A STUDY OF
WATER DIVERSION FROM THE MEKONG RIVER
TO IRRIGATE AN AREA IN NORTHEAST THAILAND

A Thesis

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SYNOPSIS

This study is divided into three parts, part one is composed of the Mekong Drainage Basin and its development particularly related to the area embracing Thailand (Chapter I and II). The second part is an interdisciplinary study of the water resources (Chapter III, IV, V, VI and VII) of the Northeast, and the last part (Chapter VIII and IX) is the diversion of water from the Mekong River to the Northeast mainly for irrigation.

ACKNOWLEDGEMENTS

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INTRODUCTION

Water Resources development for the Lower Mekong Basin is one of the well known projects in the world. This is due to the high flows carried by the Mekong River, to the political situation in the region, to the modest standard of living of the people in the basin, and the unique form of an international cooperation and assistance involved.

Irrigation is an important part of this development. It not only results in direct benefits to the farmers, but also plays an important role in the stabilization of the economy of the region. The better factor is particularly important in this part of the world.

Thailand is one of four countries which have parts of their territories situated in the Lower Mekong Basin in which agriculture is the backbone of the economy. In Thailand, irrigation is an important component of the agricultural sector of the national economic development plan. Development problems are particulary acute in Northeast Thailand. In this region, irregular topography, poor soil and a shortage of water are factors which have hindered irrigation development. This has resulted in a lower standard of living in this region than in other parts of the country. Development of water resources in Northeast Thailand represents one of several procedures required to raise the standard of living to the same level as other parts of the country.

Water diversion from the Mekong River to irrigate an area in Northeast Thailand will become attractive in the future, firstly because the increasing world population will cause an increase in food prices, and secondly because of inexpensive hydro power from the Lower Mekong Development. Time is an important factor in the development of international rivers like the Mekong. The projection of water requirements in the Northeast should be studied in conjunction with overall planning for the Lower Mekong Basin.

In general, water requirements for domestic and industrial uses are small in comparision with irrigation requirements. In this study the relation between the economy of the nation and agricultural development in the Northeast will be reviewed. Water availability (limited by capacity of storage sites) and optimum water requirements for agriculture (based on assumed improved land use and higher cropping intensities) in the Northeast will be estimated and compared. A more detailed analysis of the engineering aspects will be made of the irrigation project planned for Udon-Nongkai area. Finally, specific water diversion schemes for the Northeast will be recommended.

FIG. I MEKONG BASIN

CHAPTER I

THE MEKONG DRAINAGE BASIN

The Mekong is an international river in Asia and is one of the world's great rivers. Its headwater is in the Himalayas of Tibet and its mouth is on the South China Sea. It flows through, or forms the border between, six countries, namely, China, Burma, Thailand, Laos, Cambodia and Viet Nam. The total drainage area of the basin amounts to 795,000 square kilometres and the total length is 4,350 kilometres. In its upper basin the Mekong rises at an elevation of about 5,000 metres in the snow-covered mountain of the Tibet Plateau, where the Yangtse and Salween also take off. Then it becomes a wild and rushing river that flows through deep gorges and cascades down steep inclines. When it reaches the Tropic of Cancer, it becomes the chief border between Burma and Laos and is part of the frontier between Laos and Thailand. It then flows through central Cambodia and finally empties into the South China Sea in Viet Nam. The most important part of the Mekong River basin is the part below the Burma-Laos-Thailand frontier. Generally referred to as the Lower Mekong, it covers an area of 609,000 square kilometres of about 77% of the total area of the basin.

Water resources planning has been concentrated on the Lower Mekong. The basic elements of planning are:

1. Basic Data. Before planning begins the data below must be collected.

(a) Stream flow. A basic network of 44 stream gauging stations has been established in the four riparian countries. The total runoff at Vientiane, the upper most site, over a period of 39 years varied from 84,500 million cubic metres (68.5 million acrefeet) in 1957 to 190,000 million cubic metres (153.7 million acrefeet) in 1938 with an average of 148,200 million cubic metres (120 million acrefeet). At Kratie, the extreme downstream site, the total runoff over a period of 23 years varied from 359,000 million cubic metres (290.8 million acrefeet) in 1933 to 567,000 million cubic metres (459.1 million acrefeet) in 1939 with an average of 470,000 million cubic metres (380 million acrefeet). The additional runoff between Vientiane and Kratie on the average is 321,000 million cubic metres (260 million acrefeet) which corresponds to the additional drainage area of 347,000 square kilometres. An isohyetal map of annual precipitation at 343 stations over the basin has been produced every year from 1964.

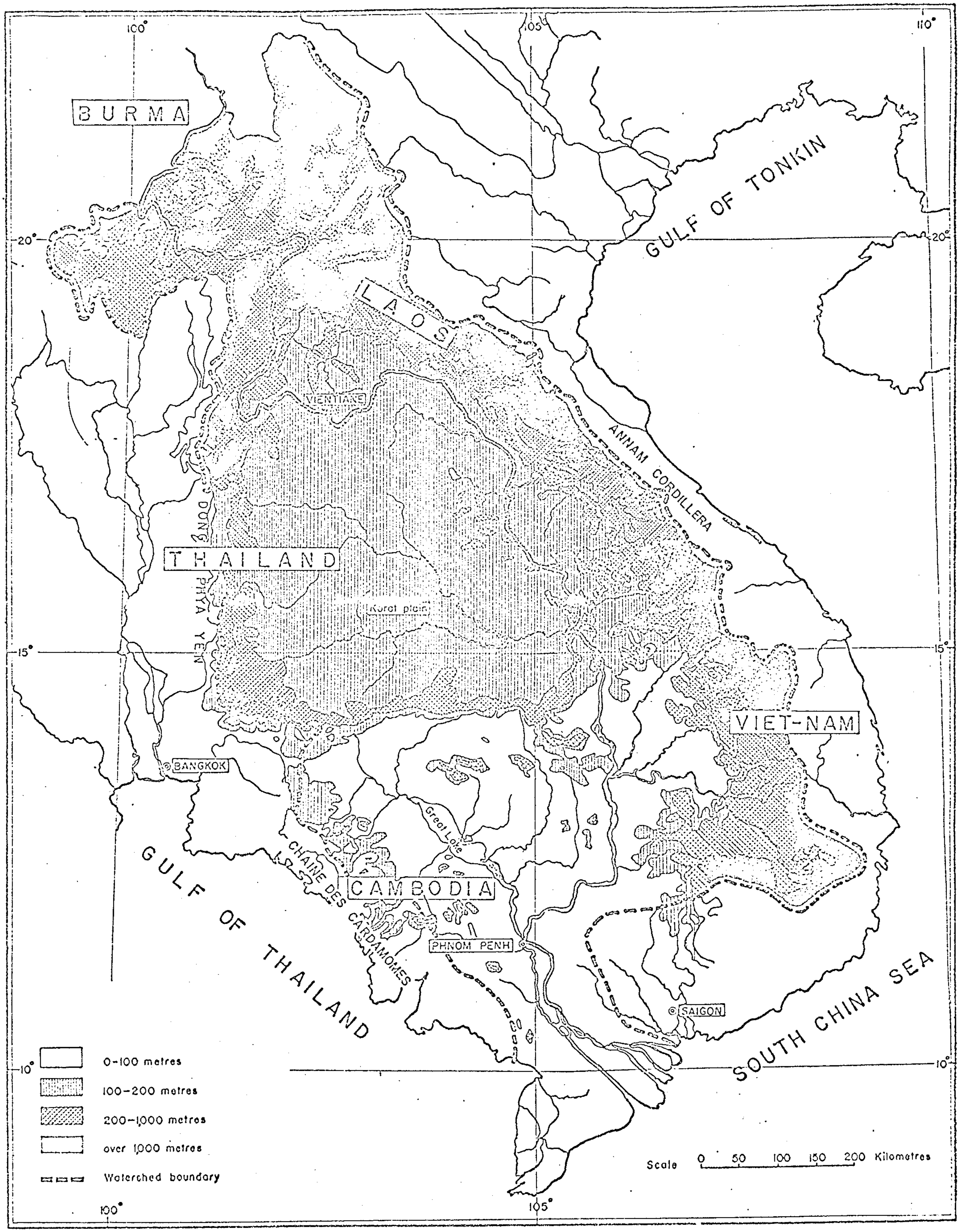

FIG. 2 LOWER MEKONG BASIN

(b) Geographical. The Mekong River flows through a valley of hills with steep banks from the border between Laos and China. The open plain of 450 kilometres long from Vientiane to Savanakhet consists of sandy gravel bed. Many steep gorges were found downstream of Savanakhet to the mouth of the Mune River. At Khon Falls about 736 kilometres above the mouth of the river navigation is impossible. The part below Kratie is alluvial, the banks are built up by sediment deposit from floods.

The lower basin may be divided into four parts, namely, the hill area, the plateau, the Mekong Plain, and the Mekong Delta (fig. 2). The hill area includes approximately all areas with an altitude higher than 200 metres above mean sea level (fig. 3A). It comprises the entire region in the northeast part of Laos. The plateau (fig. 3B), with an elevation of 100 to 200 metres above mean sea level, consists of the Northeast part of Thailand (see more details in Chapter III). The Mekong Plain (fig. 3C) comprises a flat area in Cambodia, having an elevation below 100 metres and located between the Cambodian-Laotian border. The most extensively cultivated area is found near Battambang (fig.4). The Mekong Delta begins downstream from Kampong Cham (fig.I and fig. 3D). Every year from September to November, flood waters flow over the river banks, spreading in a vast sheet inundating 3 to 4 million hectares of land in Cambodia and Viet Nam. This area is under paddy cultivation.

(c) Economic. Some 20 million of people of four nations: Laos, Thailand, Cambodia and Viet Nam are located in the Lower Mekong Basin. The economy of the region depends mainly on agricultural products which depends on the annual cycle of monsoon rains. The major cities of Southeast Asia are: The Thailand capital Bangkok, at about 40 kilometres from the mouth of the Chao Phraya River, with a population of about 1.6 million is outside the basin. The Vietnamese capital Saigon-Cholon, on the eastern edge of the Mekong Delta, with a population of a million. The Cambodian capital Phnom Penh with the population of 500,000 and 100,000 in the Laotian capital Vientiane. The population in the basin is largely rural. The main occupation of the people is rice growing in the rainy season which lasts about seven months. Most of them leave their lands during the dry season due to lack of water and few grow upland crops where water is available during this period. The income of the region depends on agricultural surplus for export rice, rubber, teak and a few other field and forest products. These constitute the principal commodities of the economic

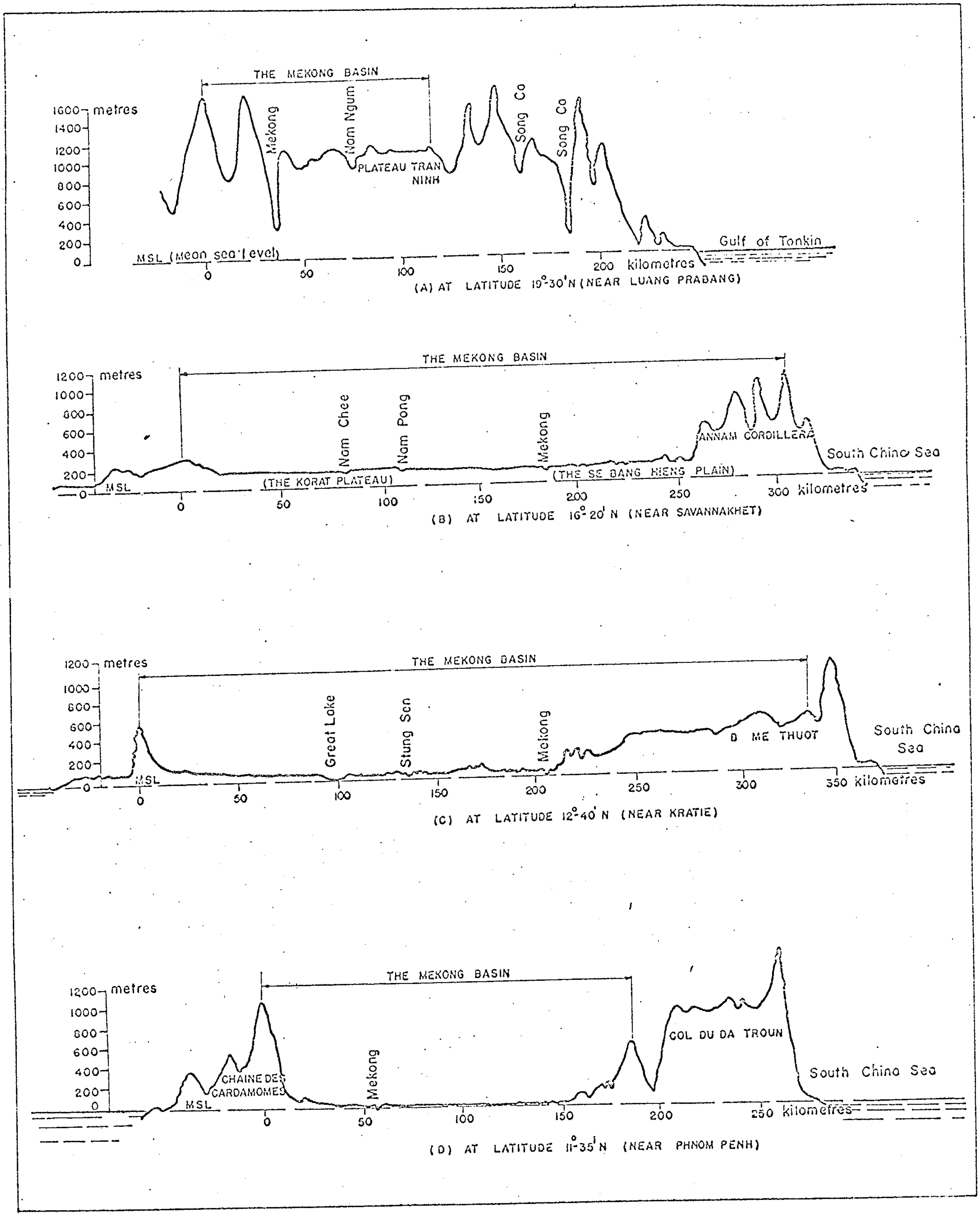

FIG. 3 CROSS-SECTIONS OF LOWER MEKONG BASIN

of the four countries, which are exchanged among them and exported to the world outside. During the past 10 years, great number of refugees have moved from the North to the Delta in Viet Nam; and there also has been a steady immigration from the Korat Plateau into the central of Thailand and the city of Bangkok.

(d) Jurisdictional. According to the political history of the region during this period, the continuation of work seems cooperative. Twice since the formal planning of the Mekong began, Cambodia and Thailand have broken off diplomatic relations, Laos and Viet Nam have each been divided by civil war. This is hardly the setting for international collaboration in resources management. Politics have excluded the upper basin, which lies within Red China, from the planning to date, China, not being a member of the United Nations, does not participate in the activities of the ECAFE.[1] This has removed from consideration 186,000 square kilometres of the total drainage area. At the present time there are no precedents under state practice or international river law, which may be compared to the activities, procedures and achievements of the Mekong Coordination Committee.

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1. Economic Commission for Asia and the Far East.

The work done in the legal field is certainly important and the difficulties involved are not to be overlooked. However, as the recent agreement signed between Laos and Thailand for the supply of power, encourages the committee that it might be brought to final agreement among all co-riparians.

2. Economic Base Projection. The population statistics of the four countries in the year 1963 totaled about 48 million and about 20 million are located in the Lower Mekong Basin. The rate of growth will be about 3 percent per year. At this rate the population of the four countries will exceed 90 million in the next 23 years. To secure the food requirements for this number of people and a surplus for the foreign exchange necessary to generate a modest 50 percent increase in income from the other economic activities, it will require an increase in production of milled rice from a total of 8 million tons to 17 million tons. Current export of rice from Thailand, Cambodia and Viet Nam run at about 2 million tons, in the interest of foreign exchange it will be desirable to increase this figure. In the recent years rice production in the three countries has

been increasing at about 2 percent per year; at this rate population growth will soon overtake production and each up the surplus. It is apparent that the rate of increase in rice production must be accelerated to a 3.5 or 4 per cent per year. The increase in secondary crops during the dry season and livestock products in response to changes in food habits and nutritional needs must also be included in the plan. Toward the support of economic growth, external demands for the forest products of the basin and for rubber may be expected to grow. If the 50 percent improvement in income per capita is to be achieved, industrial output will have to grow at a rate of 6 to 7 percent per year. A substantial portion of this activity is likely to be in the processing of agricultural and forest products. Without assuming the building of large industry serving regional or world markets it appears that electric demand might increase five to seven fold.

3. Water Requirements.

(a) Domestic and industrial uses. At the present time most of the rural areas on the Lower Mekong Basin are situated along the river banks or other natural sources of water. In some areas, water is scarce during the dry period followed by the decrease in water for household use. The amount of water required for industrial use is very small.

Although the population of 20 million in the basin will be double in the next 25 years, associated with the industrial growth rate of 6 to 7 percent per year, and water is assumed to be plentiful all year round by the development of the Lower Mekong Basin, the amount of water for domestic and industrial uses associated with waste disposal requirements appears to be small when it is compared with the available water on the basin.

(b) Irrigation requirements. At present most of the crops that are grown in the Mekong Area, depend on rainfall only. Rice is the major crop and is grown in the rainy season. Second crops are grown only where water is available. The total paddy lands on the Lower Mekong Basin are estimated at about 7,180,000 hectares. (750,000 hectares in Laos, 2,800,000 hectares in Thailand, 1,630,000 hectares in Cambodia and 2,000,000 hectares in Viet Nam). The water requirements for rice growing is estimated at 1,300 mm. in the rainy season and 1,200 mm. in the dry season (shorter period of growing). The effective rainfall is assumed to be 700 mm. and 50 mm. during the first and second periods of growing respectively in Thailand, 800 mm. and 50 mm. in Laos. Cropping intensities is assumed to be 1.5 and a loss of 50 percent of divert water is assumed. The annual optimum water requirements in Thailand and Laos will be 76,320 million cubic metres which is about 51.5% of the average annual runoff recorded at Vientiane. This does not include the runoff on the tributaries in Thailand and Laos which flow to the Mekong below Vientiane. The percentage of irrigation water required to runoff will be decreased in the downstream direction.

(b) Navigation requirements. When rapids are submerged by the construction of a series of dams associated with channel improvements, navigation would be possible from the South China Sea to Luang Prabang for a distance of about 2,150 kilometres. Besides the paddy products the transport of industrial products and raw materials would be increased. In the next 25 years the paddy transport expected would be 300,000 tons from Phnom Penh and 700,000 tons to Saigon. Industries might be developed if cheap power were available, namely, pig-iron in the vicinity of Chieng Karn, Soda pulp and ammonium sulphate at Khemarat and aluminium at Khone and Sambor. If the Mekong would become navigable throughout, the export of large quantities of timber from Laos is possible. Laos has an accessible forest area of 4 million hectares and 11 million hectares of virgin forest. Main land China is also a potential timber market. Under the average conditions in the Mekong Basin, the cost of river transport is decidedly the lowest. For the same distance, rail transport is 2.2 times, and road transport 5.7 times more costly than river transport, if an adequate 50 - metre channel where available. The possible value of export, by way of the Mekong might be well over $250 million a year. The minimum water requirement would be about 2,500 cms. and the minimum depth estimated at 2.00 metres.

(c) Power requirements. According to the high streamflow of the Mekong River, the power potential both mainstream and large tributaries would be in the order of 20 million kilowatts. The completed planning of the main river would be composed of twelve project sites. The minimum discharge for power generation would be at the site near Vientiane. This might be due to the ample amount of irrigation water requirements. The maximum discharge for power generation should be at a downstream site. The annual power output of tributaries in the four countries would be in the order of 47,070 million kwh., and 81,270 million kwh. would be on the main river. The prospects of increase of electric consumption in Cambodia and Viet Nam in the year 1983 would be 1,100 million kwh. and 4,440 million kwh. on the average respectively. In Laos and Thailand in the year 1985 it would be in the order of 133 million kwh. and 10,408 million kwh. on the average respectively.

(d) Flood control requirements. The areas effected by flood are on the lower reaches of the main Mekong. These areas are fertile and populated. The method to prevent flooding of these large delta areas in Viet Nam is to create big storage reservoirs in the upper reaches of the main Mekong associated with storage reservoirs on the large tributaries. It is estimated that flooding in the delta would disappear if the water level at Phnom Penh is kept below 8.00 metres MSL. A total storage of 130 billion cubic metres would give complete protection against flooding.

(e) Recreation requirements. Reservoir behind the dam would be an artificial lake which would be suitable for recreation. Beautiful areas around the reservoirs must be reserved. Pa Mong Dam would create a reservoir with surface area of 700 square kilometres that could become a recreation resource. This is a by-product of the reservoir that might be given some intangible credit. When the Lower Mekong Development would be completed a series of reservoirs along the river would become the most attractive place for recreation of the people of the four countries.

4. Development of Plan. Planning of the Lower Mekong Basin is underway. Preliminary survey teams were

organized in the year 1951. The work was interrupted by the war in Indo-China during 1953-1956. In the year 1956, the four riparian Governments requested ECAFE to undertake a comprehensive reconnaissance investigation of the basin.

(a) Priority of water use. No priority of water use is set up in the Lower Mekong Basin. This is due to the ample supply of unused water. If one would be set up, domestic water supply may have the highest priority of all types of water utilization as has been set up in some other regions of the world, possibly followed by industrial and agricultural requirements, depending on economic considerations.

(b) Alternative plans. The investigation of one plan is not enough, at the present time the Pa Mong proposed No. 1 and No. 2 have been investigated. New plans must be repeated until all view points have been considered, therefore it might be followed by another proposed project before the construction begins. The alternate plans can be compared on the basis of their benefits and costs. The other projects have been carried on the same process as the Pa Mong.

(c) Economic analysis. The study of the demand for project services should cover power markets, the demand for water, the benefits from flood control and irrigation, and the demand for transportation. Power from any one of the major mainstream dams will exceed the domestic demand for power, therefore a detailed analysis is required of the power market. According to the first investigation in 1956, if the projects are developed independently, the unit cost of firm energy delivered at load centre would vary from 0.36 United States cents to 0.41 cent per kwh. This figure might change because of the later proposed projects. No allocation of cost for navigation and irrigation have been found.

(d) Selection of plan. According to the population prediction the first priority of water requirements from the Mekong is for irrigation. Therefore the multiproposed projects with irrigation benefits would become the first priority in investigations.

