REPORT ON THE PRELIMINARY STUDIES
OF
THE COMPREHENSIVE DEVELOPMENT
OF
THE NAM GAM BASIN

DECEMBER 1962

JAPANESE INVESTIGATION TEAM
ON THE NAM GAM PROJECT

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LETTER OF TRANSMITTAL

Tokyo, December 1962

His Excellency, Mr. Masayoshi Ohira
Minister of Foreign Affairs, Government of Japan

Excellency,

As the leader of the Japanese Government Investigation Team on the Nam Gam Project, I have the honor of presenting herewith the comprehensive report on the investigations which the Team has undertaken.

The Nam Gam basin, in which the Team has conducted investigations and prepared preliminary designs, lies in the northeastern area of Thailand, which borders on the northern part of Laos, and is one of the areas in the Mekong basin where development is considered to be of immediate importance.

As a result of our studies and investigation it has been found that an extremely favorable multi-purpose project can be developed in the Nam Gam basin.

The Team hopes that the result of its studies and investigations will contribute to an early development of the said area and that it may act as a pilot project for the future development of the Lower Mekong Basin.

Yours respectifully,

T. Tokuno
Takeshi Tokuno
Leader, Japanese Investigation Team
on the Nam Gam Project

F O R E W O R D

The Japanese Investigation Team on the Nam Gam Project was organized as part of the Japanese government's contribution to the United Nations' sponsored coordinated investigations of the Lower Mekong Basin.

The objectives of the Team are the establishment of a multi-purpose development plan for the Nam Gam basin, a tributary of the Mekong River in Thailand, and the preparation of preliminary designs for hydro-electric power generation by means of a multi-purpose dam to be built on the Nam Pung, a tributary of the Nam Gam, as well as, for irrigation by utilization of Nam Pung Reservoir and Lake Nong Han.

A general description of the scheme for the development of the Nam Gam basin is given in the Comprehensive Reconnaissance Report on the Major Tributaries of the Lower Mekong Basin, dated September 1961, of the Japanese Government.

However, immediately after the presentation of the said report it was found that there were serious errors in the hydrological data, obtained from the authorities of Thailand, which were used in determining the development scheme of the Nam Gam basin and that the development possibilities were over-estimated. Under these circumstances, the Team was compelled to re-examine the hydrological data, make corresponding corrections to the development plan as early as possible and communicate the corrections to the people concerned.

The first field studies were conducted in October 1961 by a team of 4 who returned to Japan after consulting the Government of Thailand on field investigations which were to be continued in the rainy season.

The second field studies by a team of 15 members were conducted in December 1961. This team conducted investigations of an extensive area. These included topographic surveys, borings, investigations of embankment materials and geological surveys essential for the designing of the Nam Pung multi-purpose dam. In addition, surveying and soil studies of the proposed irrigation district were made, as well as, surveying necessary for flood control and water utilization of Lake Nong Han. The team also conducted other various investigations necessary for the establishment of electricity utilization program and crop rotation program of the irrigation district. As a result of efforts to obtain hydrological data the Team was able to locate observation records for the past 13 years that would provide the data for computation of the daily flow from the Lake Nong Han.

The Team returned to Japan at the end of March 1962 after completing the field surveys.

As a result of analytical studies of the hydrological data obtained from the authorities of Thailand, it has been found that the run-off in the Nam Gam basin and the proposed dam site on the Nam Pung corresponds to 25-41 per cent of the figures contained in the Comprehensive Reconnaissance Report on the Major Tributaries of the Lower Mekong Basin of the Japanese Government.

Re-examination of the plan for development of the Nam Gam basin in accordance with the data collected and corrected hydrological data, resulted in the formulation of the first stage development scheme of the Nam Gam basin, and it was submitted to the Committee for Coordination of Investigation of the Lower Mekong Basin in August 1962 by the Japanese Government as an Interim Report on Preliminary Studies of Nam Gam.

With the determination of the scale of the first stage development, there arose the necessity to conduct supplementary field studies with respect to power transmission and sub-stations, dam construction and crop rotation in the irrigation area. Therefore, the third field studies (Supplementary Studies) were made in September 1961 by a team of six members. The team returned to Japan in October 1962 after consulting with the Government of Thailand.

The result of the investigations indicated that the early completion of the first stage development of the Nam Gam basin will be most advantageous in view of the present situation in the Mekong basin and that it will be the most suitable pilot project for the promotion of the development of the entire basin of the Mekong.

The investigations also revealed that it would be possible to carry out the second and third stage developments in the Nam Gam basin when the development of the main stream of the Mekong and other tributaries progresses in the future.

This Report contains the conclusions of the studies and investigations. In presenting this Report, the Team wishes to express its heartfelt thanks to ECAFE, the Committee for Coordination of Investigation of the Lower Mekong Basin and the Government of Thailand for the various facilities that have been extended to the Team.

Below is the list of the names, duties and posts of the members of the Team who took part in the three field studies.

Name	Profession	Post
(1) First (rainy season) Survey		
Nobumichi Shuto	(Economics)	Electric Power Development Co., Ltd.
Hitoshi Yoshinaga	(Civil engineer)	"
Shigekatsu Watanabe	(Agricultural engineer)	Agriculture-Forestry Ministry
Gakuji Kimura	(Pedologist)	"

Name	Profession	Post
(2) Second (dry reason) Survey		
Takeshi Tokuno (Leader)	(Civil engineer)	Electric Power Development Co., Ltd.
Hitoshi Yoshinaga	(")	"
Nasuo Toyama	(")	"
Hamaaki Aoki	(Electrical engineer)	"
Hiroshi Suetomi	(Geologist)	"
Mitsuhiro Ohata	(Civil engineer)	"
Gakuji Kimura	(Pedologist)	Agriculture-Forestry Ministry
Hiroshi Kato	(Irrigation engineer)	"
Kunio Iki	(")	"
Ryozo Nogami	(Surveyer)	Electric Power Development Co., Ltd.
Atsushi Odaira	(")	"
Koichi Honda	(")	"
Sadao Koyama	(Statistical engineer)	"
Akira Akimoto	(Boring specialist)	Koken Shisui Kogyo K.K.
Masatoshi Atarashi	(Liaison)	Association for Investigation of Integrated Development of the Mekong
(3) Third (supplementary) Survey		
Takeshi Tokuno (Leader)	(Civil engineer)	Electric Power Development Co., Ltd.
Nasuo Toyama	(")	"
Norikazu Murakami	(Electrical engineer)	"
Masaharu Matsui	(Agricultural engineer)	"
Sozo Minemura	(Electrical engineer)	"
Sadao Koyama	(Statistical engineer)	"

CONTENTS

Page

TABLE

Page

Page

F I G U R E S

Page

S U M M A R Y

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For the convenience of those concerned, the contents of this Report is summarized below.

A. This Report contains the conclusion of investigations conducted with respect to the development of water resources of the Nam Gam basin, which is one of the tributaries of the River Mekong, draining through the territory of Thailand, and the preliminary designs including hydro-electric power and agricultural development for the first stage development of the Nam Gam basin.

Chapter I deals with the geographical features, hydrological conditions, and natural resources in the Nam Gam basin, as well as, the possibilities of their exploitation.

Chapter II is on the analysis of hydrological data which were used in determining the development schemes of water resources in the Nam Gam basin. This work involved the analysis of 13-years stage gauging records of the main Nam Gam and other hydrological data in order to prepare analysed data necessary to formulate plans for the development of the Nam Gam basin including the Nam Pung.

Chapter III is on the fundamental considerations of the first stage development of the Nam Gam basin including concrete descriptions with respect to the Nam Gam Reservoir scheme (122,000,000 m^3), Lake Nong Han utilization scheme (196,000,000 m^3), flood control scheme, hydro-electric power scheme (maximum output 5,400 kW), and agricultural development scheme (14,500 ha), as well as, on the results of investigations and studies with respect to schedules of development and development of other related industries.

Chapter IV concerns the result of studies on fund requirements and electric power needs, as well as, the economic feasibility of the agricultural and other development schemes of the first stage development stated above.

Chapter V gives the studies made with respect to development of the Nam Gam basin in the second and subsequent stages. These include an agricultural development scheme (52,600 ha), and estimates of power demands (21,920 kW), as well as, results of studies and investigations relating to measures of reinforcing power sources to meet future growth of demands by various industries.

Chapter VI is the conclusion which includes general recommendations. And based on the conclusion that the early development of the water resources of the Nam Gam basin is necessary and extremely beneficial, this Chapter indicates the studies, investigations and actions which must be initiated or taken by the people concerned.

In the appendix is included list of organizations that conducted analytical studies of hydrological data, test of fill materials and aggregates for concrete for the Nam Pung dam, as well as, necessary soil tests for agricultural development that were essential in the preparation of this report.

A general description of the Upper Nam Theum scheme (maximum output 120,000 kW) studied by the Team in connection with measures to reinforce power sources is also included in the appendix.

Attached to this Report in a separate volume are preliminary designs for the Nam Pung hydro-electric, namely preliminary designs for the electric power project and preliminary designs for the Nam Pung irrigation project. The development with priority of these projects, among the various schemes in the comprehensive development of the Nam Gam basin, would be beneficial and are recognized appropriate as pilot projects for the development of the Mekong basin. Consequently, the two projects were prepared in accordance with the Plan of Operation.

B. The Team makes the following recommendations in connection with the promoting of the comprehensive development of the Nam Gam basin.

(a) Early development of the Nam Gam hydro-electric project

(b) Preparations for establishment of experimental stations, as well as, construction of irrigation work.

For this purpose the following investigations and studies are necessary:

(a) Continuation of hydrological surveys

(b) Various researches and investigations at the agricultural experimental and extension service stations.

(c) Studies of plan to reinforce power sources

The recommendations mentioned hereinabove are the conclusions arrived by the Team in the course of studing and preparing the development plan for the Nam Gam basin and the construction program. These studies are matters which must be taken into consideration in order to promote the development smoothly and effectively.

C. The Nam Gam is one of the tributaries of the Mekong within the territory of Thailand which is blessed with abundant water resources. It is especially blessed with water available for irrigation during the dry season. Accordingly, the immediate commencement of various studies and researches relating to irrigation during the dry season by the development, in advance, of a part of the Nam Gam basin will be greatly beneficial to the future large scale agricultural development of the Mekong basin. And, by the construction of the Nam Pung multi-purpose dam, power for irrigation pumps will become available.

The Nam Gam basin is one of the areas in Thailand which in the future can utilize most economically the abundant hydraulic resources of the Mekong River. The Team believes that the early development of power consuming industries in this area will, in the future, contribute enormously to the progress and development of Thailand, as well as, the entire Mekong basin.

CHAPTER I.

GENERAL CONDITIONS OF THE WATERSHED

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A. TOPOGRAPHY AND GEOLOGY

The Nam Gam basin is located in the north-eastern part of Korat Plateau in Thailand. The Nam Pung, which rises from an elovation of 500m above sea level on the western edge of a hilly region and several other rivers, which drain into the right bank of the Nam Gam, flow north-eastward according to the natural terrain and empty into Lake Nong Han and the main Nam Gam. In the upper reaches of Nam Pung there are several falls, which form an ideal site for the development of hydroelectric power.

The rivers draining into the left bank of the Nam Gam rise in the hilly regions which form the divide with the Nam Song Gram (EL. about 200 m), flow gently in a south-eastern direction and empty into the main Nam Gam.

The main Nam Gam rises from Lake Nong Han, passes through a control gate and meanders along its course for some 133 kilometers before draining into the main stream of the Mekong River at a point about 1,170 kilometers upstream of its mouth. (See Fig. I-1)

The catchment area of Lake Nong Han is 1,561 km^2. This lake has a surface area of about 100 km^2 under normal conditions (lake water level: EL 156.50m and the maximum depth 3.50m), but, during abnormal flood run-off, it acts to control the discharge into the main Nam Gam (H.W.L. 158.72m, maximum depth 5.70m). This condition creates a lake about 17 kilometers from north to south and about 14 kilometers from east to west, which corresponds to about one-tenth of its catchment area. Lake Nong Han is rich in variety and yield of fish. The Department of Fisheries of the Government of Thailand has installed gates at the outlet of the lake to maintain the lake water level in the dry season as means of protecting fish life in the lake.

At the western side of the lake is the city of Sakol Nakron (population 16,500, and 153,600 inclusive of suburbs) which is the center of political and economic activities in this part of the country. From Sakol Nakorn, along the main stream of the Nam Gam River, there is a highway extending to That Phanom (population 11,000, and 68,900 inclusive of suburbs) near the confluence with the Mekong River, where population is relatively concentrated and agriculture, principally paddy field rice, is developed on a comparatively extensive scale.

The district lying along the Mekong from the confluence of the Nam Gam and the Mekong is located outside of the catchment area, but population there is relatively concentrated, farming is developed, a highway serves the district and at a point some 55 kilometers upstream of the confluence lies Nakorn Phanom (population 12,000, and 65,200 inclusive of suburbs). At a point some 45 kilometers downstream of the confluence lies Mukdahan (population 12,000, and 70,200 inclusive of suburbs). These cities, which confront the major cities of Takhek and Savannakhet in Laos across the river, are important centers of the trade between the two nations.

The general geological conditions of the Nam Gam basin is a large land block jutting south-eastward, the bed rock of which is the Korat Series belonging to triassic to turassic. The Korat Series is composed chiefly of sandstone and conglomerate of terrigenous deposit, and the bed rock (which has formed almost horizontally and with extremely gentle folds) at the proposed dam site in the upper reaches of the Nam Pung appears to belong to the younger geologic time in the Korat Series. Covering the bed rock is yellow and yellowish brown sandy soil. In the flat section were observed small blocks of laterite which have undergone lateritigation.

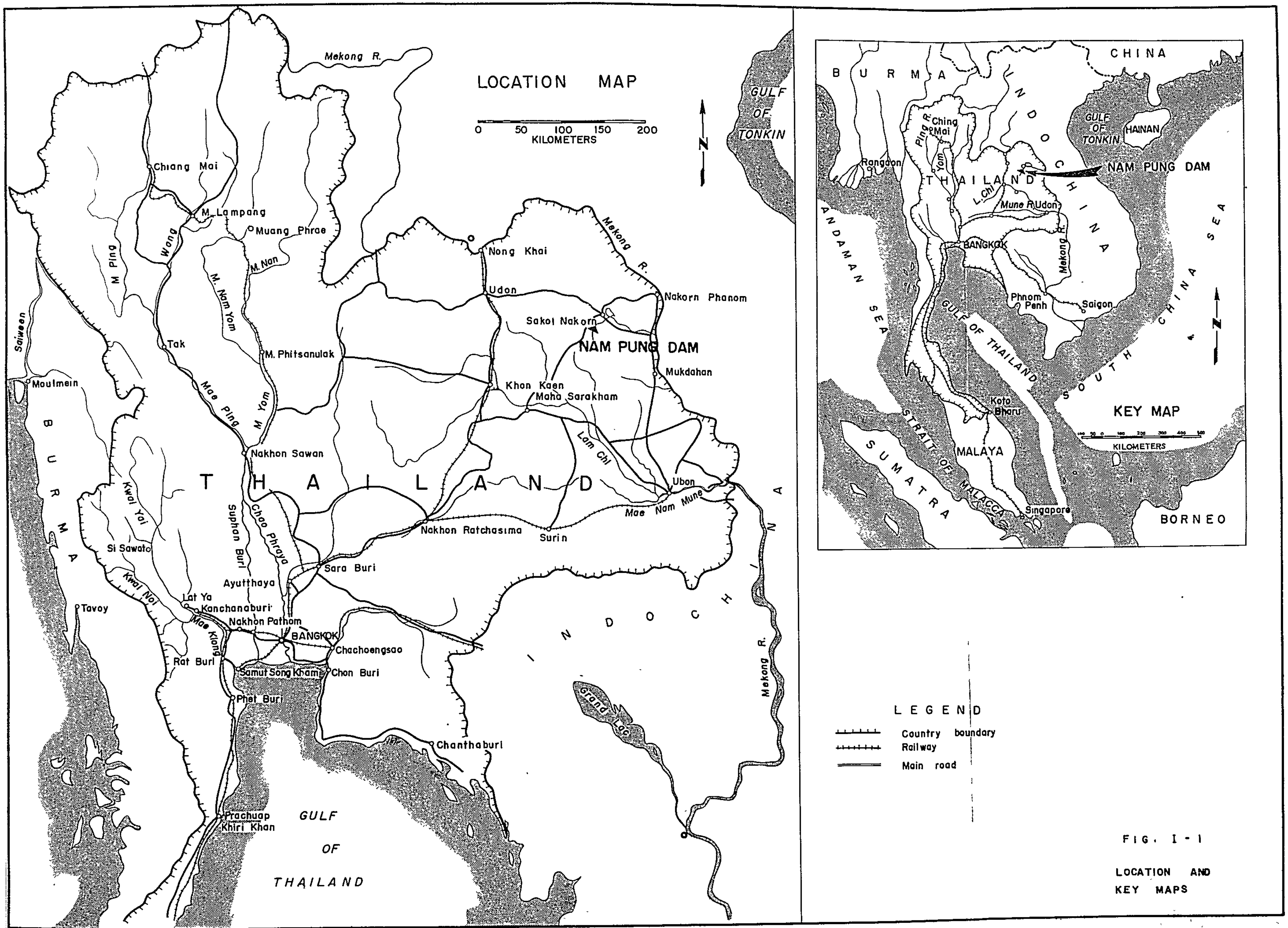


FIG. I-1

LOCATION AND KEY MAPS

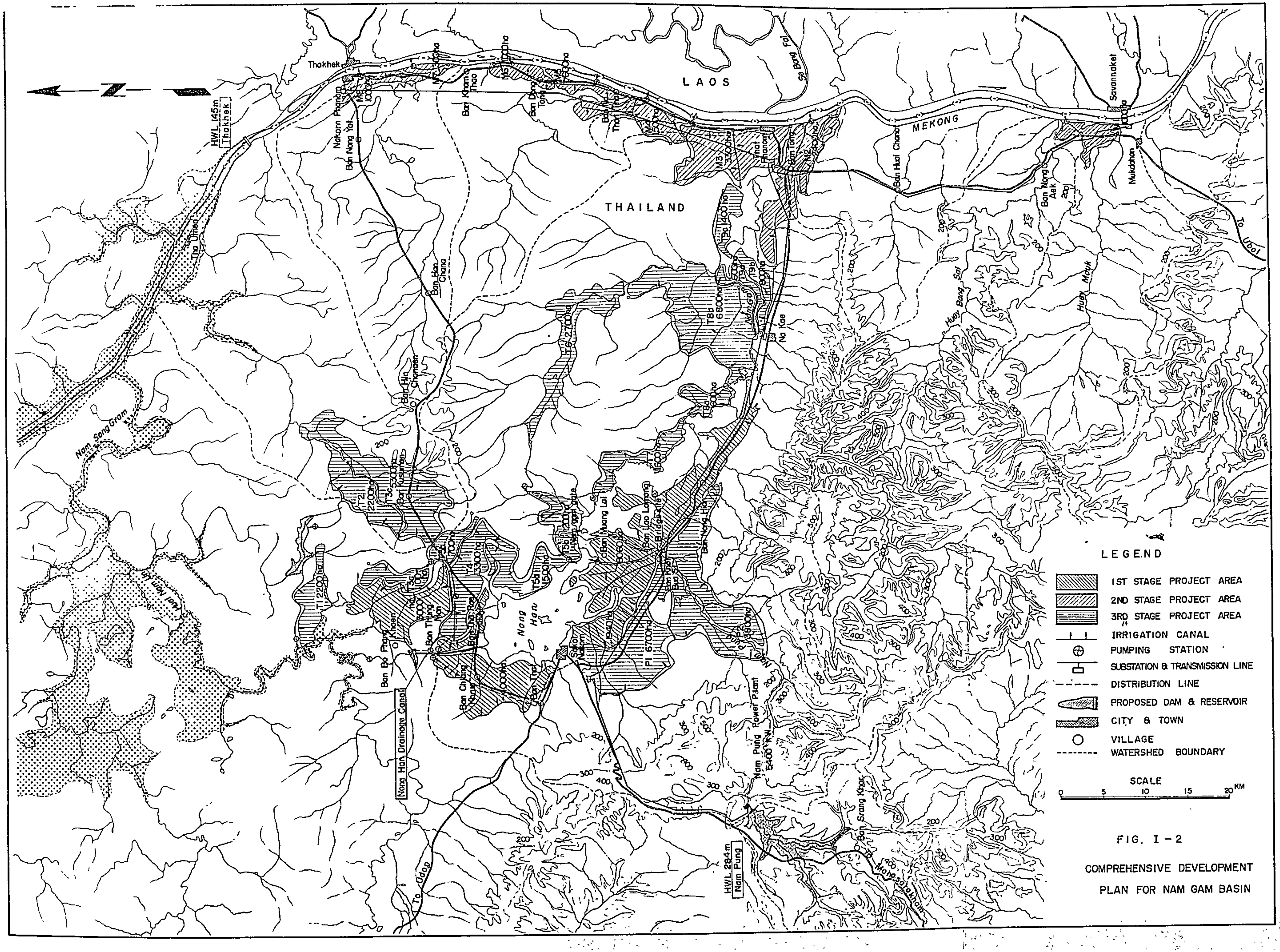
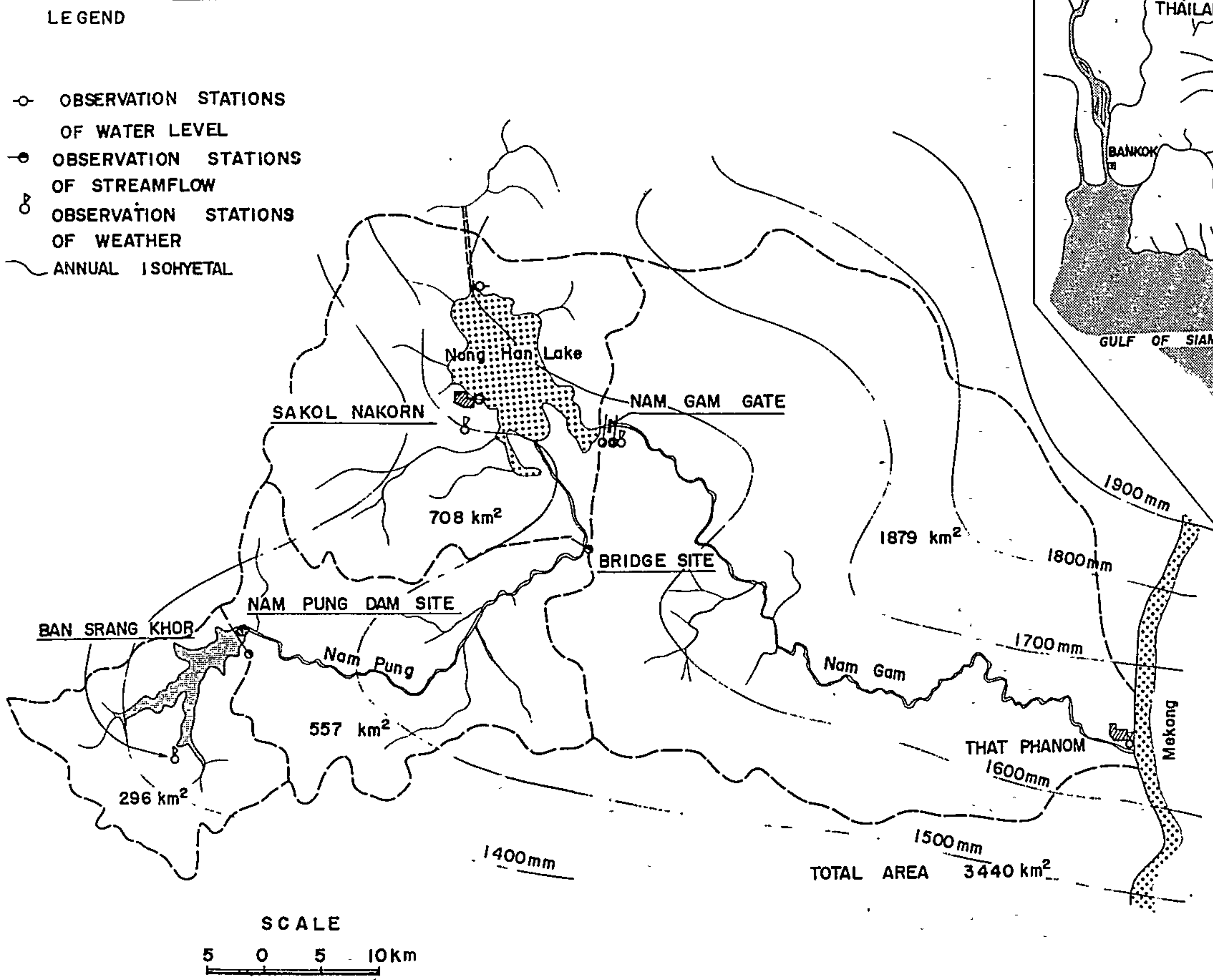


FIG. I-2

COMPREHENSIVE DEVELOPMENT PLAN FOR NAM GAM BASIN

DRAINAGE AREA OF STATION

STATION	DRAINAGE AREA
NAM PUNG DAM SITE	296 km^2
NAM PUNG BRIDGE	853 "
NAM GAM GATE	1.561 "
NONG KAHI	307.000 "
NAKORN PHANON	384.400 "
MUKDAHAN	402.450 "
KRATIE	651.000 "



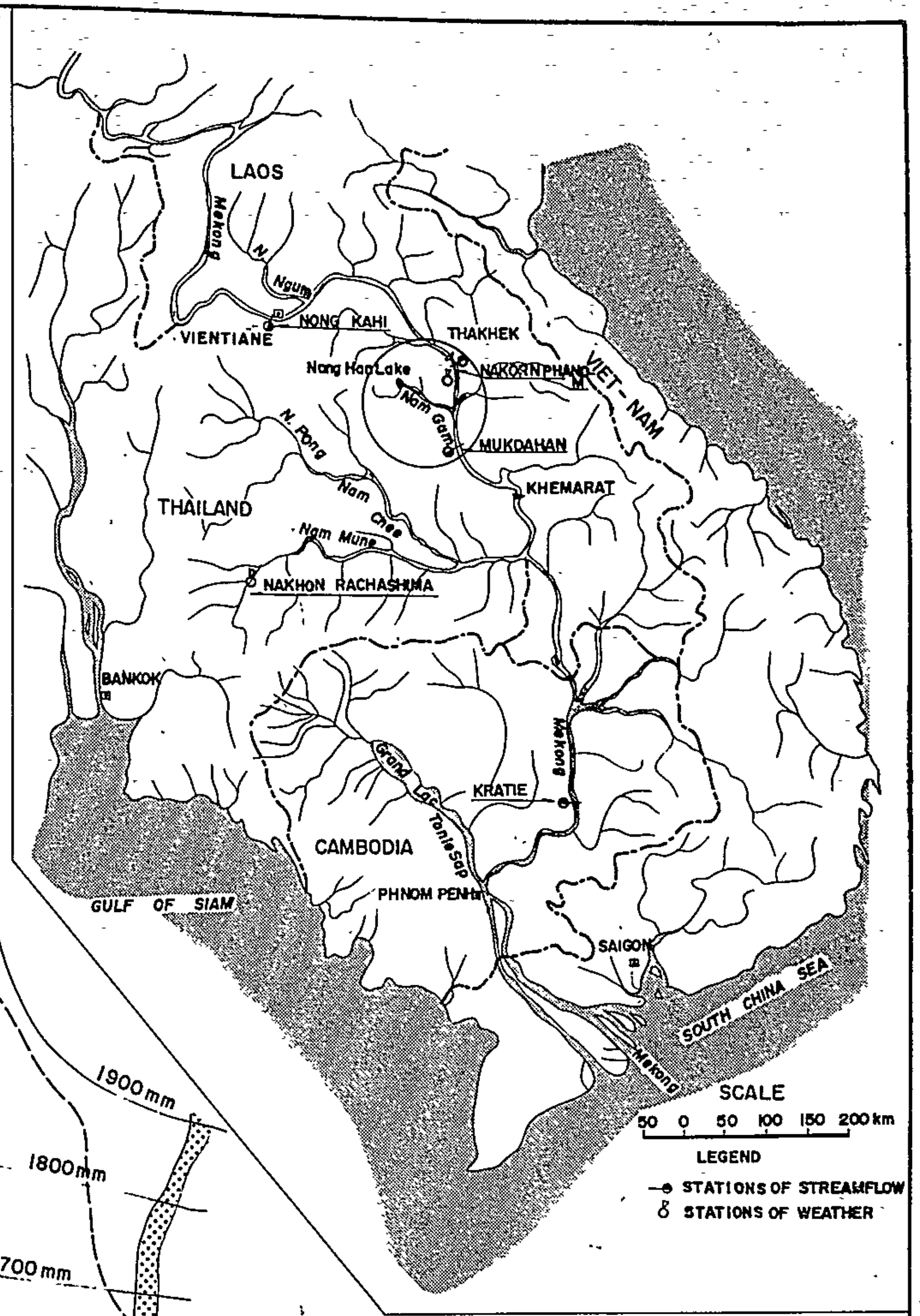


FIG. I - 3

LOCATIONS OF STATIONS AND ISOHYETAL MAP OF NAM GAM BASIN.

B. HYDROLOGY

This district is the so-called tropical field climate according to the classification by Af. W. Köppen and compared with the district having tropical rain forest climate, which is also a classification by Af. W. Köppen, and where tropical vegetation is thick, rainfall which varies from season to season is comparatively little.

In summer (May to September) this district is influenced by prevailing south westerly winds which cause days of continuous rain. While in winter (November - April) due to effects of dry north-easterly winds, rainfall is very scarce which causes the temperature to fall during the night creating a desert climate. Because of this phenomenon one will see the intergrowth of vegetation of tropical plants.

The annual rainfall in this district is around 1500 mm and the temperature seldom falls below 10°C. The lowest is about 5°C. Temperature variation throughout a year is comparatively small, but there is an appreciable difference between high and low in a day which is typical of continental climate. The distribution of annual rainfall, as indicated in Fig. I-1, has the tendency to gradually decrease towards the upper stream of the watershed. This fact shows that closer to the main Mekong, land becomes more suited for the cultivation of paddy-field rice.

The hydrology in the catchment area is described in detail in the following chapter. The Mekong River, influenced by the above stated atmospheric condition, has no recognizable run-off during the months of December to April, while most of the annual discharge is concentrated in the months of June to October. Consequently, at the end of the rainy season each year an extensive area around Lake Nong Han and along the banks of the main Nam Gam are inundated, and also affected by the flood discharge of the main stream of the Mekong River, a vast stretch of land in the lower Nam Gam is flooded.

In addition, around the end of the rainy season, typhoons which strike the Indo-China Peninsula bring about strong winds and concentrated rainfall to the district and cause great damages to rivers, roads and other structures, but the frequency is occasional.

C. RESOURCES AND INDUSTRIES

(a) Land and Population

The north eastern district of Thailand lies between 101° E to 106° E and 14° N to 18° 30'N. Geographically, this district is called the Korat Plateau. The two provinces of Sakol Nakorn and Nakorn Phanom, which are in the Nam Gam basin and the area of study in this Report, is located in the north eastern part of the district. The area is 19,287 km^2 with a population of 835,000. The population density is 43 per km^2 which is somewhat below the 52 per km^2 for the north eastern district.

(b) Resources

The north eastern district of Thailand, inclusive of the area under study, has an annual average precipitation of about 1,000 to 1,500 mm, but this precipitation is concentrated during the months of June to September and/or October, and especially in August and September. During this period the climate is extremely warm, and except for some of the hilly sections, the plateau area some 200 meters above sea level is influenced by Savanna climate. Vegetation on the southern edge and western edge of mountainous regions is general thick growth of tropical plants, while the slightly rolling part of the plateau section is sparcely covered with tropical plants. The Nam Pung and the Nam Gam basins which embrace these areas are blessed with water resources and, consequently, agriculture consisting mainly of paddy fields is developed at various locations in the basin.

Paddy field farming practiced in the region is generally by natural rainfall and late harvest variety of rice is planted in nurseries before transplanting during the rainy season which is around July. Rice plants are commonly subject to damages from drought during growth period and also from floods or heavy rainfall in the flowering season.

As to mineral resources, the Team was not able to obtain necessary data for studies in this Report.

(c) Industry (Agriculture)

Thailand is well known as one of the biggest rice producing countries. Generally speaking, rice production in the north eastern part of the country, compared with other districts, is low on the average because of the low productivity of the soil, as well as, the non-existence of the practice to use fertilizer. Main products of the north eastern area, such as, corn, castor oil plants, cotton, kenaf have made remarkable progress in productivity compared with other districts, but so far nothing worthy of mention has been achieved in the basin.

D. FUTURE POSSIBILITIES OF DEVELOPMENT OF RESOURCES

(a) Agriculture

Agricultural production is the fundamental object of industries in this district, and the agricultural pattern may be comparatively easily altered gradually from traditional rice cultivation to field crop cultivation which has a higher productivity. That is, this district is most favorably blessed with water resources compared with other areas in the north eastern district. By utilizing the water resources, we believe that a structural change of agricultural production will be possible as a result of year-round irrigation.

In relation to this, for the promotion of agricultural development, it will be necessary to strengthen the organizational functions of the present cooperative associations, as well as, to make available additional funds at longer amortization periods and lower interest rates. Also a system for the collection of irrigation water charges for the use of water year-round should be studied immediately.

For the present, it is deemed that the study of these matter for their implementation is very important for the development of the area.

(b) Forestry

It is desirable that detailed investigations be made in addition to what has been done so far in order that a coordinated forestry policy may be established based on the preservation of forest and nourishing of forest resources. On this basic policy, utilization of forest resources for the purposes of manufacturing pulp and hardboard and the like should be considered. The Team believes that studies for the utilization of forestry resources in the basin should be made after the hydro-electric power development.

(c) Fish and Livestock

The Team believes that careful studies should be made in the future with respect to the development of fishing industry in this area, as there appear to be great potentials in Lake Nong Han, as well as, the Mekong River. As to livestock, this should be studied in relation to the maintenance of fertility and nourishing of soil with the progress of field crop cultivation which will become possible by dry season irrigation. For the promotion of field crop cultivation in this district, studies, we believe, should be made with respect to increased use of chemical fertilizer and organic fertilizer (from livestock raising).

(d) Industrial Resources

Since this district is situated inland from the coast, the utilization to the utmost of available resources in the district to produce goods which may be marketed within the district and in neighboring districts would be promising. Also, as to materials produced within the district and which may be shipped out as raw materials, it will become possible to process and shipped them out in manufactured form.

From this point of view, in this district, the textile industry and the oil extracting industry are most promising. Further, in districts were means of communication are developed various industries which consume timber for their raw materials are worth consideration. As to the mining industry, due to lack of related geological data, it is difficult at this stage to consider suitable locations for that industry.

(e) Electric Power

For the development in the basin of the various industries stated above, for the time being, required power may be supplied from the Nam Pung hydro-electric project which is included in the first stage development of the Nam Gam basin. However, power needs for the second and subsequent stages of development may have to be supplied from sources outside the basin.

CHAPTER II.

ANALYSIS OF HYDROLOGICAL DATA

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A. INTRODUCTION

The estimation of the run-off of the Nam Gam basin from available hydrological data only is impossible in view of the inadequancy and reliability of the data. The Team estimated the run-off in the basin at essential locations by analyzing the hydrological data obtained, which involved very complicated work.

In this Chapter will be recorded only the hydrological data used, the methods of calculations employed and the values obtained as a result of the calculations, and the details of the procedures of the analytical studies shall be omitted. The type of data obtained, period of the data and the location of the gauging stations are given below.

Stream Flow Records

Location of Station	Period of Observation	Administered by
Nam Pung Dam site	July 1961 to date	N.E.A.
Nam Pung Bridge site	(May 1957 to November 1958	R.I.D.
	(February 1962 to date	N.E.A.

Stage Guaging Records

Location of Station	Period of Observation	Administered by
Nam Gam gate (down-steam)	January 1949 to date	Fishery Office
Nam Gam gate (upsream)	November 1949 to date	"
Lake Nong Han	May 1959 to date	"

Precipitation Records

Location of Station	Period of Observation	Administered by
Sakol Nakorn	January 1949 to date	Meteorological station
Ban Srong Khor	July 1956 to date	"

Precipitation Records (cont'd)

Location of Station	Period of Observation	Administered by
Nam Gam gate	January 1953 to date	Fishery Office
Lake Nong Han (west shore)	January 1959 to date	"

Rainfall, temperature and evaporation recorded at the above stations were relied upon and used on the assumption that all the apparatus functioned properly. With respect to streamflow data, those available are the approximately one year observation at the Nam Pung dam site and 1957, 1958 and 1962 observations at the Nam Pung Bridge site, which are extremely inadequate. Fortunately, 13 years of continuous stage gauge records at the Nam Gam gate, which is at the outlet of Lake Nong Han, are available. This record which is maintained by the Fishery Office of the Government of Thailand was recognized to be reliable.

The Team developed a calculation formula adoptable to the structure of the Nam Gam gate, and calculated the discharge from the gate by correlating the water level downstream of the gate to the gate opening and also prepared a water level-discharge curve by correlating the water level of Lake Nong Han to the gate opening. From these, the daily discharge from Lake Nong Han for the past 13 years was calculated.

The discharge at the Nam Pung dam site is being measured several times in a day. The Team while in the field made actual measurements to test its accuracy and, therefore, the recorded data at that site are believed to be reliable.

The computed values were compared with the actual recorded values at the Nam Pung dam site in 1961. The results showed that the computed values are extremely proper and appropriate. A comparison of the recorded data (1957 and 1958) at Nam Pung Bridge site with the aforementioned computed values and the values at the dam site revealed that the recorded values at the Bridge site are much too big. That is, the 1958 streamflow at the site, which is 1,003,000,000 m^3 exceeds the total run-off of the entire Lake Nong Han catchment area, which is 467,000,000 m^3. Therefore, it was found that the data at the Bridge site could not be used.

Thus, the Team analyzed the run-off condition of the basin from the water level records of Nam Gam gate and Lake Nong Han, the streamflow records of Nam Pung dam site and the precipitation records of all stations in the basin.

B. HYDROLOGICAL ANALYSIS OF LAKE NONG HAN

Following is the formula used for calculating the discharge at the Nam Gam gate.

$$Q = C \cdot A \sqrt{2g \left(h + \frac{Va^2}{2g}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where: Q = run-off in m^3/s

$\frac{Va^2}{2g}$ = approach velocity head

A = cross-section area of flow (m^2)

C = run-off coefficient = 0.9

h = difference of water level between the upstream and downstream of the gate

g = acceleration by gravity

wide of gate = 4 m by 2 gates = 8 m

Fig. II-1 is the water level-discharge curve prepared from the values obtained from the foregoing formula and the streamflow which was measured by the Team. From the inflow to Lake Nong Han which is based on the recorded steamflow at the Nam Pung dam site (NEA data from July 1961 to January 1962), the run-off at Nam Gam gate was calculated by applying a specific run-off with the following formula (2).

$$Qo = Qi + Qp - Qe + Qc \quad \text{.............................} \quad (2)$$

Where: Qo = run-off at Nam Gam gate (m^3)

Qi = inflow to Lake Nong Han (m^3), computed from the run-off at Nam Pung dam site by specific run-off

Qp = rainfall in the lake (m^3)

Qe = evaporation from the lake (m^3)

Qc = increase or decrease of water in lake (m^3); increase (–) and decrease (+)

In computing the discharge at Nam Gam gate, the water level records missing for the period of September 11, 1956 to July 20, 1958 at the Nam Gam gate lower site were supplemented by calculations made with the following formula (3) which gives the correlation between the Nam Gam gate upper water level.

$$Y = -0.0215 (X - 150)^2 + 1.2472 (X - 150) + 149.1952 \quad \text{......} \quad (3)$$

Where: Y = Nam Gam gate upper water level (Fishery Office datum in EL m)

X = Nam Gam gate lower water level (Fishery Office datum in EL m)

Note: Fishery datum is elevation used by the Fishery Office. The datum used in this scheme is the Indian datum which is officially adopted by the Government of Thailand. The difference in elevation between Indian datum and Fishery datum is 0.54 m. That is, 0.54 m deducted from the Fishery Office datum is the value of Indian datum.

In this way the streamflow (Qo) at Nam Gam gate in the past 13 years of August 1949 to August 1962 were computed. And, the inflow to Lake Nong Han shown in Table II-1, was computed by formula (4) which is another expression of formula (2).

$$Qi = Qo - Qp + Qe - Qc \quad \text{..................................} \quad (4)$$

In this case Qp is the average values of the recorded data at the north shore of Lake Nong Han, Sakol Nakorn observatory and Nam Gam gate site; Qe, which is evaporation, is the values obtained by applying the average values of the 2 years records of 1960 and 1961 to the past 12 years records. Although the evaporation records available are 2 years only, and there are noticeable monthly fluctuations the monthly variations of the respective years is not too great. The relation between the measured evaporation with a circular pan (surface area 1 m^2) and lake surface evaporation, was examined by comparative studies at times when the gates were closed. The results as shown in the following table revealed a ratio of 100% to 118%. Therefore, the observed evaporation was taken as the lake surface evaporation.

	(1) Decrease of lake water level (mm)	(2) Rainfall in lake (mm)	(3) Inflow to lake (mm)	(4) Evaporation from lake surface (mm)	(5) Measured evaporation (mm)	Ratio (%) (6)=(4)/(5)
January 1961	5.16	0	0.93	6.09	5.16	118
February 1961	4.64	0.08	0.72	5.44	5.44	100
March 1961	3.23	1.07	1.21	6.11	6.10	100

Since water level records of Lake Nong Han at the time when the gate is opened are missing for the period before April 1959, Qc was obtained by finding the correlation between the gate upper water level and the lake water level with formula (5) and corrected with measured values preceding and following the missing section. (See Fig. II- 3(1) to 3(4))

When $X < 155.50$ $\quad Z = 1.266\ (155.50 - X) + 156.46$

When $155.50 < X < 158.00$

$$Z = 0.0717\ (X-150)^2 + 1.7789\ (X - 150) + 148.8413$$

When $X > 158.00$ $Z = 0.8764 (X - 158) + 158.48$

Where X = Nam Gam gate upper water level (Fishery Office datum - EL m)

Z = Lake Nong Han water level (Fishery Office datum - EL m)

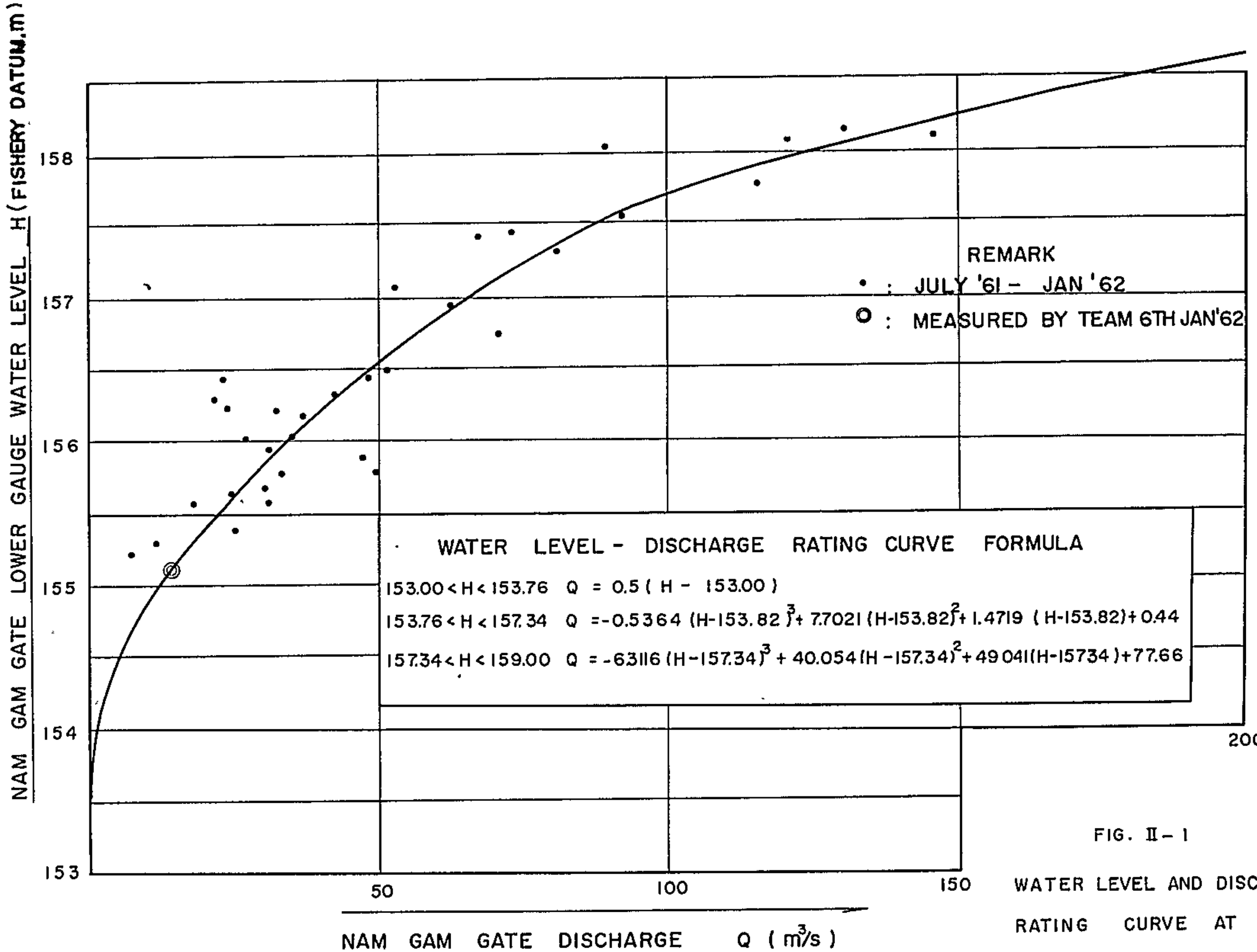
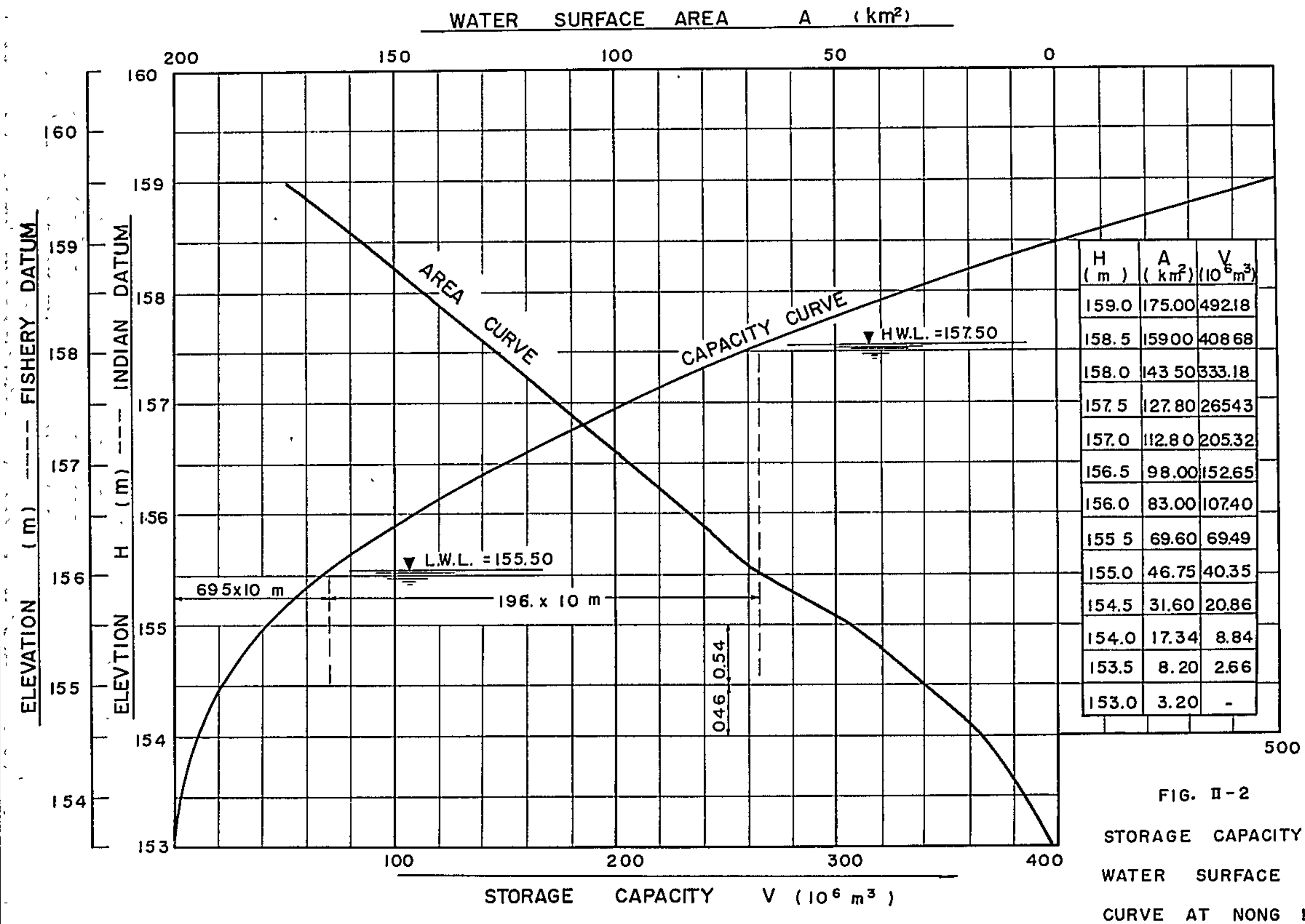


FIG. II - 1

WATER LEVEL AND DISCHARGE RATING CURVE AT NAM GAM GATE LOWER GAUGE



H (m)	A (km²)	V ($10^6 m^3$)
159.0	175.00	492.18
158.5	159.00	408.68
158.0	143.50	333.18
157.5	127.80	265.43
157.0	112.80	205.32
156.5	98.00	152.65
156.0	83.00	107.40
155.5	69.60	69.49
155.0	46.75	40.35
154.5	31.60	20.86
154.0	17.34	8.84
153.5	8.20	2.66
153.0	3.20	-

FIG. II-2

STORAGE CAPACITY AND WATER SURFACE AREA CURVE AT NONG HAN LAKE

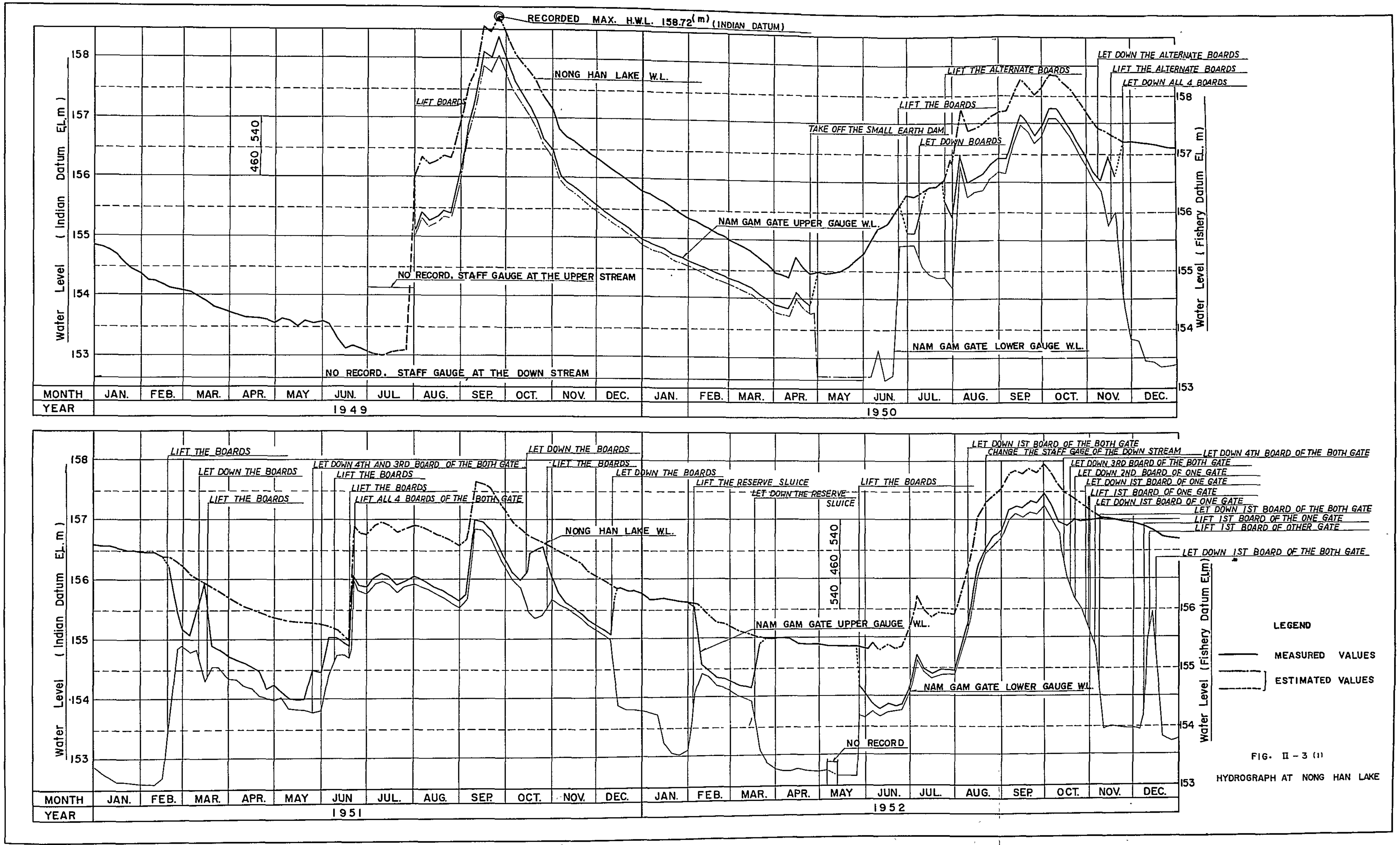


FIG. II - 3 (1)

HYDROGRAPH AT NONG HAN LAKE

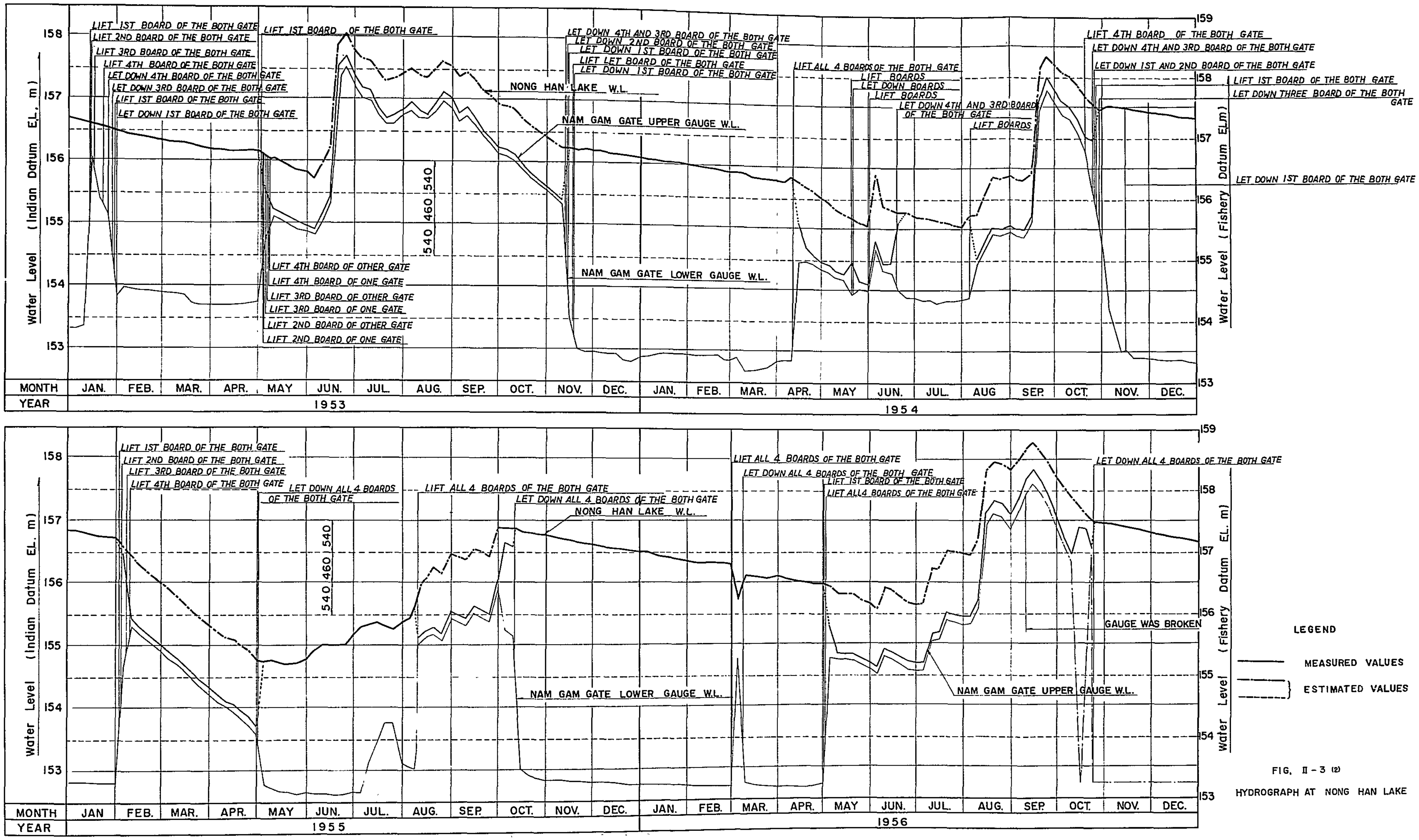


FIG. II - 3 (2)
HYDROGRAPH AT NONG HAN LAKE

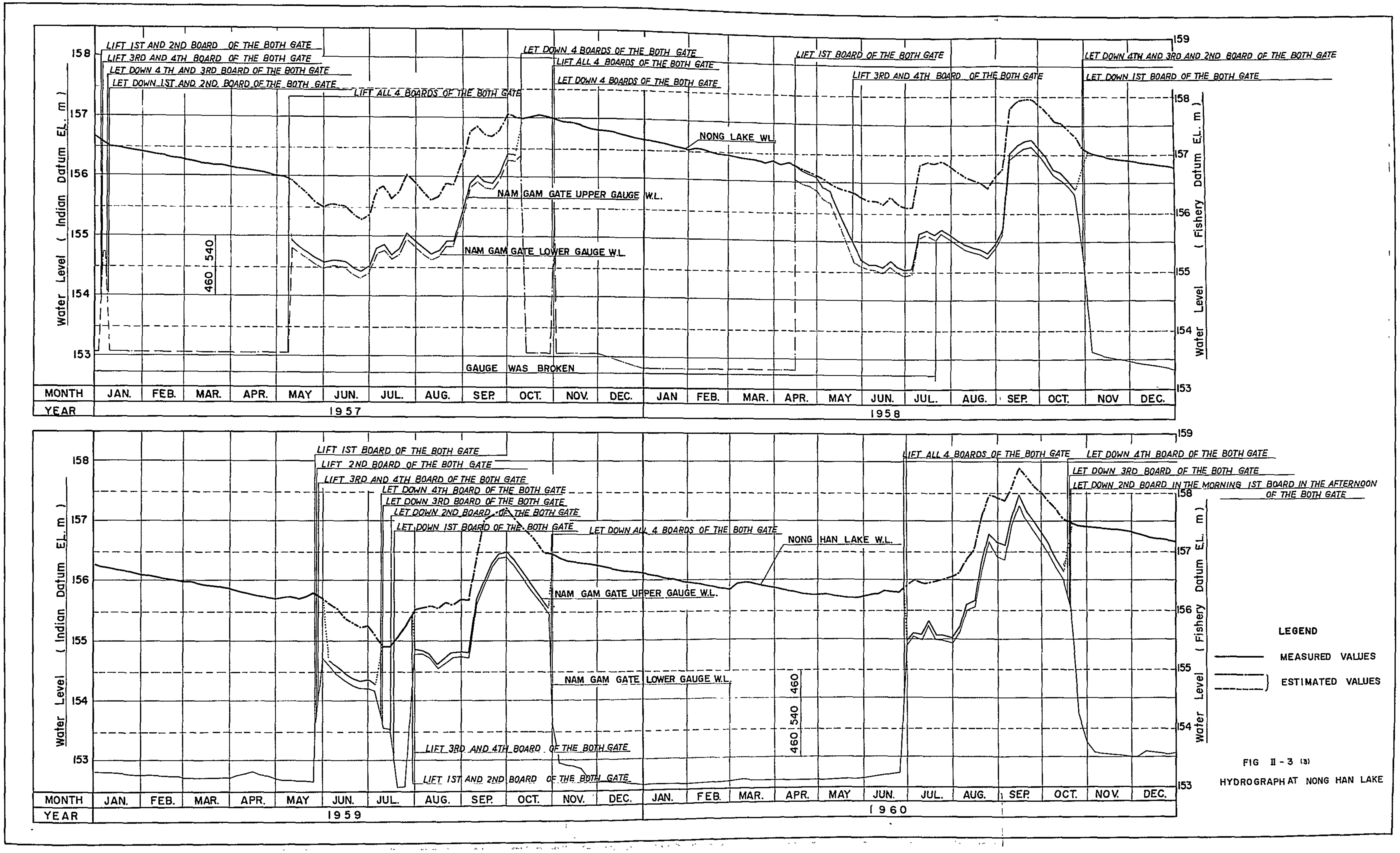


FIG II - 3 (3)

