding is further controlled.

(7) Economic benefits from commercial utilization of aquatic weeds.

These economic costs and benefits, as well as the economic effects of proposed weed control programs, must be carefully considered as decisions regarding various control programs are made.

DISCUSSION

Results of field investigations, published data and reports, and discussions with Thai scientific personnel have lead the assessment team to make the following conclusions:

(1) Aquatic weed problems in Thai water systems are manifestations of water quality problems associated with enrichment or eutrophication.

(2) Enrichment has resulted from a combination of natural and cultural factors, including those associated with multiple usage.

The major aquatic weed problems in Thailand are associated with the irrigation systems and natural lakes, although some reservoirs also contain serious or potential problems. Irrigation systems are infested with both floating and submersed weeds which hinder or block water flow and perpetuate silting in canals. The acceleration of succession in the natural lakes is alarming, and attention should be given to elimination of both floating and submersed weeds.

In comparison to that of other Asian countries, the aquatic weed situation in Thailand is considered moderate, but it could become a problem of major import as it has elsewhere. In Indonesia, Bangladesh, Sri Lanka and India major lakes, reservoirs and irrigation systems are now virtually inaccessible to man. Should this situation develop in Thailand it would have a very detrimental effect on the economy because of the country's dependence on adequate water supplies in all areas of life.

The major noxious cosmopolitan aquatic weeds, *Eichhornia crassipes*, *Hydrilla verticillata*, *Pistia stratiotes*, *Potamogeton* spp. and *Ceratophyllum* *demersum*, are present and causing some damage. *Najas graminea*, one of the most serious submersed aquatic problems in Thailand, is of little consequence elsewhere in the world. The only major water weed species not currently found in Thailand is the notorious water fern *Salvinia molesta*, better known as the "Kariba weed." This pest established its reputation by producing serious infestations on the newly constructed Lake Kariba in Africa during the 1960s. It has since spread throughout central, east and south Africa and more recently to Indonesia and Malaysia. *Salvinia molesta* is an aggressive weed causing serious problems in rice fields. If this species reaches the rice-growing area of central Thailand, it will cause severe problems. There is little doubt that it will reach Thailand, since it is now flourishing in central Malaysia. Every effort should be made to prevent its entrance into the country.

The findings of the assessment team accent the need for a long-range plan to manage water weeds in Thailand. Thailand has available considerable scientific expertise and well-organized agencies responsible for water systems (RID, EGAT, Fisheries and Aquaculture). These agencies are aware of the dangers of aquatic weed infestations and the need to initiate action programs as soon as possible.

RECOMMENDATIONS

It is the conclusion of the assessment team that the aquatic weed situation in Thailand is developing to serious levels in many valuable water systems. Steps should be taken to initiate both short and long-range control programs of both floating and submersed weed species. The greatest short-term priority is the hyacinth problem in the Chao Phraya Irrigation Project, where significant reduction in productivity is occurring. An immediate action control program is recommended for this area.

The development of an effective long-term aquatic weed management program for Thailand will require a minimum of five years. This effort must include:

1. Education of the people
2. Education and training of personnel to conduct the needed research and action programs
3. Development of an interagency group to organize and conduct both research and action programs
4. Economic impact analysis
5. Basic and applied research
6. Integration and implementation of control programs
7. Monitoring and evaluation
8. Technical assistance

Education of the People

A concerted effort should be made to make the people aware of the impact of water weeds on their standard of living, transportation, agriculture, and water loss. Radio, television, and other mass media should be used. Information should be disseminated in public school education programs.

Education and Training of Personnel

An excellent nucleus of qualified Thai scientists, representing several agencies, is available to participate in a long-range program. In addition, adequate research and supporting facilities are available. The 25 participants in the training course are qualified to assist in programs under the direction of senior Thai scientists. Senior scientists and their agencies include:

Scientist	Field of Expertise	Agency
Dr. Banpot Napompet	Biological control	Kasetsart University
Mr. Kosol Charernsom	Biological control	Kasetsart University
Mr. Taval Maneewarn	Ecology, water quality management	EGAT
Ms. Saowanee Thamasara	Chemical analysis, chemical control	RID
Ms. Umpai Yongboongerd	Plant Taxonomy	Kasetsart University
Ms. Rajanee Virabalin	Plant Ecology	Chulalongkorn University
Dr. Narong Chomchalow	Utilization	Applied Scientific Research Corporation of Thailand

Taval, Kosol, and Saowanee have received advanced training in aquatic weed management in the United States.

A good nucleus of research and supporting facilities are available in Thailand, including:

Facility	Agency
Chemical Analysis Laboratory	RID
Aquatic Weed Control Laboratory	RID
National Biological Control Center	Kasetsart University
Utilization of Aquatic Weeds	ASRCT
Pollution Control Facility	EGAT

In addition, various potential research facilities are located in many of the Thai universities. In such cases where qualified faculty are also available, involvement of graduate students in aquatic weed research projects should be encouraged.

Kasetsart and Chulalongkorn Universities should be encouraged to initiate graduate courses in aquatic weed control in order to train additional personnel. In some cases it may be advisable to send a limited number of Thai scientists to the United States for specific training.

It must be stressed that Thailand has the most qualified scientists in the world in aquatic weed control, aside from the United States.

Inter-Agency Coordinating Group

Because of the diversity in the problems caused by aquatic weed infestations, several government agencies will be involved in the national control effort. The Coordinating Subcommittee on Aquatic Weeds for the National Research Council involved all concerned agencies and was responsible for the 6 week training and assessment program. A smaller similar body should be established to organize and supervise the total national program. Six to eight high ranking officials should be designated to constitute the Coordinating Group from the following ministries concerned with water weeds.

1. Office of the Prime Minister
   (EGAT and NEA)
2. Ministry of Agriculture and Cooperative
   (RID and Fisheries Department)
3. Ministry of Industry
   (Industrial Water Quality Control)
4. Ministry of Communication
   (Water Transportation)
5. Ministry of Public Health
   (Water Analysis Control)
6. Ministry of Interior
   (Potable Water for Urban and Rural Areas)
7. Ministry of Education
   (Universities)

The function of the Coordinating Group should be to develop areas of research or control responsiblity for the various agencies and to constitute joint agency programs and methods for funding recommended activities.

Economic Impact Analysis

Because resources for economic analysis of benefits and costs of aquatic weeds are limited, economic evaluation should be initiated where the greatest economic losses are now occurring. The Chao Phraya River Basin is a likely choice. Aquatic weeds have an adverse effect in the large irrigated flood plain, the agricultural production of which provides a significant dimension to Thailand's economy. The large metropolitan area of Bangkok, through which the Chao Phraya flows, is also affected.

A cooperative research team including economists from the Ministry of Agriculture, Kasetsart University, Royal Irrigation Department, and the Bureau of Fisheries, should be involved in the development and implementation of a comprehensive economic research program under supervision of the Coordinating Group. In addition to analysis of costs and benefits of aquatic weed infestations, the team must also consider the economic impact of chemical, biological, and mechanical control methods and weed utilization schemes. Physical, technical, and economic data must be developed in the field and/or provided by public agencies and university researchers. Finally, economic evaluation of treatment plants should become an integral part of all future water development plans for Thailand since they are bound to reduce further natural flushing capabilities of monsoons.

Basic and Applied Research

Before a long-range water weed management program can be implemented some basic research must be completed. The Coordinating Group should delegate the following research activities to the most qualified agency.

1. Vegetation maps of the major water weeds should be completed and updated at 6-month intervals.

2. A thorough classification of the fresh water bodies and systems in Thailand should be completed as soon as possible.
3. Water quality studies should be completed and repeated at 6-month intervals. Determinations should be made for: potassium, nitrate-nitrogen, total nitrogen, available phosphate, total phosphate, pH, total hardness, calcium carbonate, magnesium carbonate, carbonate alkalinity, copper, iron, water color, and turbidity. Detailed information should be developed on nutrient sources and loadings to surface waters as an integral part of the aquatic weed control planning program. Emphasis should be placed upon watershed areas which have the more serious aquatic weed problems. Because it is important to consider a watershed area in its entirety, it is recommended that the watershed selected for initial study be small. Emphasis should be directed toward development of criteria for limiting nutrient input from various point and non-point sources. Various multiple use concepts and their relationship to the enrichment process should be reviewed and evaluated. Results of this effort could then serve as a guide for remedial measures on other problem watershed areas and for future water resource project planning.
4. Phytoplankton and benthic fauna should be identified and populations monitored yearly.
5. Physical parameters, including rate of sedimentation, oxygen, temperature profiles, and light penetration, should be recorded for selected water systems. These factors are important to the overall trophic level of a body of water.
6. Aquatic weeds in concerned water systems should be surveyed and

identified and the natural enemies associated with them determined. This information will help to detect unoccupied ecological niches and predators present which might attack and limit the success of biotic agents planned for introduction. There must be close cooperation with government agencies concerned with fisheries and wildlife. As early as possible, these agencies must identify the aquatic plants they consider vital to fish and wildlife.

7. Priority biotic agents should be imported for quarantine studies. Since the white amur, or grass carp, is currently under study in Thailand, it should be screened for weed preference, stocking rates, etc. It is the most important biotic agent available for submersed weed control. Exotic insect studies should be conducted in the National Biological Control Center. Biological agents available for consideration are listed in Table 5. These studies should involve screening of indigenous host plants and receive release approval by the concerned Thai government agency. First priority should be given to water hyacinth insects.

   Certain control methods, such as mechanical harvesting or chemical control, can be implemented at will. Research must determine the susceptibility of all beneficial plants to candidate herbicides, methods of application, and residual effect. Applied biological control will require longer periods of study. Primary emphasis should be placed on the release of the grass carp for submersed weed control and the recommended insects for control of water hyacinth and water fern.