5. The Mekong Committee. The committee for co-ordination of investigation of Lower Mekong Basin is composed of representatives from Laos, Thailand, Cambodia and Viet Nam. Its purpose was to promote, coordinate, supervise and control the planning and investigation of water resources development projects in the Lower Mekong Basin. The committee maintains liaison with various United Nations agencies, and with private groups who have offered assistance.

The Mekong River

Riparian countries of the whole river basin:

China, Burma, Laos, Thailand, Cambodia, and Viet Nam.

Total length	4,350	kilometres
Total drainage area	795,000	sq. km.
Mean annual rainfall	1,380	mm.
Mean annual runoff	728	mm.
Runoff coefficient	52.8	percent

Discharge: measured at Kratie with 682,000 sq. km. of drainage area.

Maximum discharge	75,700	m^3/sec,
Minimum discharge	1,250	m^3/ sec.
Average discharge	15,000	m^3/sec.
Specific flood discharge	0.116	m^3/sec./sq. km.
Average unit discharge	0.023	m^3/sec./sq. km.

For maximum silt content measured at Vientiane with the drainage area of 305,000 sq. km., the average silt content and annual silt runoff measured at Mukdahan with the drainage area of 391,000 sq. km.

Maximum content	0.31	percent by weight
Average content	0.06	percent by weight
Average annual silt runoff	170,000,000	tons
Average annual silt runoff per unit area	435	tons/sq. km.

CHAPTER II

THE MEKONG DEVELOPMENT

Development Possibility in The Upper Basin

Generally speaking the entire stretch of the river should be included in the planning, except for two reasons. There is no development possibility for large scale irrigation projects on the upper basin as it is rough terrain with sparse population. Secondly there are sites for large scale hydroelectric power installations by way of storage. This would reduce flood discharges in the downstream during the high flow. The development of the upper basin would not involve the diversion of water, therefore this would not adversely affect the development schemes in the lower basin. On the contrary they would be helpful to water management downstream. An other reason is that the Mekong flow is essentially governed by the Lower Mekong Basin itself.

The Development of The Lower Basin

The comprehensive development of the water resources in the lower basin includes the main stream and tributaries. Multipurpose works are composed of hydroelectric power, irrigation, flood control, drainage, navigation improvements, water management and water supply which are related to the economy and the social growth of the people of the area. At the present time less than 3 percent of the basin is irrigated, while a vast portion of the land has left. Ample supply of water from the Mekong River could bring great benefits by means of irrigation to the basin. Tremendous hydroelectric power potential of the river and its tributaries is suitable for large industrial development. Planning of the Lower Mekong Basin is composed of overall basin planning, main stream project planning and tributaries projects.

<u>The Possible Development Project</u>. About 12 sites on the main-stream and 22 sites on the tributaries may be developed over a reasonable period. This does not include the development project on the tributaries in the Northeast by the Royal Irrigation Department of Thailand. Pak Beng on the extreme upstream end, Pa Mong, and Strung Treng about 120 kilometres upstream of Kratie would create the large storage dams, while at the other sites the dams will not involve appreciable storage but could generate a lot of electric power and help in getting over the rapids for navigation purposes.

I. Development of tributaries. Development of large tributaries will be mentioned, while more details of tributary development in the Northeast Thailand will be emphasised.

Laos

1. Nam Ngum Project. Nam Ngum River flows into the Mekong at about 90 kilometres downstream of Vientiane with 420 kilometres long. The construction of a dam on this river would create a reservoir with the capacity of 8,500 million cubic metres, power generation from release water will be 120,000 kilowatts. Irrigation on Vientiane plain will be possible on the area of 32,000 hectares.

Thailand

At the present time the government of Thailand is paying attention to the water resources development in the Northeast. Several projects have been completed, some are under construction and many are under planning.

Eight water resource development projects which are described below are shown in fig. 6.

1. Lam Pong Project. The development on the Pong River is composed of storage dams for hydroelectric power and diversion works downstream for irrigation. The maximum

flow on the Pong River in 1959 was 1,225 m^3/sec. Benefits of the project are from 24,900 kilowatts of power generation and 53,000 hectares of irrigated land.

2. Lam Pao Project. The Lam Pao is a branch of the Chi River. The dam on Lam Pao creates a reservoir with capacity of 9,000 million cubic metres. Water from the reservoir is released for irrigation downstream of 16,000 hectares in the wet season and 12,000 hectares during the dry season. Power generation will be possible in the future.

3. Lam Pra Plerng Project. The Lam Pra Plerng is one of the branches of the Mune River. Water from Lam Pra Plerng Reservoir with 152 million cubic metres in capacity can be released to irrigate an area of 10,640 hectares in the wet season and 4,800 hectares during the dry season.

4. Lam Takong Project. The Lam Takong is another branch of the Mume River. The dam on the Lam Takong creates a reservoir with capacity of 220 million cubic metres. Released water could irrigate an area of 33,600 hectares in the wet season and 24,000 hectares during the dry season.

5. Lam Nam Oon Project. Lam Nam Oon River is one of the major tributaries of the Nam Songkram River in the

upper right of the plateau. Nam Songkram River flows into the Mekong at about 45 kilometres below the Lam Nam Oon confluent. The total project area would be 36,000 hectares while 273,000 hectares having possibility for gravity irrigation. The capacity of regulating storage would be 475 million cubic metres.

6. Nam Pung Project. Nam Pung is a branch of Nam Kam River which flows into the Mekong in the east. The active storage of the reservoir on this river is 150 million cubic metres. Part of the total power generation of 7,000 kilowatts from this reservoir could be used in pumping water from the Mekong to irrigate an area of 8,000 hectares and the other 16,000 hectares could be irrigated by gravity.

7. Lam Dom Noi. Lam Dom Noi is a branch of the Mume River. Power generation from water storage would be 22,000 kilowatts and irrigation would be possible on the area of 25,000 hectares.

8. Hui Bang Sai. Hui Bang Sai is a branch of the Mekong River on the east of the plateau. Power generation from Hui Bang Sai reservoir would be 5,000 kilowatts and water released from the reservoir could irrigate an area of

8,000 hectares.

Many projects are under planning in the Northeast, namely, Lam Mume, Huey Kayoong, Lam Dom Yai, are on the branches of the Mume River. The branches of the Chi River are Upper Chi, Nam Young. Huey Hee is on a branch of the Nam Songkram River and Huey Tuey, a tributary of the Mekong River.

Cambodia.

1. Prek Thnot Project. Prek Thnot is a multipurpose development of the Lower Prek Thnot, a tributary of the Mekong River, to provide for irrigation, power generation and flood control. The project is consisted of the main dam across the Prek Thnot together with a series of small dams connecting a number of lowhills and creates a reservoir with a capacity of 980 million cubic metres and generating power capacity of 18,000 kilowatts.

Prek Thnot irrigation Project is to divert water of the Prek Thnot River to irrigate an area of 70,000 hectares which is about 30 kilometres from Phnom Penh.

2. Battambang Project. Battambang tributary project on the Strung Songker River in western Cambodia can irrigate

an area of 68,000 hectares and power generation of 5,000 kilowatts.

Viet Nam.

The Upper Se San Tributary Project. The Se San is one of the major tributaries of the Mekong River. Its total length is 360 kilometres with the drainage area of 18,000 square kilometres. The Upper Se San is a multi-purpose project with power generation, irrigation and flood control. The power potential would be in the order of 640,000 kilowatts and this scheme could irrigate an area of 21,400 hectares, while 6,400 hectares could be commanded by gravity, the other 15,000 hectares by pumping.

II. Development of the Mainstream.

1. The First Priority of Investigations. The three mainstream projects with the top priority in planning are the Sambor, the Tonle Sap and the Pa Mong.

Sambor Project. The mainstream dam at Sambor in the eastern part of Cambodia about 600 kilometres north of the river mouth with the total catchment area of 650,000 square kilometres is given the highest priority among all the mainstream projects. The water releases from the reservoir of 1.1 billion cubic metres in capacity could generate the power of 625,000 kilowatts. By both pumping and gravity methods agricultural development along the Mekong below Sambor would be 67,000 hectares. The construction cost of the installed capacity of 320,000 kilowatts in the first stage is estimated at U. S. $300 million and the cost of the electricity at the sending end would be about 4 mill per kwh.

Tonle Sap Barrage Project. The proposed Tonle Sap Barrage will regulate the maximum water level of the Great Lake and increase the depth of the lake during the dry period. Barrage gates would be opened in the early part of the flood season and would be closed to prevent small and medium floods entering into the lake.

To reduce flood magnitude in the Mekong Delta, Great Lake would act as flood detention storage, that is, the maximum flood is absorbed into the Great Lake with the storage regulation capacity of 84 million cubic metres. Water released from barrage will also improve navigation downstream. Benefits from the project would be: increase fish production, reduction of flood damage, improve navigation in Cambodia and Viet Nam, irrigation on the west bank area of the Tonle Sap and the area around the lake during the dry season. The increase in discharge of about 3,000 cms. at Phnom Penh would push back the salt water towards the sea.

Pa Mong Project. Pa Mong Dam will be located at about 30 kilometres upstream from Vientiane, Laos, and about 1,600 kilometres above the mouth of the Mekong River. Project area lies on both banks of the Mekong where the river forms the boundary between Northeast Thailand and Northwest Laos. Water will be available at Pamong to generate approximately 1,000,000 kilowatts of power. Energy requirements in the service area indicate that the demand for power will have increased to the point where Pa Mong project will be required by 1975-1979.

The maximum full supply level of the reservoir will be at elevation 230 metres above mean sea level. The active storage capacity between elevations 210 and 230 will be $10,170 \times 10^6$ cubic metres or about 7 percent of the average annual flow. Therefore large spills will occur each year averaging $80,000 \times 10^6$ cubic metres per year. To irrigate an area in Vientiane Plain, gravity irrigation is possible with water surface elevation of 200 M.S.L. at upstream of the dam. A large increase in yield could be realized by an increase in active storage capacity of the project. This will be limited by the topography of the storage and the length of the dam.

Nam Mong. Nam Mong Damsite would be located about 53 kilometres south of Pa Mong Damsite on a small tributary which flows into the Mekong between Vientiane and Nongkai. The two reservoirs are separated by a low saddle with an elevation of about 230 M.L.S. If a connecting channel between the two reservoirs could be excavated, the flood flow would spill over Pa Mong Reservoir, enabling it to fill every year. The Nam Mong Dam would provide a large amount of additional storage of $7,764 \times 10^6$ cubic metres at an elevation of 230 M.S.L.

Nam Mong release could then be made to provide irrigation, domestic, and municipal water supply to Thailand, while water release could be made from Pa Mong Reservoir for power, navigation, and to supply irrigation, domestic and municipal water to Laos.

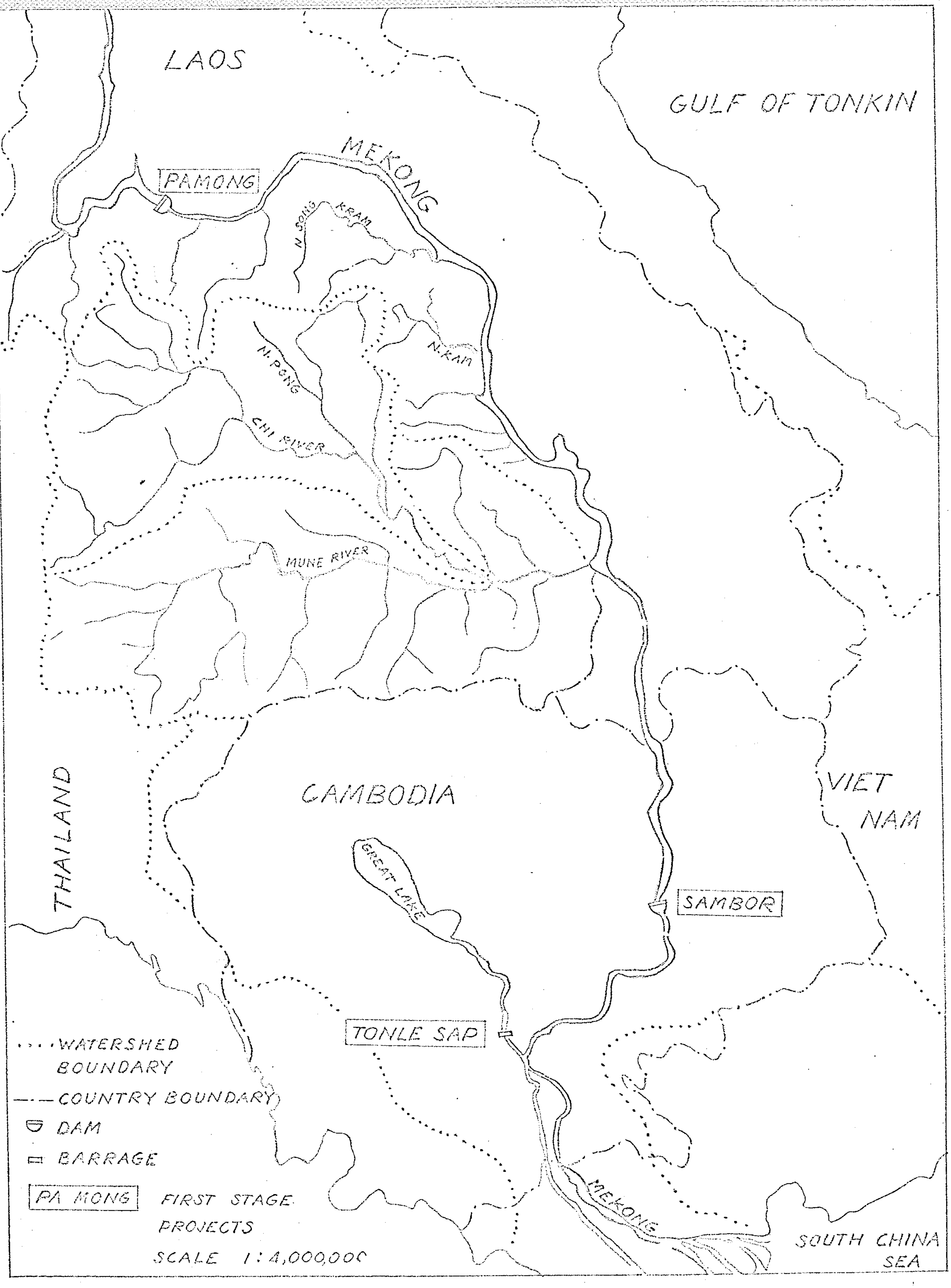


FIG. 5 LOWER MEKONG BASIN: DEVELOPMENT PROJECTS

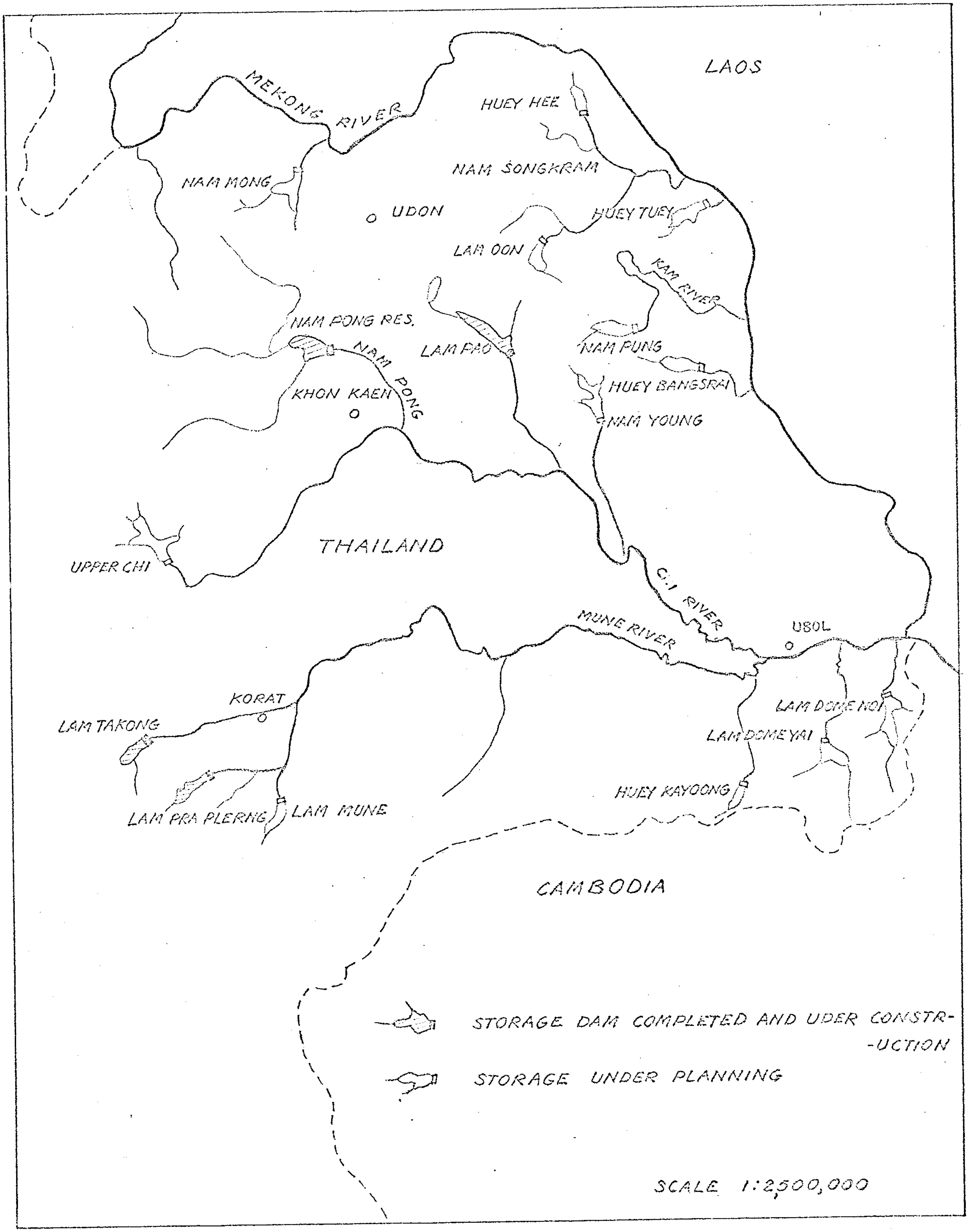


FIG. 6 WATER RESOURCES DEVELOPMENT PROJECTS

NORTHEAST THAILAND

CHAPTER III

NORTHEAST THAILAND

Northeast Thailand or Korat Plateau is situated between 14°30' and 18° 00' latitude north and 101° and 105° 30' longtitude east. The length from north to south is approximately 425 kilometres, and from east to west is about 450 kilometres with the total area of 170,266 square kilometres.

On the basis of monsoons the climate may be divided into: The southwest monsoon season, which begins in May and ends in September, causing appreciable rainfall throughout the plain; this monsoon ends in October. Then the northeast monsoon begins in November, it brings dry and cool air from the north; the retreating northeast monsoon extends from March to mid-May.

The tropical cyclone that has a large influence on the supply of water to the Northeast Thailand, occurs about the same period with monsoons in the west Pacific. (This cyclone is classified as, Depression, Tropical Storm or Typhoon depending on wind speed of the cyclonic circulation.) The heavy rain of the cyclone reaches the Northeast in June. In July the cyclonic path has moved northwards far beyond the watersheds of Thailand, there is a temporary period of drought lasting from three weeks to a month. Then the cyclone follows the sun Southwards. In August the Northeast region again gets some of its rain, and in September the heaviest rain of each year for the cyclonic path passes through the plain on a wide front. In October its centre moves further South.

In the Northeast the average annual rainfall is about 1,270 mm. (50 inches). The maximum total rain is registered at Nakorn Phanom (lat. $17^{o}30'$ N, long. 104^{o} $20'$ E.) with 2,210 mm. (87 inches), while the minimum is at Chaiyaphum (lat. 15^{o} $45'$ N., long. 101^{o} $50'$ E.) with 1,040 mm. (41 inches).

The maximum temperature is $40^{o}C$ ($109^{o}F$.) in May and the minimum temperature is $5.1^{o}C$ (41^{o} F.) in January. In summer or dry season, daily temperature varies between 6^{o} to $10^{o}C$ while the variation is 8^{o} to $15^{o}C$ in the cold season. However cold air from Siberia and Mainland China occasionally bring temperatures down to $0^{o}C$. The mean monthly relative humidity between January to March varies from 55 to 60 percent, and is increased to 80 and 85 percent in August and September. The variation in relative humidity of the plain in the same month is not significant.

From November to April, the seepage rate is in the order of 10 to 20 cm. per month or is 60 cm. in the period of six months. Reservoirs with high depth of water, the above rate become 15 cm. per month or 5 mm. per day.

TABLE I

Mean Monthly Rainfall, Temperature, Potential Evaop-Transpiration, and Soil Moisture Deficit at Udon, Latitude 17°26'.

	Rainfall	Temperature	Potential Evapo-transpiration	Soil Moisture Deficit
	mm.	°C	mm.	mm.
January	7.9	22.5	68	60.3
February	19.6	24.9	97	77.8
March	40.2	27.9	151	111.2
April	96.6	29.8	149	70.6
May	223.2	29.4	138	-
June	215.8	29.0	105	-
July	199.8	28.4	68	-
August	248.0	27.9	162	-
September	266.6	27.8	167	-
October	88.5	26.8	177	49.2
November	17.4	25.1	171	87.9
December	4.3	22.3	171	63.4
	1427.9		1624	520.4

The Northeast Thailand, the north and the east are bounded by the Mekong River, the West and the South are the mountain ranges. The plain elevation varies from 100 to 200 metres above mean sea level. The area is slightly undulating plain sloping gently towards south-east, where the Mume River drains into the Mekong River. It is composed chiefly of sandstones, and the soil mostly derived from sandstone, is not very fertile. Patches of alluvial along the tributaries and the main stem of the Mune River have been opened for rice cultivation. Since this area is sheilded on the west and the south by mountain ranges, it receives less rain than neighbouring areas even during the period of the southwest monsoon. During the remainder of the year there is a shortage of water.

Population and Economic Activities.

The population of the Northeast in 1960 was 8,992,000 or about one third of Thailand's population, with the density of 53 per square kilometre. The standard of living is the lowest in the country and also, unfortunately, where development presents the greatest difficulties. About 88.3% lived in agricultural households and the total agricultural household was 77.4%.

Rural education in Thailand has been markedly improved during the past decade. However, the literacy rate for adult-farmer is still very low. (The percentage of literacy of the country in 1960 was 71%). It is this illiteracy that prevents them from seeking employment with better prospects. It is also this illiteracy that keeps them to continuing, traditional methods of farming. The introduction of any desirable changes in farming systems and practices would require the up-grading of the managerial abilities of these farms.