HYDROGRAPH AT NONG HAN LAKE

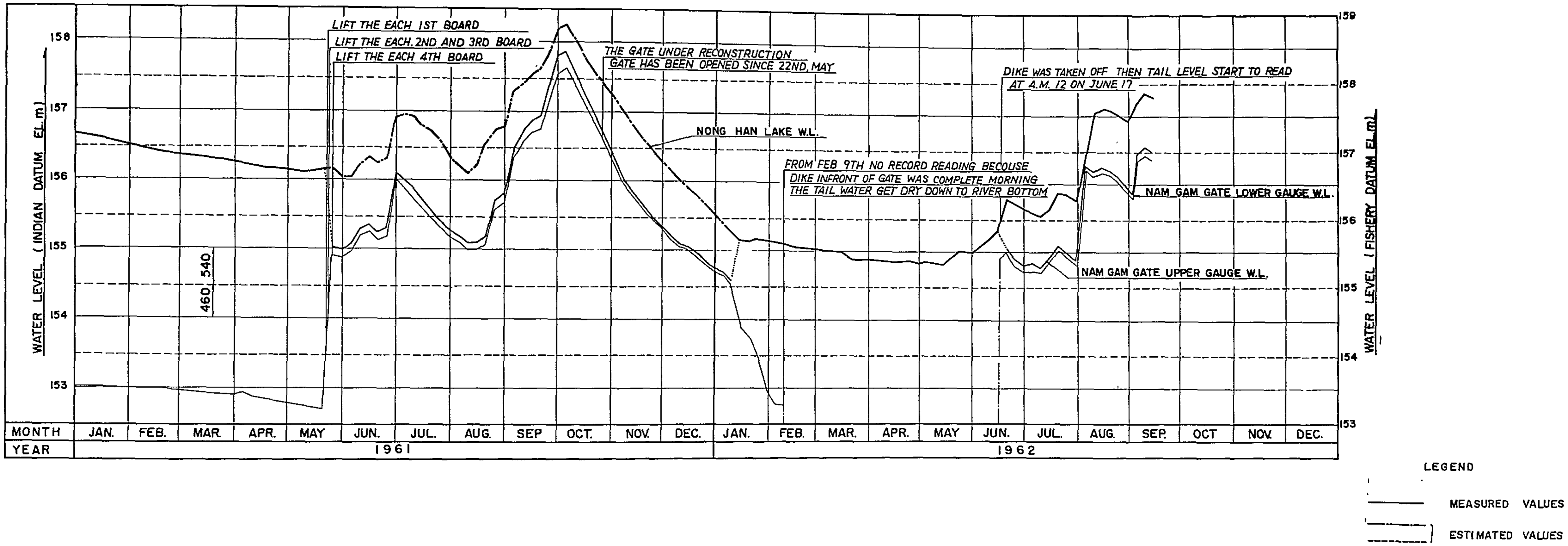


FIG. II - 3 (4)

HYDROGRAPH AT NONG HAN LAKE

Table-II-1 (1) Inflow to Nong Han Lake

Year \ Month / Division		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1949	Catchment area km^2	-	-	-	-	-	-	-	1,465	1,428	1,425	1,456	1,476	
	Inflow in mm	-	-	-	-	-	-	-	93.2	337.5	63.4	39.4	25.6	
	Inflow in $10^3 m^3$	-	-	-	-	-	-	-	136,539	481,917	90,388	57,404	37,814	
1950	"	1,491	1,506	1,523	1,531	1,527	1,504	1,477	1,456	1,437	1,437	1,450	1,459	1,456
	"	16.1	9.1	5.7	7.9	7.9	39.7	59.4	132.8	148.2	110.4	32.1	3.3	572.6
	"	23,934	13,721	8,687	12,077	11,992	59,650	87,685	193,297	212,964	158,650	46,532	4,742	833,937
1951	"	1,463	1,468	1,479	1,492	1,501	1,480	1,454	1,457	1,456	1,455	1,469	1,481	1,463
	"	2.0	1.9	1.7	5.8	4.2	112.7	91.1	54.9	146.1	36.9	34.4	10.5	502.2
	"	2,956	2,850	2,577	8,679	6,324	166,816	132,404	79,990	212,751	53,694	50,156	15,612	734,809
1952	"	1,487	1,497	1,511	1,517	1,520	1,514	1,502	1,465	1,427	1,432	1,447	1,454	1,451
	"	3.1	2.9	1.3	0.8	4.3	13.0	25.9	209.3	199.2	61.7	3.0	2.2	526.7
	"	4,650	4,287	2,039	1,179	6,581	19,741	38,828	306,552	284,300	88,359	4,383	3,253	764,158
1953	"	1,461	1,466	1,471	1,474	1,479	1,454	1,431	1,435	1,442	1,458	1,469	1,474	1,465
	"	2.2	2.2	2.6	5.8	10.5	231.6	105.4	143.3	69.2	56.7	20.9	3.2	653.6
	"	3,220	3,186	3,797	8,549	15,601	336,819	150,838	205,683	99,788	82,617	30,676	4,651	945,425
1954	"	1,477	1,480	1,483	1,488	1,503	1,509	1,510	1,498	1,455	1,438	1,450	1,453	1,463
	"	1.5	2.4	3.1	5.0	2.7	17.4	3.8	58.3	206.1	57.7	10.8	4.8	373.6
	"	2,241	3,575	4,659	7,417	4,095	26,224	5,666	87,300	299,824	82,904	15,601	6,988	546,494
1955	"	1,456	1,468	1,489	1,512	1,523	1,515	1,503	1,481	1,459	1,454	1,458	1,462	1,475
	"	3.9	1.3	2.4	4.4	3.9	9.4	10.6	85.1	78.6	18.3	10.9	2.6	230.5
	"	5,717	1,932	3,570	6,651	6,013	14,315	15,969	126,045	114,735	26,614	14,526	3,856	339,943
1956	"	1,467	1,470	1,473	1,478	1,483	1,488	1,476	1,445	1,426	1,439	1,452	1,457	1,447
	"	1.5	2.0	2.4	0.9	9.9	21.0	85.9	201.2	171.8	12.6	2.5	1.0	512.7
	"	2,220	2,908	3,595	1,331	14,749	31,317	126,799	290,801	244,942	18,082	3,683	1,390	741,817

Table II - 1 (2)

Year	Division \ Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1957	Catchment area km^2	1,463	1,469	1,472	1,476	1,486	1,496	1,490	1,476	1,459	1,448	1,452	1,456	1,407
	Inflow in mm	2.3	1.8	2.5	1.5	2.8	5.6	53.2	43.1	119.9	36.1	4.2	2.3	275.3
	Inflow in 10^3m^3	3,344	2,594	3,607	2,224	4,191	8,397	79,230	63,625	174,900	52,221	6,146	2,311	403,790
1958	"	1,461	1,464	1,467	1,471	1,480	1,487	1,480	1,473	1,457	1,451	1,465	1,469	1,463
	"	0.8	1.4	3.7	0.5	5.4	9.5	50.0	18.7	173.2	33.5	19.1	3.5	319.3
	"	1,174	2,015	5,413	770	8,057	14,061	73,939	27,618	252,342	48,542	27,920	5,160	467,011
1959	"	1,473	1,477	1,480	1,483	1,487	1,495	1,497	1,489	1,465	1,455	1,469	1,463	1,470
	"	1.9	1.4	3.3	4.3	8.9	6.1	18.8	31.2	158.4	31.8	2.7	1.9	270.7
	"	2,793	2,108	4,871	6,312	13,174	9,099	28,141	46,432	232,073	46,261	3,950	2,800	398,014
1960	"	1,479	1,483	1,484	1,485	1,487	1,485	1,479	1,457	1,436	1,444	1,454	1,458	1,451
	"	1.3	1.0	5.6	2.0	3.8	9.0	41.9	159.8	136.2	40.3	4.3	3.2	408.4
	"	1,930	1,413	8,257	3,001	5,579	13,371	61,931	232,641	195,515	58,126	6,316	4,615	592,695
1961	"	1,462	1,466	1,469	1,479	1,476	1,464	1,460	1,462	1,434	1,426	1,455	1,480	1,444
	"	2.4	1.7	2.8	4.6	3.5	87.4	32.9	67.2	245.3	97.2	16.1	5.6	566.7
	"	3,576	2,536	4,059	6,763	5,171	127,914	47,976	98,316	351,714	138,614	23,466	8,264	818,369
1962	"	1,500	1,511	1,516	1,519	1,518	1,502	1,487	1,468					
	"	2.1	1.0	1.4	1.8	2.7	32.8	37.8	135.4					
	"	3,120	1,466	2,118	2,681	4,145	49.225	56,203	198,738					

C. ANALYSIS OF INFLOW AT NAM PUNG DAM SITE

Measured streamflow data at the Nam Pung dam site are available for 1 year only from June 12, 1961. The daily streamflow for the other years will have to be computed in some way from the inflow to Lake Nong Han which is mentioned in the preceding paragraph.

The Nam Pung reservoir and power generation schemes described in the Interim Report are based on the streamflow at the dam site estimated by applying an annual run-off coefficient obtained from the annual precipitation at the dam site to the measured streamflow in 1962.

The recorded streamflow at the dam site in 1961 is 77% of the inflow to Lake Nong Han which was computed in relation to its catchment area. A comparison of the rainfall at the dam site and Lake Nong Han showed a ratio of 93% which indicates also that the run-off coefficient at the dam site is less than that of the lake. (See Fig. II-4, II-5, Table II-2, II-3, II-6)

In order to determine the available discharge for the irrigation scheme, it became necessary to calculate the daily run-off at the Nam Pung dam site. This was accomplished through a complicated calculation in which the correlation between the recorded run-off at the dam site in 1961 and the inflow to Lake Nong Han, and the average monthly rainfall in Lake Nong Han catchment area and in the catchment area of the dam site was obtained.

In planning the reservoir scheme described in this report, the following formula (6) and (7) (See Fig. II-6) which are logical and which have many advantages in formulating the scheme were used instead of the direct calculation method which is the estimation of run-off in ratio to its catchment area and the estimation of the annual run-off coefficient in relation to the annual rainfall that were used in the Interim Report. Formula (6) was used for estimating the run-off from April to December, and formula (7) for estimating the run-off from January to March.

$$Q_B = K \cdot \frac{A'}{A} \cdot Q_N = 3.70 + 0.1825\, Q_N \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Where:

$$K = \frac{\text{Ban Srang Khor rainfall}}{\text{Average rainfall in Lake Nong Han catchment area}}$$

$$\frac{\text{inflow at Nam Pung dam site}}{\text{inflow to Lake Nong Han}}$$

Q_B = monthly inflow at Nam Pung dam site in m^3/s

Q_N = monthly inflow to Lake Nong Han in m^3/s

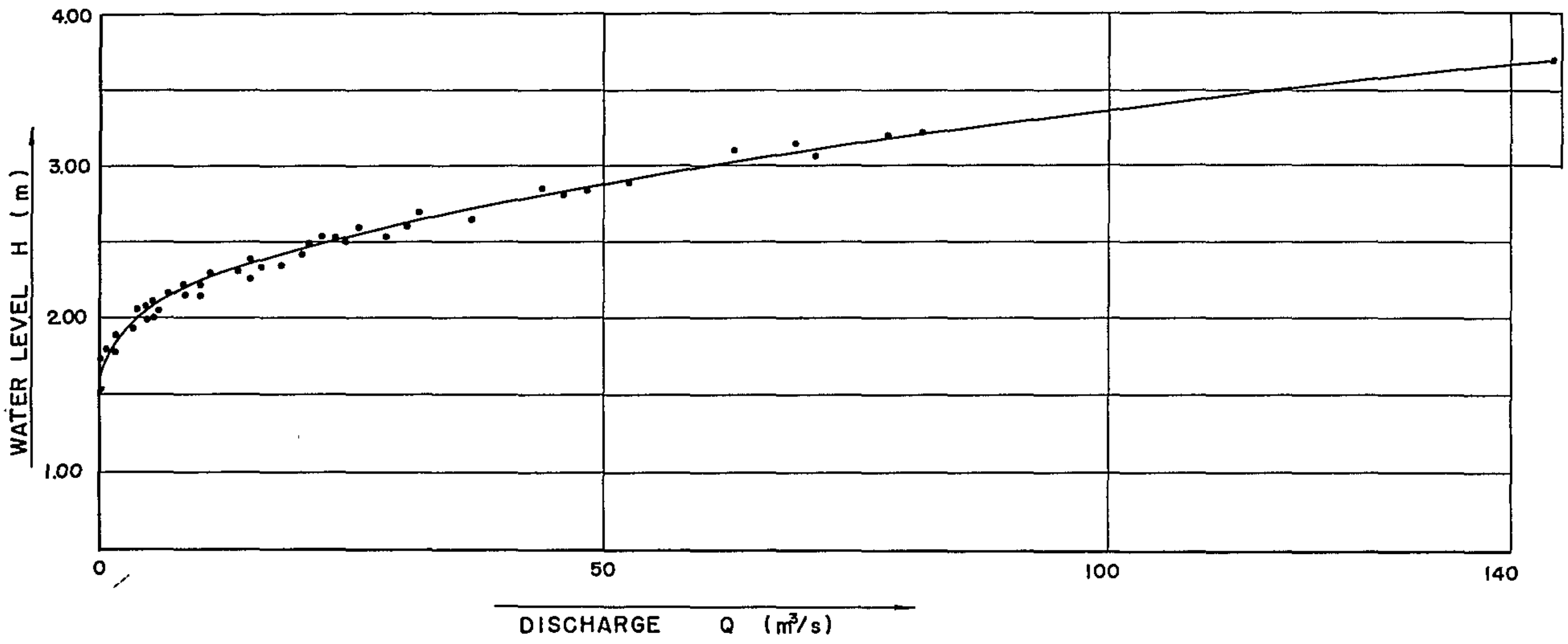
A = catchment area of Lake Nong Han in km^2

A' = catchment area of Nam Pung dam site in km^2

$$\text{i year run-off} = \frac{\text{(i - 1) annual precipitation}}{\text{1961 precipitation}} \times \text{1962 run-off} \ldots \ldots\ldots\ldots\ldots \quad (7)$$

The inflow at Nam Pung dam site estimated by formula (6) and (7) are shown in Table II-3.

The available flow of the Nam Pung for irrigation downstream of the dam site was computed in ratio to the catchment area of Lake Nong Han.



WATER LEVEL — DISCHARGE RATING CURVE FORMULA

$1.53 < H < 1.70$	$Q = 28.16 - 36.76H + 12.00H^2$
$1.70 < H < 2.20$	$Q = 55.816 - 70.317H + 22.17H^2$
$2.20 < H$	$Q = 100.545 - 120.597H + 35.783H^2$

FIG II-4

WATER LEVEL AND DISCHARGE RATING CURVE AT NAM PUNG DAM SITE

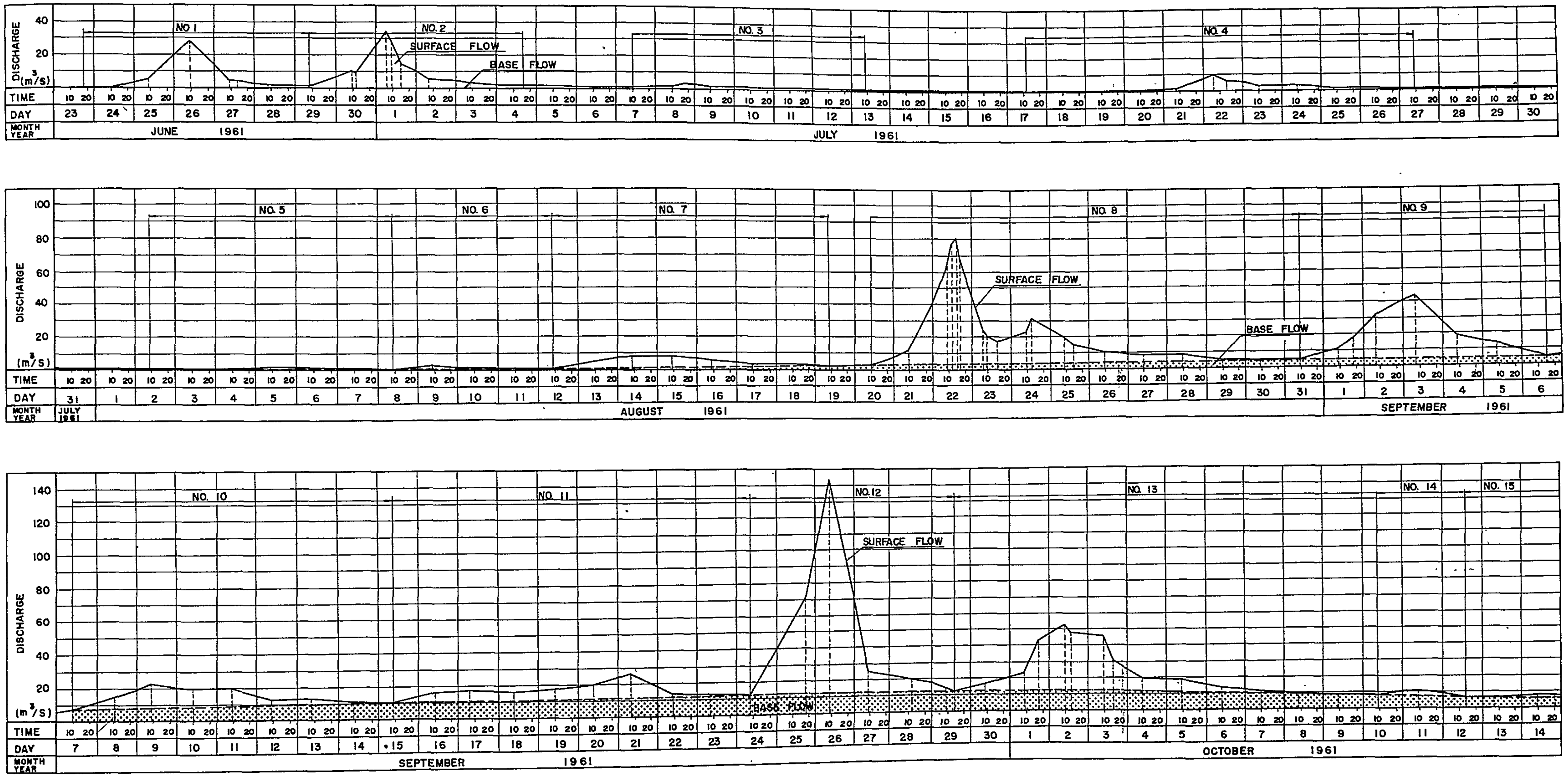


FIG. II - 5 (1)

HYDROGRAPH AT NAM PUNG DAM SITE

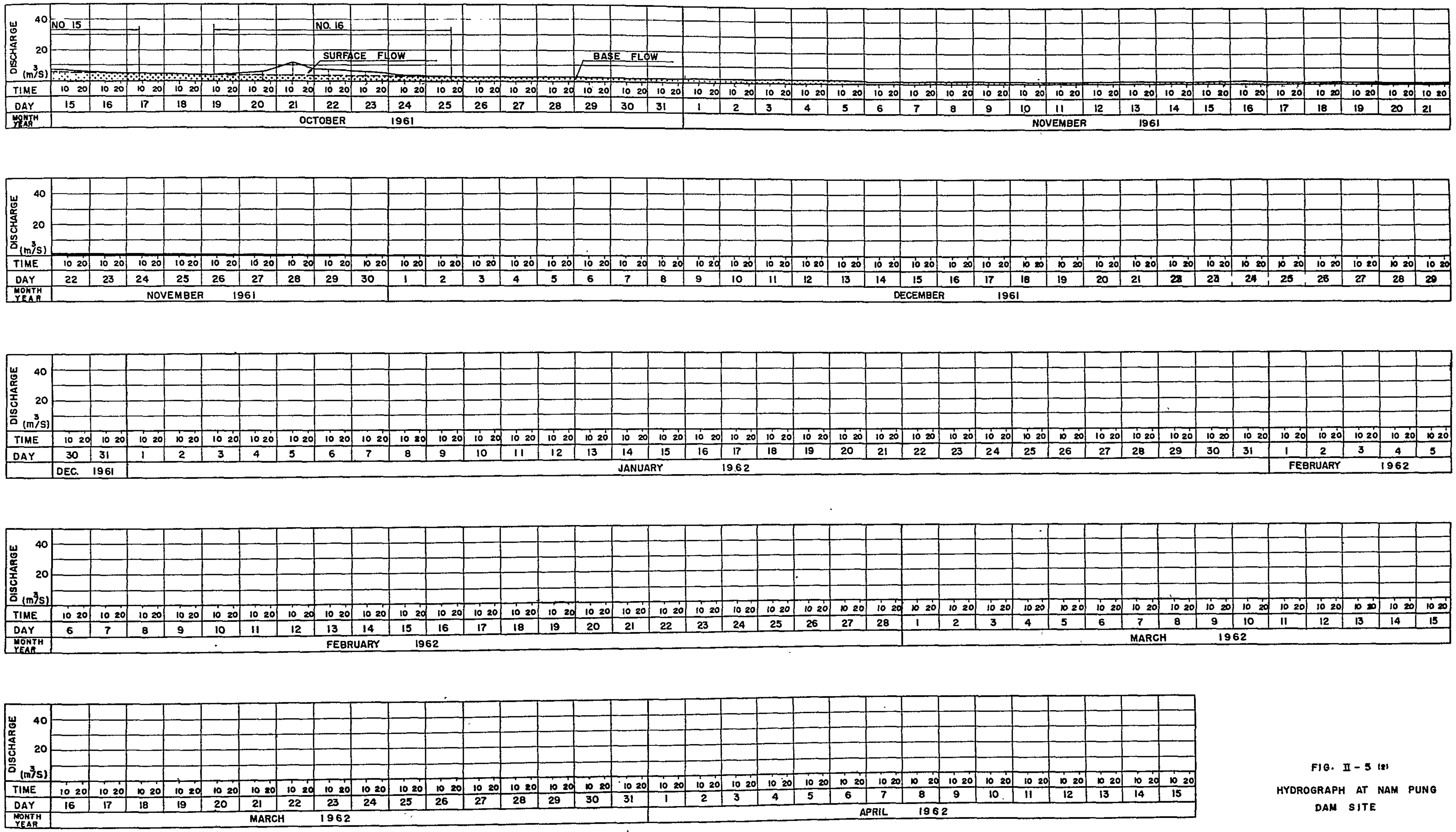


FIG. II - 5 (2)

HYDROGRAPH AT NAM PUNG DAM SITE

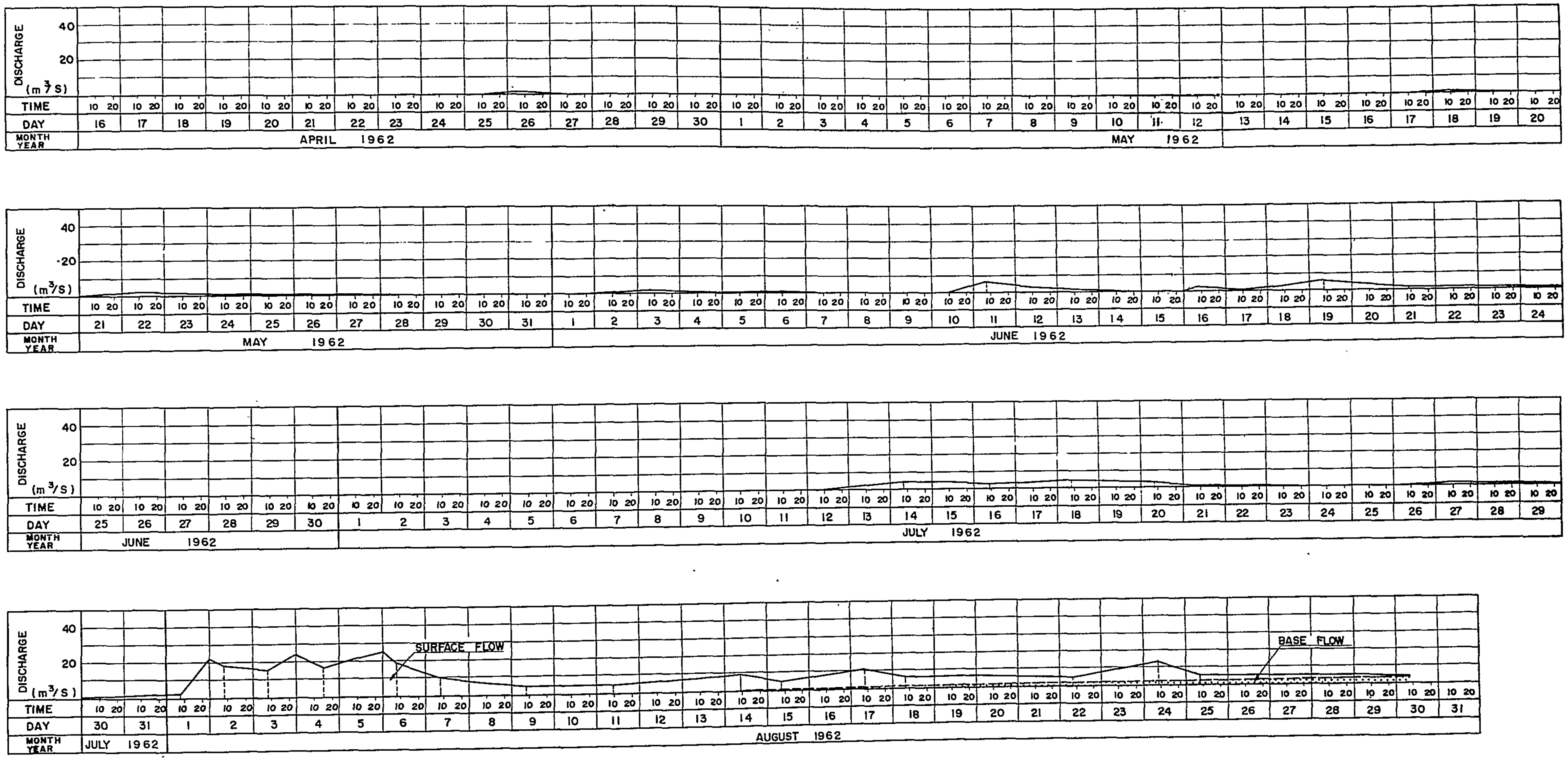
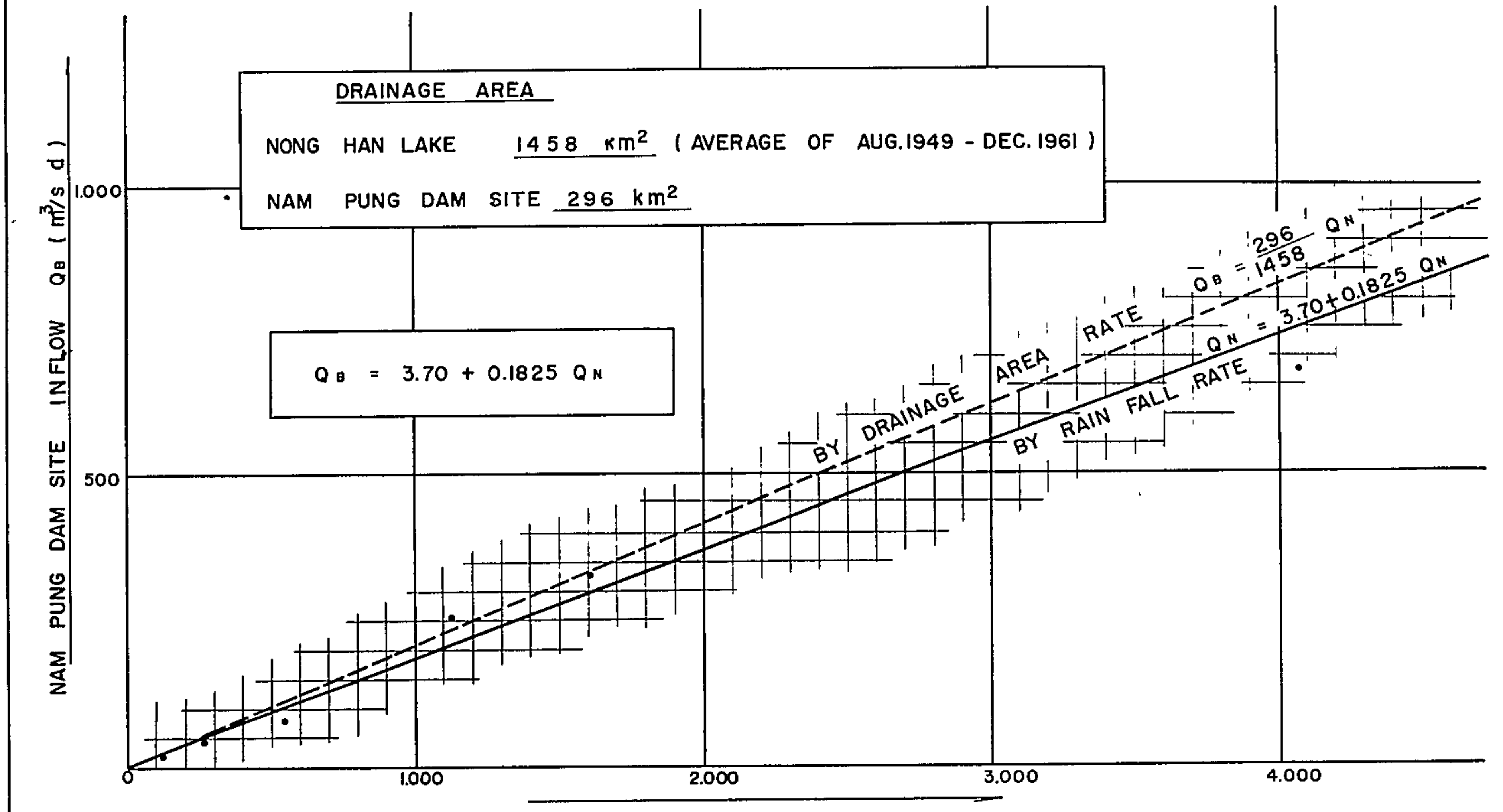


FIG. II-5 (3)

HYDROGRAPH AT NAM PUNG DAM SITE



NOTE: QB AND QN IS MONTHLY.

• MARK IS OBSERVATION VALUE OF JUL. 1961 — DEC.1961.

FIG. II - 6

CORELATION BETWEEN INFLOW TO NAM PUNG DAM SITE AND INFLOW TO NONG HAN LAKE

Table-II - 2 Analysis of Run-off at Nam Pung Dam Site, 1961

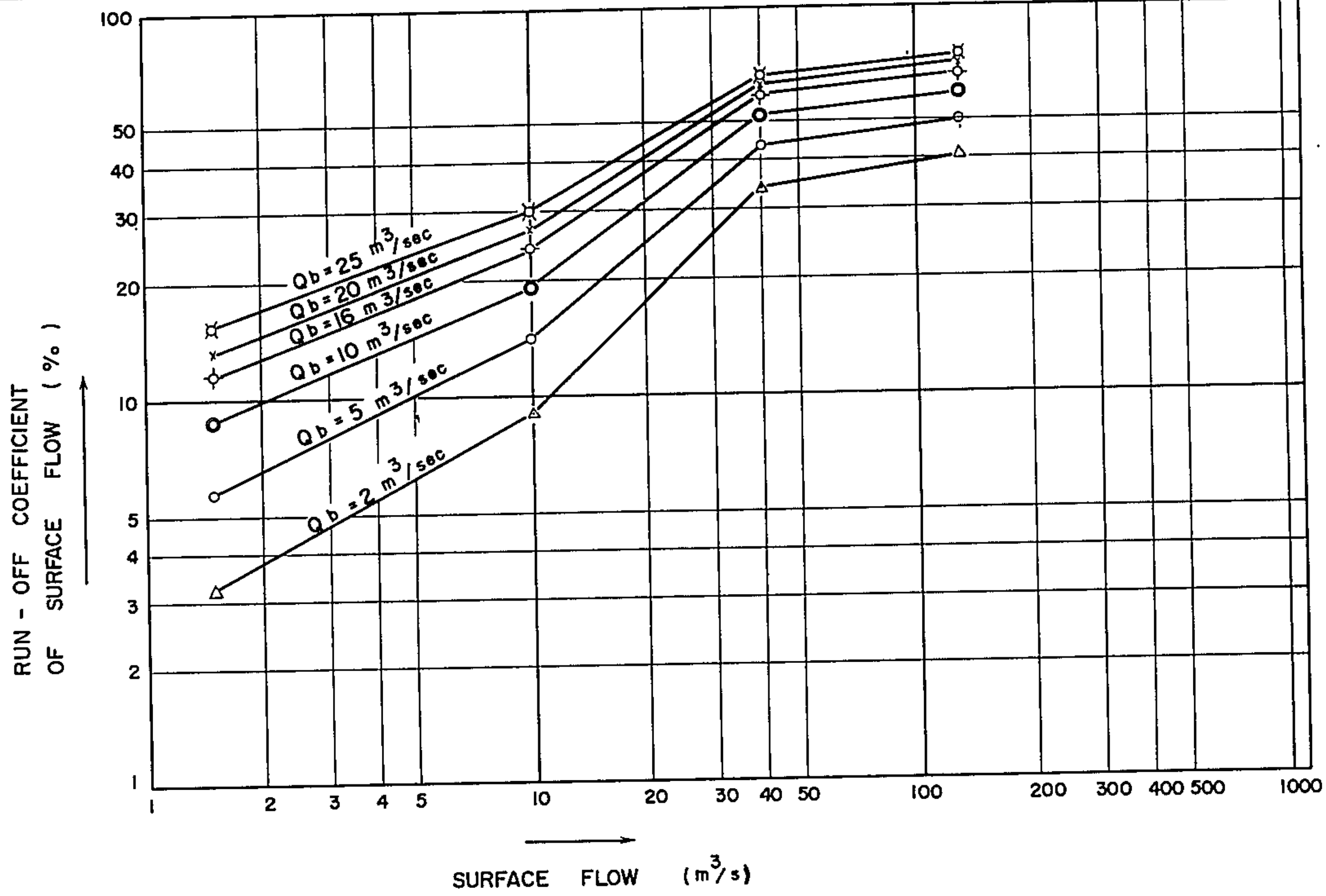
No.	Period	Precipitation					Run - off														
		Period (mm)	Daily max.		Mass		Base flow		Maximum (m^3/s)				Volume (10^3m^3)			Height (mm)			Coefficient of Run-off (%)		
			Date	(mm)	Date	(mm)	Date	(m^3/s)	Date	Base	Surface	Total	Base	Surface	Total	Base	Surface	Total	Base	Surface	Total
1	23-29, June	87.5	25	45.4	-22	487.7	23	0.06	26	0.08	28.53	28.61	35	3,580	3,615	0.1	12.1	12.2	0.1	13.8	13.9
2	29, June-4, July	94.0	29	88.3	-28	575.2	29	0.11	1	0.12	34.75	34.87	60	4,143	4,203	0.2	13.9	14.1	0.2	14.8	15.0
3	7-13, July	27.7	7	24.0	- 6	669.2	7	0.19	8	0.19	3.11	3.30	131	627	758	0.4	2.1	2.5	1.4	7.6	9.0
4	17-27, July	126.5	19	48.5	-16	696.9	17	0.47	22	0.55	9.78	10.33	487	1,596	2,083	1.6	5.4	7.0	1.3	4.3	5.6
5	2-8, Aug.	51.1	2	26.0	- 1	841.1	2	0.78	5	0.81	1.41	2.22	413	271	684	1.4	0.9	2.3	2.7	1.8	4.5
6	8-12, Aug.	19.7	8	15.8	- 7	892.2	8	0.88	9	0.88	2.22	3.10	359	230	589	1.2	0.8	2.0	6.1	4.1	10.2
7	12-19, Aug.	96.7	13	46.5	-11	911.9	12	1.45	14	1.65	7.11	8.76	1,097	2,248	3,345	3.7	7.6	11.3	3.8	7.9	11.7
8	20-31, Aug.	155.7	21	81.2	-29	1,023.8	30	3.25	22	3.52	78.00	81.52	3,801	12,686	16,487	12.8	42.9	55.7	8.2	27.6	35.8
9	31, Aug.-6, Sept.	65.5	31	38.0	-30	1,164.3	31	4.85	3	4.85	38.78	43.67	2,587	8,167	10,754	8.7	27.6	36.3	13.3	42.1	55.4
10	7-14, Sept.	78.7	7	26.4	- 6	1,229.8	7	7.40	9	8.00	14.42	22.42	6,007	4,347	10,354	20.3	14.7	35.0	25.8	18.7	44.5
11	15-24, Sept.	111.9	18	25.0	-14	1,308.5	15	10.50	21	12.20	14.39	26.59	8,908	4,342	13,250	30.1	14.7	44.8	26.9	13.1	40.0
12	24-28, Sept.	86.8	24	65.8	-23	1,413.4	24	12.75	26	12.75	131.45	144.20	5,772	16,365	22,137	19.5	55.3	74.8	22.5	63.7	86.2
13	29, Sept.-8, Oct.	56.9	1	35.6	-28	1,507.2	29	12.75	2	12.50	40.46	52.96	9,530	9,343	18,873	32.2	31.6	63.8	56.7	55.5	112.2
14	10-12, Oct.	3.4	10	3.4	- 9	1,564.1	10	7.90	11	7.20	3.47	10.67	1,427	359	1,786	4.8	1.2	6.0	141.2	35.3	176.5
15	12-17, Oct.	14.6	13	14.6	-11	1,567.5	12	6.80	14	6.00	1.74	7.74	2,387	297	2,684	8.1	1.0	9.1	55.5	6.8	62.3
16	19-25, Oct.	37.6	20	26.2	-18	1,582.1	19	4.60	21	4.17	8.32	12.49	2,253	1,341	3,594	7.6	4.5	12.1	20.2	12.0	32.2
1-16	Total	1,114.3											45,254	69,942	115,196	152.7	236.3	389.0	13.7	21.2	34.9
	23, June-25, Oct. Total	1,132.0											48,350	70,483	118,833	163.2	238.1	401.3	14.4	21.0	35.4

Remarks: Precipitation .... For Ban Srang Khor Meteorological Station data.

Run-Off .... For Nam Pung Dam Site National Energy Authority data.

Table-II-3 Inflow at Nam Pung Dam Site (m^3/S day)

year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Annual ($10^3 m^3$)	Remarks
1951								172.66	453.09	117.12	109.64	36.68	-	-	
1952	2.43	0.68	0.31	6.19	17.60	45.40	85.72	651.22	604.22	190.34	12.96	10.57	1,627.64	140,628	
1953	2.41	0.66	0.31	21.76	36.65	715.15	322.31	438.16	214.48	178.21	68.50	13.52	2,012.12	173,847	
1954	2.84	0.89	0.37	19.37	12.35	59.09	15.67	188.10	637.01	178.82	36.65	18.46	1,169.62	101,055	
1955	2.51	0.71	0.31	17.75	16.40	33.94	37.43	269.94	246.05	59.92	34.38	11.84	731.18	63,174	
1956	1.74	0.49	0.22	6.51	34.85	69.85	271.53	617.95	521.08	41.89	11.48	6.64	1,584.23	136,877	
1957	2.60	0.64	0.31	8.40	12.55	21.44	171.06	138.09	373.14	114.00	16.68	10.69	869.60	75,133	
1958	2.59	0.72	0.34	5.33	20.72	33.40	159.88	62.04	536.71	106.23	62.67	14.60	1,005.23	86,852	
1959	2.73	0.76	0.34	17.03	31.53	22.92	63.14	101.78	493.90	101.42	12.04	9.61	857.20	74,062	
1960	2.61	0.65	0.31	10.04	15.48	31.94	134.52	495.10	416.68	126.48	17.04	13.45	1,264.30	109,236	
1961	2.36	0.63	0.31	17.99	14.62	273.89	77.22	252.45	678.17	328.79	41.77	14.51	1,702.71	147,114	
1962	2.96	0.81	0.37	5.06	17.41	49.36	49.86	-	-	-	-	-	-		
10 years Average	2.48	0.68	0.31	13.04	21.28	130.70	133.85	321.48	472.14	142.61	31.42	12.39	1,282.38	110,798	Jan. 1952 to Dec. 1961
11 years Average	2.53	0.70	0.32	12.31	20.90	123.31	126.21	307.95	470.41	140.29	38.53	14.60	1,258.06	108,696	Aug. 1951 to July 1962



NOTE : Qb = BASE FLOW (m^3/s)

FIG. II - 7

CORRELATION BETWEEN BASE FLOW AND RUN-OFF COEFFICIENT OF SURFACE FLOW AT NAM PUNG DAM SITE

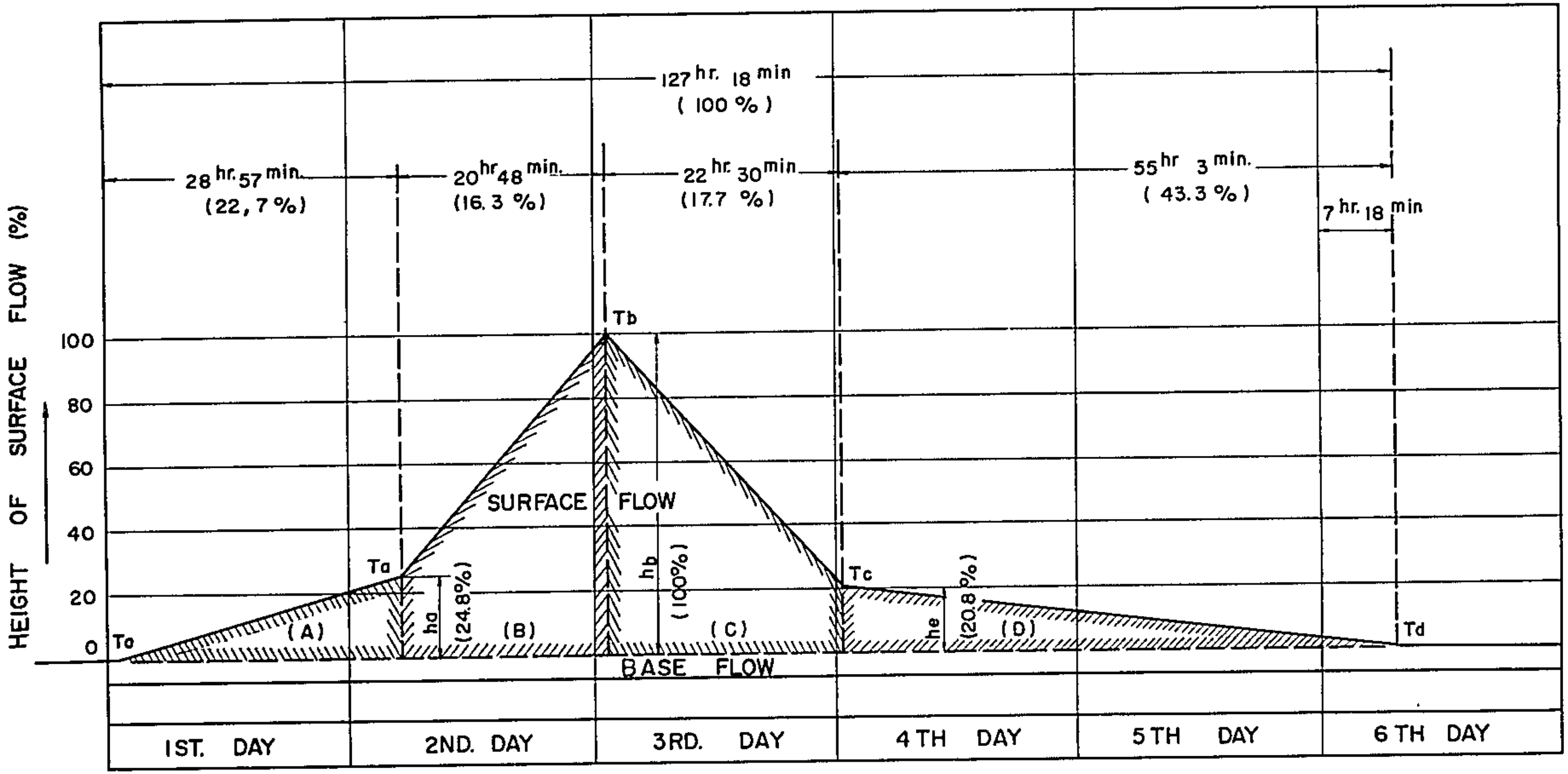


FIG. II - 8

DISCHARGE DIAGRAM

AT

NAM PUNG DAM SITE

Table-II-4 Calculation of Maximum Flood Discharge at Nam Pung Dam Site

Division	Date of Surface Flow		Hours of Run-off (Hr. min)	① Surface Flow			② Base Flow		③ = ① + ② Flood Discharge		Remarks
	Refer to Fig.	(%)		Volume (10^3m^3)	Average (m^3/s)	Discharge (m^3/s)	Volume (10^3m^3)	Discharge (m^3/s)	Volume (10^3m^3)	Discharge (m^3/s)	
A	$\frac{0.227 \times 0.248}{2} = 0.0281$	9.99	28.57	8.072	77.45	0 154.90	1.667	16.00 16.00	9.739	16.00 170.90	Catchment Area 296 Km^2
B	$\frac{0.248+1.00}{2} \times 0.163 = 0.1017$	36.09	20.48	29.163	389.46	154.90 624.02	1.198	16.00 16.00	30.361	170.90 640.02	Run-off co-effecient of maximum Flood Discharge 76%
C	$\frac{1.00+0.208}{2} \times 0.177 = 0.1069$	37.94	22.30	30.659	378.51	624.02 130.32	1.296	16.00 16.00	31.955	640.02 146.32	Base flow 6% Surface flow 70%
D	$\frac{0.208 \times 0.433}{2} = 0.045$	15.98	55.03	12.914	65.16	130.32 0	3.171	16.00 16.00	16.085	146.32 16.00	Precipitation 1,000 years
Total	0.2817	100	127.18	80.808	176.32		7.332		88.140		Probability 390 mm

Table-II - 5 Calculation of Maximum Flood Discharge at Nong Han Lake

Division	① Surface flow					② Easc flow		③ Evaporation		④ = ① + ② - ③ Flood Discharge	
	Period (sec)	Rate of flow (%)	Volume ($10^3 m^3$)	Average (m^3/s)	Discharge (m^3/s)	Volume (m^3/s)	Discharge (m^3/s)	Volume ($10^3 m^3$)	Discharge (m^3/s)	Volume ($10^3 m^3$)	Discharge (m^3/s)
A	209,484 (58hr/min)	9.99	30,628	146.21	0 292.42	15,355	73.30 73.30	-	-	45,983	73.30 365.72
B	150,516 (41.49)	36.09	110.648	735.12	292.42 1,180.46	11,033	73.30 73.30	-	-	121,681	365.72 1,253.76
C	162,792 (45.13)	37.94	116.321	714.54	1,180.46 245.98	11,932	73.30 73.30	814	5.00 5.00	127,439	1,253.76 314.28
D	398,340 (110.39)	15.98	48,993	122.99	245.98 0	29,198	73.30 73.30	1,992	5.00 5.00	76,199	314.28 68.30
Total	921,132 (255.52)	100	306,590	332.84	-	67,518	-	2,806	-	371,302	-

Remarks:

Catchment Area of the Lake's circumference (A) = 1,446 km^2
Lake Surface Area (A') = 115 km^2
Run-off Coefficient of Maximum Flood Discharge = 76.2%

- Base flow = 13.9%
- Surface flow
  - Lake Surface (f) = 100%
  - Lake's Circumference (f) = 60%
  - Average = 62.3% (Include Evaporation Loss)
    = 306,590 x $10^3 m^3$

Volume of Surface Flow

- Lake Surface = $A_1 \cdot f_1 \cdot r$ = 115 km^2 x 1.00 x 312 mm = $10^3 m^3$
- Lake's circumference = A.f.r. = 1446 km^2 x 0.60 x 312 mm = 270,690 x $10^3 m^3$

Four Days continuous precipitation (100 years probability) (2) = 312mm

D. COMPUTATION OF FLOOD DISCHARGE

(a) Computation of Flood Discharge at Nam Pung Dam Site

Flood discharge records are available for the year 1961 only. Therefore, the flood discharge probability percentage was obtained by converting the precipitation data into run-off. In this calculation, the run-off ratio was found by obtaining the relation between the surface run-off for each consecutive rainfall in 1961 and the total annual precipitation.

The probability percentages (4 consecutive days) of precipitation obtained from statistical analysis of past 13 years records are as follows:

rainfall of 100 years probability percentage - 312 mm

rainfall of 200 years probability percentage - 340 mm

rainfall of 1000 years probability percentage - 390 mm

Since the Nam Pung dam will be a fill type structure, a precipitation of 390 mm, which is the probability percentage for 1,000 years, was taken, and the computed 1,000 years probability percentage run-off (abnormal flood discharge) is 640 m^3/s. (See Fig. II-8 and Table II-4)

(b) Computation of Flood Discharge of Lake Nong Han

The flood discharge of Lake Nong Han was computed by taking 312 mm as the 100 years probability percentage of precipitation, by estimating the flood wave type from the relation between the flood wave type at Nam Pung dam site and the arrival time of flood discharge from the dam site to Lake Nong Han (1961 recorded data), and by a run-off coefficient which was determined taking into account the characteristics of the Nam Pung catchment area. The flood discharge of Lake Nong Han which was computed in this manner is shown in Table II-5 and the computed maximum flood discharge is 1,254 m^3/s.

E. RUN-OFF CONDITION OF THE MAIN MEKONG RIVER BETWEEN NAKORN PHANOM AND MUKDAHAN

The downstream reaches of the Nam Gam are influenced by backwater effects of the main Mekong River during flood discharges. The area influenced by this backwater effect is about one half of the river channel distance of the main Nam Gam.

From the records of Nakorn Phanom and Mukdahan gauging stations, the Team estimated the run-off and other conditions of the main Mekong River for the period 1959 to 1961. As a result of this work, the following were found:

(a) the alleviated inundation condition of the downstream reaches of the Nam Gam after completion of the proposed Pa Mong project.

(b) the conditions on which to determine the pumping head for pumps necessary in the second stage development of the Nam Gam basin and the power needs of irrigation pumps.

(c) the relation between the fluctuation of annual run-off of the main Mekong River at Nakorn Phanom and Mukdahan, and the annual run-off of the Nam Gam and adjoining areas.

With respect to (c) above, it will be seen from the table which follows that there is a wide difference of run-off condition between the main Mekong River and the Nam Gam. That is, the greater part of the annual run-off of the tributary - Nam Gam is concentrated in the 5 months of June to October and there is almost no run-off in the other 7 months. In comparison with this condition, on the main Mekong River approximately 80% of the annual run-off comes between June and October and the remaining 20% of the run-off comes in the other 7 months.

Table-II - 6 Run-off data of Gauging Stations in and around the Nam Gam Basin

Year	Station	Catchment Area	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Annual	
			mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%	mm	%
1959	Nam Pung Dam Site	296 km²	0.7	0.3	0.2	0.1	0.1	0.1	4.3	2.0	7.9	3.7	5.7	2.7	15.8	7.4	25.4	11.9	123.5	57.7	25.3	11.8	3.0	1.4	2.4	0.9	214.3	100
	Nong Han Lake	1,444 "	1.9	0.6	1.4	0.5	3.3	1.2	4.3	1.6	8.9	3.3	6.1	2.3	18.8	7.0	31.2	11.6	158.4	58.3	31.8	11.8	2.7	1.0	1.9	0.7	270.7	100
	Nakorn Phanom	384,400 "	13.2	2.2	10.8	1.8	11.4	1.9	10.7	1.8	13.6	2.3	30.0	5.1	59.6	10.1	134.8	22.8	167.7	28.3	84.4	14.3	35.5	6.0	20.4	3.4	592.1	100
	Mukdahan	402,450 "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Kratie	651,000 "	10.3	2.0	8.0	1.5	7.3	1.4	5.8	1.1	8.8	1.7	18.7	3.6	48.6	9.3	105.0	20.2	149.7	28.8	99.3	19.1	40.9	7.9	17.8	3.4	520.0	100
1960	Nam Pung Dam Site	296 km²	0.7	0.2	0.2	0.1	0.1	0	2.5	0.8	3.9	1.2	8.0	2.5	33.6	10.6	123.8	39.1	104.0	32.9	31.6	10.0	4.3	1.4	3.4	1.2	316.1	100
	Nong Han Lake	1,444 "	1.3	0.3	1.0	0.2	5.6	1.4	2.0	0.5	3.8	0.9	9.0	2.2	41.9	10.3	159.8	39.1	136.2	33.4	40.3	9.9	4.3	1.1	3.2	0.7	408.4	100
	Nakorn Phanom	384,400 "	15.9	2.6	12.4	2.1	10.7	1.8	8.7	1.4	10.3	1.7	24.3	4.1	64.0	10.6	163.9	27.3	148.0	24.6	87.9	14.6	32.9	5.5	22.1	3.7	601.1	100
	Mukdahan	402,450 "	15.9	2.6	13.0	2.1	11.2	1.8	8.4	1.4	9.7	1.6	26.8	4.4	63.4	10.3	167.1	27.2	149.4	24.3	92.0	15.0	33.9	5.6	22.9	3.7	613.9	100
	Kratie	651,000 "	11.8	1.9	8.8	1.4	7.0	1.1	5.5	0.9	7.6	1.3	25.1	4.1	55.7	9.1	162.7	26.5	143.4	23.4	116.8	19.0	45.3	7.4	24.0	3.9	613.7	100
1961	Nam Pung Dam Site	296 km²	0.6	0.1	0.2	0.1	0.1	0	4.5	1.1	3.7	0.9	68.4	16.1	19.3	4.6	63.1	14.8	169.5	39.9	82.2	19.4	10.4	2.5	3.6	0.5	425.6	100
	Nong Ham Lake	1,444 "	2.4	0.4	1.7	0.3	2.8	0.5	4.6	0.8	3.5	0.6	87.4	15.4	32.9	5.8	67.2	11.9	245.3	43.3	97.2	17.2	16.1	2.8	5.6	1.0	566.7	100
	Nakorn Phanom	384,400 "	15.2	2.2	11.4	1.7	11.7	1.7	11.9	1.7	15.4	2.2	58.7	8.6	77.8	11.3	121.0	17.6	175.7	25.6	121.2	17.7	41.0	6.0	25.3	3.7	686.3	100
	Mukdahan	402,450 "	15.9	2.2	12.1	1.7	11.7	1.6	11.8	1.6	16.0	2.2	63.4	8.8	81.8	11.4	126.6	17.6	185.9	25.8	126.3	17.6	42.2	5.9	26.2	3.6	719.9	100
	Kratie	651,000 "	13.3	1.6	8.5	1.0	7.8	0.9	7.5	0.9	16.5	2.0	66.5	7.9	120.5	14.4	163.3	19.5	198.3	23.7	163.3	19.5	45.1	5.4	26.3	3.2	836.8	100
Average	Nam Pung Dam Site	296 km²	0.7	0.2	0.2	0.1	0.1	0	3.7	1.0	5.1	1.7	27.3	8.6	22.9	7.2	70.7	22.2	132.3	41.5	46.7	14.6	5.9	1.9	3.1	1.0	318.7	100
	Nong Ham Lake	1,444 "	1.9	0.5	1.4	0.3	3.9	0.9	3.6	0.9	5.4	1.3	34.1	8.2	31.2	7.5	86.1	20.8	180.0	43.4	56.4	13.6	7.7	1.9	3.6	0.7	415.3	100
	Nakorn Phanom	384,400 "	14.8	2.4	11.5	1.9	11.3	1.8	10.4	1.7	13.1	2.1	37.7	6.0	67.1	10.7	139.9	22.3	163.8	26.1	97.8	15.6	36.5	5.8	22.6	3.6	626.5	100
	Mukdahan	402,450 "	15.9	2.4	12.6	1.9	11.4	1.7	10.1	1.5	12.9	1.9	45.1	6.8	72.6	10.8	146.8	22.0	167.7	25.1	109.1	16.4	38.1	5.7	24.6	3.8	666.9	100
	Kratie	651,000 "	11.8	1.8	8.4	1.3	7.4	1.1	6.2	1.0	11.0	1.7	36.7	5.6	74.9	11.4	143.7	21.9	163.8	24.9	126.5	19.3	43.7	6.7	22.7	3.3	656.8	100

Notes: 1. Run-off at Nam Pung dam site - July to December 1961: NEA Data
Jan. 1959 to June 1961: computed values from inflow to Nong Han Lake.
2. Run-off at Nakorn Phanom and Mukdahan - computed from water level-discharge curve based on recorded water level and discharge records of NEA.
3. Run-off at Kratie - Harza Engineering Co. International data.

