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DRAFT FIELD REPORT

KHON KAEN, THAILAND

Case Studies in the Environmental Sustainability of Water Resource Management

Prepared for the

Irrigation Support Project for Asia and the Near East

Under the Sponsorship of the

U.S. Agency for International Development
Bureaus for Asia and the Near East
&
USAID Thailand

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PREFACE

If the ISPAN study of environmentally sustainable water resource management in Asia and the Near East highlights one common lesson that donors and host country governments must heed, it is the interrelated nature of resource requirements among the urban, agricultural and industrial sector. The analysis of sustainable natural resource management is often framed in terms of *growing demand*, *competition* and *conflict* between these sectors for access to resources. Donor programs have, to some extent, exacerbated these demands, competition and conflict in their support for centralized public institutions at the expense of the public, and public participation in natural resource policy. Donors must develop the same levels of coordination and cooperation between their own sectoral programs as they demand of the governments that they seek to support.

Thailand faces the same constraints to effective natural resource conservation and management as many of it neighbors: limited funding, inadequate human resources and technical skills, bureaucratic inertia, and a pressing need for greater public awareness of the problems. But the Royal Thai Government's manifest commitment to environmental issues, as demonstrated in the breadth of its environmental policy and legislation, as well as the commitment of individuals in public, private and non-governmental institutions is far more dynamic than in the other countries that have been the focus of this study. The energy, resourcefulness and deep reverence of life of the Thai people, when fully applied to the major environmental problems facing the country, will surely place Thailand at the forefront of sound natural resource management in the developing world.

The study team is indebted to the Water Resources and Environment Institute of Khon Kaen University for its technical and logistic support during our stay in Thailand. We also wish to thank all those individuals in Bangkok and Khon Kaen who gave their time to our inquiry, and we hope we have done justice to the knowledge that they have imparted to us.

INTRODUCTION

This report is part of a regional study on the environmental sustainablility of water resource management supported by the Irrigation Support Project for Asia and the Near East (ISPAN). ISPAN is a water resources and water policy project sponsored by the Asia and Near East Bureaus of the U.S. Agency for International Development. The objective of the study is to examine the evolution of competing demands for water resources between urban and rural sectors -- particularly with reference to food security, energy and potable water -- in Pakistan, Egypt, Morocco and Thailand. The purpose of the study is to determine the social, economic, institutional and technical requirements for the countries under study to strengthen their water resources management capacity, and to develop or improve environmentally sustainable strategies for water resource conservation and management. The results of the study will be of direct use to AID and other donor agencies and host country governments in their efforts to promote environmentally sound development strategies in the decades to come.

Environmental Sustainability: An Operational Definition

The study has adopted an operational definition of environmentally sustainable management of water resources based on the broader concept of sustainable development put forth in the report of the World Commission on Environment and Development (commonly known as the "Bruntland Report"):

> *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*

The application of this concept to water resource development and management requires planners and policy makers to focus on the ecological, social and institutional dimensions of water use. This focus is fully consistent with AID's strategic objectives for water resource development, namely:

- to increase the efficient use of water by promoting water conservation in all sectors to reduce consumption;
- to enhance water quality by encouraging pollution prevention and monitoring to increase and protect usable water supplies; and
- to improve water management by fostering private sector solutions, by increasing government accountability and by promoting local empowerment

in the management of water resources (AID 1993:v)

This study aims to draw on lesson's learned from the Thailand case to recommend strategies for the achievement of AID's water resource development objectives that are relevant not only to Thailand, but to countries and AID programs throughout the region.

Study Framework

This study was conceived by the AID Asia and Near East Bureaus and the ISPAN staff to link the regional water resource development strategies with AID's evolving environmental and sustainable development objectives. Since the beginning of the decade, AID has supported the development of environmental research and information dissemination through a series of centrally-funded projects. In addition, AID has begun to address the environmental crises arising from growing urbanization and industrialization in a number of developing countries through its support of specific urban waste management and industrial pollution prevention projects.[1]

ISPAN convened a team in December 1992 to begin formulating a study to address the environmental implications of AID's water resource development and management activities. In consultation with project officers of the AID Asia and Near East Bureaus, the team members developed a paper that reviewed the concepts of environmental sustainability and applied these concepts to water resource management. This concept paper was subsequently disseminated to participating Missions (Pakistan, Egypt, Morocco and Thailand) for review. Study team members followed up on the delivery of the concept paper with reconnaissance visits to each of the Missions in order to review the Mission's water project portfolios and determine appropriate projects for consideration. Following on these reconnaissance missions, the team chose to narrow the study focus to the competition for water resources between urban/industrial and rural/agricultural sectors in order to highlight what it considered to be the most critical environmental issues related to water resource development and management.

With the approval of the Missions and the AID Bureaus, the study team scheduled field visits to each participating country. The team, working with local consultants, will prepare draft case studies for each country and leave copies of the case study for review by Mission personnel. On completion of each case study and receipt of comments by each Mission and the AID Bureaus, the team will prepare a synthesis report of lessons learned from all case studies.

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[1] Among the projects cited are: the Environmental Protection and Training Project (EPAT), GREENCOM, Environmental Pollution Prevention Project (EP3); (PRIDE); the Privatization of Urban Services Project (PURSE/Indonesia); and (IEMP/Philippines).

Methodology and Personnel

The three week time allotted for each country study precluded extensive data collection in the field. After careful consideration of data collection and field logistics constraints in Thailand, the team selected the northeastern province of Khon Kaen as the most suitable area for its case study.

The team made extensive use of secondary data and rapid appraisal methods to construct the chain of events linking development interventions with observed impacts, to analyze major development issues, and to identify key lessons learned. The team employed several sources of information and appraisal techniques, including:

- **USAID Project Documents** -- Project papers, technical reports and evaluations of the major USAID-funded water resource projects of the last two decades: the North East Small-Scale Irrigation Project and the Lam Nam Oon Integrated Rural Development Project;

- **Other International and National Agencies** -- Project design, technical reports, progress reports and evaluations generated by other foreign assistance donors (the World Bank, the Asian Development Bank, the European Economic Community, the Ford Foundation, the Mekong Secretariat, the Thailand Development Research Institute, the Royal Irrigation Department, the Provincial Water Works Department, and the Electricity Generating Authority of Thailand);

- **Key Informant Interviews** -- USAID project officers; officials of other donor agencies; officials of government line agencies at the national, provincial, district and municipal levels; technical staff of on-going donor-funded projects; knowledgeable environmental and related technical specialists, including faculty and staff of Khon Kaen University; industry managers; NGO representatives, and farmers.

- **Field Visits** -- Visits USAID and other donor agency project sites, irrigation and drainage works, water and sewage treatment facilities, farms and factories in Khon Kaen and neighboring provinces.

A complete list of documents and reports cited for this study can be found in the References section. A list of all individuals consulted and the itinerary of the study team is attached as Annex C.

The ISPAN Study team was represented by Dr. Richard English, Anthropologist & Institutional Development Specialist and Dr. Michael Colby, Environmental Management Specialist. The study team was ably supported by a

team of consultants brought together by the Water Resources and Environment Institute of Khon Kaen University. These consultants were: Dr. Sanguan Patamatamkul, Water Resource Engineer and Team Leader; Dr. Wanpen Wirojanagud, Industrial and Toxic Waste Specialist; Mrs. Sinee Chuangcham, Social Research and Rural Development Specialist; and Mr. Suparerk Sinsupan, Environmental Engineer.

Report Format

The report begins with a brief review of water resource issues related to urban and industrial growth in the developing world. This review is followed by a profile of Thailand's water resources, and the environmental implications of the country's management of those resources. The national profile then turns to the water resource issues of Thailand's northeast region and particularly Khon Kaen province. This background section concludes with a justification for the selection of Khon Kaen as a case study for environmentally sustainable water resource management in Thailand.

The body of the report falls in three chapters: Water Quantity Issues; Water Quality Issues; and Related Environmental Issues (e.g., public health, biodiversity and climax phenomena such as flooding). Each of these chapters follows a general format that examines three interrelated themes: 1) the rationale and impact of historical water management actions; 2) the nature and effectiveness of development interventions made to remedy the negative impacts of historical water management actions; and 3) alternative measures -- based on current knowledge -- that may have been more effective and environmentally sound approaches to the management of water resources. Within each chapter, the report considers these three themes in terms of the hydrological, technological, institutional, policy, economic and social contexts that shape water resource management and use in Thailand. The report concludes with a discussion of lessons learned from the review of the Thailand experience and the implications of those lessons for broader environmentally sustainable water resource management policy in developing countries.

SECTION ONE

BACKGROUND

"Unless you start saving water now,
in the next five years you will not have
even a single drop to use."

--Bangkok Metropolitan Waterworks Authority
(Bangkok Post, 6-2-93)

This chapter reviews the overall theme of the study -- the competing demands for water resources between urban and rural sectors -- within the context of developing economies and their attendant intensification of agricultural production, industrial development and urbanization. This review serves as a framework for discussing the development of water resource management in Thailand at the national, regional (Northeast) and provincial (Khon Kaen) levels.

The Competition for Water Resources: Urban vs. Rural

Agriculture remains the principle economic sector of the majority of developing nations. However, the late twentieth century is witnessing inexorable growth in population, urbanization and industrialization throughout much of the developing world. Development indicators suggest that the advances made in food production during the "Green Revolution" are not sustainable in the face of current trends in population growth despite donor and host government attempts to make improved agricultural technology, inputs and practices widely available. Rural poverty has persisted and, in many areas, increased despite a generation of programs aimed at improving the living standards of rural populations. The degradation of agricultural resources due to soil erosion, depletion of natural nutrients, agro-chemical pollution and poor cultural practices, the growing population pressure on limited land holdings, and the loss of agricultural land to commercial and urban development are but a sampling of the factors that drive rural people to the cities in search of a better life for themselves and their children.

Countries rich in natural resources and possessing a skilled labor force such as Thailand, Brazil and Kenya have been able to pursue vigorous development of the private sector and rapid industrial growth. Low wage rates have helped to fuel this growth while providing expanded employment opportunities that can absorb an underemployed rural labor force. This growth has not only driven the expansion of major cities but of regional population centers as well. While standards of living

Table 1.1
Water Use by Sector (% of total water used)
in Thailand and other Near East and South Asia Countries

Country	Agriculture	Industry	Municipal & Domestic
Thailand	**90**	**6**	**4**
Pakistan-[1]	95	2	3
Pakistan	98	1	1
Egypt	88	5	7
Morocco	91	3	6
Israel	79	5	16
Lebanon	84	4	11
Oman	94	3	3
Tunisia	80	7	13
Yemen	93	2	5
India	93	4	3
Middle East/ North Africa	**89**	**5**	**6**
Thailand	90	6	4
Cambodia	94	1	5
Laos	82	10	8
Burma	90	3	7
Vietnam	78	9	13
Malaysia	47	30	23
S. Korea	75	14	11
Indonesia	76	11	13
Southeast Asia Ave.	**94**	**3**	**2**

have increased for many urban dwellers, the consequences of this urbanization for water consumption are serious. Urban dwellers use from five to ten times the water on a per capita basis that rural dwellers.

For the majority of developing countries, agriculture outpaces all other productive sectors in its demand for water by a factor of five (see Table 1.1). However, there are clear signals that, as competition for water grows between the agricultural, municipal and industrial sectors, donors and host governments alike must support more comprehensive water management policy and practice to conserve both the quantity and quality of water resources consumed. Many governments for which the cost of bringing new lands under cultivation is politically and economically prohibitive are facing the need to balance the cost of maintaining adequate water supplies for agriculture with the costs of promoting industrial development and providing environmental infrastructure (e.g., potable water supply, sewerage and drainage) to their urban populations.

Against this background of urban/rural competition *for what have long been considered unlimited resources*, this report examines the development of water resource management in northeast Thailand. The report attempts to draw from very specific social, economic, technological and institutional developments some general principles that apply to the planning of environmentally sustainable water resource management in the 21st Century.

Thailand: The Country Context

Thailand, with a total land area of 513,000 km^2, is bordered by Burma (Myanmar) to the west and northwest, Laos to the northeast, Cambodia to the southeast, and the Gulf of Thailand and Malaysia to the south (see Figure 1.1, Map of Thailand). As of 1986, 47% of this land area was agricultural, and 29% remained in forest, with the latter declining at an average rate of about 1% per year from 1961 through 1985 (TDRI, 1987, p.81).

Thailand's population grew rapidly from 1950 (17.44 million) to 1980 (47 million), and surpassed 58 million in 1992, yielding an average density of 113.5 persons/km^2. The growth rate has declined considerably over the past decade, to 1.4%/year, though the growth in absolute numbers remains at about 800,000 per year. Thus, the total population is still expected to reach 70 million by 2010, with almost all of the future growth anticipated to accrue in urban areas. Rural areas may even decline in population after 2010. As of 1990, the Bangkok Metropolitan Region (BMR) was believed to be home to about 8 million people (Sethaputra et al, 1990).

Starting in the 1960s, economic growth in Thailand has rapidly outpaced that of its neighboring countries. Thailand's GDP grew at an average rate of 7.5 percent between 1960 and 1985, yielding an 18-fold increase. It doubled again between 1987 and 1992. In the course of this expansion, industry has supplanted agriculture as the largest sector of the economy. About half of the GDP is generated in the BMR.

Thailand's Water Resources

Thailand has a tropical monsoon climate. The Northern, Northeastern, and Central regions receive some 85% of their rainfall during the southwest monsoon season, from May to October. The Southern region receives equal amounts of rain from the SW from the northeast monsoon (November through February. Mean annual rainfall ranges from about 1,100 mm in parts of the North and Northeast to over 2,000 mm in the south. Wet season rainfall is generally adequate for rice cultivation, but irrigation is usually required for dry season crops, except in the south. Total rainfall amounts to about 800 billion cubic meters (BCM) per year.

Thailand has 25 river basins. The largest is the Chao Phraya (178,000 km^2), draining most of the Central and Northern regions. Most of the Northeast and a small portion of the North drains into the Mekong River, which forms part of Thailand's border with Laos. The seasonal distribution of rainfall causes a marked difference between wet and dry season flows. The Royal Thai Government (RTG) has constructed hundreds of dams and reservoirs over recent decades in order to regulate flows and reduce flooding, and capture a greater portion of the runoff for productive purposes.

There is considerable variation in estimates of Thailand's total renewable freshwater flows. The World Resources Institute puts the figure at 110 BCM/y, excluding the river inflows from other countries of an additional 69 BCM/y (WRI, 1992: Table 22.1). The Thailand Development Research Institute (TDRI) estimates a renewable water resource of 171 BCM/y (TDRI, 1987:47), while the Royal Irrigation Department (RID) claims 199 BCM/y (Sethaputra et al, 1990:87), At the current population of 58 million, the RID figure equates to about 3,431 m^3 per person per year, the TDRI figure translates to 2,935 m^3 per capita, and the WRI estimate to 1,888 m^3 per capita. The Asian average was 4,236 m^3 per capita in 1990, according to the World Bank (1992).

Most of Thailand's usable groundwater occurs in the Chao Phraya floodplain. Most of the Northeast is poorly endowed with good quality groundwater outside of narrow riverine alluvial zones (Tingsanchali, 1991).

Water Use

The use of water is commonly classified into three main sectors: domestic/ municipal, industrial, and agricultural.

Compared to other sectors, the quantity of water required for domestic uses is usually small, but its quality must be high. In Thailand, domestic/municipal water for drinking, cooking, washing, laundry, sanitation, etc., is usually piped from water treatment plants in urban areas, while in rural areas sources may include rainwater jars, shallow or deep wells, man-made ponds, or direct sources such as rivers and streams. The rate of consumption ranges from 50 liters per person per day for rural areas, to as much as ten times that in urban areas with piped water connections. Approximately 60 percent of the water withdrawn for domestic use ends up in the wastewater stream. Since consumption tends to increase with living standards, and urban populations are growing the fastest, both domestic water demand and wastewater flows are expected to increase faster than the GDP (Sethaputra et al., 1990).

Industrial uses of water include cooling, processing, cleaning, and waste removal. About 85% of industrial water in Thailand is believed to become polluted wastewater. Even cooling water, while not chemically polluted, has environmental consequences when discharged, as the raised temperatures increase biological oxygen demand (BOD), a key water quality indicator, and affects fish and invertebrate reproduction/development, etc. Total industrial consumption is currently not much more than for domestic uses, but is growing very rapidly as Thailand industrializes.

Agricultural water applications in Thailand include rainfed and irrigated rice paddies, other irrigated cash crops, fish and prawn farms, and stock breeding (not to mention derivative agro-processing, which is classified as an industrial use). In Thailand, as in all the countries investigated in this study, agriculture accounts for 90% or more of water consumption. However, the biological efficiency of water (in terms of crop production requirements) in Thai irrigation is believed to be roughly only 30%. Agriculture is also generally considered the least economically-efficient use of water in terms of its contribution to GDP per unit of water consumed. Thus, relatively small gains in the efficiency of agricultural water use could release substantial amounts of water for the domestic and industrial sectors, where it can be used more efficiently to increase general welfare. Crop diversification, a strategy being applied in irrigated areas, may be one strategy to achieve more economically efficient use of agricultural water.