Integration and Implementation

As the various control methods are developed, attempts should be made to integrate two or more methods. The emphasis should be on consideration

Table 5. Potential Biological Control Agents for Aquatic Weeds Being Evaluated in the United States

	Species	Origin and Distribution	Plant Attacked	Status*
<u>Insects</u>				
Order Coleoptera	*Agasicles hygrophilus*	Argentina	*Alternanthera philoxeroides*	E
	Neochetina eichhorniae	Trinidad to Argentina	*Eichhornia crassipes*	E
	N. bruchii	Trinidad to Argentina	*E. crassipes*	I
	Neohydronomous purchelus	Argentina, Brazil	*Pistia stratiotes*	S
	Bagous lutulosus	Pakistan	*Hydrilla verticillata*	S
	B. limosus	Pakistan	*H. verticillata*	S
	Litodactylus leucogaster	Yugoslavia	*Myriophyllum spicatum*	Q
	Cyrtobagous singularis	Trinidad to Argentina	*Salvinia auricullata*	S
Lepidoptera	*Vogtia malloi*	Argentina	*A. philoxeroides*	I
	Acigona infusilla	Trinidad to Argentina	*E. crassipes*	I
	Sameodes albiguttalis	Trinidad to Argentina	*E. crassipes*	I
	Nymphula diminutalis	Pakistan, India, S.E. Asia	*H. verticillata*	S
	Nymphula spp.	W. Malaysia	*H. verticillata*	S
	Proxenus hennia	E. Malaysia	*P. stratiotes*	S
	Paraponyx stratiotata	Yugoslavia	*M. spicatum*	Q
	Samea multiplicalis	Florida to Argentina	*P. stratiotes, E. crassipes, S. minima*	N
	Arzama densa	Southeastern United States	*E. crassipes*	N
Diptera	*Hydrellia geniculata*	Pakistan	*H. verticillata*	S
Orthoptera	*Paulinia acuminata*	Trinidad	*S. minima*	S
	Cornops aquaticum	Uruguay, Argentina	*E. crassipes*	S
<u>Fish</u>				
	Ctenopharyngodon idella	China, Manchuria, Siberia	Polyphagous	I

* Status code: I = Introduced; E = Established; N = Native; S = Under study in foreign laboratories
Q = To be evaluated under quarantine in Florida

of degree of control, cost factors, and effectiveness.

This phase continues until biotic agents colonize and develop significant populations or fail to survive or become established. Released populations usually decrease in number for several generations during the first year before they start to increase. This is often caused by the necessity of adapting to new ecological conditions and it may be years before significant increases are observed. As the integrated program develops, there should be a shift in emphasis from herbicide use to greater dependency on more permanent biological agents.

Monitoring and Evaluation

An important part of any integrated control program is periodic monitoring and evaluation. Successful programs may be altered by unanticipated factors which shift the balance in favor of the target weed, such as overgrazing of pastures or pollution of water systems.

Procedures must be developed to determine the degree of control attributable to each method. Detailed measurements of water plant populations can be used to indicate the degree of control in a system.

The cost benefits of integrated control programs should be calculated in order to evaluate their true success. The benefits should be expressed in terms so that a cost-benefit analysis can be made. A realistic appraisal is dependent on detailed ecological studies of the target weeds. The development cost should be significantly reduced when compared to resulting benefits.

Technical Assistance

Although a high degree of scientific expertise and excellent research facilities exist in Thailand, a certain level of technical support will be required to develop a full scale action program for aquatic weed management. The technical assistance required is as follows:

1. A full time U.S. advisor to work with the Coordinating Group in the coordination of research and management programs.
2. Support to help develop the capabilities of the Fisheries Department to mass produce, rear, and stock the Chinese grass carp in the water systems affected by submersed aquatic weeds.
3. Support to aid the National Biological Control Research Center to conduct basic evaluation studies and to release biological control agents currently available through various international organizations.
4. Support to help explore the utilization of aquatic weeds by men or animals, for example, biogas production, paper, animal feed additives, and mulch.
5. Support to assist in conducting a thorough economic impact study of aquatic weeds on the small farmer and crop production, especially of rice.
6. Short term consultants to help their Thai counterparts coordinate specialty areas such as biological, mechanical and chemical control, utilization, ecology and economics.

LITERATURE CITED

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Hutchinson, G.E. 1967. A treatise on limnology. II. Introduction to lake biology and limnoplankton. New York: John Wiley & Sons, Inc. 1115pp.

Mortimer, C.H. 1942. The exchange of dissolved substances between mud and water in lakes, III & IV. Journal of Ecology 30:147-201.

Nelson, M.L., E.O. Gangstad, and D.E. Seaman. 1970. Report on potential growth of aquatic plants of the lower Mekong River Basin, Laos--Thailand. Report prepared for the U.S. Agency for International Development by the U.S. Army Corps of Engineers.

Ruttner, F. 1963. Fundamentals of limnology. Toronto: University of Toronto Press. 242pp.

APPENDIX A

Original Request for Technical Assistance Project

(Draft)

Request for New Technical Assistance Project

Project Title: AQUATIC WEED CONTROL RESEARCH IN THAILAND

Requesting Agencies: Coordinating Subcommittee on the Aquatic Weeds (CSAW), National Research Council of Thailand (NRC) in cooperation with the Applied Scientific Research Corporation of Thailand (ASRCT), Kasetsart University (KU), Chiang Mai University (CMU), Khon Kaen University (KKU), Prince of Songkhla University (PSU), Department of Agriculture (DOA), Royal Irriagation Department (RID), Department of Fisheries (DOF), Department of Science (DOS), Ministry of Public Health (MPH), and the Electricity Generating Authority of Thailand (EGAT).

Source of Assistance: International Plant Protection Center, Oregon State University, Corvallis, Oregon 97331, U.S.A.

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1. BACKGROUND INFORMATION AND JUSTIFICATION FOR THE PROJECT:

The aquatic weed problems in Thailand have been serious for some time and remains unsolved up till the present time. They are always a nuisance and are related to almost any activities concerned with water such as navigation, irrigation, fisheries, hydroelectric power, water resources, agriculture, public health, and many others. Studies on the solution of these problems have been undertaken by various government agencies in Thailand. At the end of 1974, the scientists interested in the study of aquatic weeds organized themselves and discussed the problems in the seminar on "Aquatic weeds". They recommended that an organization to carry out aquatic weed control be established. As a result NRC approved and set up CSAW at the end of 1975 as a body aiming at coordinating works leading to the control of aquatic weeds in Thailand.

2. DETAIL OF THE PROJECT:

2.1 PROGRAM GOAL:

To develop an effective aquatic weed management program in Thailand.

2.2 PROJECT OBJECTIVE

2.2.1 To survey and assess the economic losses due to aquatic weeds in Thailand.

2.2.2 To educate and to train research personnel.

2.2.3 To establish aquatic weed center and research facilities in Thailand.

2.2.4 To develop effective alternative control measures.

2.3 CONDITIONS EXPECTED AT THE COMPLETION OF PROJECT

At the end of the project, all concerned agencies plan to collaborate in the research and development program on aquatic weed management.

2.4 RECOMMENDED SOURCES OF INFORMATION AND DATA RELATED TO THE PROJECT NECESSARY FOR PROJECT VERIFICATION

2.4.1 Publications

Anonymous. 1975. Proceedings of the Seminar on "Aquatic Weeds, held at EGAT, Nov. 26-27, 1974. (in Thai & English)

Gangstad, E.O.; Seaman. D.E.; and Nelson, M.E. 1972. Potential growth of aquatic plants of the lower Mekong River Basin Laos-Thailand. Hyacinth Control J. 10. 4-9 (May 1972).

Nelson, M.L.; Gangstad, E.O.; and Seaman, D.E. 1970. Report on potential growth of aquatic plants of the lower Mekong River basin, Laos-Thailand. U.S. Agency for International Development, Washington, D.C.

Sovatabandhu, Kasin. 1950. Weeds in paddy fields in Thailand. Tech. Bull. 4 : 1-41. Bangkok: Dept. Agriculture (in Thai).

2.4.2 Reports

Allen, G.E. 1975. Current and potential aquatic weed problems in Thailand: Review, evaluation, and recommendations. Report by Dr. George E. Allen, Dept. Entomology and Nematology, Univ. of Florida, Gainesville, Fla., U.S.A.

Anonymous. 1975. Report of the first and second meetings of CSAW (in Thai).

______________. 1976. Report of the first, second, and third meetings of CSAW (in Thai).

2.5 DURATION OF THE PROJECT:

Three years, commencing 1976 (1976-1978) with possible extensions of two years until 1980.

2.6 PROJECT SITE

NRC, Bangkhen, Bangkok-9, Thailand.

2.7 PROJECT WORK PLAN AND ACTIVITIES

2.7.1 Detailed work plan of project activities and scope of work.

The technical aspect will emphasize the following steps on aquatic weed control:

a. Survey and construction of vegetation maps of the major aquatic weeds.

b. Study on water quality as related to aquatic weed infestation.

c. Study and identification of phytoplankton and benthic fauna and annual monitoring of the populations.

d. Compilation of the physical parameters of water bodies including rate of sedimentation, oxygen and temperature profiles, and light penetration.

e. Survey and identification of aquatic weeds in Thailand and evaluation of natural enemies associated with them.

f. Study on the introduced biotic agents for biological control.

g. Establishment of a centralized retrieval system of aquatic weeds.

2.7.2 Time schedule of project activities

WORK PLAN	1976	1977	1978	1979	1980	1981
Survey and construction of vegetation maps	-------	———	———			
Study on water quality	-------	———	———			
Identification of phytoplankton and benthic fauna	-------	———	———			
Compilation of physical parameters	-------	———	———	———	———	———
Identification of the aquatic weeds and natural enemies	-------	———	———	———	———	———
Study on introduced biotic agents for biological control	-------	———	———	———	———	———
Establishment of a centralized retrieval system of aquatic weeds	-------	———	———	———	———	———

3. DETAILS OF THE IMPLEMENTATION / OPERATING AGENCY

3.1 INSTITUTIONAL FRAMEWORK: (including coordination with other agencies concerned)

CSAW was formed in 1975 and serve as a coordinating body for aquatic weed research in Thailand. All research conducted by each agency will be reported to the CSAW for compilation and distribution to other agencies. Necessary coordination and integration could be recommended by the CSAW.

3.2 STAFF/PERSONNEL PARTICIPATING IN PROJECT IMPLEMENTATION:

At present CSAW consists of 7 Ph.D., 3 M.S., 1 M.D. and 4 B.S. They represent a total of 13 cooperating agencies. Additional manpower could be provided through cooperating institutes and agencies.