Table-II-7 Discharge Duration at Nakorn Phanom & Mukdahan

Duration	1961						1960						1952		
	Nakorn Phanom			Mukdahan			Nakorn Phanom			Mukdohan			Nakorn Phanom		
	Date	Water level (ELm)	Discharge (m^3/s)	Date	Water level (ELm)	Discharge (m^3/s)	Date	Water level (ELm)	Discharge (m^3/s)	Date	Water level (ELm)	Discharge (m^3/s)	Date	Water level (ELm)	Discharge (m^3/s)
Over 355 days	16 Mar	131.65	1,634.83	26 Mar	125.19	1,666.02	18 Apr	131.01	1,275.49	27 Apr	124.89	1,259.53	28 Feb	131.45	1,499.78
Over 275 days	3 Feb	131.99	1,891.32	7 Feb	125.47	2,057.37	25 Feb	131.72	1,684.87	29 Feb	125.33	1,860.25	2 May	131.79	1,736.34
Over 185 days	1 Dec	133.93	4,003.15	2 Dec	127.06	4,498.90	6 Dec	133.34	3,244.15	17 Dec	126.50	3,596.47	26 June	133.51	3,452.39
Over 95 days	22 July	138.11	11,922.76	2 Aug	131.17	13,055.51	16 July	136.32	9,195.01	25 July	129.73	9,569.56	21 Oct	137.01	9,630.48
Over 35 days	20 Sept	142.05	24,182.47	7 Oct	135.54	26,721.81	15 Aug	141.37	21,614.35	18 Sept	134.37	22,710.93	29 Sept	141.38	21,650.75
Maximum	29 Sept	143.16	28,779.86	30 Sept	136.93	31,821.36	24 Aug	143.79	31,612.82	24 Aug	137.65	34,605.66	18 Sept	142.95	21,871.53

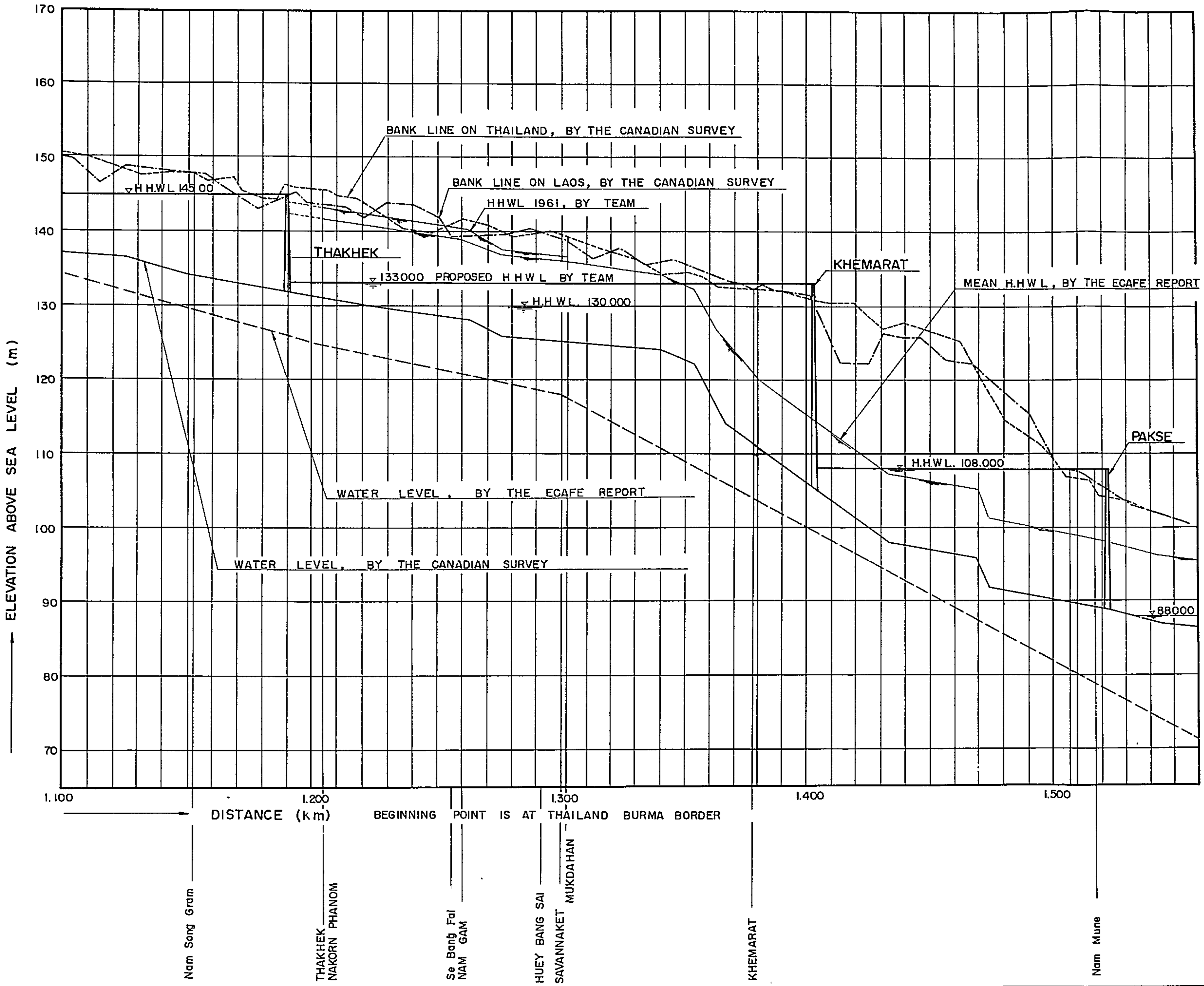


FIG. II-9

PROFILE OF THE MAIN MEKONG

(NAM SONG GRAM - NAM MUNE)

Annual run-off distribution (1961)	Nam Gam		Main Mekong		
	Nam Pung dam site	Lake Nong Han inflow	Nakorn Phanom	Mukdahan	Kratie
November to May in %	5.2	6.4	19.2	18.8	15.0
June & July in %	20.7	21.2	19.9	20.2	22.3
August & September in %	54.7	55.2	43.2	43.4	43.2
October in %	19.4	17.2	17.7	17.6	19.5
run-off in mm	425.6	566.7	686.3	719.9	836.8
Annual in %	100	100	100	100	100

Annual run-off distribution (3 years average of 1950 to 1961)	Nam Gamm		Main Mekong		
	Nam Pung dam site	Lake Nong Han inflow	Nakorn Phanom	Mukdahan*	Kratie
November to May in %	5.9	6.5	19.3	18.9	16.9
June & July in %	15.8	15.7	16.7	17.6	17.0
August & September in %	63.7	64.2	48.4	47.1	46.8
October in %	14.6	13.6	15.6	16.4	19.3
Run-off in mm	318.7	415.3	626.5	666.9	656.8
Annual in %	100	100	100	100	100

* 2 years average of 1960 and 1961

From a study of an isohyetal map of the Mekong basin, it will be seen that the figures in the foregoing table is generally appropriate, and indicates that the run-off from the Nam Gam and Nam Pung basins computed from the recorded water level at Nam Gam gate are generally appropriate.

F. CONCLUSION

In the estimation of the run-off at the Nam Pung dam site, the following 3 methods have been used.

1. method based on the annual precipitation included in the Interim Report
2. method based on the inflow to Lake Nong Han
3. method by which re-calculations were made in the present study

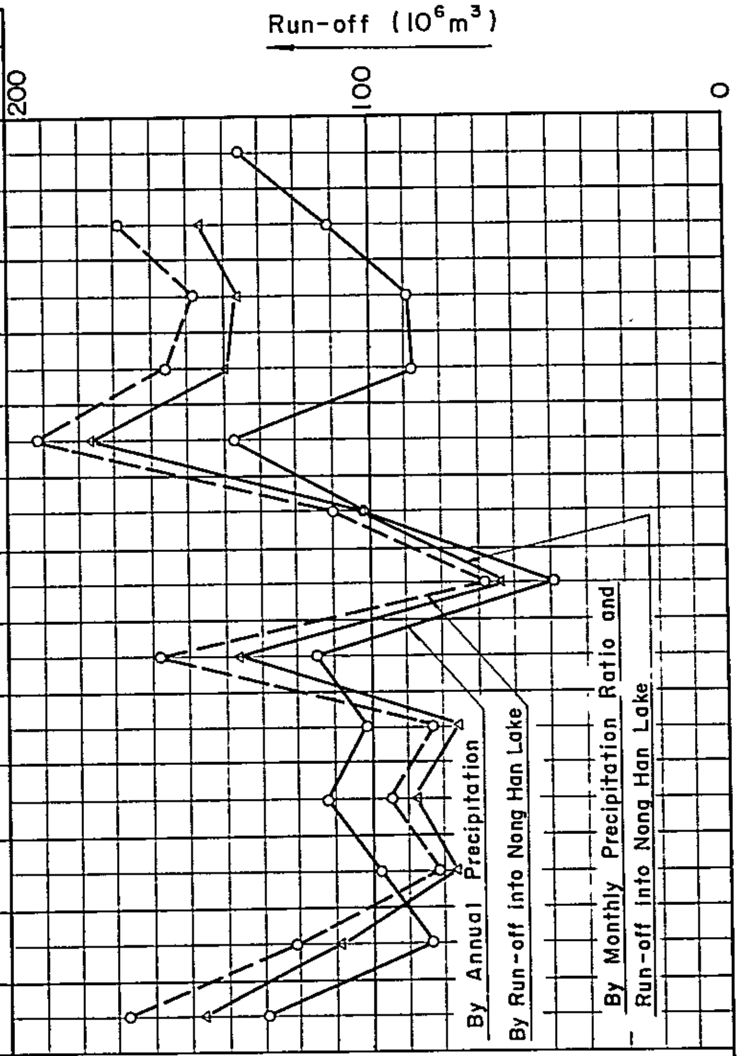
The trends and values obtained by the 3 methods of calculations, other than the years 1950 to 1953, generally agree, and it is believed that the values obtained in either of the methods may be used as approximate values. (See Fig. II-10 and Table II-8). Therefore, in this report the estimates by method 3 above, which is logical and which has advantages were used in formulating the development plan because it was believed that at the present stage it would be most proper to use the run-off for the recent past 5 years computed by method 3 which revealed the lowest values.

The calculations involved in estimating the run-off are voluminous and we have refrained from including in this report all the calculations that have been made.

FIG. II - 10

Annual Run-off at Nam Pung Damsite

Year	Run-off ($10^6 m^3$)		
	By ※	By Annual Precipitation	By Run-off into Nong Han Lake
1949	—	135.952	—
1950	147.076	111.207	169.490
1951	135.867	89.273	148.651
1952	140.628	86 964	155.903
1953	173.847	136.692	193.466
1954	101.055	101.912	110.586
1955	63.174	48.455	68.228
1956	136.877	114.700	151.759
1957	75.133	100.640	81.489
1958	86.852	110.763	94 513
1959	74.062	96.910	80.127
1960	109.236	82.968	120.886
1961	147.114	129.056	168 365
1950-1961 12 Years Total	115.0 %	100 %	127.6 %
	1.390.921	1.209.540	1.543.463
1954-1961 8 Years Total	101.0 %	100 %	111.5 %
	793.503	785.404	875.953
1952-1961 10 Years Total	109.8 %	100 %	121.4 %
	1.107.978	1.009.06	1.225.322



Remarks :

Annual Precipitation

1949 — 1956 Sakol Nakorn

1957 — 1961 Ban Srang Khor

※ Run-off into Nong Han Lake and Monthly Precipitation Ratio (Nong Han Lake Drainage Average ; Ban Srang Khor)

Table-II-8 Annual Run-off at Nam Pung Bridge Site

Year	Nong Ham Lake			Annual run-off at Nam Pung Bridge Site			Remarks
	Annual run-off	Annual inflow		Computed from annual inflow to Nong Han Lake	Thai government data		
	($10^3 m^3$)	$10^3 m^3$	Converted into precipitation (mm)	($10^3 m^3$)	(B) ($10^3 m^3$)	Converted into precipitation (mm)	
	Aug.-Dec.	Aug.-Dec.	Aug.-Dec.	Aug.-Dec.			①
1949	837.264	804.062	559.1	476.912			(A)/(B) 1957...44.9%
1950	746.592	833.937	572.6	488.428			1958...27.2%
1951	759.969	734.807	502.2	428.377			
1952	629.485	764.158	526.7	449.275			② Nam Pung
1953	1,007.743	945.425	653.6	557.521			Bridge Site
1954	420.699	546.474	373.6	318.681			catchment
1955	270.157	339.943	230.5	196.617			area 853 Km^2
1956	712.511	741.817	512.7	437.333			
1957	336.175	403.790	275.3	234.831	523.000	613	
1958	432.521	467.011	319.3	272.363	1,003.000	1,176	
1959	309.791	398.014	270.7	230.907			
1960	502.441	592.695	408.4	348.365			
1961	908.390	818.369	566.7	483.395			

CHAPTER III.

FIRST STAGE DEVELOPMENT SCHEME OF THE NAM GAM BASIN

CHAPTER III.

FIRST STAGE DEVELOPMENT SCHEME OF THE NAM GAM BASIN

A. BASIC CONSIDERATIONS OF THE DEVELOPMENT PLAN

A plan for the development of the Nam Gam basin is outlined in the Comprehensive Reconnaissance report on Major Tributaries of the Lower Mekong Basin presented by the Japanese Government in September 1961. However, as stated in the "Foreword" of this Report, the scale of development was somewhat over-estimated due to errors in hydrological data obtained from the authorities of Thailand.

As a result of the investigation and studies conducted in the entire basin of the Nam Gam, the Team has been able to estimate the maximum extent to which the potential water resource of the basin may be developed in the first stage, and the Team has found that it would be possible to proceed with the second and third stage development of the basin when the development of the main Mekong River and neighboring basins are undertaken in the future.

Development possibilities of the second and third stage are covered in Chapter V. Therefore, this Chapter will be devoted to the maximum possible extent of development of the Nam Gam basin in the first stage through the construction of a multi-purpose dam on the Nam Pung.

There are several falls in the upper reaches of the Nam Pung, which is a tributary of the Nam Gam, at a distance of about 30 kilometers to the south-west of the city of Sakol Nakorm. These falls creat a continuous rapid section where a head of about 60 meters may be developed.

Accordingly, it is proposed that a fill type dam about 32 meters in height be built on exposed bed rock on the upstream of the falls to create a reservoir having an effective storage capacity of about 122,000,000 m^3 in order to store run-off from a catchment area of 296-km^2.

Utilizing this reservoir (hereinafter called Nam Pung Reservoir) 5,400 kW of hydro-electric power may be developed. Electric power generated may be supplied not only to the city of Sakol Nakorm but also to such distant cities as Nakorm Phanom, That Phanom, Mukdahan, etc. along the main stream of the Mekong River.

Furthermore, by the construction of an intake structure at the Nam Pung Bridge site it will be possible to draw water discharged from the Nam Pung power station to irrigate arable land on the left bank of the Nam Pung (on the southern side of the Lake Nong Han) and the right bank of the Nam Pung (on the right bank of the Nam Gam) throughout the year.

With an effective drawdown of 2.0 m the effective storage capacity of Lake Nong Han is about 196,000,000 m^3. This pondage is currently not utilized in the dry seasons, serving merely as a flood retarding basin for the Nam Gam in the rainy seasons. However, on account of the insufficient drainage capacity of the main stream of the Nam Gam (between Lake Nong Han and the confluence with the Mekong) the area along the banks of the lake is inundated year after year.

Utilization of Lake Nong Ham as a reservoir is possible even in the present condition. If a pumping station is installed on the bank of the lake, utilizing a drawdown of 2.0 m, for the pumping of water for irrigation, it would be possible to reclaim 4,500 ha on the northern side of Lake Nong Ham. It would thus be possible to irrigate 14,500 ha, including the 10,000 ha along the Nam Pung, all the year round. As a result, stabilized agricultural management would be possible in the above area in both the dry and rainy seasons.

With respect to flood control measures for the low-lying swamp land along Lake Nong Han and the main stream of the Nam Gam, the construction of the Nam Pung Reservoir would greatly reduce the rising of the lake water level in the rainy season, because the reservoir would be able to store on the average approximately 64,000,000 m^3 (27,000,000 to 96,000,000 m^3) of the run-off of the Nam Pung in the rainy season.

This run-off corresponds to 8.0 to 9.6 per cent of the annual inflow into the Lake Nong Han which is 340,000,000 to 945,000,000 m^3.

The discharge capacity of the Nam Gam at the downstream of Nam Gam Gate is only 35 m^3/S. To prevent inundation of the lower reaches, it is considered that the minimum required drainage capacity of the Nam Gam, in the wet seasons, is 155 m^3/s. The Team has reached the conclusion that, in order to maintain the water level in the Lake Nong Han below EL 157.50 m in the rainy season, it is more economical to construct a drainage canal about 7.3 km long connecting the lake directly to Huai Nam Un, a small tributary of the Nam Song Gram, located on the northern side of the Nam Gam, rather than to try to improve the river channel of the main stream of the Nam Gam.

The proposed canal may not only be utilized in the pump irrigation plan for the Lake Nong Han but also be used to divert flow of the main stream of the Mekong into the Nam Gam basin in the third stage development, which should be taken up when the development of the main stream of the Mekong makes progress in the future.

Therefore, the connecting canal may become a very important structure that would serve many purposes in the development of the water resource in the Nam Gam basin in the future.

In the following pages is briefly described B., Schemes for utilization of Lake Nong Han and Nam Pung Reservoir, C., flood control scheme D., hydro-electric power development scheme E., agricultural development scheme which constitute the first stage development of the Nam Gam basin. Submitted together with this report, in a separate volume, are preliminary designs for the Nam Pung hydro-electric scheme and Nam Pung irrigation which we believe would be appropriate for early development.

B. RESERVOIR PLAN

(SCHEMES FOR UTILIZATION OF LAKE NONG HAN AND DEVELOPMENT OF HAM PUNG RESERVOIR)

(a) Plan for Utilization of Lake Nong Han

The present hydrological conditions of Lake Nong Han is described in Chapter II. At a point about 5 km downstream from the outlet of the Lake Nong Han there is installed a control gate to prevent the drop in the Lake water level in the dry season in order to protect fish life in the lake, as well as, to reduce the lake water level, as much as possible, in the beginning of a rainy season so as to serve as a flood retarding basin when the run-off in the Nam Gam basin rises in the rainy season.

It is possible and considered most desirable to take advantage of Lake Nong Han as a reservoir and to pump water from the lake during the dry season.

The outline of the plan for utilization of the lake is as follows:

Catchment area	1,561 km^2
Annual inflow	659,000,000 m^3 (average of 13 years, Sept. 1949 to Aug. 1962)
Elevation at high water level	EL. 157.50 m
Effective drawdown	2 m
Effective storage	196,000,000 m^3

The operation of Lake Nong Han as a reservoir is given in Fig. III-2 and Table III-1. The operation of the lake in the rainy season (May to September) is designed to maintain the maximum water level below EL 156.50 m (1.00 m below the high water level) so as to drain the yearly flood flows draining into the lake and in the event of a probable abnormal flood (a four-day precipitation of 312 mm is estimated), the rise of the lake water level may be kept at a maximum of 0.67 m over the high water level (EL 158.17 m) by utilization of the drainage canal. As a result, inundation of cultivated land may be reduced to about 16 days. (For details, refer to C. FLOOD CONTROL SCHEME in this Chapter).

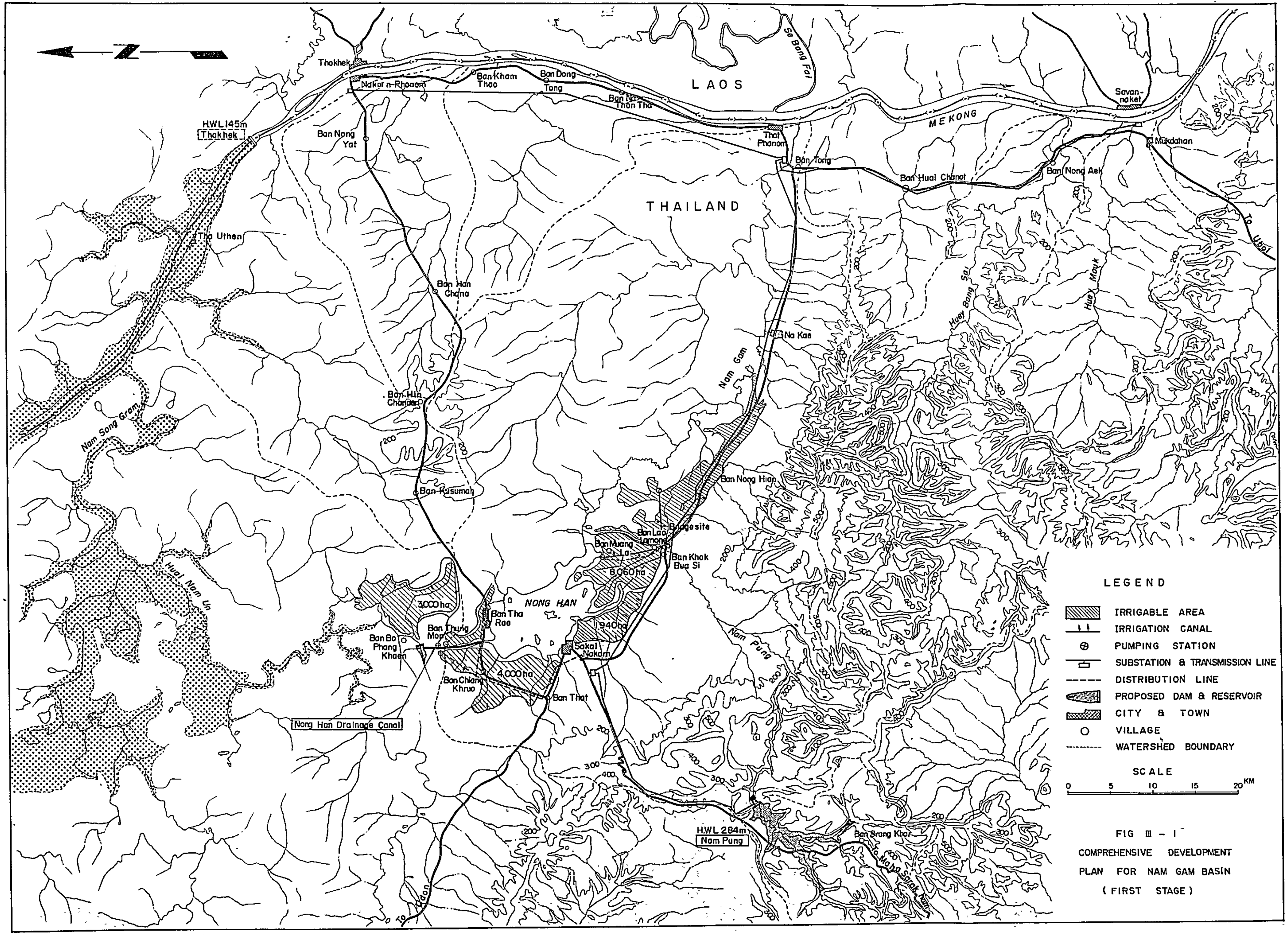


FIG III - 1
COMPREHENSIVE DEVELOPMENT PLAN FOR NAM GAM BASIN
(FIRST STAGE)

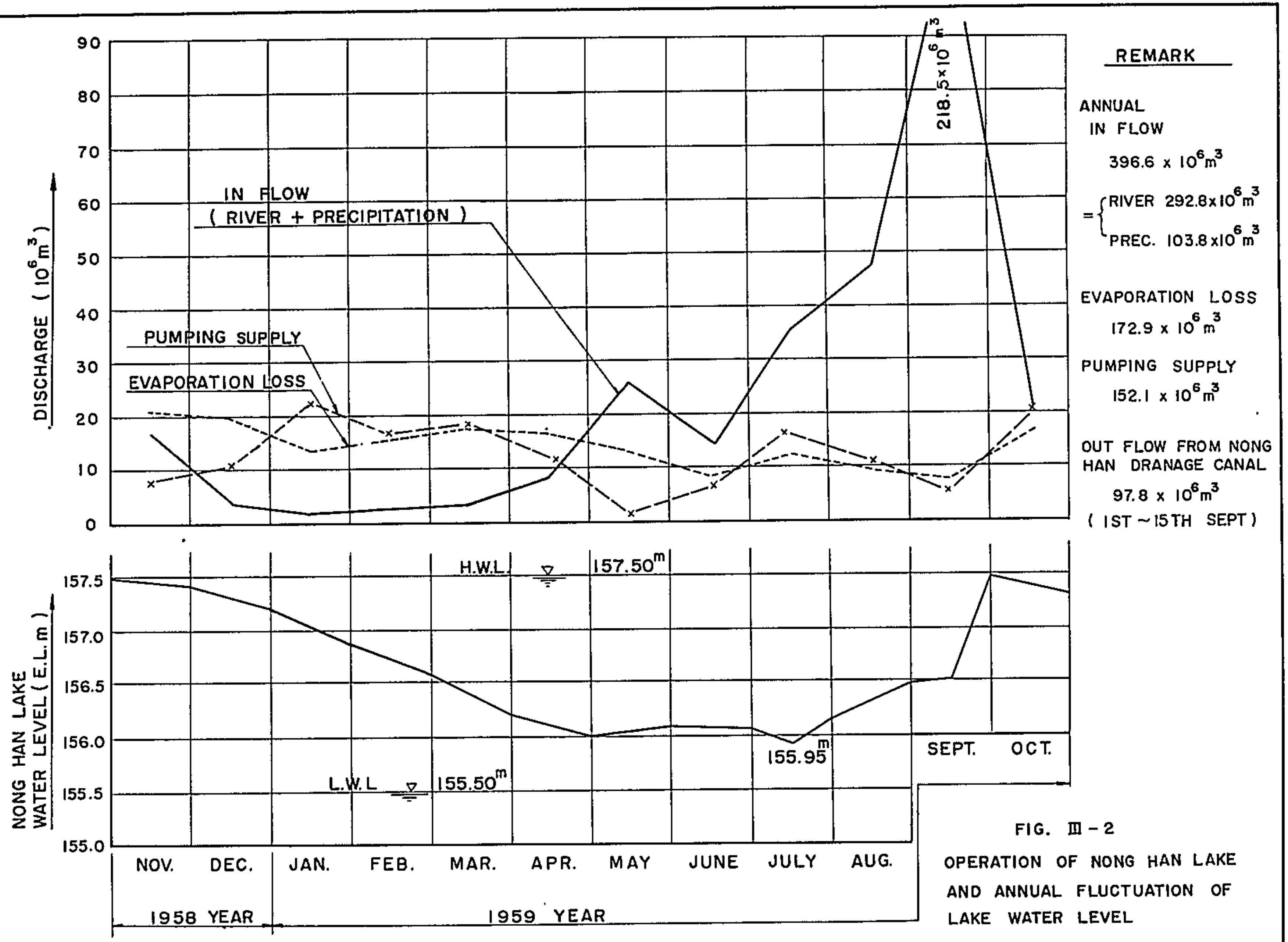


FIG. III - 2

OPERATION OF NONG HAN LAKE AND ANNUAL FLUCTUATION OF LAKE WATER LEVEL

Table - III - 1 Fluctuation of Nong Han Lake Water Surface

Year Month	① Stream Flow							② Loss			Increase or Decrease of Lake ①-②	Drainage Discharge	Reservoir (Start of Month)		Remark
	q_1	q_2		q_3			Total	Pumping Discharge	Evaporation	Total			Storage Capacity	Water Level	
		$7080-A_2$	q_2	Pr	A_2	$q_3=A_2 \cdot Pr$	$(q_1+q_2+q_3)$								
	10^6m^3	km^2	10^6m^3	mm	km^2	10^6m^3	10^6m^3	10^6m^3	10^6m^3	10^6m^3	10^6m^3	10^6m^3	10^6m^3	E.L.m	
1958 Nov.	5,409	580.2	11,050	0	127.8	0	16,459	8,765	20,500	29,265	△ 12,806	0	265,430	157.50	Water level at beginning of month
1958 Dec.	1,687	583.0	2,050	0	125.0	0	3,737	10,439	19,400	29,839	△ 26,102	0	252,624	157.43	"
1959 Jan.	0	590.0	1,123	0	118.0	0	1,123	22,253	13,680	35,933	△ 34,810	0	226,522	157.20	"
1959 Feb.	0	595.0	0.853	10.9	110.0	1,200	2,053	16,999	16,320	33,319	△ 31,266	0	191,712	156.88	"
1959 Mar.	0	590.0	1,942	13.1	118.0	1,545	3,487	18,518	17,950	36,468	△ 32,981	0	160,446	156.58	"
1959 Apr.	0.282	610.0	2,590	54.1	98.0	5,309	8,173	11,695	16,050	27,745	△ 19,572	0	127,465	156.20	"
1959 May	7,779	625.0	5,540	150.6	83.0	12,500	25,819	1,636	13,400	15,036	10,783	0	107,893	156.00	"
1959 June	2,946	621.0	3,780	86.3	87.0	7,520	14,246	6,789	8,420	15,209	△ 963	0	118,676	156.10	"
1959 July day 1 - 15	0	621.0	5,810	26.6	87.0	2,310	8,020	13,500	6,340	19,840	△ 11,720	0	117,713	156.08	"
1959 July day 16 - 31	4,054	625.0	5,900	211.6	83.0	17,550	27,504	3,386	6,560	9,946	17,558	0	105,993	155.95	Water level of the 16th
1959 Aug.	8,622	619.0	19,300	216.3	89.0	19,280	47,202	10,538	9,100	19,638	27,564	0	123,551	156.18	Water level at beginning of month
1959 Sept. day 1 - 15	51,826	610.0	28,400	263.3	98.0	25,810	106,036	2,865	3,885	6,750	1,535	97,751	151,115	156.49	"
1959 Sept. day 16 - 30	33,319	610.0	58,400	109.4	98.0	10,720	112,439	2,776	3,885	6,661	105,778	0	152,650	156.50	Water level of the 16th
1959 Oct.	1,656	581.0	18,450	0.5	127.0	0.050	20,156	21,902	17,420	39,322	△ 19,166	0	258,428 (239,268)	157.48 (157.30)	Water level at beginning of month (Water level at month end)
Total	117,580	-	175,188	1,142.7	-	103,786	396,554	152,061	172,910	324,971	△ 26,168	97,751			

Remark: q_1 = Discharge at Nam Pung Bridge Site to Nong Han Lake

q_2 = Inflow from around Nong Han Lake = $\frac{(A_1 - 8530) \text{ or } (7080 - A_2)}{\text{Nong Han Lake Catchment Area (Chapter II, Table II-1)}}$ × Nong Han Lake Inflow (Chapter II, Table II - 1)

q_3 = Nong Han Lake Water Surface Inflow = A_2 × Precipitation

A_2 = Nong Han Lake Water Surface Area A_1 = 1561.0 - A

① Precipitation is $\frac{1}{2}$ (Sakol Nakorn Pr. - Nam Gam Gate Pr.)

The available storage that may be pumped for irrigation in the dry season is about 147,000,000 m^3. This figure is arrived at by adding the effective storage of 196,000,000 m^3 to the estimated inflow of about 71,000,000 m^3 in the dry season, the rainfall in the lake area, which is about 30,000,000 m^3 and deducting the estimated evaporation amounting to about 150,000,000 m^3. The available water of the lake plus discharge from the Nam Pung Reservoir may be utilized to irrigate in the dry season, a total of 14,500 ha, comprising of the Nam Pung irrigation area and land on the northern and western side of Lake Nong Han. (For details, refer to E. AGRICULTURAL DEVELOPMENT SCHEME in this Chapter.)

(b) Nam Pung Reservoir Scheme

There is a suitable site for the construction of a reservoir in the upper reaches of the Nam Pung, a tributary of the Nam Gam, at a point of about 35 km to the south-west of the city of Sakol Nakorn.

The proposed Nam Pung Reservoir will be a multi-purpose project including the generation of power, control of flood and development of irrigation. The construction of the Nam Pung Reservoir is the prerequisite to the plan for utilization of Lake Nong Han.

The pumping of the water from Lake Nong Han depends upon electric power available from the Nam Pung dam which constitutes the main part of the first stage development of the Nam Gam basin.

The annual inflow at the Nam Pung Dam Site is estimated at 63,000,000 m^3 to 174,000,000 m^3. The effective storage capacity of 122,000,000 m^3 will not only serve to equalize flow to the downstream throughout a year but also increase available water in an extreme dry year which is 63,000,000 m^3 to 94,000,000 m^3. In addition, the effective storage was determined to be 122,000,000 m^3 in order to provide storage for 16,000,000 m^3/S of water which would be additionally required for pumping of irrigation water in dry seasons. (Refer to Fig. III-3, III-4 and Table III-2.)

Following is a discription of the Nam Pung Reservoir Scheme.

Catchment area	296 km^2
Elevation at high water level	EL. 284.00 m
Elevation at flood water level	EL. 285.50 m
Elevation at low water level	EL. 270.0 m
Available drawdown	14 m
Gross storage capacity	133×10^6 m^3
Effective storage capacity	122×10^6 m^3
Pondage area	20 km^2
Annual inflow	63,000,000 m^3 - 174,000,000 m^3

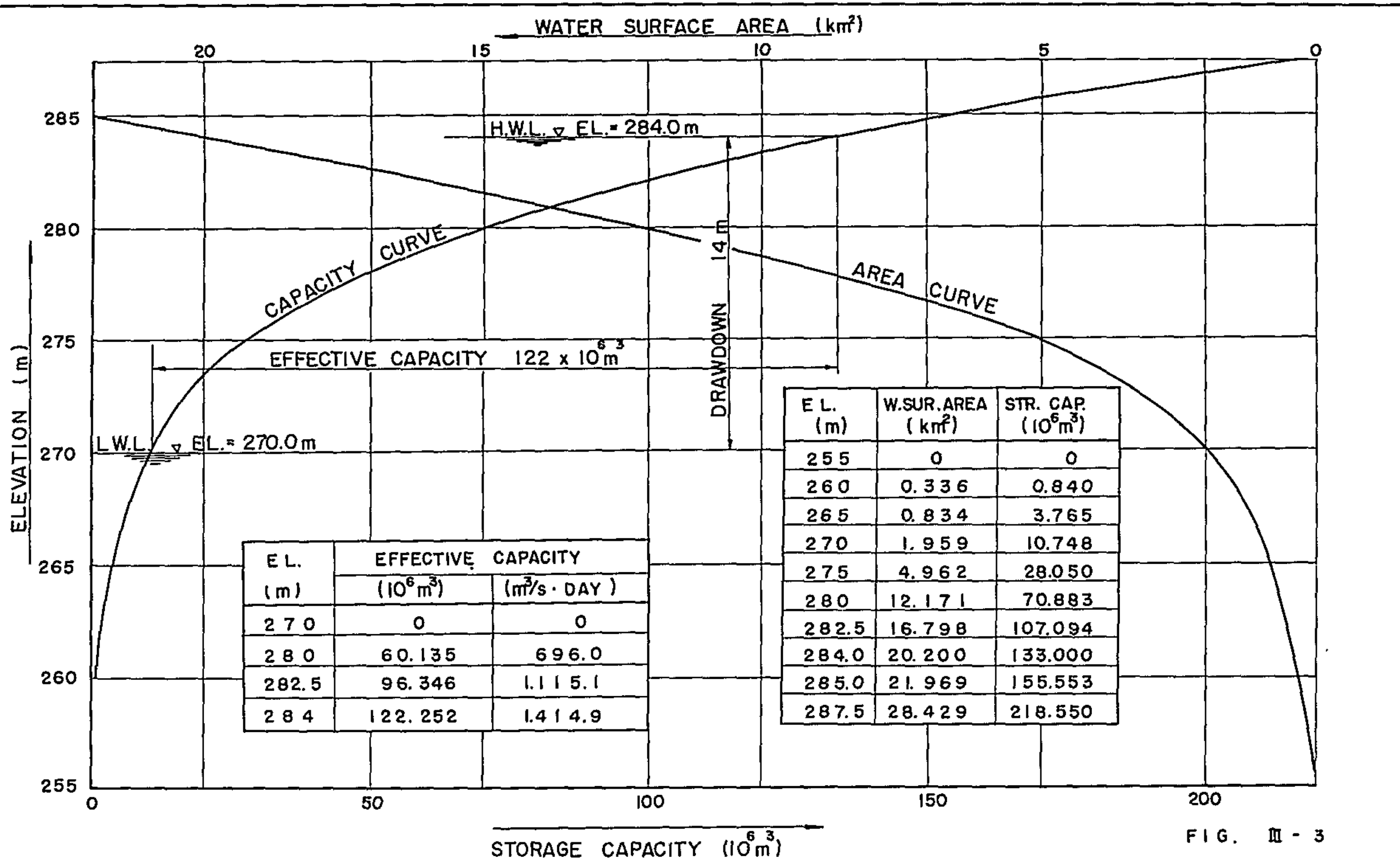
The proposed operation of Nam Pung Reservoir is as follows:

The annual inflow into the Nam Pung Reservoir will change considerably according to the amount of rainfall. The annual inflow in the ten years from 1952 to 1961 is estimated to have been 63,000,000 m^3 - 173,000,000 m^3. It was found, however, that this run-off is concentrated in the rainy season that lasts about four months, and the run-off in the dry seasons is almost zero.

The effective storage capacity of Nam Pung Reservoir, which is 122,000,000 m^3, will regulate the annual inflow and increase the minimum yearly run-off to 94,000,000 m^3 so as to ensure an annual power generation of 15,000,000 kWh.

The effective storage capacity above mentioned also includes 16,000,000 m^3 of storage to generate 3,000,000 kWh additionally during the dry season to supply irrigation pump loads. (For details, refer to D. HYDRO-ELECTRIC POWER DEVELOPMENT SCHEME in this Chapter).

The inflow into the Nam Pung Reservoir other than that to be used for power generation will be discharged into the main stream of the Nam Pung through a spillway built in the dam.



E L. (m)	EFFECTIVE CAPACITY	
	$(10^6 m^3)$	$(m^3/s \cdot DAY)$
270	0	0
280	60.135	696.0
282.5	96.346	1.115.1
284	122.252	1.414.9

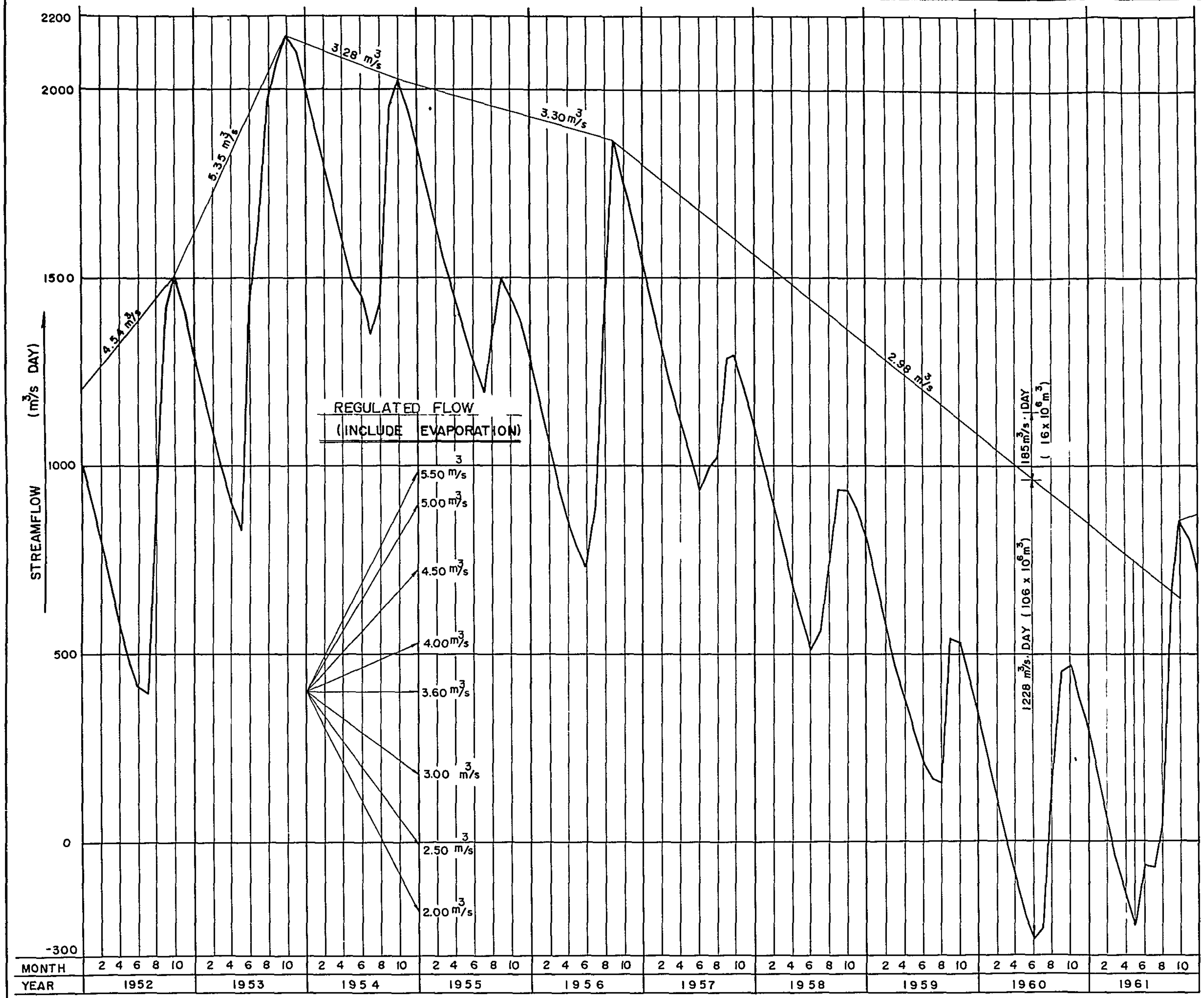
E L. (m)	W.SUR.AREA (km^2)	STR. CAP. ($10^6 m^3$)
255	0	0
260	0.336	0.840
265	0.834	3.765
270	1.959	10.748
275	4.962	28.050
280	12.171	70.883
282.5	16.798	107.094
284.0	20.200	133.000
285.0	21.969	155.553
287.5	28.429	218.550

FIG. III - 3

STORAGE CAPACITY AND

WATER SURFACE AREA CURVE

OF NAM PUNG RESERVOIR



RESERVOIR

H. W. L.	284.00 m
L. W. L.	270.00 m
DRAWDOWN	14.00 m
GROSS STORAGE	$133 \times 10^6 m^3$
EFFECTIVE STORAGE	$122 \times 10^6 m^3$

GENERAL LOAD ---- $106 \times 10^6 m^3$

DRY SEASON SUPPLY FOR IRRIGATION ------ $16 \times 10^6 m^3$

FIG. III-4

NAM PUNG RESERVOIR INFLOW MASS CURVE

Table-III-2 Available flow of Nam Pung Reservoir

Year	Inflow ① (m3/S)	Regulated ② flow (m3/S)	Evaporation ③ (m3/S)	Available ④ flow (m3/S) ②-③	Average Storage ⑤ volume (106 m3)	Average Water level (E.L. m)
1952	4.45	4.68	0.36	4.32	79.3	281.0
1953	5.51	5.00	0.46	4.54	89.0	283.0
1954	3.21	3.29	0.38	2.91	93.5	281.5
1955	2.01	3.30	0.33	2.97	77.8	280.5
1956	4.33	3.26	0.29	2.97	71.3	279.3
1957	2.38	2.98	0.36	2.62	82.2	281.0
1958	2.76	2.98	0.32	2.66	69.5	280.0
1959	2.35	2.98	0.25	2.73	56.4	278.5
1960	3.46	2.98	0.21	2.77	47.4	277.5
1961	4.66	3.17	0.32	2.85	70.2	280.0
10 years average	3.51	3.46	0.33	3.13	73.66	-

NOTE: See FIG. III-4

It has been observed that in the post heavy floods in the Mekong basin, especially in the Nam Gam basin, have mostly occurred toward the end of rainy seasons. However, since the Nam Pung Reservoir, with an effective storage capacity 122,000,000 m^3, will store the rainy season run-off of the Nam Pung, it will have great effects in reducing floods in the lower reaches of the Nam Pung, as well as, the surrounding areas of Lake Nong Han and the main stream of the Nam Gam.

The probable abnormal floods (continuous 4-day 390 mm precipitation is estimated) must be expected to occur towards the end of the rainy season when the reservoir is at high water level.

In order to reduce damages in the lower reaches of the Nam Pung from probable abnormal flood, the plan is designed to reduce peak flood discharges by means of the Nam Pung Reservoir.

The probable maximum flood flow is 640 m^3/s. The design spillway capacity is 300 m^3/s while the discharge capacity of the gate controlled spillway section is 52 m^3/s at a high water level of EL. 284 m, creating a wide difference between the two values.

Accordingly, the inflow into the reservoir during abnormal flood flows will be stored in the reservoir (rise in water level 1.50 m over the high water level or storage capacity of 33,500,000 m^3). When surcharged the spillway will be able to discharge 281 m^3/s which would reduce peak flood flows, as well as, retard the flood discharge time. (The design spillway capacity is 300 m^3/s.)

In order to insure the storage necessary for achieving the above objective, the dam is designed with a freeboard of 2.5 m over the design high water level. (For the determination of flood discharges and calculation of outflow, refer to Chapter II.)

In the design of the spillway a weir section (length - 30 m) has been incorporated so that water may flow uncontrolled when the operation of the gates is delayed or the gates are out of order. (Refer to I. "Preliminary designs of Nam Pung Hydro-electric Scheme" in the separate volume.)

C. FLOOD CONTROL SCHEME

The flood control program of the Nam Gam basin may be divided into two general groups, that is, flood control of the lower reaches of Nam Pung by regulation of flow at the Nam Pung Reservoir and flood control in the environs of Lake Nong Han and the main stream of Nam Gam.

(a) Flood Control Program of the Nam Pung Reservoir

The flood control program of the Nam Pung Reservoir is summarized in this Chapter, B, (b), "Nam Pung Reservoir Scheme" and the details regarding the estimation of flood discharge is given in Chapter II, "Analysis of Hydrological Data." This Paragraph will be devoted to the control of maximum flood discharges.

The storage capacity of the reservoir above the design H.W.L. of 284 m, for controlling peak flood discharges, when the maximum flood inflow to the Nam Pung Reservoir is 640 m^3/s, is 33,500,000 m^3 which is 1.5 m above the design high-water level. The relation between the said storage capacity and the type of flood wave which is shown in Fig. III-5 is expressed by the following equation.

$$V = \frac{q_m - q_o}{2} \cdot Tb + \frac{q_m + Q_m - 2q_o}{2} \cdot (Tx - Tb) - \frac{Q_m - q_o}{2} \cdot Tx$$

Where: V = Storage capacity (m^3) = 33,500,000

q_m (Maximum flood discharge) = 640 m^3/s (1,000 years probability)

q_o (Base flow) = 16 m^3/s (1,000 years probability).

Tb (Arrival time of peak flood) = 49.75 hrs.

Tx (Arrival time of peak flood after regulation) .... (hrs.)

Qm (Maximum flood discharge after regulation) .... (m^3/s.)

The values of Tx and Qm calculated under the said formula are respectively as follows:

Tx = 66 hrs. 30 min.

Qm = 265 m^3/s.

However, in the said formula, the control of the base flow, which is 16 m^3/s, is not taken into consideration, but if this condition is included, then the values are respectively,

Tx = 66 hrs.

Qm = 281 m^3/s.

Accordingly, the design spillway capacity was determined at 300 m^3/s, including some allowances.

The controlled flood discharge, as shown in the following table, may be discharged through the spillway in about 145 hours after the reservoir reaches to maximum water-level, or in a total of 211 hours.

Discharge time (hrs.)	66.00-72.25 6.25	72.25-127.30 55.05	127.30-210.84 83.54	Σ 66.00-210.84 144.84
1. Net discharge (m^3/s.)	0-113.68	113.68-84.00	84.00-0	
2. Inflow of flood run-off (m^3/s.)	281.00-146.32	146.32-16.00	16.00-16.00	
3. Total discharge (m^3/s.)	281.00-260.00	260.00-100.00	100.00-16.00	
Volume of discharge ($10^3/m^3$.)	1,279	19,589	12,632	Σ 33.500

As shown in the above table, by the regulation of discharge at the Nam Pung Reservoir, the peak discharge during abnormal flood flows may be retarted by 49.45 hrs. to 66 hrs. and the maximum flood discharge of 640 m^3/s may be reduced to 281 m^3/s at the foot of the dam. The effect of the said peak-cut at the Nam Pung Bridge site is estimated to reduce the maximum flood discharge of 720 m^3/s. (HHWL 165.83 m) to 540 m^3/s. (HHWL 165.13 m) and to reduce the flood water level in this vicinity by 0.70 m, thereby greatly mitigate flood damages.

(b) Lake Nong Han Flood Control Program

The Nam Pung Reservoir will contribute to some extent to the storage of discharge during the rainy season, but the average storage in relation to the annual inflow is about 64,000,000 m^3, as shown in Table III-3, which corresponds to only 8.0 to 9.6% of the annual inflow to Lake Nong Han.

Consequently, the Nam Pung Reservoir will have little of no storage space at the time of abnormal flood flows that are anticipated to come at the end of the rainy season. Therefore, the entire run-off is deemed to drain into Lake Nong Han.

Table III-3 Storage of Annual Inflow to Nam Pung Reservoir

Year	Storage of Annual Inflow ($10^6 m^3$)
1952	88.9
1953	90.7
1954	60.7
1955	27.2
1956	95.5
1957	37.1
1958	45.6
1959	36.5
1960	69.9
1961	85.1
Average	63.7

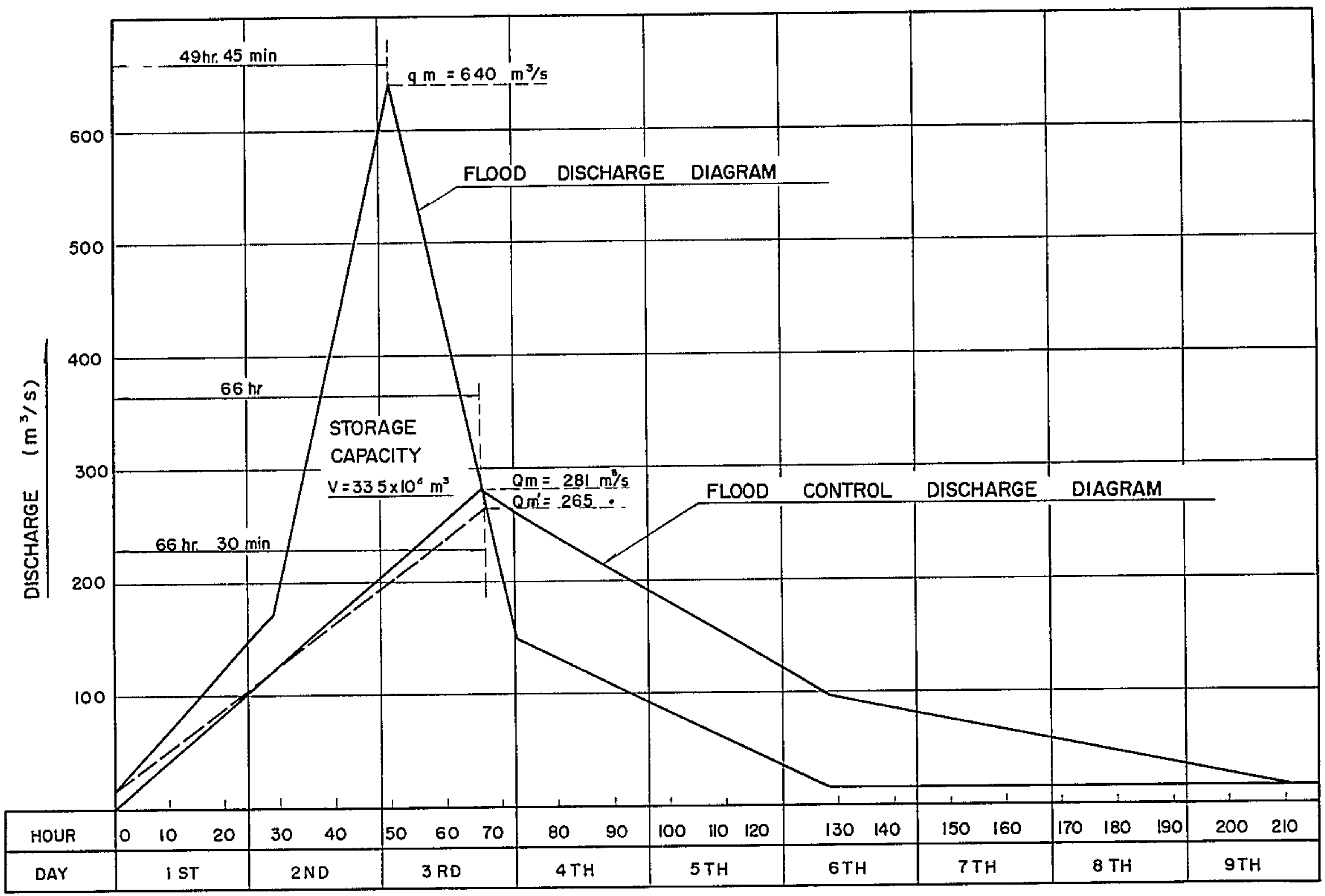


FIG · III - 5
FLOOD CONTROL OF
NAM PUNG RESERVOIR

As a result of analyzing the records of water-levels observed for the past 13 years at Nam Gam Gate installed on the main stream of the Nam Gam, it is estimated that the discharge capacity of the main Nam Gam is as shown in the table which follows. The Team has come to the conclusion that to improve the river channel to accommodate a discharge of 155 m^3/s at the design maximum high water level of 157.50 m will involve a tremendous improvement work which alone will not prevent the inundation of land in the vicinity of the main stream of the Nam Gam.

	Lake water-level (EL m.)	Water-level at Nam Gam Gate (EL m.)	Difference of water-levels between the upper & lower side of the Gate (m.)	Discharge capacity (m^3/s.)
Past recorded maximum flood flow	158.72	158.05	0.30	189.2
At design high water-level	157.50	156.66	0.15	72.7
At normal water-level during rainy season	156.50	155.58	0.10	35.3

Consequently, it would be more economical to drain water from the lake during the rainy season directly into the neighbouring basin, i.e., Huai Nam Un, a tributary of Nam Song Gram by excavating a drainage canal about 7.3 km which will create a head about 12.5 m (under present condition 13.5 m). In the event, the proposed Takhek Dam on the main Mekong is constructed in the future, its backwater will reach up to EL 145 m. on the Huai Nam Un. At present, under the influence of backwater effects caused by flood on the main stream of the Mekong during the rainy season, an extensive area up to about EL 144 m. is inundated creating a vast stretch of unattended marshland.

The drainage from Lake Nong Han is to be discharged immediately upstream of the marshland. Thus, without causing harmful effect on the Nam Song Gram basin, the prevention of inundation of land around Lake Nong Han and along the main Nam Gam will become possible.

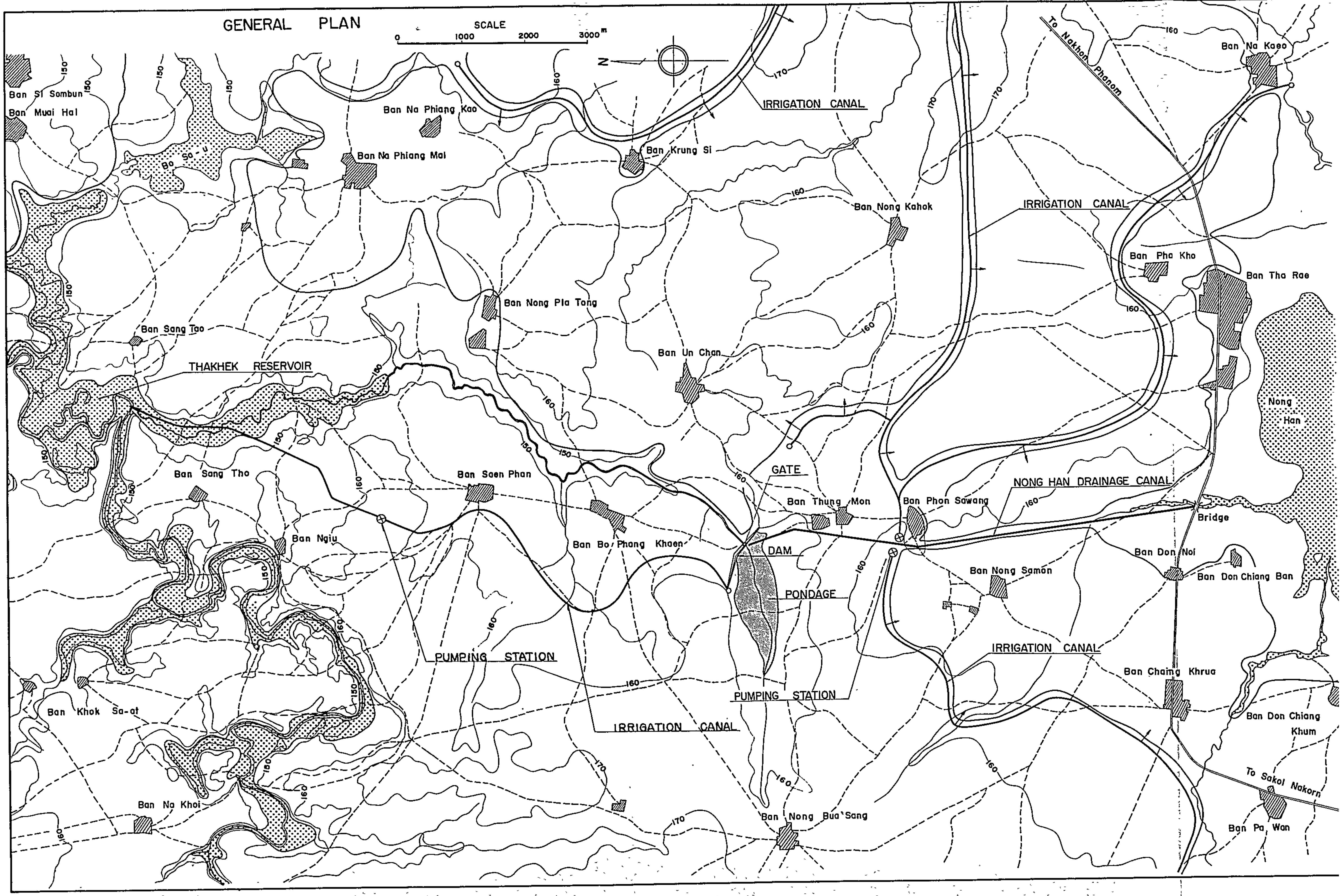
However, the inundation of land near the lower most reaches lowest of the Nam Gam, namely in the vicinity of That Phanom is believed to be due to the rise of water-level on the main Mekong. Therefore, it may not be possible to completely prevent the inundation of this area until the proposed Pa Mong Project on the Main Mekong is built.

Described in the following pages is the Lake Nong Han drainage canal. (See Fig. III-6).

Structure of Drainage Canal

Maximum water-level during dry season (Design high water-level).	EL 157.50	155 m^3/s. with gates open full
Normal water-level during rainy season	EL 156.50	68 m^3/s. with gates open full
Water-level at abnormal run-off inundation	EL 158.17	226 m^3/s. with gates open full
Controllable flood flow		205,000,000 m^3 (EL 156.50 m - EL 158.17 m)
Length of drainage canal		7,300 m
Base width of drainage canal		30 m
Depth of water in drainage canal (at maximum water-level of EL 158.17 m)		4.45 m
Gates		4 sluice gates, each 6 m high and 4.5 m wide

The discharge rating curves of the drainage canal and gates are as shown in Fig. III-7 and Fig. III-8, respectively, and Fig. III-9 gives the rating curve of the water level and discharge of Lake Nong Han.