Rice occupies the largest area of the cultivated land, produces the highest total value among all agricultural crops, and provides the best employment opportunity for the majority of the people. But earnings income per unit of land is low. The people have to use land for growing rice because of the favorable climate and topography. Therefore rice, as a single crop, is the backbone of the economy. From the available statistics, rice, not only was important in the past and is important at present, but also, in the foreseeable future, there is no other crop which can take its place.

The growing season is rather short about six to eight months, the farmers harvest their crop, but few grow other crops or raise livestock. Some have left their land during the dry season to work in the towns and cities. But when the crop season is on many of them return to their own farms.

The total cultivated land in the Northeast in 1962 was 25,180,000 rai, about 979,000 rai was irrigated land and 24,129,000 rai was non-irrigated land or a ratio of 3.9 to 96.1 respectively and became the ratio of 8.31 to 45.59 of the whole country respectively. The variation of rice acreage was 15,864,000 rai in 1953 and 17,858,000 in 1962.

Value of Rice for Sales and Home Consumption 1953 (Baht).

	Sale		Home Consumption		Total	
	Value	%	Value	%	Value	%
Northeast	298	19.7	1,211	80.3	1,509	100

Size of Farms by Zones 1953

Zone	Under 6 rai	6-15 rai	15-30 rai	30-60 rai	Over 60 rai	All sizes rai
Northeast	3.25	10.29	20.80	39.79	76.71	27.38

Percent of Double Cropping by Zone 1953

Northeast	0.05	0.08	0.14	0.18	0.58	0.17

An economic farm survey on 6,419 farms was undertaken in 1953 throughout the kingdom. The results showed that more than half of the total gross income per farm came from rice. The small farms earned more income from crops other than paddy. Paddy income was proportionally higher in the larger size groups.

Average Gross income and income from paddy per farm by size and zones, 1953 (Bahts).

	Farm Size (rai)					
	Under 6	6-15	15-30	30-60	60 and over	All sizes
Northeast Total gross income	5,205	1,373	1,758	2,232	3,782	2,093
Income from paddy	678	1,141	1,416	1,759	2,569	1,509

Family Living Expenditure in Thailand

Year	Coverage	Per Capita Yearly Expenditure (U.S.$)	Thereof spent on (%)			
			Food	Clothing	Housing etc.	Other
1953	Farm	65	71	9	7	13

The average size of farm is 27 rai, which is 5 times larger than the average size rice farm in Japan. Only 13 percent of all farmland is tenant-operated. Most of these tenants are actually part-owners. It can be concluded that the present shortage of land is caused by the inefficient utilization of the available land resource.

The primary objective of economic development in Thailand is to raise the standard of living of people with the hope that such effort will lead every citizen to a fuller, more creative, and happier life. To this end, there should be an increase in the total per capita output of goods and services. In other words, with government assistance, employment opportunities should be made available to all citizens in both agriculture and industry. Economic activities will be accelerated when people are able to enjoy maximum employment. Measures to promote the increase of agricultural production and considered as the first priority of the development plan. With the existing surplus man power in the rural areas plus three percent annual increase in population, industries in the initial stage of economic development have no room to accommodate all of them. The best alternative is to work on the farm.

Agricultural production in 1966 was satisfactory, but it did not grow substantially enough when compared with other sectors of the economy, especially when agriculture is the most important sector of the economy.

Thailand Second Plan for 1967-1971 was being geared to the necessity of broadbased economic growth. The plan would concentrate on rural developments to boost the agricultural sector to the level equal to other sectors. In irrigation, the plan included the construction of eleven irrigation projects in the Northeast. In 1965 the per capita income raised to Baht 2,500 which was about 25% higher than the average income of 1958, although since that time the population had grown at the rate of 3.2% per year. While the agricultural sector remained the heel of the national economy, the Northeast region was definitely the problem area geographically. The Government continued to spend more and more on the development of the area with both economic and strategic goals in mind.

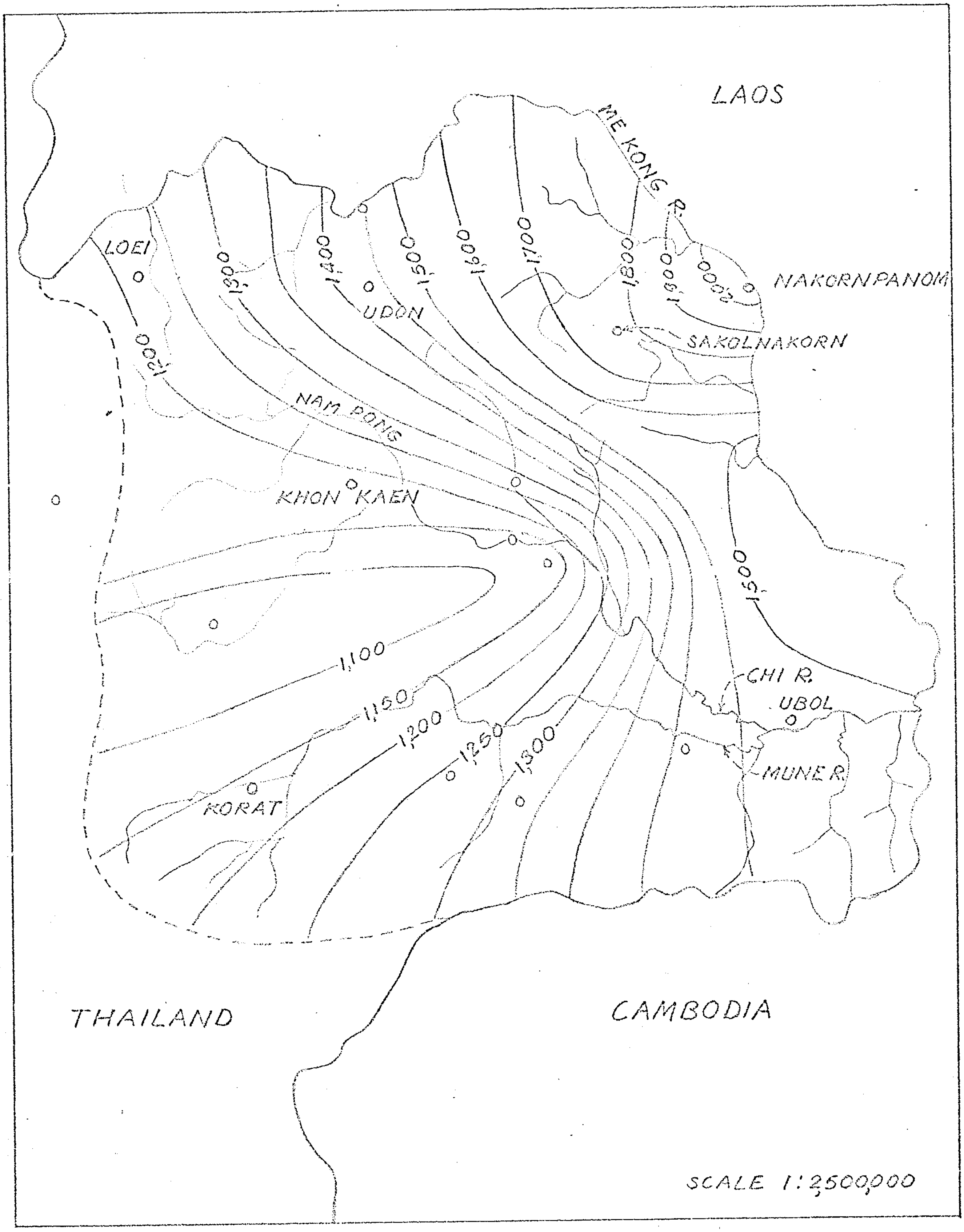


FIG. 7 KORAT PLAIN: MEAN ANNUAL RAINFALL (MM.)

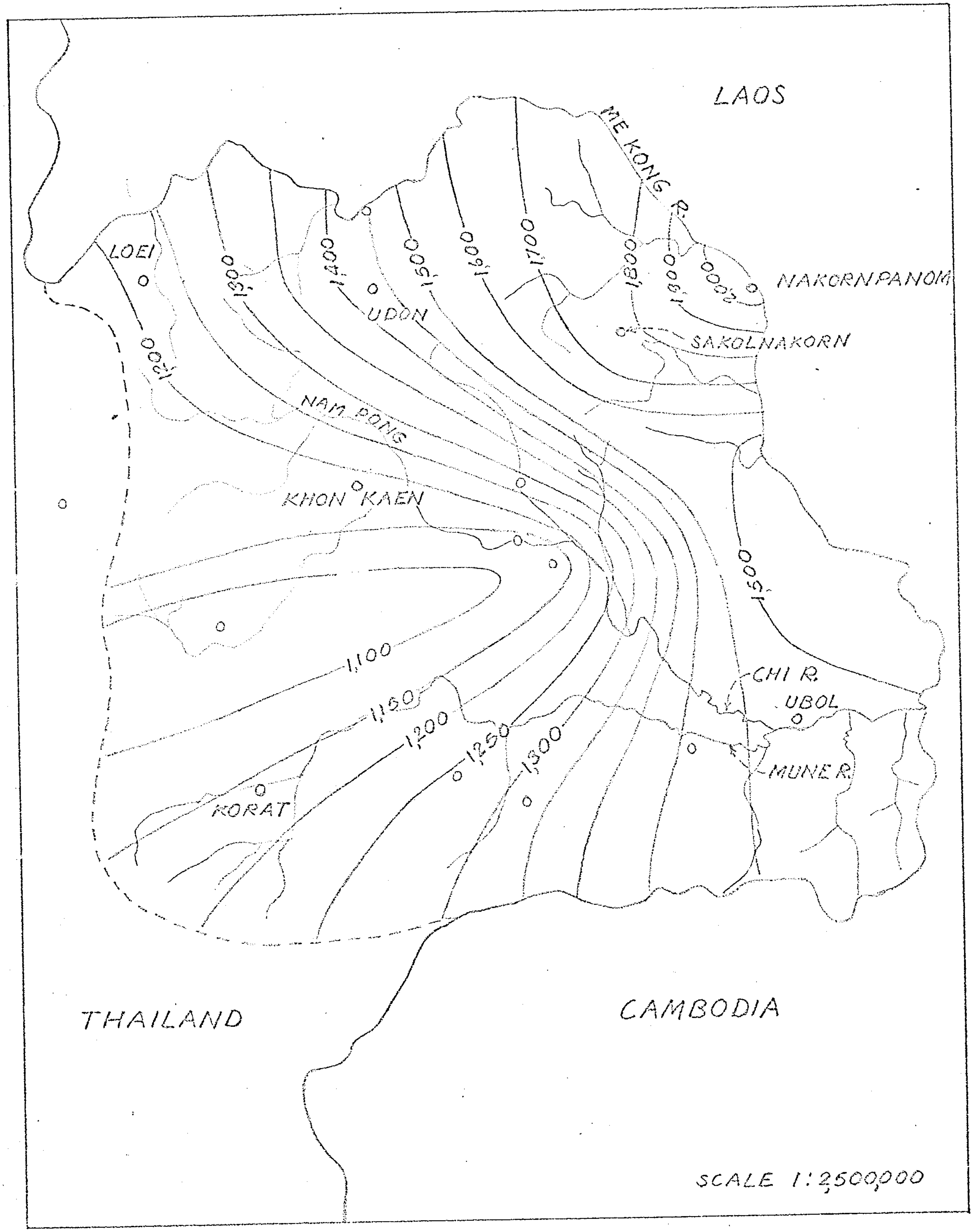


FIG. 7 KORAT PLAIN: MEAN ANNUAL RAINFALL (MM.)

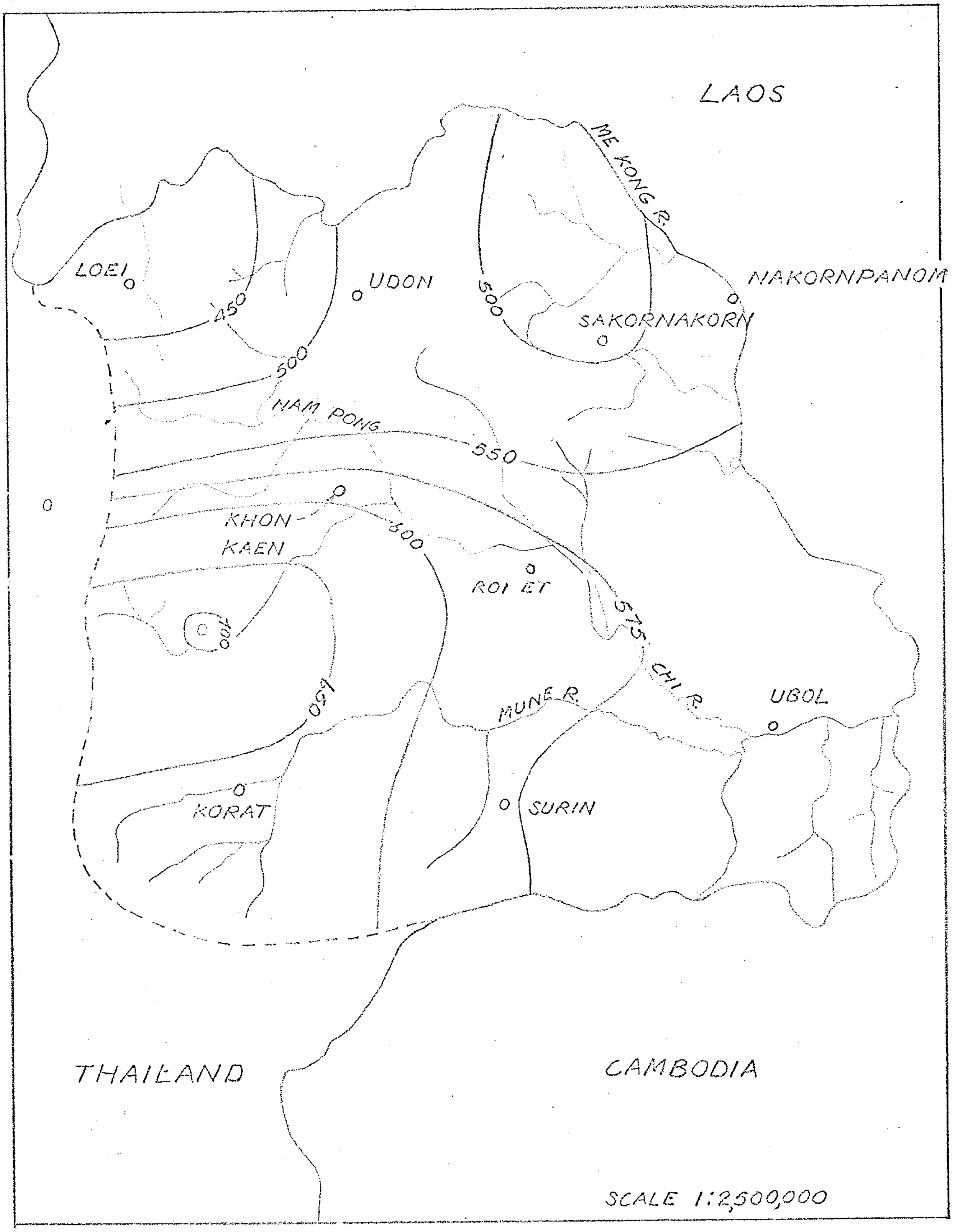


FIG. 9 MEAN ANNUAL SOIL MOISTURE DEFICIT (MM.)
KORAT PLAIN

CHAPTER IV

AVAILABILITY OF WATER

The average annual rainfall of 1,270 mm. in the Northeast, is in the same magnitude with the North and the Central of Thailand. The total annual runoff flowing into the Mekong is about 40,000 million cubic metres, which is nearly the same amount to the flow of the Chao Phraya River, the major river of Thailand. If about 50 percent of the above annual runoff could be stored and distributed over the cultivated land it would bring great benefits to the Northeast. But many factors are involved, first of all, topographical and geological conditions are limited to the construction of reservoirs. At the present time the amount of water available for cultivated land is small and damage from flood is very frequent. This might depend on:

1. This region is composed mostly of either shallow fine sandy loam, quartzitic and siliceous limestones or laterites, they are high land or hill area with high seepage rate, while the low land is alluvial deposit especially along the Chi and the Mune and the Mekong flood plain. These cause the water to inundate on the flood plain and become floods when intensity of rainfall is high.

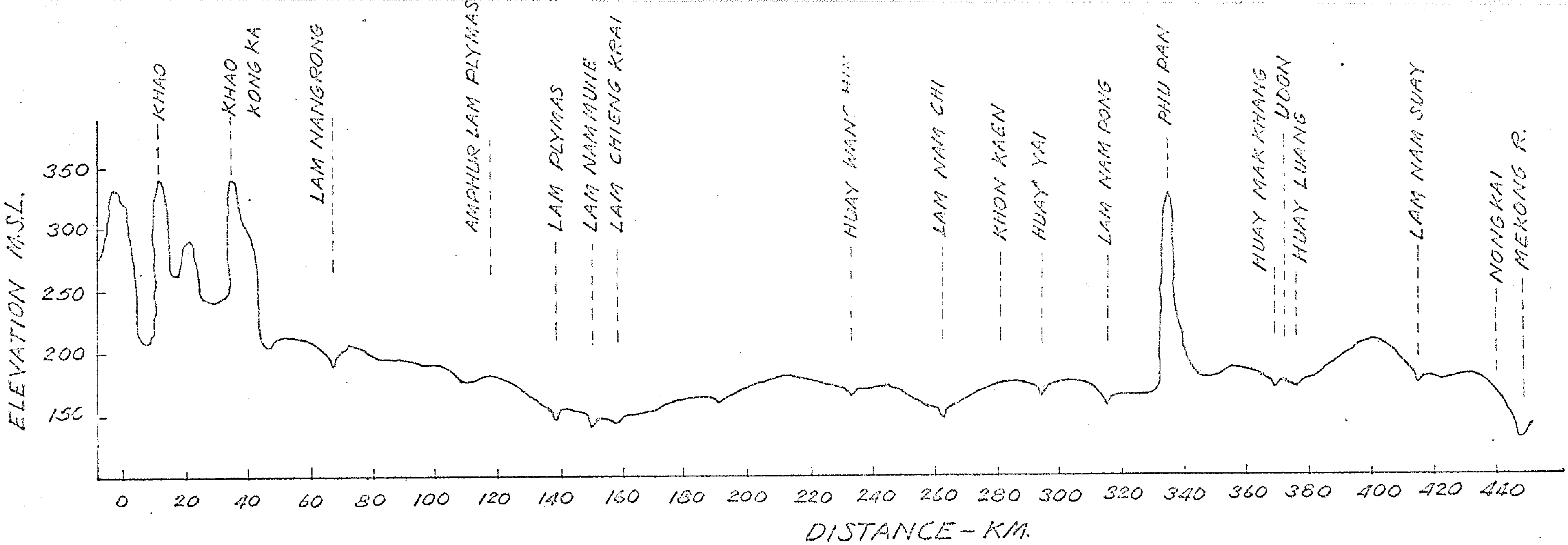
2. The extension of farm to the higher land associated with shifting cultivation (which involves clearing

an area of forest and other vegetation, farming it for two or three years and then moving on to repeat the same process in another location) reduce the natural storage of water, increase flood strength in the wet season and diminish the river flow in the dry season.

1. Natural Sources of Water. Small unit of cultivated land of one rai with high dikes (15 to 25 cm.) surrounding it, is the typical farm land for rice growing in the Northeast. This is the suitable method in the flat area, water can be conserved for the dry period of 10 to 15 days. Besides, there are several large lakes in this region and are often surrounded by farm land, namely Nong Prachak at Udon and Nong Harn at Sakolnakorn.

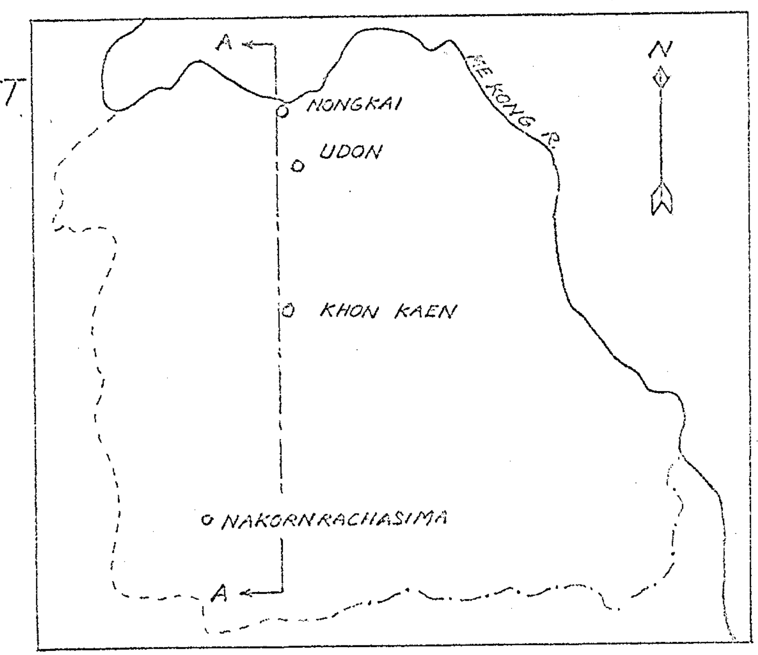
The Mune and the Chi Rivers are the major rivers in the Northeast with the annual runoff ranging from 25,000 to 30,000 million cubic metres. The maximum discharge, of the Mune and the Chi Rivers, is 4,189 and 1,900 cms. respectively. These two rivers are composed of many branch streams. Most of them flow to join the Mune and the Chi Rivers from the North, West and South. But there are still several rivers flowing to the Mekong River and their discharges are not significant when they are compared with the discharges of the Mune and the Chi Rivers.

2. River Diversion. To tap a river for water may be simple and inexpensive, if the river is close to the irrigated land. From the cross-section of the Northeast along north-south, the major rivers run along the low area of their flood plain. Therefore, to irrigate an area on the flood plain by gravity method, diversion work with long main canals running through the undulating plain before arriving at the irrigated land are needed. In the central plain, before the rivers have been regulated, water flowed over the banks of the rivers during the flood season, silts settled out on the river banks, fine particles moved further and deposited in the paddy field when velocity of water was decreased. Therefore river banks were built up higher than the paddy field. In this case river diversion is inexpensive. This is one of several advantages of irrigation work in the central over the Northeast. There is no water in the river during the dry season. It may be concluded that the river diversion alone, that has been constructed in the central plain is an uneconomic method for the Northeast and it is not the first priority in investigation at the present time.