Name	Institute	Qualification	Field activity
1. Prof. Boon Indrambaya	NRC		Fisheries Biology
2. Dr. Narong Chomchalow	ASRCT	Ph.D	Botany
3. Dr. Charoen Vashrangsi	DOS	Ph.D.	Chemistry
4. Dr. Banpot Napompeth	KU	Ph.D.	Biological Control
5. Dr. Vichian Pooswang	CMU	Ph.D.	Horticulture
6. Dr. Vichitr Benjasil	NEAC	Ph.D.	Plant Breeding
7. Dr. Thirakthan Phukaswan	DOF	Ph.D.	Fisheries Management
8. Mr. Prachern Kanchanomai	DOA	M.Sc.	Weed Science
9. Mr. Theera Sawanarath	KKU	M.Sc.	Weed Science
10. Mr. Chobvit Lubpairee	NRC	M.S.A.	General Agriculture
11. Dr. Somthas Malikul	MPH	M.D. M.T.H.	(trop. Med), Epidemiology Soc. Med. Malariology
12. Lt. Com. Kiattisak Nutataya	EGAT	B.Sc.	Chemistry
13. Miss. Saowanee Thamasara	RID	B.Sc.	Chemistry
14. Mr. Apinan Kamnanrut	PSU	B.Sc.	
15. Mrs. Phongsri Boonyasirikool	NRC	B.Sc.	Agriculture Economics

4. ASSISTANCE REQUESTED

4.1 Expert

Field of operation/activity	Total		1977		1978		1979		1980		1981	
	No.	m/m	No.	m/m	No.	m/m	No.	m/m	No.	m/m	No.	m/m
1. Aquatic Weed Management	2	6	1	3	1	3						
2. Weed Ecology	2	12	1	6	1	6						
3. Weed Loss Assessment	1*	12	1	6	1	3	1	3				
4. Biological Control of Weed	5	15	1	3	1	3	1	3	1	3	1	3
5. Limnology	2	6	1	3	1	3						

* same man.

4.1.1 Justification for requesting experts.

It is necessary in aquatic weed control work to have on certain occasion visiting experts. The service expected from the experts are certainly not the advising ones but are more on a consultation basis and are expected to render their service accordingly with their fields of specialization to the aquatic weed management in progress.

4.1.2. Job Description of each Expert Requested.

<u>Expert's Job Description Form</u>

Post title : Expert in Aquatic Weed Management

Duration : 6 months

Date required : 1977 (3 mons.), 1978 (3 mons.)

Duty station : Bangkok

Duties : Consultation on survey and construction of vegetation maps.

Qualification : a) Ph.D.
b) 5 years experience

Age limited : 40 or above

Language : English

Background information : Experience in weed science

Expert's Job Description Form

Post title : Weed Ecologist

Duration : 12 months

Date required : 1977 (6 mons.), 1978 (6 mons.)

Duty station : Bangkok

Duties : Consultant on ecological evaluation and disposal of aquatic weed.

Qualification : a) Ph.D.
b) At least 7 years of experience.

Age limit : 40 or above

Language : English

Background information : Experience in system analysis of aquatic weed.

Expert's Job Description Form

Post title : Expert in Limnologist

Duration : 6 months

Date required : 1977 (3 mons.), 1978 (3 mons.)

Duties : Consultant on the study of phytoplankton and bethic fauna.

Qualification : a) Ph.D.
b) At least 5 years experience

Age limit : 40 or above

Language : English

Background information : Experience in Limnology

Expert's Job Description Form

Post title : Expert in Assessment Specialist

Duration : 12 months

Date required : 1977 (6 mons.), 1978 (3 mons.), 1979 (3 mons.)

Duty station : Bangkok

Duties : Service and consultant on weed loss assessment

Qualification : a) Ph.D.
b) At least 3 years of experience

Age limit : 35 or above

Language : English

Background information : Experience in system analysis of aquatic weed

Expert's Job Description Form

Post title : Expert in Aquatic Biological Control Specialist

Duration : 15 months

Date required : 1977 (3 mons.), 1978 (3 mons.), 1979 (3 mons.), 1980 (3 mons.), 1981 (3 mons.)

Duty station : Bangkok

Duties : Consultant on evaluation of the natural enemy of aquatic weeds.

Qualification : a) Ph.D.
b) At least 5 years experience

Age limit : 40 or above

Language : English

Background information : Experience in biological control of aquatic weed.

4.2 FELLOWSHIPS

Field of study/training	Total		1977		1978		1979		1980		1981	
	No.	m/m	No.	m/m	No.	m/m	No.	m/m	No.	m/m	No.	m/m
1. Weed Control*	3	84	3	36	3	36	1	12	-	-	-	-
2. Weed Ecology*	3	84	3	36	3	36	1	12	-	-	-	-
3. Weed Taxonomy*	3	84	3	36	3	36	1	12	-	-	-	-
4. Biological Control*	3	84	3	36	3	36	1	12	-	-	-	-
5. Study Tour	5	15	1	3	1	3	1	3	1	3	1	3
6. Non-degree Training	20	60	4	12	4	12	4	12	4	12	4	12
7. Participation in international conferences, seminar, work-shop, etc.	10	5	2	1	2	1	2	1	2	1	2	1
Total	47	416	19	160	19	160	11	64	7	16	7	16

* 2M.S. and 1 Ph.D.

4.2.1 Justification for requesting fellowships:

Although there is a nucleus of Thai scientists capable of participating in the program, a serious need exists for the education and training of additional personnel. Therefore, it is essential to educate the junior scientists with qualified and properly trained personnel in the related disciplines of aquatic weed management. The personnel trained in such a degree training program will eventually direct the program and lead to national self sufficiency in terms of manpower requirements for research and development. In the initial stages, these requirement will be filled by visiting experts. The fellowships thus requested are the minimum required for the effective, practical and economic long-range operation of the project. Also, it is extremely important to request fellowships at the technician level for non-degree training in aquatic weed management techniques.

4.3 EQUIPMENT

Pending upon the consideration of experts.

5. THAI GOVERNMENT COUNTERPART CONTRIBUTION TO THE PROJECT WORKING SPACE FACILITIES FOR EXPERT, AND CASUAL ALLOCATION AS DUMED NECESSARY WHICH WILL BE PROVIDED BY NRC.

6. RELATED PROJECT/ACTIVITIES:

6.1 PREVIOUS ASSISTANCE RECIEVED IN THE FIELD RELATED TO THE PROJECT.

Project	Institution	Sponsored by	year
1. Evaluation of natural enemies of aquatic weeds in Thailand	KU	BIOTROP	1974
2. Biological control of Aquatic Weeds with Chinese grass carp (Ctenopharyngodon Idella Val.)	DOF & ASRCT	NBCRC*	1975
3. Collecting and Evaluating of Economic Aquatic Weeds Parasites and Predators in Thailand.	DOA & KU	NBCRC	1975
4. Investigation of the Bionomics of the Insect and Natural Enemies of Water Hyacinth and Water Lettuce in Thailand.	ASRCT	NBCRC	1975

* National Biological Control Research Center.

7. FUTURE WORK PLAN:

At the end of the project, it will be necessary to evaluate the benefits of project to determine their real success before continuing future operation of the program. To assure success in this program, it will be necessary to educate the public so that they are aware of both the harmfulness of aquatic weeds and their share of responsibility in the control as a public service.

It is also planned that when the technical assistance has phased out, the CSAW will be responsible in carrying out the program according to its goals and ultimate objectives.

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June 17, 1976

APPENDIX B

Revised Request for Technical Assistance Project

(DRAFT)

A Proposed Training Course

In

Management of Aquatic Weeds

<u>Organizer</u>: Coordinating Sub-committee on Aquatic Weeds (CSAW)

<u>Supporting Agency</u>: USAID

<u>Justification</u>:

Thailand is abound with large body of water, both natural and man-made. Like any other tropical countries, aquatic weeds have become a nuisance expecially after the recent water resource development. Aquatic weeds cause many problems that hinder the use of water resources to the maximum of their potential. It appears that aquatic weeds have caused increasing problems in most water resources throughout the country.

Proper management of aquatic weeds can help improve water quality for its ultimate planned use. Realizing that such an activity is of a prime importance in combating with the aquatic weeds problems, CSAW has been established in order to coordinate the research activities and control measures of aquatic weeds in Thailand. This sub-committee is under the umbrella of the National Research Council. It is consisted of representatives of 14 government agencies which are engaged with aquatic weed research and management.

However, being a new field of activity in Thailand, most of the staff of these agencies still lack experience in the field. It will be advantageous to these people if a training course can be organized in Thailand.

<u>Training Objectives and Course Content</u>

The course in planned to inform and train participants of the methods and techniques for identification, ecology and control of aquatic weeds with systems that are useful and practical in Thailand. Those techniques include mechanical harvesting and utilization, chemical controls, biological controls, habitat implementation and integrated control methods. In addition, assessment of loss due to aquatic weeds will be analyzed in quantitative terms.

Topics that will be covered in the course are :

- Introduction
- Types of aquatic weed problems, assessment of loss, health hazaed, etc.
- Taxonomy and morphology of aquatic weeds
- Ecology and Physiology of aquatic weeds
- Management of aquatic weeds and preventive measures

- Control of aquatic weeds
  - Mechanical control and utilization
  - Chemical control
  - Biological control
  - Integrated control
- The aquatic ecosystem
- Systems techniques for research and control
  - Systems approach in aquatic weed control
  - Research and control techniques

It is also intended that each participant, after finishing the training, will not only be able to accomplish his assigned tasks more efficiently, but will also be able to transfer his knowledge and experience to his co-workers, colleagues and other people in the field of aquatic weed management.

Suggested Participants

The course is planned primarily for those who have some training, experience or responsibility in water quality and control of undesirable aquatic weeds including those who are research workers and university instructors in the fields related to aquatic weeds. Participants should have academic degree equivalent to bachelor's level, or professional experience in the natural and biological sciences. The participants should have adequate knowledge of English. The number of participants will be 20 to 30. They should be government employees of the agencies representing in the CSAW.

Course Schedule

The course will be divided into 2 parts. The first part, which will be held at the National Research Council in Bangkok, will be confined to lectures and discussion. The duration of this part will be three weeks. The second part will be field observation, demonstration, and experimentation at the locations where aquatic weeds are creating significant problems. The proposed sites are as follows:

Bhumiphol Dam, Tak	Man-made lake
Bung Borapet, Nakon Sawan	Natural lake
Kwan Payao, Chiang Rai	Natural lake
Nam Pong Resevoir, Khon Kaen	Man-made lake
Lam Pao Resevoir, Kalasin	Man-made lake
Songkhla Lake, Songkhla	Natural lake

The duration of this part will be three weeks.