GENERAL PLAN
SCALE
0
1000
2000
3000m
N
IRRIGATION CANAL
Ban Si Sombun
Ban Muai Hai
Bo Sa-u
Ban Na Phiang Kao
Ban Na Phiang Mai
Ban Krung Si
Ban Na Kaeo
To Nakhon Phanom
Ban Nong Kahok
Ban Pha Kho
Ban Tha Rae
Ban Nong Pla Tong
Ban Sang Tao
Ban Un Chan
THAKHEK RESERVOIR
Nong Han
Ban Sang Tho
Ban Saen Phan
GATE
NONG HAN DRAINAGE CANAL
Ban Thung Mon
Ban Phon Sawang
Bridge
Ban Ngiu
Ban Bo Phang Khaen
DAM
Ban Don Noi
Ban Nong Samon
Ban Don Chiang Ban
PONDAGE
PUMPING STATION
Ban Chaing Khrua
Ban Khok Sa-at
Ban Don Chiang Khum
IRRIGATION CANAL
To Sakol Nakorn
Ban Na Khoi
Ban Nong Bua Sang
Ban Pa Wan
150
160
170

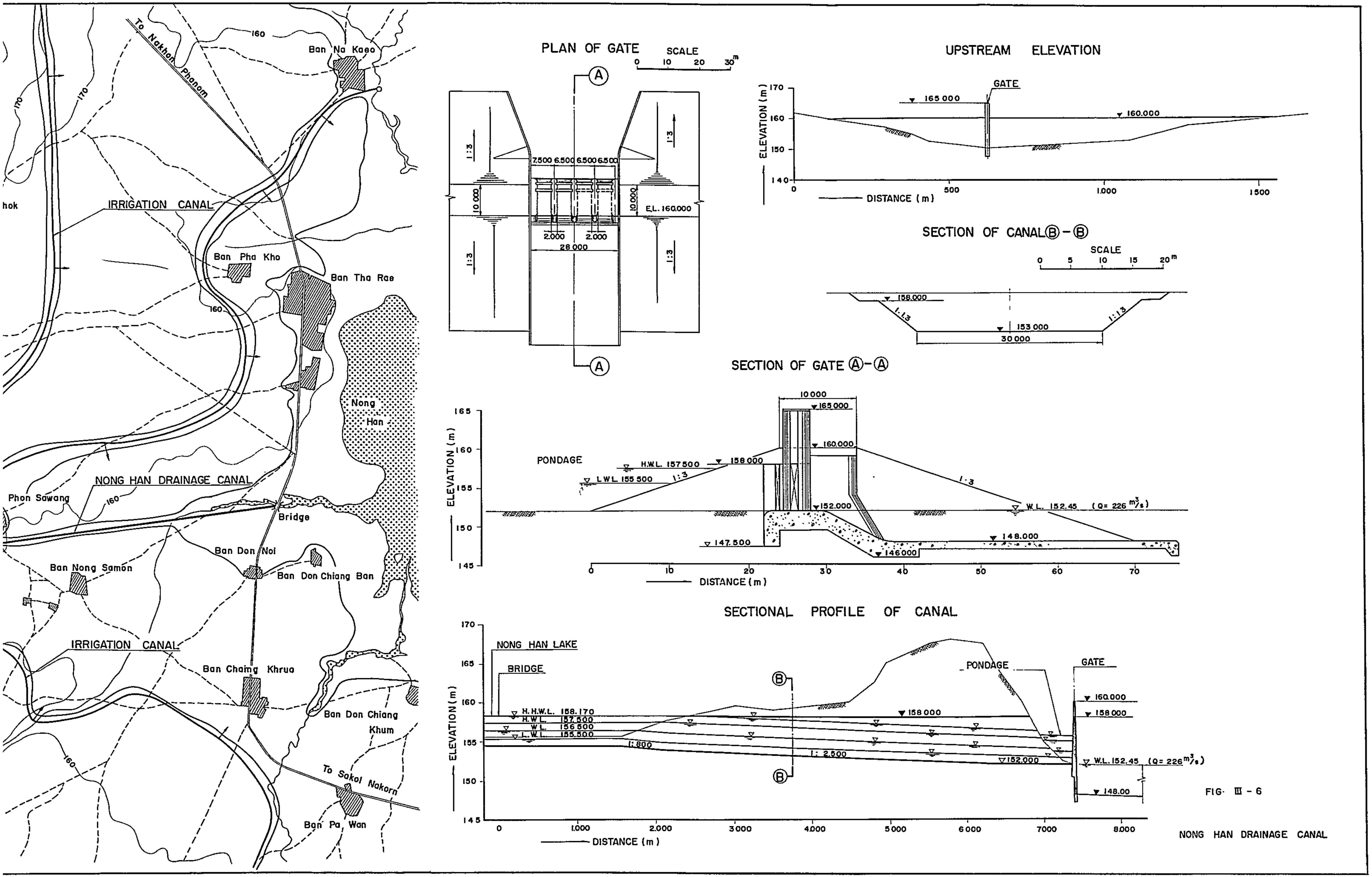


FIG. III - 6

NONG HAN DRAINAGE CANAL

Comparative studies of the flood control functions of the Lake Nong Han drainage canal and Nam Gam Gate reveals that at the maximum water-level during dry season of EL 157.50 m (design high water level), the drainage through Nam Gam Gate is 72.7 m^3/s, while the Lake Nong Han drainage canal can drain 155 m^3/s. At the time of abnormal flood flow, as per Table III-4, Table III-5 and Fig. III-10, the maximum flood discharge is 1,081 m^3/s. (the flood discharge based on 100 years probability is 1,254 m^3/s. The peak discharge may be reduced by 173 m^3/s. through regulation at the spillway of Nam Pung Reservoir, but the total flood outflow remains invariable). The Lake Nong Han drainage canal, at a maximum water-level of EL 158.17 m can drain 226 m^3/s and the duration of inundation (above EL 157.50 m) is 16 days; while the Nam Gam Gate, at a maximum water-level of EL 158.53 m, the drainage is 167 m^3/s and the duration of inundation (above EL 157.50 m) is 27 days. Thus, it is evident that in the former case, the duration of inundation above the design high water level (over EL 157.50 m) may be reduced by 11 days.

Table III-6 which follows shows the record observation records for the past 13 years.

The relationship between the inflow to Lake Nong Han and rainfall at the time of the respective maximum values underlined in Table III-6 is shown below. According to the relationship, the maximum inflow to the lake during the past 13 years is estimated to be about 540 m^3/s.

	Maximum inflow	Rainfall Period	mm
September 14, 1949	533 m^3/s	9-14, Sept.	108.3
September 8, 1951	361 m^3/s	2- 8, Sept.	198.0
September 12, 1956	240 m^3/s	31 Aug. - 13, Sept.	246.7
September 26, 1961	531 m^3/s	19-27, Sept.	164.6

The effects of draining water by constructing the Lake Nong Han drainage canal instead of releasing water from Lake Nong Han to the Nam Gam has been studied. The study showed that in the vicinity of Na Kae, which is about 70 km downstream of Nam Gam gate, the recorded 13-years maximum discharge was about 220 m^3/s. (See Fig. III-11, supplement station No. 11). By releasing flood run-off into the Lake Nong Han drainage canal the water level of the Nam Gam near Na Kae can be reduced about 2 m and the flood run-off of the Nam Gam can be discharged through the river channel. Thus, as indicated in Fig. III-11, approximately 8,700 ha. of land extending about 70 km downstream of Nam Gam gate can be completely prevented from inundation.

By the construction of Lake Nong Han drainage canal, approximately 12,000 ha. (including 9,100 ha of cultivated land) consisting of 3,800 ha around Lake Nong Han and 8,700 ha in the upper stream of Nam Gam may be prevented from flood damages.

The estimated construction costs of the Lake Nong Han drainage canal is US $2,604,520.

Cost of canal $1,500,000
Cost of dam and gates $340,000
Administrative and other costs $684,520
Total $2,604,520

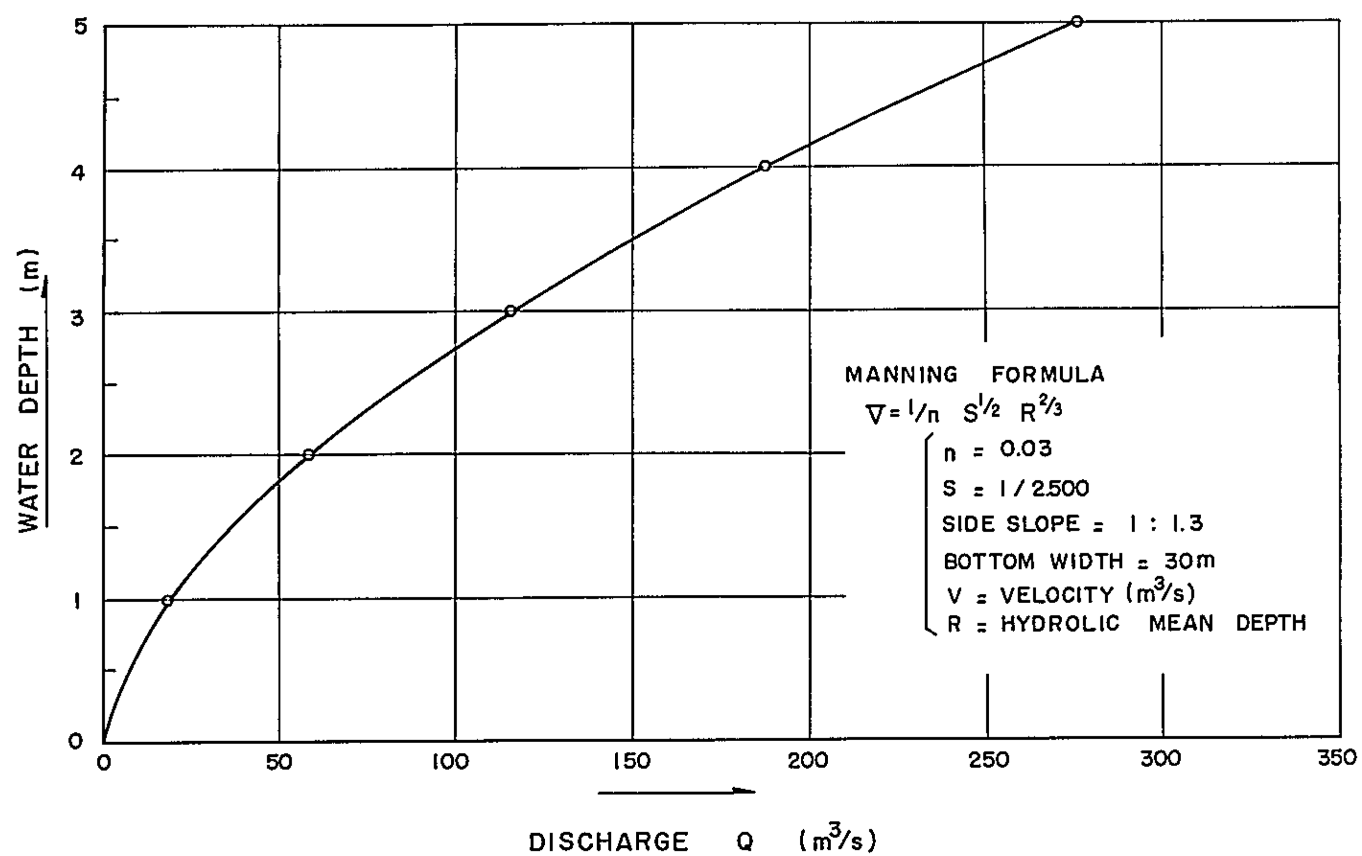


FIG. III - 7
RATING CURVE OF NONG HAN DRAINAGE CANAL

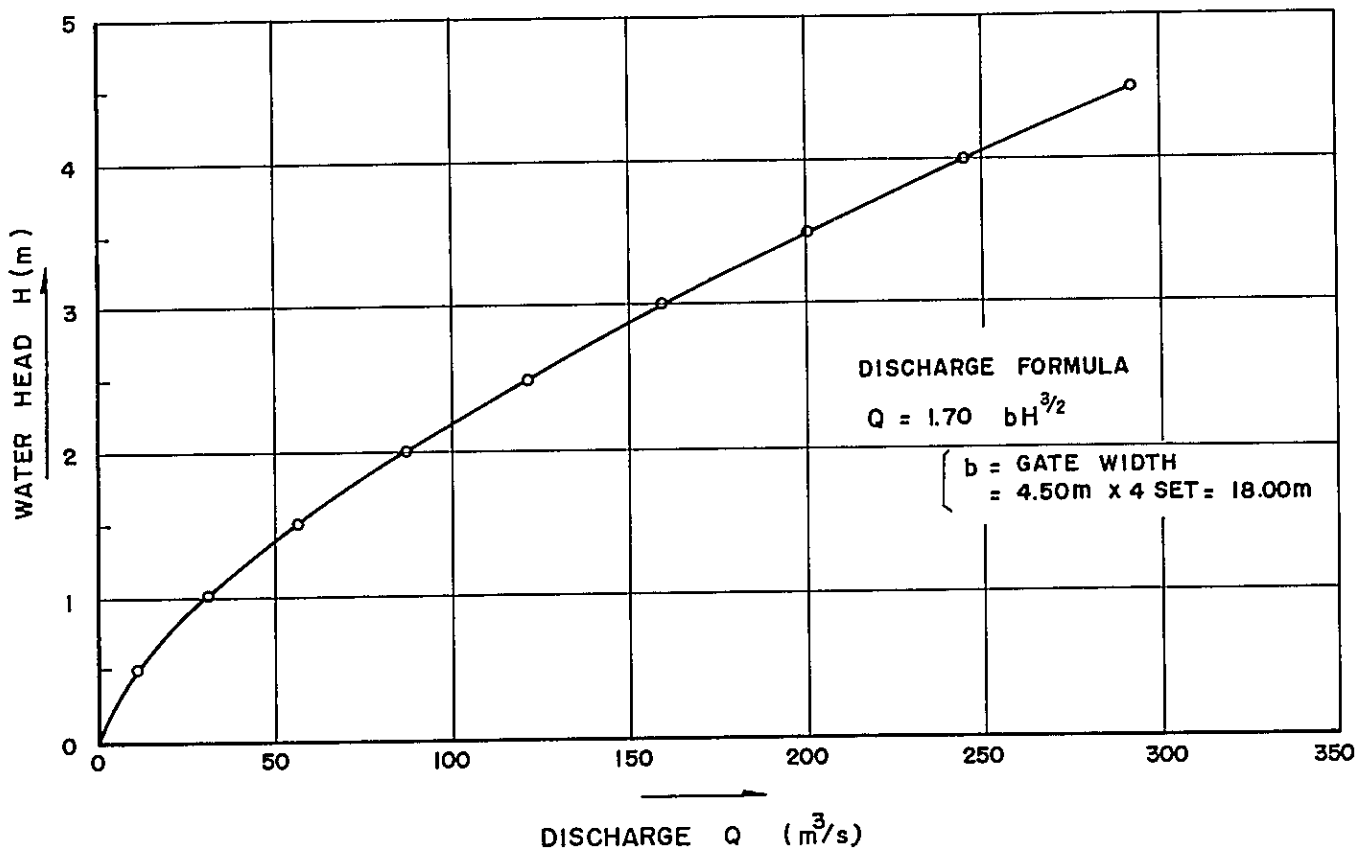
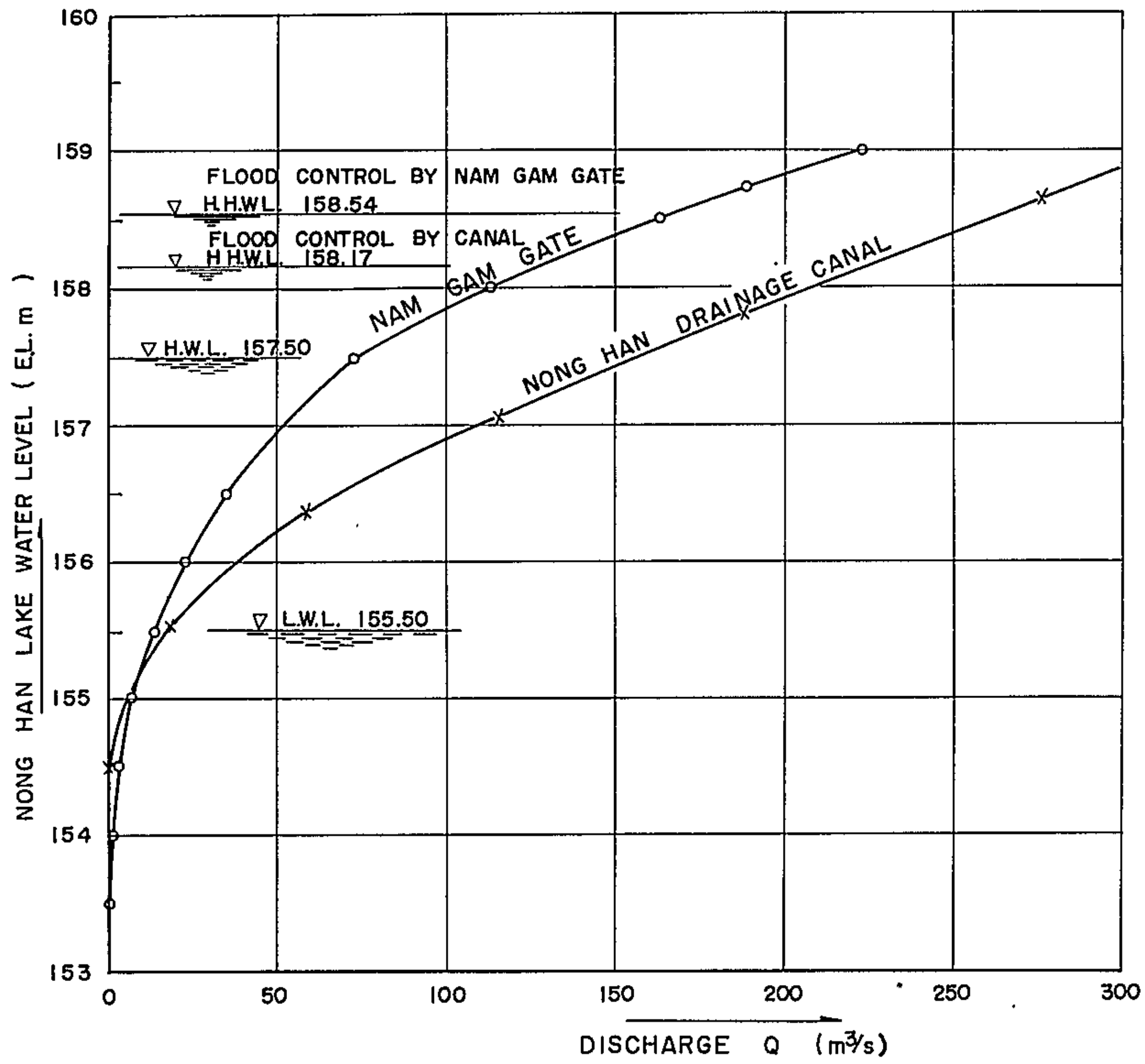


FIG. III - 8

RATING CURVE OF NONG HAN DRAINAGE CANAL GATE



NAM GAM GATE		NONG HAN DRAINAGE CANAL	
LAKE W.L. (m)	Q (m^3/s)	LAKE W.L. (m)	Q (m^3/s)
159.00	222.58		
158.72	189.22	158.64	276.00
158.50	163.77		
158.00	113.10	157.81	188.00
157.50	72.70		
157.00	52.21	157.06	115.60
156.50	35.25	156.35	58.00
156.00	22.11		
155.50	13.27	155.52	18.20
155.00	6.79		
154.50	2.45		
154.00	1.44		
153.50	0.20		

FIG. III - 9

RATING CURVE OF DISCHARGE FROM NONG HAN LAKE

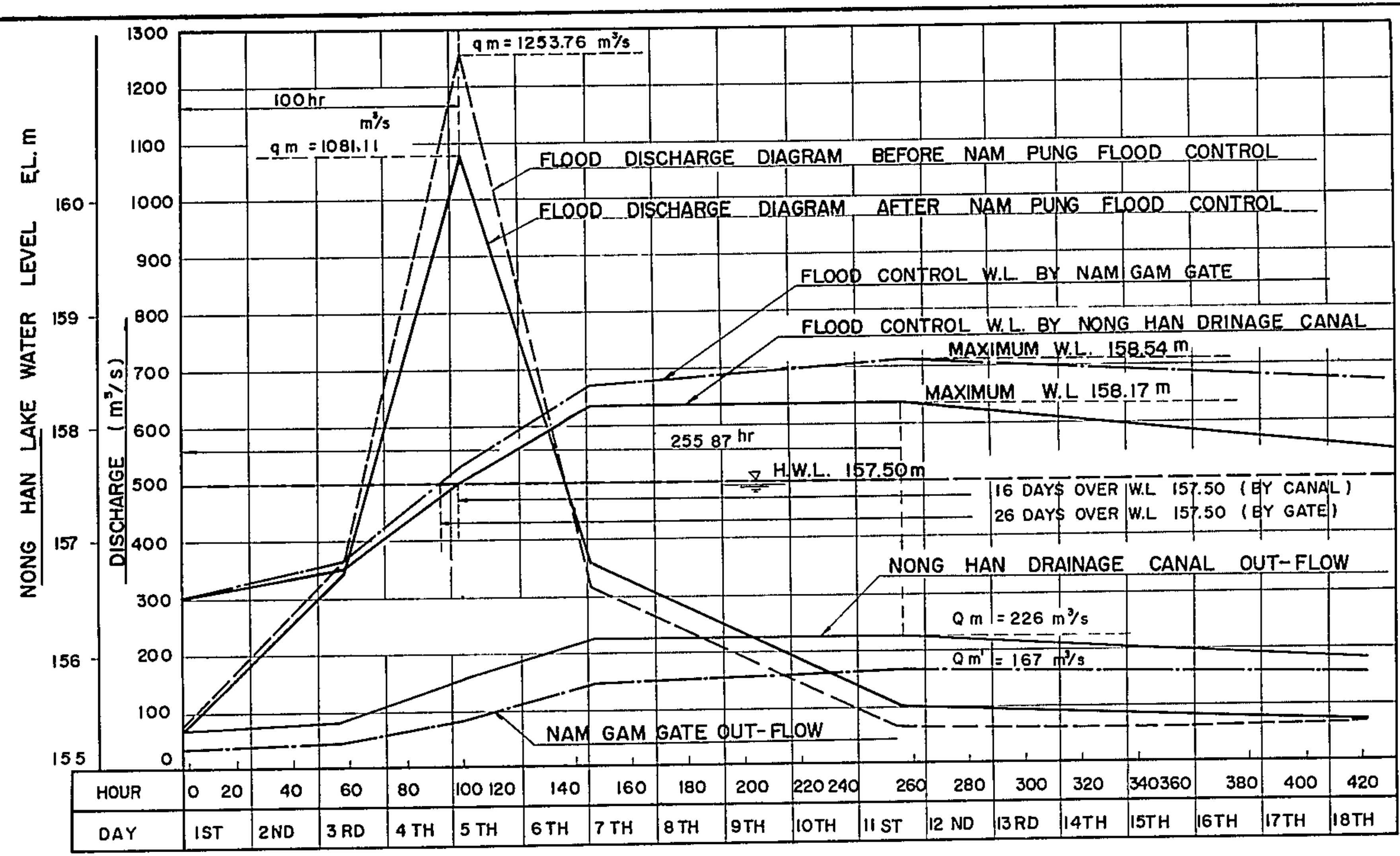


FIG III-10

FLOOD CONTROL OF
NONG HAN LAKE

Table-III-4 (Calculation of Flood Control of Nong Han Lake by Nong Han Drainage Canal)

Division	In - Flow			Lake water level (E.L.m)		Out - Flow		Lake Storage (10^3m^3)		Lake Surface Area (Km^2)	
	Period (sec)	Before Nam Pung Control (10^3m^3)	After Nam Pung Control (10^3m^3)	Initial	Final	(m^3/s)	(10^3m^3)	Gross	Effective	Initial	Final
A	209,484 hr (58.19)	45,983	43,017	156.50	156.76	68 88	16,340	179,327	26,677	98.00	105.60
B	150,516 hr (41.81)	121,681	107,183	156.76	157.52	88 157	18,438	268,072	115,422	105.60	128.38
C	162,792 hr (45.22)	127,439	118,360	157.52	158.15	157 224	31,012	355,420	202,770	128.38	147.89
D	398,340 hr (110.65)	76,199	91,829	158.15	158.17	224 226	89,627	357,622	204,972	147.89	148.51
E	596,916 hr (165.81)	53,782	64,695	158.17	157.76	226 181	121,472	300,845	148,195	148.51	135.80
Sub-Total	1,518,048 hr (421.68)	425,084	425,084				276,889				
F	210,803 hr (58.55)			157.76	157.50	181 155	35,415	265,430	112,780	135.80	127.80
Total	1,728,851 hr (480.23)	425,084	425,084				312,304		112,780		

Table-III-5 (Calculation of Flood Control of Nong Han Lake by Nan Gam Gate)

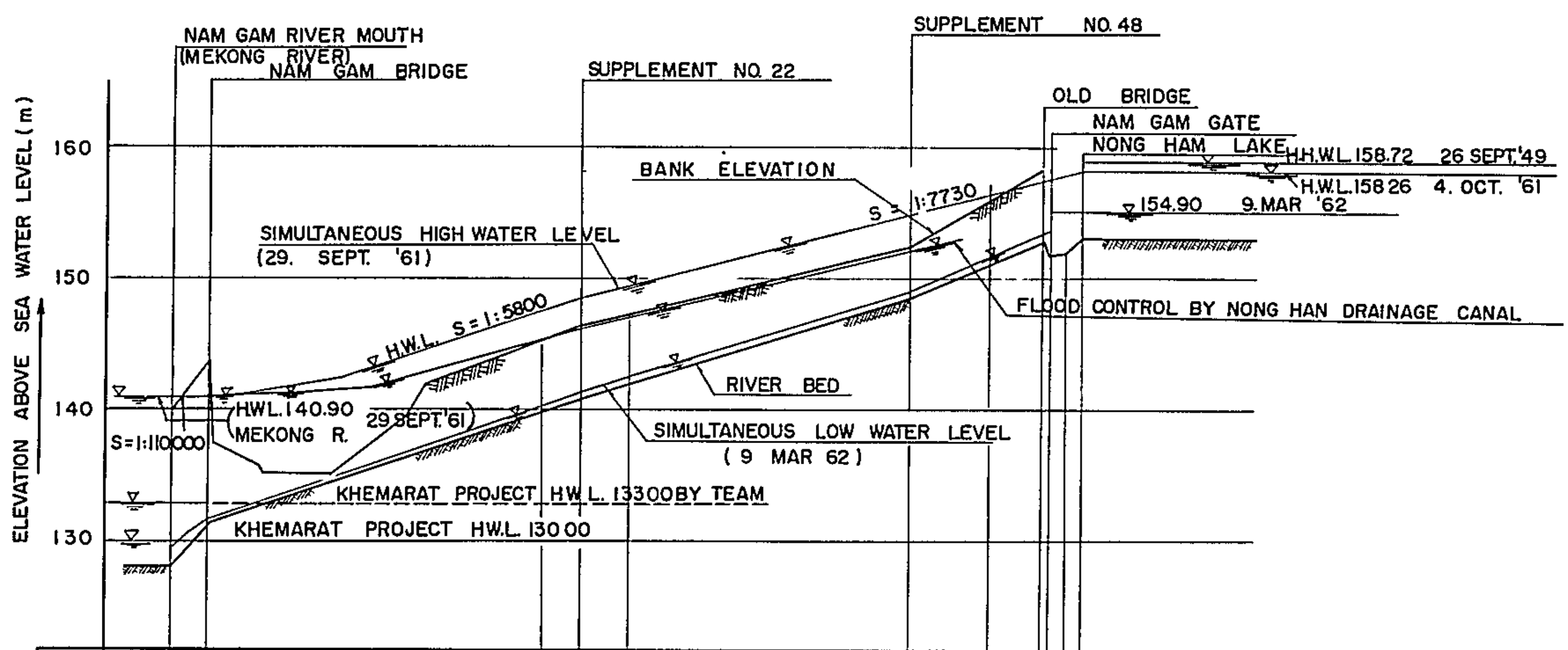
Division	In - Flow			Lake water level (E.L.m)		Out - Flow		Lake Storage (10^3m^3)		Lake Surface Area (Km^2)	
	Period (Sec)	Before Nam Pung Control (10^3m^3)	After Nam Pung Control (10^3m^3)	Initial	Final	(m^3/s)	(10^3m^3)	Gross	Effective	Initial	Final
A	209,484 hr (58.19)	45,983	43,017	156.50	156.83	35.25 45	8,407	187,260	34,610	98.00	107.70
B	150,516 hr (41.81)	121,681	107,183	156.83	157.65	45 84	9,708	284,735	132,085	107.70	132.39
C	162,792 hr (45.22)	127,439	118,360	157.65	158.35	84 142	18,395	284,700	232,050	132.39	154.00
D	398,340 hr (110.65)	76,199	91,829	158.35	158.54	142 167	61,544	414,985	262,335	154.00	160.00
E	596,916 hr (165.81)	53,782	64,695	158.54	158.35	167 147	93,716	385,964	233,314	160.00	154.00
Sub-Total	1,518,048 hr (421.68)	425,084	425,084				191,770				
F	1,097,260 hr (304.79)			158.35	157.50	147 72.7	120,534	265,430	112,780	154.00	127.80
Total	2,615,308 hr (726.47)	425,084	425,084				312,304		112,780		

Table III-6

Flood Water-Level & Duration of Inundation

in the Past of Nong Han Lake

Year	Maximum water-level (m.)	Over 157.5 m		Over 156.5 m	
		Duration (days)	Area inundated (ha.)	Duration (days)	Area inundated (ha.)
1949	158.72	47	3,820	91	6,800
1950	157.83	38	970	150	3,950
1951	157.67	11	520	157	3,500
1952	157.95	41	1,420	139	4,400
1953	158.07	30	1,720	155	4,700
1954	157.84	18	1,020	104	4,000
1955	156.89	-	-	126	1,200
1956	158.28	54	2,420	144	5,400
1957	157.07	-	-	125	1,700
1958	157.45	-	-	98	2,800
1959	157.19	-	-	43	2,100
1960	157.93	20	1,320	135	4,300
1961	158.26	39	2,320	147	5,300
Total		298	15,530	1,614	50,150
Average		23	1,195	124	3,858
Maximum	158.72	54	3,820	157	6,800



DISTANCE	0	5.5	50	55.9	61.9	69.4	100	111.9	123.9	131.8	132.8	135.4	137.9
SLOPE OF L.W.L.	1:2490	1:5790			1:6.590			1:4.580					
BANK (EL. m)	139.78	143.58	–	145.50	146.96	147.64	–	152.70	156.00	158.12	159.46	"	"
SIMULTANEOUS W.L. (EL. m)	129.51	131.72	–	139.92	141.46	142.60	–	149.05	151.67	153.40	154.90	"	"
RIVER BED (EL. m)	129.01	131.50	–	140.42	140.96	141.12	–	148.65	151.21	152.90	151.46	151.90	152.90

FIG. III - 11

PROFILE OF NAM GAM

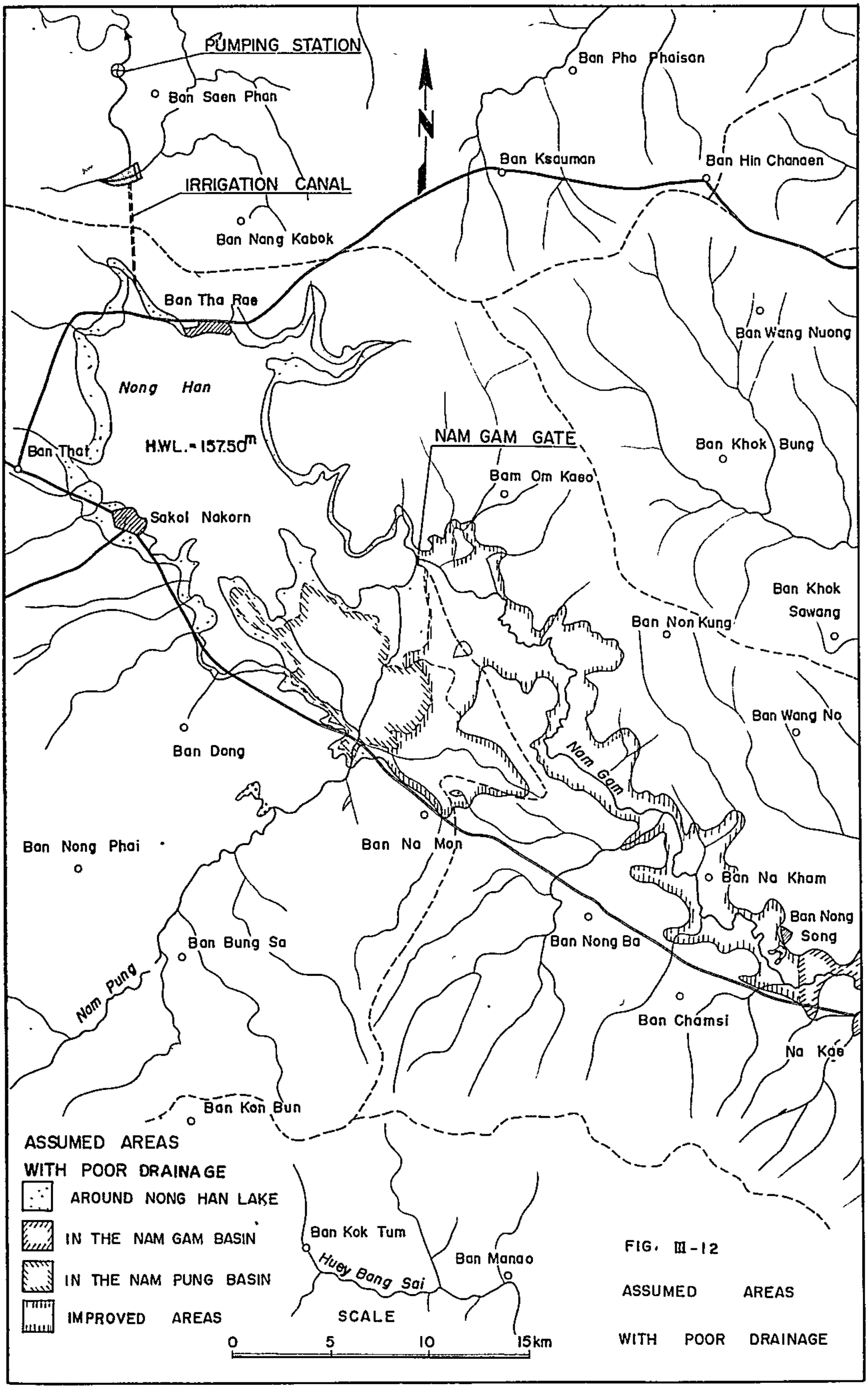


FIG. III-12

ASSUMED AREAS WITH POOR DRAINAGE

Computation of economic benefits of Lake Nong Han drainage canal should be made separately from irrigation benefits and will be extremely complicated. However, as stated above, 9,100 ha of cultivated land may be protected from inundation, canal costs of Lake Nong Han pump irrigation scheme may be reduced by about $400,000, and a part of the canal may be utilized in third stage development to supply a maximum of 34 m^3/s and 920,000,000 m^3 of water annually to irrigate 37,100 ha of land.

D. HYDRO-ELECTRIC POWER DEVELOPMENT SCHEME

(a) General Description

The hydro-electric power development scheme of the Nam Gam consists of the construction of the Nam Pung Hydro-electric Plant (maximum output 5,400 kW) which is an integrated part of the Nam Pung multi-purpose dam and the installation of transmission lines to Sakol Nakorn and the cities of Nakorn Phanom, That Phanom and Mukdahan on the Mekong basin to supply general demands and irrigation pump loads in order to promote the development of the entire Nam Gam basin.

The Nam Pung hydro-electric scheme involves the diversion of 8.5 m^3/s (maximum) of water from Nam Pung reservoir through a headrace about 1 km long to the Nam Pung power station which will utilize an effective head of 78.5 m (at normal water level) to generate a maximum of 5,400 kW of power and 15,000,000 kWh annually with 3 sets of turbine-generators. One set, which will normally be a reserve unit, is to be operated to supply pump loads.

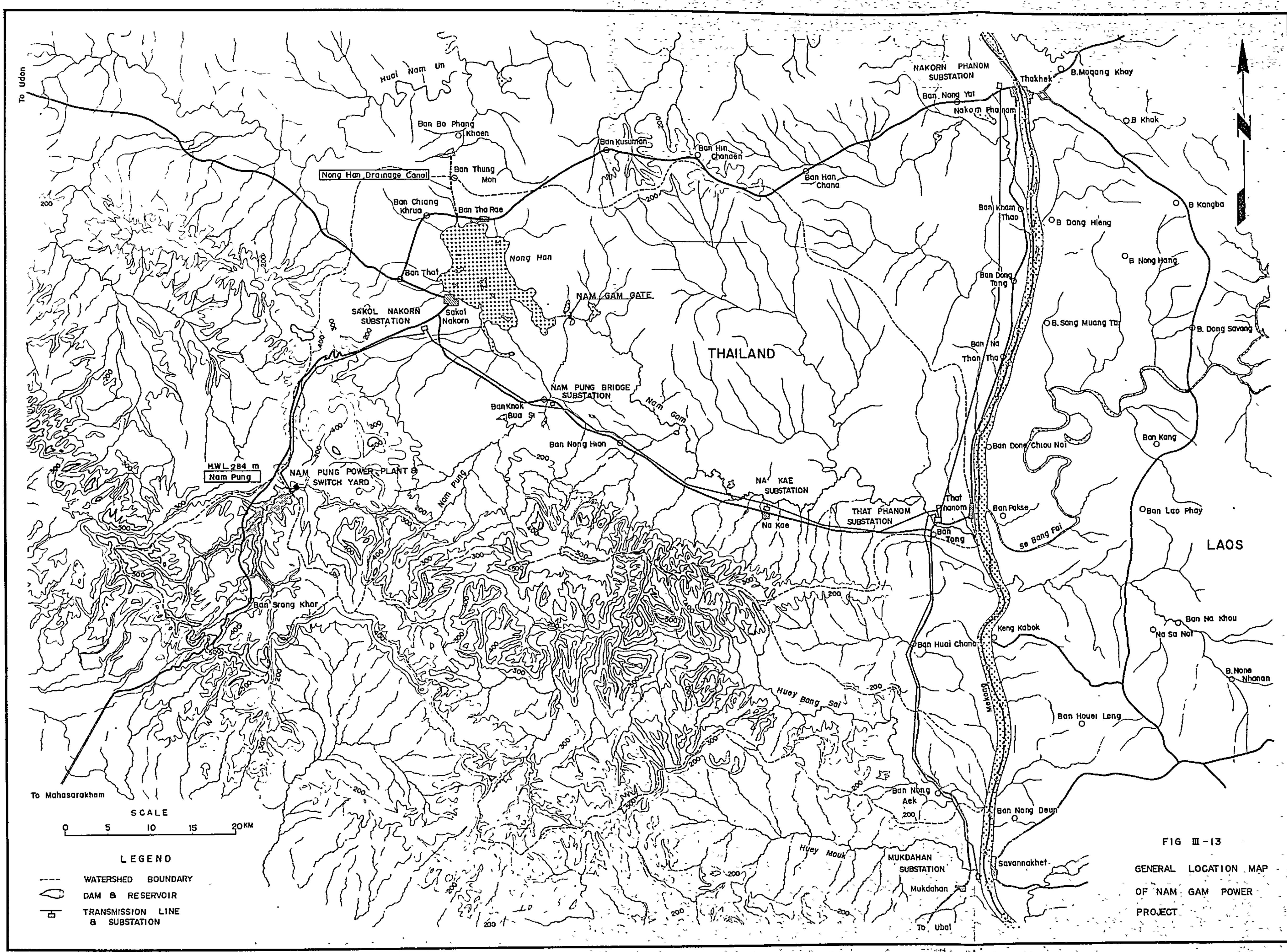
The output of the power plant is to be transmitted at a voltage of 66 kV on transmission lines with a total length of about 200 km to Sakol Nakorn sub-station (capacity 400 kVA x 6 units), Nam Pung Bridge Sub-station (capacity 400 kVA x 3 units), Na Kae Sub-station (capacity 50 kVA in 1 unit), That Phanom Sub-station (capacity 400 kVA x 3 units) and Mukdahan Sub-station (capacity 400 kVA x 3 units) to serve general demands in the Nam Gam basin, as well as, the areas along the Mekong River. Approximately 10,000,000 kWh annually of electricity may be served to general consumers and 5,000,000 kWh annually to pump stations for the pumping of irrigation water from Lake Nong Han.

(b) Determination of Powerhouse Discharge

The estimated annual run-off at the Nam Pung dam site computed from paragraph C in Chapter II. "ANALYSIS OF HYDROLOGICAL DATA" is shown below. (1961 is the measured data by NEA)

Year	Annual inflow in 1,000 m^3	m^3/s
1952	140,628	4.45
1953	173,847	5.51
1954	101,055	3.21
1955	63,174	2.01
1956	136,877	4.33
1957	75,133	2.38
1958	86,852	2.76
1959	74,062	2.35
1960	109,236	3.46
1961	147,114	4.66
Average	110,797	3.51

From the estimated values for the 10 years of 1952 to 1961, a mass curve (see Fig. III-4) of the inflow into the reservoir was drawn, and the volume of inflow which can be regulated each year in the reservoir with an effective storage capacity of 106,000,000 m^3 (design effective storage capacity is 122,000,000 m^3 which includes 16,000,000 m^3 of storage for electric pump loads in the dry seasons) was obtained in order to determine the maximum available discharge for each year. Then, from this regulated flow, evaporation losses corresponding to annual fluctuation of lake water surface was



LEGEND

- WATERSHED BOUNDARY
- DAM & RESERVOIR
- TRANSMISSION LINE & SUBSTATION

FIG III-13

GENERAL LOCATION MAP OF NAM GAM POWER PROJECT deducted to arrive at the available discharge which is given in the table which follows.

Table III-7 AVAILABLE DISCHARGE OF NAM PUNG RESERVOIR

Year	Annual inflow m^3/s	Regulated flow m^3/s	Average water level m	Evaporation m^3/s	Available discharge m^3/s	Average storage volume 10^6 m^3
1952	4.45	4.68	281.0	0.36	4.32	79.3
1953	5.51	5.00	283.0	0.46	4.54	89.0
1954	3.21	3.29	281.5	0.38	2.91	93.5
1955	2.01	3.30	280.5	0.33	2.97	77.8
1956	4.33	3.26	279.3	0.29	2.97	71.3
1957	2.38	2.98	281.0	0.36	2.62	82.2
1958	2.76	2.98	280.0	0.32	2.66	69.5
1959	2.35	2.98	278.5	0.25	2.73	56.4
1960	3.46	2.98	277.5	0.21	2.77	47.4
1961	4.66	3.17	280.0	0.32	2.85	70.2
Average	3.51	3.46		0.33	3.13	73.66

Table III-8 which follows gives the annual available energy for each year computed from the Table III-7.

Table III-8

Annual Available Energy of Nam Pung

Year	Available discharge (m^3/s)	Average intake level (m)	Average discharge level (m)	Gross head (m)	Head loss (m)	Effective head (m)	Average output (kW)	Annual available energy (10^3 kWh)
1952	4.32	281.0	192.32	88.68	6.20	82.48	2,890	25,400
1953	4.54	283.0	192.34	90.66	6.30	84.36	3,100	27,150
1954	2.91	281.5	192.17	89.33	5.70	83.63	1,970	17,250
1955	2.97	280.5	192.18	88.32	5.70	82.62	1,985	17,400
1956	2.97	279.3	192.18	87.12	5.70	81.42	1,960	17,200
1957	2.62	281.0	192.40	88.60	5.40	83.20	1,765	15,450
1958	2.66	280.0	192.42	87.58	5.50	82.08	1,768	15,500
1959	2.73	278.5	192.42	86.08	5.40	80.68	1,785	15,640
1960	2.77	277.5	192.43	85.07	5.50	79.57	1,786	15,700
1961	2.85	280.0	192.43	87.57	5.70	81.87	1,880	16,450
Average	3.13						2,090	18,300

It will be noted from Table III-8 that the firm available energy is 15,450,000 kWh and the average power output is 1,765 kW. Therefore, the firm output was taken as 1,750 kW. And, the average flow of 2.62 was taken as the firm discharge.

In the determination of the powerhouse maximum discharge, it was assumed that the annual load factors for general demands and irrigation demands are around 30%, respectively, and 8.5 m^3/s was taken as the maximum discharge in order to generate 5,400 kW under the rated head and 4,500 kW at the minimum water level.

(c) Estimate of Demand

Estimating of demand is extremely important in determining the power output and date of operation of a power project, as well as, in determining the timing of development of the next power project. In a project as the one under study which includes the installation of new power generation, transmission and sub-station facilities in order to promote the development of agriculture and industries, the estimating of demand is a prerequisite in determining the economic feasibility of the project.

In the proposed service territory of the output of Nam Pung power plant, there are individual diesel electric plants as shown in Table III-9, serving these areas. On completion of the Nam Pung power plant, it is believed that these diesel electric plants will be retired from service or transferred to other districts.

Table III-9

Operating Conditions of Diesel Electric Plants

	No. of Consumers	Installed Capacity	Maximum Demand	Load Factor	Distribution Voltage	
Sakol Nakorn	1,026	356 kVA	158 kW	26.3 %	3.3 kV	400/230 V
Na Kae	114	14	6	23.2	-	400/230
That Phanom	650	125	80	13.6	-	400/230
Nakorn Phanom	1,112	450	194	27.4	3.3	400/230
Mukdahan	1,095	160	130	25.0	3.3	400/230
Total	3,997	1,105	568	-	-	-

Almost all of the loads in the districts in the above table are lighting demands. In the cities of Sakol Nakorn, Nakorn Phanom and Mukdahan electricity is supplied throughout the day, while in the other districts electric service is available from 6 to 15 hours per day.

It will be noted from Table III-9 that in comparison to the maximum demand there is a considerable reserve in the installed capacity. However, the plants are operated with difficulty to supply peak loads in view of the condition of the plants.

This condition may be seen by comparing the operating results of Sakol Nakorn in 1956 and 1962. (See Table III-10) That is, though a sharp growth in demand is witnessed by the 1.6 times increase in customers and about 3 fold increase in energy consumption, the maximum load supplied has increased only 1.1 times, indicating that consumption during peak load hours has been curtailed.

Prevailing service rates are 2 Bahts per kWh which is extremely high and what is alarming is the growth of demand at that rate of service. If loads were unrestricted during peak load hours, consumption undoubtedly would have greatly exceeded the actual figures.

During the course of field investigations, the Team has heard at various occasions the strong desire for electric service by non-electrified rural population. The reasons for this strong desire is that electricity, in comparison with oil, is handy in many respects and that costs would not be noticeably greater than oil.

(1) Methods of estimating demand

In economically advanced countries it is a general practice in estimating demand to assume that it will double in a decade (about 7.5% annual growth). In consideration of plans to promote agricultural, as well as, industrial developments, it is believed that the foregoing rate of growth would be much too low for estimating demand in this particular area.

The estimation of demand (kW) from past records of the area would not be the proper approach in consideration of the fact that records do not reflect actual conditions in the area.

Table-III-10 Electricity Consumption in Sakol Nakorn

	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
No. of Customers	510	600	610	650	680	687	723	772	894	1,026
Maximum demand at the generating end (KW)	130	140	145	145	150	150	140	140	150	158
Demand at consuming end (KWH)	-	-	-	77.058	65.632	79.330	101.875	74.064*	194.154	164.601 (246.900)
Monthly demand at consuming end (KWH)	14.560	14.759	14.595	15.609	15.932	16.081	15.434	21.595	30.909	30.835

Note: ① Calendar year, except 1962 which is up to August. Figure in ( ) estimate for year

② Demand at consumer end— up to 1959 are estimates.

* Data partially not available.

A study of recent conditions at Ubol where supply of electricity is relatively stable reveals that the rates of increase of customers and growth of demand is 11% and 16%, respectively. This indicates that the maximum demand is not restricted by reason of supply capability and can be taken as the unrestricted demand. Therefore, the values of this district were used as the base and taking into account annual growth rates and prevailing conditions of various localities, the annual rate of growth for existing general demands were estimated as shown below.

	Annual rate of growth (kW)
Sakol Nakorn	10.5 %
Na Kae	7.0
That Phanom	8.3
Nakorn Phanom	11.8
Mukdahan	14.8

From trial estimates it has been found that new customers can be served on a paying basis provided that the routes of distribution lines are suitably arranged. Consequently, estimates of load growth by new customers were made also. This annual rate of growth is 7%.

With this amount of demand there will exist a surplus of supply and the creation of large power consumers will be necessary immediately. To consume this surplus power, what has been considered, in relation with agricultural development, are a spinning industry (6,000 spindles - 200 kW) and irrigation pump stations (4 stations - 2,320 kW).

Various other industries have been considered and these are included in Section G of this Chapter concerning development of other industries.

The estimates of energy demand were obtained by multiplying a unit value for each year, which were estimated separately, and the number of customers obtained from the demand growth estimates. The trends of growth are depicted in Fig. III-14 and Fig. III-15. The annual growth of lighting demand in Fig. III-15 is 22.4%. This value is quite similar to the 25.1% rate of growth in the city of Sakol Nakorn during the past seven years of 1956 to 1962.

In recent years, the use of electric fans, electric refrigerators, television receiving sets have developed remarkably which probably is the main cause of the large increase in the demand for electricity in the city of Sakol Nakorn. It is believed that potential demands for durable goods of this nature exist in other proposed principal areas of supply.

Therefore, the estimated 22.4% rate of growth for lighting demand is not necessarily high. Depending on the speed these durable goods are marketed, a rate of growth of demand much higher than the estimate may be developed.

FIG. III - 14

MAXIMUM DEMAND IN kW FOR THE YEAR 1962-1975

(UNIT kW)

	1962	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	Remark
Sakol Nakorn	158	175	193	308	338	389	444	483	567	610	661	717	779	846	Lighting
							200	200	200	200	200	200	200	200	Cotton Spinning
					120	270	420	570	1320	1320	1320	1320	1320	1320	Pumping up
	158	175	193	308	458	659	1064	1253	2087	2130	2181	2237	2299	2366	Subtotal
Nam Pung Bridge				500	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	Pumping up
Na Kae	6	6	7	11	12	13	14	15	16	17	18	20	21	23	Lighting
That Phanom	80	87	94	150	161	174	188	203	218	236	255	274	296	320	"
Nakon Phanom	194	217	242	387	427	472	521	576	632	703	778	861	953	1055	"
Mukdahan	130	149	171	275	310	349	394	444	501	567	642	727	825	935	"
Total	568	634	707	1631	2368	2667	3181	3491	4454	4653	4874	5119	5394	5699	"

DIFICIENCY IN kW

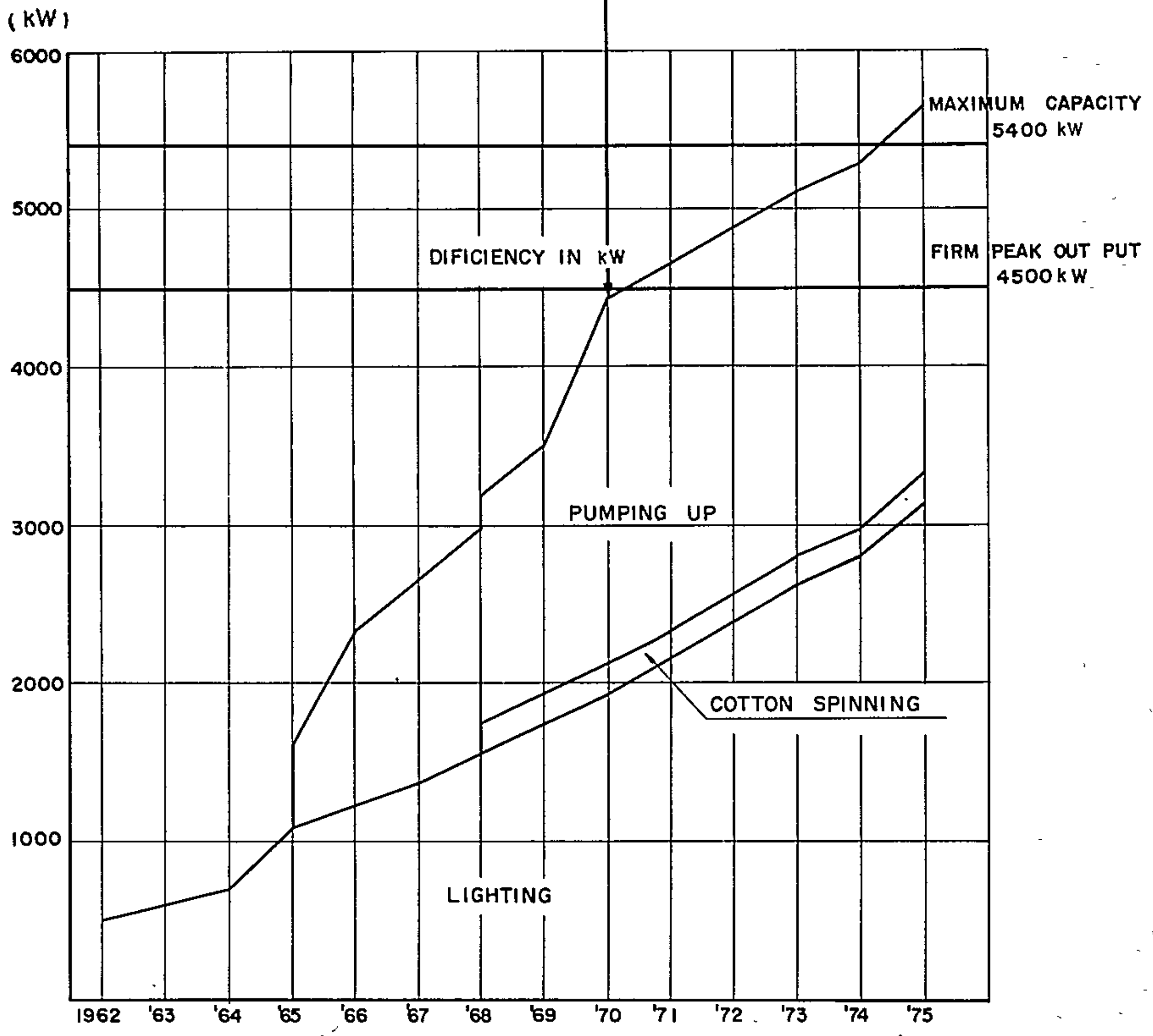


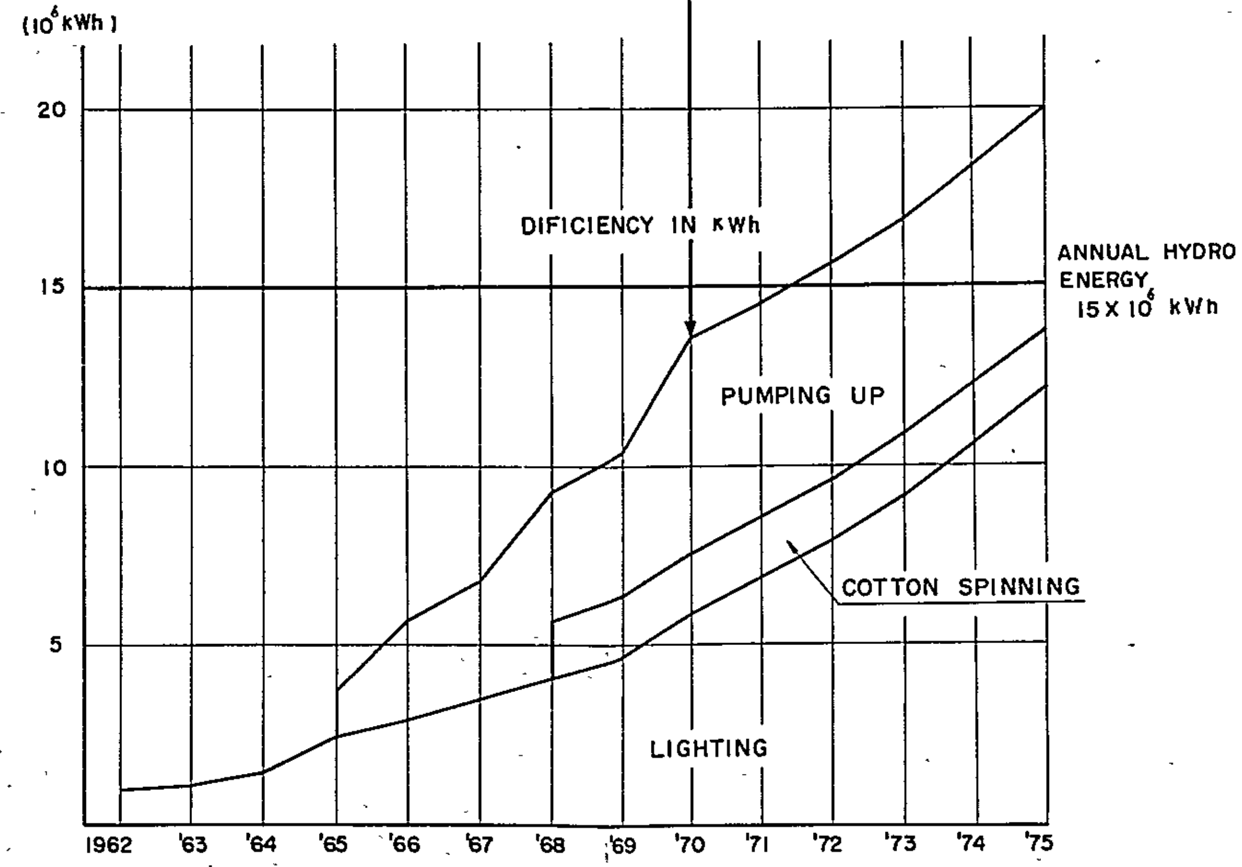
FIG. III - 15

MAXIMUM DEMAND IN kWh FOR THE YEAR 1962 - 1975

(UNIT 10^3 kWh)

	1962	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	Remark
Sakol Nakorn	264	288	368	648	756	936	1020	1068	1632	1848	2100	2352	2724	3072	Lighting
							1660	1660	1660	1660	1660	1660	1660	1660	Cotton Spinning
					323	699	1075	1450	3517	3517	3517	3517	3517	3517	Pumping up
	264	288	368	648	1079	1635	3755	4178	6809	7025	7287	7529	7901	8249	Subtotal
Nam Pung Bridge				1256	2512	2512	2512	2512	2512	2512	2512	2512	2512	2512	Pumping up
Na Kae	24	36	36	60	60	72	84	96	108	120	132	156	168	192	Lighting
That Phanom	168	168	216	372	420	492	564	648	732	840	936	1068	1200	1368	"
Nakon Phanom	288	324	408	744	876	1044	1212	1428	1644	1932	2232	2604	3012	3468	"
Mukdahan	276	324	420	496	852	1032	1248	1500	1800	2160	2556	3072	3660	4344	"
Total	1026	1140	1440	3776	5799	6787	9375	10362	13,605	14,589	15,656	16,941	18 453	20,133	"

DIFICIENCY IN kW



(d) General Description of Power Scheme

The electrical facilities and structures for the Nam Pung power station, including the Nam Pung dam are described in detail in a separate volume "Preliminary Designs of Nam Pung Hydro-Electric Power Project." Therefore, only a general description is given here. A description of the Nam Pung reservoir which will be utilized for the generation of power is described in Section B-(6) "Reservoir Plan" of this Chapter.

The geology of the dam site is mainly sandstone and conglomerate with intrusion of mudstone and shale. The foundation rock cannot be said to be sound to adequately support a concrete dam, and in view of the fact that aggregates for concrete are extremely difficult to obtain in the area, a fill type dam which the geology of the site would sustain will be more suited.

The dam is a rockfill structure, with an impervious clay core, about 32 m in structural height and containing about 764,000 m^3 of embankment. It will have an overflow spillway with a discharge capacity of 300 m^3/s, as well as, an outlet to release water below the design low water level of EL 270 m.

An intake structure of reinforced concrete tower, 22.5 m high, is to be constructed on the right bank immediately upstream of the dam. The intake will have one roller gate 2.5 m high and 3.0 m wide. Adjoining the intake will be a pressure conduit, 2 m inside diameter and 439 m long, which will connect to a pressure tunnel, 122 m long, and terminate at a simple surge tank, 2.0 m inside diameter and 34 m high. Connection from the surge tank to the power house, which will be located on the right bank of the Nam Pung about 2.5 km downstream of the dam, will be by a steel penstock 4.2 m long and 2.0 m inside diameter (tapering down to 1.5 m).

In the power station will be installed 3 sets of horizontal shaft, single wheel, single flow, spiral type francis turbines (1,900 kW each) directly coupled to horizontal shaft, rotating field, enclosed ventilated type, 3 phase synchronous alternators (2,200 kVA each) to generate a maximum of 5,400 kW and 15,000,000 kWh annually. Water discharged through the turbines will be released into the natural bed of the Nam Pung through a tailrace tunnel. The outdoor substation will have 3 sets of single phase, oil immersed, self-cooling transformers to step-up the power house output to 66 kV before transmission to centers of load.