SECTION A-A

FIG. 10 CROSS-SECTION OF THE NORTHEAST ALONG NORTH-SOUTH



KEY MAP NORTHEAST THAILAND

3. River Pumping. If river diversion by gravity becomes too costly and too complicated, direct river pumping may prove cheaper despite higher running cost and amortization. This might be justified in the Northeast when the population is increased, food price has increased and electric power becomes cheaper. At the present time there are no permanent pumping plants. There is only in emergency cases, namely, in dry years or during dry periods in July. The area to be irrigated by pumping is small when it is compared with the total cultivated area of the region.

4. Reservoir Storage. From topographical and geological point of view, there is no suitable storage site on the Mume and the Chi Rivers. When we consider, further upstream to their tributaries, it was found that many sites are suitable for storage reservoirs. Their capacities are not as high as in the north, they vary from 200-1,000 million cubic metres. About 16 to 20 of them were found. The total reservoir capacity might be in the order of 7,700 million cubic metres.

According to an undulating topography of the Northeast, many sites suitable for small reservoir are planning to be built and over a hundred have been completed. Many of them serve for domestic use only, while the others serve for both domestic and irrigation. Their capacities vary from few hundred thousand cubic metres to million cubic metres. In the future the total reservoir capacity both medium-sized and small-sized reservoirs would be in the order of 10,000 million cubic metres.

In some parts of this region, reservoirs with downstream diversion dams might become the most economic method. This also reduces the main canal cost (according to the soil conditions, lined canal is necessary in the northeast) from reservoir to irrigated land. If there is enough water, irrigation in the dry season is possible.

5. Water Deficit. From Chapter I, irrigation requirements in the wet season for an area of about 17,500,000 rai would be about 13,600,000,000 m^3. If the diversion losses are 50 percent, the diversion requirements would become 27,200,000,000 m^3. If it is further assumed that about 50 percent of cultivated land in the Northeast is proved to be suitable for irrigation from economic viewpoint. Therefore irrigation requirements of crops in the wet season alone is 13,600,000,000 m^3. which would require a storage capacity of 10,000,000,000 m^3.

To find the optimum irrigation requirements, upland crops must be introduced. If cropping intensity of 1.5 is assumed, therefore about 50 percent of irrigated land in the wet season would be also irrigated during the dry season. The upper limit of irrigation requirements is to grow rice with water requirements of 1,200 mm. (shorter period of growing) and 50 mm. of effective rainfall. Therefore the diversion requirements is 4,375,000,000 x 1,600 x 1.150 x 2 which is equal to 16,000,000,000 m^3. It might be concluded that water in the Northeast would be deficient in the future.

6. Water From The Other Sources. From topographical point of view, the western and the southern parts of the region are the mountain ranges. To bring water from the west (Pasak River) or from the south is uneconomic. The northern and the eastern regions are bounded by the Mekong River with an ample amount of water. The area of the region is slightly sloping gently towards southeast, therefore to bring the water from the east, pumping plants for lifting water before diversion is necessary. On the contrary to bring water from the north, gravity method is possible. And according to an undulating plain, pumping plant might be considered to be economical in some areas. From Chapter I the water on the

Mekong River at Vientiane is ample, provided reservoirs would be built in that area.

According to the low flow on the Mekong River during the dry period of about 4 months, the conflict of water uses between irrigation and the other purposes might occur. To store the water in the region for irrigation during the dry season might solve this conflict. But topography might limit the use of water from the Mekong River during the wet season.

CHAPTER V

SELECTION AND CLASSIFICATION OF IRRIGABLE LAND

The selection of land for irrigation encompasses social, economic and physical factors. The plans are usually selected to achieve greater economic efficiency, but social objectives play an important role in the Northeast. Interdisciplinary work, namely, soil science, agronomy, engineering, hydrology, geomorphology, sociology, economic and law must be involved. The physical factors of climate, soil, topography and drainage are all parts to determine the suitability of land for irrigation use.

I. Classification of Soils in the Northeast.

Soils of Northeast are classified into 20 series. The properties of soils included in this classification are topographical situation, horizon, texture, salt problems, drainage characteristics, growing crop and yield.

Rat Buri, Phimai, Si Thon, and Roi Et series[2] are in use for rice cultivation with excellent yields, provided the crop is not damaged by flooding. Second crops may be grown on these soils during the dry season if irrigation is feasible.

If floods could be eliminated, Ta Tum series would become agricultural land with excellent yields, while Oon series are exclusively used for paddy growing with high yields. Phen series are used for paddy growing. Pak Chong series are excellent suited for agriculture on a permanent basis provided erosion control and suitable rotation could remain productive for long time. Lop Buri series are difficult to work both when dry and wet. The agricultural potential of these soils is considerable, both for rice and upland crops.

Garden and upland crops, with a short growing season, could be grown in Chieng Mai series. Yasothon series are usually cultivated and are used for growing of fruit trees.

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2. The names of the soil series are the grouping of the map units. These groups are not an element of the classification but rather an organization of the map unit in such a way that the geographic distribution of the soils and the land use in the surveyed areas can be more easily read on the soil map. This kind of map for the Northeast is not available at the present time.

Phon Phi Say series are believed to have a moderate agricultural potential.

Udon series are believed to have a moderate agricultural potential, provided reclamation and drainage improvement must be available. Korat series; Most of Korat soils are under secondary forest and savanna. Diverse upland crops are grown in a shifting cultivation pattern. Udon series are rice growing soils. They are not suitable for long term cultivation.

Kalasin series is uneconomic for agriculture because of costly drainage difficulty. Nam Pong series, according to the present economic viewpoint, these soils can be considered as almost useless. Borabu series are not for agriculture and there are no potential agricultural values for Sakon Series.

2. <u>Basic Principle.</u> To change the water regime of agricultural land from rainfall alone to rainfall and irrigation water. The change in physical regime is expected to be small. Erosion is an important factor in an extension of irrigation to the new land in the Northeast. The other factor might be due to the difference in soil conditions between the use of the farmers' tools and the mechanized tools.

In the Northeast, value of crops, slope of land, and surface irregularities are the principal variables considered in determining costs of land development. Machinery is not yet available for use in large scale. The use of animal power in a small scale is possible.

Irrigation on agricultural land of about fifteen soil series in the Northeast is based on economic factors. In a given climate, economic parameters are a function of soil characteristics, drainage characteristics and topography characteristics. Topography plays an important role in these parameters. The effect of slope on the suitability of land for irrigation is primary influenced by the crops to be grown, the duration and intensity of rainfall, erodibility of the soil, farm income potential and the method of irrigation to be used. The relationship between agricultural land value and slope is governed by the relative important of surface drainage, erosion and water intake. Slope of 0.3% to 3% running in well-defined direction is considered to be suitable for irrigation.

3. Drainage. Kalasin series, excess water caused by water standing in topographic depressions for long periods

might be drained by surface and subsurface methods, while Ta Tum series shallow water table might be drawn down by subsurface drainage. Oon series drainage must be protected, because it may well cause irriversible drying and hardening of ground water table laterite. Udon series if good water quality could be impounded, the salt could be reached down.

Generally speaking, in the Northeast most of excess surface water should be removed by surface drainage. In irrigation project planning, supply canals might run along the high contours, while drainage canal run along the lower contour to intercept the excess water. In the northeast small creeks usually run along the lower area and these creeks would become the main drain, and drainage cost would be reduced.

4. The Irrigation Suitability Classification.

In this system, land class is defined as a land having similar physical and economic attributes which affect the suitability of land for irrigation; it is an expression of relative level of payment capacity. The economic and physical factors are correlated through the relationship of soil, topographic and drainage factors to productive capacity, cost of production, and land development costs for a given project setting. By this method land is classified into 6 classes. Class 1 has the highest level of irrigation suitability, and class 6 is land not suitable for irrigation development. This system is designed by the Bureau of Reclamation.

5. The Land Capability Classification. The land capability classification is used in the Northeast. This system is designed to emphasize the hazards and limitations in the different kind of soil. It provides three major categories of soil grouping, namely, the capability class, subclass, and unit. In Thailand, rice is the major crop and can be grown on nearly level, poorly drained, fine textured soils. Therefore land capability classification is separated into two parts, namely, classification for upland crops and classification for rice.

1. Land capability classes for upland crops are classified into 8 groups. Their properties vary from soils very well suited for upland crops to soil and land types having limitations that preclude their use for commercial plant production, and restrict their use to recreation, wild life food and cover, and water supply. The major properties of each classes are slopes, depth, texture, structure, salinity, alkalinity, acidity, crops damaged by

flood or storms, drainage, water holding capacity, crop yeilds limited by lack of water in period of little rain, and fertility.

2. Land capability classes for paddy (rice) are classified into 5 groups. The properties of each classes vary from soil very well suited for paddy land to soils generally not suited for paddy land. Their limitations are depth, texture, permeability, slope, drainage, fertility, salinity, alkalinity, acidity and damaged by storms or flood.

Limitation for land capability subclasses are erosion, soil, limitation in the root zone, lack of moisture for plant growth, favorable topography, flooding, impeded drainage, salinity or alkalinity, and soil acidity.

Soil classification in the Northeast, is under survey. From soil map of Roiet Province, Korat series is one of the major soils in this province. It is fine sandy loam. This unit appears to include most of the upland areas which are not in use for rice land and which are not stoney or hilly. Korat soils are poor soils, with low natural fertility and water holding. According to the increase in population, the improvement of this soil for long term use in agriculture would become the great benefit to the economy of the country.

CHAPTER VI

AGRICULTURAL DEVELOPMENT

1. Major Crop. Rice is the major crop which can be grown under different patterns of climate environment, most types of soil, and various level of topography, provided sufficient amount of moisture is available. It is the crop which can be best adapted to physical conditions of Thailand. The most important method is that of growing rice of wet-land, the rainfed fields. Because of the difference in land levels, this method is implemented in two ways, by broadcasting and by transplanting. The broadcasting practice is particularly suitable for the lowlands while transplanting practices are popular on the medium land. The raising of seedlings in the nursery usually take from four to six weeks during May and June, transplanting can be started as soon as the monsoon arrives. It can take at least five months to grow one rice crop.

In the Northeast at Udon, nursery begins in May and paddy period is from June to January. If irrigation and drainage facilities are available, the selection of rice varieties which require a shorter growing season of not more than 120 days would be of great benefit to the farmers. Such varieties are available both in and out Thailand. Rice leads in importance in every aspect of the national economy over other crops. But the earning capacity per unit of land is at the present the least important.

A large portion of the soils are very poor in plant nutrients, this is due to the high air temperature and heavy intermittent rains. Present farming practices pay little attention to the maintenance of suitable levels of either organic matter or plant nutrients. The average yield in 1961 was 231 kg./rai. under the present farm system, the improving soil fertility should receive prior attention. Results of field experiments and demonstration done by Rice Department indicate the increase in rice yield of 93% from the use of chemical fertilizer in the Northeast.

2. <u>The Other Principle Crops</u>. Sugarcane, cotton, fruits, kanaf, corn, mungbean, tobacco, groundnut and vegetables could be grown in the Northeast. Sugarcane is grown once a year while the others can be grown both in the wet and dry seasons. The figures for 1961-1962, the values per rai of 12 major agricultural crops were compared. Tobacco is the best money earning crop and corn is the lowest one, but it

still is higher than that of rice value. One rai of land could earn 2,544 baht from tabacco while only 334 and 220 Baht/rai could be earned from corn and rice respectively.

3. The Multiple Cropping System. The multiple cropping system means that the same piece of land which is now growing only one rice crop will be used to grow two crops or more in the same year. This system is the symbol of intensive cultivation where land is the limiting factor. The pre-requisites for introducing the multiple cropping system are the regulation of water supply, the selection of short growing season varieties, the use of labor saving devices, and the adoption of inter-cropping practices.

Double Cropping of Rice. The biggest problem in adopting double cropping of rice is the maintenance and the improvement of soil fertility. This requires more fertilizer inputs, better rotation system, and growing green manuring crops. Without fertilization, the yield of each rice crop will be reduced and the increase in total production will not justify the expenses incurred for both crops.

Double Cropping of Rice and Other Crops. The benefits from this system are:-

(1) When the supply of water is not sufficient to irrigate two crops of rice.

(2) The growth of the second crop other than rice may prove to be more profitable.

(3) It would be better rotation for the maintenance and improvement of soil fertility.

(4) The land is more suited to crops other than rice as the second crop.

(5) It encourages the diversification of agricultural production.

In an experiment conducted at Samchook Experimental Farm of the Central Plain in Thailand, it has been found that, with irrigation, there are ten ways of rotation between rice and other crops in one year.

Double Cropping of Other Crops than Rice. In the high land where moisture is insufficient even to grow one crop of rice, it could introduce two or more other crops such as corn and corn, corn and peanut, cassava and mungbean, and the other combinations. Many of these crops are soil depleting and need more fertilizer input to maintain and improve the soil fertility.

4. <u>Cropping Intensities</u>. The relation between cropping intensity and cropping pattern depends on the

growing seasons. The difficulties in fitting the crop are the overlap time, climate factors, age of crop, relation between the first and second crop, and the suitability of soil. The preparation of land for new crop requires time and in some cases pre-irrigation is needed. For example, land preparation and nursery are needed before transplanting of rice. Shortage of animal power or labor may make it impossible for some farmers to complete the harvesting and marketing of one crop in time to prepare the land for a succeeding one.

The patterns can be expected to change over a period of time in response to new opportunities to increases in intensity, change technology, and markets for farm commodities, where cropping depends on rainfall, or residual soil moisture from flooding, the concepts of cropping intensity and cropping pattern can not be applied directly.

The cropping intensity is defined as the percentage of the cultivable commanded areas which are cropped in each of the two seasons of the year added together with that of a perenial crop being counted twice. Thus 200 percent is the maximum attainable intensity. The assumption in this study is that the cropping intensity in any sizeable area will not exceed 150 percent. Optimal planting dates, proper seed bed preparation and harvesting time also limits the attainable intensities. Intensities exceeding 150 percent could be reached by the introduction of new crops or new varieties with a shorter growing season and with the modern farm machineries.

5. Cropping Pattern. Climate determines to a large extent the profitability of growing a crop. Total cropping intensity should be as high as possible not only for economic reasons but also for the efficient control of salinity. The intensities of crops are limited by the demand and economic returns, mainly to meet local demands and export possibilities.

TABLE II

Basic Cropping Pattern, Northeast Thailand

	Wet Season	Dry Season
Rice	80 %	31 %
Fruit	1.5%	1.5%
Sugarcane	2 %	2 %
Cotton	2 %	
Dry Crop A	11 %	
Dry Crop B		19 %
Total	96.5%	53.5%

The design cropping patterns of the Northeast Thailand in this study is a long-range planning which may take at least a decade before the operation of an irrigation project. When the optimum use of water in the basin is reached, and no more water supplying to agricultural land, then at that time water from the Mekong River would be attractive. At the present time several experimental farms were established in this part of the country which are useful to the study of cropping patterns in more details for particular location of this region in the future.

6. Yields Improvement Factors. Projected yields based on present yields, recent yield trends, climate, soil, cropping pattern, standard of farming and government policies. The data for construction of the yield projection curves is not available in this study. The most important yield improvement factors are, additional water supplies, removal of water logging, application of fertilizers, disease and pest control, improve seed bed preparation and cultivation practices, and improve varities.

7. Projections of The Demand. Projection of total domestic demand of rice in Thailand is based on population increase, income growth, level of per caput consumption and other uses. The annual rate of population

TABLE III: DESIGN CROPPING PATTERNS

Northeast Thailand

ITEMS	Crops	Crop Pattern Apr.May June July Aug.Sept.Oct.Nov.Dec.Jan.Feb.Mar.	Commanded Area %	Cropping Area %	Acc. Area %
1.	Main & Double Rice a.Land Preparation b.Nursery c.Transplanting	57% 23%	57	80	80
2.	Double Transplanting Rice a.Land Preparation b.Nursery c.Transplanting	8% 8%	8	16	96
3.	Second Rice & Dry Crop B a.Land Preparation b.Nursery c.Transplanting	15% 15%	15	30	126
4.	Fruits	3%	3	3	129
5.	Sugarcane	4%	4	4	133
6.	Cotton	2%	2	2	135
7.	Dry Crop A	7%	7	7	142
8.	Dry Crop A & B	4% 4%	4	8	150
			∈100		

* Remarks on Page 68.

Remarks - of Table III - Continue of Design Cropping Patterns.

Design cropping patterns of the Northeast are based on the proposed cropping pattern of Lam Nam Oon Project and Sarm Chook Experimental Farm by O & M Division, Royal Irrigation Department of Thailand (19).

- Dry Crop A consists of jute, kenaf, upland rice, maize and groundnut.
- Dry Crop B consists of tobacco, mungbean, water melon, sorghum, vegetable.
- Shaded areas are indicated to be irrigated period.
- Cropping Intensity

$$= \frac{\text{Cropping Area}}{\text{Commanded Area}}$$

$$= 1.5 \text{ or } 150\%$$

increase is 3 percent. The coefficient elasticity of the demand for rice is 0.2 before 1970 and 0.1 between 1971 and 1980. The population will reach 34.5 million in 1970 and 45.4 million in 1980. Foreign demand for paddy in 1970 on the average will be 51 million tons more than that of 1957-59 average. Special attention should be given to the increase of demand by the importers of the Far East Region where the freight rates are less.

8. Projections of the Supply. The average quantity of rice production in Thailand between 1960-1962 was 5.5 million tons and the average quantity of rice exports within the same year was 1.35 million tons. If the rice production would remain at the same level, Thailand's exports would be reduced gradually every year and would become self-sufficient in rice in 1975. The expected rate of production increase per year at least should be 3.5 percent in order to maintain the export level between 1.3 and 1.5 million tons of rice each year. During the past ten years, the actual annual increase of rice production, on the average is only 1.5 percent and 2.4 percent during the last five years. In the projection of the world demand for rice

in 1970, the difference in supply between the low and high projections is 19.4 tons of paddy. There will be 1.1 million tons short for low level projection and 7.2 million tons surplus for the high level projection.

Increase of production depends largely on acreage and yield. On the basis of land classification in the Northeast, additional land could be brought under cultivation. On the other hand the present yields per rai of Thai rice are at low level. The yields might be double or higher if the yields improvement factors were introduced. Therefore the development of cultivated land in the Northeast would play an important role in annual rise at the rate of 3.5 percent for rice in the future.

CHAPTER VII

WATER REQUIREMENTS

1. Water Demands Other Than Irrigation. With the population growth rate of about 3 percent per year, domestic and industrial water uses in the Northeast are expected to increase in a certain rate in the future. The small-sized reservoirs are considered to be suitable in supply of water, but pollution control, and watershed management for soil erosion control must be investigated. According to the nature of the rivers in the northeast, navigation is not suitable. They are intermittent streams and there is no water during the dry season. One might conclude that the other water demands are not significant when they are compared with irrigation demand, but it is necessary to estimate this future demand and what part might be supplied by ground water.

2. Available Soil Moisture. The difference in moisture content of the soil between field capacity and permanent wilting percentage is the available moisture for plant growth, or the amount of moisture that can be taken up by plant. Soil moisture content near the wilting percentage readily available to the plant and the portion of available

moisture that is most easily extracted by plant, is approximately 75 percent of the available moisture. The rate of water taken up by the plant in the different stages of growth is also different. Lack of water during the time the fruit is forming, results in great reduction in yield. Therefore when water is limited, irrigation period should be during the time of heading. Adequate drainage which may be surface, subsurface or both is usually necessary to drain the surplus water and to benefit the irrigated crop, otherwise a gradual rise of the ground water table and eventual water logging will result. The bottom of the drain should be such that the ground water level will be below the root zone of the crop.

3. Method of Irrigation. Generally speaking rice is grown by rain or flood waters over the banks of the river. If water could be controlled, the irrigation methods namely, sprinkler, corrugation, border strip and furrow could be introduced. The advantages of each method depends on soils and topography. The sprinkler method is suitable to rapidly permeable and shallow soils, where the slope is too steep or topography is too irregular. While the corrugation method finds its best application in areas with deep soils of slow, moderate, and moderately rapid permeability. It can be applied

to topography that slopes approximately 0.4 to 8 percent.

The border strip and furrow methods are especially suitable for deep soils of slow, moderate, and moderately rapid permeability, that are planted with deep-rooted crops in an area with uniform, but relatively flat slopes ranging from 0 to 3 percent. This method should be developed where it can be carried out on a large scale. The larger the area irrigated, the cheaper the unit cost becomes.

The small plot with furrow running in the side ditch direction might be suitable in some areas of the north-east. The size of plot is important, if it is too long, water also takes a long time to reach the lower end resulting in uneven depth of penetration. The direction of the furrows are not limited by the topography of the farm. They can run parallel to the longitudinal ditches or the side ditches. A study of the slope, furrow stream and soil erosion shows that furrows in the side ditch direction are more desirable (5).

4. Water Requirements. Water is an essential material for agriculture. Different kinds of crops require different moisture level. Rice needs about double the amount of water required by soybeans. Sugarcane consumes more water than rice. Water requirements are not constant throughout the

stage of plant life, and is also greatly influenced by soils, topography and climatic factors such as temperature, radiation and humidity. Therefore it is hardly feasible to give precise figures for the amount of water needed to grow a crop of rice from planting to harvesting because these amounts are determined by many factors. For instance, the amount of water already in the soil, the water storage capacity of the soil, texture and fertility of both the top and subsoils, the length of the time a crop occupies the land and the method of irrigation and husbandary, all influence the amount of water that may be needed to give best results.

a. Results in Asian Countries. In Japan, the amount of water required is mainly dependent upon the growing season of the crop. The average requirements are as follows: early crop is 1,000 mm., while 1,200 mm. for medium crop and 1,400 mm. for late crop. The average results of water requirement in Asian countries are 800 mm. to 1,200 mm. with extremes of 520 mm. and 2,549 mm., those of daily consumption are 6 mm. to 10 mm. with extremes of 5.6 mm. and 20.4 mm. The wide range of the figures indicates the variation of local conditions with influence the consumption rate. (5).