On the other hand, the apparent economic and biological inefficiency of water use in agriculture may be masking the provision of an ecological water buffer that maintains the functionality of the larger ecosystem that supports human and

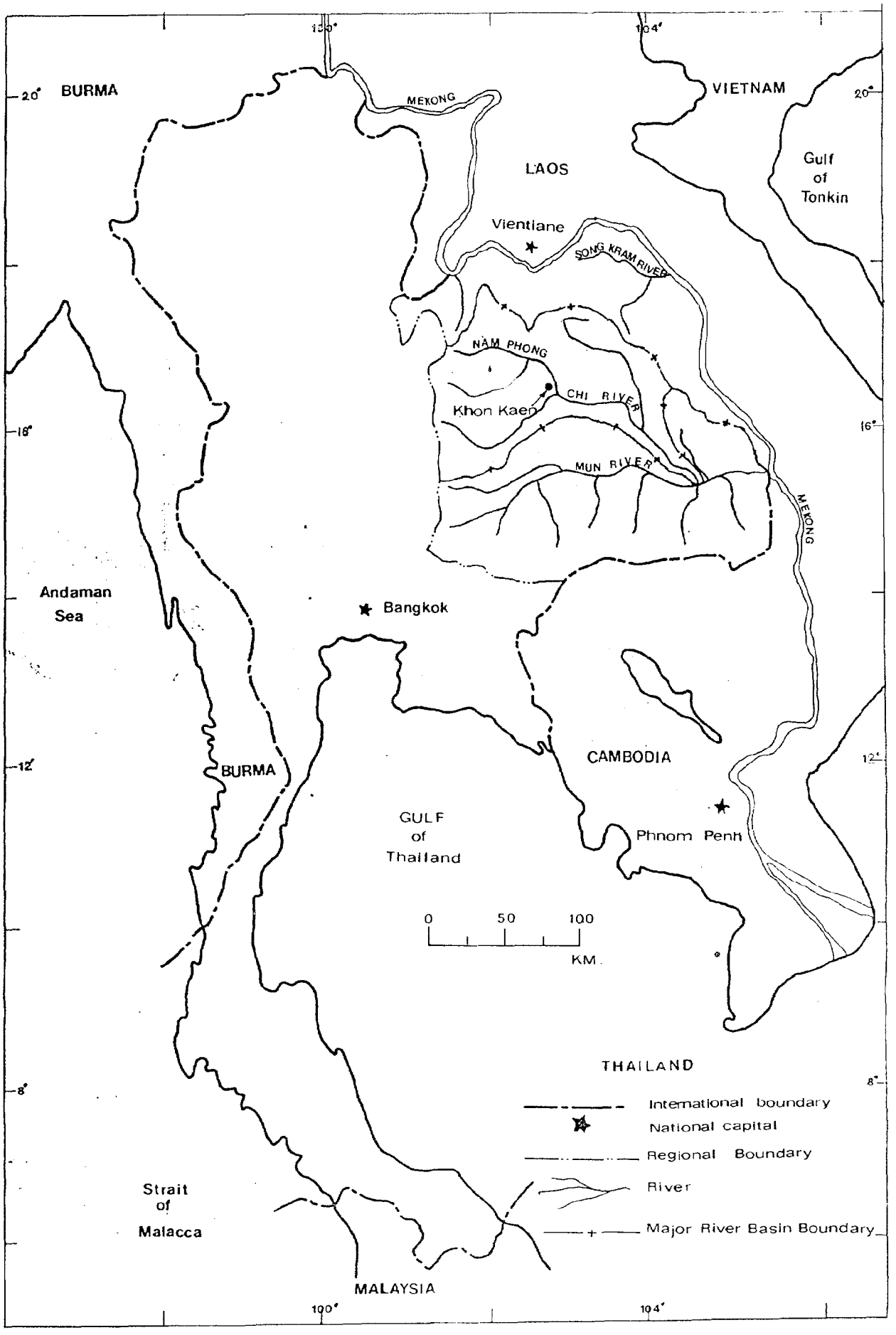


Fig. Main River in Northeast Thailand

other life in a variety of poorly measured ways. For instance, it has been estimated that about 25% of irrigation water is returned to the system for downstream use (Sethaputra, 1990), although its quality is often somewhat degraded from the accompanying runoff of agro-chemicals (pesticides and fertilizers). This water is used by the ecosystem in a variety of non-consumptive but productive ways, including: supporting fisheries, assimilating wastes, recycling nutrients, and retarding salt water infusion of coastal zones.

There are considerable differences in the data regarding Thailand's prresent and projected water resource consumption. According to WRI (1992) statistics, as of 1987 Thailand consumed 31.9 BCM of water per year, or *17.8% of its total river flows* (29% excluding inflows from other countries as a renewable resource for Thailand), with *4% (1.28 BCM) of the total withdrawals going to domestic uses, 6% (1.91 BCM) to industrial, and 90% (28.7 BCM) to agriculture.* Table 1.1 provides a comparison of the relative allocation of water amongst sectors in several Asia and Near East countries, without reference to the total resource available.

Sethaputra et al (1990), on the other hand, estimated that Thailand's in 1990, *domestic withdrawals account for 1.81 BCM, industrial uses for 1.04 BCM, and agricultural consumption for 40.32 BCM (total: 43.17 BCM).* By then assuming that the amount of annual renewable water equals total streamflow, and using RID's higher estimate of this (199 BCM/y), they calculated that 1990 consumption by sector accounted for *0.9% (domestic), 0.5% (industrial), and 20.2% (agricultural), totalling 21.7% of the country's annual renewable water flow.* They also projected that (assuming current levels of efficiency?), Thailand's domestic and industrial water requirements would increase eight-fold from 1990 to 2010 (12% growth per year from 1990-2000, and 10% from 2000-2010), while agricultural consumption would quadruple in the same period, for a combined annual growth rate of 7% for the twenty year period. The result would be that Thailand would be consuming 167 BCM/y by 2010, or 84% of its river flows. Table C.1 in Annex C compares the WRI estimations for 1987 with Sethaputra's (1990) calculations for 1990, 2000, and 2010.

Water Resource Development

The past 35 years has seen Thailand's irrigated land almost triple, from 1.4 million hectares in 1958 to 4 Mha. As of 1987, three quarters of this area was accounted for by large irrigation schemes (areas in excess of 20,000 ha), although the 1980s saw a marked increase in emphasis on small and medium scale irrigation projects, particularly in the Northeast.

Thailand's total hydropower potential is estimated at 10,600 MW. Of this

total, 2,430 MW (23%) was exploited as of 1989, supplying about 15% of Thailand's total electricity demand, which grows by about 10 percent per year. Most of the large potential sources have already been developed, although the Electricity Generating Authority of Thailand (EGAT) has investment plans for adding another 1,800 MW by the year 2000. Many of these dam schemes face growing protest on environmental and social grounds.

Groundwater has a negligible contribution to the country's irrigation potential, except in the Northern region of the country. However, groundwater has been heavily exploited for domestic and industrial purposes, however, particularly in the Bangkok Metropolitan Area, but also in other urban and some rural areas. Extraction around Bangkok was estimated to exceed the estimated safe level by at least 0.5 million m^3/day in 1986, and has not declined. As a result, land in the Bangkok region is subsiding, in some places at a rate of 10 cm/year. Saltwater intrusion is also a growing threat as a result of this unsustainable rate of exploitation.

The Bangkok Metropolitan Waterworks Authority is now making plans for a large diversion from the Mae Klong River, a hundred kilometers to the west, to quench Bangkok's ever-increasing domestic and industrial thirst. It calls for taking 1.4 BCM/y, about one quarter of the river's flow, from a basin that already faces saltwater intrusion and water shortages. This plan is drawing considerable protest from farmers in the Mae Klong Basin (*Bangkok Post*, 6-2-93), and is a clear example of growing conflict between rural and urban water uses in Thailand.

Institutional Context

The institutional apparatus for water resources management in Thailand is probably the most complex encountered by the ISPAN team. Eight national ministries with over 30 agencies/departments and some 20 committees are responsible for various aspects of water resources management and development (see Table 1.2). Several of these agencies have conflicting water quality standards (e.g., Depts. of Irrigation, Fisheries, and Industrial Works) for the same body of water. Lack of coordination often results in inefficient use of resources and conflicts between upstream and downstream users. The Nong Wai Irrigation Project on the Nam Phong River in Khon Kaen Province has been cited as an example of prolonged delays in implementation due to lack of coordination. (Ludwig, 1979). Water resources development in Thailand has lacked comprehensive planning. The emphasis over recent decades has been on the construction of dams and reservoirs (what Sethaputra et al (1990) called *Supply-Side Management*.

Table 1.2
Thailand Government Agencies Involved in Water Resources Management and Development

Ministry of Agriculture & Cooperatives
- Office of the Permanent Secretary
- Royal Irrigation Dept. (RID)
- Dept. of Agricultural Extension
- Dept. of Agriculture
- Royal Forest Dept.
- Land Development Dept.
- Dept. of Fisheries
- Dept. of Livestock Development
- Agricultural Land Reform Office
  - Royal Rain Making Research & Development Institute

Ministry of the Interior
- Local Administration Dept.
- Dept. of Public Works
- Dept. of Public Welfare
- Office of Accelerated Rural Development
- Dept. of Community Development
- Dept. of Lands
- Metropolitan Water Works Authority
- Provincial Water Works Authority

Ministry of Public Health
- Dept. of Health
  - Environmental Health Division

Office of the Prime Minister
- Electricity Generating Authority of Thailand (EGAT)

Ministry of Industry
- Dept. of Mineral Resources
- Dept. of Industrial Works

Ministry of Communications
- Dept. of Harbors
- Meteorological Dept.

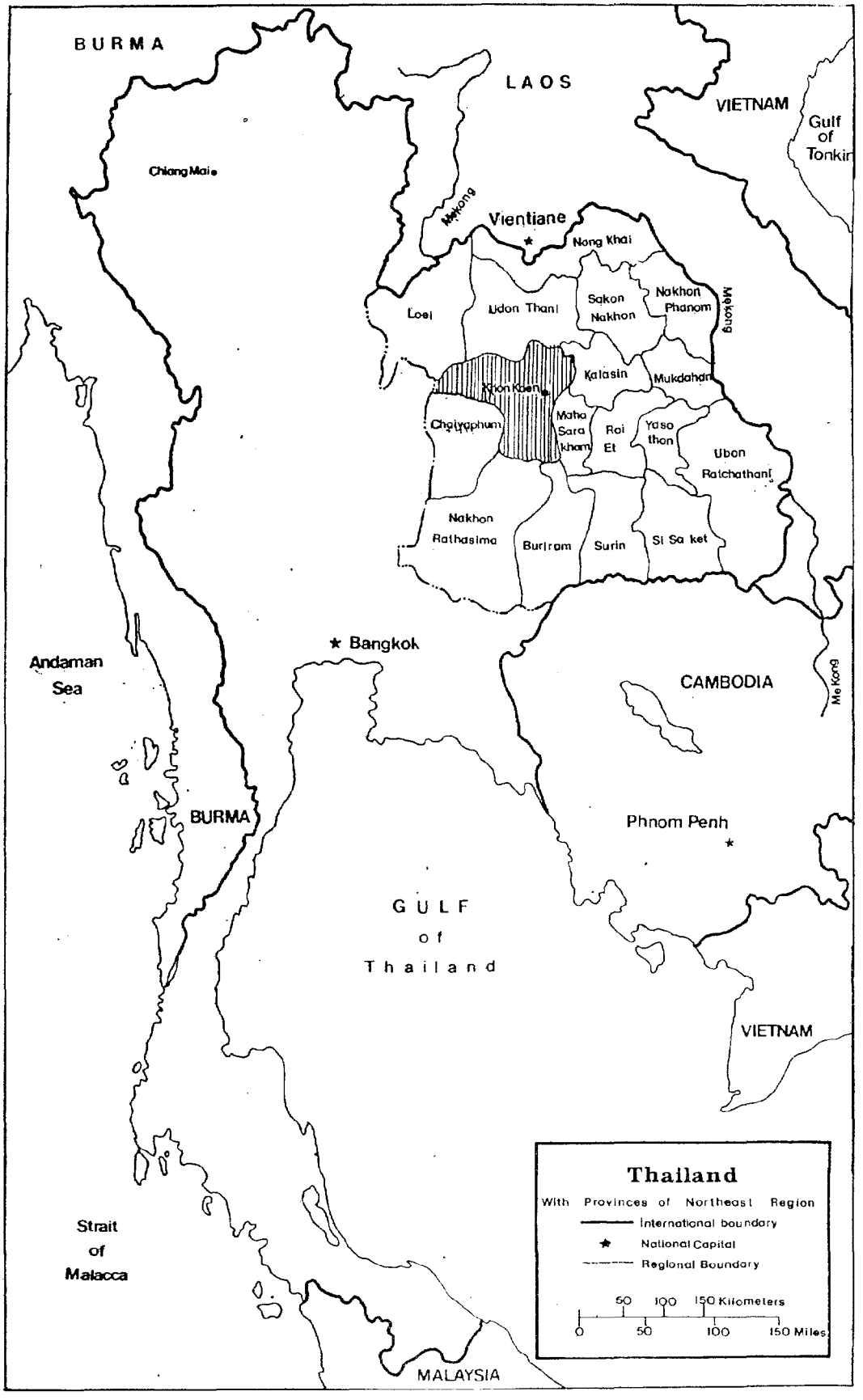
Ministry of Defence
- Naval Hydrographic Dept.
- National Security Command Headquarters

Ministry of Science, Technology, & Energy
- Dept. of Energy Development and Promotion
- National Environment Board
- National Research Council of Thailand

Source: TDRI (1987:66)

Northeast Thailand: The Regional Context

Northeast Thailand is a region of 170,000 sq. km. separated from central Thailand by the Korat Plateau. Comprising one-third of the country's land area, the region's 19 million people (1992 estimate) accounts for 35 percent of Thailand's total population. Because of erratic rainfall and generally poor soils, the agricultural production in the northeast consistently lags behind that of other regions of Thailand, particularly the central plains and the north. Despite growing diversification of agricultural production with increased investment in cash crops such as sugar cane,


BURMA
LAOS
VIETNAM
Gulf of Tonkin
Chiang Mai
Mekong
Vientiane
Nong Khai
Loei
Udon Thani
Sakon Nakhon
Nakhon Phanom
Mekong
Kalasin
Mukdahan
Khon Kaen
Chaiyaphum
Maha Sara kham
Roi Et
Yaso thon
Ubon Ratchathani
Nakhon Rathasima
Buriram
Surin
Si Sa ket
Bangkok
Andaman Sea
CAMBODIA
Mekong
BURMA
Phnom Penh
GULF of Thailand
VIETNAM
Strait of Malacca
MALAYSIA
Thailand
With Provinces of Northeast Region
International boundary
National Capital
Regional Boundary
50 100 150 Kilometers
0 50 100 150 Miles

cassava, and high value vegetables, the 1991 average per capita income of the region's agricultural population amounted to only two-third's of the national average.

In contrast to the rest of Thailand, the Northeast is classified as a semi-arid tropical agricultural region. Its longer dry season combined with wide variation in the amount and timing of rainfall from year to year, makes irrigation a necessity for much of the region. At present, of the 9.37 million ha. cultivated, only 10% are irrigated by some form of public or private system. Because of its limited water supplies, no more than 20% of the agricultural land in the Northeast is potentially irrigable (Johnson 1990:11).

Known to the Thai as *issarn*, the Northeast remains the poorest region of the country. In 1989, 37.5 percent of the regions's inhabitants are thought to earning incomes below or at the poverty line. The Office of National Statistic estimates that the majority of working age population of the Northeast (85.1%) depends on agriculture for its livelihood. In addition to agriculture, livestock raising and fishing are important subsidiary occupations for the population as is dry season off-farm wage labor employment in Khon Kaen, Korat and Bangkok.

The Northeast has three major river basins: one international basin along the Mekong and two regional basins along the Mun and Chi rivers, both of which drain into the Mekong. The Nam Phong basin, which drains more than 11,000 sq. km. including much of Khon Kaen Province, drains into the Chi River.

The amount of rainfall in the Northeast is approximately the same as that of the Central and Northern regions of the country but the distribution of rainfall fluctuates during the rainy season. Because of its poor soils, with their high surface water infiltration rates, a lack of sufficient reservoir storage and the size of its population, the per capita water resource availability in the Northeast (i.e., 2,267 m^3/yr or 6,210 ltr/d in 1989) is the lowest in the country. While the water resource availability appears to more than adequate to meet current demand throughout the region, there are localized shortages of water in many areas of the Northeast, especially during the dry season (March-May) (Tingsanchali, 1991).

The Case of Khon Kaen

The northeastern province of Khon Kaen, with a population of nearly 1.7 million, is Thailand's fifth most populous province (after Bangkok and three other Northeastern provinces: Nakhon Ratchasima, Ubon Ratchathani and Udon Thani). The province has 20 districts (*amphoe*) that are divided into administrative units of diminishing size (sanitaries, *tambon* and *muban* or village) and four municipalities. Khon Kaen city, the capital of the province, is located 360 km northeast of Bangkok on the "Freedom Highway" Highway 2) and the rail line that links all the region's