It is proposed that the course will start from March 1 and terminate April 30, 1977. Details of the course will be provided at the later date.

Assistance Needed

Since CSAW is just a sub-committee of NRC having no budget allocation from any source, it is proposed that USAID be the principal agency to provide assistance in terms of expenses for the experts including their round-trip air fares and per diem, transportation cost within Thailand for the participants, and other expenses to cover the cost of organizing such a training course. It is expected that the government agencies sending participants for this training will be responsible for the expenses (perdiem and accommodation) of each participant.

Experts and Trainers

In addition to a few Thai experts and resource persons, the following foreign experts are required for this training :

- Aquatic weed ecologist
- Weed scientist
- Limnologist
- Aquatic weed control specialist
- Entomologist
- Fishery biologist
- Quantitative ecologist

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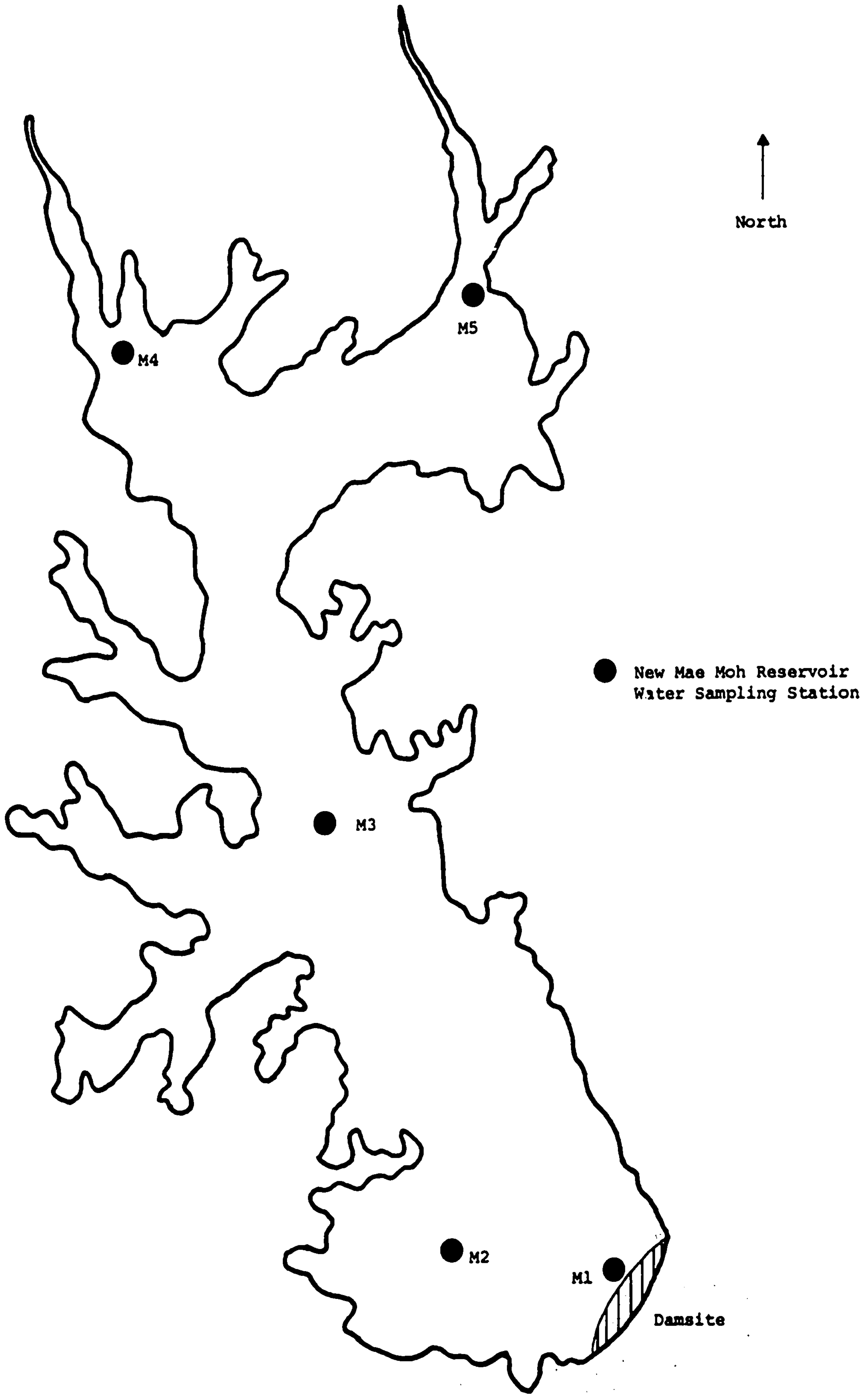
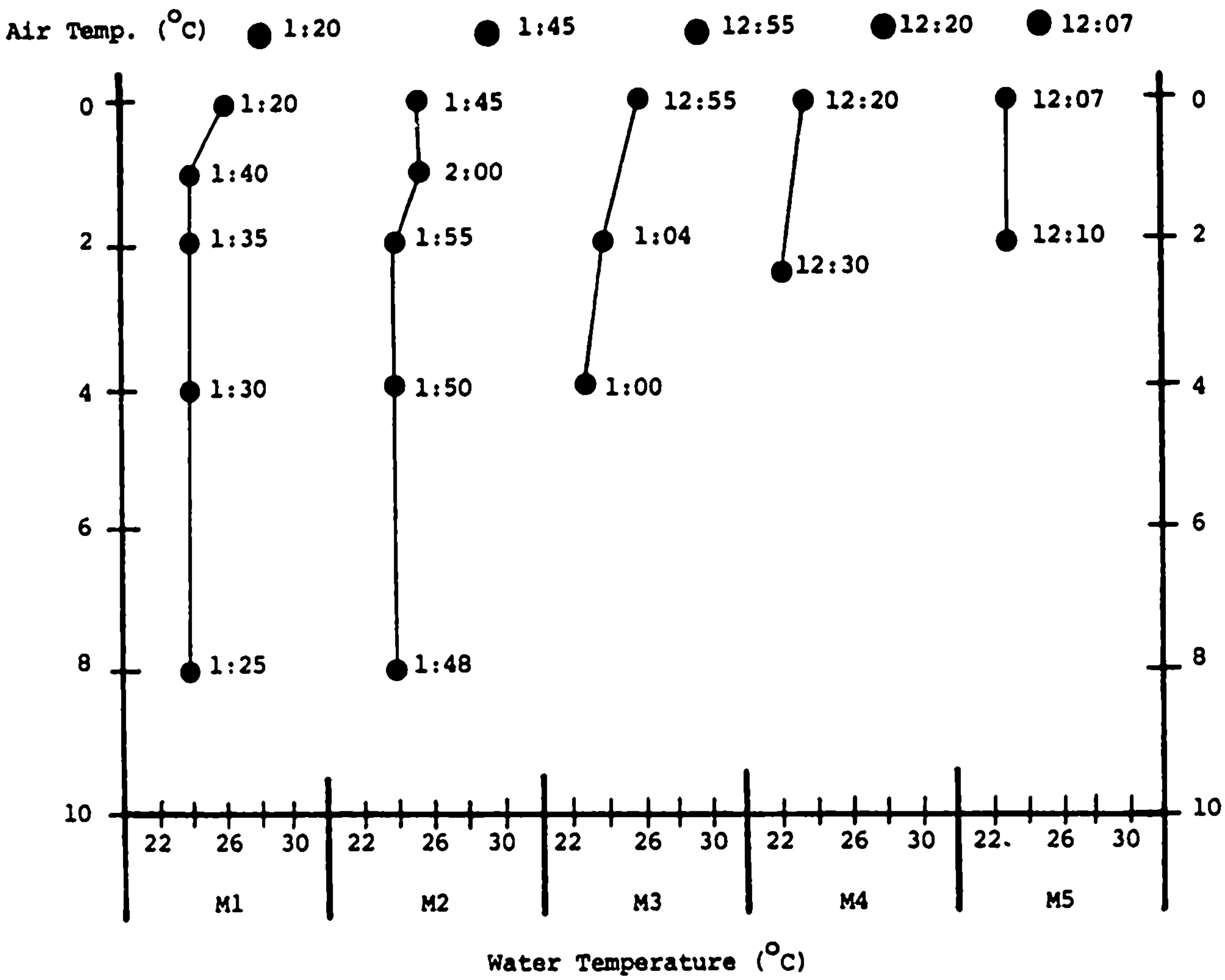
27 September 1976