TABLE IV: RESULTS OF WATER REQUIREMENT STUDY OF RICE IN SOME ASIAN COUNTRIES (5)

Country	Region	Location	Crop	Irrigation Period (day)	Transpiration Total mm.	Transpiration Daily mm.	Evaporation Total mm.	Evaporation Daily mm.	Percolation Total mm.	Percolation Daily mm.	Consumption Total mm.	Consumption Total inch	Consumption Daily mm.	Year Conducted
China	Central Yangtze Valley	Cheking, Hunan	Medium Indica	92	576	6.3	254	2.8	171	1.8	1.001	39.4	10.9	1940
	Taiwan	Tainan, Southern Taiwan	Intermediate Crop Indica	-	479	-	322	-	1,648	-	2,449	96.4	-	1922-1926
Japan	Kanto-Toson Region	Tokyo	Medium Japonica	120	Max. 425	3.5	200	1.7	1,092	9.1	1,717	67.6	14.3	-
					Min. 273	2.3	146	1.2	364	3.0	783	30.8	6.5	-
					Ave.	-	-	-	-	-	1,200	47.2	10.0	-
Korea	Han River Valley	Suwan	Japonica Type		Max. 698	-	-	-	830	-	1,528	60.1	-	-
					Min. 354	-	-	-	210	-	564	22.2	-	-
					Ave. 508	-	-	-	536	-	1,044	41.1	-	-
Thailand	Central Plain	Samchook	Main Crop	151	591	3.9	294	2.0	97	0.6	982	38.7	6.5	1964
			Second Crop (Indica Type)	90	348	3.9	346	3.8	48	0.5	742	29.2	8.2	1965

TABLE IV: RESULTS OF WATER REQUIREMENT STUDY OF RICE IN SOME ASIAN COUNTRIES (5) Continued

Country	Region	Location	Crop	Irrigation Period (day)	Transpiration Total mm.	Transpiration Daily mm.	Evaporation Total mm.	Evaporation Daily mm.	Percolation Total mm.	Percolation Daily mm.	Consumption Total mm.	Consumption Total inch	Consumption Daily mm.	Year Conducted
Philippines	-	-	Main Crop	-	1,180	-	188	-	900	-	2,268	89.3	-	-
Viet Nam	Lower Mekong Basin	Saigon	Indica Type	66	648	9.8	-	-	305	4.6	953	37.5	14.4	1961
Pakistan	East Pakistan	Amla, Kushtia	Aman Rice	78	733	9.4	382	4.9	78	1.0	1,193	47.0	15.3	1959
			Boro Rice (all Indica Type)	101	515	5.1	436	4.3	54	0.6	1,009	39.6	10.0	1958-1959

b. Results in Thailand. The design of irrigation projects is based upon an assumption that rice consumes about one centimetre of water daily. The results at Sam Chook Experimental Farm in the Central Plain are: 983 mm. of water consumed by the main crop and 743 mm. for the second crop. It takes 168 days for full growth of main crop and 107 days for second crop. (5).

The total amount of water consumed by the main crop from June 25 to December 11.

591.4 mm. or 60.2 percent by plant transpiration,
293.7 mm. or 29.9 percent by surface evaporation,
97.44 mm. or 9.9 percent by deep percolation.

Second crop from February 20 to June 8.

348.3 mm. or 46.9 percent by plant transpiration,
346.3 mm. or 46.6 percent by surface evaporation,
48.2 mm. or 6 .5 percent by deep percolation.

The average daily consumption for main crop rice is 6.4 mm. per day as compared with 8.2 mm. for the second crop. The higher daily consumption for the latter is mainly due to the higher surface evaporation in the paddy field during the hot dry months. (March, April, May.) It might conclude that water requirements for a normal crop of transplanted rice, including water for seed nursery, for soaking and preparation of land and for irrigation of the paddy field is about 1,240 mm. of water for a complete cycle of rice. They are divided into 3 stages: 40 mm. for seed nursery, 200 mm. for soaking and preparation of land and 1,000 mm. for irrigation of paddy field.

TABLE V:

APPROXIMATE PEAK DAILY WATER USE AND WATER REQUIREMENTS FOR MAJOR FARM CROPS IN THAILAND (5).

Crop	Approx. Water Use mm./day	Water Requirement mm.
Field Crops		
Rice	7-10	1,030-1,500
Maize	5-7	350- 400
Wheat	5-6	370- 500
Sorghum	4-5	300- 400
Groundnut	2-5	400- 500
Soy-bean	2-4	300- 350
Sesame	4-5	450- 525
Cotton	6-9	500- 900
Jute	6-8	600- 700
Kenaf	2-4	300- 450
Castor-bean	6-8	600- 740
Sugarcane	6-9	1,600-1,870
Vegetables		
Lettuce	4-5	245- 370
Cabbage	4-5	245- 370
Carrots	3-5	200- 245
Onion	4-5	245- 370
Fruits		
Oranges	3-4	740- 970

c. Consumptive Use. Two methods of consumptive use, namely, Blaney-Criddle Method and by using crop factor are computed for crops of rice, maize and cotton. Blaney-Criddle Method is based on the mean monthly temperature and percent of daytime in hours. Consumptive-use coefficients of 1.00, 0.75 and 0.70 will be used for rice, maize and cotton respectively. The second method mean monthly evapotranspiration at Udon and crop factor of West Pakistan are used.

Discussion of the computed consumptive use by Blaney-Criddle method and by using crop factor.

1. According to the growing crop at different stages requires the different levels of water use, therefore crop factor is a reasonable term.

2. The variation of local conditions influences crop factor.

3. When crop factor is introduced, the maximum daily consumptive use is greater than by Blaney-Criddle Method which follows by larger irrigation structures.

4. The total computed consumptive use of each crop by the Blaney-Criddle Method is greater than by using crop factor.

5. One important factor of Blaney-Criddle Method is the consumptive-use coefficients. The values used in the Western United States appear to be low when they are used in Thailand.

<u>Method of Computed Consumptive Use</u>.

1. Blaney-Criddle Method

u = kf

u = monthly consumptive use

k = monthly coefficient

f = $\frac{t \times p}{100}$ = monthly consumptive-use factor

p = percentage of day-time hours of the year, occuring during the period.

t = mean temperature in degrees Fahrenheit

2. By using Crop Factor.

Consumptive Use = Lake Evaporation x Crop Factor.

TABLE VI

Blaney-Criddle Method

Computed Normal Unit Consumptive Use of Water by Rice, Maize and Cotton, Northeast Thailand

Month	Mean Monthly Temperature °F (t)	Daytime Hours % (p)	Consumptive Use Factor (f)	Coefficient (k)	Rice Consumptive Use (u) inches	Rice Consumptive Use mm.
January	72.5	7.80	5.65	1.00	5.65	144
February	76.8	7.30	5.60	1.00	5.60	142
March	82.2	8.42	6.92	1.00	6.92	176
April	86	8.48	7.30			462
May	85	9.07	7.73			
June	84	8.90	7.48			
July	83	9.15	7.60	1.00	7.60	193
August	82.2	8.89	7.31	1.00	7.31	186
September	82	8.29	6.79	1.00	6.79	173
October	80.2	8.22	6.60	1.00	6.60	168
November	77	7.66	5.90			Σ720
December	72	7.77	5.60			

Month	f	Maize k	Maize u inches	Maize u mm.	Cotton k	Cotton u inches	Cotton u mm.
January	5.65						
February	5.60						
March	6.92						
April	7.30						
May	7.73				0.70	5.41	137
June	7.48	0.75	5.75	146	0.70	5.24	133
July	7.60	0.75	5.70	145	0.70	5.32	135
August	7.31	0.75	5.48	139	0.70	5.12	130
September	6.79	0.75	5.10	130	0.70	4.75	121
October	6.60	0.75	4.95	126	0.70	4.62	118
November	5.90				0.70	4.12	105
December	5.60						
				Σ686			Σ879

TABLE VII

Evapotranspiration-Crop Factor Method

Computed Normal Unit Consumptive Use of Water by Rice, Maize and Cotton, Northeast Thailand.

Month	Evaoptrans-piration mm.	Rice		Maize	
		Crop Factor	Consumptive Use mm.	Crop Factor	Consumptive Use mm.
January	68	0.7	48		
February	97	1.50	145		
March	151	0.85	128		
April	149		Σ 321		
May	138				
June	105			0.10	11
July	68	0.55	38	0.50	34
August	162	1.30	211	1.15	187
September	167	1.55	259	1.25	209
October	177	0.65	115	0.40	71
November	171		Σ 623		Σ 512
December	171				

Month	Evapotranspiration mm.	Cotton	
		Crop Factor	Consumptive Use mm.
May	138	0.1	14
June	105	0.35	37
July	68	0.65	42
August	162	1.15	187
September	167	1.35	227
October	177	1.15	204
November	171	0.65	111
			Σ 822

TABLE VIII

CROP FACTORS (II)

Months	4 month rice	3 month rice	3 month rice	Sugar- -cane	Fruit	Vege- tables	Maize	Cotton
Jan.			0.70	0.70	0.65	0.90		
Feb.			1.50	0.60	0.70	0.90		
Mar.			0.85	0.60	0.80	0.90		
Apr.				0.85	0.90	0.90		
May				1.10	0.90	0.90		0.10
June				1.20	0.75	0.90	0.10	0.35
July	0.55	0.70		1.20	0.70	0.90	0.50	0.65
Aug.	1.30	1.50		1.25	0.80	0.90	1.15	1.15
Sept.	1.55	0.85		1.25	0.85	0.90	1.25	1.35
Oct.	0.65			1.30	0.80	0.90	0.40	1.15
Nov.				1.20	0.75	0.90		0.65
Dec.				1.10	0.70	0.90		

Remarks: Main rice, growing period = 4 months

Double rice, growing period = 3 months

Crop factor of 3-month rice adopted from 4-month rice by use fig. 12.11 p.284 reference 12.

Crop factor based on data of West Pakistan.

In this study consumptive use computed by Blaney-Criddle Method will be used in the design of irrigation structures, the consumptive-use coefficients (k) will be adjusted to the local data.

d. Effective Rainfall. Effective rainfall is that part of the rainfall falling during the growing period of a crop which is available to meet its consumptive water requirement. It does not include deep percolation below the root zone or surface runoff. In Thailand in the wet season, from April to October, 75 percent of the monthly rainfall figures from April to September is considered as usable by plants. In October rainfall is less than that of September in amount, but heavier in intensity, its effective percentage is therefore less, and 65 percent of monthly total is considered as effective. During the dry season from November to March, 80 percent of the monthly total of November is considered as effective, and 90 percent of monthly total from December to March is considered effective.

e. Field-distribution Efficiencies. Field-distribution efficiencies is based on the data of the United States, proposed by Blaney and Criddle in 1962. The 50 and 60 percent distribution losses during July to December and from January to June respectively will be used in this study.

TABLE IX

Typical Field-distribution Efficiency in the U. S.
(Blaney and Criddle, 1962)

Sources of Water Losses	Open Porous Soil	Medium Loam	Heavy Clay
	Percent of Water Supplied		
Conveyance losses within farm	15	10	5
Surface runoff	5	10	25
Deep percolation	35	15	10
Total losses	55	35	40
Field irrigation efficiency	45	65	60

5. Return Flow. The amount of return flow depends on many factors, namely, soil conditions, diversion and conveyance, irrigation efficiency, depth of water applied, age of irrigation project and water table. According to soil conditions of the Northeast main canal is considered to be lined. This will reduce the seepage rate. In some areas rate of percolation and seepage is as high as 0.5 cm. per day. This rate will vary from high value in the high land to lower value in the flat area. Therefore return flow might be significant and becomes available for diversion to another land.

6. Water Quality. Water quality changes according to season, with higher salt concentration during lowest flow period. On the other hand water quality in different stream is also different. This depends mainly on the properties of soil in the basin. In the Northeast, water flow through Udon soil series is expected to have higher salt concentration than the others. The seasonal changes of water quality is also an important factor in the design and operation of irrigation system and farming rotation. The quality of water in the wet season is considered to be suitable for irrigation. In the dry season return flow from areas might not be suitable for irrigation.

CHAPTER VIII

UDON-NONGKAI IRRIGATION PROJECT

The purpose of the planning of the irrigation project in the Udon-Nongkai provinces in the Uppper Northeast is to utilize the water of the Nam Mong and the Mekong Rivers for an irrigation on the area of about 950,000 rai (375,000 acres). This area is bounded by the ridge dividing Khon Kaen and Udon in the south, Nam Songkram in the east the Mekong in the North. Part of this area is usually subjected to flooding from the Mekong River.

The aims of the project are:

1. To increase the yield of the paddy-rice. Rice cultivation on this area is at present dependent on precipitation during the growing season. During the dry year damage is incurred. Therefore dependable supplies of irrigation water would ensure good yields both in the dry year and during the dry season.

2. To promote the cultivation of various kinds of vegetables or other cash crops which require irrigation during the dry season. The diversification of agricultural crops by cultivation of vegetables and other cash crops are being conducted in this part.

<u>Description of the Project</u>.

The irrigation project will utilize the storage capacity of the reservoir to be formed behind the earthfill dam on the Nam Mong River with the active storage capacity of about 6,000 million cubic metres of water. The elevation of an active storage varies from 210 to 230 M. S. L. (see fig. 11 and fig. 12). Water will be released from the reservoir to the main canal by canal head regulator. The main canal will run along the contour parallel to the ridge and the surplus water on the main canal will be drained to the Nam Songkram (see fig. 13). Along the main canal of about 120 kilometres long one siphon, two highway crossings and one railroad crossing will be designed (see fig. 14). Many drainage siphons will be required when the main canal crosses small creeks. The major supply of water to the cultivation land is from the left bank of the main canal (see fig. 13) by lateral and farm turnout. Check regulators on the main canal have been provided at points to maintain the water at the required levels. Water flow into lateral and farm turnout is also controlled by regulators.

Irrigation project requires that full provision be made for field drainage, for the conveyance of storm runoff and excess irrigation water; these provisions have been included in the plan for the Udon-Nongkai Project. Natural creeks might be used for the main drain, but in some areas in which the topography is not suitable, artificial drainage must be designed.

Water Source.

The average annual flow of the Mekong River at Vientiane from the year 1925 to 1963 is 148,200 million cubic metres. After fifty years the active storage capacity in the Pa Mong Reservoir between elevations 210 and 230 M.S.L. (see fig. 15) will be reduced from 10,170 million cubic metres to 8,980 million cubic metres by sediment deposit or the reduction from 7 percent to 6 percent of the annual inflow. This is shown that after the completion of the Pa Mong Reservoir there will be enough water to fill the Nam Mong Reservoir with the storage capacity of 7,760 million cubic metres (see fig. 11) every year.

Distribution Works.

From the planning the Nam Mong Reservoir will become the headworks of the Udon-Nongkai Irrigation Project (see fig. 11 and fig. 12). The project plan was based on the contour map to scale 1: 250,000 having a 25 metre contour interval. The main canal is taken off from the reservoir at an elevation of 195 M.S.L. (see fig. 14) which is about 15 metres below the maximum elevation of the dead storage (see fig. 12). It is considered to be lined with the bottom slope of 1: 10,000 (see fig. 14, fig. 17 and fig. 18). In this planning the area on the left bank of the Nam Mong River will be irrigated by the left main canal taking off immediately from the main canal behind the reservoir (see fig. 13). This canal will carry the water over the Nam Mong River by flume (see fig. 18). Along the main canal four check regulations are designed (see fig. 19 and Table XI). The second part of the main canal, or from 77+700 km. to 120+000km. (see fig. 13), crosses the contours, drop structures might be needed to avoid canal in fill. This will require more details in topographic survey. The proposed general plan of irrigation on farm by furrow has been shown in fig. 21. The approximate dimensions of irrigation structures on the main canal and laterals have been shown in Table XI. (see also fig. 14).

The design of the drainage system must be based on:

I. The amount of drainage water from agricultural land.

II. The amount of excess rainfall not retained in the paddies.

In Prek Thnot Irrigation Project in Cambodia; one of the irrigation projects on the Lower Mekong Basin, the design of drainage system has been based on a canal capacity of 0.5 cms. per 1,000 hectares required for agricultural drainage.

Water Requirements.

The estimation of water requirements on the monthly basis is based on the design cropping pattern. The maximum water requirement is in March and the minimum is in September (see Table X). The average maximum is during the dry period. Field distribution efficiency is assumed to be 50 percent from July to December and 40 percent from January to June. The losses along the canal are assumed to be 15 percent. The annual water requirement is estimated at 2,500 million cubic metres.

Irrigable Area.

The project area is studied on the topographical map to the sale 1: 250,000. The area commanded by the irrigation canals totals about 950,000 rai (375,000 acres). This irrigable area would be about 5 times larger than the average size of irrigation project which has ever been taken in the Northeast.

Cost Estimate.

The pieces of land which are suitable for cultivation are disconnected, large pieces of unused land are found on the topographical map and because of the soil type, the project cost of the same size in this part will be higher than in the north and the central parts of the country. The construction cost of irrigation system is estimated at 65,000,000 U. S. dollars. This figure does not include the storage dam.

Benefits Effect of the Project.

After the completion of the project the rice yield is expected to increase from 200 kilograms per rai to about 400 kilograms per rai, and according to the design cropping pattern the yield of the other upland crops are also expected to increase in a certain amount. At the same time the cost of seeds, fertilizers, water, labour , taxes, interest on loans etc. are also expected to increase.

An extensive study has been made in order to estimate the probable benefits and costs per hectare of cultivated land of the Prek Thnot Irrigation Project in Cambodia which is on the same Lower Mekong Basin as the Udon-Nongkai Project; a rice yield of 2.25 tons and goundnuts yield of 2.00 tons per hectare have been assumed. A net profit of $99 per hectare can reasonable be expected ($15.6 per rai). This net benefit can be compared with $33 per acre (four months period of growing only) of the irrigation project on the Pembina River, studied by the International Joint Commission between Canada and the United States.

TABLE X: PROJECT WATER

Wet Season

Months	Rainfall mm.	Effective Rainfall %	Effective Rainfall mm.	Water Requirements mm. Main Rice	Double Rice	Fruit	Sugar-cane	Cotton	Dry Crop A	Dry Crop B	Suplement (net) mm.	Discharge cms.
April	97	75	73	40		128	128				16	26.7
May	223	75	167	240	40	135	135	137	146		31	52
June	216	75	162	195	200	131	131	133	145		28	46.5
July	200	75	150	193	250	134	134	135	139		48	64
August	248	75	186	242	242	130	130	130	130		45	60
Sept.	267	75	200	225	225	120	120	121	126		21	28.4
October	88	65	57	202		116	116	118			48	59
Dry Season												
November	17	80	13	40	40	103	103	105		89	37	50
December	4	90	3	200	200	99	99			85	85	104
January	8	90	7	187	187	99	99			99	82	137

TABLE X: PROJECT WATER

Dry Season - Continued

Months	Rainfall mm.	Effective Rainfall %	Effective Rainfall mm.	Water Requirements mm. Main Rice	Double Rice	Fruit	Sugar-cane	Cotton	Dry Crop A	Dry Crop B	Suplement (net) mm.	Discharge cms.
February	20	90	16	185	185	97	97			97	79	132
March	40	90	36	229	229	121	121			121	84	140

Note: Field distribution efficiency

From July to December 50 percent

From January to June 40 percent

Losses along canal 15 percent

Computed Consumptive Use is adjusted to the local data.

TABLE XI: DETAILS OF DISTRIBUTION WORKS

MAIN CANAL

Canal				Check Regulators			
Distance km.	Q cms.	b m.	d m.	Q cms.	b m.	d m.	No. of Gate
0-0+200	140	8	5.60				
14+200	127.3	8	5.20				
26+700	103.5	7	5.00				
				81.8	3	4.65	2
52+700	81.8	7	4.50				
				63.7	3	4.20	2
77+700	63.7	6	4.00				
90+200	52.4	5	4.00				
				24.6	4	3.20	1

LATERALS

		Left Bank					Right Bank				
		Lateral		Head Regulators			Laterals		Head Regulators		
No.	Q cms.	b m.	d m.	b m.	d m.	No. of Gates	b m.	d m.	b m.	d m.	No. of Gates
	12.7	2.40	2.40	2.50	2.55	1					
1L	23.8						3.10	3.10	4.00	3.20	1
2L	21.7						3.00	3.00	4.00	3.20	1
3L	18.1						2.80	2.80	3.00	3.00	1
IR	11.3						2.40	2.40	2.50	2.75	1
4L	27.8						3.20	3.20	4.00	3.35	1

* SEE NOTE ON PAGE 97.

Note to Table XI - Details of Distribution Works

Q is the discharge in cubic metre per second.

d is the depth of water in metre.

b (is the base width for canal in metre.
  (is the width for regulator in metre.