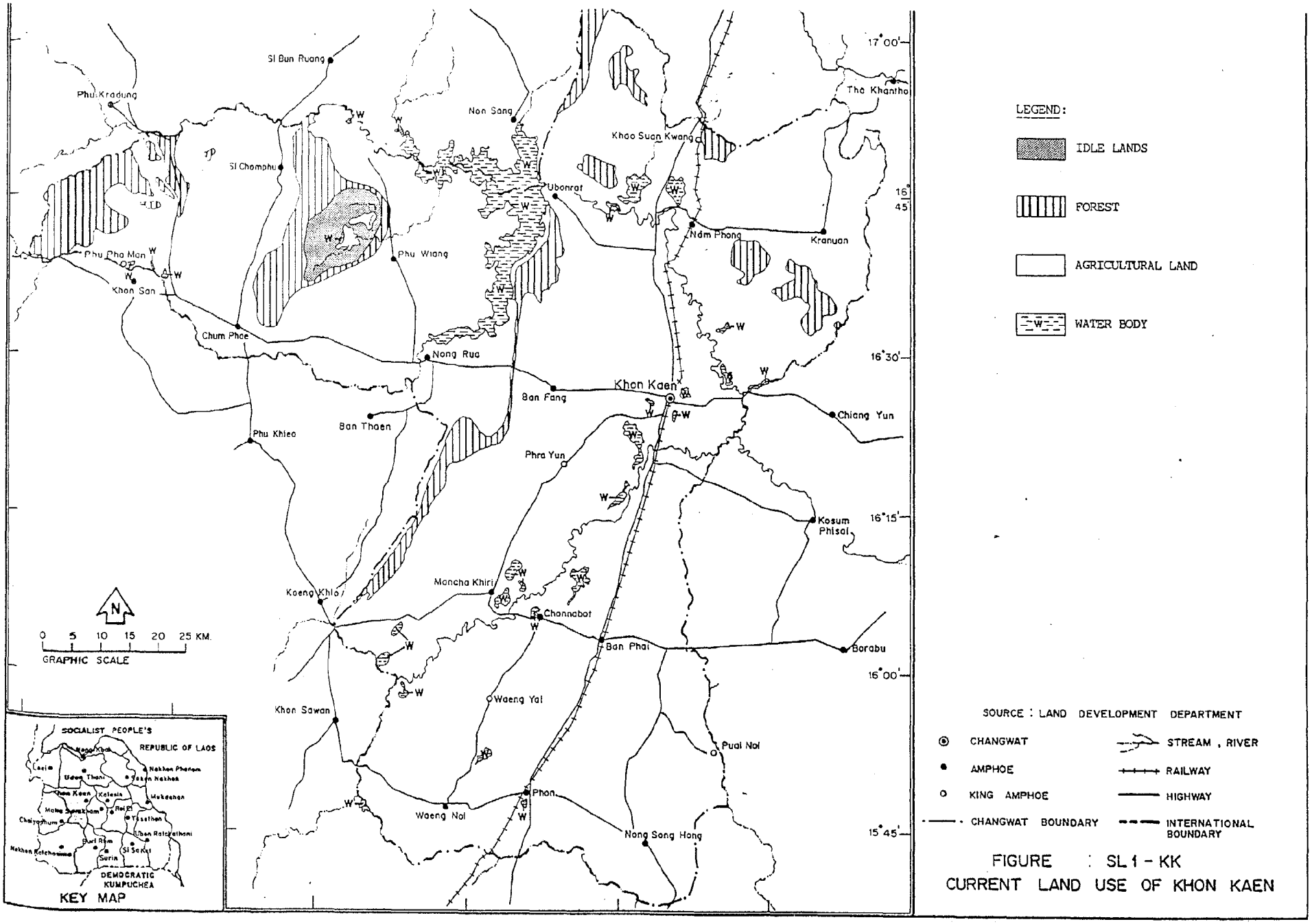


FIGURE : SL 1 - KK
CURRENT LAND USE OF KHON KAEN

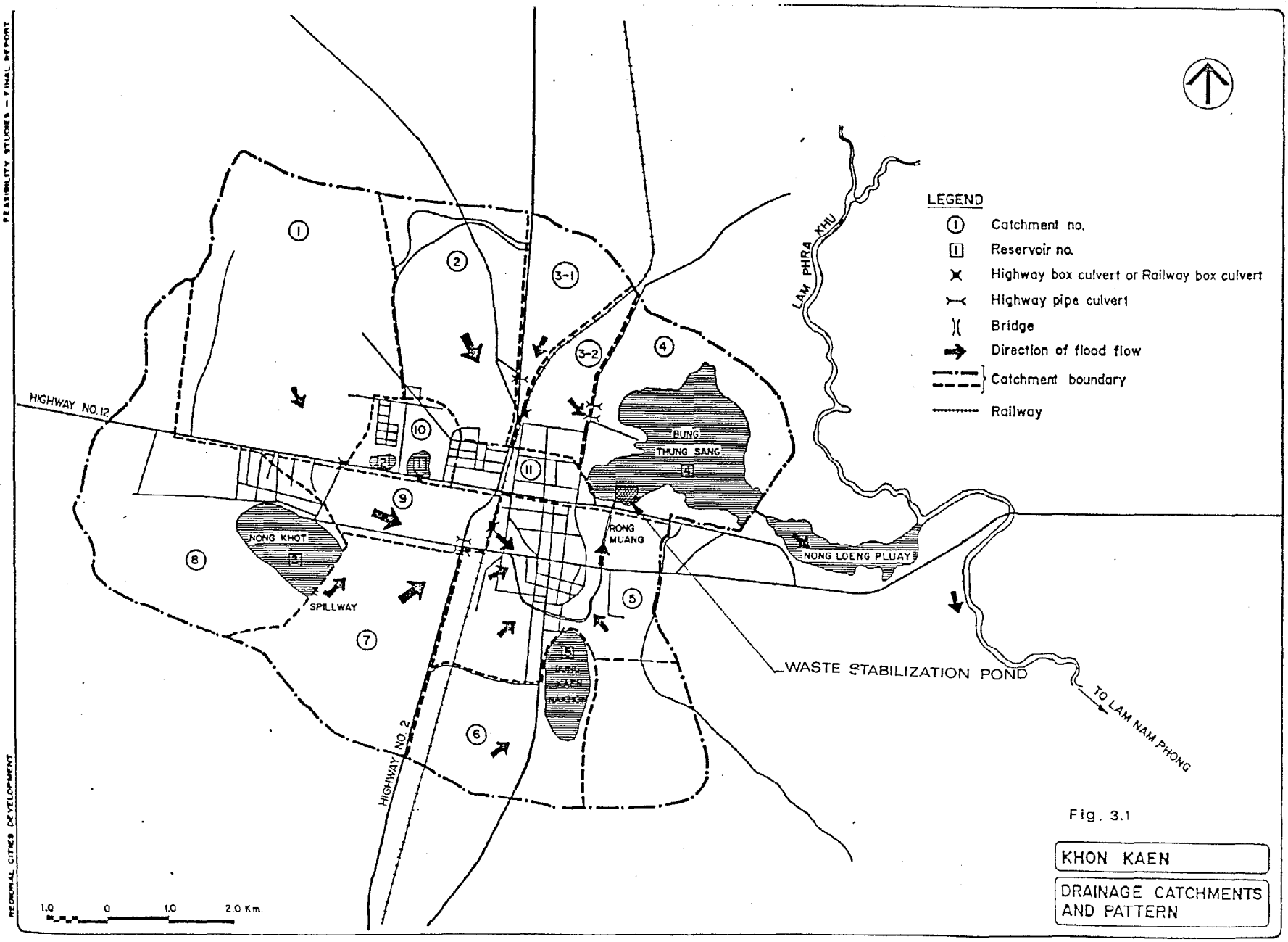


Fig. 3.1

KHON KAEN

DRAINAGE CATCHMENTS AND PATTERN

TABLE 1.3

MUNICIPAL AND PROVINCIAL POPULATION GROWTH/KHON KAEN PROVINCE

Year	Khon Kaen Municipality	% Growth	Khon Kaen District	% Growth	Khon Kaen Province	% Growth
1971	41.113	--	NA	--	1.087.764	--
1981	94.019	128.7%	158.290	--	1.354.855	24.6%
1991	131.478	39.8%	201.180	27.1%	1.694.479	25.1%
2001	149.884	14.0%	229.354	14.0%	1.931.706	14.0%

TABLE 1.4

COMPARISON OF MAJOR CROP PRODUCTION, 1972–92/KHON KAEN PROVINCE

	Cropped Area (ha)		% Total Cropped Area		Production (tons)	
	1972	1991	1972	1991	1972	1991
Nonglutinous Rice		60,981		10.2%		132,533
Glutinous Rice		249,727		41.6%		1,514,318
Cassava	2,135	54,977	0.4%	9.2%	19,733	794,531
Sugar Cane	253	9,674	0.1%	1.6%	3,875	2,312,871
Kenaf	49,378	6,871	10.3%	1.1%	60,989	8,161
Soybeans	52	11,683	0.0%	1.9%	41	17,935

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Table 1.5
Statistical Profile of Khon Kaen Province

Land Utilization (ha)	
Total Area	10,885,990
Cultivated Area	2,870,000
Irrigated Area	41,000
Unirrigated Area	2,289,000
Forested Area	1,849,270
Population & Settlement	
Municipal Population	219,160
Non-Municipal Population	1,475,319
Total	1,694,479
Districts (Amphoe)	20
Municipalities	4
Sanitaries & Tambons	213
Villages	1,892
Farming Households	66,459
Water Supply	
Municipal	
Non-Municipal	
Lg. Irr. Schemes(1)	
Md. Irr. Schemes (8)	
Sm. Irr. Schemes (192)	
Pump Irr. Schemes (8)	

Source: Khon Kaen Provincial Statistical Office (1992).

major cities from Korat to Nong Kai. Khon Kaen municipality has an area approximately 46 sq. km. The municipality and its environs have grown rapidly since the 1960s with the development of agro-industry, light manufacturing, public administration and the service sector (see Table 1.3) With an estimated 1993 population of 135,000, Khon Kaen is Thailand's sixth largest city.

Starting in the 1960s, the RTG increased its efforts to reduce poverty and increase the range of economic opportunities for the population of the Northeast. Many of these efforts were aimed at the improvement of irrigated cropping intensities with greater control ofirrigation, improved agricultural inputs and crop diversification. Table 1.6 indicates the range of development initiatives that the RTG, in many cases with donor support, has implemented in the Northeast and in Khon Kaen province specifically.

Despite more than three decades of public sector investment in irrigation infrastructureIn Khon Kaen, only 8% of the province's arable land is serviced by a perrenial system and water use efficiency on that land is poor. Agriculture is still dominated by subsistence production of rice, both glutinous and non-glutinous varieties, dominates the province's agricultural production during the wet season. Cash crops such as cassava, sugar cane, kenaph (a fibre plant use for paper pulp) and soybeans are cultivated on upland farm holdings (see Table 1.4). Government and donor-funded programs have introduced the cultivation of specialty high value vegetable crops, such as baby corn and tomatoes, in part to help farmers improve returns from cropping during the dry season but to also provide an alternative to cassava, a crop for which the by product, tapioca (for cattle feed), is facing declining world demand. The development of agro-industry in Khon Kaen province has promoted this crop diversification, particularly with the establishment of a major paper pulp factory, sugar mill, fish netting factory and a large number of cassava/tapioca processing mills. Nevertheless, the steady growth in wages for off-farm employment within the region has discouraged farmer investment in dry season cultivation of food crops, even in irrigated areas.

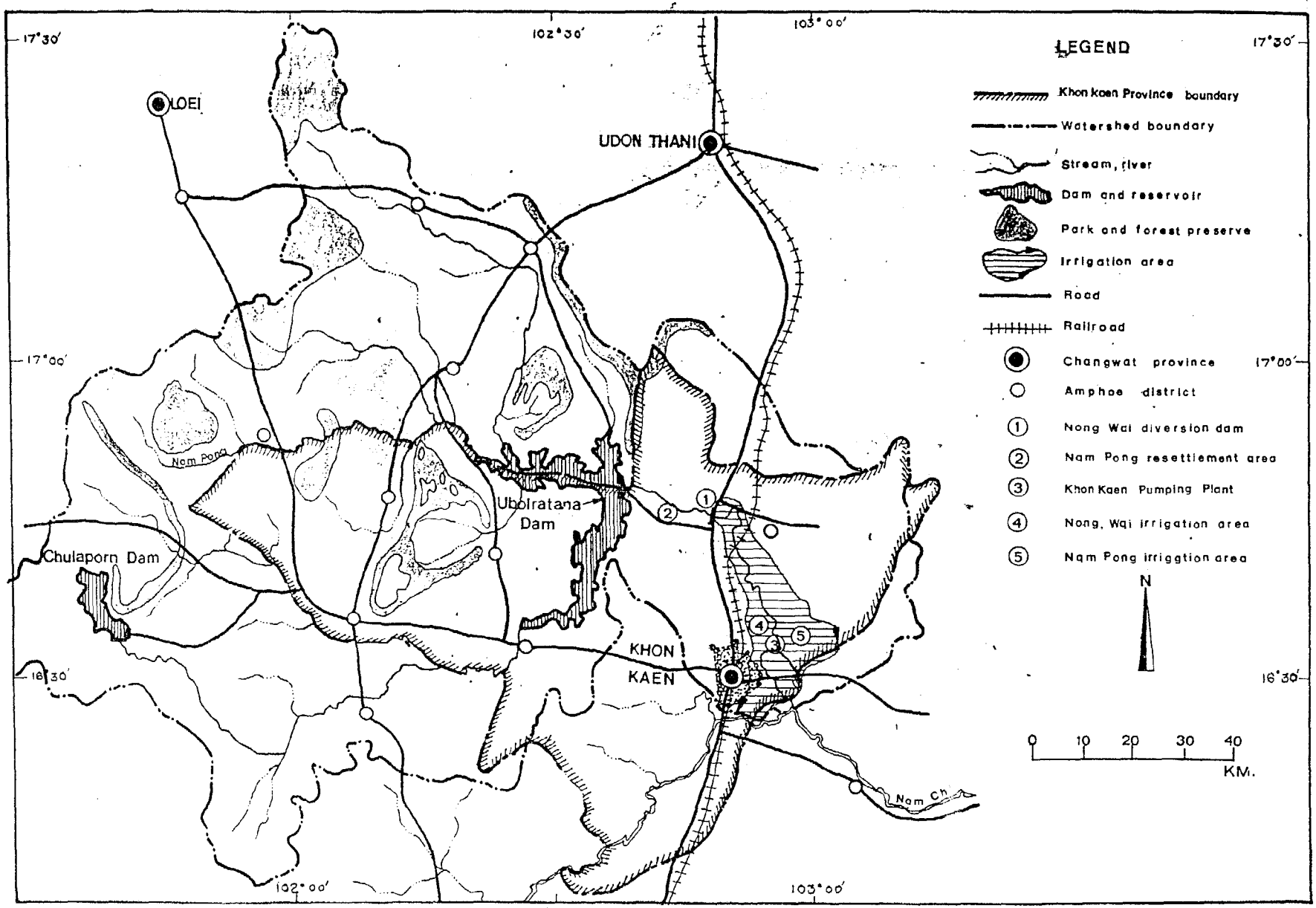

Fig NAM PHONG RIVER BASIN

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Eighty-five percent of the provinces economically active population 11 years of age and over were registered by as having agriculture as their occupation, followed by Laborers (5%), Sales Workers (4%), Professionals (2%) and Service Workers (2%) (Provincial Statistical Office, 1992).

In 1985, Khon Kaen was selected by the RTG as the northeastern municipality to receive assistance under the Regional Cities Development program. This program, supported with multilateral donor assistance, provided funds for municipal water and sewage system development. The award of this program to Khon Kaen indicates the importance with which the RTG regards the city in the development of the Northeast region and the Mekong basin.

Rationale for Selecting Khon Kaen as a Case Study

The ISPAN study team selected Khon Kaen as its case study because the city represents the trend of urban development throughout Thailand: rapid growth as a result of extensive commercial and industrial development, as well as public investment, over the past two decades. With this growth have come the concomitant problems of urban waste (sewage and solid waste) disposal and a burgeoning demand for energy and clean drinking water. The modest size of Khon Kaen municipality enabled the team to utilize methods of rapid appraisal research that would not have been effective in Thailand's larger cities, such as Bangkok, Chiang Mai, given the limited time available for data gathering and field visits. In addition, the selection of Khon Kaen as a case study enabled the team to survey a variety of donor-funded water sector activities in Khon Kaen Municipality and its hinterland. In addition, Khon Kaen University represented an valuable resource for technical expertise that was not to be found in any other province of the region.

Finally, the team's visit coincided with a growing public outcry over industrial pollution of the Nam Phong River, the province's principle source of irrigation and drinking water. A regular stream of newspaper articles on water pollution in the region and ongoin local NGO activism urging the RTG to designate the Nam Phong basin as a pollution control zone rendered Khon Kaen a "hot spot" from the perspective of water resource conservation and management.

Table 1.6
Major Resource Development Projects, Northeast Thailand

Implemented in Khon Kaen Province			
Khon Kaen (Municipality) Water Supply Expansion Project	PWA	NA	1991-P.
Regional Cities Development Project/Khon Kaen Municipal Sewerage System and Sewage Treatment Oxidation Ponds	IBRD	NA	1991-P.
Rainwater Tank Project	CIDA/ PCDA	NA	1981-85
Ubol Ratana Dam	IBRD	NA	1960-65
Nong Wai Irrigation Project	IBRD ADB Kfw	$5M $24M $92M	1975-86
Farmer Participation in Small Scale Irrigation Projects (SISS, FPSS II, FPSS III)	Ford	$1M	1985-92
The Green Northeast Project (Isarn Kyo)	RTG	$100M	1887-88
Thai Australia Village Water Supply Project	ADAB	$5M	1983-86
People's Volunteer Weir Program	DOLA/RTG	$100M	1985-P.
Farmer O&M Training Project	KfW	$3M	1990-93
Misc. Weir Projects	PDA/RTG	NA	1986-P.
Not Implemented in Khon Kaen Province:			
Northeast Small Scale Irrigation Project (NESSI)	USAID/RIG	$11M	1980-89
Lam Nam Oon Integrated Rural Development Project	USAID/RIG	$63M	1967-88
Northeast Water Management and Systems Improvement Project (NEWMASIP)	EEC/RIG	$34M	1991-97
Thai-New Zealand Small Watershed Development Project	New Zealand	$19M	1988-90

SECTION TWO

WATER QUANTITY

With its semi-arid climate and greater susceptibility to drought than in any other region of the country, Northeastern Thailand is particularly prone to water problems. Competition for water for agriculture, energy, municipal and industrial development, tourism and fresh water fish production can be found in every basin and sub-basin in the region. Particularly problematic are situations where agriculture development for cassava replacement and reforestation programs are leading to direct competition with already established irrigation systems. Public and private efforts to promote tourism and economic development are seriously stretching the limited water supplies of the region, especially the supplies in medium-scale irrigation reservoirs.

This chapter examines the existing water sources in Khon Kaen Province and the Northeast region, the attempts that the RTG with donor support has made to control and regulate that supply, and the impact that population growth, urbanization and industrial development has, and will continue to have, on the security of the water supply.

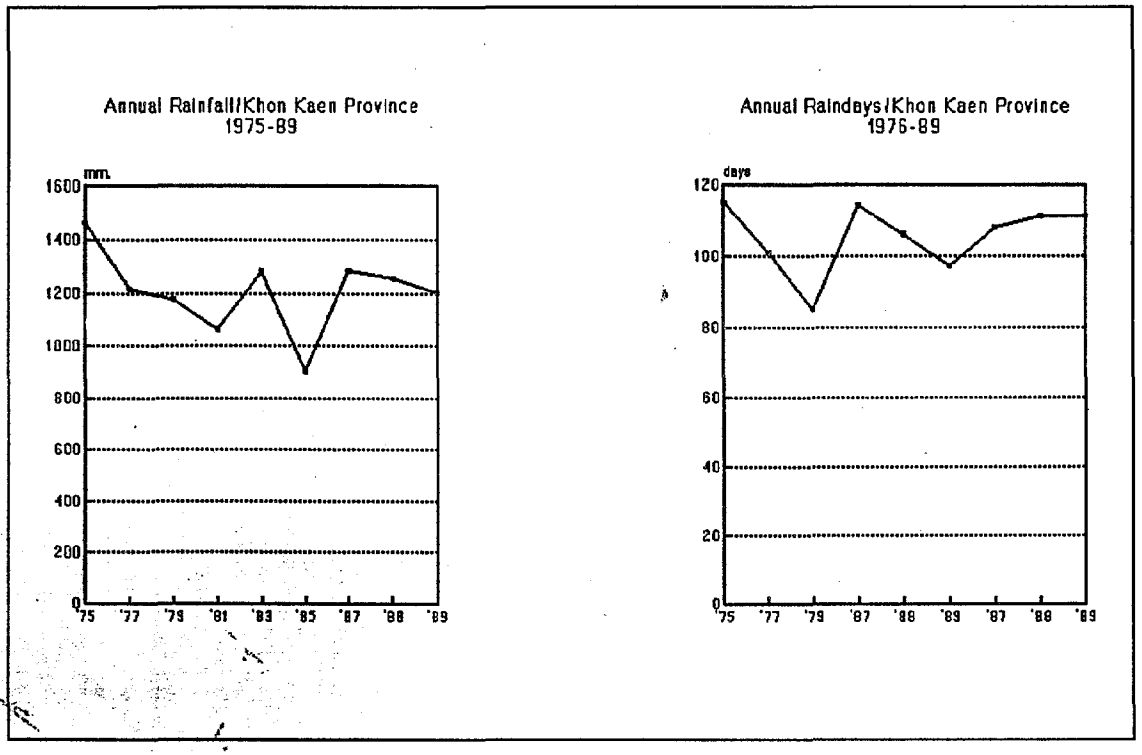
Water Supply in Khon Kaen Province

Khon Kaen Province lies almost entirely in the watershed of the Nam Phong River, one of the main tributaries to the region's largest rivers, the Mun and the Chi. The Nam Phong flows some 130 kms. from Loei Province southeast through Khon Kaen Province where it joins the Chi river just east of Khon Kaen Municipality (see Figure 2.1). Other watersheds supplying the province are the Choen, the Prom and the Chi.

Average annual rainfall for the province is 1,200 mm. yielding an average of 13.06 BCM. However rainfall is erratic throughout the year, and from year to year, as Table 2.1 indicates. An additional 3.0 BCM of water are supplied to the province by streamflow. Ground water resources are insignificant to the overall water supply of the province. The majority of deep ground water reserves in Northeast Thailand are saline due to the existence of rocksalt. Water derived from shallow wells is often brackish and used by villagers to meet non-potable household water requirements.