APPENDIX C

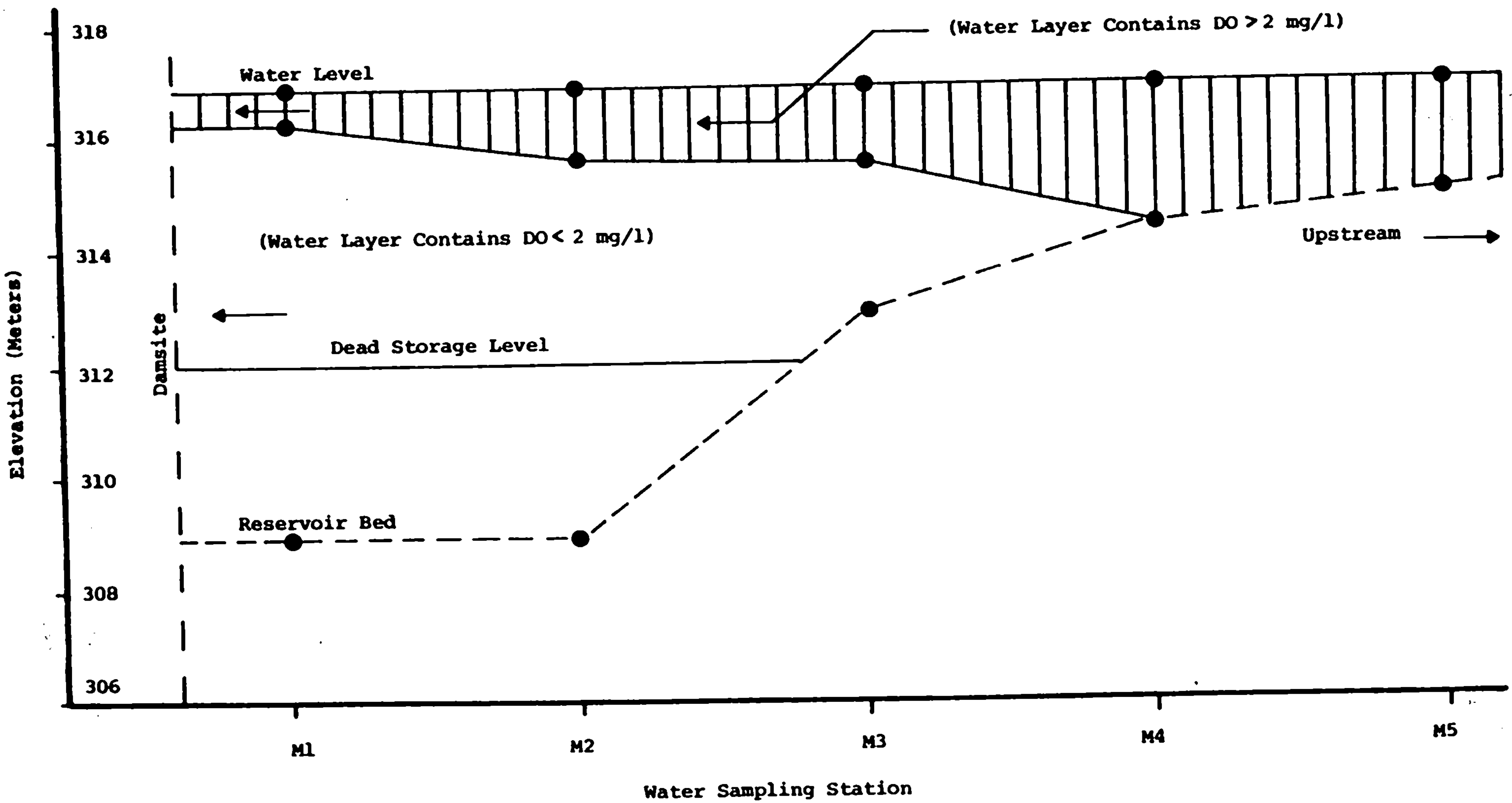
Water Quality Data For Mae Moh Reservoir

Located in Northern Thailand

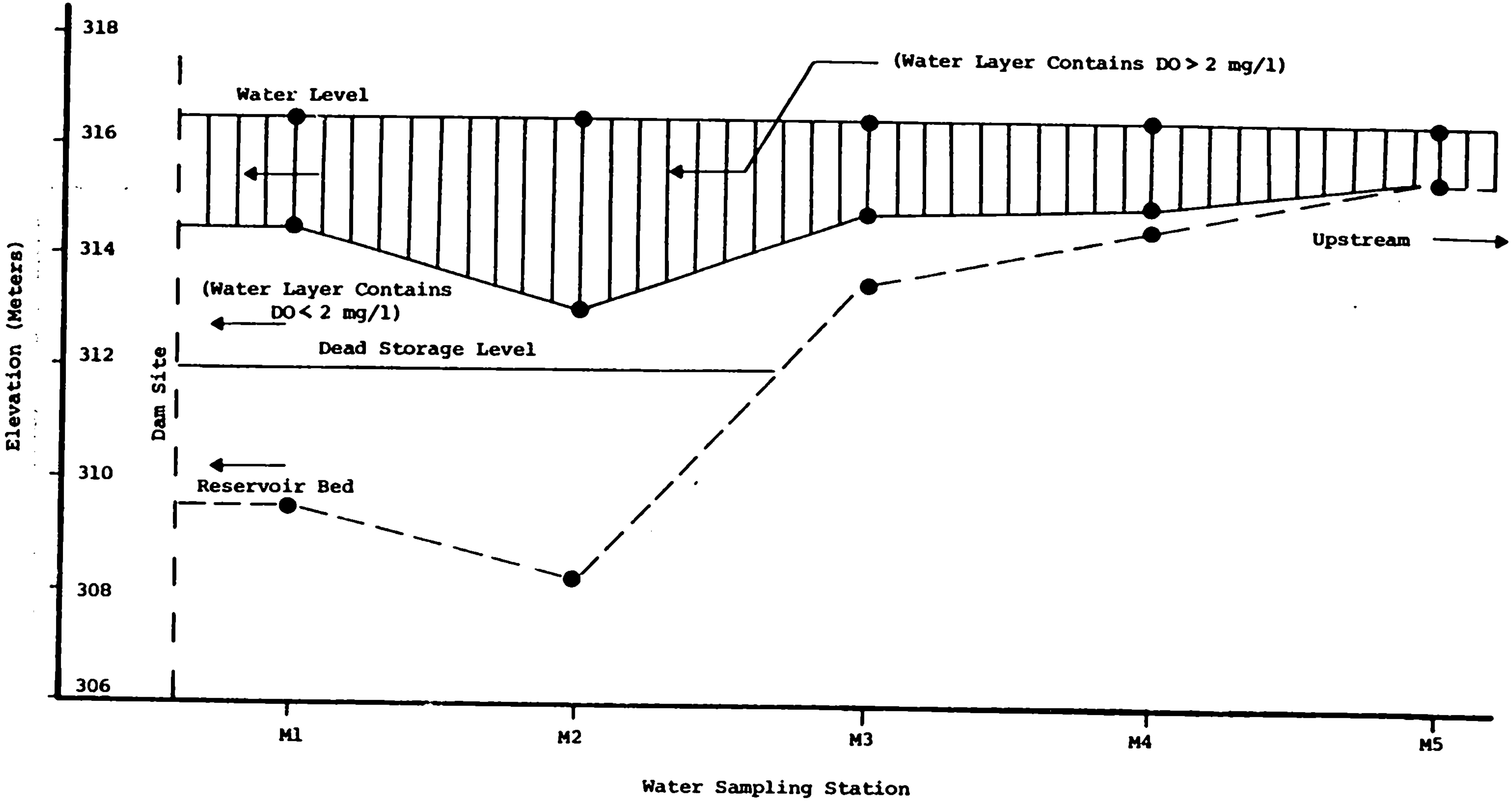

North
M4
M5
M3
M2
M1
Damsite
New Mae Moh Reservoir
Water Sampling Station



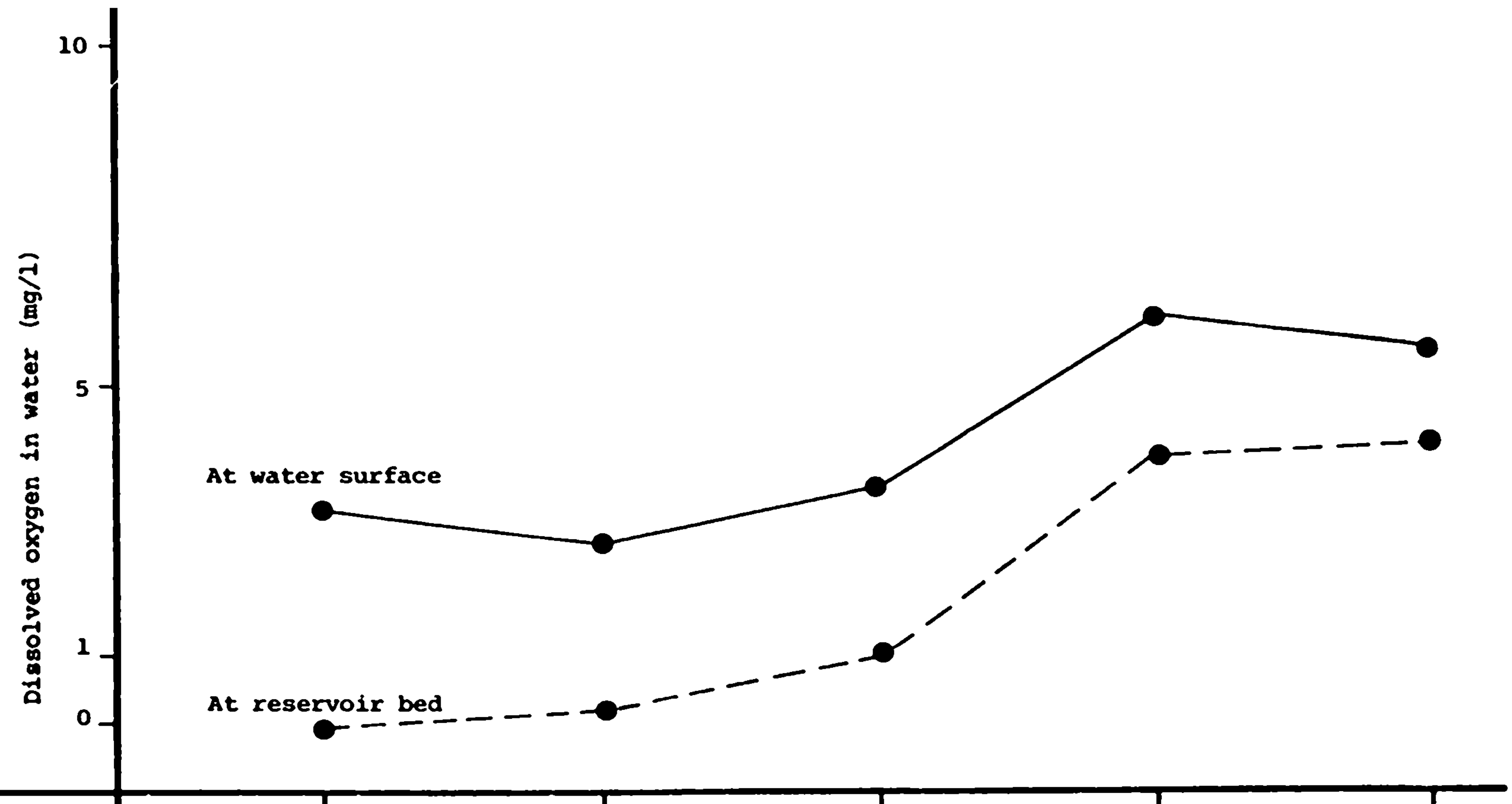
New Mae Moh Reservoir - Water temperatures at various depths of five water sampling stations.



New Mae Moh Reservoir - Dissolved oxygen in water, analyzed Dec. 16, 1976.