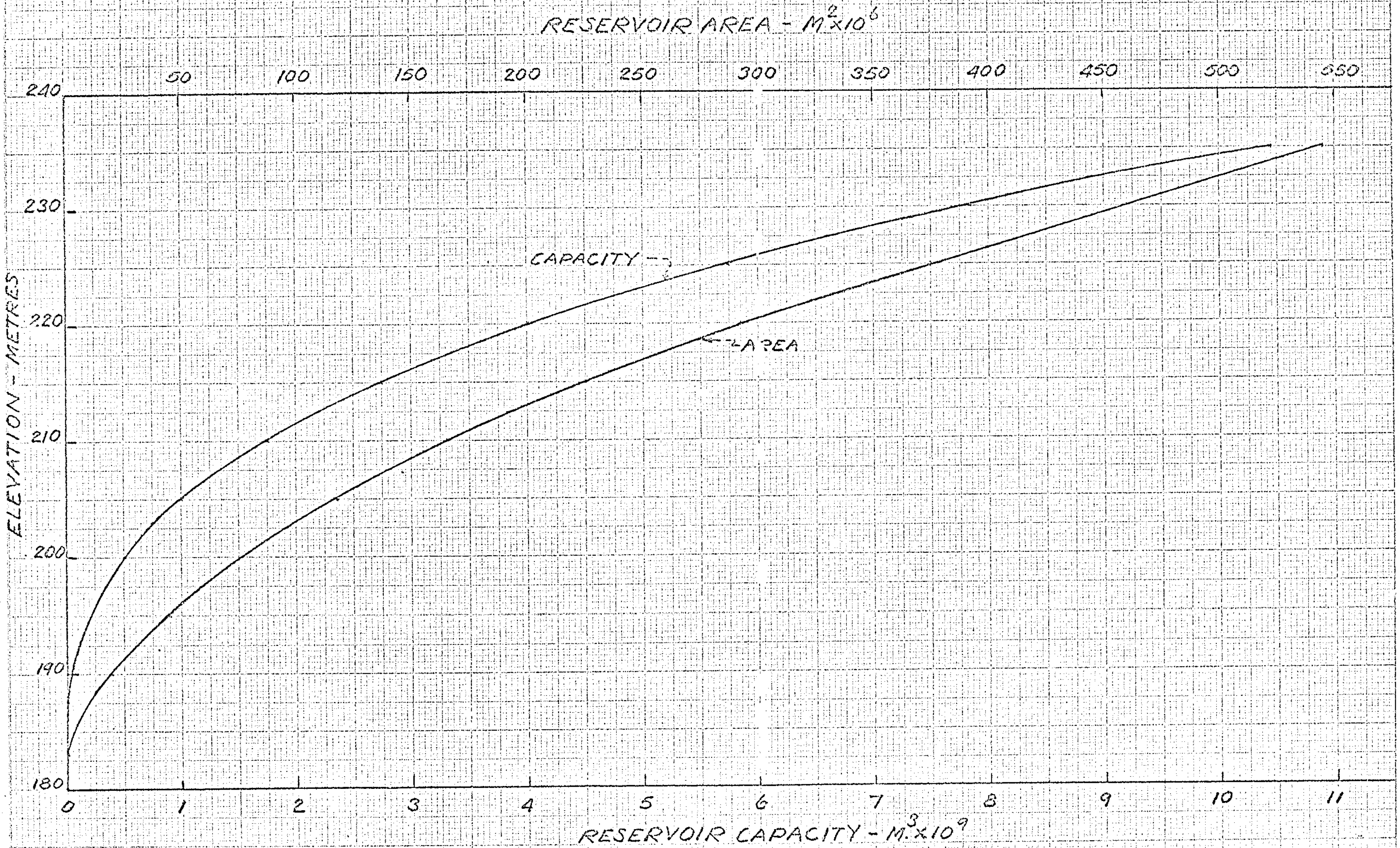


FIG. 11 NAM MONG RESERVOIR
AREA-CAPACITY CURVE

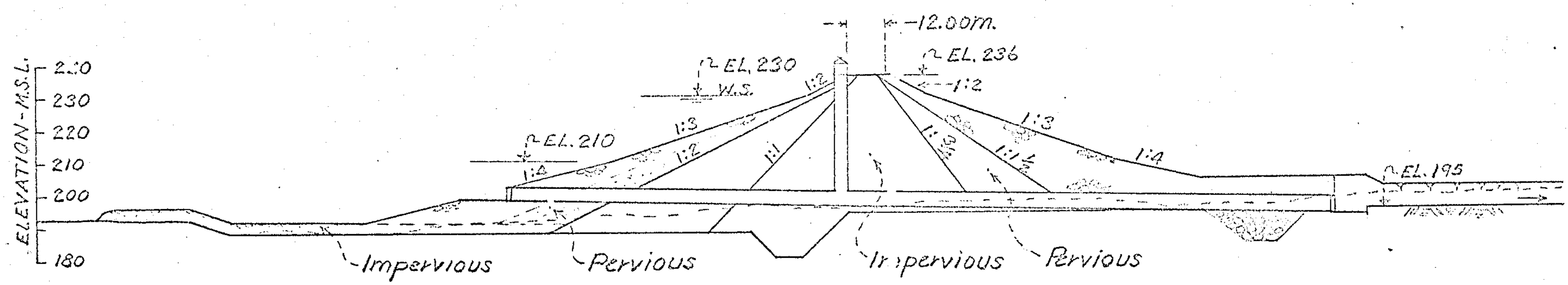
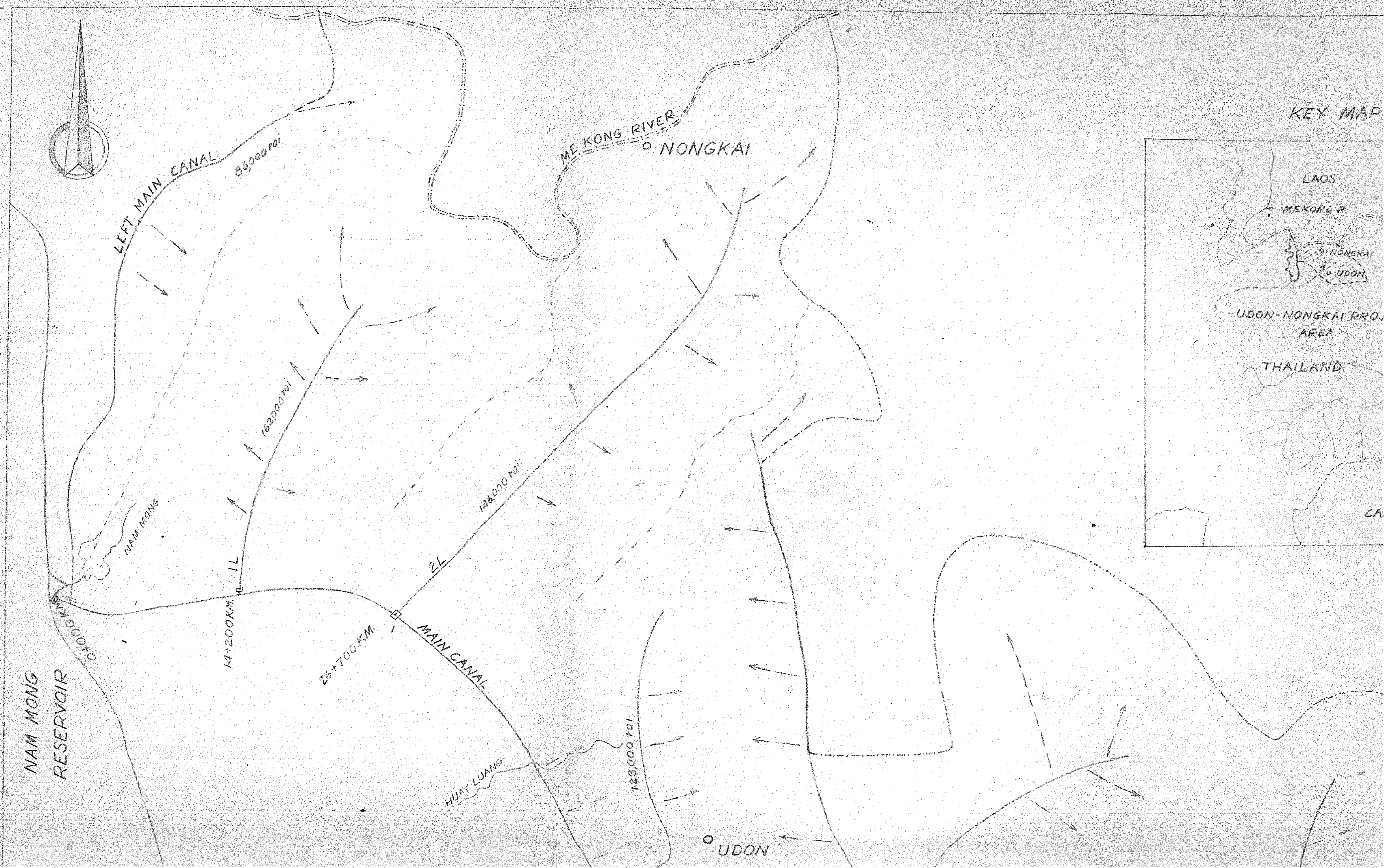


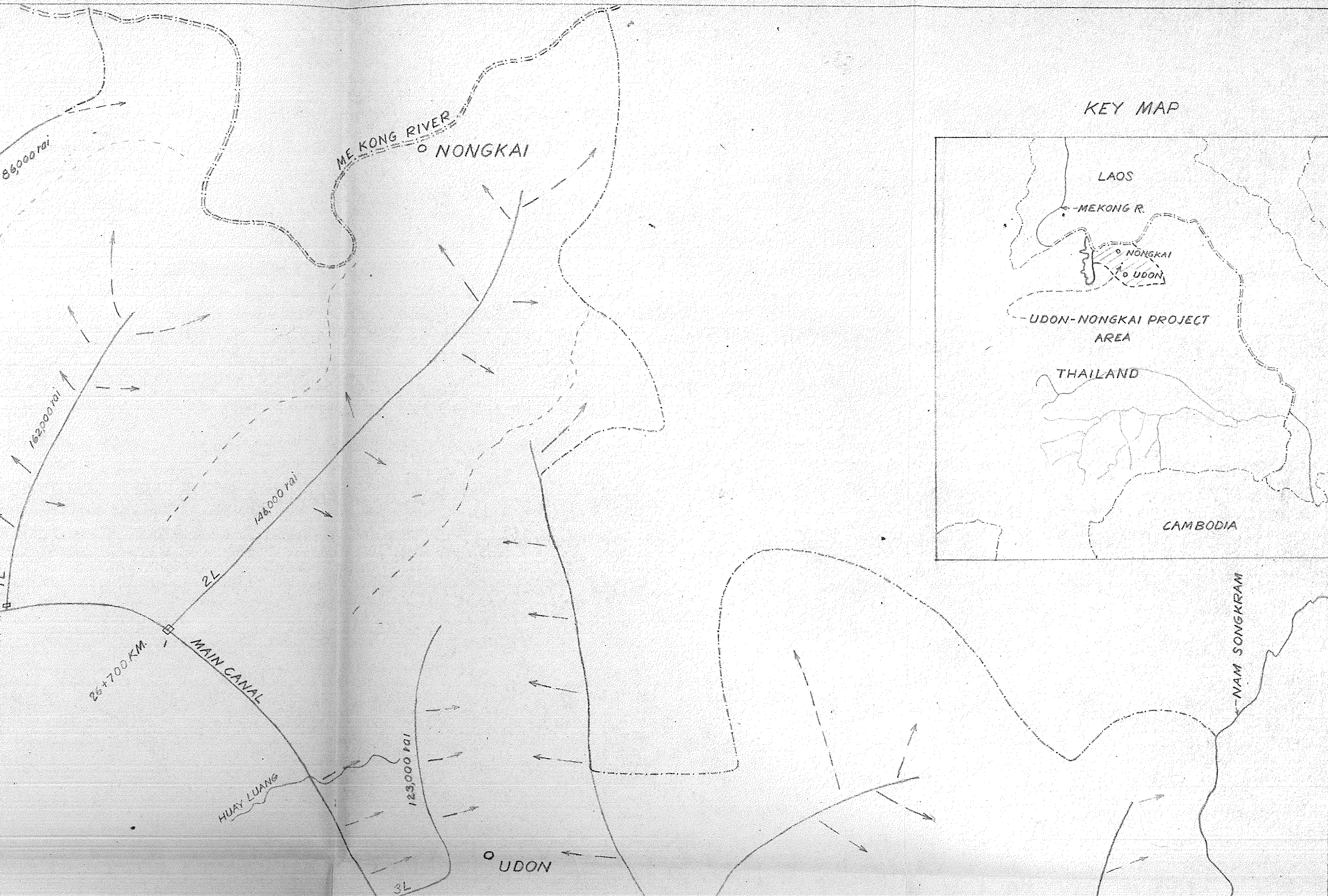
FIG. 12 PROPOSED CROSS SECTION

OF

NAM MONG DAM



LEFT MAIN CANAL
86,000 rai
ME KONG RIVER
NONGKAI
162,000 rai
146,000 rai
NAM MONG
1L
2L
14+200KM.
26+700KM.
0+000KM.
MAIN CANAL
NAM MONG RESERVOIR
HUAY LUANG
123,000 rai
UDON
KEY MAP
LAOS
MEKONG R.
NONGKAI
UDON
UDON-NONGKAI PROJ
AREA
THAILAND


86,000 rai
ME KONG RIVER
NONGKAI
162,000 rai
146,000 rai
2L
26+700 KM.
MAIN CANAL
HUAY LUANG
123,000 rai
UDON
3L
KEY MAP
LAOS
MEKONG R.
NONGKAI
UDON
UDON-NONGKAI PROJECT AREA
THAILAND
CAMBODIA
NAM SONGKRAM

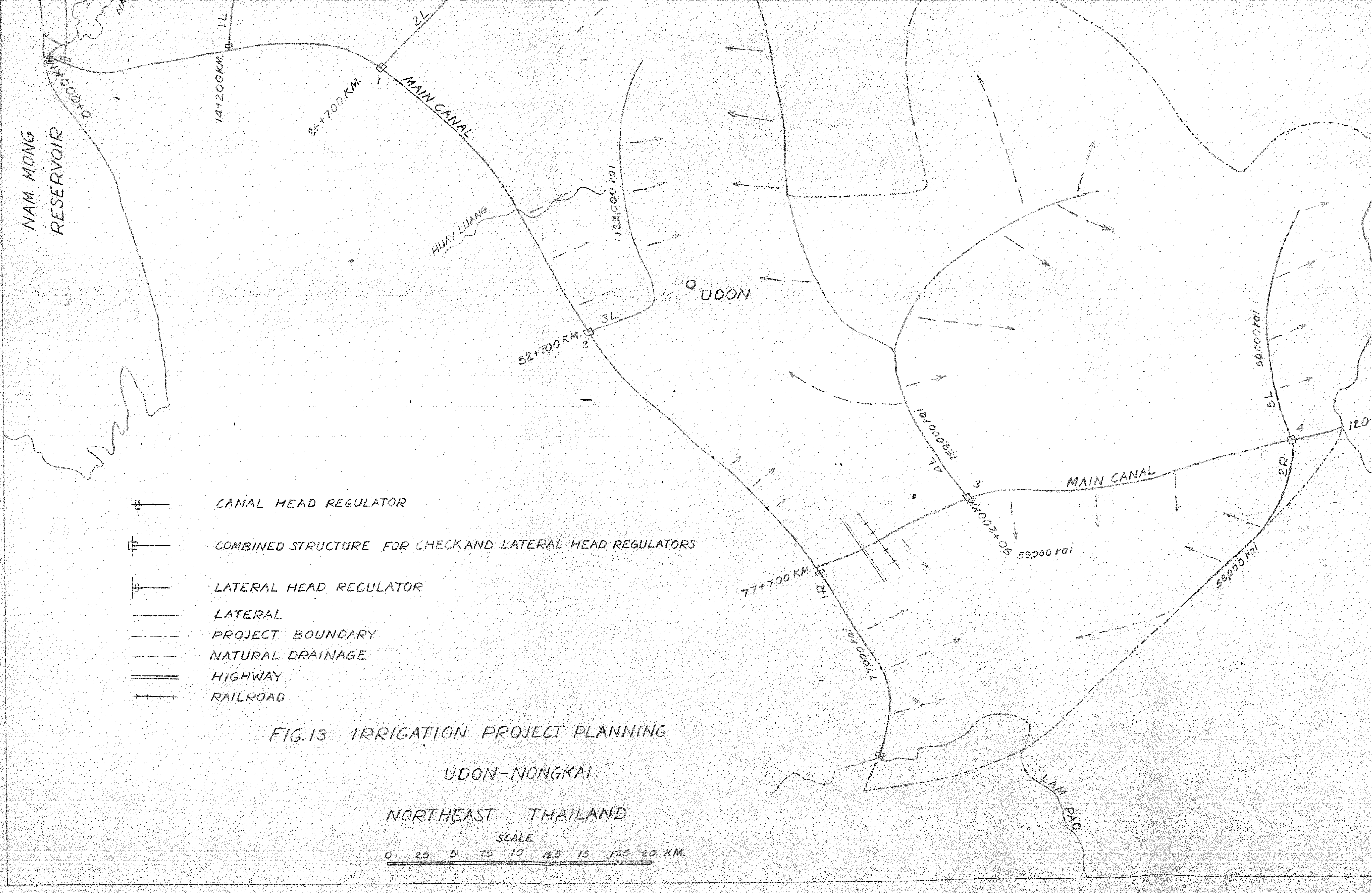
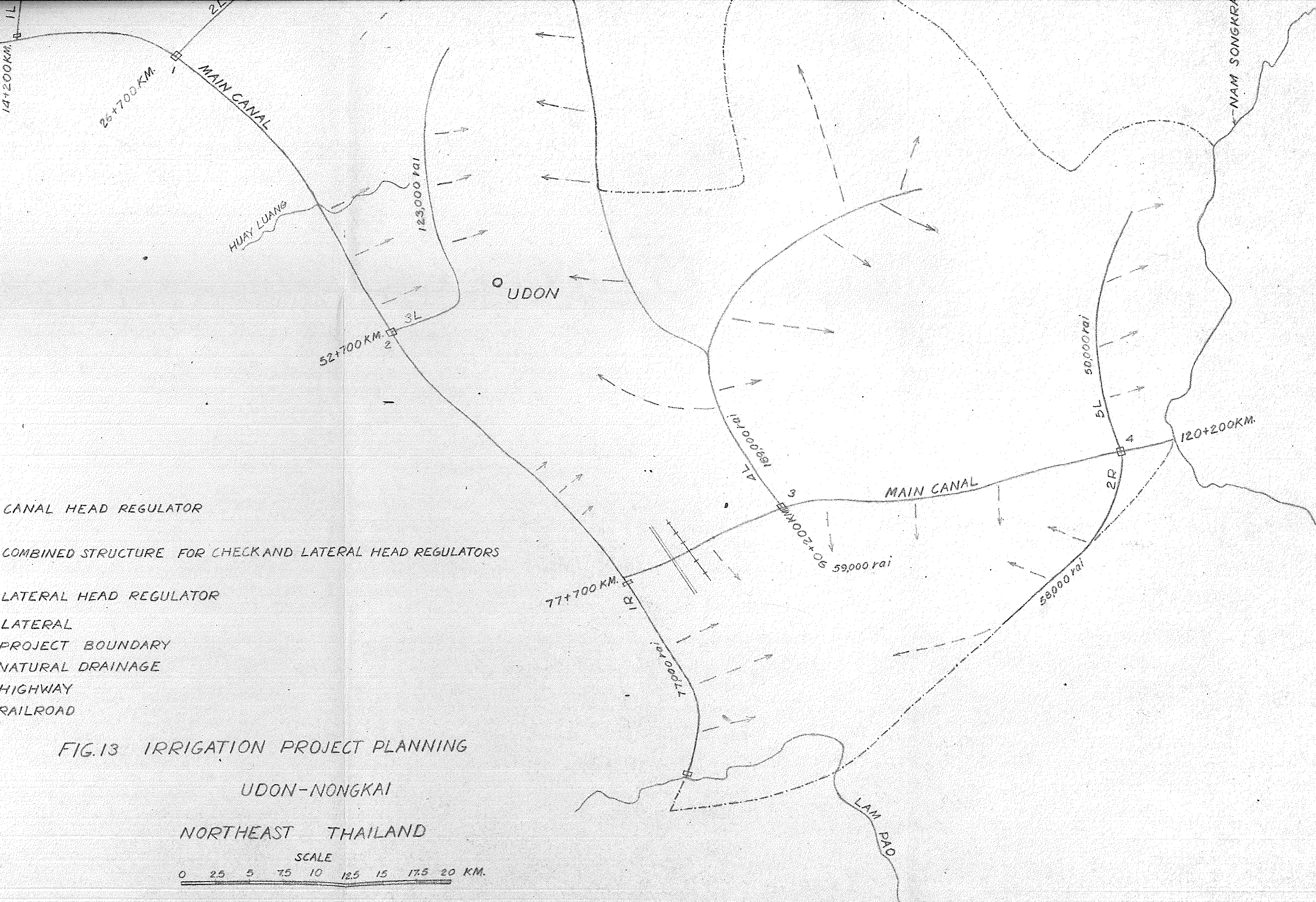


FIG. 13 IRRIGATION PROJECT PLANNING

UDON-NONGKAI

NORTHEAST THAILAND



CANAL HEAD REGULATOR

COMBINED STRUCTURE FOR CHECK AND LATERAL HEAD REGULATORS

LATERAL HEAD REGULATOR

LATERAL

PROJECT BOUNDARY

NATURAL DRAINAGE

HIGHWAY

RAILROAD

FIG. 13 IRRIGATION PROJECT PLANNING

UDON-NONGKAI

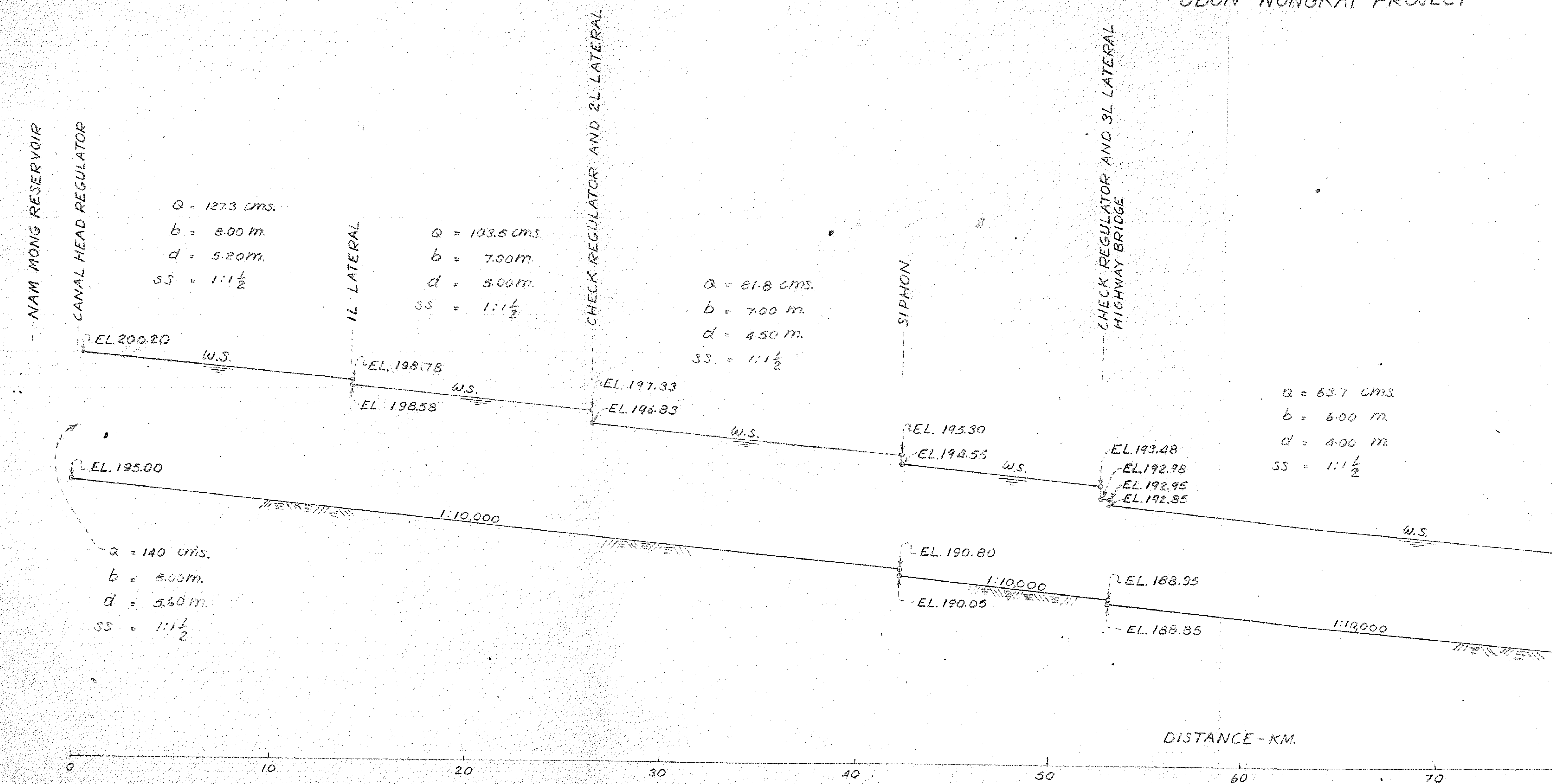
NORTHEAST THAILAND

SCALE

0 2.5 5 7.5 10 12.5 15 17.5 20 KM.