Rural drinking water is derived largely from rain water collected from the roofs of houses during the summer monsoons. This water is stored for dry season consumption in concrete jars (*ong*) for that are a ubiquitous feature of rural

Table 2.1
Annual Rainfall and Rain Days/Khon Kaen Province 1981-1989



households. These jars have a capacity of $2m^3$. An average of $6m^3$ of potable water is required to meet the needs of a family of six persons during the dry season months of November-April. Other sources of drinking water include shallow wells, natural water courses, ponds and irrigation channels. Tables 2.2 and 2.3 provide a water balance for Khon Kaen Province.

The flow of the Nam Phong River through Khon Kaen Province is regulated from the Ubol Ratana dam, a multipurpose dam built by the Electricity Generating Authority of Thailand (EGAT) in 1967 to provide flood control for the Nam Phong basin. The storage capacity of the Ubol Ratana reservoir is 2,025 MCM, making it the largest in the Northeast, and the hydro generating capacity of the dam 25 MW. The dam discharges water in a range from 50,000 to 4,200,000 m^3 per day excluding sideflow. EGAT must release and average of 400,000 m^3 per day to maintain the baseflow of the Nam Phong downstream. An average of 1.77 BCM of water are discharged from the dam per year. *Sixty percent of this water is used for domestic/municipal, industrial and agricultural purposes. Ninety-four percent of the water used is for irrigation*. Table 2.4 illustrates current demand for the waters

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TABLE 2.2
FORECAST FOR WATER USE/KHON KAEN PROVINCE

Year	Irrigation (1)	Industry (2)	Urban Water Supply		Rural Water Supply(5)	Total	% of Streamflow Exported	Per Capita 1000 cum/yr
			PWA (3)	DPW (4)				
	billion cu.m. per year							
1990	1.270	0.040	0.014	0.003	0.024	1.351	33.8	0.803
2000	1.397	0.065	0.036	0.008	0.049	1.555	38.9	0.808
2010	1.467	0.106	0.094	0.022	0.078	1.767	42.2	0.770

Note :

1. Use 10% increase for the year 2000 from the year 1990
   Use 5% increase for the year 2010 from the year 2000
2. Annual increase of 10% during the period 1990–2000 and 5% increase during the period 2000–2010
3. Annual increase of 10% during the period 1990–2010
4. Water suppled by DPW. is 23% of PWA.
5. Use consumption rate of 50 litre/day/capita for the year 1990
   Use consumption rate of 100 litre/day/capita for the year 2000
   Use consumption rate of 150 litre/day/capita for the year 2010

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TABLE 2.3

FORECAST FOR WATER AVAILABILITY/KHON KAEN PROVINCE

Year	Rainfall(1) (R)	Evapotranspiration (2) (ET)	Streamflow Imported	Streamflow Exported	Balance (3)	Population million	Per Capita (4) Thousand cubic meter/year
	Billion cubic meter/year						
1990	13.06	8.36	3.00	4.00	3.70	1.681	2.38
2000	13.06	8.36	3.00	4.00	3.70	1.948	2.05
2010	13.06	8.36	3.00	4.00	3.70	2.189	1.83

Notes: 1. Rainfall Average long term annual rainfall x total area

2. ET = 0.64 x Rainfall

3. Balance = Rainfall – ET + Imported Streamflow – Exported Streamflow

4. Per capita = Exported Streamflow/Population

TABLE 2.4

NAM PONG RIVER WATER USE/KHON KAEN PROVINCE

Sector	cu.m/month	MCM/yr	% Total Demand
Domestic			
Nong Wai Headworks Compound	51,840	0.62	
Khao Suan Kwang District W.S.	83,000	1.00	
Wang Chai Sanitary W.S.	210,000	2.52	
Nam Phong District W.S	150,000	1.80	
Air Base	180,000	2.16	
Kra Nuan Sanitary W.S.	72,000	0.86	
Kud Phang Krua Village W.S.	30,000	0.36	
Khon Kaen Municipal W.S.	1,800,000	21.60	
Khon Kaen Army Camp	48,000	0.58	
Khon Kaen University	270,000	3.24	
Chitarej Hospital	180,000	2.16	
Misc. Village W.S. (84 nos.)	75,600	0.91	
Subtotal	3,150,440	37.81	3.5%
Irrigation			
Nong Wai Irrigation Project	105,353,889	948.19	
NEA Pumping Stations (11)	6,220,800	55.99	
Subtotal	111,574,689	1,004.17	93.7%
Industry			
Phoenix Pulp & Paper	1,500,000	18.00 *	
Combined Cycle Power Plant	900,000	10.80	
Ice Factory	9,000	0.11	
Distillery	30,000	0.36	
Sugar Mill	7,000	0.08	
Tapioca Processing Mill	72,000	0.86 *	
Other	1,800	0.02	
Subtotal	2,519,800	30.24	2.8%
TOTAL DEMAND	117,244,929	1,072.22	
TOTAL SUPPLY		1,770.00	
BALANCE		697.78	

* Projected

of the Nam Phong River downstream of the Ubol Ratana Dam in all sectors. The 1.8 MCM requirement noted for Khon Kaen Municipality includes industrial demand within the municipality.

Irrigation in the Northeast and in Khon Kaen

Constraints on irrigation development and efficiency in Northeast Thailand are related in part to unfavorable physical conditions, especially limited water resources due to the pattern of rainfall and large seasonal fluctuations of natural watercourses. The regions rolling hills form a number of small watersheds that drain consecutively into the Chi, Mun and Mekong Rivers. In addition, the basins are underlaid with impermeable rock resulting in intense surface run-off and rapid rise and recession of streamflow during rainstorms. Consequently, the monsoon rains give rise to widespread flooding which occasionally causes sever crop damage, while water shortages may occur in the dry season. Periodic droughts occur throughout the region at the beginning and end of the monsoon season (Tingsanchali, 1991:13).

In the 1950s and 1960s, the Royal Irrigation Department (RID), and later EGAT, constructed a large number of storage reservoirs to regulate fluctuations in seasonal flow and to support year-round irrigation in suitable areas of the country. During the same period, the RID constructed over 200 small to medium sized irrigation projects in Northeast Thailand.[1] These systems range from 2,000 to 30,000 rai in service area size. In addition, over 2,000 small-scale systems were completed to provide increased irrigation capacity and domestic water supply. Three out of four of these systems have storage capacities of less than 5 MCM and only 10% have capacities in excess of 10 MCM.

According to the preparation report for its Northeast Irrigation Program, the Mekong Secretariat reports that approximately 50% of Northeast Thailand is comprised of farm holdings amounting to 54 million rai. Nearly 9%, or 4.7 million rai is irrigated, of which 1.1 million rai is served by 476 pumping irrigation schemes operated by the National Energy Administration (NEA). Another 2.4 million is irrigated by RID gravity schemes. The remainder is irrigated by small-scale projects established by various government agencies (Mekong Secretariat, 1991a). In addition, there are a number of other government agencies such as the Department of Local Administration (DOLA), Department of Community Development (DCD) and the Office of Accelerated Rural Development (ARD) that build small-scale irrigation projects based on small diversion weir construction. In Khon Kaen

[1] The RID classifies irrigation schemes as large, medium and small. Large scale irrigation projects have a construction cost greater than US$8M and a storage volume of more than 100 MCM. Medium-scale irrigation projects have a construction cost of between US$8m and US$0.32M and a storage capacity of less than 100 MCM. Small-scale irrigation projects have a cost of under US$0.32M and can be constructed in less than a year's time.

Province, for example, approximately 350 such schemes have been undertaken providing the province with and additional storage capacity of 10 MCM servicing and are of approximately 7,000 ha.

Khon Kaen's Nong Wai irrigation project, with a service area 41,505 ha., is one of the largest schemes in Northeast Thailand (see Table 2.5). The service area of the Nong Wai project covers two provinces (Khon Kaen and Maha Sarakham) through two main channels supplied by a diversion weir located approximately 35 kms. downstream of the Ubol Ratana dam. In addition, there are 18 medium-scale RID projects, 320 small-scale RID projects and 18 NEA pumping stations in Khon Kaen and the Nam Phong river basin that serve and additional area of 27,000 ha.

Table 2.5
Details of the Nong Wai Irrigation Project

	Right Main Canal	Left Main Canal		Total
Service Area	Khon Kaen	Khon Kaen	Maha Sarakham	
Irrigated Area				
ha	11,200	10,640	19,665	41,505
rai	70,000	66,482	122,908	259,400
Total Length (km)	47	52	31	130
Discharge (m^3/d)	10.0	45.0		55.0

Irrigation Water Use Efficiency

The predominant use of water by the agriculture sector belies its inefficient use of the resource. The total irrigated area of Khon Kaen Province is little more than 41,000 ha., or only 7% of the province's total cultivated area. Estimates place irrigation efficiency in the Nong Wai Irrigation project, the province's sole large-scale irrigation scheme, at no more than 30%. As elsewhere in the Northeast, conflicting demands for irrigation, domestic and industrial water have put pressure on the RID to find alternative sources of water storage. Adding to the strain of nonagricultural withdrawals is the inflow of sedimentation that continues to reduce reservoir storage capacity. As one donor report notes "Current methods for forecasting available water for medium scale reservoirs tend to overestimate inflows, which results in overly optimistic estimation of irrigation potential." Nor do these methods consider the impact of land use change on the runoff from reservoir catchment areas. The private development by farmers of numerous small irrigation weirs and reservoirs in these catchment areas during the last decade has further reduced reservoir inflows (Johnson, et al., 1989:x).

A joint World Bank/FAO review of Thailand's irrigation sub-sector in 1985 identified the following constraints on the country's ability to maximize returns on its irrigation investment (Plusquellec, 1985; World Bank, 1986). These constraints included:

- incomplete irrigation infrastructure;
- poor water management;
- poor crop management;
- lack of sufficient and improved agricultural inputs;
- insufficient coordination of government support services; and
- lack of farmer access to agricultural credit.

Five years later, a UNDP country-wide review of water resource use and a review of the irrigation subsector in Northeast Thailand carried out with the Support of the Mekong Secretariat found little major change in the constraints identified by the World Bank/FAO. The UNDP study noted that the poor efficiency of irrigation systems is the result of incomplete infrastructure, unregulated flow, inadequate control structures and wasteful use of water for irrigation. The study goes on to note that:

> "One of the most inefficient elements of the existing irrigation systems is often the section where water is transferred from canal outlets to farms. Improper design, unsatisfactory operation and maintenance of the canal outlets are the main causes. *While much research has been carried out on canal losses, very little has been done to reduce losses from the canal outlets to farms* (Tingsanchali, 1991:30).

The problems faced users of irrigation water in Thailand are common throughout the world: lack of proper system management and maintenance results in illegal offtakes and damage to the system that results in an irregular flow that is impossible to control. Farmers at the head regulator receive excess water most of the time while those at the tail end face shortages.

A number of donors, and in particular USAID and the Ford Foundation, have supported RTG investment in the irrigation sector that promotes the strengthening of farmer participation in system O&M and management of water deliveries. The USAID Northeast Small-Scale Irrigation Project was successful at building effective Water User Groups by providing farmers with access to improved inputs, technology, extension training and agricultural credit (USAID, 1990; Johnson, et al. 1989). The Ford Foundation's support for attempts to institutionalize support for Water User Groups in the operations of the RID through its Farmer Participation in Small-Scale Irrigation Project was not so successful (Water Resources and Environment Institute, 1987a, 1988).

Institutional Constraints to Efficient Irrigation Management

At present, irrigation systems in the Northeast are under-utilized and the economics of continued government investment in irrigation is becoming unattractive. In addition, farmer's financial returns from irrigated agriculture remain low, particularly dry season agriculture, and continued financial support by the government for operations and maintenance is necessary. Crop production in irrigated areas has not achieved expected output levels for the reasons of water use inefficiency, poor management and insufficient inputs cited above. Added to these constraints is the absence of farmer investment in the water delivery system itself. No direct charges are made to beneficiaries for irrigation services provided by public irrigation systems. Farmers thus have no vested interest in maintaining or managing the system. Nor is there in Thailand any legislation that clearly defines the rights and duties of surface water users, or the authority and duties of those who provide surface water. Thus, the farmer has no legal recourse to protect any investment that he makes in the system. As a recent World Bank review of water resources in Asia points out, lack of clarity on riparian water rights may lead to future conflicts resulting from competitive uses of water as demands from all sectors increase (World Bank, 1992:159).

Nor, in the face of Thailand's economic boom, is the government taking steps to protect *its* investment in the irrigation sector. The expansion of Khon Kaen municipality has already begun to encroach on the service area of the Nong Wei Irrigation Project. The alignment of the city's planned a ring road follows a section of the project's Right Main Canal. Following a pattern familiar to residents of Bangkok, real estate developers will quickly buy up farm land adjacent to the alignment for commercial and industrial development.

Certainly the promotion of greater participation of farmers in the maintenance of their irrigation system, and the decentralization of RID's management of the system to incorporate Water User Group participation is the most effective means of improving water use efficiency in the irrigation subsector. With regard to the pricing of irrigation water, however, such a small percentage of land in the Northeast is serviced by surface irrigation projects (7% for Khon Kaen, 20% or less for all the Northeast) that the returns on what is likely to be a politically contentious policy are likely to be marginal both in terms of revenue and in water management. While overall, the government's irrigation projects have supported more intensive paddy cropping and dry season cultivation of cash crops, the increasing returns for off-farm employment are likely to discourage farmers from more investment in irrigated agriculture than they already make.

Drinking Water Supply

Urban

Urban water supply in Thailand's provinces other than the Bangkok Metropolitan Area is the responsibility of the Provincial Waterworks Authority (PWA) and the Department of Public Works (DPW). At present, PWA only serves municipalities of large districts and DPW serves those of small districts. Khon Kaen is located in PWA Region No. 6.

Khon Kaen municipality's first water treatment plant was constructed in the early 1950s, with a capacity of 1,000 m^3/d (0.36 MCM/y). This original plant was decommissioned when the Ban Kotha Water Treatment Plant, situated on the northern boundary of the municipality, came on line in 1972, with a capacity of 12,600 m^3/d (4.6 MCM/y). Until 1991, the source of Ban Kotha's water was the Nong Wai Irrigation canal (ultimate source, the Nam Phong River), and therefore was subject to shortages from flow shut off during November and May for biannual canal maintenance. In addition, the Nong Waeng Treatment Plant was built on the southern side of Khon Kaen municipality in 1970 to supply the Tha Phra Sanitary District's villages 12 kilometers south of the city. Its capacity was reported to be 480 m^3/d, with two sources reported: the Lam Chi River and/or deep groundwater wells. As of 1988, the urban water treatment capacity totalled approximately 21,600 m^3/d, with 26,912 m^3/d distributed to 16,070 households (UNDP/WB, 1991:A4-16).

The Ban Kotha Water Treatment Plant's capacity was greatly expanded in 1991 under Phase I of the Provincial Waterworks Authority's Khon Kaen Water Supply Expansion Project, from 12,600 m^3/d to 75,600 m^3/d (27.6 MCM/y). It uses an aluminum flocculation basin/channel, sedimentation basins, and rapid sand filters. This now also supplies the villages immediately to the south of the city, with the Nong Waeng plant converted to use as a storage and pumping station. The expansion included the construction of a pumphouse on the bank of the Nam Phong River, and a 3.5 km raw water transmission pipeline, to solve the problem of limited water supply from the Nong Wai Irrigation Canal during the dry season. The canal continues to be used as a supplemental source in the wet season, but the ultimate source of the water is still the Nam Phong, as the canal is a diversion from this river.

The Phase I construction also included expanding the capacity of the city's water distribution system to a maximum of 111,500 m^3/d (40.7 MCM/y), with a maximum working water pressure of 3.5 kg/cm^2.

Ban Kotha's actual production currently averages about 60,000 m^3/d (22 MCM/year), fluctuating between 50,000 and 70,000 m^3/d. A further expansion

(Phase II) is planned for Ban Kotha in the late 1990s, to bring its capacity to 144,000 m^3/day (52.5 MCM/yr) by 2005.

The PWA reports that this treatment plant and its distribution system now service 70% of the municipality's population, with direct pipe connections to 26,000 (of 37,000) households, as well as many cottage and small industries. (This would amount to less than half of the total urban population of the province). The remainder of the city's population is reputed to obtain its water from 5 pay-standpipes (1 baht, or US$0.04 for 80 liters; see Tables 2.6 and 2.7 for PWA's progressive tariff schedule for water connections). While it was reported that no other standpipes exist in the city, the team observed at least two free standpipes during its travels about the city.

After deducting urban industrial consumption, PWA estimates the average household consumption to be 1.5-1.7 m^3/day, which includes an estimated water loss rate of 52% (two official documents earlier put the loss rate at 5% or 25%). The sources of these losses are believed to be primarily broken older service mains, connection piping, and defective meters. Wastewater flows for Khon Kaen municipality were estimated to be two-thirds (67%) of domestic consumption (UNDP, 1983).

Ban Kotha plant's cost of producing water is reportedly 1.5 baht/m^3. It was claimed that Khon Kaen is one of few city water systems in Thailand that turns a profit (see Table 2.8).

The first recommendation of PWA staff to reduce the water loss rate would be to rehabilitate the 100-plus main gate valves in the streets, so that when a pipe breaks, the water can be shut off in the area. There is also a shortage of manpower and vehicles for system maintenance.

Rural Drinking Water

Coordination of rural drinking water supply activities is mainly through a high-level inter-ministerial committee, the National Rural Water Supply Program Executive Committee (NATWEC), established in 1981 and chaired by the Permanent Secretary of the Ministry of Interior (RTG, 1989). Several government agencies are involved in a nation-wide program to provide potable water to villages, including the Environmental Health Division of the Dept. of Health (Ministry of Public Health).

Seventy-six percent of rural Thais were believed to have access to the minimum per capita drinking water target of 2 ltr/d (RTG, 1989; WRI, 1992), with 43% obtaining the preferred 5 ltr/d. However, when WHO bacteriological

Table 2.6
Progressive Tariff Schedule for PWA Water Consumers

Monthly Total Volume (Cu. m.)	Increment (Cu. m./month)	@ Rate (Baht/Cu.m.)
0-10	first 10	3.75
11-20	next 10	4.50
21-30	next 10	6.50
31-50	next 20	7.50
51-80	next 30	8.00
81-100	next 20	8.50
101-300	next 200	9.00
301-1000	next 700	9.25
1001-2000	next 1000	9.50
2001-3000	next 1000	9.75
above 3000	remainder	10.00

Table 2.7
Service, Connection, and Monthly Guarantee Charges

Connection Size	Service Charge (Baht/month)	Connection Charge(Baht)	Guarantee (Baht)
1/2"	10	2,050	200
3/4 "	15	2,750	300
1"	30	3,750	600
1 1/2"	60	6,690	1,500
2"	100	9,575	2,000

(Source: PWA; adapted from UNDP/World Bank, 1991, p.A4-25)

Table 2.8
Khon Kaen PWA Budget, 1988-92 (US$ Million)

Year	Revenue	Costs	Profit
1988	2.06	0.63	1.43
1989	2.17	0.69	1.48
1990	2.40	0.76	1.64
1991	2.76	1.10	1.66
1992	3.07	1.37	1.70

standards were included in the criteria, only 23% of the rural population was covered at the minimum level (2 ltr/day). In addition, 63% of the rural population was believed to have latrine service as of 1988, up from about 40% in 1980 (RTG, 1989).