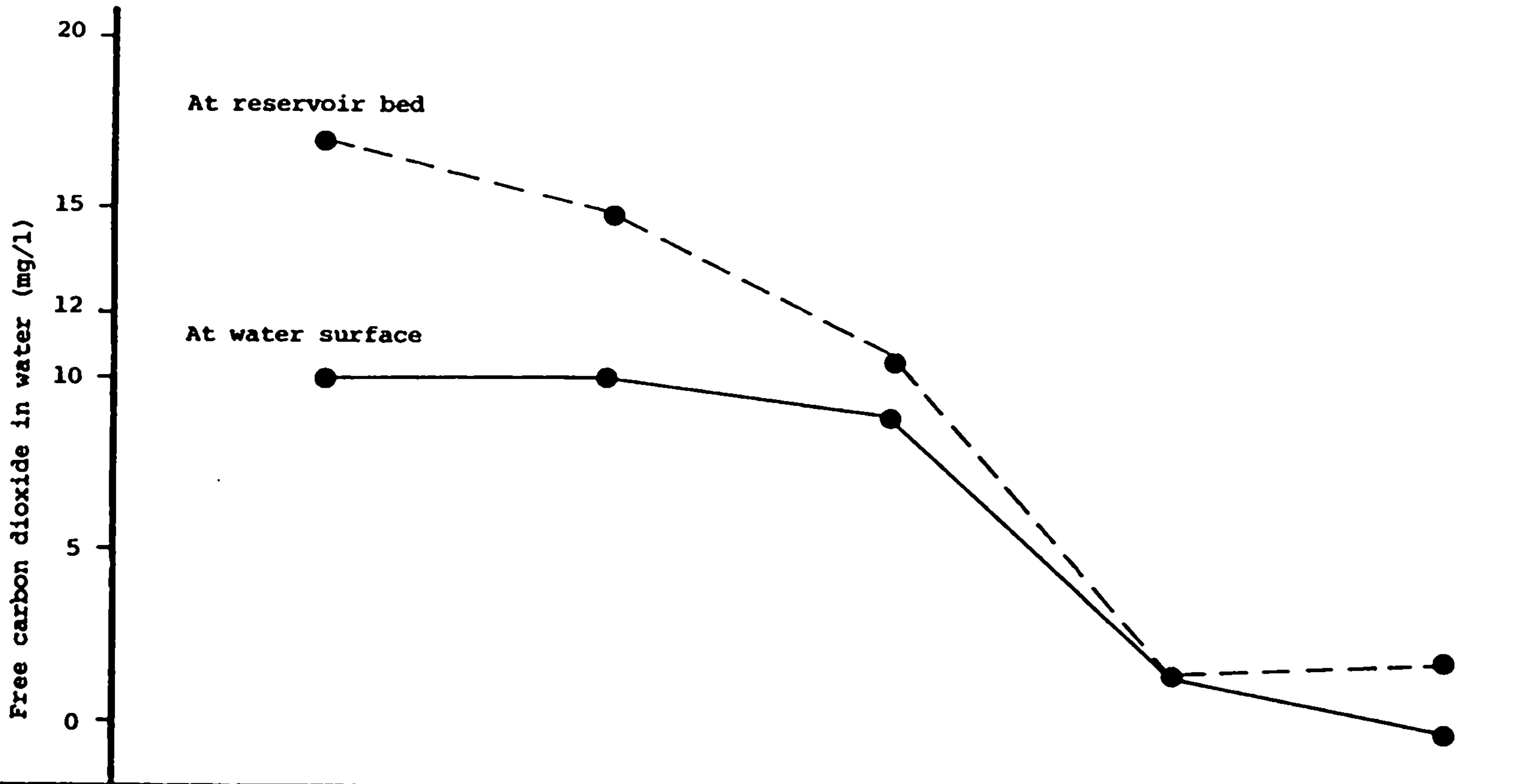


New Mae Moh Reservoir - Dissolved oxygen in water, alanyzed on July 16-17, 1976.



Water Sampling Station	M1	M2	M3	M4	M5
Depth - meters	8.00	8.00	4.00	2.50	2.00
Air temperature °C	28.00	29.00	29.00	26.00	24.00
Water temp. @ surface °C	26.00	25.00	26.00	23.00	23.00
Water temp. @ bed °C	24.00	24.00	23.00	22.00	23.00
Time	1:20	1:45	12:55	12:20	12:07
Date	Dec. 16, 76	Dec. 16, 76	Dec. 16, 76	Dec. 16, 76	Dec. 16, 76

New Mae Moh Reservoir - Dissolved oxygen at water surface and at reservoir bed from five water sampling stations.



Water Sampling Station	M1	M2	M3	M4	M5
Depth - meters	8.00	8.00	4.00	2.50	2.00
Air temperature °C	28.00	29.00	29.00	26.00	24.00
Water temp. @ surface °C	26.00	25.00	26.00	23.00	23.00
Water temp. @ bed °C	24.00	24.00	23.00	22.00	23.00
Time	1:20	1:45	12:55	12:20	12:07
Date	Dec. 16, 76	Dec. 16, 76	Dec. 16, 76	Dec. 16, 76	Dec. 16, 76

New Mae Moh Reservoir - Free carbon dioxide at water surface and at reservoir bed from five water sampling stations.

Summary of Water Analysis From New Mae Moh Reservoir

Station Oct 76 / Composition	M1		M2		M3		M4		M5		Outlet	Mean		Chemical Analysis 1973
	Surf.	Bed	Surf.	Bed	Surf.	Bed	Surf.	Bed	Surf.	Bed		Surf.	Bed	
pH	7.25	7.30	7.50	7.30	7.35	7.45	7.90	7.60	7.90	7.65	7.50	7.50	7.47	7.9
Conductivity $25^{o}C$ um/cm	184	185	187	188	188	183	174	165	177	175	192	182	181.3	376.7
Total Alkalinity (as $CaCO_3$)	123.4	120.0	116.6	116.6	120.0	120.0	123.4	103.4	113.4	103.4	120.0	144.1	113.9	-
Total Hardness (as $CaCO_3$)	96.0	100.0	101.0	106.0	106.0	104.0	93.0	84.0	94.0	92.0	107.0	98.0	98.8	147.3
Total Solids	129.5	137.5	126.0	211.5	130.5	129.0	115.5	133.0	136.0	343.0	162.0	127.5	186.0	248.7
Dissolved Solids	116.0	117.0	118.0	119.0	119.0	116.0	110.0	104.0	111.0	111.0	121.0	114.8	114.7	228.7
HCO_3	150.5	146.4	142.3	142.3	146.4	146.4	150.5	126.1	138.3	126.1	146.4	145.6	138.9	197.9
Cl	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	3.5
PO_4	0.1	trace	0.1	0.05	0.05	trace	0.05	trace	trace	0.1	trace	0.06	0.03	-
SiO_2	3.5	3.1	3.5	3.8	3.5	3.1	2.6	2.4	2.6	2.4	3.5	3.14	3.05	16.03
SO_4	1.2	1.2	trace	0.6	trace	trace	trace	trace	trace	1.5	trace	0.24	0.55	10.00
Ca	30.4	31.2	32.4	31.2	31.2	31.6	29.2	25.6	29.6	27.2	31.2	30.6	24.5	47.4
Fe	0.05	0.05	0.04	0.18	0.13	0.26	0.07	0.10	0.18	0.19	0.12	0.09	0.15	1.04
Mg	4.9	5.4	4.9	6.8	5.4	6.1	4.9	4.9	4.9	5.8	7.1	5.0	6.02	8.5
Dissolved O_2	3.2	nil	2.7	0.2	3.5	1.0	6.0	1.5	5.5	4.2	-	4.2	0.5	-
Free CO_2	10.0	17.0	10.0	15.0	9.0	11.0	4.0	1.5	nil	2.0	-	6.6	9.3	-

ELECTRICITY GENERATING AUTHORITY OF THAILAND

Water Analysis Report

Lab. No. 651-654/19 From. New Mae Moh Reservoir

Date Report. Jan. 4, 1976 Reference.

Analysed By. Suvat Date Received. Dec. 20, 1976

Kind of Sample				
Source	M1 Surface	M1 8m depth	M2 Surface	M2 7m depth
PH	7.25	7.30	7.50	7.30
Conductivity (25°C) (micromhos/cm)	184	185	187	188
Turbidity				
CONCENTRATIONS (PPM)				
Total Alkalinity (as $CaCO_3$)				
Total Hardness (as $CaCO_3$)	123.4	120	116.6	116.6
Total Solids	96.0	100.0	101.0	106.0
Dissolved Solids	129.5	137.5	126.0	211.5
Bicarbonate (HCO_3)	116	117	118	119
Carbonate (CO_3)	150.5	146.4	142.3	142.3
Chloride (Cl)				
Hydroxide (OH)				
Nitrate (HO_3)				
Phosphate (PO_4)	0.1	trace	0.1	0.05
Silica (SiO_2)	3.5	3.1	3.5	3.8
Sulfate (SO_4)	1.2	1.2	-	0.6
Calcium (Ca)	30.4	31.2	32.4	31.2
Copper (Cu)				
Iron (Fe)	0.05	0.05	0.04	0.15
Magnesium (Mg)	4.9	5.4	4.9	6.8
Oxygen Consumed				
Oxygen, Dissolved				
Remarks				

ELECTRICITY GENERATING AUTHORITY OF THAILAND

Water Analysis Report

Lab. No. 655-658/19

From New Mae Moh Reservoir

Date Report Dec. 30, 76

Reference

Analysed By Suvat

Date Received Dec. 20, 76

Kind of Sample				
Source	M3 Surface	M3 4m depth	M4 Surface	M4 2.50m depth
PH	7.35	7.45	7.90	7.60
Conductivity (25°C) (micromhos/cm)	188	183	174	165
Turbidity				
CONCENTRATIONS (PPM)				
Total Alkalinity (as $CaCO_3$)	120.0	120.0	123.4	103.4
Total Hardness (as $CaCO_3$)	106.0	104.0	93.0	84.0
Total Solids	130.5	129.0	115.5	133.0
Dissolved Solids	119	116	110	104
Bicarbonate (HCO_3)	146.4	146.4	150.5	126.1
Carbonate (CO_3)				
Chloride (Cl)				
Hydroxide (OH)				
Nitrate (HO_3)				
Phosphate (PO_4)	0.05	-	0.05	-
Silica (SiO_2)	3.5	3.1	2.6	2.4
Sulfate (SO_4)	trace	trace	trace	trace
Calcium (Ca)	31.2	31.6	29.2	2.6
Copper (Cu)				
Iron (Fe)	0.13	0.26	0.07	0.01
Magnesium (Mg)	5.4	6.1	4.9	4.9
Oxygen Consumed				
Oxygen, Dissolved				
Remarks				