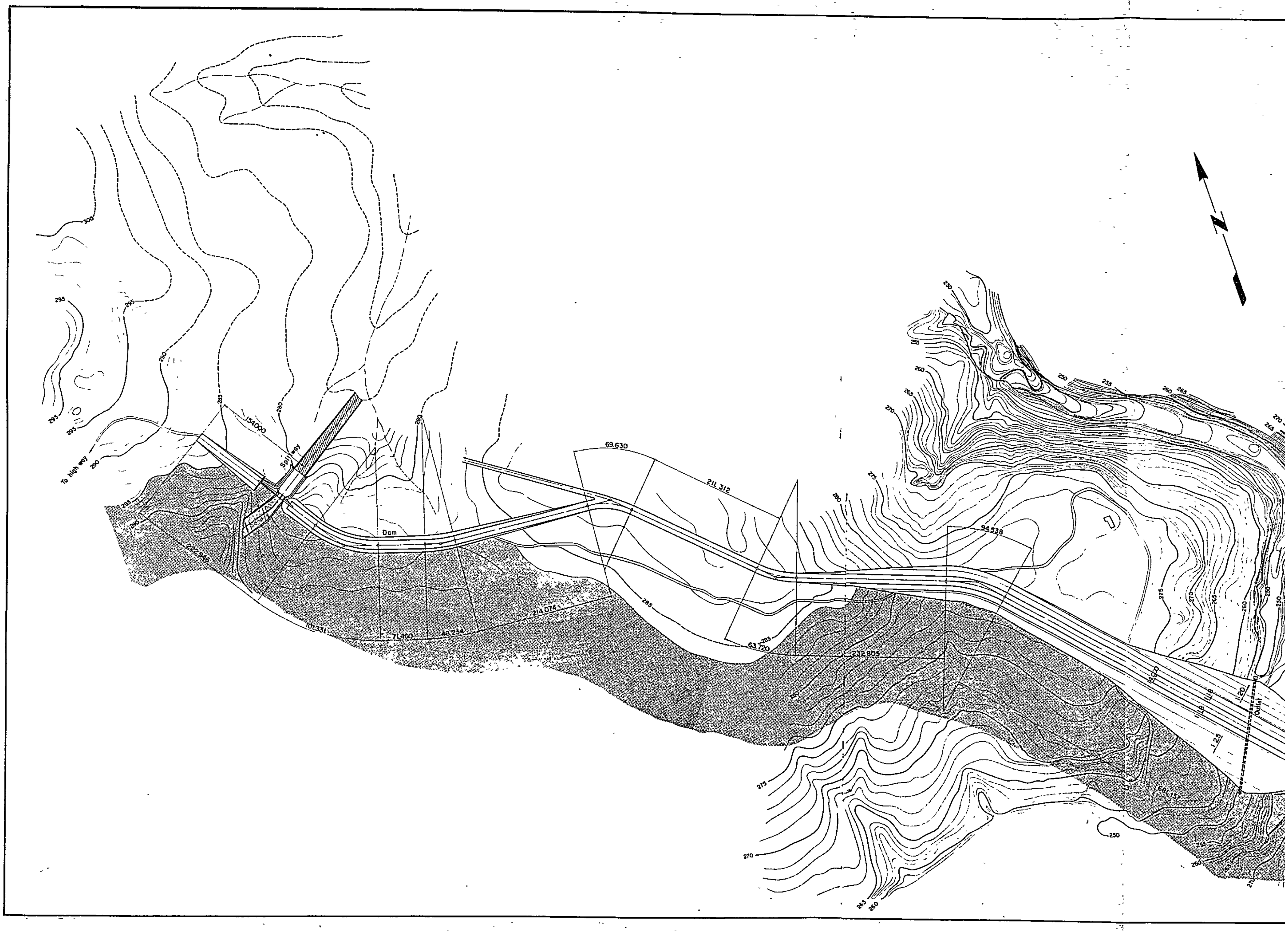
(e) General Description of Transmission Lines

The firm peak capability of Nam Pung which is 4,500 kW will, 5 years after completion of the plant, be inadequate to meet the estimated demand, and as shown in Fig. III-14, irrigation pumps may have to be operated during the off-peak load hours.

And, energy supply, as seen in Fig. III-15, may also be insufficient to supply estimated demands 5 years after completion of the plant. Therefore, it is believed that the interconnection of the Nam Pung power system to the Upper Nam Theun power system, which is anticipated to be developed in the future, will become necessary.

Listed hereunder are proposed transmission lines to transmit the output of Nam Pung to centers of demand.

Proposed transmission lines		Length
Nam Pung Power Station to Sakol Nakorn Sub-station		31 km
Sakol Nakorn Sub-station to Nam Pung Bridge Sub-station		18 km
Nam Pung Bridge Sub-station to Na Kae Sub-station		30 km
Na Kae Sub-station to That Phanom Sub-station		21 km
That Phanom Sub-station to Nakorn Phanom Sub-station		52 km
That Phanom Sub-station to Mukdahan Sub-station		48 km
Total	approx.	200 km



To high way
Spillway
Dam
154.000
69.630
211.312
94.538
222.946
101.331
71.460
46.234
214.074
63.720
232.805
681.157
Outlet

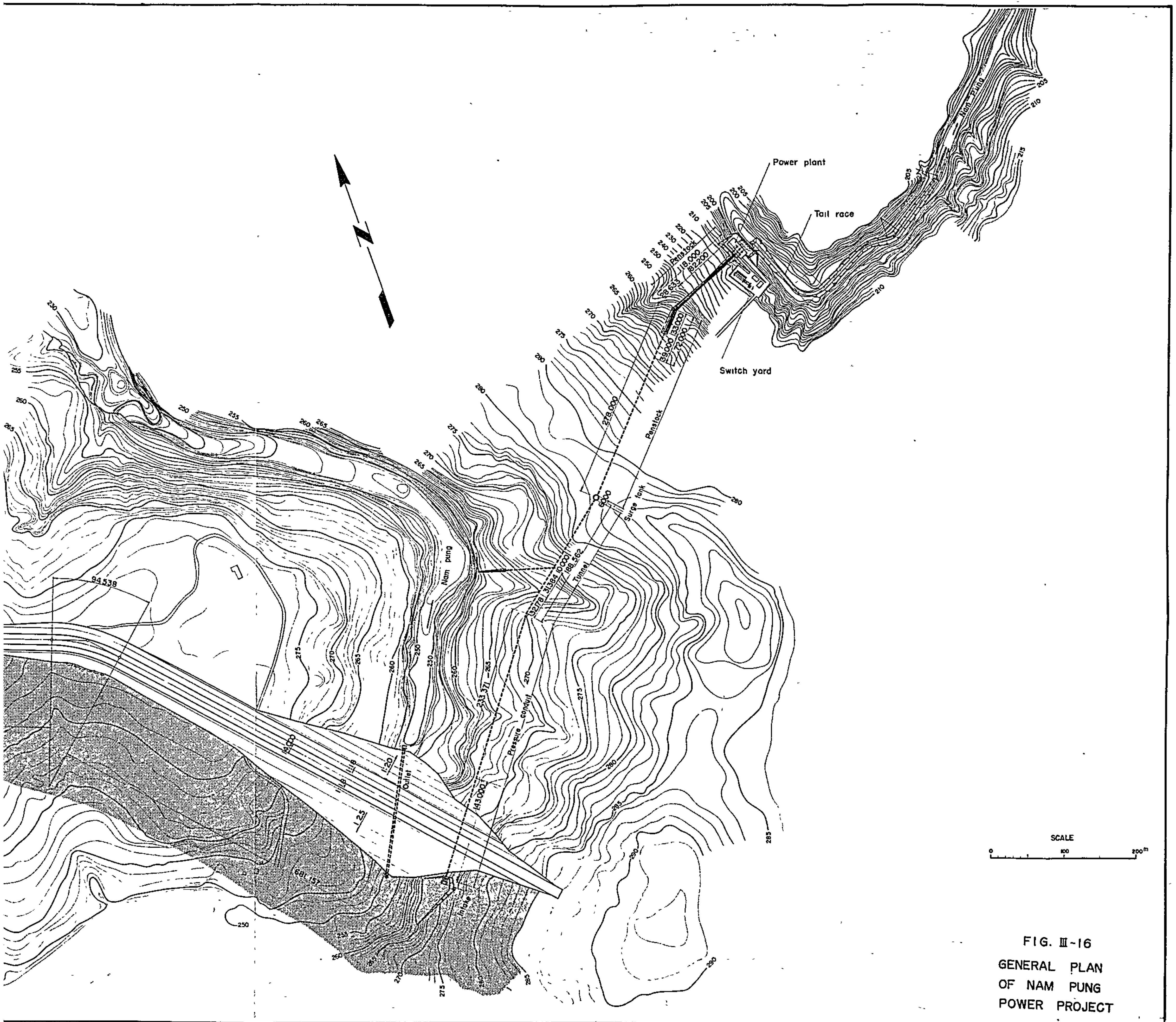


FIG. III-16
GENERAL PLAN
OF NAM PUNG
POWER PROJECT

Voltage of the transmission lines in consideration of the necessity of future interconnection with other power systems, transmission capacity, voltage fluctuation and transmission losses, has been determined as 66 kV (nominal voltage 60 kV, maximum voltage 69 kV in 1 circuit with 58 mm^2 ACSR Conductor) which we believe to be most reasonable and economical.

With this voltage, up to 1975, the estimated transmission loss during peak load hours is about 5.5% and the estimated voltage drop at Nakorn Phanom is about 8.4%.

As described above the output of Nam Pung power plant is to be transmitted on transmission lines with a total length of approximately 200 km and at a voltage of 66 kV to the following sub-stations.

Sakol Nakorn Sub-station	400 kVA single phase transformer - 6 units
Nam Pung Bridge Sub-station	400 kVA single phase transformer - 3 units
Na Kae Sub-station	50 kVA 3 phase transformer - 1 unit
That Phanom Sub-station	400 kVA single phase transformer - 3 units (including reserve unit)
Nakorn Phanom Sub-station	400 kVA single phase transformer - 3 units
Mukdahan Sub-station	400 kVA single phase transformer - 3 units

Transformers for all of the sub-stations, other than Na Kae which is expected to have a very small load, shall be single phase 400 kVA units in consideration of load growth and interchangeability of units, and the wiring system shall be delta-delta in order that operation may be possible by V-V connection in case of outage of a phase.

The reserve unit shall be a common unit for all the sub-stations and it shall be stored at That Phanom Sub-station.

Voltage of distribution lines, in addition to economic factors should be such that electric service can be extended to rural consumers over an extensive area. The voltage which has been adopted is 6.6 kV and the range of distribution is about 30 km around the cities.

The communication network which was planned for the operation and maintenance of the power station, sub-stations and transmission lines, and load dispatching, are a power line carrier telephone between the power station and Sakol Nakorn Sub-station in consideration of reliability and economies, and a VHF radio telephone for other stations east of Sakol Nakorn in consideration of intermediate sub-stations east of Sakol Nakorn.

(f) Estimates of Construction Costs and Power Cost

The estimated costs of the development of the Nam Pung Hydro-electric Power Project are given below. The Nam Pung dam is a multi-purpose structure and, consequently, the costs of the structure should be allocated in accordance with the uses. This calculation has been made separately and is included in Chapter IV. Given hereunder is the estimated cost of power computed from the construction costs chargeable to power.

Item	Costs
Dam	US$ 3,142,360
Waterways and powerhouse	1,981,140
Transmission line and sub-station (To Sakol Nakorn)	693,740
Transmission lines and sub-stations (To Nakorn Phanom and Mukdahan)	712,500
Total	6,529,740

An itemized detail of this cost is included in a separate volume "Preliminary Designs of Nam Pung Hydro-electric Power Projects." Listed here is the total costs and main items of cost in order to estimate the cost of power.

The output of Nam Pung is to be transmitted to Sakol Nakorn and the districts along the main Mekong River. The transmission lines east of Sakol

Nakorn, in comparison with their transmitting capacity, will be utilized at an extremely low factor. These lines, until interconnection is made with other power systems, will be very uneconomical and, therefore, cost estimates were made on the assumption that interest costs would be borne by the national treasury.

Assuming an interest cost of 5% per annum and operating cost including depreciation of 2 to 5% per annum, the cost of power if all charges are borne by it would be 3.56 cents per kWh. If operating costs only of the dam are borne by power until the irrigation projects are completed, then the cost of power would be 2.48 cent per kWh. And, if interest costs of transmission lines east of Sakol Nakorn are borne by the national treasury, the cost of power would be 2.24 cents per kWh. In consideration of the fact that power for agriculture will be consumed in and around Sakol Nakorn, the reasonable charge for agricultural power delivered at Sakol Nakorn would be about 1.99 cents per kWh and for general consumers at about 2.5 cents per kWh.

E. AGRICULTURAL DEVELOPMENT SCHEME

(a) Basic Conception of Development scheme

The proposed development area in this region under this scheme is 14,500 ha. The present classification of land in the respective areas is as shown in Table III-11.

Table III-11.

Area by Present Classification of Land in the Region Concerned

Area	Benefited Area in ha				Remarks
	Paddy	Upland	Forest & Others	Total	
Nam Pung Lower Basin	9,000	0	1,000	10,000	
West of Lake Nong Han	2,500	0	0	2,500	
North of Lake Nong Han	1,500	0	500	2,000	
Total	13,000	0	1,500	14,500	

This region is developed around Lake Nong Han and consists of sterile sandy loam. The weather is clearly divided into two - the dry season and the wet season. Accordingly agriculture has been exclusively limited to poor rice culture in the wet season. This region generally suffers from the lack and unsettled distribution of rainfall because of great changes in weather conditions brought about by monsoon winds. Therefore, it cannot be said that the rice culture here is stable at all.

In this scheme, the policy of developing and improving this region is, in principle, to shift the existing single paddy cropping in the wet season to a direction of cropping throughout the year. The schome also includes

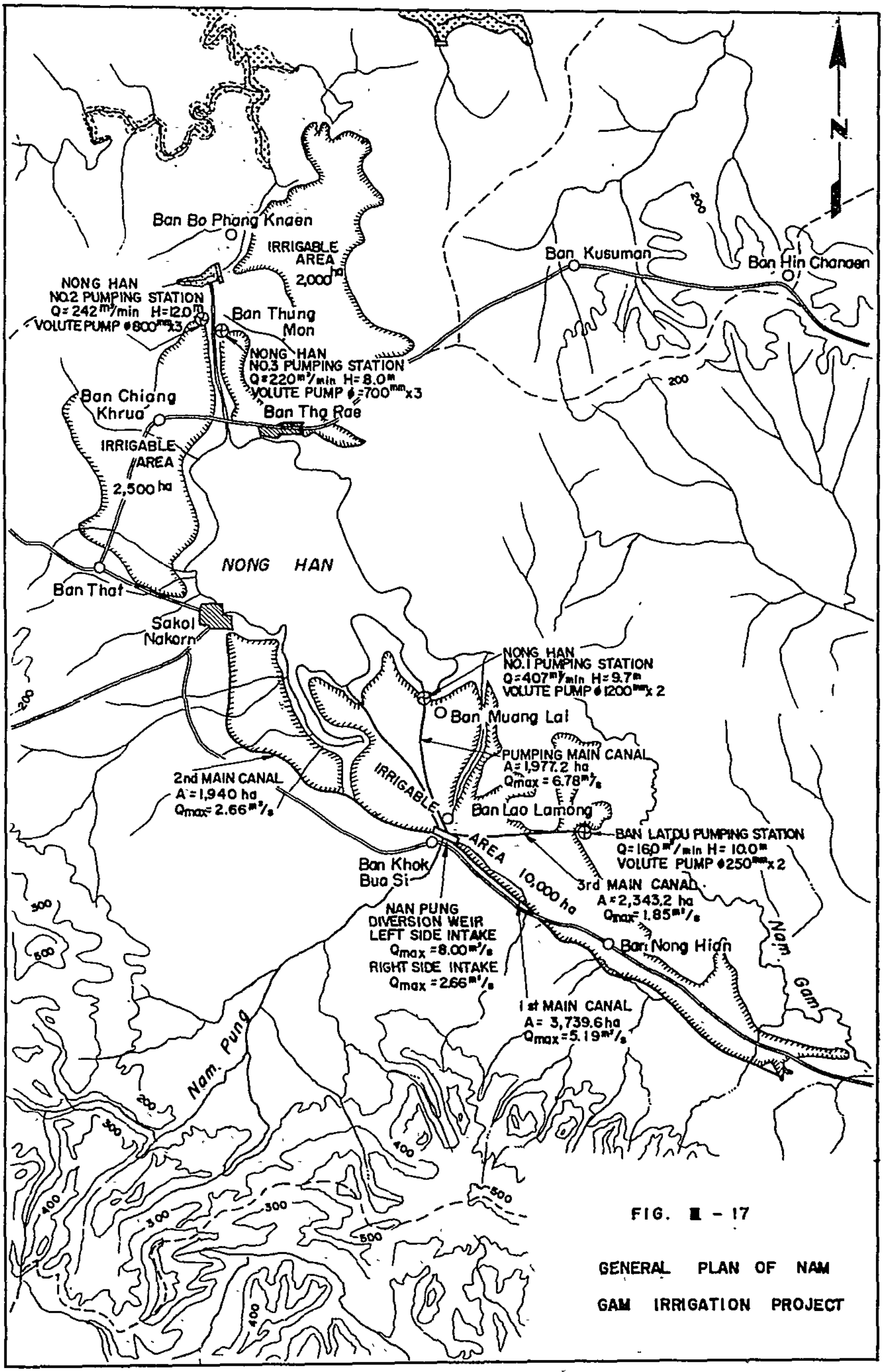


FIG. II - 17

GENERAL PLAN OF NAM GAM IRRIGATION PROJECT the introduction of upland crops as profitable as possible into places on relatively high land which are suitable for upland farming.

The present cultivated lands for paddy culture become marshy in the wet season, and even if the natural condition of cultivation is considered most of them are not suitable for upland crops throughout the year. Accordingly, they should be continued to be managed as paddy fields. Improvement should be made with a view to securing the optimum time for transplanting by constructing new irrigation facilities, and stabilizing one rice crop a year and contemplating two crops a year by securing water requirements throughout the irrigation season.

For this purpose another large-scale drainage canal should be built on the northern shore of Lake Nong Han. This canal can be used to control flood waters which inundate areas surrounding Lake Nong Han and along the Nam Gam, and alleviate annual flood damages to paddy fields. This will make it essential to select suitable varieties for cropping and breed rice. If the local price of fertilizers comes down in the future it will be possible to apply them to paddy fields.

As to the introduction of upland crops in order to improve farmers' management in this district there are two patterns. That is, one is the planting of back crops in paddy fields and the other is the establishing of permanent upland field. The securing of irrigation water will make lands that have been left intact in the dry season bear high productivity. This is the growing of back crops in the paddy field. Exceedingly high water table of paddy fields in the wet season drops about 3 - 5 m in the dry season, and, therefore, will not cause any moisture damage to upland crops which are planted as back crops. As for permanent upland fields, selection has been made of cultivated lands relatively high in topography and reclaimed forest lands where the water table will not reach the root zone of crops even in the wet season. And, irrigation water for the fields is planned to be secured throughout the year. In the case of upland field balance can be gained in the phase of profits, even if fertilizers relatively high in price are applied because high productivity can be expected accordingly.

Following such a course of policy, the area of respective cultivated lands after the implementation of the plan will be as in shown in Table III-12.

Table III-12.

Area by Classification of Land After
Completion of Development Scheme

Area	Total Area of Cultivaled Land in ha			One-Crop-a-Year Land in ha			Two-Crop-a-Year Land in ha				
	Paddy	Upland	Total	Paddy	Permanent Upland	Total	Paddy	Upland	Breakdown: Permanent Upland	Breakdown: Upland in Dry Season	Fallow
Nam Pung Lower Basin	9,000	1,000	10,000	9,000	1,000	10,000	3,000	40,000	1,000	3,000	3,000
Western Lake Nong Han	1,000	1,500	2,500	1,000	1,500	2,500	400	1,800	1,500	300	300
Northern Lake Nong Han	1,000	1,000	2,000	1,000	1,000	2,000	400	1,400	1,000	400	200
Total	11,000	3,500	14,500	11,000	3,500	14,500	3,800	43,200	3,500	3,700	3,500

Comparing Table III-11 with Table III-12, the following becomes clear:

1. In the Nam Pung Lower Basin Area, no change takes place in classification of paddy land before and after the execution of the plan. 1,000 ha of forest lands will be generally 163 - 165 m in elevation reclaimed into upland fields.
2. In Lake Nong Han West Area, 1,500 ha of relatively high land generally 162 m in elevation, out of 2,500 ha which is the present paddy fields

may be converted into upland fields. The remaining 1,000 ha is left as paddy fields.

3. In Lake Nong Han North Area, 500 ha of paddy field, 160 - 162.5 m in elevation, out of 1,500 ha of existing paddy field may be converted into upland field. Further, the present forest lands of 500 ha (160 - 162.5 m in elevation) is planned to be reclaimed into upland fields. As a result there will be 1,000 ha of upland fields and 1,000 ha of paddy fields.

Thus, the actual area of cultivated lands after completion of development of the entire region will be 14,500 ha consisting of 11,000 ha of paddy fields and 3,500 ha of upland fields.

Furthermore, as for the farming of the 11,000 ha paddy fields, about a third of each acreage in the respective areas, totaling 3,800 ha is put under the second rice crop immediately after harvesting the first rice crop. About another third, 3,700 ha is used for short-period upland crops. (Accordingly, the acreage for upland crops during this period totals 7,200 ha, including 3,500 ha of permanent upland field.) The remaining 3,500 ha is left in fallow. As for the paddy fields, in order to maintain, soil productivity and increase returns rotation of fallow, as described above, should be practiced during the period of second rice crop.

For this purpose it is especially necessary to introduce varieties of rice with a normal total growth period of 175 days (nursery period, 35 days and irrigation period, 120 days) for the first crop, and, similarly varieties with normal total growth period of 150 days (nursing period 30 days and irrigation period 100 days) for the second crop. As the area is blessed with a favorable weather of high temperature and much sunshine all the year round, diversified farming is possible, by getting away from the simple farming as has been done, if proper irrigation is practised.

To apply irrigation water through the main intake facilities and the driving channel in this plan is very important for the development of the region concerned. In order, however, to expect the wished-for production, it is necessary to further formulate a farm village plan comprising of the alignment of drainage channels, irrigation laterals and farm roads, the proper partitioning of cultivated lands and the arrangement of communities. And it is hoped that this is undertaken as a project in pace with the progress of the main construction works.

Furthermore, in order to settle the above items it may be necessary to set up agricultural experiment and extension service stations at the earliest time, insomuch that the regular test and research of methods to improve farm-management including the breeding of crops, the improved application of fertilizers and the correct distribution of labor, as well as, demonstrations of their results to farmers have great effect on the results of the project. It is also considered an urgent matter to train agricultural improvement and extension workers whose duty is to guide and advise the farmers in the area.

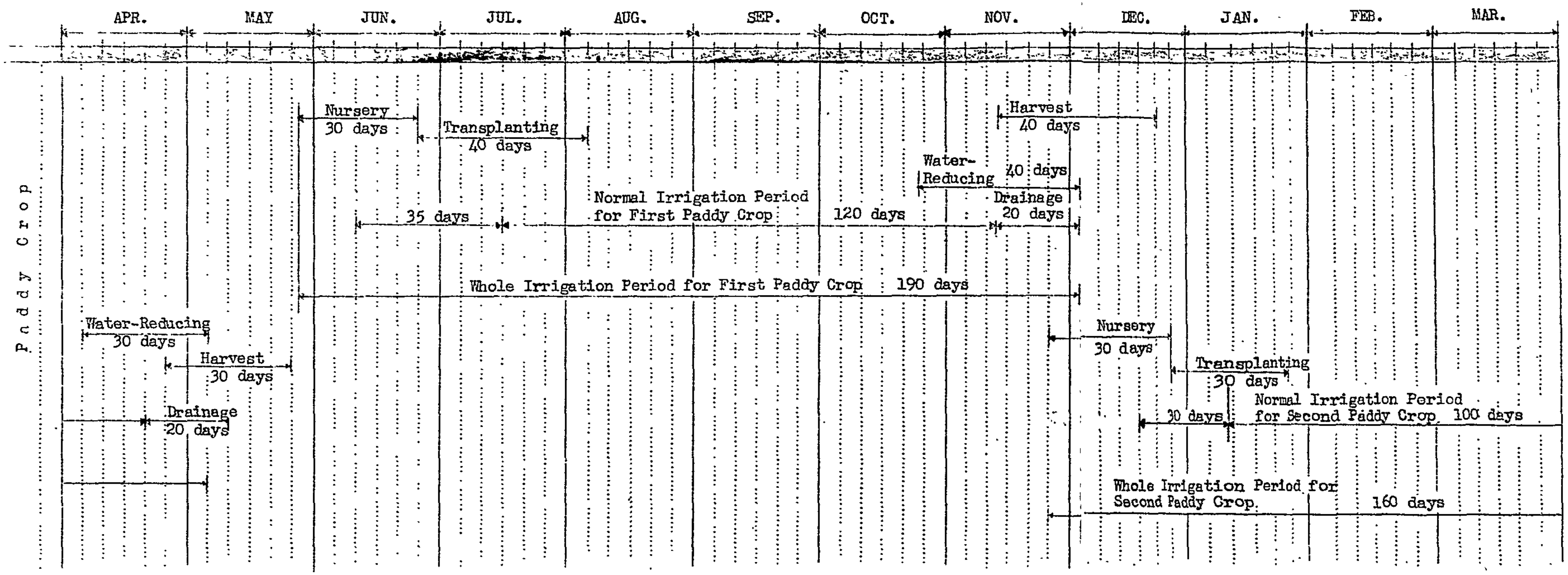
(b) Future Cropping Plan

(1) Paddy rice

At present paddy rice is grown once a year in the wet season. If irrigation water will be available in the future the second rice crop which is more favorable in growing condition than the first, can be sufficiently expected under the favorable weather condition of high temperature and much sunshine.

In the present customary rice cultivation, rice is grown at nurseries in May and June, and transplanted in June and July. The harvesting period covers a month beginning in the middle of November. Early-medium- and late-maturing varieties are grown. The early variety is harvested in 80 days after the transplanting, the medium in 120 days and the late

Table III - 13 Normal Cultivation Period for First and Second Paddy Crop



After, completion of the development the rotation of the first and second rice can be practised as shown in Table III-13.

After the harvest of the second rice crop till the transplanting of the first, the fields should be fallowed for two months (May and June). In the meanwhile green manure crops should be grown to increase soil productivity.

(2) Upland crops

As for the introduction of upland crops, a difference can be made between crops for permanent upland fields and those for paddy fields in the dry season.

Permanent upland fields should be selected on high upland zones, lest the root zone of crops is invaded by water in the wet season, so that crops which have a deep root zone or a long growth period can be cultivated there.

The kind of crops to be grown and the dimension of crop-growing area are difficult problems that should be considered prudently taking into account the suitability to soil of crops, the marketability at home and abroad of products and the marketing system; and finally they depend on the will of farmers in the region. Therefore, they can not be determined without due consideration. However, the principal crops for increased production in the proposed development area have selected taking into account the agricultural production program for the years 1962 - 1966 in the Northeast Development Plan prepared by the National Economic Board.

That is, as for the permanent upland fields of 3, 00 ha, cotton is to be cropped on an area of 2,900 ha, which is to be linked with the future spinning industry as a part of agricultural project processing industry; pasture land of 100 ha is planned as a foothold of the future dairy farming in the Northeast District; 100 ha is allotted to grow kapok which is one of the encouraged crops; and 400 ha is laid out for sweet potatoes which are at present grown in this area. Pasture, sweet potatoes and kapok are grown throughout the year, but cotton between May and December. As the period from January to April coincides with the growth period of back crops on paddy fields, various kinds of short-period upland crops analogous to the following upland crops in the dry season should be introduced into an area of 2,900 ha during this period. (See Fig. III-19)

Next, the dry-season upland crops as back crops on paddy fields may be grown for a short period of time (January to April). Tobacco, corn, sesame, castor-beans and peanuts as commercial crops which can be harvested during this short period, should be selected from among the crops that are encouraged for increased production. And, vegetables should be grown for domestic consumption and marketing, in neighbouring small towns. The cultivation of peanuts, like cotton, should be linked with the oil extracting industry which is one of the future agricultural product processing industries.

The proposed area to be cropped is as shown in Table III-14 and Table III-15.

Table III-14.

Crops on Permanent Upland Fields

Classification of Upland Field	Acreage in ha	Percentage	Growth Period	Remarks
Upland Field to be Cropped	3,500	100.0		(Second crop Jan. Apr.)
Cotton	2,900	82.8	May - Dec.	(Tobacco 200 ha (Corn 400 (Sesame 600 (Castor-beans 600 (Peanuts 600 (Kenaf 400 (Vegetables 100
Sugar Cane	400	11.4	All year round	
Pasture	100	2.9	"	
Kapok	100	2.9	"	If necessary, converted into orchards

Table III-15

Crops on Dry-Season Upland Fields

Classification of Upland Field	Acreage in ha	Percentage
Upland Field to be Cropped	3,700	100.0
Tabacco	250	6.8
Corn	500	13.5
Sesame	770	21.0
Castor-beans	770	21.0
Peanuts	770	21.0
Kenaf	510	14.0
Vegetables	130	2.7

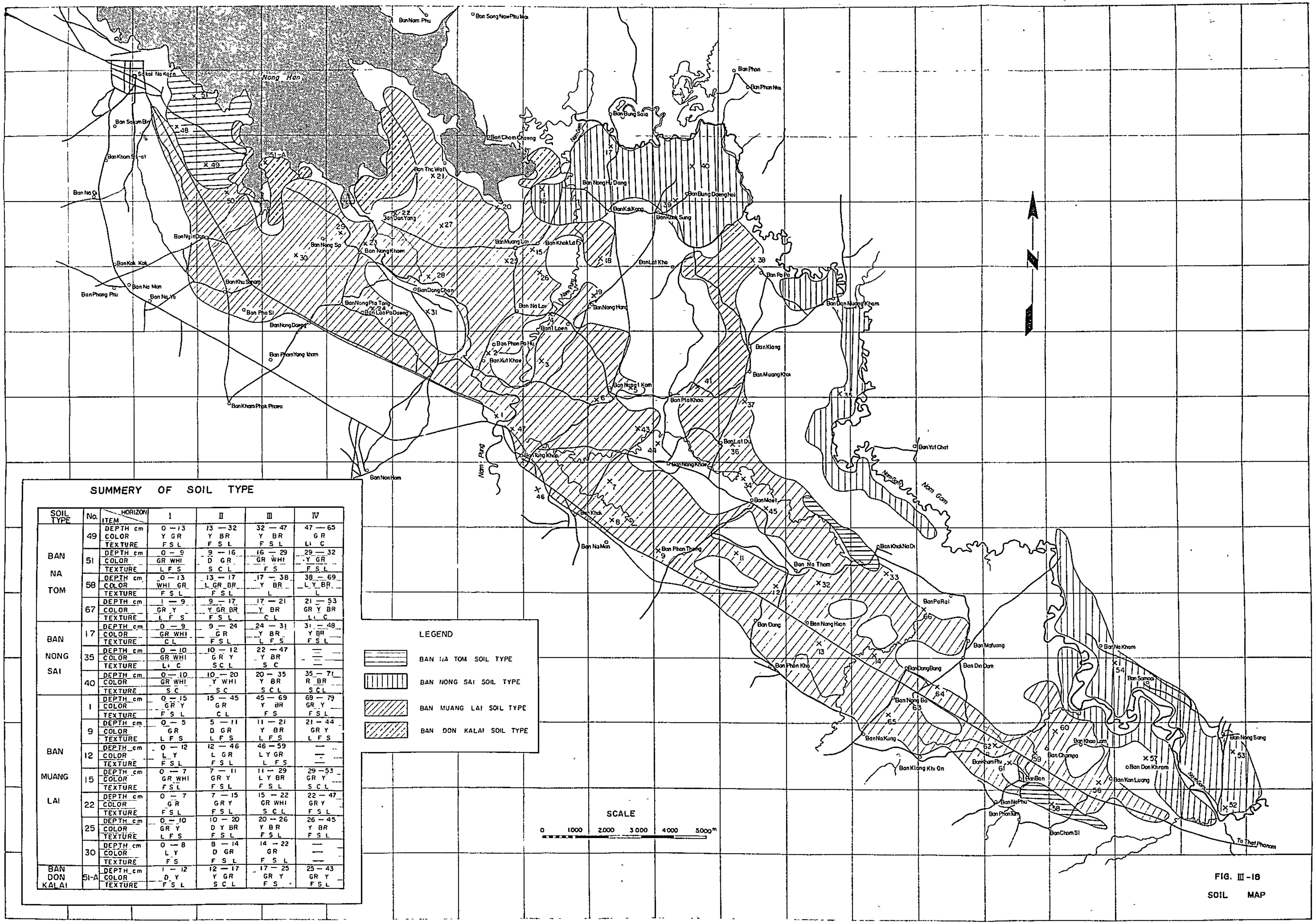
Thus, the total area for upland crops is 10,000 ha.

In the above tables are given acreage by crops in the whole region. But acreage by planned areas should be according to the above policy, and the details are given in (g) Effect of Project.

(c) Present Status of the Region

(1) Topography

The western part of this region is called Nong Han Terraces 500 m or so in elevation, from which originate two rivers, the Nam Pung and the Nam Gam that flow through the region. The topography of the region concerned is flat and with very little rolling. In the lower basin area of the Nam Pung the right bank slopes generally at $\frac{1}{1500}$ towards the east-southeast and has a slope of $\frac{1}{1200}$ along the Nam Gam. Similarly the left bank has a slope of $\frac{1}{600}$ - $\frac{1}{1500}$ towards Lake Nong Han. Lake Nong Han West Area slopes at $\frac{1}{1200}$ - $\frac{1}{1600}$ towards Lake Nong Han, and Lake Nong Han North Area slopes at $\frac{1}{700}$ - $\frac{1}{1200}$ towards the lake.



SUMMERY OF SOIL TYPE

SOIL TYPE	No.	ITEM \ HORIZON	I	II	III	IV
BAN NA TOM	49	DEPTH cm	0 — 13	13 — 32	32 — 47	47 — 65
		COLOR	Y GR	Y BR	Y BR	GR
		TEXTURE	F S L	F S L	F S L	Li C
	51	DEPTH cm	0 — 9	9 — 16	16 — 29	29 — 32
		COLOR	GR WHI	D GR	GR WHI	Y GR
		TEXTURE	L F S	S C L	F S	F S L
	58	DEPTH cm	0 — 13	13 — 17	17 — 38	38 — 69
		COLOR	WHI GR	L GR BR	Y BR	L Y BR
		TEXTURE	F S L	F S L	L	L
	67	DEPTH cm	1 — 9	9 — 17	17 — 21	21 — 53
		COLOR	GR Y	Y GR BR	Y BR	GR Y BR
		TEXTURE	L F S	F S L	C L	Li C
BAN NONG SAI	17	DEPTH cm	0 — 9	9 — 24	24 — 31	31 — 48
		COLOR	GR WHI	GR	Y BR	Y BR
		TEXTURE	C L	F S L	L F S	F S L
	35	DEPTH cm	0 — 10	10 — 12	22 — 47	—
		COLOR	GR WHI	GR Y	Y BR	—
		TEXTURE	Li C	S C L	S C	—
	40	DEPTH cm	0 — 10	10 — 20	20 — 35	35 — 71
		COLOR	GR WHI	Y WHI	Y BR	R BR
		TEXTURE	S C	S C	S C L	S C L
BAN MUANG LAI	1	DEPTH cm	0 — 15	15 — 45	45 — 69	69 — 79
		COLOR	GR Y	GR	Y BR	GR Y
		TEXTURE	F S L	C L	F S	F S L
	9	DEPTH cm	0 — 5	5 — 11	11 — 21	21 — 44
		COLOR	GR	D GR	Y BR	GR Y
		TEXTURE	L F S	L F S	L F S	L F S
	12	DEPTH cm	0 — 12	12 — 46	46 — 59	—
		COLOR	L Y	L GR	L Y GR	—
		TEXTURE	F S L	F S L	L F S	—
	15	DEPTH cm	0 — 7	7 — 11	11 — 29	29 — 53
		COLOR	GR WHI	GR Y	L Y BR	GR Y
		TEXTURE	F S L	F S L	F S L	S C L
	22	DEPTH cm	0 — 7	7 — 15	15 — 22	22 — 47
		COLOR	GR	GR Y	GR WHI	GR Y
		TEXTURE	F S L	F S L	S C L	F S L
	25	DEPTH cm	0 — 10	10 — 20	20 — 26	26 — 45
		COLOR	GR Y	D Y BR	Y BR	Y BR
		TEXTURE	L F S	F S L	F S L	F S L
	30	DEPTH cm	0 — 8	8 — 14	14 — 22	—
		COLOR	L Y	D GR	GR	—
		TEXTURE	F S	F S L	F S L	—
BAN DON KALAI	51-A	DEPTH cm	1 — 12	12 — 17	17 — 25	25 — 43
		COLOR	D Y	Y GR	GR Y	GR Y
		TEXTURE	F S L	S C L	F S	F S L

FIG. III-18
SOIL MAP

(2) Geology and soil

The geology of this region macroscopically, consists of a formation of Mesozoic psammite which is covered by a thin layer of fine sand loam derived from the psammite. This Mesozoic formation called Korat series contains halite, gypsum and lignite.

Soils covering this region are generally sandy loam brown in colour, sterile and scarce in humus. Results of survey and analysis as well as the soil classification are as shown in Fig. III-18.

(3) Quality of water

The quality of water in this region is as shown in Table III-16, and it is not unsuitable for irrigation water.

Table III-16

Analysis of River Water

Unit (mg/l)

River & Lake	Sampled Place	Date	Ca	Mg	Na	K	HCO_3	SO_4	Cl	SiO_2
Mekong	Chiang Saen	July 1956 - June 1957 average	32.1	5.9	8.4	1.7	116.9	17.1	6.9	14.4
Mekong	Nong Khai	"	31.1	5.7	7.7	1.6	115.6	14.7	6.2	15.9
Mekong	Muk-dahan	"	26.8	4.9	7.5	1.4	100.3	12.2	6.6	13.8
Nong Han	Sakol Nakorn	"	3.0	5.7	5.8	1.4	15.5	0.3	9.5	6.3

To be continued next page -

Fe	PO_4	NO_3-N	NH_4-N	Albu-min-oid	$KMnO_4$ Con-sumed	Evapor-ation Residue	Suspend-ed Matter	Turbidity *	PH	Hardness **
0.00	0.01	0.02	0.04	0.08	7.1	145.3	186.2	145.1	6.9	104.5
0.00	0.00	0.04	0.04	0.09	7.7	139.2	174.1	134.5	6.9	101.0
0.00	0.00	0.04	0.04	0.10	5.1	124.3	99.9	57.1	6.9	87.3
0.12	0.00	0.06	0.05	0.10	7.2	51.1	35.6	58.4	6.1	10.4

* Turbidity of 1 mg/l of kaolin is put at 1.

** Represented by mg/l of $CaCO_3$

(Source: Inn Kobayashi, Chemical Research of Rivers in Southeast Asian countries)

(4) Ground water

Some cultivated lands developed around Lake Nong Han are located very close to the lake surface. On the other hand, an examination of past records (1950 - 1961) shows that the fluctuation of lake water level ranges from 154.34 (1950) to 158.72 (1949). Therefore, fluctuations of the water table during a year or between years might be exceedingly great in the areas surrounding the lake.

The status of this water table is the most important condition of location, especially, when areas are selected for upland fields.

For the so-called permanent upland field where crops are grown throughout the year, location must be selected so that ground water does not soak into the root zone of upland crops. The same thing applies to during the growing period of short-period upland crops as back crops on paddy field.

It is very important in this sense to exactly grasp the actual condition of the former water table in the fields concerned. During this survey, however, no available measurement data could be obtained.

In the flood control plan for Lake Nong Han the highest water level is established as 158.17 m. Therefore, from the estimation and technical observation of the past water-tables, the elevation of the permanent upland field is generally planned to be more than 160 m for safety.

The water-table in the dry season seems to be approximately 3 - 5 m lower than that in the wet season every year. If short-period upland crops of shallow root zone are grown, there would be no particular problem in respect of elevation of paddy fields where dry-season upland crops are grown as back crops.

(5) Present state of farm management

Farm management in Thailand is small and poor. Cultivated acreage per household is a little more than 18 rai (about 3 ha), out of which 17 rai (about 2.8 ha) is paddy field. In addition to rice there are produced peanuts, sesame, beans, casava, castor-beans, kapok, corn, sugar cane, tobacco and cotton. Dairy products and meats are turned out in a small quantity. Large-size livestock are generally water buffalo and cattle. Chicken-raising has recently made remarkable progress in the suburbs of cities.

Various agricultural statistical data relating to the proposed development areas are as shown in Table III-17 to Table III-25 (Source: Thailand Economic Farm Survey, 1953).

Table III-17

Irrigated and Non-irrigated Area of

Cultivated Land by Usage

(Unit: rai = 0.16 ha)

Region	Paddy Acreage	Upland Acreage	Total Acreage	Non-irrigated Acreage	Irrigated Acreage	2-Crop a-Year Acreage	Irrigation Method (%)			
							Manpower	Animal Power	Wind or Water Power	Gravity
North-eastern district	20.11	0.37	20.48	91.45%	8.55%	0.17	13.47	1.08	0.80	0.05
National Average	17.29	0.82	18.11	-	-	0.32	-	-	-	-

Table III-18

Number of Farm Families and its Ratio

by Management Scale

Region	Number of Farm Families	Ratio of Farm Families by Management Scale (%)				
		6 rai or less	6-15 rai	15-30 rai	30-60 rai	More than 60 rai
Northeastern District	815,810	10.02	25.36	32.77	22.18	9.67
National Total or Average	2,119,287	15.05	26.81	28.41	21.26	8.47

Table III-19

Farm Area by Management Scale

(Unit: Rai)

Region	6 rai or less	6 - 15 rai	15 - 30 rai	30 - 60 rai	More than 60 rai	Average
Northeastern District	3.25	10.29	20.80	39.79	76.71	27.38
National Average	-	-	-	-	-	25.62

Table III-20

Population in Sakol Nakorn Province

I t e m	1955	1960
Population	334,687	414,832
Density	33	40
Agricultural Population	138,885	181,776
Rice-growing farmers	137,850	139,005
Other Farmers	1,035	42,771

Table III-21

Number of Farm Families and Cultivated Area

by Owner-Farmers and Tenants

Region	Owner Farmers (house-hold)	Ratio of Owner-Farmers to Total %	Tenant	Ratio of Tenants to Total %	Number of Total Farmers (household)	Owner-Farmers' Land		Tenants' Land		Total Area	
						1,000 rai	%	1,000 rai	%	1,000 rai	%
Northeastern District	792,285	97.3	21,798	2.7	814,083	26,972	99.1	250	0.9	27,222	100
Total Farmland Area	1,745,873	82.7	365,656	17.3	2,111,529	52,707	89.8	5,975	10.2	58,682	100

Table III-22

Farmers' Working Days

Region	Family Members	Members Engaged in Farming	Number of Farming Days			Members' Non-Farming Labour	Annual Number of Days (Per Capita)		
			Own Labour	Hired Labour	Total		Farming	Non-Farming	Total
Unit	Person	Person	Man-day	Man-day	Man-day	Man-day	Day	Day	Day
Northeastern District	6.59	3.36	278.21	18.99	297.20	143.00	109.5	42.6	152.1
National Average	5.90	3.19	319.91	25.50	345.41	622.00	100.3	42.0	142.3

Cultivated Area	Agricultural Income	Number of Working Days Per Rai	Agricultural Income Per Day
Rai		Man-day a Man-day b	
20.48	2,527	13.6 14.5	9.1
18.11	3,241	17.7 19.1	10.1

Table III-23

Ratio of Water-Buffalo and Cattle-Raising Farmers,

and Raised Number Per Family

Region		Ratio of Raising Farmers %						Average Raised Number Per Family					
		6 Rai or Less	6-15 Rai	15-30 Rai	30-60 Rai	More Than 60 Rai	Average	6 Rai or Less	6-15 Rai	15-30 Rai	30-60 Rai	More Than 60 Rai	Average
Water-Baf-falo	Northeastern Zone	58.33	80.44	87.24	91.71	94.63	86.48	1.43	2.06	2.70	3.18	4.66	2.79
	National Average	-	-	-	-	-	63.59	-	-	-	-	-	2.00
Cat-tle	Northeastern Zone	16.66	30.55	39.75	49.60	61.07	41.27	0.60	1.16	1.64	2.67	4.89	2.03
	National Average	-	-	-	-	-	36.02	-	-	-	-	-	1.60

Table III-24

Ratio of Farmers with Power Driven Farm-Implements

and Average Cost Per Family

Region		6 Rai or Less	6-15 Rai	15-30 Rai	30-60 Rai	More Than 60 Rai	Average
Rate of Farms with Power Driven Farm-Implements	Northeastern District	0	0.44	0.61	0.16	0	0.38
	National Average	-	-	-	-	-	3.07
Average Cost Per Family of Power Driven Farm Implements	Northeastern Part	0	3	2	4	0	3
	National Average	-	-	-	-	-	1,068

The current growth period of staple crops in this zone is as shown in Fig. III-19:

Conditions of Applying Fertilizers

In Thailand all chemical manure is imported from abroad. Therefore, ammonium sulphate, potassium chloride, Thomas phosfate, urea and other synthetic fertilizers are expensive. As the price of ammonium sulphate is 2.5 - 3 bahts per kg in Sakol Nakorn, the use of this fertilizer for rice culture will not yield any profit.

However, as some upland crops are high in price, the application of chemical manure would pay well.

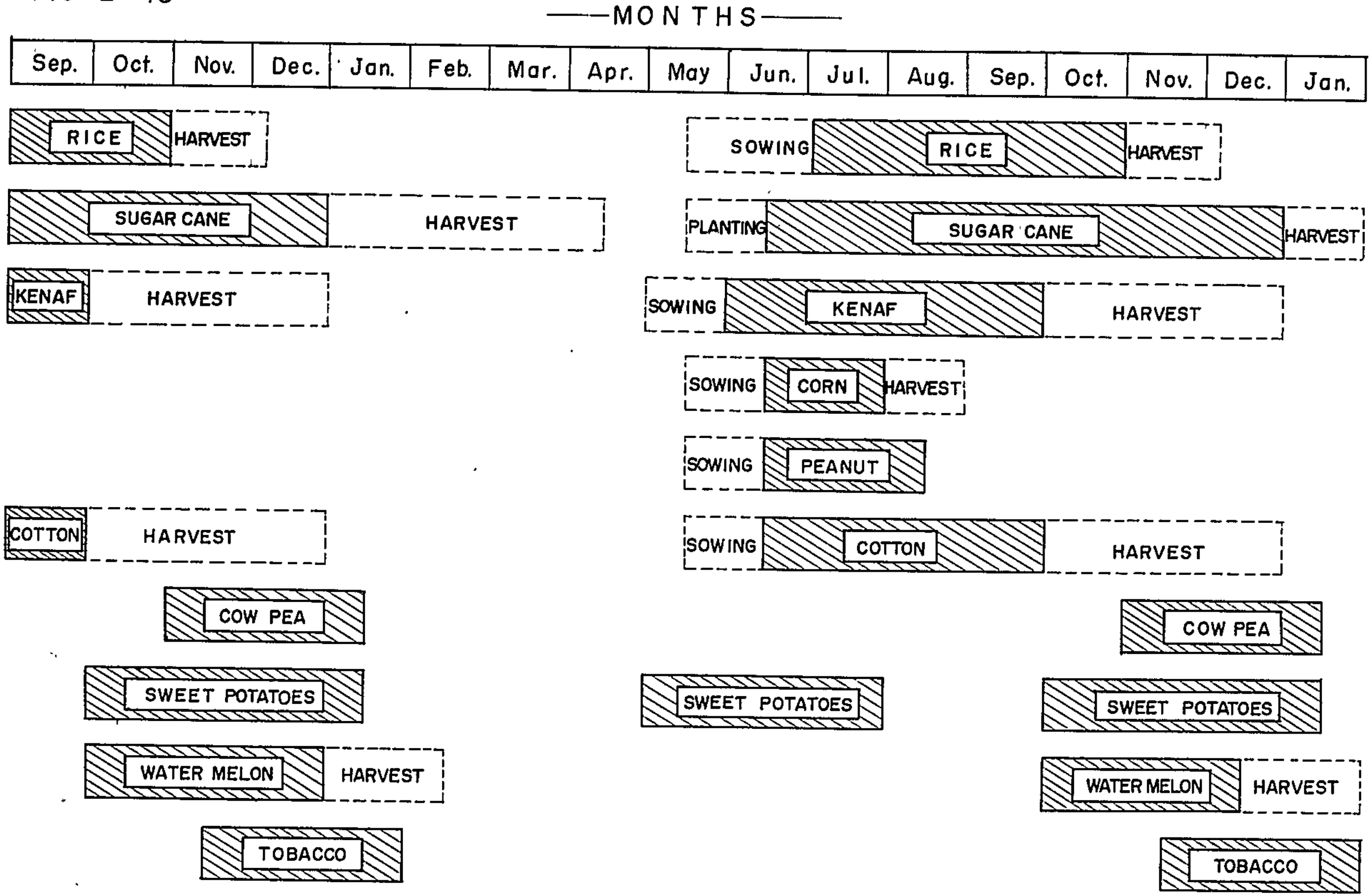
Table III - 25 Farmers' Balance Sheet
by Districts

Unit: Babt

		Central Plain	South-eastern	North-eastern	North-ern	South-Western	South-ern	National average
1	Agricultural Gross Income — Cash	2,888	3,138	954	1,611	3,213	3,684	2,149
2	Agricultural Gross Income — Goods	1,824	1,371	1,779	1,347	1,779	2,166	1,756
3	Agricultural Gross Income — Total	4,712	4,509	2,733	2,958	4,992	5,850	3,905
4	Farm-Management Expenses	1,335	420	206	346	696	623	664
5	Agricultural Income	3,377	4,089	2,527	2,612	4,296	5,227	3,241
6	Non-Agricultural Income	1,791	2,056	1,139	1,878	4,895	2,176	1,756
7	Farmers' Income	5,168	6,145	3,666	4,490	7,191	7,403	4,997
8	Household expenses — Cash	3,983	3,934	1,564	2,202	5,188	3,479	2,877
9	Household expenses — Goods	1,824	1,371	1,779	1,347	1,778	2,166	1,756
10	Household expenses — Total	5,807	5,305	3,343	3,549	6,966	5,645	4,633
11	Farmers' Economic Surplus	△ 639	840	323	941	2,225	1,758	364
12	Purchase of Capital Goods	1,016	1,031	246	271	631	385	554
13	Balance (11-12)	△1,655	△ 191	77	670	1,594	1,373	△190
14	Farm Management Expenses(4) / Agricultural Gross Income(3)	28.4%	9.2%	7.6%	11.7%	14.0%	10.6%	17.0%
15	Agricultural Income (5) / Agricultural Gross Income(3)	71.6%	90.8%	92.4%	88.3%	86.0%	89.4%	83.0%
16	Purchase of Capital Goods(12) / Faimers' Income(7)	19.7%	16.8%	6.6%	6.0%	6.9%	5.2%	11.1%
17	Engel's Coefficient	62.4	66.6	72.5	71.2	66.4	65.9	66.8

FIG. III - 19

CROP PLANTING SCHEDULE



(d) Irrigation Scheme

(1) Outline of irrigation scheme

The proposed irrigation area is roughly divided into three areas - Nam Pung Lower Basin Area, Lake Nong Han West Area and Lake Nong Han North Area. Among them Nam Pung Lower Basin Area is most extensive. In addition to the existing paddy fields of 9,000 ha, forest lands of 1,000 ha is to be reclaimed into upland fields. And cultivated lands 10,000 ha in total area are planned to be irrigated.

As for intake facilities a diversion weir is to be constructed at a site 700 m downstream of the Nam Pung Bridge, and Nong Han No. 1 Pumping Station is to be newly installed at the southern shore of Lake Nong Han. The cultivated lands concerned are divided into two parts—one is to be irrigated with river water taken in from the diversion weir (including cultivated lands to be irrigated by pumping from the lake when there is a shortage of river water), and the other to be irrigated exclusively by means of pumps.

The former is the area which will be in principle, irrigated by utilizing the natural discharge of the Nam Pung and discharge from the Nam Pung Dam. The acreage concerned is 7,237.6 ha of paddy field and 785.2 ha of upland field, totaling 8,022.8 ha.

The latter is the area which is to be irrigated exclusively with lake water pumped up by Nong Han No. 1 Pumping Station, without relying upon water taken in from the diversion weir. The acreage concerned is 1,762.4 ha of paddy field and 214.8 ha of upland field, totaling 1,977.2 ha.

Of the acreage to be irrigated with water taken in from the diversion weir, 214.8 ha of upland field can not be irrigated because of higher elevation, so the plan is to irrigate that land by lifting water in the second stage by means of pumps to be installed at Ban Lat Du.

Lake Nong Han West Area is to be irrigated with lake water pumped up by Nong Han No. 2 Pumping Station. This station is planned to be installed in the western part of Ban Thung Mon on the left bank of a large drainage canal to be excavated north of Lake Nong Han in order to control flood waters in the lake.

The area to be irrigated with the water consists of paddy field of 1,000 ha and upland field of 1,500 ha, totaling 2,500 ha.

Lake Nong Han North Area, like Lake Nong Han West Area, is to be irrigated with lake water pumped up by Nong Han No. 3 Pumping Station to be installed in the neighbourhood of Ban Phon Sawang on the right bank of the drainage canal. The area to be irrigated comprises of paddy and upland fields covering 1,000 ha each, totaling 2,000 ha. A plan to supply irrigation water to the respective areas concerned should be formulated to fulfil the proper distribution of water to such paddy and upland fields, and with a view to meeting this demand water requirements by periods and areas should be calculated and various structures designed.

(2) Water requirements

Water requirements are calculated for rice crops and upland crops respectively.

(i) Irrigation period

As for the first rice crop, seeds should be, as the standard, sown in nurseries on June 10, and 35-day-old seedlings transplanted on July 15. After then irrigation is to be practised for 120 days. And they may be harvested in 140 days after the transplanting (December 3).

As for the second rice crop, seeds are to be sown in nurseries on Dec. 10, and 30-day-old seedlings transplanted on Jan. 4. After then irrigation is to be practised for 100 days. They may be harvested in

120 days after the transplanting. As the region is vast in area the growth period becomes longer as is shown in Table III-13. In order to complete puddling operation in each area within 40 days, as will be stated later, it is planned to complete about 2/3 of the total irrigation area in the first half of the puddling period.

Upland irrigation will be in principle carried out all the year round.

(ii) Duty of water

1. Paddy fields

Water requirements for paddy fields vary according to topography, soil texture, water-table, weather condition and rice growth period, and they should be determined based on measurement data for 3-5 years. During this survey no measurement data could be obtained because of a very short stay. Therefore, water requirements for puddling is determined as 150 mm by adopting the duty of water of 10 mm/day used at present to form a plan for irrigation tank in the northeastern part of Thailand.

2. Upland fields

Water requirements for upland irrigation have been calculated by Blaney-Criddle Formula. As for the hours of sunshine, the calculation is based on the average value over 5 years from April 1957 to March 1962 at Nakorn Phanom because no observation data at Sakol Nakorn is found. As for the mean temperature, the average value over 10 years from 1947 to 1958 at Sakol Nakorn is used. The duty of water is as shown in Table III-26.

Blaney-Criddle Formula

$$U = K \cdot f = K \cdot (t \cdot P)$$

in which,

U : monthly consumed water (inch)

K : crop coefficient (0.75 this calculation)

t : monthly mean temperature (F°)

P : ratio of monthly sunshine time to annual sunshine time (%)

Table III-26

Calculation of Water Requirements

for Upland Crops

Month	Mean Monthly Sun-shine Time	Ratio of P (left) Annual Total %	Monthly Mean Temperature		t x P	Crop Coeffi-cient K	Monthly Water Consum-ption U(inch)	Monthly Water Consum-ption U (mm)	5-Days Water Consum-ption (mm)
			C°	F°					
Jan.	264.3	11.3	21.8	71.2	8.05	0.75	6.04	153	24.7
Feb.	211.0	9.1	23.9	75.0	6.83	0.75	5.12	130	23.2
Mar.	196.9	8.5	27.5	81.5	6.93	0.75	5.20	132	21.3
Apr.	217.8	9.4	29.3	84.7	7.96	0.75	5.97	151	25.2
May	191.4	8.2	28.8	83.8	6.87	0.75	5.15	131	21.1
Jun.	134.1	5.8	28.3	82.9	4.81	0.75	3.61	92	15.3
Jul.	127.0	5.4	27.9	82.2	4.44	0.75	3.33	85	13.7
Aug.	129.8	5.6	27.7	81.9	4.53	0.75	3.40	86	13.9
Sep.	152.7	6.6	27.3	81.1	5.35	0.75	4.01	102	17.0
Oct.	211.8	9.1	26.2	79.2	7.21	0.75	5.41	137	22.1
Nov.	243.4	10.5	23.6	74.5	7.82	0.75	5.87	149	24.8
Dec.	244.9	10.5	21.7	71.1	7.47	0.75	5.60	142	22.9
	2,325.1	100						1,490	

(iii) Net water requirements

Net water requirements are calculated by multiplying the duty of water by the acreage of the respective areas concerned.

This is an amount of water required for the growth of crop plants. Moreover, as for water requirements for puddling paddy fields the acreage puddled per day varies in every area. Usually the duty of water is required from the day following the puddling operation.

The net water requirements by areas and periods are as shown in Table III-27.

Table III-27

Net Water Requirements by Areas and Periods

Area	Item / Period	Net Water Requirements (10^3m^3)			Per-cent-age	Remarks
		Paddy Field	Upland Field	Total		
Nam Pung Lower Basin	Jun - Nov	125,357	13,349	138,706	67.2	
	Dec - May	35,364	32,186	67,550	32.8	
	Yearly Total	160,721	45,535	206,256	100	
Lake Nong Han West	Jun - Nov	13,358	9,985	23,343	54.3	
	Dec - May	4,526	15,005	19,531	45.7	
	Yearly Total	17,884	24,990	42,874	100	
Lake Nong Han North	Jun - Nov	13,358	6,506	19,864	55.0	
	Dec - May	4,526	11,747	16,273	45.0	
	Yearly Total	17,884	18,253	36,137	100	
Total	Jun - Nov	152,073	29,840	181,913	63.7	
	Dec - May	44,416	58,938	103,354	36.3	
	Yearly Total	196,489	88,778	285,267	100	

Furthermore, the detailed calculation of the net water requirements by areas and by semi-month is as shown in Tables III-39 to III-41.

(iv) Amount of water supply

1. Rainfall

As for effective rainfall for paddy fields, by using the rainfall records of the Sakol Nakon Meteorological Station, rainfalls of 5 mm or more have been summed up by semi-month, disregarding daily rainfall of less than 5 mm. The upper limit of the semi-month rainfall has been placed at 150 mm, and the effective rainfall for a paddy field was calculated at 80% of the semi-month rainfall.

As for effective rainfall for upland fields, daily rainfalls of 5 mm or more have been summed up by semi-month and 80% of the semi-month rainfall has been taken as the effective rainfall. However, the upper limit of effective rainfall has been taken as 50 mm of the semi-monthly rainfall.

The summation of effective rainfalls by years and by months is as shown in Table III-28.

2. Estimated natural discharge of the Nam Pung at the diversion weir site

Yearly and monthly discharges into Lake Nong Han from the catchment are, including the nam pung is as estimated in the Chapter concerning hydrology.

By the storage of water in the Nam Pung Dam, inundation on the lower lower reaches of the river may be controled. The catchment area from the Nam Pung Dam site to the proposed diversion weir site is 557 km^2.