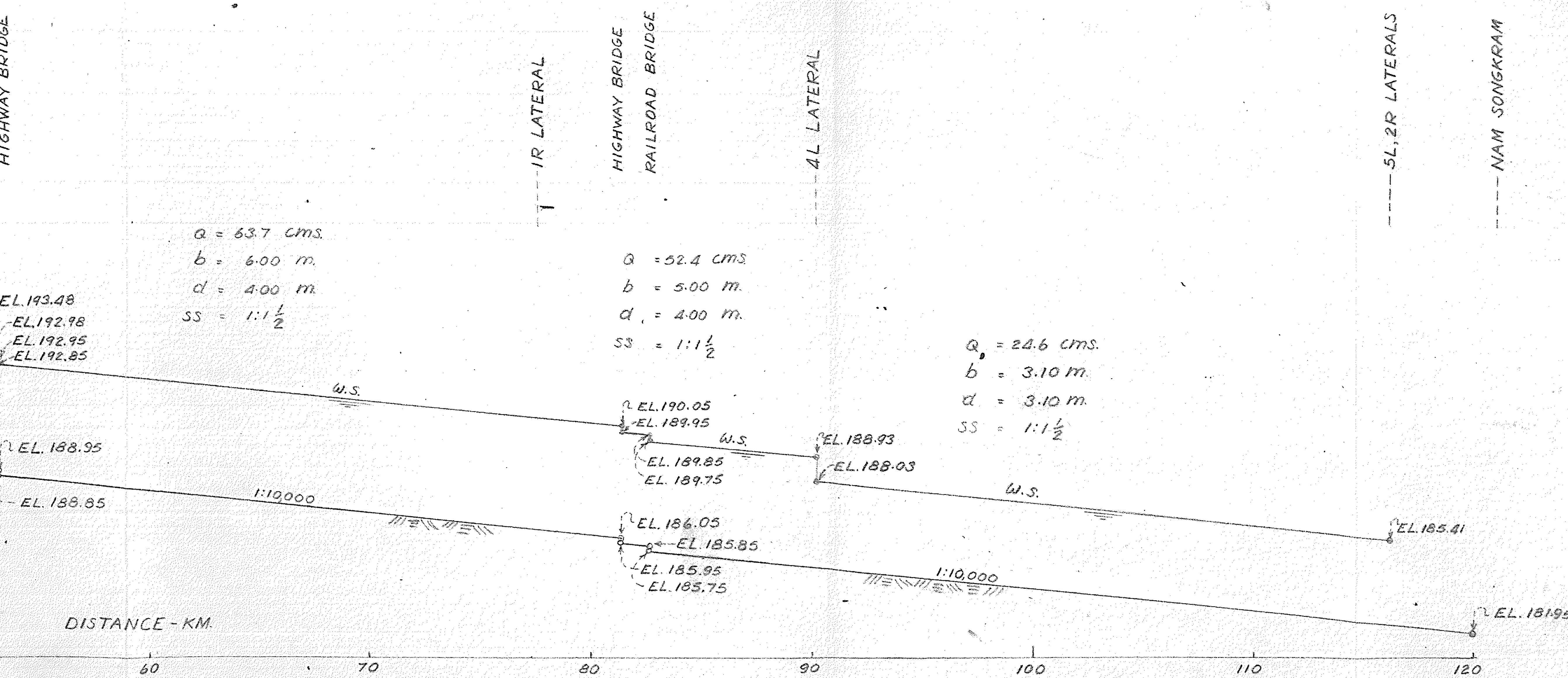
FIG.14 LONGITUDINAL PROFILE OF MAIN CANAL

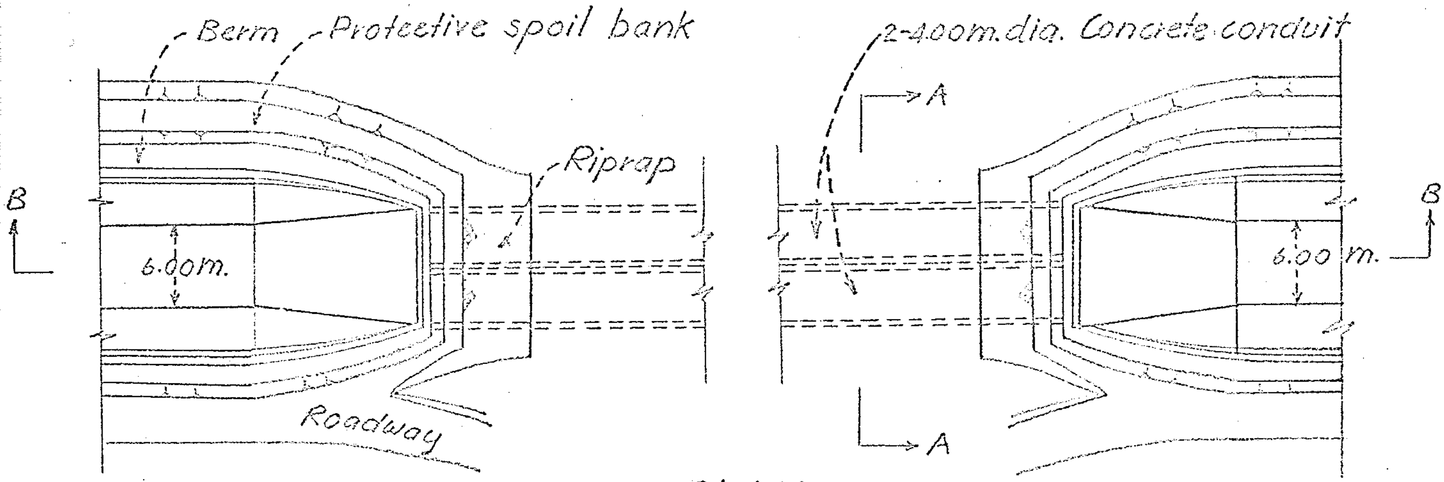
UDON-NONGKAI PROJECT



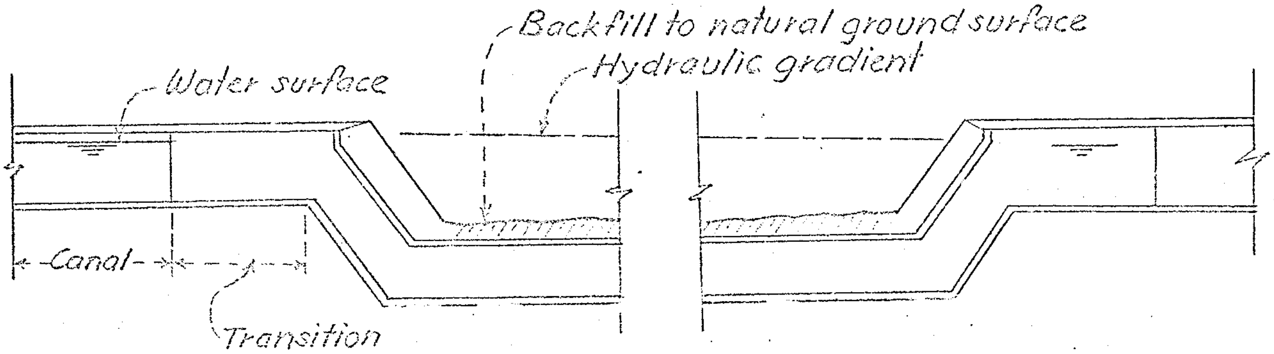
ONGITUDINAL PROFILE OF MAIN CANAL

UDON - NONGKAI PROJECT

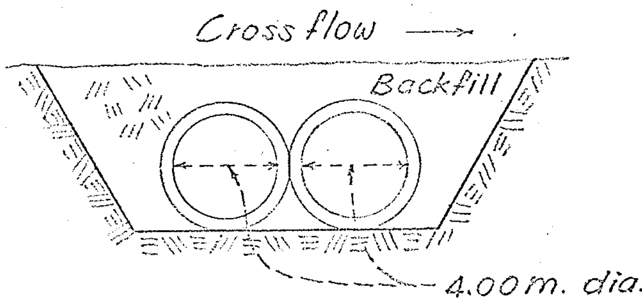




PLAN



SECTION B-B



SECTION A-A

FIG. 15 HUAY LUANG SIPHON

UDON-NONGKAI PROJECT

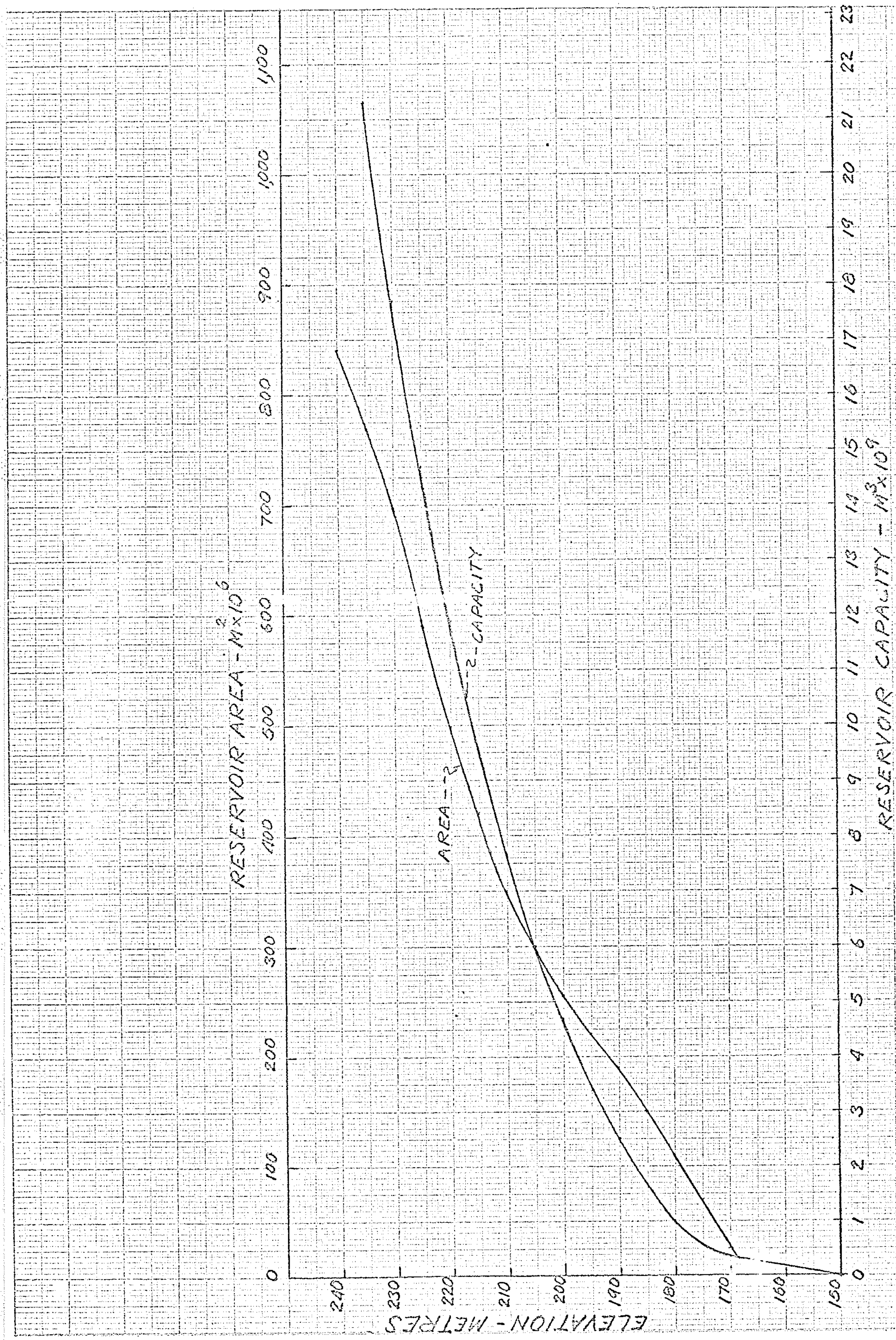
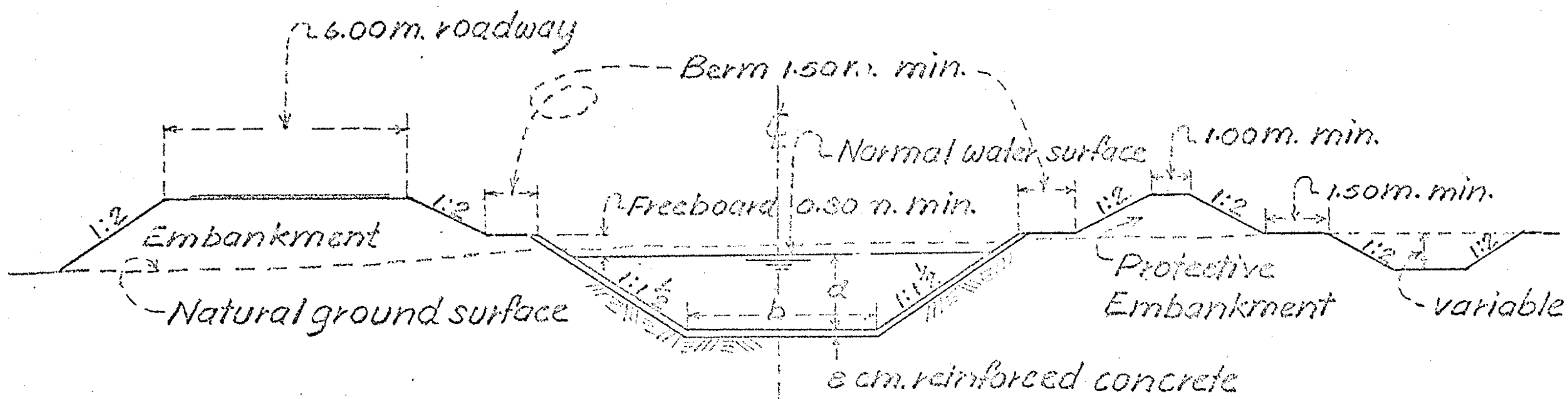


FIG. 13 PA MONG RESERVOIR

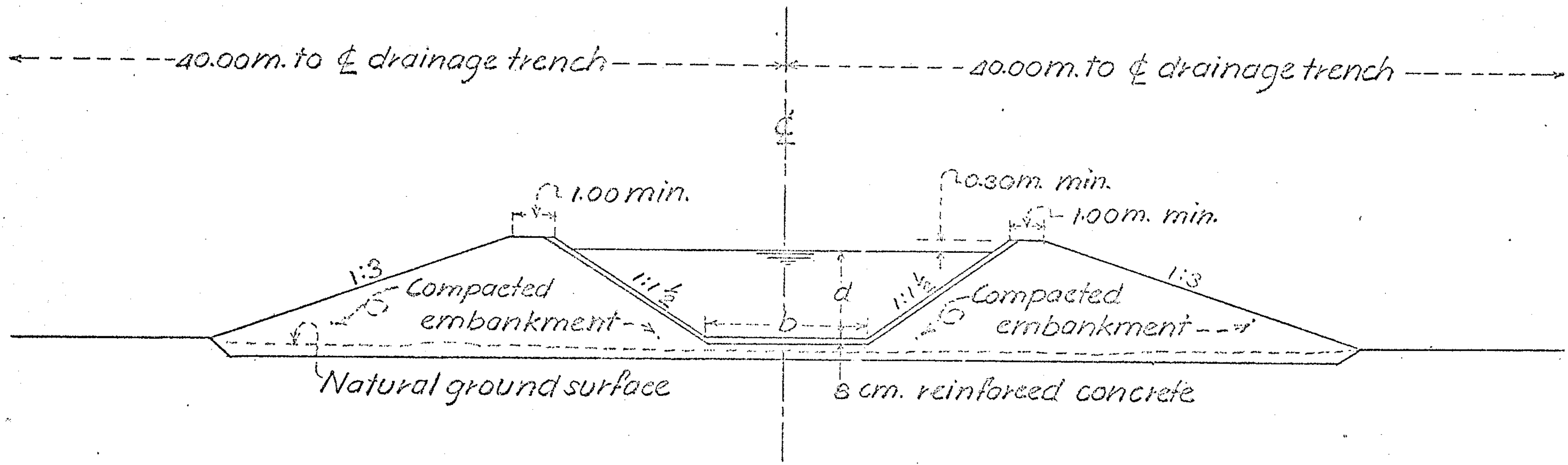
AREA CAPACITY CURVE



b = Canal base width

d = Depth of water in canal

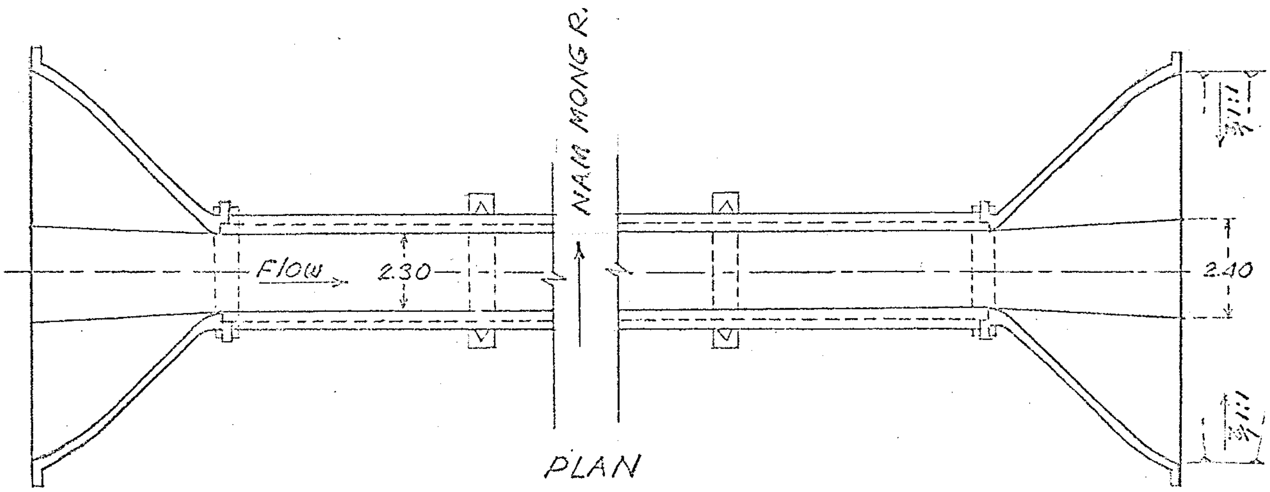
FIG. 17 TYPICAL CROSS SECTION OF CANAL

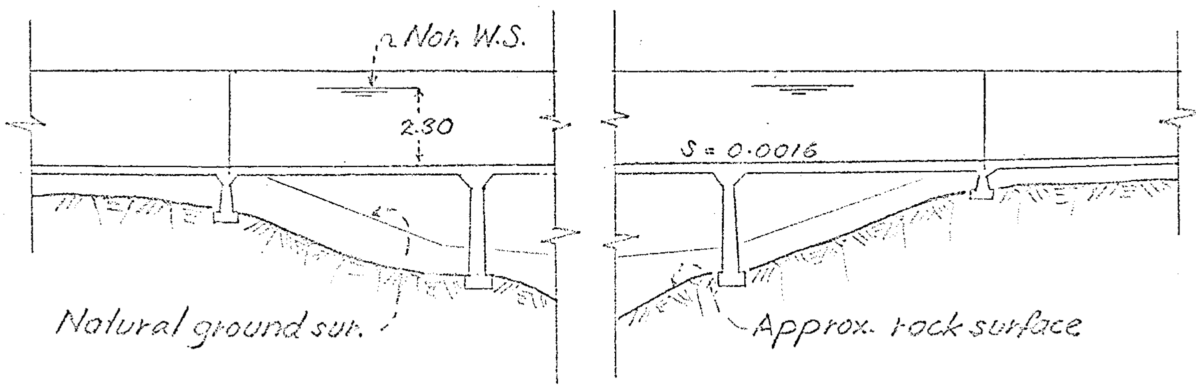


d = Depth of water in canal

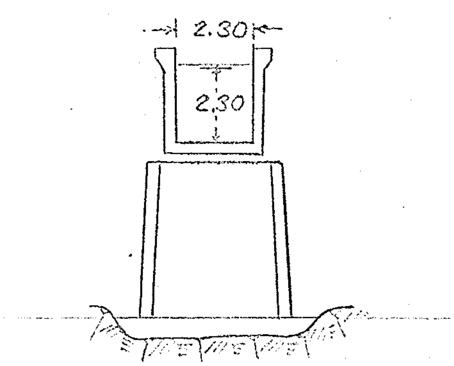
b = Canal base width

FIG. 18 TYPICAL CROSS SECTION OF CANAL





LONGITUDINAL SECTION ON ℄

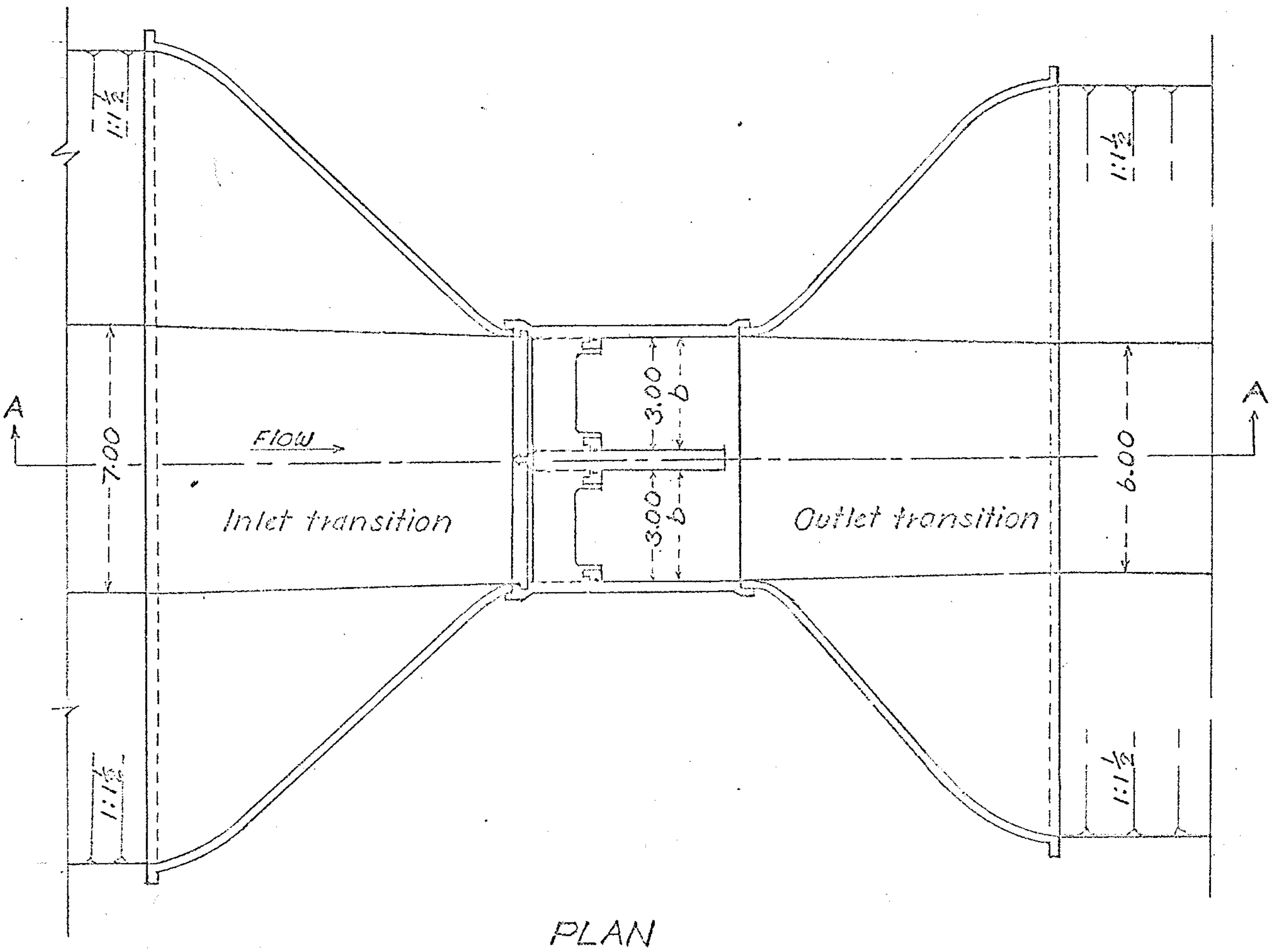


TRANSVERSE SECTION

All dimensions are metres except otherwise shown.