In most rural communities of Khon Kaen Province, like the rest of the Northeast, drinking water is obtained by harvesting rainwater off of household roofs into 2 cubic meter tanks ("jars"). The government conducted a massive nation-wide program over the past decade to promote the use of such jars. In a few cases, a village may have a small sand filter treatment system (e.g., 20 m^3/hr), or a piped supply directly from a raw water source such as a river or a tubewell, but most groundwater in the Northeast is too saline for drinking. However, groundwater is often used for the remainder of domestic consumption (washing, etc.). More recently, the Environmental Health Division has begun promoting the use of 100 m^3 "water banks" for villages, to facilitate the storage of water delivered by truck from the municipal water plant when rains are inadequate to supply household/village needs.

As of January 1993, the Environmental Health Division Center in Khon Kaen calculated that 84% of the Province's rural population received the government per capita target of 5 ltr/d of clean water. Eighty-six percent of this population was found to have latrine facilities, and 46% adequate sewage treatment. These figures were each up about 2% over 1992.

At the preferred goal of 5 ltr/d per capita, and an average household size of 6 persons, rural drinking water demand should be almost 1 cubic meter per household per month. A family of 6 would therefore need three 2 m^3 jars to securely supply itself with drinking water through the dry season. While the chemical quality of water from the rainwater jars usually meets WHO standards, the bacteriological quality often does not.

With a total rural population of 1,197,792 as of January 1993, the demand for rural drinking water in Khon Kaen province, using the official target of 5 liters per person per day, would be 6,750 m^3/d (2.40 MCM/y). Using the target for rural total domestic water supply of 50 ltr/person/day, rural Khon Kaen's total domestic water demand can be estimated at 67,500 m^3/d (24.6 MCM/y), approximately equal to the current production of Khon Kaen municipality's water treatment plant.

Total Provincial Domestic Water Demand

To estimate the total provincial domestic water demand, it is essential to understand the settlement of Khon Kaen's population. Khon Kaen Province comprises 20 districts. Among these, there are four municipalities and 15

sanitaries (a local administrative body for urban areas smaller than a municipality). Currently, domestic water supply of all municipalities is provided by DPW. PWA will gradually assume DPW's responsibility as the municipalities grow in size and population. For Thailand, DPW's share of water supply services accounted for 23% of the water supplied by PWA.

The percentage of urban and rural inhabitants in Khon Kaen Province in 1990 was approximately 21% and 79% respectively. Therefore, the total domestic water demand for Khon Kaen Province can be estimated at 1.75 BCM/y (see Table 2.3).

Given that the Ban Kotha treatment plant's production of approximately 60,000 m^3/d currently supplies about 70% of Khon Kaen city's domestic needs, and the city accounts for about 42% of the province's urban population, one might estimate the total urban domestic use to be 206,000 m^3/day. Adding the rural demand of 65,000, yields a total provincial domestic use demand of 271,000 m^3/d, or 99 MCM/y.

SECTION THREE

WATER QUALITY

In the context of competing urban-rural demands on water resources, this study has identified four general types of water quality problems: two that are derived from rural and agricultural activities (i.e., salinization and agro-chemical pollution); and two that are usually associated with urban development (i.e., sewage disposal and industrial pollution). However, both these latter problems can be found in rural areas as well. This section reviews the problems associated with water quality for Thailand as a whole and relates these problems to the specific case of Khon Kaen.

Overview of Water Quality Problems in Thailand

Urban population growth and industrialization are the predominant sources of Thailand's growing water quality problems. Bangkok and its main water source in particular, the Chao Phraya River, are suffering from water quality deterioration.

As of 1988, 67% of urban inhabitants in Thailand have access to improved, piped drinking water, up from 51% in 1980. Eighty-four percent were estimated to have access to latrine services, up from 64% in 1980 (World Resources Institute (WRI), 1992).

Rural water supply coverage lagged behind the urban areas. In 1988, 76% of rural inhabitants were estimated to have access to the minimum per capita drinking water target of 2 ltr/d (RTG, 1989; WRI, 1992). Of these inhabitants, 43% had access to the preferred target of 5 ltr/d per capita. However, when WHO bacteriological standards were included in the criteria, only 23% of the rural population had access to the minimum standard (2 ltr/d/per capita). In addition, 63% of the country's total rural population was estimated to have access to a latrine as of 1988, up form about 41% in 1980 (39.5% as of 1983 for the Northeast region (RTG, 1989)).

Sanitation

There is growing recognition of the urgent need to address the problems of urban sanitation and water pollution in Thailand. Bangkok's first sewage treatment plant was constructed by the National Housing Authority (at Huay Khwang) in 1975. The NHA now has 14 small plants in Bangkok (including 5 activated sludge plants, 3 oxidation ditches, 1 aerated lagoon, and one oxidation pond), serving less than 100,000. Other agencies involved in sanitation include the Bangkok

Metropolitan Administration (BMA), the Department of Health (DOH), and the Public Works Department (DPW). Numerous studies and master plans for sewerage systems for Bangkok were prepared between 1960 and 1891, but due to BMA's limited budget, few proposals were fully implemented. As of 1992, less than 2% of Bangkok's population was connected to its sewer system with the balance relying on septic tanks, cesspools or city's canals (TDRI, 1987; UNDP/WB, 1991; RTG, 1992).

A JICA study predicted that anaerobic conditions would become commonplace on the lower Chao Phraya during periods of low water flow, and recommended the installation of a disaggregated sewerage system and treatment plants, at an estimated cost of US $1.5 billion (TDRI, 1987). Most of this cost was to cover the construction of sewer drains (37.4%) and house connections (25.7%) with the funding for treatment facilities accounting for only 7.6% of the total proposed budget. The BMA instead proposed in 1992 a two-stage sewerage and treatment plant project expected to cost US $800 million.

A 1991 study of Thailand's urban sewage and wastewater sector identified 18 specific issues related to legal, institutional, policy, finance, technical and public participation requirements to facilitate proper development of the urban sewage and wastewater sector. The study highlighted the total lack of a national legal framework specifically addressing sewage and wastewater, inadequate monitoring and enforcement of regulations, and lack of clarity about the division of roles and responsibilities among at least 11 national government agencies involved in the sector (Unkulvasapaul and Seidel, 1991). The study recommended remedies to some of the problems in the sector, including:

- requiring water discharge permits;
- gradual institution of sewer tariffs based on water usage to cover full operation and maintenance costs;
- privatization of sanitation services;
- separation of sewage from industrial and storm wastewater in cases where systems have yet to be installed;
- utilizing stabilization ponds for sewage treatment in population settlements other than Bangkok;
- a strong and continuous public education program; and
- training and development of skilled personnel.

Over the past decade, many of the larger hotels, shopping centers, hospitals, universities, government housing estates and other major institutions have constructed their own self-contained sewage treatment facilities. In many cases, these facilities are packaged activated sludge plants. Industrial estates have built self-contained hazardous waste collection and treatment facilities as well.

Industrial Pollution

Until rather recently, the vast majority of industrial production in Thailand was located within the Bangkok Metropolitan Region (BMR). Hence, in 1989, 71% of hazardous waste generation was concentrated around Bangkok, with the lowest proportion coming from the Northeast region (1.2%), according to Engineering Science Inc., et al (1989). Pollution will continue to be concentrated in the BMR for the foreseeable future, but there are signs that it is growing in other areas. The same study evaluated the environmental risk associated with various types of hazardous wastes, and the cost-effectiveness of their treatment in the context of Thailand. It found that by far and away, the number one priority for risk reduction should be treatment (or prevention) of heavy metal sludges and solids. A distant second priority should be photographic chemical wastes, followed by (3) alkaline wastes, (4) acid wastes, and (5) infectious wastes (see Table C.2 in Annex C for complete accounting).

The largest industrial sources of BOD in Thailand are the tapioca, pulp/paper, alcoholic brewery/distillery, rubber, and sugar industries. Different sources (TDRI, 1987; Phantumvanit & Panayatou, 1990) rank these sources differently (the former also includes mono sodium glutamate as a major source in the Central region),

Legal & Institutional Framework for Water Quality

Thai legislation directly related to water quality management has been very limited. The Public Health Act of 1941 regulated rubbish disposal and unsanitary dwelling places, latrines, etc., although penalties for violations were minimal, not exceeding US$2-4. The 1960 Act for the Cleanliness and Tidiness of the Country prohibited the dumping of waste into rivers and canals, but it went largely unenforced. The 1979 Building Control Act gave municipal authorities power to control the number and type of bathrooms and toilets, and control storm and wastewater drainage. The 1969 Factories Act theoretically imposed requirements on industries discharging defined levels of effluents with high BOD, heavy metals, or other polluting chemicals.

Until 1992, Thailand's pollution control system relied exclusively on the establishment of effluent standards, which implies end-of-pipe treatment, rather than reduction of pollution sources via process and technology changes which would be stimulated by pollution charges. Thailand has not had the enforcement resources (or will) to ensure compliance with the standards.

Since 1988, the government has commissioned a total of four hazardous waste treatment plants, the second of which is expected to commence operation in 1993. New industries are encouraged to site themselves in industrial estates, which have waste collection and treatment systems.

Two agencies are largely responsible for domestic and industrial pollution control: the Department of Industrial Works (DIW) under the Ministry of Industry, and the Office of the National Environment Board (ONEB) under the Ministry of Science, Technology and Energy (MSTE). Until 1992, the latter was a policy coordinating body, with no actual powers of regulation enforcement. The former has often been curtailed from enforcing regulations under a policy climate that favored the unmitigated promotion of industrial expansion, and perceived pollution control as a restriction on economic growth.

1992, however, saw the passage of a two major new environmental laws, the Industry Act and the Water Quality Control and Promotion Act, which created an Environment Fund supported by the collection of pollution fees from industry. This also enables municipalities to tap the Fund for wastewater infrastructure investment loans.

WATER QUALITY IN KHON KAEN PROVINCE

Rural Drinking Water Quality

The Thai Australia Village Water Supply Project (1986) found that rainwater storage jars and tanks, and sanitary (covered) wells have a low probability of faecal (bacteriological) contamination, whereas about 80% of open wells and surface storages (ponds) were polluted. The limited ground water resources in the Northeast are generally brackish and wells drilled deeper than 20 m are likely to encounter highly saline water due to downward capillary movement. Less than 10% of the deep wells tested met WHO chemical standards for drinking water, which confirmed surveys showing that only some 10% of deep wells were used for drinking.

Salinization

Soil salinity affects only 1.5% of the entire region (Mekong Secretariat, 1991c:3-4,5). Those areas most affected are Korat (Nakhon Rathasima), and parts of Maha Sarakham and Udon Thani provinces (where surface salts are mined). Figure C-1 shows the distribution of saline areas in Khon Kaen and indicates pockets of slightly affected areas within the province. Seasonal saturation of soils by the monsoon rains and relatively good drainage serves to retard the upward capillary movement of salts to the surface. There is evidence of salt contamination of small and medium-scale reservoirs in the saline-affected areas, which could eventually affect the quality of irrigation water provided by these reservoirs (Sethaputra, 1986). There is also some concern among experts that soil salinity may increase in irrigated areas with the expansion of the area and intensity of dry season cultivation.

Salinization of soils or surface water therefore appears not to be a significant problem in Khon Kaen province at the present time.

Agro-chemicals

There is a paucity of information about agro-chemical use in Northeast provinces. Although known to be on the increase as a result of year-round irrigation (paddy and other cash crops), intensification of land use, use of pesticides and fertilizers is believed to still be well below the levels of other countries. A study by the Faculty of Science at KKU found little difference in water quality between rainfed and irrigated (Nong Wai) areas along the Nam Phong. (Turbidity was higher in the irrigation area than the level recommended for fisheries, but overall suitability for

freshwater organisms was not found to be significantly different; Khon Kaen University, 1987.) As a result, agro-chemical pollution is not perceived to be a serious problem as of yet.

Of course, it would be best if care were taken in advance to ensure that it does not become serious in the future. It would therefore be advisable to develop and monitoring and information system to determine the distribution and use of pesticides, and trace their movement through the agro-ecosystem and waterbodies. Non-persistent pesticides should be promoted over persistent ones.

Eutrophication can also accrue from livestock wastes. A study of water quality on the Nam Phong between 1988 and 1993 did find one such source, a pig farm, affecting the lower Nam Phong.

Sanitation

The city of Khon Kaen received priority in the Regional Cities Development Project (UNDP, 1983), funded in part by the World Bank, for the construction of intercepting sewers and an oxidation/ stabilization pond system designed to serve 118,000 people, as well as upgrading solid waste collection in the city (see Figure 3.1). It is a combined sewer system, which is probably adequate, as Khon Kaen's largest chemically polluting industries are either located outside the city directly on the Nam Phong River, and/or have constructed their own wastewater treatment systems.

The oxidation pond treatment system, covering 19 hectares, went into operation in 1989. It consists of two large facultative ponds and three smaller maturation ponds, requiring a total of about 12 days for wastewater to move through the entire process. It cost about US$1 million to construct. Its capacity is currently 25,000 cum/d, which is about two thirds of the city's discharges, and requires only four persons to operate/maintain. The processed wastewater is subsequently discharged into a large nearby wetland lagoon/lake system, which previously received the sewage untreated. This has led to a considerable improvement in the water quality of the lake, with attendant benefits for fisheries and recreational uses.

Septic tanks and cesspools are common in the city as well; many now overflow into the sewer system. Interceptor drains and sewer mains continue to be added to the system; several were under construction during the mission. The budget under the current five-year plan for the sewerage system (1992 to 1996) includes US$3.5 million for road and drain improvements, and US$2.5 for sewer mains.

At the time it was designed, it was anticipated that the treatment system capacity would eventually have to be expanded by another 14,000 cum/d to cover the full population of the city and anticipated future demand. It is not scheduled for implementation in the near future, however.

Currently, there is no sewerage/wastewater tariff in Khon Kaen (or Thailand). Residents do pay for incoming piped domestic water, but wastewater is managed by a different agency that does not share in the revenues. Since wastewater flow is proportional (c. 60%) to water consumption, implementation of a progressive sewerage fee tied to water consumption would simultaneously serve to encourage water conservation, thereby reduce the additional treatment capacity requirements, and fund the balance of system expansion needs.

The Khon Kaen municipality's sewage treatment system appears to be working reasonably well, and would probably serve as a good model for other small and medium-sized cities (Bangkok likely being the only inappropriate case in Thailand). Additional training of operational personnel would be beneficial. Cities starting with no sewerage system at all should consider establishing separate collection and treatment facilities for industrial wastes, however. Separating storm runoff from domestic/sanitary flows is probably unnecessary with the use of oxidation pond treatment systems, as long as they have sufficient storage capacity.

As of January 1993, the Environmental Health Division Center in Khon Kaen calculated that 86% of the Province's rural population had latrine facilities, and 46% adequate sewage treatment. These figures were each up about 2% over 1992.

There is no evidence of urban-rural conflict over water as a result of sanitary sewage in Khon Kaen.

Industrial Pollution

In the Northeast region, the most significant industrial sources of BOD are (1) tapioca, (2) pulp, (3) alcohol, and (4) sugar (TDRI, 1987:217). All four of these are found in Khon Kaen province, with a major pulp mill, distillery, and sugar mill located on the bank of the Nam Phong River between the Ubol Ratana Dam and Khon Kaen City (see Figure 3.2). Tapioca mills tend to be small and dispersed, whereas the pulp, alcohol, and sugar plants are large point sources. Table 3.1 provides an inventory of major industries in the Province.

In the past year and a half, water quality on the Nam Phong has become a nationally controversial issue, due to three events.

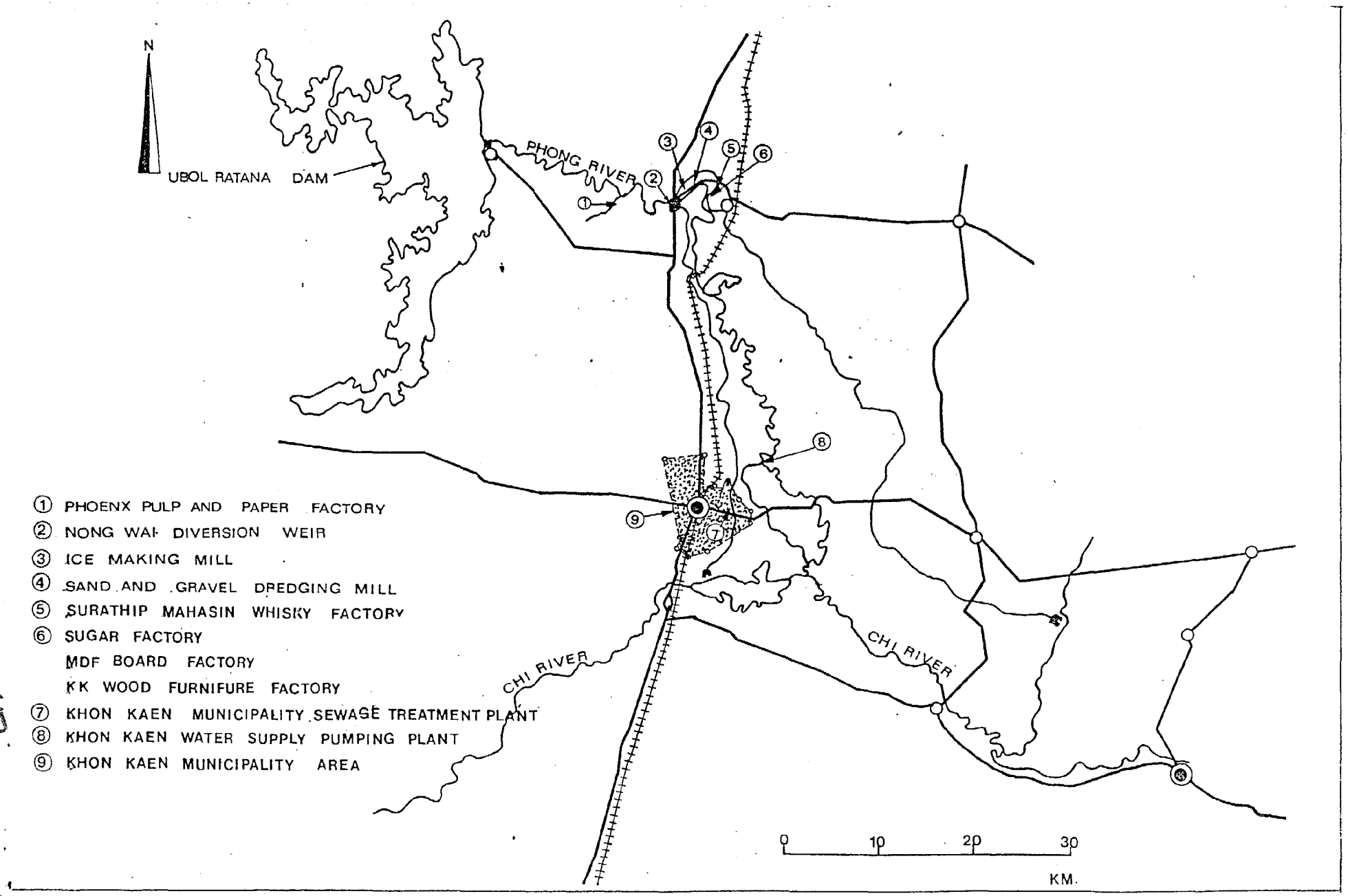


Fig. Major Water Users on Nam Phong River

Table 3.1 Khon Kaen Industries with Over 100 total Workers

Type of Industry	# of Businesses (1991)	# of Workers (1991)
Pulp mills	1	828
Sugar mills	1	410
Whiskey Distillery	1	220
Tapioca	4	144
Rice mills - large	55	534
Rice mills - small	3,528	3,546
Kenaf & Tobacco	16	2,657
Fish net manufacture	5	2,579
Cassava pellet/slice mills	236	1,894
Food canning	1	150
Ice production	15	120
Non-alcoholic Beverages (water and soft drinks)	4	202
Sack making	1	400
Clothes production	6	625
Plywood	1	210
Window & door frames	16	197
Fiber	1	443
Printing	19	118
Plastic wares	8	221
Brick, tile, pipes	12	198
Concrete	52	741
Windmill repair	51	324
Agricultural machinery	19	628
Automotive parts	28	354
Engine repair	94	684
Mattress/Spinning	12	184
Noodles	23	188
Grass screens	1	513
Sawmills	9	490
Wooden furniture-small	25	260
Wooden furniture-large	1	500
Folk medicine	7	174
Steel windows/doors	30	123
Salt production	1	173

The most dramatic event involved a large, apparently accidental spill of molasses from the sugar mill during a fire at an adjacent facility in 1992. It caused a massive fish kill as it flowed down the Phong, into the Chi, and then the Mekong Rivers.