Table III - 28 (1) Annual Rainfall and Effective Rainfall

Unit: mm

	Month	Annual Rainfall and Effective Rainfall	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
Wet Season	Jun.	1. Rainfall	98.8	298.8	341.0	196.6	465.7	167.7	210.7	214.4	182.5	138.4	101.8	354.1	398.4
		2. Effective Rainfall for Paddy Field	79.1	234.2	202.9	145.6	424.6	97.8	154.9	161.4	132.7	94.3	74.7	274.2	303.7
		3. Effective Rainfall for Upland Field	79.1	223.7	187.7	145.6	324.2	97.8	154.9	161.4	132.7	94.3	74.7	265.6	288.3
	July	1. "	371.2	181.3	225.4	215.7	269.7	120.8	87.0	279.6	211.1	184.0	166.9	282.2	56.3
		2. "	298.5	124.9	175.4	155.5	211.2	77.5	56.5	205.6	162.0	127.9	114.0	209.4	33.7
		3. "	292.3	124.9	175.4	155.5	211.2	77.5	56.5	205.6	162.0	127.9	114.0	209.4	33.7
	Aug.	1. "	412.5	313.2	90.1	381.9	231.8	274.3	246.0	468.0	269.6	196.9	189.7	337.0	298.1
		2. "	321.8	239.5	55.4	293.4	173.4	202.0	174.2	363.1	210.2	151.9	128.7	250.7	171.8
		3. "	301.4	215.7	55.4	293.4	173.4	177.6	174.2	321.1	210.2	151.9	128.7	250.7	161.6
	Sep.	1. "	442.1	276.0	227.0	242.9	186.0	375.4	214.5	249.7	195.0	310.1	392.5	269.3	425.5
		2. "	419.8	208.6	176.5	188.7	129.2	285.9	162.2	179.2	150.1	230.7	296.2	205.7	318.2
		3. "	364.6	208.6	172.2	188.7	129.2	164.5	126.7	179.2	150.1	230.1	296.2	205.7	298.2
	Oct.	1. "	30.5	96.9	85.7	47.4	86.8	79.3	5.9	25.2	22.3	84.5	1.0	64.9	89.1
		2. "	24.4	67.4	59.5	29.1	41.8	56.8	4.2	17.1	11.4	60.5	0	39.8	70.6
		3. "	24.4	67.4	59.5	29.1	41.8	56.8	4.2	17.1	11.4	60.5	0	39.8	70.6
	Nov.	1. "	48.4	0	5.2	5.4	5.1	0.5	0	0	0	0	2.1	0.8	0
		2. "	38.7	0	0	0	0	0	0	0	0	0	0	0	0
		3. "	38.7	0	0	0	0	0	0	0	0	0	0	0	0
	Sub-total	1. "	1,403.5	1,166.2	974.4	1,089.9	1,245.1	1,018.0	764.1	1,236.9	880.5	913.9	854.0	1,308.3	1,267.4
		2. "	1,182.3	874.6	669.7	812.3	980.2	720.0	552.0	926.4	666.4	665.3	613.6	979.8	898.0
		3. "	1,100.5	840.3	650.2	812.3	879.8	574.2	516.5	884.4	666.4	664.7	613.6	971.2	852.4

Table III - 28 (2) Annual Rainfall and Effective Rainfall

Unit: mm

Season	Month	Annual Rainfall and Effective Rainfall	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
Dry Season	Dec.	1.Rainfall	0		0.4	0	0	0.4	0	0	0	0	0	0	0
		2.Effective Rainfall for Paddy Field	0	0	0	0	0	0	0	0	0	0	0	0	0
		3.Effective Rainfall for Upland Field	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan.	1. "	17.0	0	2.4	0	30.4	38.5	0	0	0	17.9	0	0.6	0
		2. "	13.0	0	0	0	0	28.3	0	0	0	14.2	0	0	0
		3. "	13.6	0	0	0	0	28.3	0	0	0	14.2	0	0	0
	Feb.	1. "	0	0	0.8	.0	93.4	8.1	0	27.4	0.6	32.6	14.8	19.3	4.3
		2. "	0	0	0	0	70.1	0	0	21.7	0	18.8	11.5	11.4	0
		3. "	0	0	0	0	70.1	0	0	21.7	0	18.8	11.5	11.4	0
	Mar.	1. "	36.5	42.5	69.4	98.4	4.3	2.3	16.6	54.1	47.8	61.0	12.1	139.8	60.9
		2. "	29.2	30.8	52.6	76.1	0	0	11.7	39.6	33.1	45.3	0	109.5	48.2
		3. "	29.2	30.8	52.0	76.1	0	0	11.7	39.6	33.1	45.3	0	100.6	48.2
	Apr.	1. "	64.2	74.0	113.1	45.3	116.8	150.7	97.0	47.1	10.4	69.9	30.3	75.9	79.6
		2. "	44.4	54.2	79.4	33.2	84.4	116.1	75.9	28.7	0	48.0	19.4	58.8	63.0
		3. "	44.4	54.2	79.4	33.2	84.4	110.3	75.9	28.7	0	48.0	19.4	58.8	63.0
	May	1. "	179.8	250.7	204.4	114.3	214.1	246.9	114.2	190.7	169.3	144.8	221.1	135.5	244.7
		2. "	142.1	193.7	154.1	81.3	152.9	186.1	80.7	147.3	120.9	101.5	164.1	105.0	184.7
		3. "	142.1	193.7	154.1	81.3	152.9	150.9	80.7	147.3	120.9	101.5	164.1	105.0	169.1
	Sub-total	1. "	287.5	367.2	390.5	258.0	459.0	446.9	227.8	319.3	228.1	326.2	278.3	371.1	389.5
		2. "	229.3	278.7	286.1	190.6	307.4	330.5	168.3	237.3	154.0	227.8	195.0	284.7	295.9
		3. "	229.3	278.7	286.1	190.6	307.4	289.5	168.3	237.3	154.0	227.8	195.0	275.8	280.3
	Total	1. "	1,701.0	1,533.4	1,364.9	1,347.9	1,704.1	1,464.9	991.9	1,556.2	1,108.6	1,240.1	1,132.3	1,679.4	1,656.9
		2. "	1,411.6	1,153.3	955.8	1,002.9	1,287.6	1,050.5	720.3	1,163.7	820.4	893.1	808.6	1,264.5	1,193.9
		3. "	1,329.8	1,119.0	936.3	1,002.9	1,187.2	863.7	684.8	1,121.7	820.4	892.5	808.6	1,247.0	1,132.7

Table III - 29 Estimated Natural Discharge by Tears and by Months at Diversion Weir Site (Catchment Area 557 km^2)

Year	Item \ Unit	Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1949	1. Amount of Monthly Run-off	$10^3 m^3$	-	-	-	-	-	-	-	51,913	187,975	35,331	21,960	14,270	-
	2. Unit Discharge	m^3/s	-	-	-	-	-	-	-	19.38	72.52	13.19	8.47	5.33	-
1950	1. "	"	8,941	5,075	3,177	4,394	4,374	22,093	33,067	73,947	82,548	61,495	17,875	1,810	318,796
	2. "	"	3.34	2.10	1.19	1.70	1.63	8.52	12.35	27.61	31.85	22.96	6.90	0.68	-
1951	1. "	"	1,125	1,081	971	3,240	2,347	62,781	50,721	30,580	81,389	20,555	19,018	5,872	279,680
	2. "	"	0.42	0.45	0.36	1.25	0.88	24.22	18.94	11.42	31.40	7.67	7.34	2.19	-
1952	1. "	"	1,742	1,595	748	433	2,412	7,263	14,399	116,552	110,971	34,369	1,687	1,246	293,417
	2. "	"	0.65	0.64	0.28	0.17	0.90	2.80	5.38	43.52	42.81	12.83	0.65	0.47	-
1953	1. "	"	1,228	1,211	1,438	3,231	5,875	129,029	58,712	78,202	38,545	31,562	11,631	1,758	362,422
	2. "	"	0.46	0.50	0.54	1.25	2.19	49.78	21.92	29.20	14.87	11.78	4.49	0.66	-
1954	1. "	"	845	1,345	1,750	2,776	1,518	9,680	2,090	32,461	114,778	32,112	5,993	2,679	208,027
	2. "	"	0.32	0.56	0.65	1.07	0.57	3.73	0.78	12.12	44.28	11.99	2.31	1.00	-
1955	1. "	"	2,187	733	1,335	2,450	2,199	5,263	5,918	47,405	43,802	10,195	5,549	1,469	128,505
	2. "	"	0.82	0.30	0.50	0.95	0.82	2.03	2.21	17.70	16.90	3.81	2.14	0.55	-
1956	1. "	"	843	1,102	1,359	501	5,540	11,723	47,850	112,094	95,675	6,999	1,413	531	285,630
	2. "	"	0.31	0.44	0.51	0.19	2.07	4.52	17.87	41.85	36.91	2.61	0.55	0.20	-
1957	1. "	"	1,270	984	1,365	839	1,571	3,126	29,618	24,010	66,771	20,088	2,358	1,267	153,267
	2. "	"	0.47	0.41	0.51	0.32	0.58	1.21	11.06	8.96	25.76	7.50	0.91	0.47	-
1958	1. "	"	448	767	2,055	292	3,032	5,267	27,827	10,443	96,468	18,634	10,637	1,949	177,819
	2. "	"	0.17	0.32	0.77	0.11	1.13	2.03	10.39	3.90	37.22	6.96	4.10	0.73	-
1959	1. "	"	1,058	780	1,838	2,395	4,945	3,388	10,407	17,361	88,651	17,728	1,498	1,066	151,115
	2. "	"	0.40	0.32	0.69	0.92	1.85	1.31	3.89	6.48	34.20	6.62	0.58	0.40	-
1960	1. "	"	727	531	3,099	1,126	2,090	5,015	23,324	88,937	75,837	22,421	2,420	1,763	227,290
	2. "	"	0.27	0.21	1.16	0.43	0.78	1.93	8.71	33.21	29.26	8.37	0.93	0.66	-
1961	1. "	"	1,360	964	1,539	2,547	1,951	48,668	18,303	37,470	136,614	54,143	8,983	4,580	317,122
	2. "	"	0.51	0.40	0.57	0.98	0.73	18.78	6.83	13.99	52.71	20.21	3.47	1.71	-

Estimated discharge from the catchment area by years and by months calculated from inflow to Lake Nong Han is as shown in Table III-29.

3. Estimated discharge from the catchment area by years and by months

The ratio of the net water requirements between June and November, which is the wet season, to the yearly net water requirements is 63.7% and that in the dry season 36.3%. The ratio of the net water requirements for paddy fields in the wet season is 83.6%, and that for upland fields 16.4%. In this irrigation scheme stress is placed on rice culture in the wet season In other words the determination of tho basic year for the planning is to be made on the effective rainfall for paddy field in the wet season and the discharge of the Nam Pung in the same season. However, this scheme aims at tiding over a shortage of water which will probably occur once in five years From this point of view, both the yearly effective rainfall and that in the wet season in 1959 is the second smallest over the past 13 years. And, the yearly discharge of the Nam Pung in the same year is the second lowest over the past 12 years. Therefore, the year 1959 has been fixed as the irrigation-planning basic year.

In determining a series of more detailed irrigation schemes, a period between November 1958 and October 1959 has been made the planning basic period for calculating water requirements, because the second rice crop, as seen in the standard rice planting plan on Table III-13, begins in the last decade of November.

4. Puddling period and daily puddled area

When effective rainfalls for paddy field during the puddling period from June 26 to August 4 are summed up from the rainfall records of Sokol Nakorn, Table IV-30 can be obtained.

As puddling operation at present depends upon a 100% rainfall on the total area, the rice-transplanting period is unsettled owing to the distribution of rainfall in the year. It is advisable that puddling operation in an extensive area should be finished as early as possible in order to economize the total water requirements by utilizing the effective rainfall in the cultivation season. However, puddling water requirements are about 15 times the daily water supplies to paddy fields, so that the canal cross-section becomes too large if it is determined based on the puddling water requirements. This is uneconomical. Accordingly, the water-carrying capacity of a canal should be determined based on the maximum water supply. And consideration has been given in the plan so that puddling operation is finished within 40 days with the canal water carrying capacity.

As the maximum number of successive dry days is 17 in the puddling period from Table III-30, it is assumed that 2/3 of the total area concerned is completely puddled in case there happens to be 20 continuous days without rainfall. Let daily water supply be A mm/day in the plan for paddy field, and an amount of water required for puddling be B mm/day.

If the total area is 100% and $\frac{A}{B} = P$,

an area which can be puddled on the first day,

$$\text{---------}\quad 100\,P \quad \%$$

that on the second day

$$\text{---------}\quad 100\,P\,(1-P) \quad \%$$

that on the third day

$$\text{---------}\quad 100\,P\,(1-P)^2 \quad \%$$

that on the n-th day

$$100\,P\,(1-P)^{n-1} \quad \%$$

hence, the summation until n day

$$S = 100 - 100\,(1-P)^n \quad \%$$

Table III - 30 Effective Rainfall by Years (1949 - 1961)

Item / Year	Jun. 26 - Jul. 15		Jul. 16 - Aug. 4		Jun. 26 - Aug. 4		Jun.26 - Aug. 4	Remark
	Effective Rainfall mm	%	Effective Rainfall mm	%	Effective Rainfall mm	%	Number of Successive Dry Days	
1949	90.9	21	336.3	79	427.2	100	9	In calculating the number of successive dry days, less than 5 mm is neglected.
1950	100.2	53	88.2	47	188.4	100	7	
1951	106.4	55	88.5	45	194.9	100	10	
1952	100.0	49	102.2	51	202.2	100	9	
1953	107.0	41	155.4	59	262.4	100	8	
1954	43.8	28	112.7	72	156.5	100	17	
1955	46.2	45	55.6	55	101.8	100	7	
1956	158.5	54	137.2	46	295.7	100	7	
1957	153.6	66	77.8	34	231.4	100	11	
1958	98.4	75	32.6	25	131.0	100	10	
1959	64.4	35	120.3	75	184.7	100	11	Planning Basic Year
1960	242.1	73	89.0	26	331.1	100	5	
1961	89.9	70	38.9	30	128.8	100	9	
Average	107.8	49	110.4	51	218.2	100	9	

If $S = 2/3 = 66.67$ and $n = 20$

$$(1-P)^{20} = 0.3333$$

$$(1-P) \doteq 0.9465$$

$$P = 0.0535 < \frac{A}{B} = \frac{10}{150} = 0.0666$$

Therefore, it is on the safe side.

In case $P = 0.0535$ and $n = 40$

$$S = 100 - 100\ (1-0.0535)^{40} = 88.92\%$$

Therefore, in cases where an area which can be puddled a day is determined at this value of P = 0.0535, it becomes sufficient if 88.92% of the puddling water requirements is supplied with irrigation water and the remaining 11.08% depends on the effective rainfall during the puddling period. This possibility is considered based on the effective rainfalls in the last half of the puddling period from July 16 to August 4 from Table 21. The minimum effective rainfall about once in five years is 55.6 mm. As 66.66% of the total area concerned, C, will be completed, an amount of water that can be saved during this period is:

$$55.6 \times 0.667\ C \doteqdot 37.1\ C$$

Also, for 0.1108 C corresponding to the above 11.08 %,

Puddling water requirement:

$$150\ \text{mm} \times 0.1108\ C \doteqdot 16.6\ C$$

Water supply (on the safe side):

$$0.1108\ C \times 10\ \text{mm/day} \times 19\ \text{day} \doteqdot 21.1\ C$$

$$\text{Total} \doteqdot 37.7\ C$$

In addition, rainfall used:

$$55.6\ \text{mm} \times 0.1108\ C \doteqdot 6.2\ C$$

Therefore, $37.1\ C + 6.2\ C = 43.3\ C > 37.7\ C$

Accordingly, it is on the safe side.

Based upon the above way of thinking an area puddled per day in Nam

Pung Lower Basin Area may be determined. The summation of such areas for every five days is shown on Tables III-31-32.

In Lake Nong Han West and North Areas calculation is made in a similar way: and the summation for every five days is shown on Tables III-33-34.

5. Area of nurseries and nursery water requirements

Area of nurseries has been calculated at 1/20 of the total transplanting area, nursery-preparing water-requirement at 150 mm, and water supply at 10 mm/day. (See Table II-35, Table III-36, Table III-37 and Table III-38)

6. Calculation of amount of irrigation water supplied in the basic year

Required water supplies have been calculated for every five days from November, 1958 to October, 1959.

However, for water supplies the irrigation efficiency in the upland field is estimated at 80% and the canal loss at 20%. The discharge from the dam was obtained by adding to the 1.7 m^3/s discharge for lighting and general power demands and the discharge required for the generation of power for irrigation pump loads.

Calculated amounts for Nam Pung Lower Basin Area, Lake Nong Han West Area and Lake Nong Han North Area are as shown on Table III-39, Table III-40 and Table III-41 respectively.

Ban Lat Du Pumping Area consists of upland fields covering 214,8 ha. The same calculation has been made with the other areas, and the summation by months is shown on Table III-42.

Table III - 31 Calculated Amounts of Puddling Water in Wet Season in Nam Pung Lower Basin Area (9,000 ha)

Date		Puddled Area (ha)	Water-Supplied Area (ha)	Puddling Water 10^3m^3	Water Supplied 10^3m^3	Total 10^3m^3
Jun.	26 - 30	2,162	2,162	3,243	456	3,699
Jul.	1 - 5	1,642	3,804	2,462	1,427	3,889
	6 - 10	1,246	5,050	1,868	2,165	4,033
	11 - 15	946	5,996	1,419	2,724	4,143
	16 - 20	967	6,963	1,451	3,199	4,650
	21 - 25	795	7,758	1,193	3,646	4,839
	26 - 31	734	8,492	1,177	4,858	6,035
Aug.	1 - 5	508	9,000	687	4,385	5,072
	Total	9,000	-	13,500	22,860	36,360

Table III - 32 Calculated Amounts of Puddling Water in Dry Season in Nam Pung Lower Basin Area (3,000 ha)

Date		Puddled Area (ha)	Water-Supplied Area (ha)	Puddling Water 10^3m^3	Water Supplied 10^3m^3	Total 10^3m^3
Dec.	26 - 31	890	890	1,336	186	1,522
Jan.	1 - 5	678	1,568	1,018	588	1,606
	6 - 10	517	2,085	777	893	1,670
	11 - 15	392	2,477	589	1,126	1,715
	16 - 17	298	2,775	449	1,302	1,751
	21 - 25	225	3,000	339	1,436	1,775
	Total	3,000	-	4,508	5,531	10,039

Table III - 33 Calculated Amounts of Puddling Water in Wet Season in Nong Han West and North Areas (1,000 ha)

Date	Puddled Area (ha)	Water-Supplied Area (ha)	Puddling Water 10^3m^3	Water Supplied 10^3m^3	Total 10^3m^3
Jun. 26 - 30	400	400	600	80	680
Jul. 1 - 5	300	700	450	260	710
6 - 10	200	900	300	390	690
11 - 15	100	1,000	150	470	620
Total	1,000	-	1,500	1,200	2,700

Table III - 34 Calculated Amounts of Puddling Water in Dry Season in Nong Han West and North Areas (400 ha)

Date	Puddled Area (ha)	Water-Supplied Area (ha)	Puddling Water 10^3m^3	Water Supplied 10^3m^3	Total 103m3
Dec. 26 - 31	280	280	420	75	495
Jan. 1 - 5	120	400	180	170	350
Total	400	-	600	245	845

Table III - 35 Calculated Amounts of Water Needed for Nursery in Wet Season in Nam Pung Lower Basin Area (450 ha)

Date	Nursery Area (ha)	Water-Supplied Area (ha)	Water Requirement for Nursery 10^3m^3	Water Supplied 10^3m^3	TOTAL 10^3m^3
May : 26 - 31	150	150	225	30	255
June : 1 - 5	100	250	150	95	245
6 - 10	50	300	75	135	210
11 - 15	50	350	75	160	235
16 - 20	50	400	75	185	260
21 - 25	50	450	75	210	285
TOTAL	450	-	675	815	1,490

Table III - 36 Calculated Amounts of Water Needed for Nursery in Dry Season in Nam Pung Lower Basin Area (150 ha)

Date	Nursery Area (ha)	Water-Supplied Area (ha)	Water Requirement for Nursery 10^3m^3	Water Supplied 10^3m^3	TOTAL 10^3m^3
Nov. : 25 - 30	50	50	75	10	85 (569)
Dec. : 1 - 5	35	85	53	32	85 (258)
6 - 10	25	110	38	47	85
11 - 15	20	130	30	59	89
16 - 20	10	140	15	67	82
21 - 25	10	150	15	72	87
TOTAL	150	-	226	287	513

Note: Parenthesized figures include water-supply for crops in wet season.

Table III - 37 Calculated Amounts of Water Needed for Nursery in Wet Season in Nong Han West and North Areas

(50 ha)

Date	Nursery Area (ha)	Water Supplied Area (h)	Water Requirement for Nursery 10^3m^3	Water Supplied 10^3m^3	TOTAL 10^3m^3
May 26 - 31	15	15	23	3	26
June 1 - 5	10	25	15	10	25
6 - 10	10	35	15	15	30
11 - 15	5	40	8	18	26
16 - 20	5	45	8	21	29
21 - 25	5	50	8	23	31
TOTAL	50	-	77	90	167

Table III - 38 Calculated Amounts of Water Needed for Nursery in Dry Season in Nong Han West and North Areas

(20 ha)

Date	Nursery Area (ha)	Water Supplied Area (ha)	Water Requirement for Nursery 10^3m^3	Water Supplied 10^3m^3	TOTAL 10^3m^3
Nov. 26 - 30	10	10	15	2	17
Dec. 1 - 5	5	15	8	6	14
6 - 10	5	20	8	8	16
11 - 15	—	20	—	10	10
16 - 20	—	20	—	10	10
21 - 25	—	20	—	10	10
TOTAL	20		31	46	77

Table III - 39 (1) Calculated Amounts of Water Suppl[y]
in Nan Pung Lower Basin Area

Date	Period	Number of Days	Effective Rainfall mm		Cultivated Area ha		Available Rainfall 10^3m^3		Net Water Requirement 10^3m^3		Required Water-Supply 10^3m^3		Required Water-Supply Including Losses 10^3m^3	
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland
1958 Nov.	1 - 5	5	0	0	5,196.0	1,000	0	0	3,073	248	3,073	248	3,688	372
	6 - 10	5	0	0	3,951.0	1,000	0	0	2,335	248	2,335	248	2,802	372
	11 - 15	5	0	0	3,005.1	1,000	0	0	1,776	248	1,776	248	2,132	372
	16 - 20	5	0	0	2,037.8	1,000	0	0	1,301	248	1,301	248	1,561	372
	21 - 25	5	0	0	1,272.4	1,000	0	0	854	248	854	248	1,025	372
	26 - 30	5	0	0	578.4	1,000	0	0	569	248	569	248	682	372
	Total	30	0	0	-	-	0	0	9,908	1,488	9,908	1,488	11,890	2,232
Dec.	1 - 5	5	0	0	50	2,000	0	0	258	458	258	458	310	687
	6 - 10	5	0	0	85	2,000	0	0	85	458	85	458	102	687
	11 - 15	5	0	0	110	2,000	0	0	89	458	89	458	107	687
	16 - 20	5	0	0	130	4,000	0	0	82	916	82	916	98	1,374
	21 - 25	5	0	0	140	4,000	0	0	87	916	87	916	104	1,374
	26 - 31	6	0	0	150	4,000	0	0	1,522	1,100	1,522	1,100	1,826	1,650
	Total	31	0	0	-	-	0	0	2,123	4,306	2,123	4,306	2,547	6,459
1959 Jan.	1 - 5	5	0	0	890	4,000	0	0	1,606	988	1,606	988	1,927	1,482
	6 - 10	5	0	0	1,568	4,000	0	0	1,670	988	1,670	988	2,004	1,482
	11 - 15	5	0	0	2,085	4,000	0	0	1,715	988	1,715	988	2,058	1,482
	16 - 20	5	0	0	2,477	4,000	0	0	1,751	988	1,751	988	2,101	1,482
	21 - 25	5	0	0	2,775	4,000	0	0	1,775	988	1,775	988	2,130	1,482
	26 - 31	6	0	0	3,000	4,000	0	0	1,800	1,184	1,800	1,184	2,160	1,776
	Total	31	0	0	-	-	0	0	10,317	6,124	10,317	6,124	12,380	9,186

Date	Period	Breakdown of Required Water Supply 10^3m^3						Possib[le]
		Pump Area			Weir Area			Natural Dischar[ge]
		Paddy	Upland	Total	Paddy	Upland	Total	
1958 Nov.	1 - 5	722	80	802	2,966	292	3,258	2,882
	6 - 10	549	80	629	2,253	292	2,545	2,439
	11 - 15	417	80	497	1,715	292	2,007	1,995
	16 - 20	306	80	386	1,255	292	1,547	1,551
	21 - 25	201	80	281	824	292	1,116	1,107
	26 - 30	134	80	214	548	292	840	66
	Total	2,329	480	2,809	9,561	1,752	11,313	10,63
Dec.	1 - 5	61	74	135	249	613	862	42
	6 - 10	20	74	94	82	613	695	38
	11 - 15	21	74	95	86	613	699	33
	16 - 20	19	275	294	79	1,099	1,178	29
	21 - 25	20	275	295	84	1,099	1,183	25
	26 - 31	358	330	688	1,468	1,320	2,788	25
	Total	499	1,102	1,601	2,048	5,357	7,405	1,94
1959 Jan.	1 - 5	377	296	673	1,550	1,186	2,736	18
	6 - 10	392	296	688	1,612	1,186	2,798	17
	11 - 15	403	296	699	1,655	1,186	2,841	17
	16 - 20	411	296	707	1,690	1,186	2,876	16
	21 - 25	417	296	713	1,713	1,186	2,899	16
	26 - 31	423	355	778	1,737	1,421	3,158	18
	Total	2,423	1,835	4,258	9,957	7,351	17,308	1,0

Table III - 39 (1) Calculated Amounts of Water Suppl[y]
in Nan Pung Lower Basin Area

e	Net Water Requirement 10^3m^3		Required Water-Supply 10^3m^3		Required Water-Supply Including Losses 10^3m^3		Breakdown of Required Water Supply 10^3m^3						Possible Intake by Gravity 10^3m^3				Amount Used 10^3m^3	Amount Not Used 10^3m^3	Shortage of Water (Amount Supplied by Pumps) 10^3m^3	Amount Pumped Up 10^3m^3
							Pump Area			Weir Area			Natural Discharge	Released Water from Dam		Total				
pland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Total	Paddy	Upland	Total		Normal	Additional					
0	3,073	248	3,073	248	3,688	372	722	80	802	2,966	292	3,258	2,882	734	281	3,897	3,258	639	0	802
0	2,335	248	2,335	248	2,802	372	549	80	629	2,253	292	2,545	2,439	734	281	3,454	3,545	909	0	629
0	1,776	248	1,776	248	2,132	372	417	80	497	1,715	292	2,007	1,995	734	281	3,010	2,007	1,003	0	497
0	1,301	248	1,301	248	1,561	372	306	80	386	1,255	292	1,547	1,551	734	216	2,501	1,547	954	0	386
0	854	248	854	248	1,025	372	201	80	281	824	292	1,116	1,107	734	216	2,057	1,116	941	0	281
0	569	248	569	248	682	372	134	80	214	548	292	840	663	734	406	1,803	840	963	0	214
0	9,908	1,488	9,908	1,488	11,890	2,232	2,329	480	2,809	9,561	1,752	11,313	10,637	4,404	1,681	16,722	11,313	5,409	0	2,809
0	258	458	258	458	310	687	61	74	135	249	613	862	421	734	169	1,324	862	462	0	135
0	85	458	85	458	102	687	20	74	94	82	613	695	380	734	169	1,283	695	588	0	94
0	89	458	89	458	107	687	21	74	95	86	613	699	339	734	169	1,242	699	543	0	95
0	82	916	82	916	98	1,374	19	275	294	79	1,099	1,178	298	734	216	1,248	1,178	70	0	294
0	87	916	87	916	104	1,374	20	275	295	84	1,099	1,183	257	734	216	1,207	1,183	24	0	295
0	1,522	1,100	1,522	1,100	1,826	1,650	358	330	688	1,468	1,320	2,788	254	881	819	1,954	1,954	0	834	1,522
0	2,123	4,306	2,123	4,306	2,547	6,459	499	1,102	1,601	2,048	5,357	7,405	1,949	4,551	1,758	8,258	6,571	1,687	834	2,435
0	1,606	988	1,606	988	1,927	1,482	377	296	673	1,550	1,186	2,736	184	734	683	1,601	1,601	0	1,135	1,808
0	1,670	988	1,670	988	2,004	1,482	392	296	688	1,612	1,186	2,798	179	734	683	1,596	1,596	0	1,202	1,890
0	1,715	988	1,715	988	2,058	1,482	403	296	699	1,655	1,186	2,841	174	734	683	1,591	1,596	0	1,250	1,949
0	1,751	988	1,751	988	2,101	1,482	411	296	707	1,690	1,186	2,876	169	734	761	1,664	1,664	0	1,212	1,919
0	1,775	988	1,775	988	2,130	1,482	417	296	713	1,713	1,186	2,899	163	734	761	1,658	1,658	0	1,241	1,954
0	1,800	1,184	1,800	1,184	2,160	1,776	423	355	778	1,737	1,421	3,158	189	881	825	1,895	1,895	0	1,263	2,041
0	10.317	6,124	10,317	6,124	12,380	9,186	2,423	1,835	4,258	9,957	7,351	17,308	1,058	4,551	4,396	10,005	10,005	0	7,303	11,561

Table III - 39 (2) Calculated Amounts of Water Supply in Nan Pung Lower Basin Area

Date	Period	Number of Days	Effective Rainfall mm		Cultivated Area ha		Available Rainfall 10^3m^3		Net Water Requirement 10^3m^3		Required Water Supply 10^3m^3		Required Water-Supply Including Losses 10^3m^3		Breakdown of Required Water Supply: Pump Area			Weir	
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Total	Paddy	Upla
1959 Feb.	1 - 5	5	0	0	3,000	4,000	0	0	1,500	928	1,500	928	1,800	1,392	352	278	630	1,448	1,1
	6 - 10	5	0	0	3,000	4,000	0	0	1,500	928	1,500	928	1,800	1,392	352	278	630	1,448	1,1
	11 - 15	5	0	0	3,000	4,000	0	0	1,500	928	1,500	928	1,800	1,392	352	278	630	1,448	1,1
	16 - 20	5	0	0	3,000	4,000	0	0	1,500	928	1,500	928	1,800	1,392	352	278	630	1,448	1,1
	21 - 28	8	11.5	11.5	3,000	4,000	345	460	2,400	1,484	2,055	1,024	2,466	1,536	483	308	791	1,983	1,2
	Total	28	11.5	11.5	-	-	345	460	8,400	5,196	5,055	4,736	9,666	7,104	1,891	1,420	3,311	7,775	5,6
Mar.	1 - 5	5	0	0	3,000	4,000	0	0	1,500	852	1,500	852	1,800	1,278	352	256	608	1,448	1,0
	6 - 10	5	0	0	3,000	4,000	0	0	1,500	852	1,500	852	1,800	1,278	352	256	608	1,448	1,0
	11 - 15	5	0	0	3,000	4,000	0	0	1,500	852	1,500	852	1,800	1,278	352	256	608	1,448	1,0
	16 - 20	5	0	0	3,000	4,000	0	0	1,500	852	1,500	852	1,800	1,278	352	256	608	1,448	1,0
	21 - 25	5	0	0	3,000	4,000	0	0	1,500	852	1,500	852	1,800	1,278	352	256	608	1,448	1,0
	26 - 31	6	0	0	3,000	4,000	0	0	1,800	1,020	1,800	1,020	2,160	1,530	423	306	729	1,737	1,2
	Total	31	0	0	-	-	0	0	9,300	5,280	9,300	5,280	11,160	7,920	2,183	1,586	3,769	8,977	6,3
Apr.	1 - 5	5	0	0	3,000	4,000	0	0	1,500	1,008	1,500	1,008	1,800	1,512	352	302	654	1,448	1,2
	6 - 10	5	0	0	2,110	4,000	0	0	1,314	1,008	1,314	1,008	1,577	1,512	309	302	611	1,268	1,2
	11 - 15	5	0	0	1,432	4,000	0	0	912	1,008	912	1,008	1,094	1,512	214	302	516	880	1,2
	16 - 20	5	7.5	7.5	915	4,000	69	300	607	1,008	538	708	646	1,062	127	212	339	519	8
	21 - 25	5	10.3	10.3	523	4,000	54	412	374	1,008	320	596	384	894	75	179	254	309	7
	26 - 30	5	0	0	225	4,000	0	0	198	1,008	198	1,008	238	1,512	47	302	349	191	1,2
	Total	30	17.8	17.8	-	-	124	712	4,905	6,048	4,782	5,336	5,739	8,004	1,124	1,599	2,723	4,615	6,4

Water Supply
in Area

(Req)uired Water-(Sup)ply Including (Lo)sses 10^3m^3		Breakdown of Required Water Supply 10^3m^3						Possible Intake by Gravity 10^3m^3				Amount Used 10^3m^3	Amount Not Used 10^3m^3	Shortage of Water (Amount Supply by Pumps) 10^3m^3	Amount Pumped Up 10^3m^3
		Pump Area			Weir Area			Natural Discharge	Released Water from Dam		Total				
(Pa)dy	Upland	Paddy	Upland	Total	Paddy	Upland	Total		Normal	Additional					
00	1,392	352	278	630	1,448	1,114	2,562	152	734	562	1,448	1,448	0	1,114	1,744
00	1,392	352	278	630	1,448	1,114	2,562	146	734	562	1,442	1,442	0	1,120	1,750
00	1,392	352	278	630	1,448	1,114	2,562	141	734	562	1,437	1,437	0	1,125	1,755
00	1,392	352	278	630	1,448	1,114	2,562	136	734	562	1,432	1,432	0	1,130	1,760
66	1,536	483	308	791	1,983	1,228	3,211	205	1,175	899	2,279	2,279	0	932	1,723
66	7,104	1,891	1,420	3,311	7,775	5,684	13,459	780	4,111	3,147	8,038	8,038	0	5,421	8,732
00	1,278	352	256	608	1,448	1,022	2,470	296	734	562	1,592	1,592	0	878	1,486
00	1,278	352	256	608	1,448	1,022	2,470	296	734	562	1,592	1,592	0	878	1,486
00	1,278	352	256	608	1,448	1,022	2,470	296	734	562	1,592	1,592	0	878	1,486
00	1,278	352	256	608	1,448	1,022	2,470	296	734	562	1,592	1,592	0	878	1,486
00	1,278	352	256	608	1,448	1,022	2,470	296	734	562	1,592	1,592	0	878	1,486
60	1,530	423	306	729	1,737	1,224	2,961	358	881	674	1,913	1,913	0	1,048	1,777
60	7,920	2,183	1,586	3,769	8,977	6,334	15,311	1,838	4,551	3,484	9,873	9,873	0	5,438	9,207
00	1,512	352	302	654	1,448	1,210	2,658	457	734	562	1,753	1,753	0	905	1,559
77	1,512	309	302	611	1,268	1,210	2,478	457	734	562	1,753	1,753	0	725	1,336
94	1,512	214	302	516	880	1,210	2,090	457	734	562	1,753	1,753	0	337	853
46	1,062	127	212	339	519	850	1,369	369	734	260	1,363	1,363	0	6	345
84	894	75	179	254	309	715	1,024	312	734	260	1,306	1,024	282	0	254
38	1,512	47	302	349	191	1,210	1,401	343	734	260	1,337	1,337	0	64	413
39	8,004	1,124	1,599	2,723	4,615	6,405	11,020	2,395	4,404	2,466	9,265	8,983	282	2,037	4,760

Table III - 39 (3) Calculated Amounts of Water Supply in Nan Pung Lower Basin Area

Date	Period	Number of Days	Effective Rainfall mm		Cultivated Area ha		Available Rainfall 10^3m^3		Net Water Requirement 10^3m^3		Required Water Supply 10^3m^3		Required Water Supply Including Losses 10^3m^3	
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland
1959 May	1 - 5	5	4.8	4.8	0	4,000	0	192	64	844	64	652	768	978
	6 - 10	5	39.8	39.8	0	4,000	0	1,952	0	844	0	0	0	0
	11 - 15	5	34.4	34.4	0	4,000	0	1,376	0	844	0	0	0	0
	16 - 20	5	41.3	41.3	0	4,000	0	1,652	0	844	0	0	0	0
	21 - 25	5	25.1	25.1	0	4,000	0	1,004	0	844	0	0	0	0
	26 - 31	6	18.9	18.9	0	4,000	0	756	255	1,012	255	256	306	384
	Total	31	164.3	164.3	-	-	0	6,932	319	5,232	319	908	1,074	1,362
Jun.	1 - 5	5	0	0	150	4,000	0	0	245	612	245	612	294	918
	6 - 10	5	0	0	250	4,000	0	0	210	612	210	612	252	918
	11 - 15	5	0	0	300	4,000	0	0	235	612	235	612	282	918
	16 - 20	5	20.5	20.5	350	4,000	72	820	260	612	188	0	226	0
	21 - 25	5	0	0	400	4,000	0	0	285	612	285	612	342	918
	26 - 30	5	54.2	50.0	450	4,000	244	2,000	3,699	612	3,455	0	4,146	0
	Total	30	74.7	70.5	-	-	316	2,820	4,934	3,672	4,618	2,448	5,542	3,672
Jul.	1 - 5	5	0	0	2,161.8	2,000	0	0	3,889	274	3,889	274	4,667	411
	6 - 10	5	0	0	3,803.4	2,000	0	0	4,033	274	4,033	274	4,840	411
	11 - 15	5	10.2	10.2	5,049.0	2,000	515	204	4,143	274	3,628	70	4,354	105
	16 - 20	5	32.1	32.1	5,994.9	2,000	1,924	642	4,650	274	2,726	0	3,271	0
	21 - 25	5	10.9	10.9	6,962.2	2,000	759	218	4,839	274	4,080	56	4,896	84
	26 - 31	6	60.9	50.0	7,757.6	2,000	4,724	1,000	6,035	328	1,311	0	1,573	0
	Total	31	114.1	103.2	-	-	7,922	2,064	27,599	1,698	19,677	674	23,601	1,011

Breakdown of Required Water Supp[illegible]

Pump Area			Weir [illegible]	
Paddy	Upland	Total	Paddy	Upl[illegible]
151	196	347	617	[illegible]
0	0	0	0	
0	0	0	0	
0	0	0	0	
0	0	0	0	
0	0	0	0	
60	77	137	246	[illegible]
211	273	484	863	1,[illegible]
58	184	242	236	[illegible]
49	184	233	203	[illegible]
55	184	239	227	[illegible]
44	0	44	182	
67	184	251	275	[illegible]
812	0	812	3,334	
1,085	736	1,821	4,457	2,[illegible]
914	44	958	3,753	[illegible]
948	44	992	3,892	[illegible]
853	11	864	3,501	[illegible]
641	0	641	2,630	
959	9	968	3,937	
307	0	307	1,266	
4,622	108	4,730	18,979	[illegible]

ts of Water Supply
r Basin Area

Required Water Supply Including Losses 10^3m^3		Breakdown of Required Water Supply 10^3m^3						Possible Intake by Gravity 10^3m^3				Amount Used 10^3m^3	Amount Not Used 10^3m^3	Shortage of Water (Amount Supply by Pumps) 10^3m^3	Amount Pumped Up 10^3m^3
		Pump Area			Weir Area			Natural Discharge	Released Water from Dam		Total				
Paddy	Upland	Paddy	Upland	Total	Paddy	Upland	Total		Normal	Additional					
768	978	151	196	347	617	782	1,399	516	734	173	1,423	1,399	24	0	347
0	0	0	0	0	0	0	0	516	734	0	1,250	0	1,250	0	0
0	0	0	0	0	0	0	0	516	734	0	1,250	0	1,250	0	0
0	0	0	0	0	0	0	0	1,215	734	0	1,949	0	1,499	0	0
0	0	0	0	0	0	0	0	1,215	734	0	1,949	0	1,499	0	0
306	384	60	77	137	246	307	553	967	881	62	1,910	553	1,357	0	137
1,074	1,362	211	273	484	863	1,089	1,952	4,945	4,551	235	9,731	1,952	7,779	0	484
294	918	58	184	242	236	734	970	716	734	121	1,571	970	601	0	242
252	918	49	184	233	203	734	931	601	734	121	1,456	937	519	0	233
282	918	55	184	239	227	734	961	504	734	121	1,359	961	398	0	239
226	0	44	0	44	182	0	182	503	734	121	1,358	182	1,176	0	44
342	918	67	184	251	275	734	1,009	406	734	121	1,261	1,009	252	0	251
4,146	0	812	0	812	3,334	0	3,334	658	734	1,210	2,602	2,602	0	782	1,594
5,542	3,672	1,085	736	1,821	4,457	2,936	7,393	3,388	4,404	1,815	9,607	6,661	2,946	782	2,603
4,667	411	914	44	958	3,753	367	4,120	477	734	1,210	2,421	2,421	0	1,699	2,657
4,840	411	948	44	992	3,892	367	4,259	475	734	1,210	2,419	2,419	0	1,840	2,832
4,354	105	853	11	864	3,501	94	3,595	295	734	1,210	2,239	2,239	0	1,356	2,220
3,271	0	641	0	641	2,630	0	2,630	2,216	734	143	3,093	2,630	463	0	641
4,896	84	959	9	968	3,937	75	4,012	3,572	734	268	4,574	4,012	562	0	968
1,573	0	307	0	307	1,266	0	1,266	3,372	881	42	4,295	1,266	3,029	0	307
23,601	1,011	4,622	108	4,730	18,979	903	19,882	10,407	4,551	4,083	19,041	14,987	4,054	4,895	9,625

Table III - 39 (4) Calculated Amounts of Water Supply in Nan Pung Lower Basin Area

Date	Period	Number of Days	Effective Rainfall mm		Cultinated Area ha		Available Rainfall 10^3m^3		Net Water Requirement 10^3m^3		Required Water Supply 10^3m^3		Required Water Supply Including Losses 10^3m^3		Breakdown of Required Water Supply 10^3m^3					
															Pump Area			Weir Area		
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Total	Paddy	Upland	Total
1959 Aug.	1 - 5	5	20.7	20.7	8,421.6	1,000	1,743	207	5,072	139	3,329	0	3,994	0	782	0	782	3,212	0	3,212
	6 - 10	5	6.2	6.2	9,000	1,000	558	62	4,500	139	3,942	77	4,730	116	926	25	951	3,604	91	3,895
	11 - 15	5	0	0	9,000	1,000	0	0	4,500	139	4,500	139	5,400	209	1,057	45	1,102	4,343	164	4,507
	16 - 20	5	48.8	48.8	9,000	1,000	4,392	488	4,500	139	108	0	130	0	25	0	25	105	0	105
	21 - 25	5	30.5	30.5	9,000	1,000	2,745	305	4,500	139	1,755	0	2,106	0	413	0	413	1,693	0	1,693
	26 - 31	6	22.4	22.4	9,000	1,000	2,016	224	5,400	166	3,384	0	4,061	0	795	0	795	3,266	0	3,266
	Total	31	128.6	128.6	-	-	11,454	1,286	28,472	861	17,018	216	20,421	325	3,998	70	4,068	16,423	255	16,678
Sep.	1 - 5	5	4.9	4.9	9,000	1,000	441	49	4,500	170	4,059	121	4,871	182	954	39	993	3,917	143	4,060
	6 - 10	5	118.9	50.0	9,000	1,000	10,701	500	4,500	170	0	0	0	0	0	0	0	0	0	0
	11 - 15	5	54.3	50.0	9,000	1,000	4,887	500	4,500	170	0	0	0	0	0	0	0	0	0	0
	16 - 20	5	75.3	50.0	9,000	1,000	6,777	500	4,500	170	0	0	0	0	0	0	0	0	0	0
	21 - 25	5	23.8	23.8	9,000	1,000	2,142	238	4,500	170	2,358	0	2,830	0	554	0	554	2,276	0	2,276
	26 - 30	5	18.7	18.7	9,000	1,000	1,683	187	4,500	170	2,817	0	3,380	0	662	0	662	2,718	0	2,718
	Total	30	295.9	197.4	-	-	26,631	1,974	27,000	4,260	9,234	121	11,081	182	2,170	39	2,209	8,911	143	9,054
Oct.	1 - 5	5	0	0	9,000	1,000	0	0	4,500	221	4,500	221	5,400	332	1,057	71	1,128	4,343	261	4,604
	6 - 10	5	0	0	9,000	1,000	0	0	4,500	221	4,500	221	5,400	332	1,057	71	1,128	4,343	261	4,604
	11 - 15	5	0	0	9,000	1,000	0	0	4,500	221	4,500	221	5,400	332	1,057	71	1,128	4,343	261	4,604
	16 - 20	5	0	0	9,000	1,000	0	0	4,500	221	4,500	221	5,400	332	1,057	71	1,128	4,343	261	4,604
	21 - 25	5	0	0	9,000	1,000	0	0	4,500	221	4,500	221	5,400	332	1,057	71	1,128	4,343	261	4,604
	26 - 31	6	0	0	6,382.2	1,000	0	0	4,944	265	4,944	265	5,933	398	1,162	85	1,247	4,771	313	5,084
	Total	31	0	0	-	-	0	0	27,444	1,370	27,444	1,370	32,933	2,058	6,447	440	6,887	26,486	1,618	28,104
Yearly Total	Grand Total	365	806.9	693.3	-	-	46,792	16,248	160,721	45,535	119,795	33,007	148,034	49,515	28,982	9,688	38,670	119,052	39,827	158,879

Calculated Amounts of Water Supply
in Nan Pung Lower Basin Area

Required Water Supply 10^3m^3		Required Water Supply Including Losses 10^3m^3		Breakdown of Required Water Supply 10^3m^3						Possible Intake by Gravity 10^3m^3				Amount Used 10^3m^3	Amount Not Used 10^3m^3	Shortage of Water (Amount Supply by Pumps) 10^3m^3	Amount Pumped Up 10^3m^3
				Pump Area			Weir Area			Natural Discharge	Released Water from Dam		Total				
Paddy	Upland	Paddy	Upland	Paddy	Upland	Total	Paddy	Upland	Total		Normal	Additional					
3,329	0	3,994	0	782	0	782	3,212	0	3,212	3,086	734	199	4,019	3,212	807	0	782
3,942	77	4,730	116	926	25	951	3,804	91	3,895	4,103	734	307	5,144	3,895	1,249	0	951
4,500	139	5,400	209	1,057	45	1,102	4,343	164	4,507	1,260	734	1,210	3,204	3,204	0	1,303	2,405
108	0	130	0	25	0	25	105	0	105	2,968	734	7	3,709	105	3,604	0	25
1,755	0	2,106	0	413	0	413	1,693	0	1,693	846	734	134	1,714	1,693	21	0	413
3,384	0	4,061	0	795	0	795	3,266	0	3,266	5,098	881	228	6,207	3,266	2,941	0	795
17,018	216	20,421	325	3,998	70	4,068	16,423	255	16,678	17,361	4,551	2,085	23,997	15,375	8,622	1,303	5,371
4,059	121	4,871	182	954	39	993	3,917	143	4,060	2,558	734	432	3,724	3,724	0	336	1,329
0	0	0	0	0	0	0	0	0	0	19,488	734	0	20,222	0	20,222	0	0
0	0	0	0	0	0	0	0	0	0	30,870	734	0	31,604	0	31,604	0	0
0	0	0	0	0	0	0	0	0	0	10,315	734	0	11,049	0	11,049	0	0
2,358	0	2,830	0	554	0	554	2,276	0	2,276	12,570	734	160	13,464	2,276	11,188	0	554
2,817	0	3,380	0	662	0	662	2,718	0	2,718	12,850	734	216	13,800	2,718	11,082	0	662
9,234	121	11,081	182	2,170	39	2,209	8,911	143	9,054	88,651	4,404	808	93,863	8,718	85,145	336	2,545
4,500	221	5,400	332	1,057	71	1,128	4,343	261	4,604	4,006	734	476	5,261	4,604	612	0	1,128
4,500	221	5,400	332	1,057	71	1,128	4,343	261	4,604	3,473	734	476	4,683	4,604	79	0	1,128
4,500	221	5,400	332	1,057	71	1,128	4,343	261	4,604	4,359	734	476	5,569	4,604	965	0	1,128
4,500	221	5,400	332	1,057	71	1,128	4,343	261	4,604	2,607	734	864	4,205	4,205	0	399	1,527
4,500	221	5,400	332	1,057	71	1,128	4,343	261	4,604	1,642	734	864	3,240	3,240	0	1,364	2,492
4,944	265	5,933	398	1,162	85	1,247	4,771	313	5,084	1,641	881	1,037	3,559	3,559	0	1,525	2,772
27,444	1,370	32,933	2,058	6,447	440	6,887	26,486	1,618	28,104	17,728	4,551	4,193	26,472	24,816	1,656	3,288	10,175
119,795	33,007	148,034	49,515	28,982	9,688	38,670	119,052	39,827	158,879	161,137	53,584	30,151	244,872	127,292	117,580	31,637	70,307

Table III - 40 (1) Calculated Amounts of Water Supply in Nong Han West Area

Unit: $10^3 m^3$

Date	Period	Number of Days	Effective Rainfall mm		Cultivated Area (ha)		Available Rainfall		Net Water Requirement		Required Water-Supply		Required Water-Supply Including Losses		
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Total
1958 Nov.	1 - 5	5	0	0	100	1,500	0	0	110	372	110	372	132	558	690
	6 - 10	5	0	0	0	1,500	0	0	30	372	30	372	36	558	594
	11 - 15	5	0	0	0	1,500	0	0	0	372	0	372	0	558	558
	16 - 20	5	0	0	0	1,500	0	0	0	372	0	372	0	558	558
	21 - 25	5	0	0	0	1,500	0	0	0	372	0	372	0	558	558
	26 - 30	5	0	0	0	1,500	0	0	17	372	17	372	20	558	578
	Total	30	0	0	-	-	0	0	157	2,232	157	2,232	188	3,348	3,536
Dec.	1 - 5	5	0	0	10	1, 00	0	0	14	367	14	367	17	551	568
	6 - 10	5	0	0	15	1, 00	0	0	16	367	16	367	19	551	570
	11 - 15	5	0	0	20	1, 0	0	0	10	401	10	401	12	602	614
	16 - 20	5	0	0	20	1,800	0	0	10	412	10	412	12	618	630
	21 - 25	5	0	0	20	1,800	0	0	10	412	10	412	12	618	630
	25 - 31	6	0	0	20	1,800	0	0	495	495	495	495	594	744	1,338
	Total	31	0	0	-	-	0	0	555	2,454	555	2,454	666	3,684	4,350
1959 Jan.	1 - 5	5	0	0	250	1,800	0	0	350	445	350	445	420	668	1,088
	6 - 10	5	0	0	400	1,800	0	0	200	445	200	445	240	668	908
	11 - 15	5	0	0	400	1,800	0	0	200	445	200	445	240	668	908
	16 - 20	5	0	0	400	1,800	0	0	200	445	200	445	240	668	908
	21 - 25	5	0	0	400	1,800	0	0	200	445	200	445	240	668	908
	26 - 31	6	0	0	400	1,800	0	0	240	533	240	533	288	800	1,098
	Total	31	0	0	-	-	0	0	1,390	2,758	1,390	2,758	1,668	4,140	5,808

Table III - 40 (2) Calculated Amounts of Water Supply in Nong Han West Area

Unit: $10^3 m^3$

Date	Period	Number of Days	Effective Rainfall mm		Acultivated Area (ha)		Available Rainfall		Net Water Requirement		Required Water-Supply		Required Water-Supply Including Losses		
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Total
1959 Feb.	1 - 5	5	0	0	400	1,800	0	0	200	418	200	418	240	627	867
	6 - 10	5	0	0	400	1,800	0	0	200	418	200	418	240	627	867
	11 - 15	5	0	0	400	1,800	0	0	200	418	200	418	240	627	867
	16 - 20	5	0	0	400	1,800	0	0	200	418	200	418	240	627	867
	21 - 28	8	11.5	11.5	400	1,800	46	207	320	668	274	461	329	692	1,021
	Total	28	11.5	11.5	-	-	46	207	1,120	2,340	1,074	2,133	1,289	3,200	4,489
Mar.	1 - 5	5	0	0	400	1,800	0	0	200	383	200	383	240	575	815
	6 - 10	5	0	0	400	1,800	0	0	200	383	200	383	240	575	815
	11 - 15	5	0	0	400	1,800	0	0	200	383	200	383	240	575	815
	16 - 20	5	0	0	400	1,800	0	0	200	383	200	383	240	575	815
	21 - 25	5	0	0	400	1,800	0	0	200	383	200	383	240	575	815
	25 - 31	6	0	0	400	1,800	0	0	240	459	240	459	288	689	977
	Total	31	0	0	-	-	0	0	1,240	2,374	1,240	2,374	1,488	3,564	5,052
Apr.	1 - 5	5	0	0	150	1,800	0	0	150	454	150	454	180	681	861
	6 - 10	5	0	0	150	1,800	0	0	45	454	45	454	54	681	735
	11 - 15	5	0	0	150	1,800	0	0	0	454	0	454	0	681	681
	16 - 20	5	7.5	7.5	150	1,800	113	135	0	454	0	319	0	479	479
	21 - 25	5	10.3	10.3	150	1,800	155	185	0	454	0	269	0	404	404
	26 - 30	5	0	0	150	1,800	0	0	0	454	0	454	0	681	681
	Total	30	17.8	17.8	-	-	268	320	195	2,724	195	2,404	234	3,607	3,841

Table III - 40 (3) Calculated Amounts of Water Supply in Nong Han West Area

Unit: $10^3 m^3$

Date	Period	Number of Days	Effective Rainfall mm		Cultivated Area (ha)		Available Rainfall		Net Water Requirement		Required Water-Supply		Required Water-Supply Including Losses		
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Total
1959 May	1 - 5	5	4.8	4.8	0	1,800	0	86	0	380	0	294	0	441	441
	6 - 10	5	39.8	39.8	0	1,800	0	716	0	380	0	0	0	0	0
	11 - 15	5	34.4	34.4	0	1,800	0	559	0	380	0	0	0	0	0
	16 - 20	5	41.3	41.3	0	1,800	0	743	0	380	0	0	0	0	0
	21 - 25	5	25.1	25.1	0	1,800	0	451	0	380	0	0	0	0	0
	26 - 31	6	18.9	18.9	0	1,800	0	340	26	455	26	115	31	173	204
	Total	31	164.3	164.3	-	-	0	2,895	26	2,355	26	409	31	614	645
Jun.	1 - 5	5	0	0	15	1,500	0	0	25	230	25	230	30	345	375
	6 - 10	5	0	0	25	1,500	0	0	30	230	30	230	36	345	381
	11 - 15	5	0	0	35	1,500	0	0	26	230	26	230	31	345	376
	16 - 20	5	20.5	20.5	40	1,500	8	308	29	230	21	0	25	0	25
	21 - 25	5	0	0	45	1,500	0	0	31	230	31	230	37	345	382
	26 - 30	5	54.2	50	50	1,500	27	750	680	230	653	0	784	0	784
	Total	30	747	70.5	-	-	35	1,058	821	1,380	786	920	943	1,380	2,323
Jul.	1 - 5	5	0	0	400	1,500	0	0	710	206	710	206	852	309	1,161
	6 - 10	5	0	0	700	1,500	0	0	690	206	690	206	828	309	1,137
	11 - 15	5	10.2	10.2	900	1,500	92	153	620	206	528	53	634	80	714
	16 - 20	5	32.1	32.1	1,000	1,500	321	482	500	206	179	0	215	0	215
	21 - 25	5	10.9	10.9	1,000	1,500	109	164	500	206	391	42	469	60	529
	26 - 31	6	60.9	50.0	1,000	1,500	609	750	600	246	0	0	0	0	0
	Total	31	114.1	103.2	-	-	1,131	1,549	3,620	1,276	2,498	507	2,998	758	3,756

Table III - 40 (4) Calculated Amounts of Water Supply in Nong Hang West Area

Unit: $10^3 m^3$

Date	Period	Number of Days	Effective Rainfall mm		Cultivated Area (ha)		Available Rainfall		Net Water Requirement		Required Water-Supply		Required Water-Supply Including Losses		
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Total
1959 Aug.	1 - 5	5	20.7	20.7	1,000	1,500	207	311	500	209	293	0	352	0	352
	6 - 10	5	6.2	6.2	1,000	1,500	62	93	500	209	438	116	526	174	700
	11 - 15	5	0	0	1,000	1,500	0	0	500	209	500	209	600	314	914
	16 - 20	5	48.8	48.8	1,000	1,500	488	732	500	209	12	0	14	0	14
	21 - 25	5	30.5	30.5	1,000	1,500	305	458	500	209	195	0	234	0	234
	26 - 31	6	22.4	22.4	1,000	1,500	224	336	600	332	376	0	451	0	451
	Total	31	128.6	128.6	-	-	1,286	1,930	3,100	1,377	1,814	325	2,177	488	2,665
Sep.	1 - 5	5	4.9	4.9	1,000	1,500	49	74	500	255	451	181	541	272	813
	6 - 10	.5	118.9	50.0	1,000	1,500	1,189	750	500	255	0	0	0	0	0
	11 - 15	5	54.3	50.0	1,000	1,500	543	750	500	255	0	0	0	0	0
	16 - 20	5	75.3	50.0	1,000	1,500	753	750	500	255	0	0	0	0	0
	21 - 25	5	23.8	23.8	1,000	1,500	238	357	500	255	262	0	314	0	314
	26 - 30	5	18.7	18.7	1,000	1,500	187	281	500	255	313	0	376	0	376
	Total	30	295.9	197.4	-	-	2,959	2,962	3,000	1,530	1,026	181	1,231	272	1,503
Oct.	1 - 5	5	0	0	1,000	1,500	0	0	500	332	500	332	600	498	1,098
	6 - 10	5	0	0	1,000	1,500	0	0	500	332	500	332	600	498	1,098
	11 - 15	5	0	0	1,000	1,500	0	0	500	332	500	332	600	498	1,098
	16 - 20	5	0	0	1,000	1,500	0	0	500	332	500	332	600	498	1,098
	21 - 25	5	0	0	600	1,500	0	0	420	332	420	332	504	498	1,002
	25 - 31	6	0	0	300	1,500	0	0	240	530	240	530	288	795	1,083
	Total	31	0	0	-	-	0	0	2,660	2,190	2,660	2,190	3,192	3,285	6,477
Yearly Total	Grand Total	365	806.9	693.3	-	-	6,025	10,921	17,884	24,990	13,421	18,887	16,105	28,340	44,445

Table III - 41 (1) Calculated Amounts of Water Supply in Nong Han North Area

Unit: $10^3 m^3$

Date	Period	Number of Days	Effective Rainfall mm		Cultivated Area (ha)		Available Rainfall		Net Water Requirement		Required Water-Supply		Required Water-Supply Including Losses		
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Total
1958 Nov.	1 - 5	5	0	0	100	1,000	0	0	110	248	110	248	132	372	504
	6 - 10	5	0	0	0	1,000	0	0	30	248	30	248	36	372	408
	11 - 15	5	0	0	0	1,000	0	0	0	248	0	248	0	372	372
	16 - 20	5	0	0	0	1,000	0	0	0	248	0	248	0	372	372
	21 - 25	5	0	0	0	1,000	0	0	0	248	0	248	0	372	372
	26 - 30	5	0	0	0	1,000	0	0	17	248	17	248	20	372	392
	Total	30	0	0	-	-	0	0	157	1,488	157	1,488	188	2,232	2,420
Dec.	1 - 5	5	0	0	10	1,400	0	0	14	321	14	321	17	482	499
	6 - 10	5	0	0	15	1,400	0	0	16	321	16	321	19	482	501
	11 - 15	5	0	0	20	1,400	0	0	10	321	10	321	12	482	494
	16 - 20	5	0	0	20	1,400	0	0	10	321	10	321	12	482	494
	21 - 25	5	0	0	20	1,400	0	0	10	321	10	321	12	482	494
	26 - 31	6	0	0	20	1,400	0	0	495	385	495	385	594	578	1,172
	Total	31	0	0	-	-	0	0	555	1,990	555	1,990	666	2,988	3,654
1959 Jan.	1 - 5	5	0	0	250	1,400	0	0	350	346	350	346	420	519	939
	6 - 10	5	0	0	400	1,400	0	0	200	346	200	346	240	519	759
	11 - 15	5	0	0	400	1,400	0	0	200	346	200	346	240	519	759
	16 - 20	5	0	0	400	1,400	0	0	200	346	200	346	240	519	759
	21 - 25	5	0	0	400	1,400	0	0	200	346	200	346	240	519	759
	26 - 31	6	0	0	400	1,400	0	0	240	414	240	414	288	621	909
	Total	31	0	0	-	-	0	0	1,390	2,144	1,390	2,144	1,668	3,216	4,884

Table III - 41 (2) Calculated Amounts of Water Supply in Nong Han North Area

Unit: $10^3 m^3$

Date	Period	Number of Days	Effective Rainfall mm		Cultivated Area (ha)		Available Rainfall		Net Water Requirement		Required Water-Supply		Required Water-Supply Including Losses		
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Total
1959 Feb.	1 - 5	5	0	0	400	1,400	0	0	200	325	200	325	240	488	728
	6 - 10	5	0	0	400	1,400	0	0	200	325	200	325	240	488	728
	11 - 15	5	0	0	400	1,400	0	0	200	325	200	325	240	488	728
	16 - 20	5	0	0	400	1,400	0	0	200	325	200	325	240	488	728
	21 - 28	8	11.5	11.5	400	1,400	46	161	320	519	274	358	329	537	866
	Total	28	11.5	11.5	-	-	46	161	1,120	1,819	1,074	1,658	1,289	2,489	3,778
Mar.	1 - 5	5	0	0	400	1,400	0	0	200	298	200	298	240	447	687
	6 - 10	5	0	0	400	1,400	0	0	200	298	200	298	240	447	687
	11 - 15	5	0	0	400	1,400	0	0	200	298	200	298	240	447	687
	16 - 20	5	0	0	400	1,400	0	0	200	298	200	298	240	447	687
	21 - 25	5	0	0	400	1,400	0	0	200	298	200	298	240	447	687
	26 - 31	6	0	0	400	1,400	0	0	240	357	240	357	288	536	824
	Total	31	0	0	-	-	0	0	1,240	1,847	1,240	1,847	1,488	2,771	4,259
Apr.	1 - 5	5	0	0	150	1,400	0	0	150	353	150	353	180	530	710
	6 - 10	5	0	0	0	1,400	0	0	45	353	45	353	54	530	584
	11 - 15	5	0	0	0	1,400	0	0	0	353	0	353	0	530	530
	16 - 20	5	7.5	7.5	0	1,400	0	105	0	353	0	248	0	372	372
	21 - 25	5	10.3	10.3	0	1,400	0	108	0	353	0	245	0	368	368
	26 - 30	5	0	0	0	1,400	0	0	0	353	0	353	0	530	530
	Total	30	17.8	17.8	-	-	0	213	195	2,118	195	1,905	234	2,860	3,094

Table III - 41 (3) Calculated Amounts of Water Supply in Nong Han North Area

Unit: $10^3 m^3$

Date	Period	Number of Days	Effective Rainfall mm		Cultivated Area (ha)		Available Rainfall		Net Water Requirement		Required Water-Supply		Required Water-Supply Including Losses		
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Total
1959 May	1 - 5	5	4.8	4.8	0	1,400	0	67	0	295	0	228	0	342	342
	6 - 10	5	39.8	39.8	0	1,400	0	557	0	295	0	0	0	0	0
	11 - 15	5	34.4	34.4	0	1,400	0	482	0	295	0	0	0	0	0
	16 - 20	5	41.3	41.3	0	1,400	0	578	0	295	0	0	0	0	0
	21 - 25	5	25.1	25.1	0	1,400	0	351	0	295	0	0	0	0	0
	26 - 31	6	18.9	18.9	0	1,400	0	265	26	354	26	89	31	134	165
	Total	31	164.3	164.3	-	-	0	2,300	26	1,829	26	317	31	476	507
Jun.	1 - 5	5	0	0	15	1,000	0	0	25	153	25	153	30	230	260
	6 - 10	5	0	0	25	1,000	0	0	30	153	30	153	36	230	266
	11 - 15	5	0	0	35	1,000	0	0	26	153	26	153	31	230	261
	16 - 20	5	20.5	20.5	40	1,000	8	205	29	153	21	0	25	0	25
	21 - 25	5	0	0	45	1,000	0	0	31	153	31	153	37	230	267
	26 - 30	5	54.2	50	50	1,000	27	500	680	153	653	0	784	0	784
	Total	30	74.7	70.5	-	-	35	705	821	918	786	612	943	920	1,863
Jul.	1 - 5	5	0	0	400	1,000	0	0	710	137	710	137	852	206	1,058
	6 - 10	5	0	0	700	1,000	0	0	690	137	690	137	828	206	1,034
	11 - 15	5	10.2	10.2	900	1,000	92	102	620	137	528	35	634	53	687
	16 - 20	5	32.1	32.1	1,000	1,000	321	321	500	137	179	0	215	0	215
	21 - 25	5	10.9	10.9	1,000	1,000	109	109	500	137	391	28	469	42	511
	26 - 31	6	60.9	50.0	1,000	1,000	609	500	600	164	0	0	0	0	0
	Total	31	114.1	103.2	-	-	1,131	1,032	3,620	849	2,498	337	2,998	507	3,505

Table III - 41 (4) Calculated Amounts of Water Supply in Nong Han North Area

Unit: $10^3 m^3$

Date	Period	Number of Days	Effective Rainfall mm		Cultivated Area (ha)		Available Rainfall		Net Water Requirement		Required Water-Supply		Required Water-Supply Including Losses		
			Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland	Total
1959 Aug.	1 - 5	5	20.7	20.7	1,000	1,000	207	207	500	139	293	0	352	0	352
	6 - 10	5	6.2	6.2	1,000	1,000	62	62	500	139	438	77	526	116	642
	11 - 15	5	0	0	1,000	1,000	0	0	500	139	500	139	600	209	809
	16 - 20	5	48.8	48.8	1,000	1,000	488	488	500	139	12	0	14	0	14
	21 - 25	5	30.5	30.5	1,000	1,000	305	305	500	139	195	0	234	0	234
	26 - 31	6	22.4	22.4	1,000	1,000	224	224	600	166	376	0	451	0	451
	Total	31	128.6	128.6	-	-	1,286	1,286	3,100	861	1,814	216	2,177	325	2,502
Sep.	1 - 5	5	4.9	4.9	1,000	1,000	49	49	500	170	451	121	541	182	723
	6 - 10	5	118.9	50.0	1,000	1,000	1,189	500	500	170	0	0	0	0	0
	11 - 15	5	54.3	50.0	1,000	1,000	543	500	500	170	0	0	0	0	0
	16 - 20	5	75.3	50.0	1,000	1,000	753	500	500	170	0	0	0	0	0
	21 - 25	5	23.8	23.8	1,000	1,000	238	238	500	170	262	0	314	0	314
	26 - 30	5	18.7	18.7	1,000	1,000	187	187	500	170	313	0	376	0	376
	Total	30	295.9	197.4	-	-	2,959	1,974	3,000	1,020	1,026	121	1,231	182	1,413
Oct.	1 - 5	5	0	0	1,000	1,000	0	0	500	221	500	221	600	332	932
	6 - 10	5	0	0	1,000	1,000	0	0	500	221	500	221	600	332	932
	11 - 15	5	0	0	1,000	1,000	0	0	500	221	500	221	600	332	932
	16 - 20	5	0	0	1,000	1,000	0	0	500	221	500	221	600	332	932
	21 - 25	5	0	0	1,000	1,000	0	0	420	221	420	221	504	332	836
	26 - 31	6	0	0	1,000	1,000	0	0	240	265	240	265	288	398	686
	Total	31	0	0	-	-	0	0	2,660	1,370	2,660	1,370	3,192	2,058	5,250
Yearly Total	Grand Total	365	806.9	693.3	-	-	5,457	7,671	17,884	18,253	13,421	14,005	16,105	21,024	37,129

Table III - 42, Calculated Amounts of
Water Supply at Ban Lat Du

Month	Effective Rainfall Upland (mm)	Cultivated Area (ha)	Rainfall Availed 10^3m^3	Net Water Requirement 10^3m^3	Required Water Supply 10^3m^3	Required Water Supply Including Losses 10^3m^3
1958 Nov.	0	214.8	0	320	320	440
Dec.	0	214.8	0	305	305	419
1959 Jan.	0	214.8	0	329	329	452
Feb.	11.5	214.8	25	279	254	349
Mar.	0	214.8	0	284	284	391
Apr.	17.8	214.8	38	324	286	393
May	164.3	214.8	231	279	48	66
Jun.	70.5	214.8	66	198	132	182
Jul.	103.2	214.8	109	180	71	98
Aug.	128.6	214.8	139	186	47	65
Sept.	197.4	214.8	196	222	26	36
Oct.	0	214.8	0	294	294	404
TOTAL	6933		804	3,200	2,396	3,295

(e) Main Construction Plan

(1) General description

For Nam Pung Lower Basin Area a diversion weir is to be built at a site about 700 m downstream of the Nam Pung Bridge. The method is to take in water from both bank.