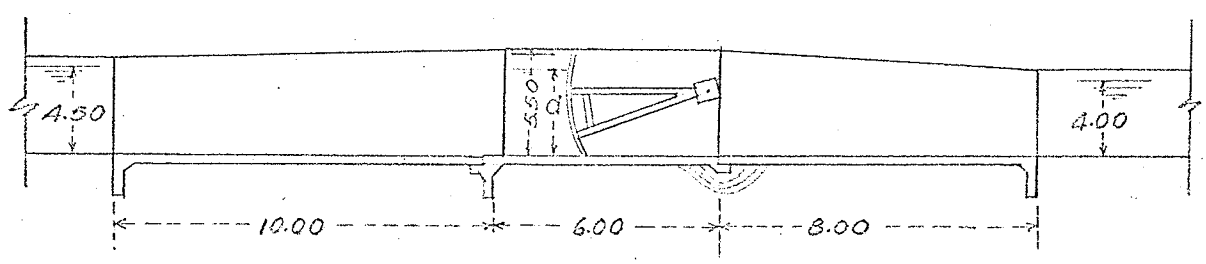
FIG. 19 NAM MONG FLUME

UDON-NONGKAI PROJECT



PLAN

All dimensions are metres except otherwise shown.



SECTION A-A

FIG. 20 GENERAL PLAN AND SECTION OF CHECK (KM. 77+700)

UDON-NONGKAI PROJECT

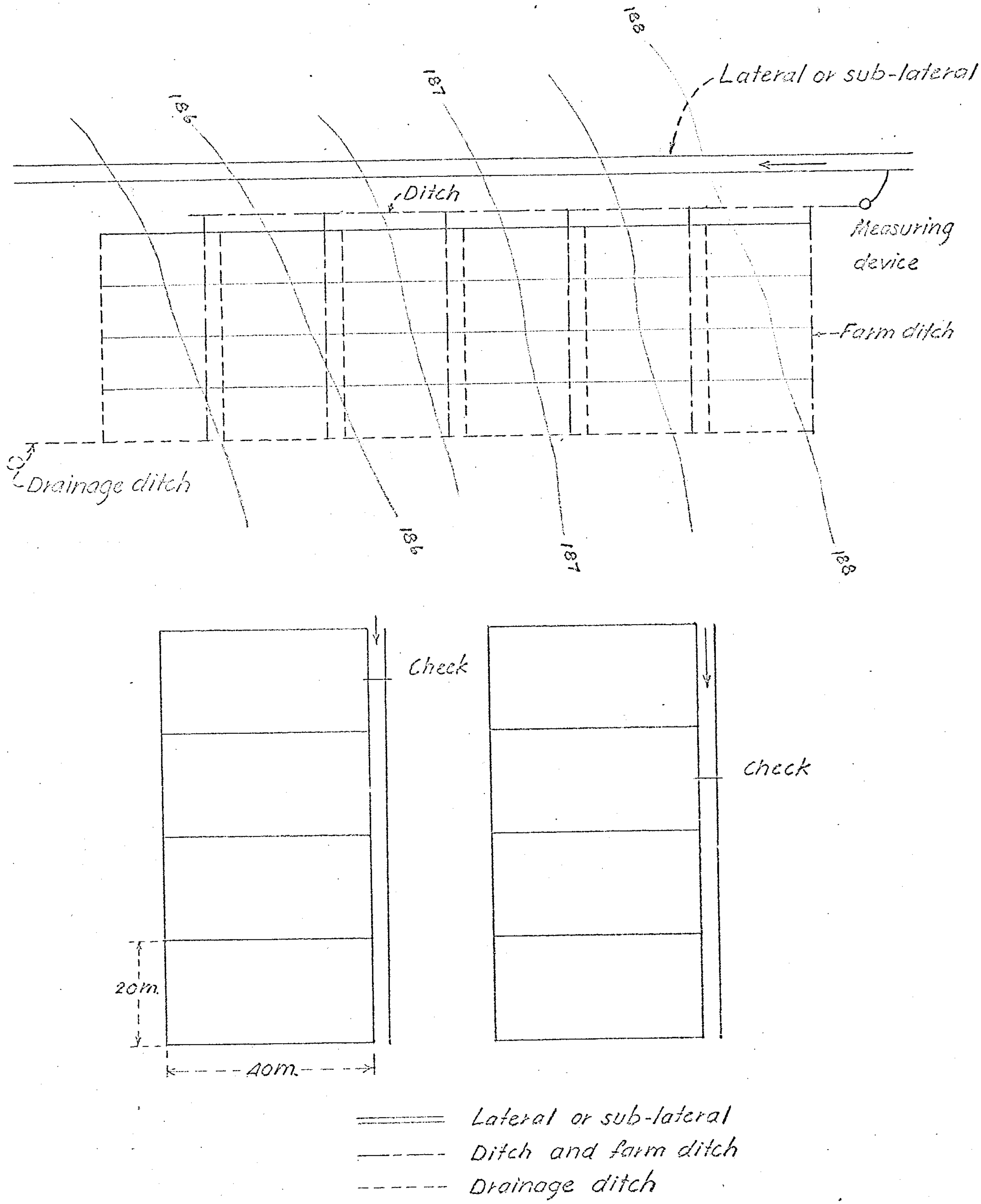


FIG. 21 PROPOSED DEMONSTRATION FARM

UDON-NONGKAI PROJECT

CHAPTER IX

CONCLUSION AND RECOMMENDATIONS

It is concluded that the available water in the Northeast Basin will become insufficient for the development of agricultural land of the region by means of irrigation in the future. However, there is an adequate supply of water on the Mekong River. The Udon-Nongkai Irrigation Project is one of several projects which are being planned on the Lower Mekong Basin. The major part of available water will be from the Mekong mainstream and the minor part will be from the Nam Mong tributary. To irrigate this area by gravity method is possible. It is expected that this large irrigation scheme would become the first priority of investigation among the others in the Northeast when the water from the Pa Mong Reservoir is available. This might be due to the low cost of diversion. The increase in cropping intensity by rotation of crops with the use of yield improvement factors will make this scheme more attractive. The agricultural experiments and demonstration farms play an important role in the development of the cropping pattern.

The planning and the construction of this project might be advanced so that the operation could be started as soon as the Pa Mong and the Nam Mong Reservoirs are completed. The more advanced the more benefits are expected to accrue to this region.

The planning of this irrigation project might be divided into two stages: the first stage would depend on the available hydrological data of the Nam Mong tributary alone and should be developed more quickly. The second stage will be the full scale development after the completion of the Pa Mong Reservoir. This might be a proper arrangement for the budget of Thailand.

Because of the ample amount of available water at Pa Mong and Nam Mong Reservoirs the extension of the following irrigation schemes would be possible in the future:

1. The irrigable area of Udon-Nongkai Project may be extended to the east to Nam Oon Irrigation Project with an additional area of about 200,000 rai (79,000 acres). The water requirement is estimated at 600 million cubic metres (see fig. 22-1).

2. Water from the Nam Mong Reservoir might be diverted into Lam Pao. This additional water of about 1,400 million cubic metres might extend the irrigated area downstream of Lam Pao Reservoir of about 300,000 rai (118,000 acres) (see fig. 22-2).

3. The minimum elevation of the active storage of Nam Mong Reservoir is at 210 M.S.L., diversion of water from Nam Mong Reservoir to the Nam Pong River (at upstream of Nam Pong Irrigation Headworks) by gravity method is possible. This additional water will increase the irrigated area on the Nam Pong Irrigation Project during the dry season (see fig. 22-3).

4. If a dam would be built on the Chi River downstream of the Nam Pong outlet, water along the Nam Pong River could be lifted up over a head of about 25.00 metres by pumping and then a vast area on the Mune and the Chi Rivers of about 1,500,000 rai (590,000 acres) could be irrigated by gravity method (see fig. 22-4). This will require a main canal of one hundred kilometres before arriving at the major irrigable area.

5. The alternative of plan 4. will be to divert the water along the Lam Pao. This additional water must flow through the spillway of the Lam Pao Reservoir. The dam should be built on the Chi River downstream of the Lam Pao outlet and water must be lifted up by pumping for a head of about 50.00 metres and then irrigation on the triangular area of the Chi and the Mune Rivers by gravity method will be possible. (see fig. 22-5). This plan will require a shorter length of main canal than 4.

The amount of diversion water required to irrigate on a triangular area is estimated at 7,500 million cubic metres.

The total diversion requirements of Udon-Nongkai and the other proposed projects comparing with the annual runoff of the Mekong River at Vientiane has been shown in Fig. 23.

These schemes are a part of the medium term water requirements in Northeast Thailand which should be studied in more detail in cooperation with the water resources planning on the Lower Mekong Basin.

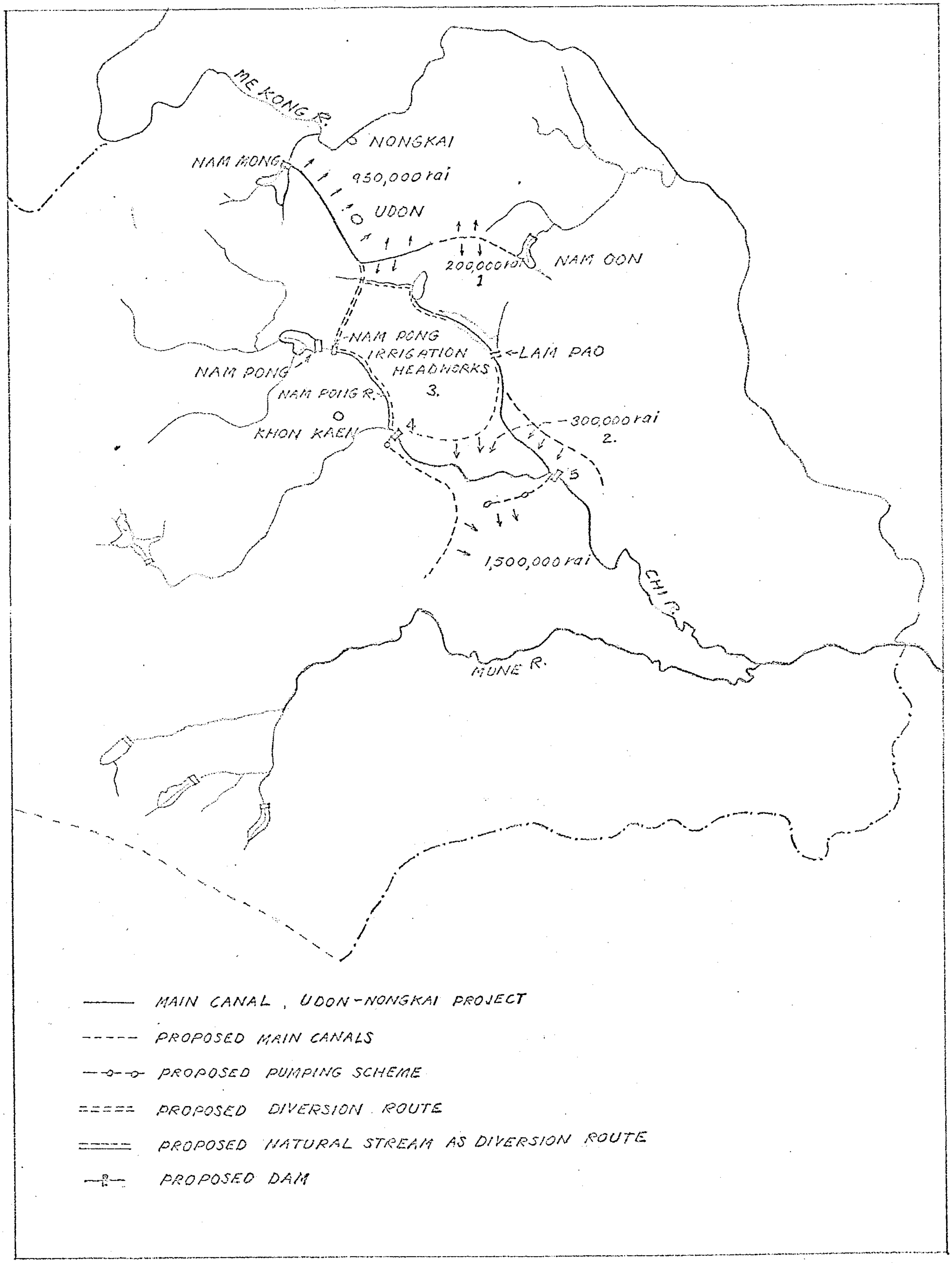


FIG. 22 PROPOSED DIVERSION SCHEME

NORTHEAST THAILAND

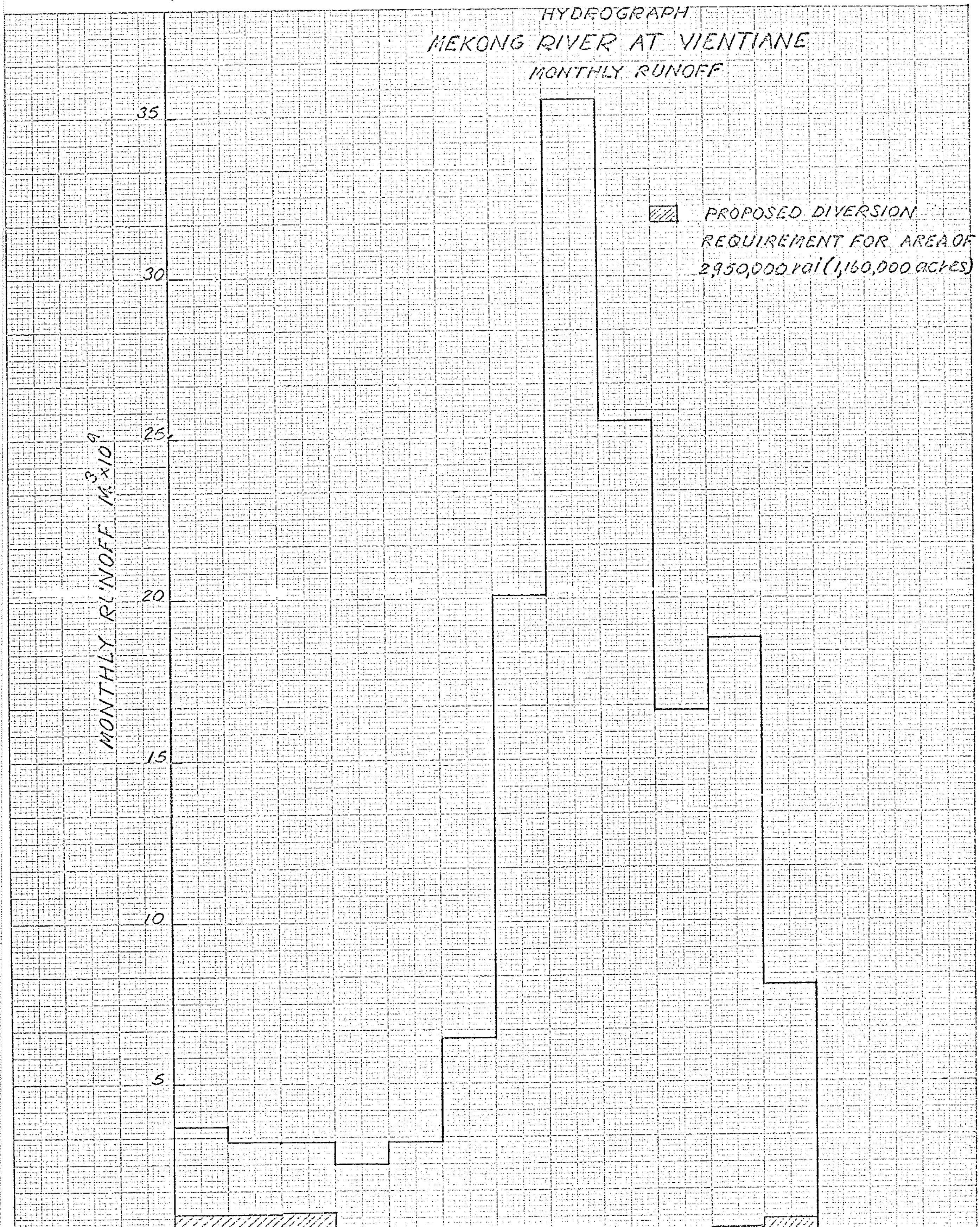


FIG. 23 COMPARISON OF DIVERSION REQUIREMENT AND ANNUAL RUNOFF

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Abbett, R. W. - American Civil Engineering Practice. Vol. II. New York: Wiley, 1956.

2. Attanatoe, J. - "Planning of Tank Irrigation Project in N. E. Region," Northeast Irrigation Project, Royal Irrigation Department, Thailand.

3. Bankok Bank Limited. "A Statistical Portrait of Thailand Economy," Second ed. Bangkok, Thailand, 1964.

4. Committee for Coordination of Investigations of the Lower Mekong Basin, "Annual Reports," 1964-66.

5. Committee for Coordination of Investigations of the Lower Mekong Basin." Seminar on Agricultural Experimentation and Demonstration on Irrigated Land," 1966.

6. David, C. V. - Handbook of Applied Hydraulics. New York and London: McGraw Hill Book Company, 1942.

7. Gillup, D. L., and others. - "A Soil Survey Interpretation Handbook for Northeast Thailand," Part II Land Capability Classification. Department of Land Development in Cooperation with FAO and USOM, Bangkok, Thailand, 1967.

8. Hagan, R. M., and others. - Irrigation of Agricultural Lands. No. 11 in the series of Agronomy. Madison, Wisconsin: ASA Publisher, 1967.

9. Houk, I. E. - Irrigation Engineering. 2 Vols. New York: Wiley, 1951-56.

10. Indian Journal of Power and River Valley Development. "The Mekong Project Number," Vol. XVI, Calcutta, India, 1966.

11. International Bank for Reconstruction and Development "Programme for the Development of Irrigation and Agriculture in West Pakistan," Comprehensive Report. Sir Alexander Gibb & Partners, International Land Development Consultants N. V., London and Arnhem, 1966.

12. Israelsen, O. W. and Hansen, V. E. - Irrigation Principle and Practices. New York: Wiley, 1962.

13. Kambhu, M.L.X. - "Water Resources Development in Thailand and Its Policy," Water Resources Series No. 28. United Nations Publication, 1965, pp. 340-51.

14. Kuiper, E. - "Ebro Basin Water Resources Deveopment," Madrid, Spain, 1964.

15. Kuiper, E. - Water Resources Development. London: Butterworths, 1965.

16. Leliavski, S. - Design Textbook in Civil Engineering. Vol. 1 Irrigation Engineering: Canals and Barrages. Chapman & Hall, 1965.

17. Ministry of Agriculture. "Rice Economy of Thailand," Bangkok, Thailand, 1964.

18. Moormann, F. R., and others. - "Soils of Northeast Thailand," Land Development Department, Bangkok, Thailand, 1964.

19. Royal Irrigation Department. "Hydrology and Water Studies of the Lam Nam Oon Project," Bangkok, Thailand, 1965.

20. Schaaf, C. H. and Fifield, R. H. - The Lower Mekong. New Jersey: D. Van Nostrand Company, 1964.

21. Scouille, O. J. and Thieme, A. Jr. - "Agricultural Development in Thailand," USOM, Bangkok, Thailand, 1964.

22. United Nations. "Flood Control Series," No. 3, 14 and 15. United Nations Publication, 1952-60.

23. White, G. F., and others. - "Economic and Social Aspects of Lower Mekong Development." A Report to the Committee for Co-ordination of Investigation of the Lower Mekong Basin, 1962.

24. Year Book. - "Far Eastern Economic Review," Hongkong, 1967, pp. 361-70.

25. Zimmerman, J. D. - Irrigation. New York: Wiley, 1966.

APPENDIX

1 Hectare	=	2.5	Acres
1 Acre	=	2.54	Rai
1 Mile	=	1.6	Kilometres
1 Metre	=	3.28	Feet
1 Acre-foot	=	43,560	Cubic Feet
	=	1,235	Cubic Metres
1 Million m^3.	=	810	Acre-ft.
M.S.L.	=	Mean Sea Level	
210 M.S.L.	=	210 metres above mean sea level.	