The pulp mill has been temporarily closed down on two occasions, blamed for fish kills in the river. The second shutdown occurred just as the ISPAN study began, and was to last for one month. The mill has an activated sludge and lagoon wastewater treatment system, which it is currently in the process of expanding (see Figure 3.3). It currently withdraws 30,000 cum/d of river water, returning 26,500 cum/d of treated wastewater. The pulp mill claims that there are other, downstream sources causing much of the problem, which is serious only when the river flow is at a dry season low point (as it was in May). The Department of Fisheries, however, as a result of its ad hoc monitoring program after the recent event, claims to have narrowed the problem to the area between the pulp mill's outfall and the Nong Wai barrage, and there are no other significant sources in this stretch of the river. A study by Khon Kaen University also suggested that the pulp mill was the source of the recent fish kill, and blamed the Dept. of Industrial Works for weak regulations.

A second pulp plant (same company) is under construction adjacent to the first, and will withdraw an additional 20,000 cum/d. The treated effluent from this second plant, however, is not to be allowed back into the river, and is to be used for irrigation -- provided that this plan can overcome resistance from farmers, who are fearful of applying wastewater, even if treated, to their farmland and crops. To assuage these fears, care must be taken to educate farmers about the acceptable uses of wastewater on non-food crops. If the fears are not overcome, it is unclear what the pulp company will do with this additional 20,000 cum/d of wastewater.

One of the institutional problems is that water quality monitoring on the river is conducted too infrequently and sporadically. The Dept. of Health's Environmental Health Center only samples the river at four stations, and them only three times per year. As mentioned above, Fisheries and the University tend to conduct sampling on an ad hoc basis.

Resulting discussions in turn pointed out another legal/institutional weakness of water quality management in Thailand: different agencies can have very different water quality standards for the same body of water. They each have jurisdiction over different water users, with no one agency having ultimate authority. Hence, the Dept. of Industrial Works, the Dept. of Fisheries, and the Dept. of Irrigation all have different standards for Nam Phong water quality, while only DIW has

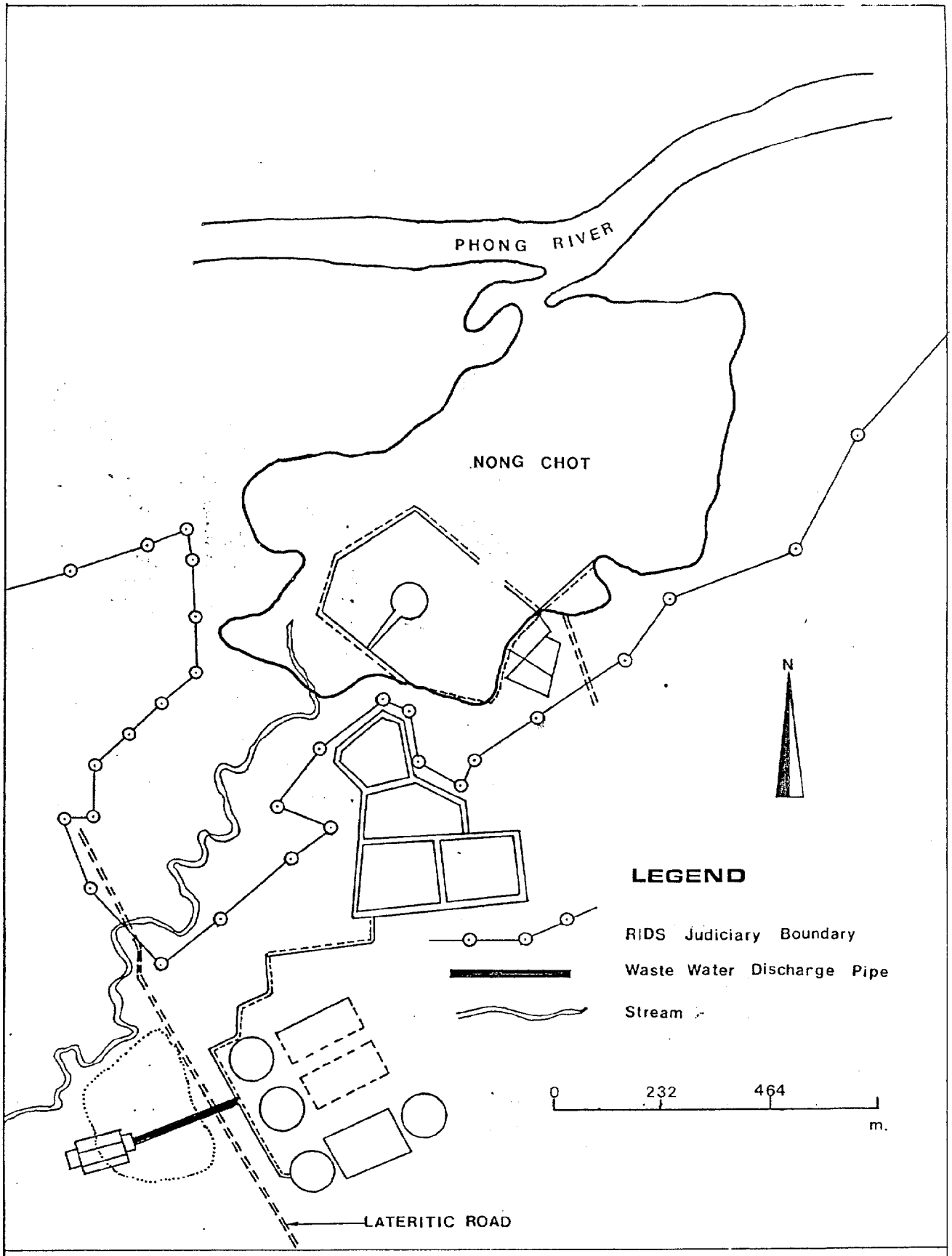


Fig. 3.3 Water Treatment Facilities Of PPP

jurisdiction over the industrial plants (see Table 3.2). As a result, DIW can allow an industrial plant to discharge water that meets its standards, but not the needs (standards) of the downstream users such as Irrigation and Fisheries.

NGOs and Industrial Pollution

A number of northeast Thailand's public interest NGOs have begun to develop farmer support activities to promote natural resource conservation and draw attention to environmental pollution. As a result of the incidents at the sugar and pulp mills on the Nam Phong, the NGO Coordinating Committee for Rural Development in Northeast (NGO COORD) is leading an initiative to have the RTG declare the Nam Phong River basin a "Pollution Control Zone." NGO COORD, based in Khon Kaen, coordinates the activities of more than 60 diverse NGOs throughout the region. It feels this Pollution Control Zone designation would give local organizations of farmers and urban dwellers a stronger hand in directing government and private sector initiatives that effect the region's natural resources. Normally, only cities and official industrial estates receive the Pollution Control Zone designation. The NGOs and farmers believe that it is necessary for the Nam Phong, and that it will allow them to take a role in regular water quality monitoring on the river, fine the companies for violations, etc.

The NGO COORD has served as a catalyst for promoting farmer and general public awareness of industrial pollution of the region's rivers through its organization of public meetings, seminars and press conferences. NGO COORD opposes the government's efforts to restructure the Thai economy through industrialization. Instead, it seeks to promote the development of alternative methods and technology that support the agricultural sector and empower farmers with more control over their economic and natural resources.

Pollution Control Zone

The National Environmental Board (NEB) has the power to declare any area in which pollution problems pose a threat to public health or create adverse environmental impacts as a *pollution control zone*. The NEB action required the governor of the affected province to develop and implement an action plan, in coordination with the relevant local agencies, to reduce or eliminate the pollution problem within 120 days. The governor can draw on funding from the Department of Pollution Control and the Environmental Fund to finance remedial actions. The recognition of the Nam Pong Basin as a pollution control zone would require the RID Regional Office, the provincial Department of Industrial Works. the Department of Health's Environmental Health Center, the Office of Fisheries, and the Agriculture Department, among others, to develop a common plan of action for the governor's approval.

SECTION FOUR

RELATED ENVIRONMENTAL CONCERNS

Health

The Province and the Municipality of Khon Kaen have made major progress in past decade on the provision of high quality drinking water (both rural and urban) and in the handling of domestic waste (mainly urban). Gastrointestinal diseases have declined as a result of these programs. There is no malaria in the province. Liver flukes from eating raw fish can be a problem. As a whole, public health concerns have declined. One newly emerging issue is related to industrial pollution on the Nam Phong: some farmers have experienced skin infections from bathing in the river at periods of low flow.

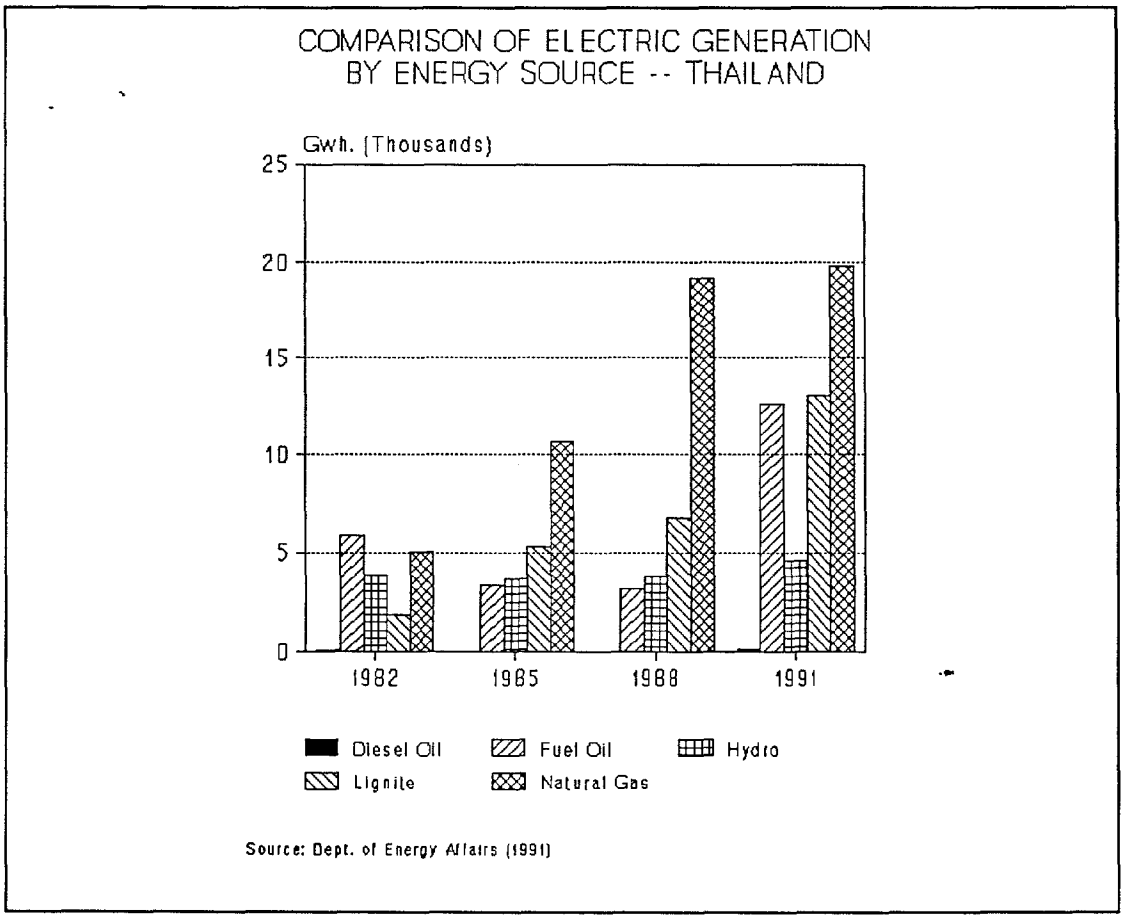
Deforestation

Deforestation ranks as a principal constraint to efficient water use conservation and management. Forest cover in Khon Kaen Province has declined by nearly 60% over the last 20 years as farmers have harvested timber and bamboo for expanding industrial and housing development markets, and cleared land for upland cash crop production (cassava and sugar cane). The widespread and indiscriminate clearing of forest land in a watershed upsets the natural modulation of water flows that forest cover provides, resulting in greater extremes at both the drought and the flood ends of the spectrum. At the same time, deforestation, results in upland soil erosion that exacerbates siltation of irrigation infrastructure, such as water conveyances and control structures, and to the more rapid sedimentation of reservoirs. Small- and medium-sized reservoirs are particularly vulnerable to sedimentation, which reduces storage capacity and the ability of farmers and the Royal Irrigation Department to regulate water supplies for irrigation. As mentioned above, the low river flow rates during the dry season results in lower water quality, and greater drinking water treatment costs. The reductions in both quality and the quantity of river flows harms fisheries and other aquatic life.

Thus, the overall picture is of an ecosystem with reduced ability to provide several basic services required to support and protect the human economy: security from droughts and floods, water for domestic and industrial use, wastewater assimilation and processing, food production.

Energy

Unlike many developing countries, energy demand appears to have a limited impact on water resource conservation and management in Thailand. Hydropower accounts for only 12% of the country's electricity generation and further demand for hydropower can be met far more cheaply from existing and proposed regional sources than through additional investment in domestic hydroelectric development. Thailand's recent negotiations with the government of Laos to cooperate in the development of the Mekong for hydroelectric power. Thailand currently purchases half of Laos' generating capacity of 215 MW.



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SECTION FIVE

SUMMARY AND CONCLUSIONS

An ISPAN study team examined the environmental implications of government and donor-funded water resource development and management initiatives in the Khon Kaen province of northeast Thailand. The objective of the study was to examine the evolution of competing demands for water resources between urban and rural sectors -- particularly with reference to food security, energy, potable water supply and public health. The purpose of the study was to identify lessons learned from Thailand that are applicable to other countries in the Asia and Near East regions as these countries attempt to develop or improve environmentally sustainable strategies for water resource conservation and management.

Water resources in Thailand are under increasing pressure, due to the rapidly rising demand for water in urban areas (for domestic, industrial and commercial uses) competing with demand in rural areas for rainfed and irrigation agriculture. Deforestation of watersheds has caused the supply of water to become more irregular, leading to greater incidence of water shortages in rural areas. Runoff of agrochemicals may be contributing to the decline of surface water quality in some areas, but the main pollution sources are discharges of untreated sewage and industrial wastes in the Bangkok Metropolitan Region. Extraction of groundwater, also mainly in the Bangkok area, has led to depletion of aquifers, with consequent problems of subsidence and/or saltwater intrusion.

The city of Khon Kaen represents the trend of urban development throughout Thailand: rapid growth as a result of extensive commercial and industrial development over the past two decades, and the concomitant problems of waste disposal and burgeoning demand for energy and water supply. At the same time, returns on agriculture are becoming increasingly marginal. Despite more than three decades of public sector investment in irrigation infrastructure, agriculture in the province remains almost entirely dependent on erratic seasonal rains and fluctuating river flows. Only 7% of Khon Kaen's arable land is permanently irrigated and the water use efficiency on that land is poor. The steady growth in wages for off-farm employment discourages farmer investment in dry season cultivation of food crops, even in irrigated areas.

The size of Khon Kaen Municipality (46 sq. km, population 135,000) enabled the team to utilize methods of rapid appraisal research that would not have been effective in Thailand's larger cities, such as Bangkok, Chiang Mai, given the limited time available for data gathering and field visits. In addition, the selection of Khon Kaen as a case study enabled the team to survey a variety of donor-

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funded water sector activities in Khon Kaen Municipality and its hinterland. The team's visit also coincided with a growing public outcry over industrial pollution of the Nam Phong River, the province's principle source of irrigation and drinking water. A regular stream of newspaper articles on water pollution in the region and ongoin local NGO activism urging the RTG to designate the Nam Phong basin as a pollution control zone rendered Khon Kaen a "hot spot" from the perspective of water resource conservation and management.

The report is organized along three major themes: Water Quantity Issues; Water Quality Issues; and Environmental Concerns Related to Water Resource Management. Within the context of each theme, the report considers: the status of water resources and their management; donor and government efforts to protect and conserve water resources; and alternative approaches that would improve the environmental sustainability of water resource management.

Water Quantity Issues

Because of the region's erratic rainfall patterns, seasonal drought remains a primary concern for water resource management agencies throughout the Northeast. Demand for water is inelastic and urban per capita water demand outpaces rural demand by as much as a factor of five. Expanding municipal and industrial demand on drought-restricted water supply exacerbates the strain on water stocks not only by competing with agriculture but with the rural populations who, in times of water scarcity, must rely on existing stocks for drinking water.

The population of Khon Kaen Province has grown from 1.08 million in 1971 to 1.7 million in 1990. During that time, the per capita water supply for the province has dropped from 3,400 cubic meters per year to 2,200 cubic meters per year, a decline of 35%. Projections for 2010 indicate that per capita water supply will drop to 1,690 cubic meters per year -- an additional 23% decline from 1990 as a result of population growth alone. In 1990, agriculture accounted for at least 90% of Khon Kaen's water requirement.

As the urban population and standards of living in Khon Kaen Province have increased, urban water consumption has also increased. Domestic and commercial/ industrial water requirements in Khon Kaen Province will double between 1990 and 2000 to 109 MCM/y. Industrial growth will account for nearly 60% of that increase. Rural water supply is expected to increase by *fourteen times* during the same period. Forcasts for a steadily expanding demand for water in the agriculture sector do not appear to be supported by the data gathered for this study. Yet, while no crisis is looming for overall water supply in the Province, it is clear that any expansion in the area of irrigated agriculture combined with the

pace of municipal and industrial demand will place strains on the total available water supply, especially the buffer stock that is vital for the natural regulation of riparian ecosystems.