The intake canal on the right bank will connect to No.1 and No.2 main canal. The two canals will be connected to the pumping main canal at a point about 200 m below the diversion weir in order to feed water from Pumping Station No.1, in case of shortage of natural flow.

The intake gate on the left bank is connected to No.2 canal.

The above-mentioned Nong Han No.1 Pumping Station is to be constructed near Lake Nong Han, at an intermediate point between Ban Tha Wat and Ban Yang At. Ban Lat Du pumping equipment is to be installed at the end of No.3 Main Canal. These mains are in a principle earth canals. Especially, in sections which will require large-scale embanking work, asphalt lining is to be executed in order to prevent seepage of water and for safety of the structure. From the results of soil tests, the slopes of the earth canals are designed to a gradient of 2:1 in order to protect them from possible damages caused by erosion.

Lake Nong Han west and north areas are to be supplied with irrigation water from Nong Han No.2 and Nong Han No.3 pumping stations which are to be built on both banks of a large drainage canal to be constructed to drain flood discharges from Lake Nong Han. This drainage canal will be excavated in a northeasterly direction from the northern end of the lake.

Earth canals, similar to those for the Nam Pung lower basin area, connecting with these pumping station are to be constructed.

(2) Diversion weir

The diversion structure will be a movable weir, instead of fixed weir in order to allow abnormal flood water in the wet season to flow down without hindrance. Also in order to regulate the discharge from the power house, the highest intake level is 0.5 m above the design intake level. This will enable the regulation of approximately 100,000 m^3 of flow per day.

The design intake level for the diversion weir is E.L. 163.70 m, and the water level during regulation of flow is 164.20 m. The maximum intake is 8.00 m^3/s on the right bank, and 2.66 m^3/s on the left bank.

(3) Pumping reuipments

(i) Design discharge

The design discharge is determined based on the tables showing calculated amounts of water supplies in various areas - Table III-39, to Table III-42.

Nong Han No.1 Pumping Station has been designed to discharge 1,954,000 m^3/5 days, which is the maximum required discharge in January, by 16-hour operation per day.

Nong Han No.2 Pumping Station has been planned to discharge 1,161,000 m^3/5 days, which is the maximum required discharge in July, by 16-hour operation per day.

Nong Han No.3 Pumping Station has been planned to discharge 1,058,000 m^3/5-days, which is the maximum required discharge in July, by 16-hour operation per day.

Ban Lat Du Pumping Station has been designed to discharge 74,000 m^3/5-days, which is the maximum required discharge in April, by 16-hour operation per day.

(ii) Dimensions of pumps

Dimensions of each pump are as shown on Table III-43.

Table III - 43 Dimensions of Pumps

Pumping Station	Design Discharge (m^3/min)	Maximum Head (m)	Bore (mm)	Number of Pumps	Prime Mover	Number of Prime Movers	Total installed capacity (kW)	Average energy Consumption per m^3 of water (kWh)
Nong Han No.1	407	9.7	1,200	2	6,000v motor	2	1,000	36.73×10^{-3}
Nong Han No.2	242	12.0	800	3	6,000v motor	3	750	46.71×10^{-3}
Nong Han No.3	220	8.0	700	3	6,000v motor	3	450	30.10×10^{-3}
Ban Lat Du	16	10.0	250	2	400v motor	2	50	52.08×10^{-3}
Total							2,250	

Note: Fluctuations in the water level of Lake Nong Han is 2 m during a year. Therefore, Nong Han No.1, No.2 and No.3 Pumping Stations are designed for variable head of 2 m.
Average energy consumption per m^3 of water has been calculated by reducing the maximum head by one meter.

(iii) Discharge, Operation hour and electricity required by months.

Discharge, operating hour and electricity required by months are shown in Table III-44.

Table III-44

Discharge, Operating Hour and Electricity Required by Months

Source	Name	Item \ Month	Nov. 1958	Dec.	Jan. 1959	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Total
Lake Nong Han	Nong Han No.1 Pumping Station	Discharge 10^3m^3	2,809	2,435	11,561	8,732	9,207	4,760	484	2,603	9,625	5,371	2,545	10,175	70,307
		Operating Time hr	115	100	473	358	377	195	20	107	394	220	104	417	2,880
		Electricity kWh	103,175	89,438	424,636	320,726	338,173	174,835	17,777	95,608	353,526	197,277	93,478	373,728	2,582,377
	Nong Han No.2 Pumping Station	Discharge 10^3m^3	3,536	4,350	5,808	4,489	5,052	3,841	645	2,323	3,756	2,665	1,503	6,477	44,445
		Operating Time hr	239	294	392	303	341	265	44	157	253	180	107	437	3,012
		Electricity kWh	165,167	203,189	271,292	209,681	235,979	179,413	30,128	108,507	175,442	124,482	70,205	302,541	2,074,026
	Nong Han No.3 Pumping Station	Discharge 10^3m^3	2,420	3,654	4,884	3,778	4,259	3,094	507	1,863	3,505	2,502	1,413	5,250	37,129
		Operating Time hr	183	277	370	286	323	234	38	141	265	190	114	398	2,819
		Electricity	72,842	109,985	147,008	113,718	128,196	93,129	15,261	56,076	105,501	75,310	42,531	158,025	1,117,582
Ban Lat Du Pumping Station		Discharge 10^3m^3	440	419	452	349	391	393	66	182	98	65	36	404	3,295
		Operating Time hr	458	436	470	363	407	409	69	190	102	68	38	421	3,431
		Electricity kWh	22,915	21,825	23,540	18,176	20,363	20,467	3,437	9,479	5,103	3,385	1,875	21,040	171,605
Total		Discharge 10^3m^3	9,205	10,858	22,705	17,348	18,909	12,088	1,702	6,971	16,984	10,603	5,497	22,306	155,176
		Operating Time hr	995	1,107	1,705	1,310	1,448	1,103	171	595	1,014	658	363	1,673	12,142
		Electricity kWh	364,099	424,437	866,476	662,301	722,711	467,844	66,603	269,670	639,572	400,454	208,089	855,334	5,945,580

Note: Regarding discharge, see Tables III-39, 40, 41 and 42. Operating time is obtained by dividing monthly discharge by design unit discharge. Electricity is obtained from average energy consumption per m^3 of water shown on Table III-43.

(4) Canals

The canal is in principle of a trapezoidal cross section and with earth lining. The longitudinal gradient of the canals is within the range of 1/2,000 - 1/6,500.

The length of canals in each area is as shown on Table III-45.

Table III - 45 Length of Canals in Each Area

Area	Main Canal	Branch Canal	Total
Nam Pung Lower Basin	53 km	67 km	120 km
Lake Nong Han West	27	17	44
Lake Nong Han North	23	13	36
Total	103 km	97 km	200 km

In the above table: the main canal in Nam Pung Lower Basin Area includes 20 siphons, 2,170 m in total length and 3 culverts, 910 m long.

The main canal in Lake Nong Han West Area includes 3 siphons, 150 m in total length.

And in Lake Nong Han North Area there are 3 siphons, 150 m in total length.

(5) Appurtenant structures to canals

Appurtenant structures to the main canal in each area are as shown in Table III-46.

Table III - 46 Appurtenant Structures to Main Canal by Areas

Name	Nam Pung Lower Basin Area	Lake Nong Han West Area	Lake Nong Han North Area	Total
Regulating Gate	11	7	10	28
Diversion Work	26	14	11	51
Direct Intake Work	44	23	23	90
Drop	1	0	0	1
Canal Spill-way	14	7	10	31
Highway Bridge	20	6	11	37
Farm Road Bridge	42	40	32	114

(f) Construction Costs

The total construction costs are as follows:

Table III - 47 Total Construction Cost

	Total Cost US $	Foreign Currency US $	Local Currency Baht
Nam Pung Lower Basin Area	8,756,030	4,993,965	78,062,827
Lake Nong Han West Area	2,757,090	1,635,734	23,268,138
Lake Nong Han North Area	1,939,410	1,062,302	18,199,992
Total	13,452,530	7,692,001	119,530,957

Details of costs by Areas are as shown on Table III-48, Table III-49 and Table III-50.

Table III - 48 Nam Pung Lower Basin Area

($1 = ¥360 = 20,75 Bahts)

Name	Total Cost US $	Foreign Currency US $	Local Currency Baht
1. Canals, Structures, Diversion Weir	4,178,222	2,563,000	33,515,856
2. Pumping Equipment Works	947,888	713,305	4,867,597
3. Land Improvement Works	1,739,944	582,472	24,017,543
Total	6,866,054	3,858,777	62,400,996
4. Contingencies	686,611	385,889	6,239,983
Cumulative Total	7,552,665	4,244,666	68,640,979
5. Overhead Expenses	552,695	378,222	3,620,314
a. Investigations and design work	271,166	271,166	0
b. Supervision of construction	107,056	107,056	0
c. Thai Government expenses	174,473	0	3,620,314
Cumulative Total	8,105,360	4,622,888	72,261,293
6. Interest during construction	650,670	371,077	5,801,534
Grand Total	8,756,030	4,993,965	78,062,827

Table III - 49 Lake Nong Han West Area

($1 = ¥360 = 20,75 Baht)

Name	Total Cost US $	Foreign Currency US $	Local Currency Baht
1. Canals, Structures	986,250	626,269	7,469,606
2. Pumping Equipment Works	649,860	487,397	3,371,107
3. Land Improvement Works	523,194	175,269	7,219,444
Total	2,159,304	1,288,935	18,060,157
4. Contingencies	215,944	128,902	1,806,122
Cumulative Total	2,375,248	1,417,837	19,866,279
5. Overhead Expenses	179,089	101,394	1,612,171
a. Investigations and design work	66,811	66,811	0
b. Supervision of construction	34,583	34,583	0
c. Thai Government expenses	77,695	0	1,612,171
Cumulative Total	2,554,337	1,519,231	21,478,450
6. Interest during construction	202,753	116,503	1,789,688
Grand Total	2,757,090	1,635,734	23,268,138

Table III - 50 Lake Nong Han North Area

($1 = ¥360 = 20,75 Baht)

Name	Total Cost US $	Foreign Currency US $	Local Currency Baht
1. Canals, Structures	630,000	400,050	4,771,463
2. Pumping Equipment Works	315,556	236,667	1,636,947
3. Land Improvement Works	546,111	182,947	7,535,653
Total	1,491,167	819,664	13,944,063
4. Contingencies	149,166	81,966	1,394,400
Cumulative Total	1,640,833	901,630	15,338,463
5. Overhead Expenses	154,133	78,078	1,578,141
a. Investigations and design work	55,022	55,022	0
b. Supervision of construction	23,056	23,056	0
c. Thai Government expenses	76,055	0	1,578,141
Cumulative Total	1,794,966	979,708	16,916,604
6. Interest during construction	144,444	82,594	1,283,388
Grand Total	1,939,410	1,062,302	18,199,992

(g) Effect of Project

(1) Cropping area

As stated earlier, the proposed development area covering 14,500 ha is to be irrigated with the natural flow of the Nam Pung, the discharge from the dam and the water pumped up from Lake Nong Han. With irrigation, the cultivation of paddy and upland crops are expected from a total cropping area of 22,000 ha which is summarized below:

Paddy field:				
	First crop	11,000 ha		
	Second crop	3,800 ha	Sub-total	14,800 ha
Upland field:				
	Permanent	3,500 ha		
	Dry season	3,700 ha	Sub-total	7,200 ha

(2) Planned agricultural production and estimated income

On the premise that fertilizers coupled with irrigation are to be applied to upland fields, it is necessary to initiate at an early stage experiments on the breeding of various kinds of paddy and upland crops, and the improvement of farm management at agricultural and experimental service station in order that the results of experiments may be reflected upon the merits of the project.

In the table which follows are given the present average yields and the anticipated after-the-plan yields by crops in this region that were estimated from test results at the Sakol Nakorn Agricultural Experiment Station and its demonstration farms, and the Ban Ken Agricultural Experiment Station, as well as, from the data of the Agricultural Station in Sakol Nakorn Province.

Table III-51 Yields by Crops per Unit Area

Item / Crop	Yields before project	Yields after project				Remarks
	kg/ha	kg/ha	Baht/kg	Baht/ha	US$/ha	1. Rice price before project: 812 Bath/ha=39.1 $/na
Rice	1,160	1,750	0.7	1,225	59	
Sugar cane	-	42,000	0.1	4,200	200	
Peanuts	-	3,000	2	6,000	289.1	2. Increased production of first rice crop: 590 kg/ha - 413 B/ha - 19.9 $/ha
Sesame	-	950	3	2,850	137.3	
Kenaf	-	2,250	1.8	4,050	195.2	
Corn	-	3,000	0.9	2,700	130.1	3. Second rice crops and upland crops having never been grown, yields after project are all reckoned in as increased production.
Cotton	-	1,400	2.6	3,640	175.4	
Kapok	-	6,300	1.8	11,340	546.5	
Castor beans	-	1,560	2	3,120	150.4	
Tabacco	-	1,360	9	12,240	589.9	
Pasture	-			1,440	69.4	
Vegetables	-			1,720	82.9	

Table-III - 52 Increased Production by Areas
Nam Pung Lower Basin Area

Classification of Land	Crops		Area ha	Gross Profits B/ha	Gross Profits $/ha	Gross Profits Baht	Gross Profits Dollar	Net Profits Ratio: Paddy, 80% Upland, 70%	
Paddy Field		First Rice	9,000	413	19.9	3,717,000	179,100	2,973,600B	143,280$
		Second Rice	3,000	1,225	59.0	3,675,000	177,000	2,904,000	141,600
		Total	12,000	-	-	7,392,000	356,100	5,913,600	284,880
Upland Field	Upland Crops, Dry Season Upland	Tobacco	200	12,240	589.9	2,448,000	117,980		
		Corn	400	2,700	130.1	1,080,000	52,040		
		Sesame	630	2,850	137.3	1,795,500	86,499		
		Castor Beans	630	3,120	150.4	1,965,600	94,752		
		Peanuts	630	6,000	289.1	3,780,000	182,133		
		Kenaf	420	4,050	195.2	1,701,000	81,984		
		Vegetables	90	1,720	82.9	154,800	7,461		
		Subtotal	3,000	-	-	12,924,900	622,849		
	Upland Crops, Permanent Upland	Cotton	800	3,640	175.4	2,912,000	140,320		
		Sugar Cane	120	4,200	200.0	504,000	24,000		
		Pasture	40	1,440	69.4	57,600	2,776		
		Kapok	40	11,340	546.5	453,600	21,860		
		Subtotal	1,000	-	-	3,927,200	188,956		
		Tobacco	60	12,240	589.9	734,400	35,394		
		Corn	110	2,700	130.1	297,000	14,311		
		Sesame	170	2,850	137.3	484,500	23,341		
		Castor Beans	170	3,120	150.4	530,400	25,568		
		Peanuts	170	6,000	289.1	1,620,000	49,147		
		Kenaf	100	4,050	195.2	405,000	19,520		
		Vegetables	20	1,720	82.9	34,400	1,658		
		Subtotal	800	-	-	3,505,700	168,939		
	Total, Upland Crops		4,800	-	-	20,357,800	980,744	14,250,460	686,521

Net Profits, Total 20,164,060 Bahts = 971,401 $
US$ = 20.75 Bahts

Table-III - 53 Inereased Production by Areas
Nong Han West Area

Classification of Land			Crops	Area ha	Gross Profits B/ha	Gross Profits $/ha	Gross Profits Baht	Gross Profits Dollar	Net Profits Ratio: Paddy, 80% Upland, 70% (B)	Net Profits ($)
Paddy Field			First Rice	1,000	Note. 1		-805,000	-38,750	-644,000B	-31,000$
			Second Rice	400	1,225	59	490,000	23,600	392,000	18,880
			Total	1,400	-	-	-315,000	-15,150	-252,000	-12,120
Upland Field	Upland crops	Dry Season Upland	Tobbaco	20	12,240	589.9	244,800	11,798		
			Corn	40	2,700	130.1	108,000	5,204		
			Sesame	60	2,850	137.3	171,000	8,238		
			Castor Beans	60	3,120	150.4	187,200	9,024		
			Peanuts	60	6,000	289.1	360,000	17,346		
			Kenaf	40	4,050	195.2	162,000	7,808		
			Vegetables	20	1,720	82.9	34,400	1,658		
			Subtotal	300	-	-	1,267,400	61,076		
		Permanent Upland	Cotton	1,250	3,640	175.4	4,550,000	219,250		
			Sugar Cane	170	4,200	200.0	714,000	34,000		
			Pasture	40	1,440	69.4	57,600	2,776		
			Kapok	40	11,340	546.5	453,600	21,860		
			Subtotal	1,500	-	-	5,775,200	277,886		
			Tobacco	90	12,240	589.9	1,101,600	53,091		
			Corn	180	2,700	130.1	486,000	23,418		
			Sesame	270	2,850	137.3	769,500	37,071		
			Castor Beans	270	3,120	150.4	842,400	40,608		
			Peanuts	270	6,000	289.1	1,620,000	78,057		
			Kenaf	180	4,050	195.2	729,000	35,136		
			Vegetables	40	1,720	82.9	68,800	3,316		
			Subtotal	1,300	-	-	5,617,300	207,697		
	Total, Upland Crop			3,100	-	-	12,659,900	609,659	8,861,930	426,761
								Total	8,609,930B=414,641$	

US$ = 20.75 Bahts

Note 1. Before the plan: Paddy field, 2,500ha × 812 B/ha = 2,030,000B = 97,750$
After the plan: Paddy field, 1,000ha × 1,225 B/ha = 1,225,000B = 59,000$
(-) 805,000B = (-) 38,750$

Table-III - 54 Nong Han North Area

Classification of Land		Crops	Area ha	Gross Profits B/ha	Gross Profits $/ha	Gross Profits Baht	Gross Profits Dollar	Net Profits Ratio: Paddy, 80% Upland, 70% (Baht)	Net Profits (Dollar)
Paddy Field		First Rice	1,000	Note 1		7,000	350	5,600B	280$
		Second Rice	400	1,225	59.0	490,000	23,600	392,000	18,880
		Total	1,400	-	-	497,000	23,950	397,600	19,160
Upland Field	Upland Crops: Dry Season Upland	Tobacco	30	12,240	589.9	367,200	17,697		
		Corn	60	2,700	130.1	162,000	7,806		
		Sesame	80	2,850	137.3	228,000	10,984		
		Castor Beans	80	3,120	150.4	249,600	12,032		
		Peanuts	80	6,000	289.1	480,000	23,128		
		Kenaf	50	5,050	195.2	202,500	9,760		
		Vegetables	20	1,720	82.9	334,400	1,658		
		Subtotal	400	-	-	1,723,700	83,065		
	Upland Crops: Permanent Upland	Cotton	850	,640	175.4	3,094,000	175,400		
		Sugar Cane	110	4,200	200.0	462,000	22,000		
		Pasture	20	1,440	69.4	28,800	1,388		
		Kapok	20	11,340	546.5	226,800	10,930		
		Subtotal	1,000	-	-	3,811,600	209,718		
		Tobacco	50	12,240	589.9	612,000	29,495		
		Corn	110	2,700	130.1	297,000	14,311		
		Sesame	160	2,850	137.3	456,000	21,968		
		Castor Beans	160	3,120	150.4	399,200	24,064		
		Peanuts	160	6,000	289.1	960,000	46,256		
		Kenaf	120	4,050	195.2	486,000	23,424		
		Vegetables	40	1,720	82.9	68,800	3,316		
		Subtotal	800	-	-	3,279,000	162,834		
		Total, Upland Crops	2,200	-	-	8,814,300	455,617	6,170,010	318,932
							Total	6,567,610B	=338,092$

Note 1. Before the plan: Paddy field, 1,500ha × 812 B/ha = 1,218,000B = 58,650$
After the Plan: Paddy field, 1,000ha × 1,225 B/ha = 1,225,000B = 59,000$
(+) 7,000B = (+) 350$

Table III - 55 Incremental Income from Entire Development

A r e a	Baht	$
Nam Pung Lower Basin	20,164,060	971,401
Lake Nong Han West	8,609,930	414,641
Lake Nong Han North	6,567,610	338,092
Total	35,341,600	1,724,134

Even though irrigation water is obtained according to this plan, the above incremental income cannot be expected unless, as stated later, agricultural experiment and extension service stations promote tests and researches in various kinds of agricultural techniques and disseminate new techniques to the farmers of the area. For the dissemination of new techniques for practical application by farmers, great enthusiasm and thinking will be required of agricultural supervisors.

F. STUDY OF CONSTRUCTION SCHEDULE

The construction program for the first stage development of the Nam Gam basin has been already described. The economic feasibility of the said development will be discussed in the following chapter.

On the premise that the development projects should be completed at the earliest possible timing, an optimum construction schedule which we consider to be most economical and most effective from a financial standpoint is discussed hereinafter.

Other than the preliminary investigations and preliminary design work which the Team has conducted, preparations necessary for execution of the development scheme have not been made. Accordingly, detailed investigations and design work must be conducted before construction work may be started on the projects. This work will require at least one year. The projects, included in the first stage development of the Nam Gam basin, which should be built with top priority are the Nam Pung multi-purpose dam and the Nam Pung hydro-electric power project.

The power obtained from the development may be transmitted to Sakol Nakorn and also to cities along the Mekong River, and to supply pump loads of the proposed pump irrigation scheme of Lake Nong Han.

The development of the Nam Pung multi-purpose dam will make possible the Nam Pung irrigation scheme. Therefore, the Nam Pung irrigation scheme should be completed simultaneously with the Nam Pung hydro-electric power project. However, the execution of the irrigation project will require a large investiment (national funds). In consideration of the fact that about 70 per cent of the Nam Pung Reservoir construction cost would be investments allocable to agricultural development and also in consideration of the efficient utilization of the investments, it is believed appropriate to defer completion of the entire irrigation projects to 2 years after completion of the Nam Pung Power Project.

The flood control program of the Nam Gam basin aims at the increased utility of land by means of prevention or mitigation of flooding, and on completion of the irrigation projects, the utility of land will increase tremendously. Therefore, it is desirable that this project also be completed simultaneously with the irrigation projects.

Especially, in view of the fact that the Nong Han drainage work will require an enormous volume of excavation, from the viewpoint of construction procedure, the execution of this phase immediately after completion of the Nam Pung dam will make possible the employment of heavy equipment used at the dam and thus make possible savings in construction costs. Also, the Nong Han pump irrigation scheme is designed to pump up water from the Nong Han drainage canal and, therefore, it is desirable that the drainage work

DESCRIPTION	1963	1964	1965	1966	1967	1968	REMARKS
CIVIL ENGINEERING WORKS FOR THE DEVELOPMENT OF ELECTRIC POWER	$ 142.800 (INCLUDING ELECTRICAL WORKS) INVESTIGATION DESIGN & SPEC. PREPARATORY WORKS	CONTRACT	CONSTRUCTION WORKS $ 492.780				
ELECTRICAL WORKS FOR THE DEVELOPMENT OF ELECTRIC POWER	SURVEY DESIGN & SPEC.	CONTRACT	ELECTRICAL WORKS $ 2.094.160				
NAM PUNG IRRIGATION PROJECT		INVESTIGATION DESIGN & SPEC. $ 271.170	CONTRACT	CONSTRUCTION OF INTAKE FACILITIES $ 2.120.290 CONSTRUCTION OF CANALS $ 6.364.570			
NONG HAN PUMP UP IRRIGATION PROJECT		INVESTIGATION DESIGN & SPEC $ 121.830	CONTRACT	CONSTRUCTION OF INTAKE FACILITIES $ 1.209.420 CONSTRUCTION OF CANALS $ 3.365.250			
DRAINAGE WORKS FOR LAKE NONG HAN		INVESTIGATION DESIGN & SPEC. $ 87.550	CONTRACT	CONSTRUCTION WORKS $ 2.516.970			
CONSTRUCTION COST	$ 260.700 ($ 142.800)	$ 1.469.650 ($ 1.107.000)	$ 7.408.940 ($ 5.279.940)	$ 8.710.700 (POWER DEVELOPMENT ONLY)	$ 4.736.800		TOTAL $ 22.586.790 ($ 6.529.740)

FIG. III - 20
NAM GAM PROJECT FIRST STAGE
CONSTRUCTION SCHEDULE

and the pump irrigation scheme be simultaneously executed.

In view of the foregoing considerations, the appropriate time for completion of the Nong Han drainage canal may be one year after completion of the Nam Pung Dam. Taking into account the necessary periods of time for investigations, design work, and execution of the power, irrigation and drainage projects, the Team has prepared and included in this Report a construction schedule, which it considers to be most reasonable.

According to the construction schedule, the power project may be completed at the end of 1965, the irrigation scheme between 1966 and 1967, and the Nong Han drainage canal in 1966. An alternative program that may be considered is the execution of the power project only and defer the execution of the other purposes to the future.

G. STUDIES ON DEVELOPMENT OF OTHER INDUSTRIES

(a) Conditions on Industrialization

According to the Five Year Plan for the North-Eastern Districts (1962-1966), the Government of Thailand has designated Khonkaen and Sakol Nakhorn the two big industrial zones of the district and it is promoting the industrialization of the 2 cities.

However, the estimated cost of power, from the development of the Nam Pung hydro-electric scheme at Sakol Nakhorn is almost the same or slightly lower than the cost of diesel electric power. Therefore, it would not be proper, from the standpoint of cost of power and available output, to supply power from Nam Pung to bulk power consuming industries, such as, chemical fertilizer, aluminium, etc. Rather, it would be advisable to supply the said power to other industrial, irrigation and general consumer demands.

As stated earlier, agricultural development includes the use of year-round regulated flow downstream of the Nam Pung dam which over the year storage capacity, as well as, to pump water from Lake Nong Han for irrigation. Since the object of irrigation is to make possible the raising of two crops of rice a year in existing paddy fields, and to reclaim year-round cultivable farmland, it is most advisable to consider the development of industries to process upland crops.

(b) Probable Industries

Some industries which may be suitable to the area are as follows:

(1) Cotton spinning

The Team thinks it advisable to establish cotton spinning enterprises on scale, as a first step, not smaller than the economic operation unit, mainly for the purpose of meeting the needs in Korat plateau and Laos. The source of raw cotton will be the fields irrigated by the water from Nam Pung and Lake Nong Han shall (the latest improved species (--long fiber cotton about 1-1/4") should be introduced). In case raw cotton be insufficient, the shortage can be supplied from cotton fields in the Korat Plain.

For the time being, the industry should be developed through local medium and small enterprises, as well as, cottage industries, for the purpose of encouraging their development.

(2) Silk spinning

In order to enhance the traditional craftmanship in this district and promote its industrialization, we think it advisable, like cotton spinning, to encourage the raising of silk worms and the development of silk spinning industry. Like the cotton industry, the development of local medium and small enterprises or cottage industries should be encouraged.

(3) Oil extracting industry

If mills are built and operated to extract oil from peanuts and sesame seeds raised in the proposed irrigation district, as well as, from peanuts, sesame seeds and castor beans raised in adjoining areas, oil cakes thus obtained may be used as feed stuff or fertilizer to nourish soil.

(4) Hemp industry

For the purpose of meeting domestic and export needs, gunny bags may be manufactured at localities where kenaf can be easily collected.

(5) Sugar refining industry

The sugar refining industry to supply domestic demands may be feasible at points where sugar canes can be collected. If the quantity of sugar cane processed is of sizeable volume, perhaps the production of bagas pulps may be worth consideration. However, economic studies on the feasibility of receiving power from the Nam Pung Hydro-electric for this industry will require further studies in detail from the economic point of view.

(c) Other Probable Industries

Although the nursing of fresh water fishes in Lake Nong Han is a necessary undertaking, the volume of catch and processing of fishes, will depend upon whether or not rapid increase of demand can be expected.

Regarding the machine repairing industry, it may depend upon the local needs which may be created in proportion to the development of various industries, as well as, the degree of skill of repairmen.

CHAPTER IV.

STUDIES OF ECONOMIC FEASIBILITY OF THE DEVELOPMENT SCHEMES

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In the economic studies of the development schemes, the present electric rate structure was used to estimate general power revenues and the wholesale agricultural products market prices in Bangkok discounted by 30% were used to estimate the agricultural income.

The cost of Nam Pung dam was allocated to power and irrigation. And, in the allocation of the cost to irrigation, the calculations were based on the assumption that the area to be benefited by irrigation in the Nam Pung basin is 10,000 ha and that 6,100 ha of the said area would be irrigated with water released from the Nam Pung dam.

From calculations assuming an interest charge of 6% per annum on investments inclusive of construction period, and depreciation on a straight-line method, it was found that the development schemes are economically justificable. Therefore, it is believed that the present electric services rates may be reduced if funds with interest cost less than 6% could be invested.

In the following pages are briefly described the calculations that were made by the Team.

A. FUND REQUIREMENTS FOR NAM GAM DEVELOPMENT PROJECTS

(a) Total Fund Requirements

Total fund requirements for the Nam Gam development projects are as follows:

Hydro-electric project	US$ 6,529,740
Dam	3,142,360 (see Preliminary Designs of Nam Gam Project - separate volume)
Waterways	1,276,970

Powerhouse	1,254,990	
Transmission lines	855,420	
Irrigation Project	US$12,454,663	
Lower Nam Pung area	8,105,360	(see Chapter III-E(f), Table III-48)
Area around Lake Nong Han	4,349,303	(see Chapter III-E(f), Table III-49 and 50)
Flood Control Project	US$ 2,500,000	
Waterways	2,057,000	
Dam	443,000	
Total	US$21,484,403	

(b) Total Fund Requirements Including Interest during Construction

The total costs of the Nam Gam development schemes, including interest during construction of 6% per annum, would be as shown in the table which follows.

Water stored behind the dam will be utilized to generate a maximum of 5,400 kW and 15,000,000 kWh annually. By utilizing the water released through the power station and the natural flow downstream of the dam, 5,500 ha of paddy fields and 600 ha of upland field may be irrigated. Therefore, the dam is a common structure for power generation and irrigation.

With respect to flood control benefits, essential data were extremely scarce and, therefore, allocation of cost to flood control was not attempted.

	Construction cost (US$)	US$ expenditure (US$)	Baht expenditures (1000 Bahts)
Common structure (dam)	3,294,931	1,601,336	35,142
Power generating facilities	3,528,028	2,324,525	24,973
Waterways	1,343,217	676,578	3,833
Powerhouse	729,256	641,724	1,816
Substations	569,972	519,244	1,053
Transmission lines	885,583	486,979	8,271

	Construction cost (US$)	US$ expenditure (US$)	Baht expenditures (1000 Bahts)
Irrigation facilities	13,452,534	5,692,175	119,527
Area in downstream reaches of Nam Pung	8,756,031	4,993,564	78,071
Area around Lake Nong Han	4,696,503	2,698,611	41,456
Total	20,275,493	11,618,036	179,642
Flood control facilities	2,604,520		
Grand total	22,880,013		

Outlays in US$ and bahts are respectively 57.3% and 42.3% of the total cost of US$20,275,493 (excluding flood control facilities).

The conversion rate used in the estimates is 1 US$ equals 20.75 Bahts.

(c) Allocation of Costs of Common Structures

Common structures are the dam and intake which will be used for the dual purposes of power generation and irrigation. The ratio of justificable expenditures are 54.99% for power and 45.01% for irrigation. The construction costs and annual costs of the common structures allocated to the two uses by the above stated ratio are shown in the following table.

	Construction Costs		Annual Costs	
	(US$)	(1000 Bahts)	(US$)	(1000 Bahts)
Power	1,811,884	37,597	162,622	3,374
Irrigation	1,483,047	30,773	133,111	2,762
Total	3,294,931	68,370	395,733	6,136

The total construction costs of power facilities including the costs of common structures allocated to it are as follows.

	US$	1000 Bahts
Power facilities	3,884,357	80,600
Dam (allocated amount)	1,811,884	37,597
Waterways	1,343,217	27,871
Powerhouse	729,256	15,132
Substations	569,972	11,827
Transmission lines	885,583	18,376
Total	5,339,912	110,803

And, the construction costs of irrigation facilities including the costs of common structures allocated to irrigation are shown in the table which follows:

	US$	1000 Bahts
Irrigation facilities for lower Nam Gam basin	10,239,078	212,461
Dam (allocated amount)	1,483,047	30,773
Irrigation facilities	8,756,031	181,688
Irrigation facilities for areas around Lake Nong Han	4,696,503	97,452
Total	14,935,581	309,913

B. ECONOMIC FEASIBILITY OF THE POWER PROJECT

(a) Cost-benefit Ratio

Investments for the power phase of the development as stated before is 110,803,000 Bahts. To this investments appropriate costs of depreciation, operation and maintenance, as well as, interest charges calculated at 6% per annum were added to obtain the cost of power. Benefits were calculated in accordance with prevailing rate bases and were estimated at 2 Bahts per kWh for lighting demands and 1.3 Bahts per kWh for general power demands, taking into account separately rental charges for meters; and for irrigation pump loads a charge of 0.55 Bahts per kWh was assumed. Based on these calculations, the following cost-benefits values for the fiscal year 1970 were obtained. The electric charge for irrigation pump loads was based on the allocated costs of the dam and waterways and the operating and maintenance costs of a new power station and sub-stations, and on the assumption that in actual practice the pumps will be operated to avoid system peak load hours.

in 1000 Bahts

Costs		Benefits	
Power production expenses	7,966	lighting revenues	11,832
Sub-stations expenses	1,082	General power revenues	2,158
Transmission expenses	1,979	Irrigation power revenues	3,316
(Sub-total	*11,027)	Meter rental revenues	36
		(Sub-total	17,342)
		Less: Distribution expenses	2,654
		Sales expenses	1,675
Surplus benefits	1,986	(Sub-total	4,329)
Total	13,013	Total	*13,013

Note: * To obtain cost-benefit ratio

The cost-benefit ratio calculated from the foregoing table is 1.180 and the surplus benefit is 18% of the costs. Therefore, at an interest charge of 6% per annum it is believed that the project will be a relatively beneficial undertaking from the standpoint of national economy.

(b) Study of Operating Revenues

If the prevailing rate system of not charging for electric services to government offices and public lighting is assumed to continue until 1970, the estimated power revenues are as follows:

in 1000 Bahts

Expenditures		Revenues	
Generation expenses	7,966	Lighting sales	11,832
Transformation expenses	1,082	General power sales	2,158
Transmission expenses	1,979	Pump power sales	3,316
(Sub-total	11,027)	Meter rentals	36
		Less: Public lighting sales	592
		(Sub-total	16,750)
		Less: Distribution expenses	2,654
		Sales expenses	1,675
Profit	1,394	(Sub-total	4,329)
Total	12,421	Total	12,421

The total of profit and interest is 8,042,000 Bahts which is 7.26% of the total investment of 110,803,000 Bahts. The estimated unit costs of electricity are 0.62 Baht at the generating end, 0.77 Bahts at the primary step-down sub-station, which is about the cost of diesel power, and 1.13 Bahts at the consuming end. If the rate of interest could be reduced by 1%, the unit cost of power at the sub-station may be reduced by 10%. Therefore, it is desirable to deep interest costs on construction investments as low as possible.

The merits of transmission interconnection with other hydro-electric power systems which would greatly stabilize supply capability should not be overlooked.

C. ECONOMIC FEASIBILITY OF THE IRRIGATION SCHEME

(a) Cost-Benefit Ratio

The areas to be benefited with irrigation water are 11,000 ha of paddy fields and 3,500 ha of upland fields which will utilize the flow downstream of the Nam Pung dam. These areas are listed below:

(Unit: in ha)

District	Paddy field	Upland field	Total
Areas downstream of the Nam Pung dam to to be irrigated by gravity flow	5,500	600	6,100
Lower Nam Pung basin areas by pump irrigation	3,500	400	3,900
Lake Nong Han western and northern areas	2,000	2,500	4,500
Total	11,000	3,500	14,500

Investments for the irrigation scheme including the allocated cost of the dam is 309,913,000 Bahts. To the investments were added, necessary depreciation, operation and maintenance costs, interest charges calculated at 6% per annum, as well as, the increments of farmers' expenditures to arrive at the costs. And, for benefits the incremental gross agricultural production, which was calculated at 30% discount of wholesale market prices in Bangkok, was obtained to give the cost-benefit in the fiscal year 1970 which is shown in the following table.

in 1000 Bahts

Costs		Benefits	
Labor (Hired 1,166) (Domestic 8,951)	10,117	Gross agricultural production	52,040
Fertilizer and feed	451		
Farm implements and building	1,881		
Land rentals, interest, taxes	128		
(Sub-total	12,577)		
Irrigation water charges	28,792		
Total	*41,369		

Costs		Benefits	
Surplus benefit	10,671		
Grand Total	52,040	Grand Total	52,040

1. *To obtain cost-benefit ratio
2. See Chapter III, E (g)

The cost-benefit ratio in the above table is 1.258 and the surplus benefit is 25.8%. It can be said, therefore, that the undertaking is feasible at an interest cost of 6% per annum.

(b) Operating Revenues

The estimated operating revenues of the irrigation scheme are shown in the table which follows:

in 1000 Bahts

Expenditures		Revenues		
Operating expenses	3,999	Gross agricultural production		52,040
Depreciation	6,198			
Interest	18,595	Less:	Labor cost	10,117
			Fertilizer and feed	451
			Farm implements and building	1,881
			Land rental, interest and taxes	128
Surplus	10,671	(Sub-total		12,577)
Total	39,463	Total		39,463

The surplus of 10,671,000 Bahts is the sum obtained by deducting farmer's operating costs and irrigation water charges including interest cost at 6% per annum and depreciation from gross agricultural production. This surplus is 3.44% of the construction cost which is 309,913,000 Bahts. If this surplus is applied to retire borrowings, according to calculations, it can be retired in 29 years. Assuming that construction funds could be borrowed at a rate of interest less than 6%, then the retirement of borrowings can be accomplished in a less shorter period.

CHAPTER V.

SECOND AND SUBSEQUENT STAGES OF DEVELOPMENT OF THE NAM GAM BASIN

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SECOND AND SUBSEQUENT STAGES OF DEVELOPMENT OF THE NAM GAM BASIN

The development plan and economic justification of the first phase development of the Nam Gam basin have been described in the preceding Chapter.

Our studies of the second and subsequent stages of development of the Nam Gam basin have revealed that there are great possibilities of expanding the irrigation area in the basin. That is, a gradual expansion of the irrigation area will be feasible, when the pumping of irrigation water from the main stream of the Mekong becomes possible with the development of other hydro-electric potentials, and when progress in the development of the main stream of the Mekong makes possible the diversion of water into the area through the Nam Song Gram basin. Furthermore, the early development of the Nam Gam basin will attract various industries into the area, which in turn will create a considerable growth in the demand for electric power.

Following is a description of the proposed second and subsequent stages of development of the Nam Gam basin.

A. AGRICULTURAL DEVELOPMENT SCHEME ALONG THE MEKONG BASIN

A stretch of land on the right bank of the Mekong River, for about 100 km, between Nakorn Phanom and Mukdahan, which is served by a highway, relatively populated and along the route of the proposed transmission line, can be irrigated throughout the year by pumping up water from the main Mekong River. As shown in Fig. V-1 and Table V-1, some 11,100 ha of land can be irrigated year-round in the above area. This area is a fertile land influenced by alluvium deposited by the main stream of the Mekong and at present, tobacco, fruits, etc. are cultivated to some extent. Accordingly, when extremely low cost power is supplied to the above area from places outside the basin (other than Nam Pung) to meet the estimated demand of about 3,200 kW (7,550,000 kWh annually) to pump required water which is 14 m^3/s. (maximum) in the dry season, to irrigate the said 11,100 ha, the area will be turned into a most promising irrigation area in view of convenient traffic, fertile soil and low cost irrigation water.

In addition, there is a possibility of raising the planned high water level at Khemarat, a main stream project by 3 m to EL 133 m. Therefore, after completion of the Khemarat project the pumping head will be reduced from the present 13 - 17 m to 9 - 12 m. As a result, power consumption will be down to 5,800,000 kWh per year, which is a considerable economization of operating costs.

The development of the above area was assumed to be in the second stage because the pumping head will be higher compared with the pump irrigation scheme in the first stage development of the Nam Gam basin, and, consequently, the estimated pump loads cannot be supplied with the output of Nam Pung. Hence, the priority of development of the above area has been deferred.

However, it should be pointed out that it may be worthwhile to study the possibility for the early development of suitable parts of irrigation district M_1 near Mukdahan, irrigation district M_3 near That Phanom and irrigation district M_8 near Nakorn Phanom a· experimental stations, by incorporating them in the first-stage agricultural development which are scheduled to utilize electric power generated at Nam Pung.

If the above arrangement can be made, it will be possible to conduct various investigations and studies including crop rotation by irrigation during dry seasons in the whole of the Nam Gam basin, and thereby attaining the objective of making the comprehensive development of the Nam Gam basin the pilot project for the development of the Meking basin.

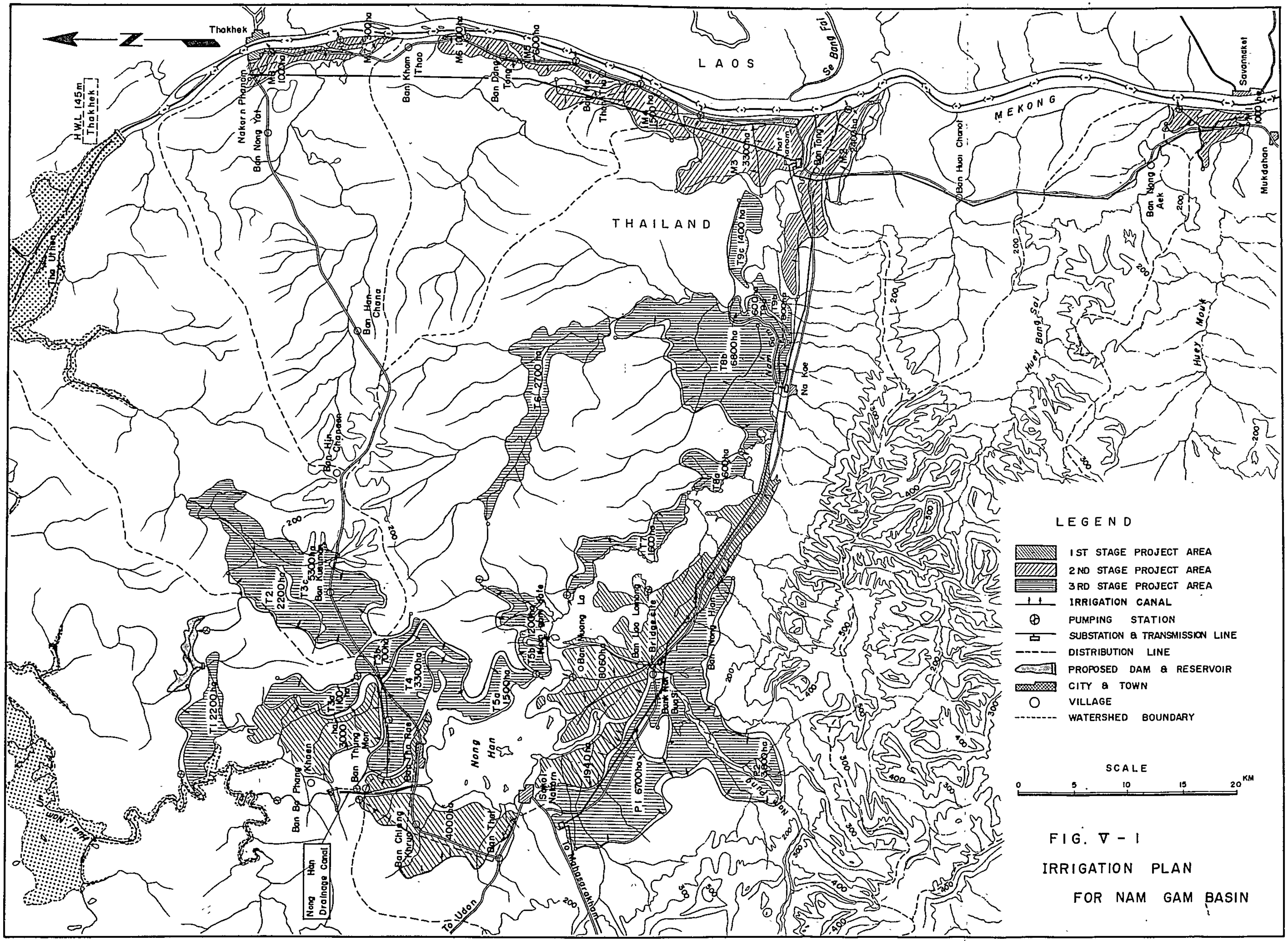


FIG. V - I
IRRIGATION PLAN
FOR NAM GAM BASIN

Table - V - 1 Irrigation Program in the Second Stage Development
(Between Mukdahan and Nakorn Phanom along the Mekong River)

Irrigation district	Pumping station	Area (ha)	Head (m)			Pumping Capacity (m^3/s)	Pumps			Length of main canal (Km)	Location of pumping station, (km from Mukdahan)	Remarks
			Elevation of pumped water 1	Elevation of source water 2	Actual head 3=1-2		Bore (mm)	Number of Units	Capacity (KW)			
M_1	Mekong River N o 1	1,000	142.50	125.65	16.85	1.26	600	2	360	14.1	8.9	
M_2	Mekong River N o 2	2,400	143.50	128.77	14.73	3.03	750	3	660	30.7	43.9	Near the confluence of Nam Gam and Mekong River
M_3	Mekong River N o 3	3,300	143.50	129.22	14.28	4.16	850	3	930	27.6	55.4	
M_4	Mekong River N o 4	1,500	144.00	129.51	14.49	1.89	700	2	440	20.5	52.9	
M_5	Mekong River N o 5	600	143.00	129.75	13.25	0.76	500	2	160	7.8	69.8	
M_6	Mekong River N o 6	1,000	143.00	130.14	12.86	1.26	600	2	260	11.1	84.6	
M_7	Mekong River N o 7	300	144.50	130.63	13.87	0.38	350	2	100	4.9	92.0	
M_8	Mekong River N o 8	1,000	144.50	130.89	13.61	1.26	600	2	280	10.2	98.6	
Total	-	11,100	-	-	-	14.00	-	-	3,190	126.9		consumption 7,550,000 kwh

B. AGRICULTURAL DEVELOPMENT OF THE NAM GAM BASIN BY DIVERSION OF WATER FROM THE MAIN MEKONG INTO LAKE NONG HAN

The scheme to construct a drainage canal (Nong Han Drainage Canal) to connect Lake Nong Han with Huai Nam Un, a tributary of Nam Song Gram, which lies on the northern side of the Nam Gam basin, has been described in Chapter III, C, FLOOD CONTROL SCHEME.

When the Thakhek Dam (design high water level of EL. 145 m) is constructed at a point of about 10 km upstream of Nakorn Phanom in the future as proposed in the "Comprehensive Reconnaissance Report on the Major Tributaries of the Lower Mekong River" (Chapter V-5) dated September 1961 and prepared by the Mekong Reconnaissance Team organized by the Government of Japan, the back water will reach up to near the above stated Nong Han Drainage Canal. When such condition is created, it will be possible to reclaim 41,500 ha of land through year-round irrigation, as per Fig. V-1 and Tab. V-2, by pumping water from Thakhek Reservoir to Lake Nong Han, or direct to the irrigation district.

To be more precise, the scheme is to supply irrigation water to irrigation area T_1 and T_2 directly from Thakkek Reservoir, and to the other areas, water is first stored in Lake Nong Han and then supplied to areas T_3, T_4, T_5, and T_6, while areas T_7, T_8 and T_9 are irrigated by pumping from Nam Gam or a diversion weir. However, in the first stage development, the entire Nam Pung irrigation district will be supplied with water by pumping from Lake Nong Han and the run-off downstream of Nam Pung reservoir will be utilized to irrigate areas P_1 and P_2 (9,500 ha). In this way, an effective utilization of water resources may be realized.

Electric power required for the above scheme, which is the third-stage development, is estimated at about 19,000 kW and the annual energy requirement is 44,300,000 kWh. In consideration of the fact that the third-stage development is to be initiated after the development of the Thakhek Dam on the main stream of the Mekong, the required power can be supplied from Thailand's share of the power-output of development sites on the main stream of the Mekong to which Thailand would rightfully have ownership.

C. PROMOTION OF DEVELOPMENT OF OTHER HYDRO-ELECTRIC POTENTIALS AS MEANS TO REINFORCE THE SUPPLY OF ELECTRIC POWER

The hydro-electric power development of the Nam Pung, as well as probable demands for power have, also, been covered in detail.

As the Government of Thailand has enthusiastically promoted the development of the northeastern part of the country, it is presumed that the demand for electric power in the service area of the Nam Pung Power Plant will show a rapid growth which will exceed our estimations. Accordingly, the time will come in about ten years when the power output of Nam Pung Power Plant cannot meet the demand in the service area. Therefore, it is necessary to consider measures to reinforce the supply of electric power.

The main stream of the Mekong embraces many places in the territory of Thailand, such as, Pa Mong, Bung Kan, Thakhek, Khemarat, Pakse, etc., where hydro-electric power can be developed. However, the development of these sites, with the exception of Pa Mong, will be impossible until completion of the Pa Mong Dam. Accordingly, before completion of the Pa Mong Dam, the reinforcing of supply capability in the northeastern area of Thailand must depend upon the construction of thermal power plants.

It may be added that in Laotian territory bordering on northeastern Thailand, there are many tributaries of the Mekong, such as, Nam Ngum, Nam Theun, Se Bang Fai, Se Bang Hieng, Se Done, etc., which from the terrain appear to be potential sources of low cost and abundant power when the projects become feasible in the future. Among them the two tributaries, Nam Theun and Se Bang Fai, are the closest to the Nam Gam basin, and are the

Table - V - 2 Irrigation Program in the Third Stage Development
(Diversion of water to the Nam Gam Basin After Completion of Thakhek Dam)

Irrigation district	Pumping station	Area	Head (m)			Pumping Capacity (m^3/sec)	Pumps			Length of main canal (Km)	Location of pumping Station	
			Elevation of pumped water ①	Elevation of source water ②	Actual head ③=①-②		Bore (mm)	Number of Units	Capacity (kw)			
$T_1 \cdot T_2$	Huai Nam Un N º 1	4,400 (T1=2,200, T2=2,200)	162.14	145.00	17.14	5.54 (T1=2.77, T2=2.77)	950	3	1,470	10.7	On a tributary of Nam Song Gam	
T_2	Huai Nam Un N º 2	2,200	175.00	160.00	15.00	2.77	700	3	660	41.0	At the end of T. Block Cunal Reservair Site	
T_3	Nong Han (Northern) N º 2	7,100	173.00	159.40	13.60	8.95	1,150	3	1,890	21.4	Nong Han (Nouthern) Right Bank Canal	
T_4	Nong Han (Northern) N º 1	3,300	168.50	160.62	7.88	4.15	800	3	570	21.1	Nang Han (Nouthern) Right Bank Canal	
$T_5 \cdot T_6$	Nong Han (Eastern) N º 1	5,400 (T5=2,700, T6=2,700)	166.0	155.50	10.50	6.80 (T5=3.40, T6=3.40)	1,000	3	1,140	31.0	Nong Han Lake (Eastern)	
T_6	Nong Han (Eastern) N º 2	2,700	169.33	161.40	7.93	3.40	750	3	450	7.0	T_5 Block Canal	
T_7	Nam Gam N º 2	1,600	160.00	155.50	4.50	2.02	700	2	180	19.5	124km upstream from the mouth of Nam Gam	
T_8	Nam Gam N º 1	7,400	160.00	146.14	13.86	9.32	1,200	3	2,040	45.2	70km upstream from the mouth of Nam Gam	
T_9	-	2,800	-	-	-	3.53	-	-	-	34.7	-	Diversion weir is to be built about 56km upstream from the mouth of Nam Gam
$P_1 \cdot P_2$	Nong Han (Southern) (Extension)	9,500 (P1=6,700, P2=2,800)	163.50	155.50	8.00	6.80	1,200	2	1,000	61.5 P1=37.0 P2=24.5	Adjoining Pumping Station is to be installed in the First Stage	P1P2 districts are to be irrigated by gravity flow
$T_3 \cdot T_4$	Nong Han (Nouthern) Right Bank Extention	10,400 (T3=7,100, T4=3,300)	162.50	155.50	7.00	13.10 (T3=8.95, T4=4.15)	1,600	3	1,530	12.4 T3= 4.9 T4= 7.5	Adjoining Pumping Station is to be installed in the First Stage	
$T_3 \cdot T_4 \cdot T_5 \cdot T_6 \cdot T_7 \cdot T_8 \cdot T_9 \cdot P_1 \cdot P_2$	Huai Nam Un N º 3	37,100	159.00	144.04	14.96	34.00 (41.57)	2,250	3	7,800	12.3	On a tributary of Nam Song Gram	Water level of Huai Nam Un at the irrigation intake is 145m
Total	11	41,500	-	-	-	39.54	-	-	18,730	317.8		Annual energy consumption 44,300,000 kwh

closest source of power that can be transmitted to the northeastern area of Thailand by constructing a tie transmission line across the Mekong River.

It is estimated that the development of the Upper Nam Theun will take about seven years at the minimum, including the time required for investigations.

For information only, our studies with respect to the development of the Upper Nam Theun is included in the appendix of this report.

CHAPTER VI.

C O N C L U S I O N

CHAPTER VI.

CONCLUSION

The Team has studied the feasibility of development of water sources in the Nam Gam basin. As a result, it has come to the conclusion that the completion, as early as possible, of the first stage development of the Nam Gam basin will be not only necessary but extremely advantageous.

Also, it is evident that irrigation water can be supplied to a vast stretch of land, year-round, in the second and third stages of development by diverting water from the main Mekong River.