ELECTRICITY GENERATING AUTHORITY OF THAILAND

Water Analysis Report

Lab. No. 659/19 - 661/19

From New Mae Moh Reservoir

Date Report Dec. 30, 76

Reference

Analysed By Suvat

Date Received Dec. 20, 76

Kind of Sample				
Source	M5 Surface	M5 2m depth	Outlet	
PH	7.90	7.65	7.50	
Conductivity (25°C) (micromhos/cm)	177	175	192	
Turbidity				
CONCENTRATIONS (PPM)				
Total Alkalinity (as $CaCO_3$)	113.4	103.4	120.0	
Total Hardness (as $CaCO_3$)	94.0	92.0	107.0	
Total Solids	136.0	343.0	162.0	
Dissolved Solids	111	111	121	
Bicarbonate (HCO_3)	138.3	126.1	146.4	
Carbonate (CO_3)				
Chloride (Cl)				
Hydroxide (OH)				
Nitrate (HO_3)				
Phosphate (PO_4)	trace	0.1	trace	
Silica (SiO_2)	2.6	2.4	3.5	
Sulfate (SO_4)	trace	1.5	trace	
Calcium (Ca)	29.6	27.2	31.2	
Copper (Cu)				
Iron (Fe)	0.18	0.19	0.12	
Magnesium (Mg)	4.9	5.8	7.1	
Oxygen Consumed				
Oxygen, Dissolved				
Remarks				

APPENDIX D

Water Quality Data For Selected Irrigation Tanks Located in Northwestern Thailand

Chemistry Laboratory

Research and Laboratory Section

Royal Irrigation Department

Report of Water Analyses

Location: Changwad Khon Kaen, Upstream of Nam Pong Dam

Date Sampled	Oct. 66	Nov. 66	Dec. 66	Jan. 67	Feb. 67
pH	7.1	7.5	7.4	7.8	7.1
$ECx10^6$ at 25°C	115	110	109	109	110
SiO_2 ppm	12	12	12	12	-
Oxygen consumed ppm	2.50	1.95	2.85	2.60	2.49
Dissolved oxygen ppm	1.26	1.29	1.40	1.74	-
Nitrogen Ammonia ppm	-	.22	.03	.13	-
Nitrogen organic ppm	0	0	0	.16	-
Albuminoid nitrogen ppm	0.11	0	.03	.26	-
SAR	.3	.8	.5	.4	-
SSP	18	39	25	23	-
RSC meq/l	0.02	.25	.12	.10	-
Ca meq/l (ppm)	.76(15)	.58(12)	.71(14)	.76(15)	-
Mg meq/l (ppm)	.25 (3)	.23 (3)	.29 (3)	.29 (3)	-
Na* meq/l (ppm)	.23 (5)	.51 (12)	.33 (8)	.31 (7)	-
Fe total meq/l (ppm)	trace (.18)	trace (.15)	trace (.15)	trace (.15)	-
Fe dissolved meq/l (ppm)	trace (.05)	trace (.05)	trace (.05)	trace (.05)	-
Mn meq/l (ppm)	trace (.05)	trace (.05)	trace (.08)	trace (.08)	-
CO_3 meq/l (ppm)	0 (0)	0 (0)	0 (0)	0 (0)	-
HCO_3 meq/l (ppm)	1.03(63)	1.06(65)	1.12(68)	1.15(70)	-
Cl meq/l (ppm)	.21 (7)	.26 (9)	.21 (7)	.21 (7)	-
SO_4 meq/l (ppm)	0 (0)	0 (0)	0 (0)	0 (0)	-
NO_3 meq/l (ppm)	0 (0)	0 (0)	0 (0)	0 (0)	-
NO_2 meq/l (ppm)	trace (.01)	trace (.01)	0 (0)	0 (0)	-
H_2S meq/l (ppm)	trace (.80)	trace (.96)	0 (0)	trace (.63)	-

* Calculated Na = (CO_3 + HCO_3 + Cl + SO_4 + NO_3) - (Ca + Mg)

Chemistry Laboratory

Research and Laboratory Section

Technical Division

Royal Irrigation Department

Bangkok, Thailand

Report of Water Analyses

From:

1.	Upstream of Nam Pong Dam	Khon Kaen
2.	Downstream of Nam Pong Dam	Khon Kaen
3.	Mune River, Lam Pra Plerng	Khorat
4.	Lam Pao River	Kalasia
5.	Kalasin Experiment Station	Kalasia
6.	Huey Chorakay Mark Tank	Buri-ram
7.	[illegible]d Liag Ngow Tank	Udon
8.	Kang Loeng Chang Tank	Mahasarakam
9.	Huey Aeng Tank	Roi-Et
10.	Huey Pla Dag Tank	Ubol

Compiled by: Arassri Rodjang

Chemist

Reviewed by: La-or Sonthornchai

Chief, Chemistry Laboratory

Chemistry Laboratory

Research and Laboratory Section

Royal Irrigation Dopartment

Report of Water Analyses

Location: Mune River
Station: Lam Pra Plerng (M39)

Date Sampled	Sept. 64	Oct. 64	Aug. 65
pH	8.0	8.1	8.5
$ECx10^6$ at 25^oC	90	130	240
SAR	0.2	.3	.5
SSP	17	16	22
RSC meq/l	.02	0	0
TS ppm	474	314	176
TDS ppm	-	-	162
Turbidity ppm	290	75	25
SiO_2 ppm	-	-	-
Ca meq/l	0.64	0.74	1.38
Mg meq/l	0.08	.37	.52
Na* meq/l	0.15	.22	.54
CO_3 meq/l	0	0	.38
HCO_3 meq/l	0.74	1.07	1.42
Cl meq/l	0.10	.12	.28
SO_4 meq/l	trace	.12	.28
NO_3 meq/l	0.03	.02	.01
River Stage Elevation m.	231.74	-	-
Sample Location from Reference Point m.	2.00	-	-
Total Depth m.	0.30	-	-

(M39) is the number of the station showing location of stream flow measuring and level station of survey division, hydrology section, Royal Irrigation Department

* Calculated Na = $(CO_3 + HCO_3 + Cl + SO_4 + NO_3) - (Ca + Mg)$

Chemistry Laboratory

Research and Laboratory Section

Royal Irrigation Department

Report of Water Analyses

Location: Changwad Khon Kaen, Downstream of Nam Pong Dam

Date Sampled	Oct. 66	Nov. 66	Dec. 66	Jan. 67	Feb. 67
pH	7.3	7.6	7.5	7.7	7.3
$ECx10^6$ at 25°C	115	110	109	109	110
SiO_2 ppm	12	12	12	12	-
Oxygen consumed ppm	4.10	2.13	2.77	3.47	1.81
Dissolved oxygen ppm	1.76	1.62	2.10	2.04	-
Nitrogen Ammonia ppm	-	.27	0	.15	-
Nitrogen organic ppm	0	0	0	.13	-
Albuminoid nitrogen ppm	.12	0	.11	.23	-
SAR	.4	.9	.4	.5	-
SSP	21	41	23	24	-
RSC meq/l	.05	.30	.10	.10	-
Ca meq/l (ppm)	.69(14)	.59(12)	.76(15)	.73(15)	-
Mg meq/l (ppm)	.26 (3)	.20 (2)	.28 (3)	.34 (4)	-
Na* meq/l (ppm)	.25 (6)	.54(12)	.32 (7)	.34 (8)	-
Fe total meq/l (ppm)	trace (.18)	trace (.15)	trace (.15)	trace (.15)	-
Fe dissolved meq/l (ppm)	trace (.05)	trace (.05)	trace (.05)	trace (.05)	-
Mn meq/l (ppm)	trace (.05)	trace (.05)	trace (.08)	trace (.08)	-
CO_3 meq/l (ppm)	0 (0)	0 (0)	0 (0)	0 (0)	-
HCO_3 meq/l (ppm)	1.00(61)	1.09(66)	1.14(69)	1.17(71)	-
Cl meq/l (ppm)	.20 (7)	.24 (8)	.22 (8)	.24 (8)	-
SO_4 meq/l (ppm)	0 (0)	0 (0)	0 (0)	0 (0)	-
NO_3 meq/l (ppm)	0 (0)	0 (0)	0 (0)	0 (0)	-
NO_2 meq/l (ppm)	trace (.01)	trace (.01)	0 (0)	0 (0)	-
H_2S meq/l (ppm)	trace (1.01)	trace (.33)	trace (.42)	trace (.42)	-

* Calculated Na = $(CO_3 + HCO_3 + Cl + SO_4 + NO_3) - (Ca + Mg)$

Chemistry Laboratory

Research and Laboratory Section

Royal Irrigation Department

Report of Underground Water

Location: Kalasin Experiment Station

	Boring						
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
pH Nov. 66	5.6	5.6	6.2	6.7	6.7	6.9	5.2
Dec. 66	7.2	7.3		7.4	7.4	7.0	4.6
$ECx10^6$ at 25^oC							
Nov. 66	33	36	60	55	35	3475	530
Dec. 66	33	25		50	27	2200	590
SAR Dec. 66						13.1	
SSP Dec. 66						85	
RSC meq/l							
Dec. 66						0	
TDS ppm Dec. 66						-	
Ca meq/l Dec. 66						1.39	
Mg meq/l Dec. 66						1.28	
Na* meq/l Dec. 66						15.18	
CO_3 meq/l Dec. 66						0	
HCO_3 meq/l Dec. 66						0.71	
Cl meq/l Dec. 66						16.93	
SO_4 meq/l Dec. 66						0.21	
NO_3 meq/l Dec. 66						-	

* Calculated Na = $(CO_3 + HCO_3 + Cl + SO_4 + NO_3) - (Ca + Mg)$

Chemistry Laboratory

Research and Laboratory Section

Royal Irrigation Department

Report of Water Analyses

Location: Lampao River, Lower Lampao Damsite Station (E34)

Date Sampled	Feb 64	Dec 64	Feb 65	Mar 65	May 65	Jul 65	Aug 65	Oct 65
pH	3.4	7.9	8.1	8.7	8.3	7.5	7.6	8.5
$ECx10^6$ at 25^oC	430	250	400	410	133	180	185	150
SAR	1.8	1.8	2.3	-	.8	1.4	2.4	1.6
SSP	45	54	54	-	40	52	69	54
RSC meq/l	0	0	0	.23	.15	0	0	0
TS ppm	234	282	280	280	230	492	160	226
TDS ppm	254	208	258	208	108	150	108	72
Turbidity ppm	30	25	25	25	85	150	45	25
SiO_2 ppm	14	-	-	-	-	-	-	-
Ca meq/l	1.63	.73	1.40	1.44	.65	.66	.43	.53
Mg meq/l	.73	.40	.45	.66	.16	.23	.16	.26
Na* meq/l	1.94	1.34	2.24	-	.54	.96	1.32	1.01
CO_3 meq/l	0.10	0	0	.34	0	0	0	0
HCO_3 meq/l	2.00	.90	1.69	1.99	.96	.67	.56	.78
Cl meq/l	1.94	1.56	2.20	1.58	.30	1.09	1.06	.82
SO_4 meq/l	0.25	trace	.10	-	.08	.08	.27	.10
NO_3 meq/l	0.01	.01	.10	trace	.01	.01	.02	.10
River Stage Elevation m.	-	135.52	135.35	139.36	139.98	141.28	140.71	140.11
Sample Location from Reference point m.	-	68.60	70.10	69.70	66.80	-	65.70	65.50
Total Depth m.	-	0.30	.30	.95	1.40	-	2.15	1.65

E34 is the number of the station showing location of stream flow measuring and level station of survey division, hydrology section, Royal Irrigation Department.