Water Quality Issues

The Province and the Municipality of Khon Kaen have made major progress in past decade on the provision of high quality drinking water (both rural and urban) and in the handling of domestic waste (mainly urban). As a result, public health concerns have declined.

The most pressing water resource conflict between the rural, urban, and industrial sectors derives from industrial wastes, both treated and untreated, that contaminate the Nam Phong River. The Nam Phong is a major source for both urban and rural domestic water supply, irrigation, and fisheries. Severity of contamination increases during the dry season, when the Nam Phong's flow is low, making water quantity insufficient to assimilate wastewater effectively. This problem points to an important relationship between water quality and quantity.

The number of major industries discharging wastewater into the Nam Phong is limited, and most have installed at least some degree of wastewater treatment. Nevertheless, industrial use and discharges are growing, and the level of treatment is not always sufficient to prevent costs from accruing to the other sectors: the drinking water plants have to increase the intensity of their treatments, kills of fish and other aquatic life are becoming increasingly common, and farmers fear their crops are suffering from degraded water quality.

Related Environmental Concerns

Unlike many developing countries, energy demand appears to have a limited impact on water resource conservation and management in Thailand. Hydropower accounts for only 12% of the country's electricity generation and further demand for hydropower can be met far more cheaply from existing regional sources such as natural gas than through additional investment in domestic hydro development.

Deforestation ranks as a principal constraint to water use conservation and efficient management. Forest cover in Khon Kaen Province has declined by nearly 60% over the last 20 years as farmers have harvested timber and bamboo for expanding housing and industrial markets, and cleared land for upland cash crop production (cassava and sugar cane). The widespread and indiscriminate clearing of forest land in a watershed upsets the natural modulation of water flows that forest cover provides, resulting in greater extremes at both the drought and the

flood ends of the spectrum. At the same time, deforestation, results in upland soil erosion that exacerbates siltation of irrigation infrastructure, such as water conveyances and control structures, and to the more rapid sedimentation of reservoirs. Small- and medium-sized reservoirs are particularly vulnerable to sedimentation, which reduces storage capacity and the ability of farmers and the Royal Irrigation Department to regulate water supplies for irrigation. As mentioned above, the problem of exacerbated low flows during the dry season results in lower water quality, and greater drinking water treatment costs. The reductions in both quality and the quantity of river flows harms fisheries and other aquatic life.

Thus, the overall picture is of an ecosystem with reduced ability to provide several basic services required to support and protect the human economy: security from droughts and floods, water for domestic and industrial use, wastewater assimilation and processing, food production.

Responses for Conservation and Protection of Water Resources

The government and donor supported water resource management initiatives in Thailand's Northeast can be summarized in the following pattern:

- **Flood Control and Water Conservation** -- Construction of large- and medium-scale reservoirs throughout the region to regulate fluctuating water supplies;

- **Irrigation Infrastructure** -- The extensive construction of large- and medium-scale irrigation works, and pumping schemes to provide more intensive agricultural production, improve food production and farm incomes; the promotion of farmer-constructed small-scale weir and reservoir schemes to expand the area of irrigated agriculture and water conservation.

- **Water Use Efficiency** -- Support for the rehabilitation of poorly maintained irrigation works through promotion of farmer participation and investment in system O&M. Promotion of cash crop production through provision of agricultural inputs and access to credit to foster increased dry-season use of irrigation water.

- **Drinking Water Systems** -- Programs to improve access of rural populations to potable water through development of shallow well technology and rain water harvesting

- **Water treatment systems** -- for domestic water use and both municipal and industrial wastewater. Khon Kaen Municipality's new

sewage treatment system is a model for other small and medium-sized cities.

As the government's efforts to develop and manage water resources more effectively expanded, the number of line agencies responsible for implementing the government's programs mushroomed. There are at least 16 agencies in Khon Kaen Province alone that are responsible for water development projects. As a result, there has been a proliferation of under-coordinated programs, many of which have achieved their narrowly defined objectives, but in some cases have caused conflicts at a more macro level.

More Sustainable Approaches

The ISPAN study team concluded that water resource management strategies could be made more sustainable through the implementation of the following policy and procedural recommendations:

- **Separation of Resource Streams** -- A fundamental strategy for conservation of resources is the separation of resource streams from their inception. Once fresh and salt water streams are mixed, the cost of reclaiming the freshwater is enormous. Once heavy metals and other toxic substances (e.g., dioxins) are added to domestic sewage, removal of these contaminants to enable the reuse of wastewater for irrigation becomes prohibitively expensive. The extent of any ecological damage from the toxic waste may also be greatly expanded.

  Khon Kaen has already taken an important step in the separation of its resource streams by requiring most new industries to install their own wastewater treatment systems. In a few cases where plants are connected to the municipal sewerage system or discharge into the Nam Phong River, pollutant source reduction (through process innovation and wastewater recycling, stimulated by pollution fees and a goal of zero discharge) will probably be the most effective way to achieve resource stream separation. Separation of stormwater drainage from municipal sewage is less critical with the land extensive oxidation pond treatment system used by the city.

- **Zoning** -- Regional and district-level zoning is another mechanism for ensuring the separation of waste streams discussed above, and for increasing its cost-effectiveness, as it allows for the creation of industrial estate type of waste collection and treatment systems. Zoning should separate and direct industrial development away from prime agricultural/irrigation lands, as well as residential areas.

- **Sustainable Pricing of Water** -- In most developing countries, water is seriously underpriced, often free. Thais, however, already pay a significant tariff on domestic treated water. There are two areas where instituting water pricing could make a marginal improvements in efficiency of water use, albeit probably much less dramatic in the case of Northeast Thailand than elsewhere.

Adding a sewage fee to municipal water bills, based on water consumption (which is proportional to wastewater discharge) would reduce demand both for domestic water consumption and for expansion of sewage treatment capacity. Dedication of the collected fees to operations and maintenance of the sewer system would improve service and help finance expanding the service area (without requiring so large an expansion in the treatment system).

Charging farmers for irrigation water is likely to stimulate more efficient water use and their interest in proper operations and maintenance of the whole irrigation system, extending all the way back to the management of the basic water resource, rather than simply the ditches on their farms. The scale of overall water savings would not be so dramatic as in other regions, however, because only 10% of the Northeast is currently irrigated, with a potential of perhaps 20%.

- **Protecting Biodiversity** -- Biodiversity in Khon Kaen Province has already been greatly reduced through centuries of extensive land use and harvesting of every available food resource. There is little wildlife remaining in the region. Growth in the use of modern farming methods such as biocide inputs threatens to exacerbate this problem, wiping out beneficial, often nearly invisible non-target organisms in return for what increasingly seems to only be short-term gains against the targeted pests. *Vigorous research and promotion of integrated pest management techniques* is called for, for rice paddies in particular.

In addition, industrial pollution is beginning to pose a serious threat to aquatic life in the major river of the Province. There is an immediate, need for two short-term or interim measures, followed by implementation of a long-term strategy. The interim measures are *(1) accident prevention and containment* (e.g., oil spill type technology, such as inflatable booms), and *(2) expansion of the definition of uses of the Ubol Ratana Reservoir to include river quality maintenance*, i.e., requiring greater releases in the dry season to dilute industrial pollution.

The long-term strategy is to implement the concept of zero discharge. Once derided as utopian, the concept is now being discussed

very seriously in industrial countries, and even implemented in ways that increase competitiveness. As Thailand pursues its rapid industrialization, it should consider leap-frogging the "pollution haven" strategy/stage to state-of-the-art, super-resource-efficient (economical) industrial production processes that will place it in a more strategic position for accessing future world markets.

- **Institutional Issues**

(1) Integrated Water Quantity and Quality Information Systems --

As the ISPAN team conducted its rapid surveys for data on water quantity and quality, it was continuously struck by the fact that there is a plethora of agencies responsible for managing small portions of the resource, and very little systematic collection of the data needed to support such management, let alone sharing of the data between agencies. In some cases, as many as four different agencies applied four different sets of water quality standards for the same body of water, yet they rarely sampled the water, let alone compared the results or attempted to resolve conflicts between different users' water quality needs. Much more regular data collection on both water quantity and quality is needed, and a common databank is probably required so that the multitude of users can contribute and share equally in the benefits.

(2) A Watershed Dispute-Resolution Commission --

This study has shown that the frequency, diversity of types, and severity of disputes over water resources (both quantity- and quality-related), is if not already, then on the verge of increasing in Khon Kaen Province as well as the rest of Thailand. There are a multitude of agencies involved in the development of resources, but few in their protection. None has ultimate authority, so the "solution" is often just to act first. There is little provision for public participation in most decisions.

The ISPAN team considered the idea of creating new institution that would have overall responsibility for water management and development at the watershed level. It concluded, however, that this would probably end up as just another one of many stakeholders, without enough power to accomplish the goal, or as a new, huge level of bureaucracy added to all the existing ones. A more streamlined approach might be to create small watershed dispute resolution commissions, modeled after the International Joint Commission of the United States and Canada, except that non-governmental (citizen) organizations should be given a greater role in the process of determining what disputes need to be addressed.

Such Commissions need not become large, bureaucratic organizations. A panel of Commissioners could be appointed, with a small

professional staff, and specific Advisory Boards created for each issue determined to be significant enough to require the services of the Commission. These Advisory Boards would be composed of technical experts and representatives of each major stakeholder group involved in their particular issue. They would investigate the problem at hand and make recommendations to the Commission, which in turn would use this information to arbitrate a resolution. The goal would be to seek lasting, win-win consensus-based resolutions, rather than compromise, majority vote decisions.

Responsible, sustainable resource management policy is closely tied to education and full opportunities for public participation in the political and decision-making processes of society. Information is a prerequisite to both public education and to effective management institutions. In addition to information, people need a mechanism to participate in the decision-making processes that affect their development options and sustainability of their livelihoods. The development of an Integrated Water Resources Information System and the proposed Watershed Dispute Resolution Commissions would promote the participation of a population that is educated to the limits of natural resource exploitation, and that can press both public and private sectors for responsible management of those resources.

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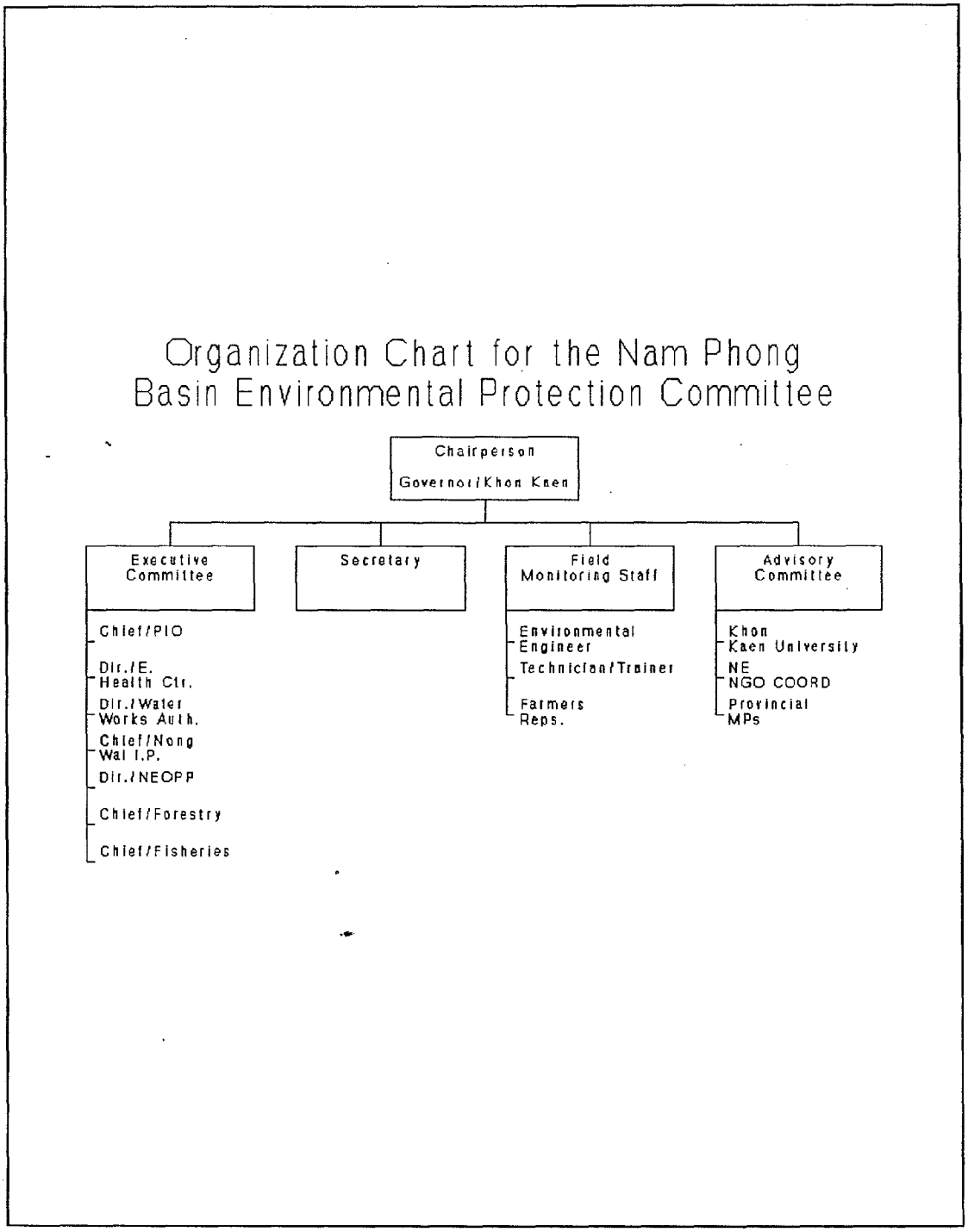
Organization Chart for the Nam Phong Basin Environmental Protection Committee
Chairperson
Governor/Khon Kaen
Executive Committee
Secretary
Field Monitoring Staff
Advisory Committee
Chief/PIO
Dir./E. Health Ctr.
Dir./Water Works Auth.
Chief/Nong Wai I.P.
Dir./NEOPP
Chief/Forestry
Chief/Fisheries
Environmental Engineer
Technician/Trainer
Farmers Reps.
Khon Kaen University
NE NGO COORD
Provincial MPs

Figure 5.1

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ANNEX A

ACRONYMS & TERMS USED IN THIS REPORT

Bcm	Billion cubic meters (or BCM)
cum	cubic meters
cum/d	cubic meters per day
Mcm/y	Million cubic meters per year
BMA	Bangkok Metropolitan Administration
BMR	Bangkok Metropolitan Region
CIDA	Canadian International Development Agency
DIW	Dept. of Industrial Works
JICA	Japan International Cooperation Agency
ltr/d	Liters per day
MOSTE	Ministry of Science, Technology, & Energy
NATWEC	National Rural Water Supply Program Executive Committee
ONEB	Office of the National Environment Board
PWA	Provincial Waterworks Authority (Ministry of Interior)
PCDA	Population and Community Development Association
RID	Royal Irrigation Department
RTG	Royal Thai Government
UNCED	United Nations Conference on Environment & Development
UNDP	United Nations Development Programme
WB	World Bank
WHO	World Health Organization

ANNEX B

Individuals Consulted

Individual	Designation & Agency
May 28/Bangkok	
Mr. Chamroon Chindasanguan	Deputy Dir. General/Engineering Royal Irrigation Department
June 1/Khon Kaen	
Mr. S.K. Mittal	Director & General Manager/Technical Phoenix Pulp and Paper Co. Ltd.
June 2/Bangkok	
Mr. Kamol Chantanumate	Project Officer, USAID
Mr. Mintara Silawatshananai	Chief Engineer, USAID
Mr. Vanchai Jaisin	Engineer, USAID
June 3/Bangkok	
Dr. Dhira Phantumvanit	President, Thailand Environmental Institute
Dr. Rita Klees	Environmental Engineer, USAID
Dr. John Austin	Environmental Engineer, MOSTE/RTG
Ms. Julie Otterbein	Deputy Dir, RHUDO, USAID
June 5/Khon Kaen	
Mr. Prasit Makwong	Chairman, Northeast NGO Coordinating Committee
June 6/Khon Kaen	
Mr. Prawit Thaima	Production Chief, Ban Kotha Water Treatment Plant
Mr. Keb Bualuang	Provincial Wateworks Authority
Mr. Kamol Senapraiwan	Senior Sanitarian, Environmental Health Center
Mr. Sala Phromdetbun	Environmental Health Center

June 8/Khon Kaen

Mr. Chuck Sarikaphuti	Regional Director, RID
Mr. Prateep Saiprasit	Chief, Engineering Section, RID
Mr. Preeda Naktaramin	Chief, Khon Kaen Irrigation Project/RID
Mr. Veera Wongsangnak	Field Manager, NEMASIP
Mr. Arnoud Haag	Design Engineer, NEWMASIP
Mr. Brian Duncan	Agricultural Economist, NEWMASIP
Mr. Kumthorn Dilokkomol	Director, Provincial Dept. of Industrial Works, NationalMinistry of Industry
Dr. Chumnarn Pongsi	Inland Fishery Development Center
Mr. Aree Derat	Fisheries Dept.
Mr. Supon Chongudomtarn	Dept. of Local Administration (Municipal Sewerage System)
Mr. Paibol Boonyakanjana	Dept. of Environmental Engineering

June 9/Nam Pong & Huai Aeng

Mr. Suphol Ueranant	Director, EGAT/Region 2
Mr. Charoen Krut Kasat Thai	Chief/Maintenance, EGAT/Region 2
Mr. Narong Nongsiri	Chief/O&M, Huai Aeng Irrigation Project/RID
Mr. Chanta Wilitchai	Chairman, Huai Aeng Irrigation Project Water User Association

June 10/Khon Kaen

Mr. Samran Tammultri	Chief, Non Wai Irrigation Project/RID

June 16/Bangkok

Dr. Manida Unkulvasapaul	Environmental Specialist/World Bank

ANNEX C

Table C1. Comparative Estimates and Projections of Water Use in Thailand by Sector.

Table C2, Hazardous Waste: Environmental Risk Factors and Cost Effectiveness of Treatment, 1991 .
(from Engineering Science Inc et al, 1989.)