The Team hopes that the water sources development of the Nam Gam basin will be executed at an early stage and in an effective way, and also hopes that in preparation for the execution of the development, the people concerned will devote their efforts and studies, particularly on the following matters.

A. EARLY EXECUTION OF THE NAM PUNG HYDRO-ELECTRIC POWER SCHEME

The development of the Nam Pung multi-purpose dam and the Nam Pung hydro-electric power scheme will form the basis of development of the water resources of the Nam Gam basin. The Government of Thailand is carrying out some preparatory field work in expectation of an early starting of the Nam Pung project. It is, however, desirable that detail investigations, design work, and preparation of specifications which are necessary for commencement of the construction work be started without delay. About one full year may be needed for completion of the above stated work, and the completion of the construction work may require some two years.

Completion of the Nam Pung hydro-electric power scheme will also enable and will act to hasten the execution of the Nam Pung irrigation project and the Lake Nong Han pump irrigation project.

B. ESTABLISHMENT OF EXPERIMENTAL AND EXTENSION SERVICE STATIONS AND PREPARATION FOR COMMENCEMENT OF IRRIGATION SCHEMES

Considering the fact that electricity for pumping, which is required for the first stage agricultural development project of the Nam Gam, will demand about 40 per cent of the output of the Nam Pung power station, it may be said that some 80 per cent of the necessary fund for the first stage development of the Nam Gam basin will be invested in the agricultural development.

Benefits of agricultural development is the main object of the development of the Nam Gam basin, and, therefore, minutely and detailed preparations should be made before starting on the development work.

Although it is fully acknowledged by the people concerned that irrigation in the dry season in the Mekong basin will greatly increase agricultural production, there are no actual experience. Therefore, studies of crop rotation are necessary.

The Team believes that the primary step is the development of the Nam Pung hydro-electric scheme and as the secondary step, recommends that detail investigations, design work and preparation of specifications for the irrigation scheme should be started. Furthermore, we recommend that two or three experimental stations be established within the proposed irrigation area, so that studies may be started at once on paddy field cultivation and field crop rotation programs with year-round irrigation. These experimental stations should be located near Lake Nong Han in order to secure irrigation water in dry season. On completion of the Nam Pung hydro-electric power project, the districts along the Mekong River, too, may be supplied electricity. Therefore, it is desirable that two or three experimental stations be established in suitable sections of the proposed district for the second stage development of the Nam Gam basin with a view to conduct studies and experiments of irrigation in dry season by pumping water from the main Mekong River.

The Team believes that pump irrigation from the main Mekong River will be an important future problem, not only in Thailand, but in the Mekong delta. Accordingly, the establishment of experimental stations along the banks of the Mekong, as stated above, will not only be beneficial to the surrounding area, but will eventually be greatly valuable to the agricultural development of the entire Mekong basin.

C. FUTURE INVESTIGATIONS AND STUDIES

It has been stated herein that the early development of the Nam Gam catchment area is necessary, and that in order to put forward its development: (a) the Nam Pung hydro-electric power project, and (b) the establishment of experimental stations and the preparation for commencement of the irrigation project should be started at an early stage.

In the following paragraphs are some of the investigations and studies which we think are necessary for development of the two big projects in the aforementioned basin and for development of projects to be undertaken in the second and subsequent stages of development of the Nam Gam basin.

(a) Continuation of Hydrological Surveys

In the Nam Gam catchment area, at present, gauging of run-off is being made at the Nam Pung Dam site and at Nam Pung Bridge site (installed by the Japanese Government Team). Also, stage gauging of Lake Nong Han and at the upstream and downstream of Nam Gam Gate is being made.

However, observation records, except at the Nam Gam Gate, are available for extremely short periods (1 to 3 years) and it is very difficult to analyze the actual run-off conditions of the Nam Gam basin.

Accordingly, on carrying forward the development of water sources in the Nam Gam basin, it is necessary to continue recordings at those stations and to measure run-off at the downstream of Nam Gam Gate, from which discharge rating curves should be prepared to estimate the outflow from Lake Nong Han.

(b) Establishment of Agricultural Experiment and Extension Station

Agriculture practiced in the proposed project area is the cultivation of one crop of paddy field rice in the wet season. Under prevailing conditions, an ideal pattern of farming is not possible due to shortage of irrigation water from the transplanting stage through to harvest time. After the project is completed, the area will be blessed with assured supplies of irrigation water which will enable the stabilized cultivation of first crop paddy field rice followed by second crop of paddy field rice in the dry season, as well as, the introduction of field crops, thus greatly improve agricultural economy of the area. In order to fully utilize the new condition which may be created and to produce greatest results, before starting on the irrigation scheme, agricultural experimental stations should be established and crop experiments conducted. The results of experiments at the station should be exhibited and dissiminated to farmers for their knowledge and practical use.

The first stage development area and the second stage development area of the Nam Gam basin from the standpoint of agricultural development, have different nature of soil and, particularly, the nature of water for irrigation. Therefore, it is considered appropriate to establish experimental farms in each of the proposed irrigation area.

The experimental stations in the first and second stage development areas, stated in the foregoing paragraph, should be divided into two farms, one for paddy field experiments and the other for field crop experiments. The size of the farms may be 15 ha to 20 ha, and each should be located where water can be easily obtained.

In the first stage development area of the Nam Gam basin, perhaps, the paddy field experimental farm could be located at Ban Lao Lamond and the field crop experimental farm at Ban Moet, while for the second stage area the vicinity of That Phanom is thought to be appropriate.

The experiments that should be made at the experimental farms are as follows:

(1) Experimental investigation related to rural project

- (i) Determination of appropriate acreage per farm family and size of farm
- (ii) Proper location of irrigation and drainage canals, and paths
- (iii) Planning of location of villages and fields

(2) Experiments on crops and planting

- (i) Plant breeding (paddy field rice and field crops)
- (ii) Irrigation techniques
- (iii) Fertilization (in relation to irrigation)
- (iv) Insect control
- (v) Methods of cultivation
- (vi) Distribution of labor power

(c) Study of Reinforcement of Power Sources

The output of the Nam Pung hydro-electric scheme only, in consideration of growth of general demands, may create a shortage of supply several years after completion of all the projects included in the first stage development of the Nam Gam basin.

Accordingly, the Team thinks it would be necessary to immediately begin studies on means of supplying power necessary for the second stage development of the Nam Gam basin and for the development of various industries in the basin. The measures which can thought for the reinforcement of power are the following three methods:

(1) Transmission interconnection between the Nam Pung Power System and the Nam Pung Power System.

There is a plan to construct the Wang Chai Power Station (7,500 kW) by a re-regulating dam for the Nam Pung Electric Power System. By interconnecting both power systems it may be possible to supply a part of the output of Wang Chai Power Station to the Nam Pung Power System.

(2) Construction of thermal plants at suitable site adjacent to centers of demand

In case that the reinforcing of hydro-electric power sources stated in (1) above is delayed, the construction of thermal plants may be inevitable to meet the increasing power demands.

The pursuance of the foregoing studies will not only involve assumptions of general nature of the long-range development program for the northeast part of Thailand, but, will cover development of hydro-electric potentials in other districts which we believe will not be proper for discussion in this Report.

A P P E N D I X

In this Appendix is listed the names of organizations that conducted analytical studies of hydrological data, laboratory tests of soil, aggregates and drill cores, which were brought to Japan from the field, that were necessary in formulating the development plans of the Nam Gam basin.

Also included in the Appendix, as reference information, is a general description of the proposed Upper Nam Theun project which is referred to in Chapter V concerning studies on the second and subsequent stages of development of the Nam Gam basin.

I. ANALYSIS OF HYDROLOGICAL DATA

Analysis of hydrological data were conducted by the Team with the assistance of Project Development Department and Electronic Computing Section, Planning Department of Electric Power Development Company. Data which were used in this analytical studies were received from the following organizations.

National Energy Authority (N.E.A.) (Thailand)
Royal Irrigation Department (R.I.D.) (Thailand)
Bangkok Head Office and Sakol Nakorn Station,
Meteorological Department, Royal Thai Navy
Bangkok Head Office and Sakol Nakorn Branch, Fishery
Department, Ministry of Agriculture (Thailand)

II. TESTS OF FILL MATERIALS FOR DAM

Engineering Laboratory of Civil Engineering Department,
Electric Power Development Co., Ltd. (Japan)

III. TESTS OF AGGREGATE FOR CONCRETE

Engineering Laboratory of Civil Engineering Department,
Electric Power Development Co., Ltd. (Japan)

IV. GEOLOGICAL TESTS

Geology Section, Project Planning Department, Electric Power Development Co., Ltd. (Japan)

K.K. Applied Geological Survey Co., Ltd. (Japan)

V. TESTS OF SOIL MATERIALS FOR IRRIGATION CANAL

Agricultural Engineering Experiment Station, Ministry of Agriculture and Forestry of Japan

VI. SOIL TESTS

Agricultural Engineering Experiment Station, Ministry of Agriculture and Forestry of Japan

Japan Soil Foundation

Laboratory of Agricultural Biology, Faculty of Agriculture, Okayama University (Japan)

Based on the calculations, tested values and conclusions obtained from items I to VI above, the development plans for the Nam Gam basin, and preliminary designs for the Nam Pung hydro-electric project and irrigation development schemes were prepared.

Since the calculations and values obtained from the various laboratory tests are voluminous, we have refrained from including them in this report. For reference only, a description of the proposed Upper Nam Theun Project is included.

VII. UPPER NAM THEUN PROJECT

A. INTRODUCTION

From the very beginning when the development of the Lower Mekong basin was taken up for discussion, it has been emphatically maintained by people concerned that the development of the Nam Theun should be promoted.

In the ECAFE Report published in 1957, a hydroelectric power scheme was suggested by diverting flow from the Upper Nam Theun to the Se Bang

List of Errata

Page	Line	Column	In the Text	To be Corrected as
Letter of Transmittal	19		Respectifully yours	Respectfully yours
6	25		Topograph	Topography
7	8		Discription	Description
I-1	17		See Fig. I-1	See Fig. I-1, Fig. I-2 Fig. I-3
I-3	7		(May to September)	(June to September)
I-3	18		Fig. I-1	Fig. I-3
II-1	21		(down-steam)	(down-stream)
"	22		(upsream)	(upstream)
"	27		Ban Srong Khor	Ban Srang Khor
II-5	1		north	western
"	21		Z = 1.266	Z = − 1.266
"	23		Z = 0.0717	Z = − 0.0717
II-6 (Table II-1(1))	21	13	10.9	10.0
II-7	9		1962	1961
II-8	4		$\frac{\text{inflow at - - -}}{\text{inflow to - - -}}$	$= \frac{\text{inflow at - - -}}{\text{inflow to - - -}}$
II-8 (Table II-3)	7	7	69.85	67.85
II-8 (Table II-4)	2	2	Refer to Fig.	Refer to Fig. II-8
II-8 (Table II-5)	2	2	(58^{hr}/min)	(58 hr 11 min)
"	11		Lake Surface (f)	Lake Surface (f_1)
"	15		Lake Surface = $A_1 \cdot f_1 \cdot r$	Lake Surface = $A' \cdot f_1 \cdot r$
"	"		= $10.^3 m^3$	= 35,900 x $10^3 m^3$
"	17		(2) = 312 mm	(r) = 312 mm

Page	Line	Column	In the Text	To be Corrected as
II-9	7		the total annual precipitation	the precipitation
II-10	9		the following were found:	the following were found: (Refer to Table II-6, Table II-7, Fig. II-9)
II-10 (Table II-6)	Notes: 1		computed values from inflow to the Nong Han Lake	computed values in the present study
II-10 (Table II-7)	4	9	131.01	131.07
"	7	10	9,195.01	9,195.07
II-11	8 and 17	1	Run-off in mm	(Run-off in mm)
II-12 (Table II-8)	16	3	546.474	546.494
"	9	2,3,5 and 6	10^3m^3	10^6m^3
III-4 (Table III-1)	3	3	7080 - A_2	708.0 - A_2
"	4	2,4,7,8, 9,10,11, 12,13 and 14	10^6m^3	10^3m^3
"	10	7	5,309	5,301
"	14	7	17,550	17,520
"	17	4	58,400	68,400
"	21		(A_1-8530) or (7080-A_2)	(A_1-853.0) or (708.0-A_2)
"	23		A_1 = 1561.0 - A	A_1 = 1561.0 - A_2
"	24		Sakol Nakorn Pr. - Nam Gam Gate Pr.	Sakol Nakorn Pr. + Nam Gam Gate Pr.
III-7	1		post heavy flood	past heavy floods
III-10	10		little of no	little or no
III-11	9	3	Water-level at Nam Gam Gate	Lower side water-level at Nam Gam Gate
III-12	5		the lower most reaches lowest of	the lower most reaches of

Page	Line	Column	In the Text	To be corrected as
III-13	16		shows the record observation records for	shows the observation records for
III-14	8	3	2 - 8, Sept.	2 - 9, Sept.
"	15		No. 11	No. 22
III-15	22		One set, which will normally a reserve unit, is to	One set is to
III-23	7		B - (6)	B - (b)
"	26		4.2 m	412 m
III-24	16		to the Upper Nam Theun	either to the Nam Pong System or the Upper Nam Theun
III-28 (Fig. III-17)			Nan Pung Diversion Weir	Nam Pung Diversion Weir
"			Left Side Intake Qmax = 8.00 m^3/s	Left Side Intake Qmax = 2.66 m^3/s
"			Right Side Intake Qmax = 2.66 m^3/s	Right Side Intake Qmax = 8.00 m^3/s
III-29	11		For this	Moreover for this
III-32	28		the late	the late in 150 days
III-34	15		have selected	have been selected
"	17		National Economic Board	National Economic Development Board.
"	22		the North cast District	the Northeast District.
"	23,24,25		sweet potatoes	Sugar cane
III-29	23		high water	high ground water
"	28		the water table	the ground water table
III-35 (Table III-14)	Remarks		Jan. Apr.	Jan. ~ Apr.
III-38 (Table III-16)			Inn Kobayashi	Jun Kobayashi
III-38	8		this water table	this ground water table

Page	Line	Column	In the Text	To be corrected as
III-39	4		the past water-tables	the past ground water tables
III-48 (Table III-26)		3	Ratio of P (left)....%	Ratio of (left).... P%
III-50	2,8,9, 11,13,14 and 16		semi-month	every 5 days
"	25		lower reaches	reaches
III-50 (Table III-29)	1		Tears	Years
III-51	3		3. Estimated .... by months	3. Determination of Basic year for planning.
"	26		Table IV-30	Table III-30
III-53	13		Table 21	Table III-30
"	14		66.66 %	66.67 %
"	17		0.667 C	0.6667 C
III-54	8		Table II-35	Table III-35
III-54 (Table III-40(1))		7	1, 00 1, 00 1, 0	1,600 1,600 1,750
III-55	6		No. 1 and No. 2	1st and 3rd
"	10		No. 2 canal	2nd main canal
III-57 (Table III-44)	16	Total	5,945,580	5,945,590
III-67	27		Nam Pung dam which over the year	Nam Pung dam which has over the year
III-68	8		(1) Cotton Spinning	(1) Cotton Spinning and Weaving
"	20		(2) Silk Spinning	(2) Silk Spinning and Weaving
IV-6	17		desirable to deep interest cost	desirable to keep interest cost
IV-8	6		52,040	52,040*

Page	Line	Column	In the Text	To be corrected as
V-4 (Table V-2)		13		Remarks.
"	8	4	166.0	166.00
"	6	12	At the end of T. Block	At the end of T_1 Block
VI-5	25		The measures which can thought	The measures which can be thought
"	28		The Nam Pung Power system	The Nam Pong Power system

VI-6

The following corrections are to be made on page VI-6 of the Report. Following "(2) Construction of thermal plants at suitable site adjacent to centers of demand", the page is corrected to read as follow:

"(3) Importation of power which may become available from the development of other nearby tributaries of the Mekong River.

The pursuance of the foregoing studies will not only involve assumptions of general nature of the long-range development program for the northeast part of Thailand, but, will cover development of hydro-electric potentials in other districts which we believe will not be proper for discussion in this Report.

Listed above are the methods which we believe that may have to be taken in the future to reinforce power sources."

AP-4	14		Pleiku	Plei Krong
AP-10 (Table AP.VII-1)	7	11	L_2, L_3, L_5, 28.0	(L_2, L_3, L_5, 28.0)

Fai basin.

In the Report on the Second Phase of Reconnaissance Survey on the Main Tributaries of the Mekong presented by the Japanese Government in June 1959, a 120,000 kW power development scheme on the Upper Nam Theun was suggested with a view to meeting the power demands in the neighboring districts.

Also, in the Comprehensive Reconnaissance Report on the Major Tributaries of the Lower Mekong Basin presented by the Japanese Government in September, 1961, a scheme was described for the development of 1,725,000 kW in the Nam Theun basin inclusive of a 1,052,000 kW Nam Theun diversion project.

The Team has investigated and studied the comprehensive development of the Nam Gam basin in Thailand for the past twelve months and has come to the conclusion that if the Nam Gam basin and its vicinities were to be developed according to the scheme, in the near future, the power needs of the area could not be satisfied even if other hydro power potentials in Thailand were developed.

The development of the Upper Nam Theun will enable the whole of southern Laos and north-eastern Thailand, as well as, the power demand in the above-mentioned areas to be provided with low cost electricity.

In view of the potential, the Team proposes that investigations be initiated immediately to attain an early development of the Upper Nam Theun. Described hereinafter is the Upper Nam Theun development scheme including power, transmission network and irrigation which we have studied on the basis of data that we had obtained.

B. UPPER NAM THEUN HYDRO-ELECTRIC SCHEME

(a) Determination of Discharge

The Nam Theun development scheme which was described in the

Comprehensive Reconnaissance Report on the Main Tributaries of the Lower Mekong Basin, was prepared on streamflow that was estimated from the isopluvial map in the ECAFE Report because at that time there were almost no hydrological data of the basin.

Later, with streamflow data of the Nam Ngum and the Upper Se San becoming available, the run-off on which the Upper Nam Theun scheme was based has been modified taking into account the available data. The modified run-off compared with the Nam Theun development scheme, is somewhat on the safe side in terms of run-off per unit of area.

That is, the recorded run-off of the Nam Ngum and the Upper Se San in 1960, converted into rainfall is as follows:

Nam Ngum (14,300 km^2) 1,063 mm

Upper Se San (2,660 km^2) 823 mm (Kon Tum)

Upper Se San (3,090 km^2) 1,010 mm (Pleiku)

The flood discharge of the Mekong River in 1960 was not necessarily large, or rather its maximum discharge was recorded to be less than the average year. And according to the isopluvial map in the ECAFE Report, the rainfall distribution in the Nam Theun cannot necessarily be said to exceed that in the Nam Ngum and the Upper Se San. Therefore, the annual run-off of the Nam Theun was taken as 1,000 mm, and by including some allowance in the storage capacity of the reservoir it was estimated that sufficient discharge would be available for power generation.

Based on the above assumption, it is estimated that the annual inflow and annual available discharge, after allowing evaporation losses, of the Upper Nam Theun basin, with a catchment area of 834 km^2, are 834,000,000 m^3 and 750,000,000 m^3 respectively, and that the effective storage capacity of the reservoir is 400,000,000 m^3.

The available discharge for power generation was estimated on the assumption that the annual average discharge is 23.8 m^3/s, the maximum discharge 43.2 m^3/s, and the annual load factor about 54%.

(b) Description of Power Generation Scheme

The Upper Nam Theun scheme includes the construction of a dam about 45 meters high at Nam One, 9 kilometers upstream from the proposed site for the intake of the Nam Theun diversion No.1 power station, to create a reservoir with an effective storage capacity of 400,000,000 m^3 which is believed to be adequate to regulate annually an estimated run-off of 830,000,000 m^3 at Nam One with a catchment area of 830 km^2.

By diverting the stored water to Nam In on the upstream of Se Bang Fai through a tunnel about 1.5 km long, 120,000 kW of capacity to produce 547,000,000 kWh annually can be developed by utilizing an available head of about 330 m.

The development of the Upper Nam Theun should be executed in 2 stages: first stage (60,000 kW) and second stage (60,000 kW), so that addition of capacity may be made corresponding to growth of demand.

Pertinent data of the hydroelectric power scheme are as follows:

Catchment area	834 km^2
Annual run-off	834,000,000 m^3
Reservoir	
H.W.L.	540 m
Reservoir area	60 km^2
Drawdown	10 m
Effective storage capacity	400,000,000 m^3
Power generation	
Type of power generation	Dam waterway type
Intake level	540 m
Tailrace level	200 m

Gross head	340 m
Effective head	325 m
Max. discharge	43.2 m^3/s
Annual average available discharge	23.8 m^3/s
Average available discharge	23.8 m^3/s
Maximum output	120,000 kW
Annual average output	66,000 kW
Winter average output	66,000 kW
Annual generation	541,000,000 kWh
Winter month generation	270,000,000 kWh

Principal structures

Dam

Type	Concrete gravity dam
Height	36.0 m
Crest length	225.0 m
Volume content	110,000 m^3
Spillway	5 tainter gates, each 6.0 m high and 8.0 m wide

Intake

Type	Reinforced concrete tower
Height	15.5 m

Pressure tunnel

Inside diameter	4.0 m	1 line
Total length	1,300 m	

Surge-tank

Type	Reinforced concrete simple surge-tank
Inside diameter	8.0 m
Height	30.0 m

Penstock	
Upper part	Pressure tunnel lined with steel-plate
Inside diameter	4.0 m 1 line
Total length	65 m
Lower part	Steel penstock
Inside diameter	3.1 m tapering to 2.4 m 2 lines (1 line for the first stage, 1 line for the second stage)
Total length	1,370 m
Power station	
Dimension	13 m wide and 60 m long
Tailrace	
Tunnel	
Inside diameter	4.5 m
Total length	750 m
Open canal	
Base width	8.0 m
Total length	1,300 m

Machinery

Turbine	
Type	Vertical shaft single-wheel single-flow vortex type Francis turbine
Number of units	3 units for the first stage 3 units for the second stage
Output	20,700 kW per unit
Revolutions	500 r.p.m.
Generator	
Type	Vertical shaft rotating field, enclosed ventilated type, 3-phase synchronous alternator

Frequency	50 cycles
Capacity	22,000 kVA per unit
Number of units	3 units for the first stage 3 units for the second stage
Transformer	
Type	Outdoor use 3-phase forced-oil Air cooled type transformer
Capacity	22,000 kVA
Number of units	3 units for the first stage 3 units for the second stage

(c) Influences on the Large-scale Nam Theun Development Scheme

The Nam Theun Diversion No.1 Project includes the construction of a dam about 85 meters high on the main stream of the Nam Theun, to regulate the discharge of a catchment area of 5,230 km^2 and to divert water to the upper stream of Se Bang Fai for generation of electricity. However, the Upper Nam Theun Project involves the diversion of water from the Nam One (catchment are 830 km^2). Consequently, the catchment area of the Nam Theun scheme will be reduced to 4,400 km^2.

Based on this catchment area of 4,400 km^2 and the modified run-off coefficient of 1,000 mm, the Nam Theun Diversion No.1 Project will have a power potential of 600,000 kW in the first stage. In the second stage, by the construction of a high dam on the Nam Nhang, a tributary of the Nam Theun, run-off from a catchment area of 2,530 km^2 can be diverted into the Nam Theun reservoir through a short waterway to increase the output by 300,000 kW to an ultimate capacity of 900,000 kW.

As for the Lower Nam Theun development project, which is estimated to have a power output of 673,000 kW in the Report on the Second Phase of Reconnaissance Survey on the Major Tributaries of the Mekong, the power output will decrease to some extent as a result of the diversion from the

Nam Nhang catchment area.

C. POWER TRANSMISSION SCHEME

The entire power output of the Upper Nam Theun scheme in consideration of the centers of demand, will have to be first transmitted to Thakhek some 80 kilometers away, and from there supplied to southern Laos and to Thailand on the opposite bank of the Mekong River.

By the time the Upper Nam Theun scheme is completed, the electric power systems of the Nam Pong and the Nam Pung in north-eastern Thailand, including interconnection of both systems, should be in service. Therefore by the erection of several new transmission lines and a connnecting line between Thakhek and Nakorn Phanom, across the Mekong River, transmission of electricity to the whole area of north-eastern Thailand will be possible.

On the other hand, in Laos, electric power will be probably transmitted from Thakhek to Pakse by way of Savannakhet by a newly erected transmission line.

On the basis of assumed probable loads for the various centers of consumption in Laos and Thailand, it is believed that the required voltage of the transmission lines for the Upper Nam Theun scheme is 110 kV or 130 kV.

D. SE BANG FAI PUMP IRRIGATION SCHEME

Water discharged from the Upper Nam Theun flows into the Se Bang Fai. As a result the run-off of the Se Bang Fai is increased by 23.8 m^3/s on the average during the dry-season. This shows that a fairly large-scale irrigation project can be carried out by utilizing the water together with the natural flow of the Se Bang Fai. In addition, in the district on the left bank of the Mekong, downstream of Thakhek, pumping from the main Mekong will be possible.

That is, by installing pumps at the Highway Bridge Site and 7 other places on the Se Bang Fai and at 3 locations on the left bank of the main Mekong some 44,700 ha of cultivated field below elevation 157 meters in the downstream of the Se Bang Fai may be provided with irrigation water throughout the year. The required pump capacity is about 15,300 kW and the required energy is 36,200,000 kWh annually. This power requirement can be supplied from the Upper Nam Theun scheme. A description of this irrigation scheme is given in FIG-AP-IV-4 and in Table AP-VII-1.

In case the design H.W.L. (EL. 130 m) of Khemarat Reservoir on the Main Mekong River is modified to EL 133 m (see Chapter II "Analysis of Hydrologic Data"), the pumping head of 10 m to 17 m in irrigation districts L_1, L_6, L_7 and L_8 will be reduced to 9 m to 14 m, and consequently will result in a saving of 1,200,000 kWh. of energy annually.

E. CONCLUSION

It is a well known fact to people concerned that the hydraulic potentials of the Nam Theun are the richest and most economical among the numerous main tributaries in the lower reaches of the Mekong River.

On several occasions recommendations have been made by people concerned that either the Nam Theun, the Se Bang Fai, the Se Bang Hieng, or the Se Done should be developed so that it may be the pilot project for the development of southern Laos and subsequently, for the development of the Lower Mekong basin. To this day, however, such project has not yet become definite.

In preparation of the development plan for the Nam Gam basin in Thailand, the Team thought that it might be difficult to supply the entire electric power needs of the Nam Gam basin development scheme from hydroelectric power sources in Thailand.

Electric power which will be produced by developing the Upper Nam

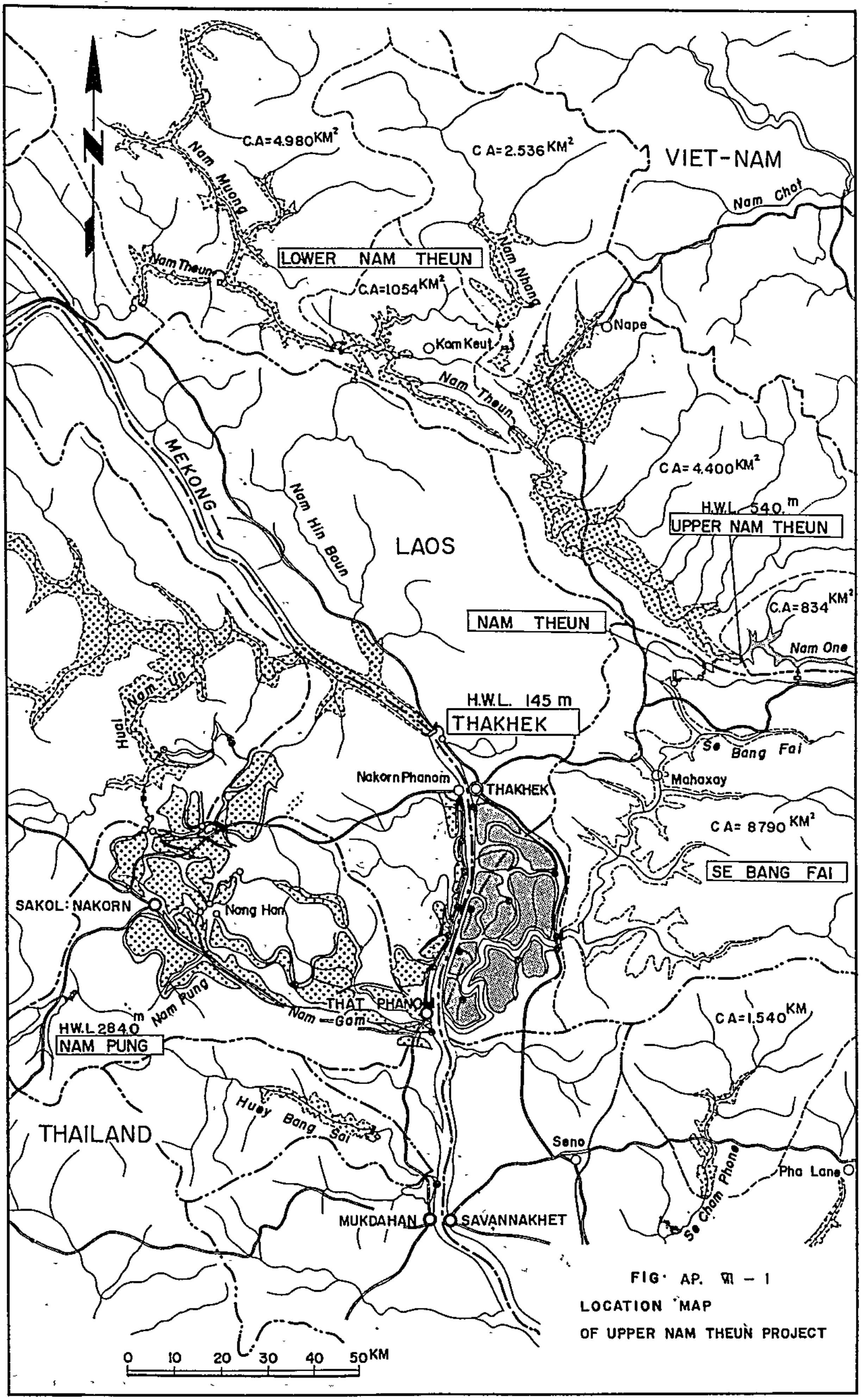
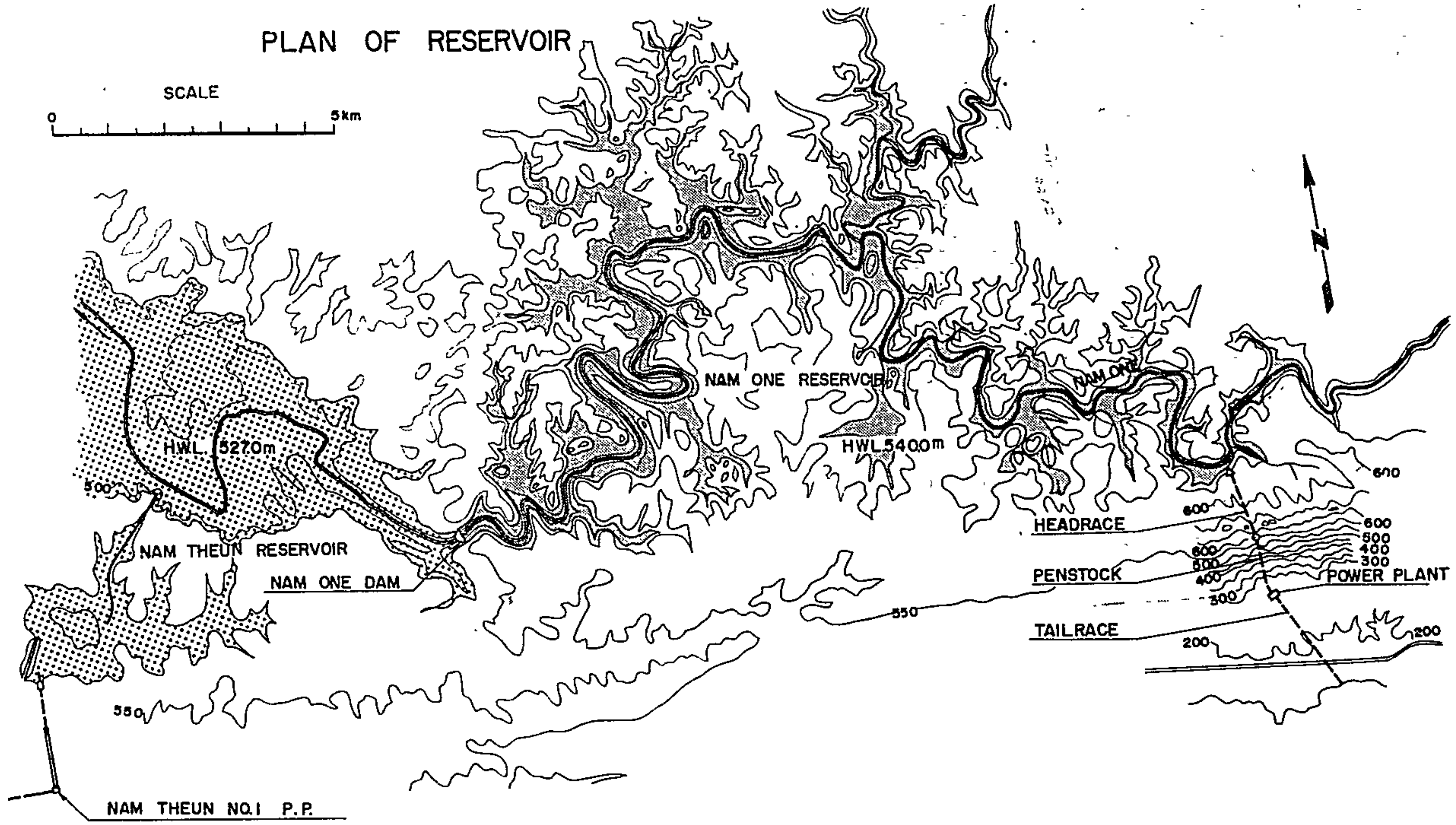
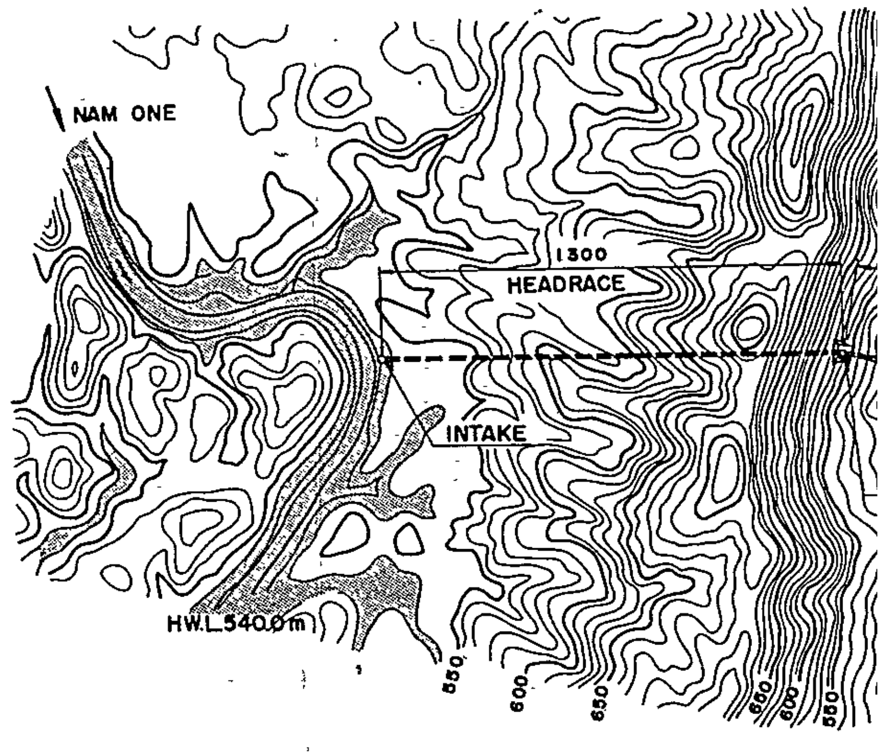


FIG. AP. VII – 1
LOCATION MAP
OF UPPER NAM THEUN PROJECT

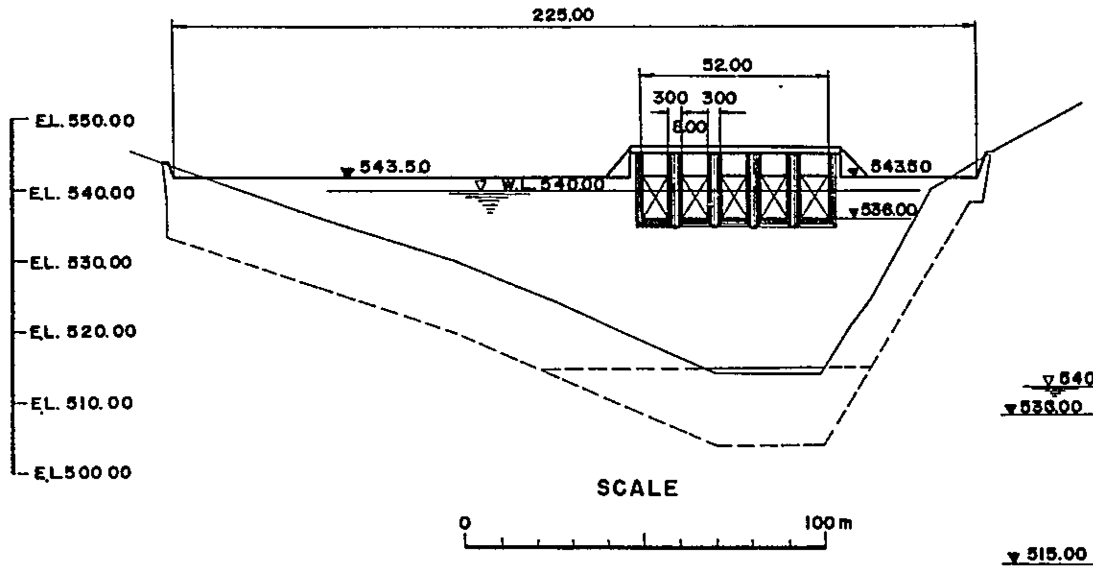
PLAN OF RESERVOIR



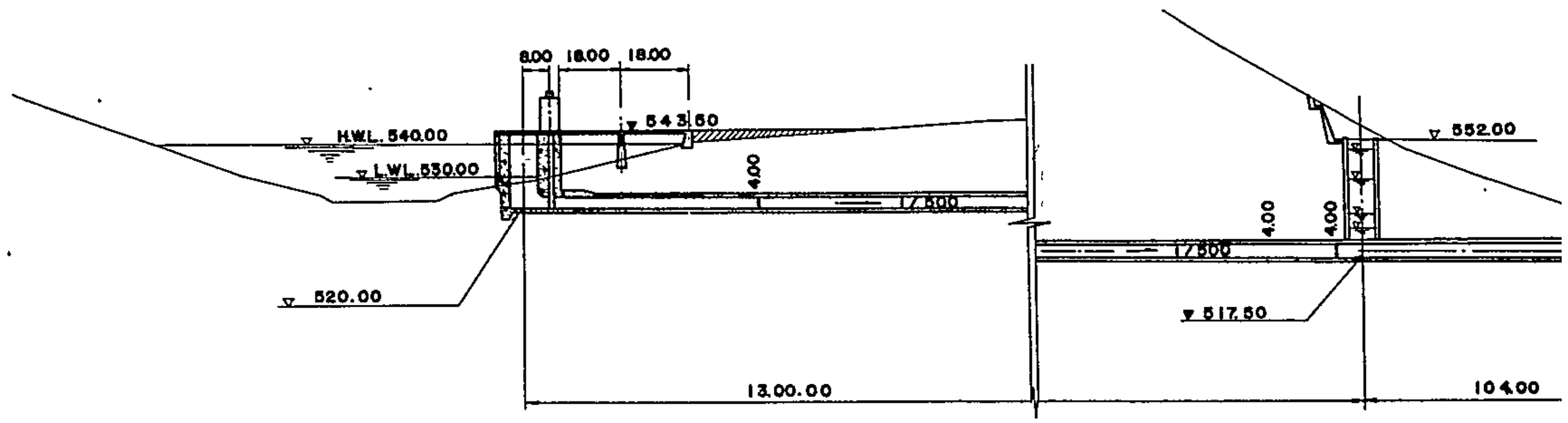
PLAN OF OUT



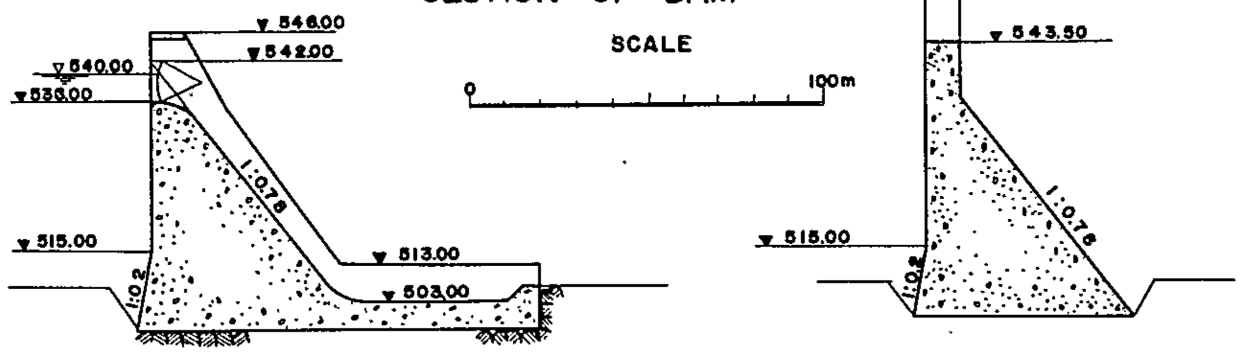
UPSTREAM ELEVATION OF DAM

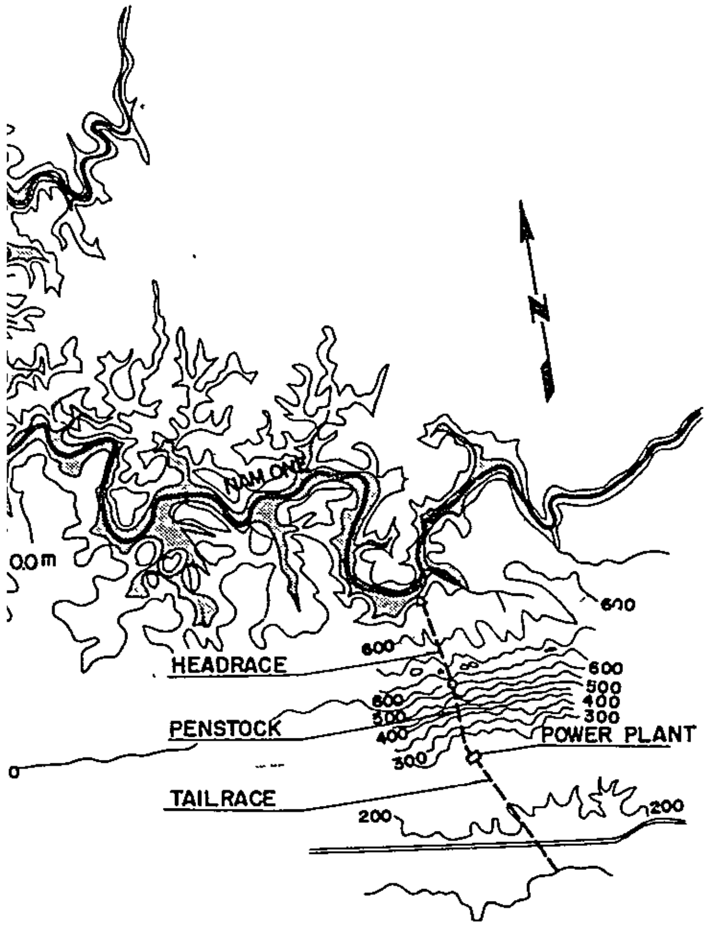


PROFILE OF OUTLET WO

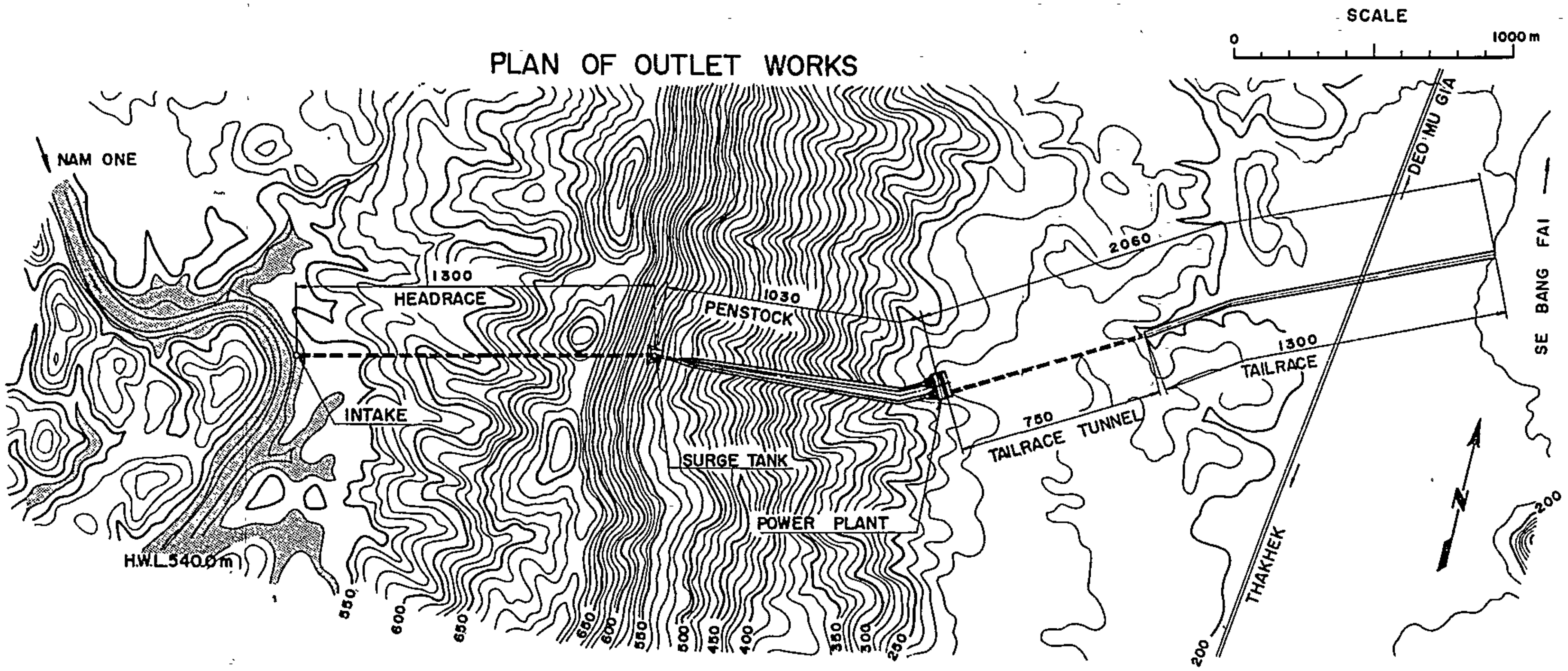


SECTION OF DAM

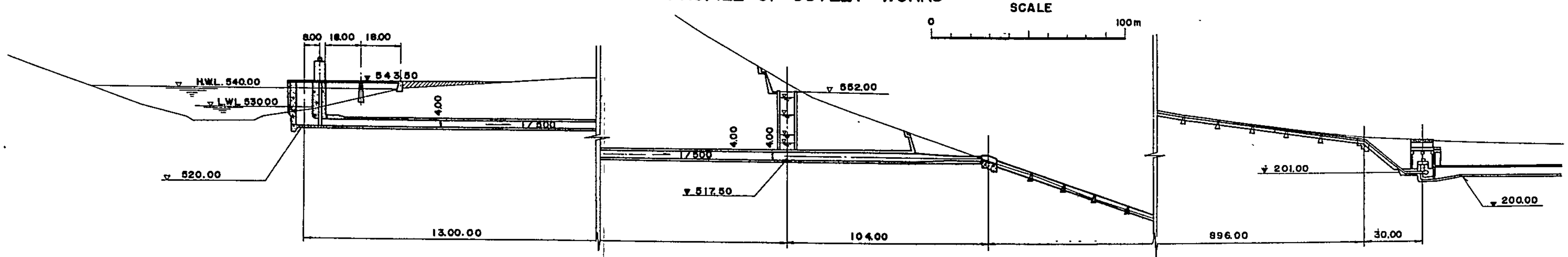




PLAN OF OUTLET WORKS



PROFILE OF OUTLET WORKS



SECTION OF DAM

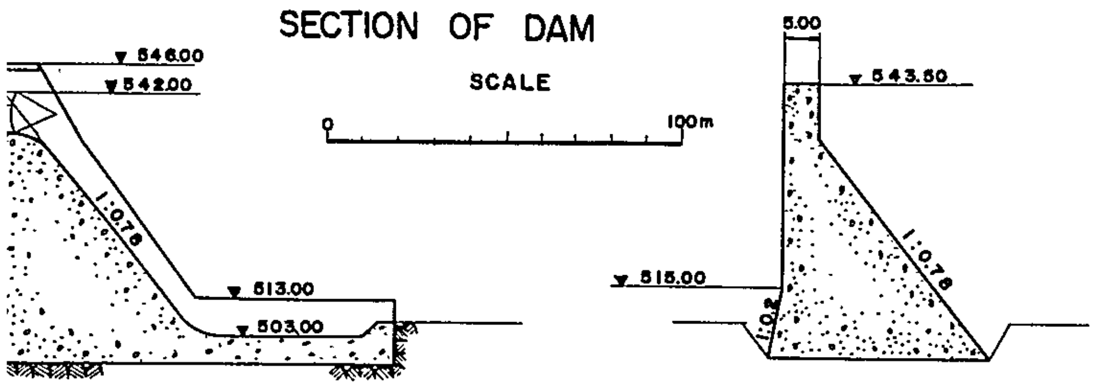


FIG. AP. VII - 2
UPPER NAM THEUN HYDRO-ELECTRIC POWER PLANT

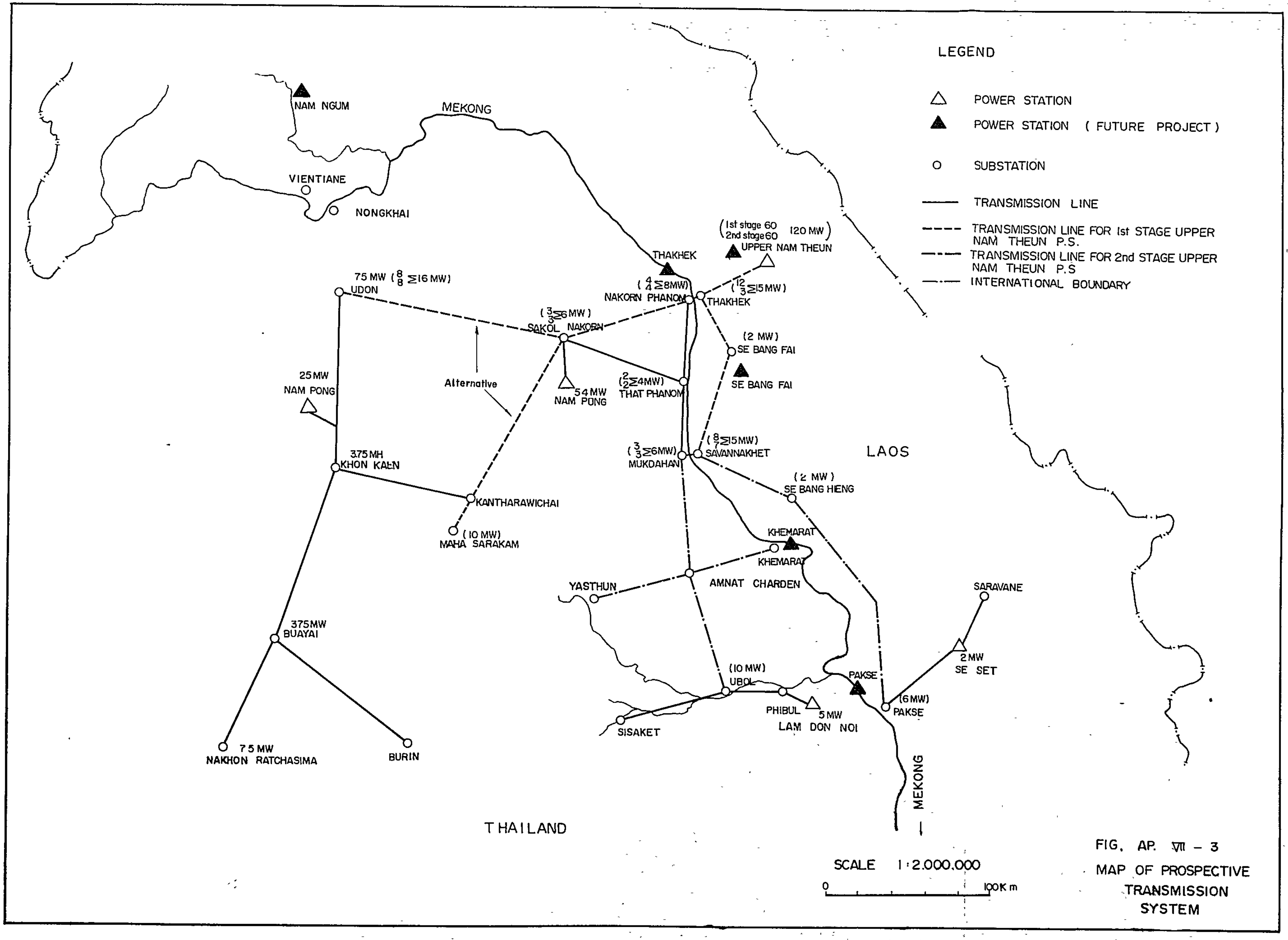


FIG. AP. VII – 3
MAP OF PROSPECTIVE TRANSMISSION SYSTEM

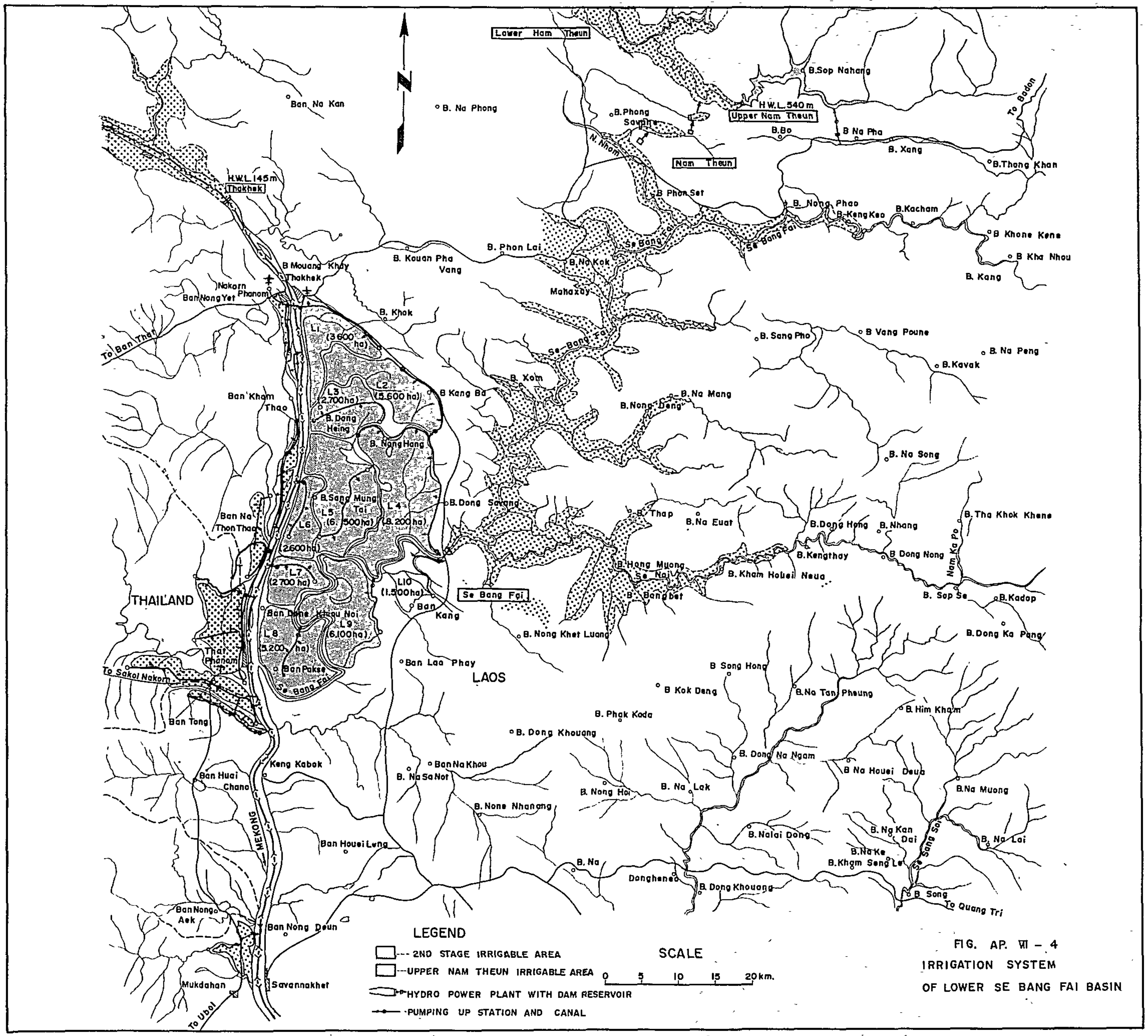


FIG. AP. VI - 4
IRRIGATION SYSTEM
OF LOWER SE BANG FAI BASIN

Table - AP. VII - 1 Se Bang Fai Pump Irrigation Scheme
(Southern Thakhek)

Irrigation District	Pump Station	Irrigation Area (ha)	Lift			Max. discharge (m^3/s)	Pumps			Length of main canal (km)	Location of pump stations	Application
			Elevation of pumped water ①	Elevation of source water ②	Net head ③=①-②		Bore (mm)	Number (Unit)	Capacity (kw)			
L1	No.1	3,600	145.50	130.90	14.60	4.54	850	3	900	10.5	Along the Mekong River, 55km upstream on the Nam Gam	
L6	No.2	2,600	147.00	130.10	16.90	3.28	750	3	870	14.0	Along the Mekong River, 34.5km upstream on the Nam Gam	
L7	No.3	2,700	143.50	129.55	13.95	3.40	750	3	750	11.0	Along the Mekong River, 20km upstream on the Nam Gam	
L2.L3.L4.L5	No.4	23,000	151.00	140.00	11.00	28.98	2,200	3	5,130	L2,L3,L5,28.0 17.0	Along the Se Bang Fai, 72km upstream from its mouth	
L2	No.5	5,600	161.00	147.60	13.40	7.06	1,000	3	1,440	14.0	Along No.4 main canal, 17km	
L3	No.6	2,700	156.00	154.80	1.20	3.40	750	3	120	8.0	Along No.4 main canal, 26km	
L5	No.7	6,500	161.00	142.00	19.00	8.19	1,100	3	2,370	6.0	Southern end of No.4 main canal, 5km	
L8	No.8	5,200	142.00	131.80	10.20	6.55	1,000	3	1,050	6.5	Along the Se Ban Fai, 32km upstream from its mouth	
L9	No.9	6,100	152.50	134.00	18.50	7.69	1,050	3	2,160	10.0	Along the Se Ban Fai, 57km upstream from its mouth	
L10	No.10	1,500	154.00	140.00	14.00	1.89	700	2	420	11.5	Along the Se Ban Fai, 72km upstream from its mouth	
Total	10 Stations	44,700				56.33		29	15,300	108.5		

Annual energy requirements 36,200,000 kwh.

Theun will be the cheapest of all power that may be available in the near future to the north-eastern district of Thailand and southern Laos in the Mekong basin. According to estimates the Team made, the cost of power of the Upper Nam Theun scheme is 0.7 cent/kWh at the generating end in the first stage and 0.3 cent/kWh in the second stage, and the average cost of power at the receiving end in southern Laos is 0.74 cent/kWh and in north-eastern Thailand it is 0.77 cent/kWh.