* Calculated Na = $(CO_3 + HCO_3 + Cl + SO_4 + NO_3) - (Ca + Mg)$

APPENDIX E

Assessment Form for Water Weed Problems

ASSESSMENT FORM FOR WATER WEED PROBLEMS

GENERAL

1.1 Locality ____________________

____

____

1.2 Latitude ____________ 1.3 Longitude ____________

1.4 Visit No. ____ 1.5 Type of water body ________

1.6 Age of water body ____

2. Names of five most important plants contributing directly to the problem in approximate order of biomass. If alien, mark 1, if native, mark 2

2.1 ________ 2.2 ________ 2.3 ________

2.4 ________ 2.5 ________

3. Period of infestation ______ 4. Probable method of introduction ______

WEED STATUS

5. Purposes of water body (in order of importance)	6. Related annual economic value	7. Estimated annual economic loss consequent on presence of weed
5.1 ____	6.1 ________	7.1 ________
5.2 ____	6.2 ________	7.2 ________
5.3 ____	6.3 ________	7.3 ________
5.4 ___	6.4 ________	7.4 ________
5.5 ___	6.5 ________	7.5 ________

ENVIRONMENTAL STATUS

8. Stability of hydrological regime for weed growth: rate from 1 (very unstable) to 5 (very stable) ______

9. Light penetration into water: rate from 1 (very poor) to 5 (very good) ______

10.1 Monthly mean maximum screen temperature: (°C) for warmest summer month ____

10.2 Monthly mean minimum screen temperature: (°C) for coldest winter month ____

11. Days of frost every year ______

12. Nutrient status: rate from 1 (low) to 5 (high) ________

PLANT STATUS

13. Area of infestation of all species 13.1 Total ________

13.2 % suitable habitat ______ 13.3 % of water body ________

14. Growth rate (as doubling time). 14.1 Summer ___|___|___|___|___

14.2 Winter ___|___|___|___

15. Vigor (assess on basis of 10 random sub samples, or 30 if material is very variable).

15.1 Size: Mean ___|___|___|___ Range ___|___|___|___|___ to ___|___|___|___|___

15.2 Health: rate from 5 (no evidence of disease/deficiency) to 1 (all plants diseased/ deficient ________

16. Growth form: 16.1 differences present/absent ________ If present, proportion (as %) which is: 16.2 mature/crowded ________ 16.3 intermediate ________ 16.4 young/invading ________

17. Reproduction; 17.1 vegetative without specialized propagules (yes:no) _____

17.2 seeds: absent/scarce/common/abundant ____________

17.3 other resistant propagules: (assess as for 17.2) ______________

18. Risk of reinfestation from outside water body: rate from 5 (high) to 1 (nil): ______________

PLACE IN ECOSYSTEM

Rate from 5 (large or important) to 1 (small or unimportant)

19. Primary production______ 20. Direct food source ______ 21. Invertebrate habitat ______ 22. Substrate for epiphytes ______ 23. Shelter for vertebrates______ 24. Competition with other nonweed plants ________

OTHER NOTES

25. Notes to explain or amplify answers and/or to draw attention to important factors (Continue overleaf if necessary). ___|___|___|___|___|___|___

26. Completed by: ___|___|___|___|___|___|___|___|___|___|___|___|___|___|___|___|___|___|___|___|___|___|___|___

27. Date: ___|___|___|___|___|___|___|___|___|___|___|___

NOTES ON COMPILATION OF WATER WEED ASSESSMENT FORM

The assessment should be carried out on a relatively homogenous area of the infestation. If the infestation is small, the assessment can be carried out on the total area. If it is large, as in a large lake infested with *Eichhornia crassipes* or an extensive irrigation system infested with *Elodea canadensis*, representative homogenous units of manageable size should be assessed and one overall assessment worked out from the individual assessments.

GENERAL

1. 1.1 Locality must be given in sufficient detail to allow a subsequent visitor to find the site with certainty on a map or on the ground and must be described in 40 characters or less.
   1.2 Latitude
   1.3 Longitude
   1.4 Enter the first visit as 01, the second as 02, etc.
   1.5 Enter the appropriate number representing the type of water body according to the following key:

1 Spring	5 Irrigation canal	9 Small dam (manmade lake less than 2 ha)
2 Stream	6 Irrigation drain	
3 River	7 Pond (less than 2 ha)	10 Manmade lake (larger than 2 ha)
4 Ditch	8 Lake (more than 2 ha)	11 Swamp

   1.6 Age in years of existence, i.e., 0-1 year = 01, etc. up to 50. All ages greater than 50 years recorded as 51

2. Record scientific names as first two letters of generic name and first three letters of specific name, e.g., *Eichhornia crassipes*=EICRA. Give full name in parentheses after abbreviation.

3. Record period of recent infestation in months with the prefix 1, i.e., 0-1 month=101, etc. up to 124. Periods longer than 2 years are recorded in years with the prefix 2, e.g., 2-3 years=203. All periods longer than fifty years are recorded as 251.

4. The most likely method of introduction is recorded as follows:

1 unknown	3 wind dispersal	5 garden/aquarium escape
2 water dispersal	4 bird dispersal	6 other (specify)

WEED STATUS

5. | | |
   |---|---|
   | 1 Irrigation | 5 Hydroelectricty |
   | 2 Stock drinking supply | 6 Recreation |
   | 3 Domestic water supply | 7 Waste disposal |
   | 4 Industrial water supply | |

6. Record in hundreds of normal currency unit, e.g., dollars, pounds, etc.

7. Ditto to 6

8. Assess stability according to following guidelines:

   5: little or no changes in water level or in rate of flow, sheltered from wind
   4: liable to slight changes in water level or rate of flow, slightly exposed to wind

3: permanent water body liable to moderate changes in water level or rate of flow, exposed to about half the winds
2: normally permanent water body but liable to extensive and rapid changes in water level or rate of flow, exposed to wind
1: transitory water body liable to extensive and rapid changes in water level and rate of flow, very exposed to wind

9. Assess penetration of light into water according to the following guidelines.

5: water very clear, secchi disc more than 5m
4: water slightly clouded, secchi disc 3m-5m
3: water clouded, secchi disc 1m-2.99m
2: water turbid, secchi disc 10-99cm
1: water very turbid, secchi disc less than 10 cm

10. 10.1 The monthly mean maximum screen temperature (°C) for the hottest calendar month of the year. Temperatures from the nearest Meteorological Station can be given if the data is considered to be comparable. An average over a number of years can be given.

10.2 As for above, except that the mean minimum temperature for the coldest winter month is given.

11. Data from nearest Meteorological Station can be given if appropriate. An average over a number of years can be given.

12. 5: very eutrophic water, such as one continuously supplied with sewage effluent, and with clear manifestations of high nutrient status, such as periodic algal blooms
4: eutrophic water body periodically receiving nutrient-rich run-off or effluent.
3: mesotrophic, moderate nutrient status.
2: oligotrophic water but supporting some populations of plants
1: very oligotrophic water, nutrient-poor inflow, no obvious evidence of algal or other plant populations.

13. 13.1 Give area in ha
13.2 Subjective assessment
13.3 Ditto

14. This should be measured in a brief experiment, if possible; otherwise leave blank. Doubling time should be required in days.

15. 15.1 The most appropriate measure of size should be used: for most plants this would be height or length of vegetative parts. Record in appropriate units to fit in three spaces or less. The characteristics measured and the units used must be entered on the computer card. Use the same characteristic and unit of measurement in all subsequent visits.

15.2 5: no evidence of disease, annual feeding damage, or nutrient deficiency
4: incipient symptoms in less than 25% of plants
3: serious symptoms in few plants or slight symptoms in 26-50% of plants
2: less than half plants badly affected or, if all affected, symptoms are slight
1: all plants show marked evidence of disease, damage and/or deficiency

16. Differences in growth form can be found by examining the differences between plants in the middle of a crowded population and those growing on the margins or in isolated positions. Not all plant species show morphological differences and in this case a 1 should be entered in the space. If differences are present, a 2 should be entered and spaces 16.2-16.4 completed. Enter zero percent as 0.

17. 17.1 For yes, enter2; for no, enter 1.
    17.2 Absent=1, scarce=2, common=3, abundant=4
    17.3 As for 17.2.

18. This is a subjective assessment based on local inquiries, original mode of infestation and other factors.

19-24. The answers to these questions can be subjective but, wherever possible, objective quantitative data should be obtained. In every case the assessment must be based on a careful examination of the situation, possibly with the assistance of any local expertise that may be available.

25. This information will not be entered on the computer card. However, if it is essential for the understanding of the form, the code 999 should be entered in front of the comments and circled. This will be entered into the computer and will mean that reference to these comments on the original form should be made before the data on the form is utilized or analyzed.

26. Abbreviate name if neccessary to fit 10 spaces.

27. Enter date as follows: day: 01-31; months: 01-12: year: 77 for 1977, etc.

ACKNOWLEDGEMENTS

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