ANNEX D

THEMATIC MAPS / KHON KAEN PROVINCE

SOURCE: MEKONG SECRETARIATE (1991 b)

Table A3.10 Hazardous Waste: Environmental Risk Factors and Cost Effective of Treatment, 1991
(Ref. A30, A31)

Hazardous Waste Type	Tons a/	Relative Risk Factor	Exposed Population Million b/	Environmental Risk Factor c/	Cost of Treatment: Baht per (x)	Cost of Treatment: 1,000 Baht	Risk Reduction: Per Mill of Baht	Risk Reduction: Rank
Oils	219,467	1	57	13,000	637	139,822	100	9
Liquid organic residues NII	21	1	17	0	577	12	0	12
Liquid organic residues II	290	1,000	17	5,000	8,343	2,419	2,100	6
Organic sludges NII	1,563	1	16	0	577	902	0	11
Organic solids NII	1,759	1	16	0	8,343	14,675	0	11
Organic sludges and solids II	3,352	1,000	16	54,000	8,343	27,966	2,000	7
Inorganic sludges and solids	19,254	1	42	1,000	146	2,811	500	8
Heavy metal sludges & solids	136,810	10,000	13	17,785,000	158	21,616	823,000	1
Solvents II	6,806	100	41	28,000	1,976	13,449	2,100	6
Acid wastes	29,357	10	41	12,000	3,195	93,796	100	10
Solvents NII	125,428	100	32	401,000	257	32,235	12,500	4
Alkaline wastes	34,235	100	33	112,000	77	2,636	42,800	3
Off spec products	25	1	7	0	2,907	73	0	11
PCB	247	10,000	11	27,000	*	*	*	*
Aqueous organic residues	242	100	10	0	146	35	0	11
Photo wastes	16,345	100	52	85,000	54	883	96,300	2
Municipal wastes	11,757	1	75	1,000	2,410	28,334	10	10
Infectious wastes	76,075	100	57	434,000	577	43,895	9,900	5
Total	683,039				626	427,620		

Note: *Thailand stopped importing PCBs, in 1985, PCB waste from past imports is currently sent abroad for treatment.
II = halogenated
NII = nonhalogenated
a/ Estimated quantities in 1991
b/ 1991 population in provinces where specific waste type is being generated
c/ Waste quantity a relative risk factor X exposed population/1,000 rounded off to nearest 1,000

Source: Engineering Science Inc (1990)

BEST AVAILABLE DOCUMENT

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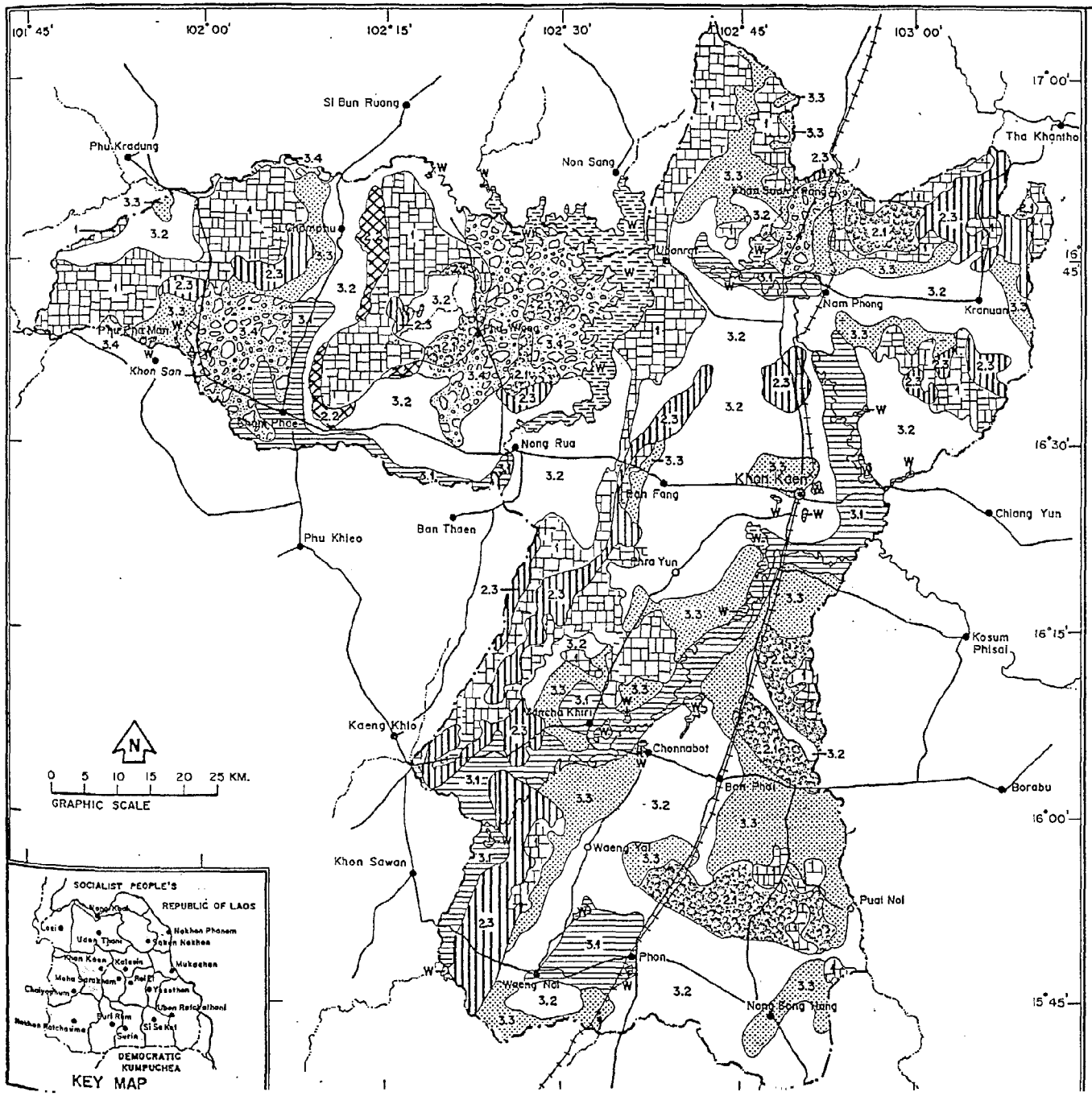
Table C.1
Comparative Estimates and Projections of Water Use in Thailand by Sector

Data Source>	WRI	Sethaputra et al	Sethaputra et al	Sethaputra et al
for Year>	**1987**	**1990**	**2000**	**2010**
Volume used:				
Domestic	1.3 Bcm	1.8 Bcm	5.6 Bcm	14.6 Bcm
Industrial	1.9 Bcm	1.0 Bcm	3.2 Bcm	8.3 Bcm
Agriculture	28.7 Bcm	40.3 Bcm	76.1 Bcm	144.1 Bcm
TOTAL USE:	**31.9** Bcm	**43.1** Bcm	**84.9** Bcm	**167.0** Bcm
% of Total Volume used:				
Domestic	4%	4.2%	6.6%	8.7%
Industrial	6%	2.3%	3.8%	5.0%
Agricultural	90%	93.5%	89.6%	86.3%
% of Total Resource Used:				
REFERENCE Total Resource	**110 BCM**	**199 BCM**	**199 BCM**	**199 BCM**
Domestic	1.2%	0.9%	2.8%	7.3%
Industrial	1.7%	0.5%	1.6%	4.2%
Agricultural	26.1%	20.3%	38.2%	72.4
TOTALUSE:	**29.0%**	**21.7%**	**42.7%**	**83.9%**



LEGEND :

1. PRESERVATION ZONE

Zone still being natural condition which is to be preserved for ecological balance

2. CONSERVATION ZONE

Reforestation zone in encroached forest reserve area

Zone of existing natural forest being prepared as leal forest reserve area

Zone of completely deteriorated forest area which is suitable for agriculture development

3. DEVELOPMENT ZONE

3.1 Paddy zone suitable for irrigation

3.2 Rainfed paddy zone

3.3 Upland crop cultivation zone

3.4 Livestock zone

SALINE SOIL

W RESERVOIR WITH HIGH POTENTIAL FOR FISHERIES DEVELOPMENT

SOURCE : LAND DEVELOPMENT DEPARTMENT

CHANGWAT — STREAM , RIVER

AMPHOE — RAILWAY

KING AMPHOE — HIGHWAY

CHANGWAT BOUNDARY — INTERNATIONAL BOUNDARY

FIGURE : SL5 – KK

LAND USE ZONING OF KHON KAEN

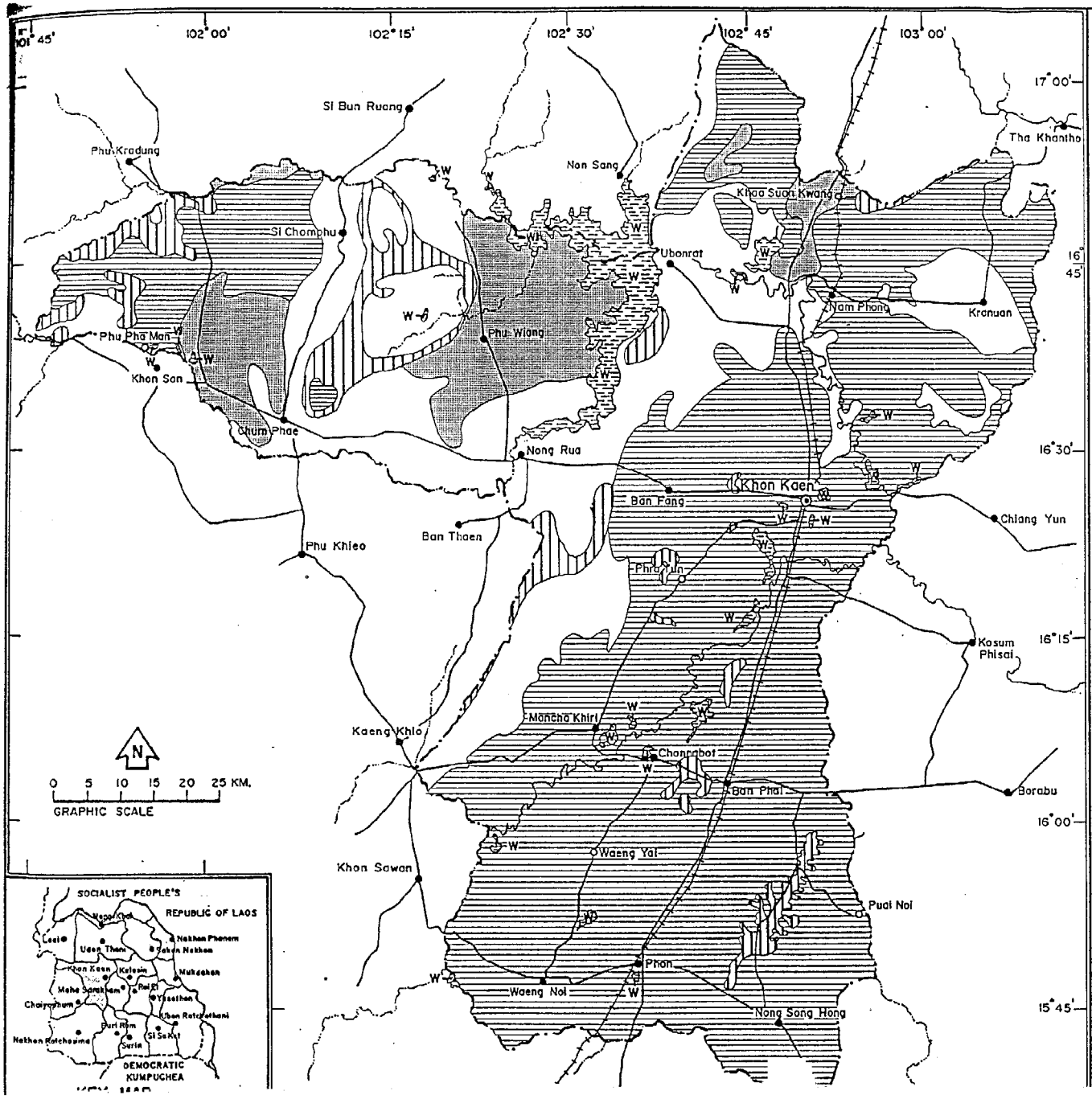


FIGURE : SL 4 - KK
LAND SUITABILITY FOR WATER STORAGE OF KHON KAEN

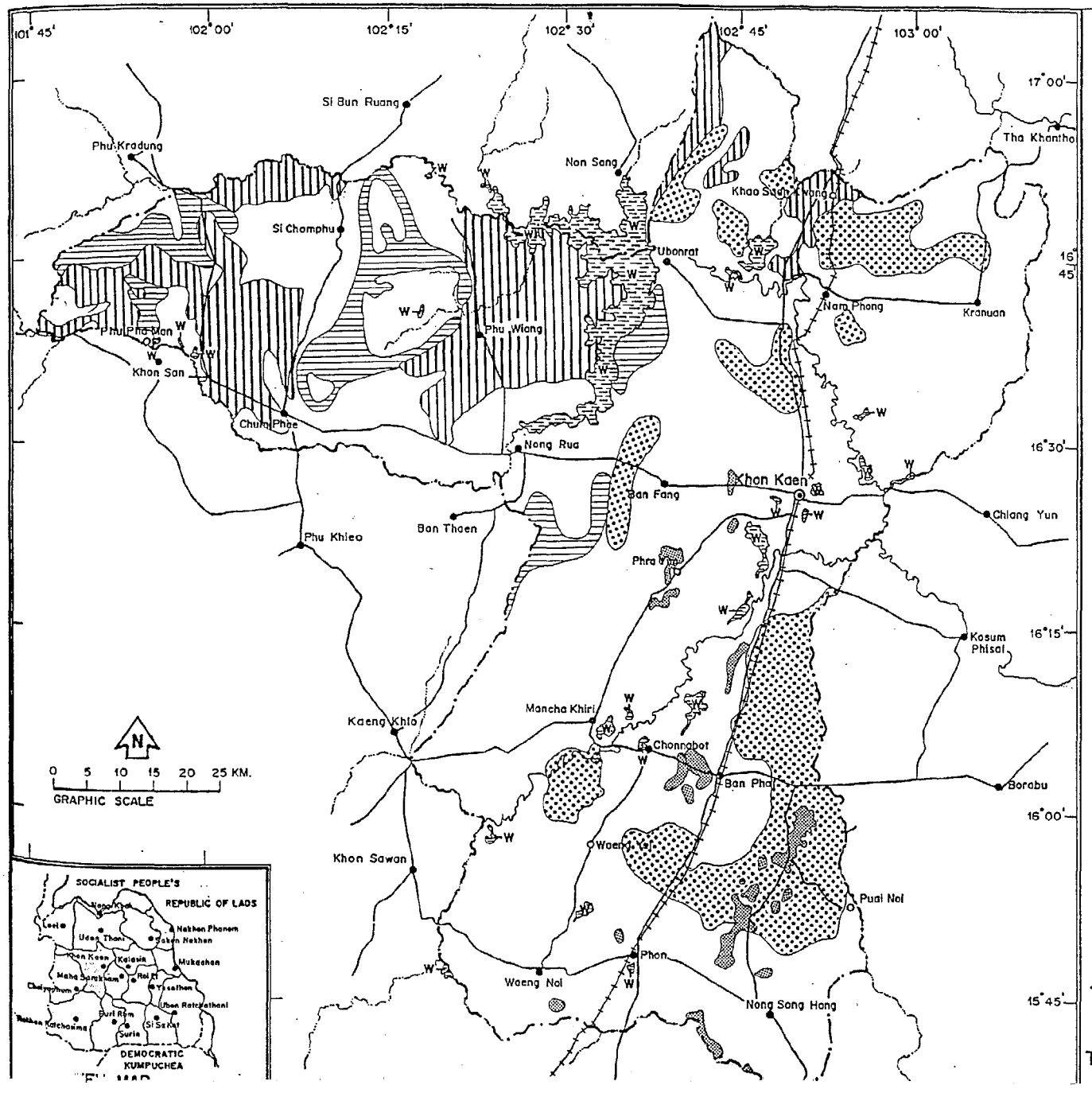


FIGURE : SL 2 - KK
TYPES OF PROBLEM SOILS IN KHON KAEN

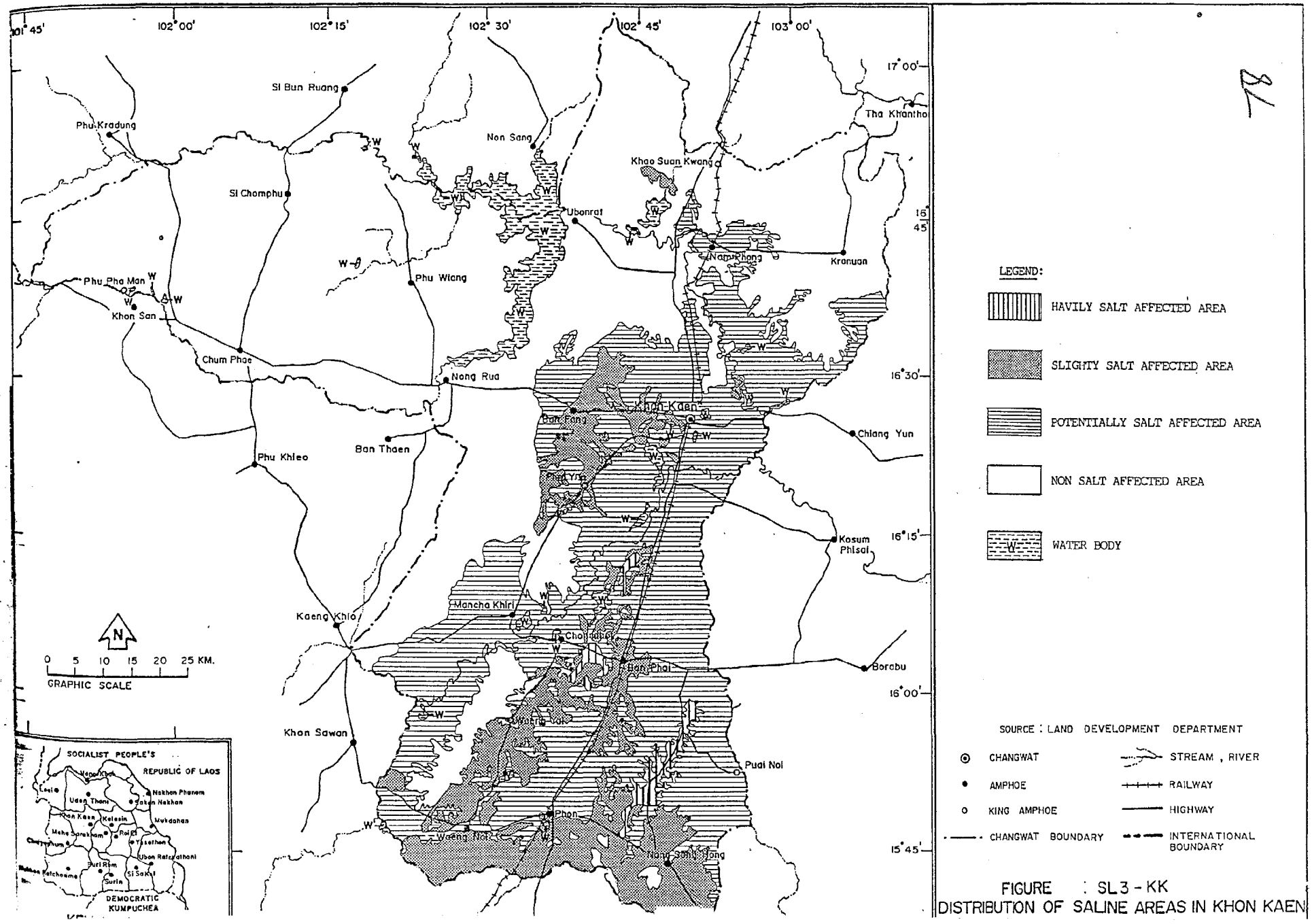


FIGURE : SL3 - KK
DISTRIBUTION OF SALINE AREAS IN KHON KAEN