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No. 9

THE ROYAL GOVERNMENT

OF

THE KINGDOM OF THAILAND

REPORT ON THE STUDY OF WATER SUPPLY PROJECT TO LAOTIAN DISPLACED PERSONS IN THE KINGDOM OF THAILAND

NAKHON PHANOM CAMP AND PAK CHOM CAMP

NOVEMBER, 1982

Japan International Cooperation Agency

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PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a survey on water supply project for refugee camps, and entrusted the survey to the Japan International Cooperation Agency. The J.I.C.A. sent to the Kindgom of Thailand survey teams headed by Mr. Ko Kuwata from February 4 to April 15 and by Mr. Terukazu Hagiwara from May 20 to October 16, 1982.

The teams exchanged views with the officials concerned of the Government of the Kingdom of Thailand and conducted a field survey in Nakhon Phanom and Pak Chom Camps. After the teams returned to Japan, further studies were made and the present report has been prepared.

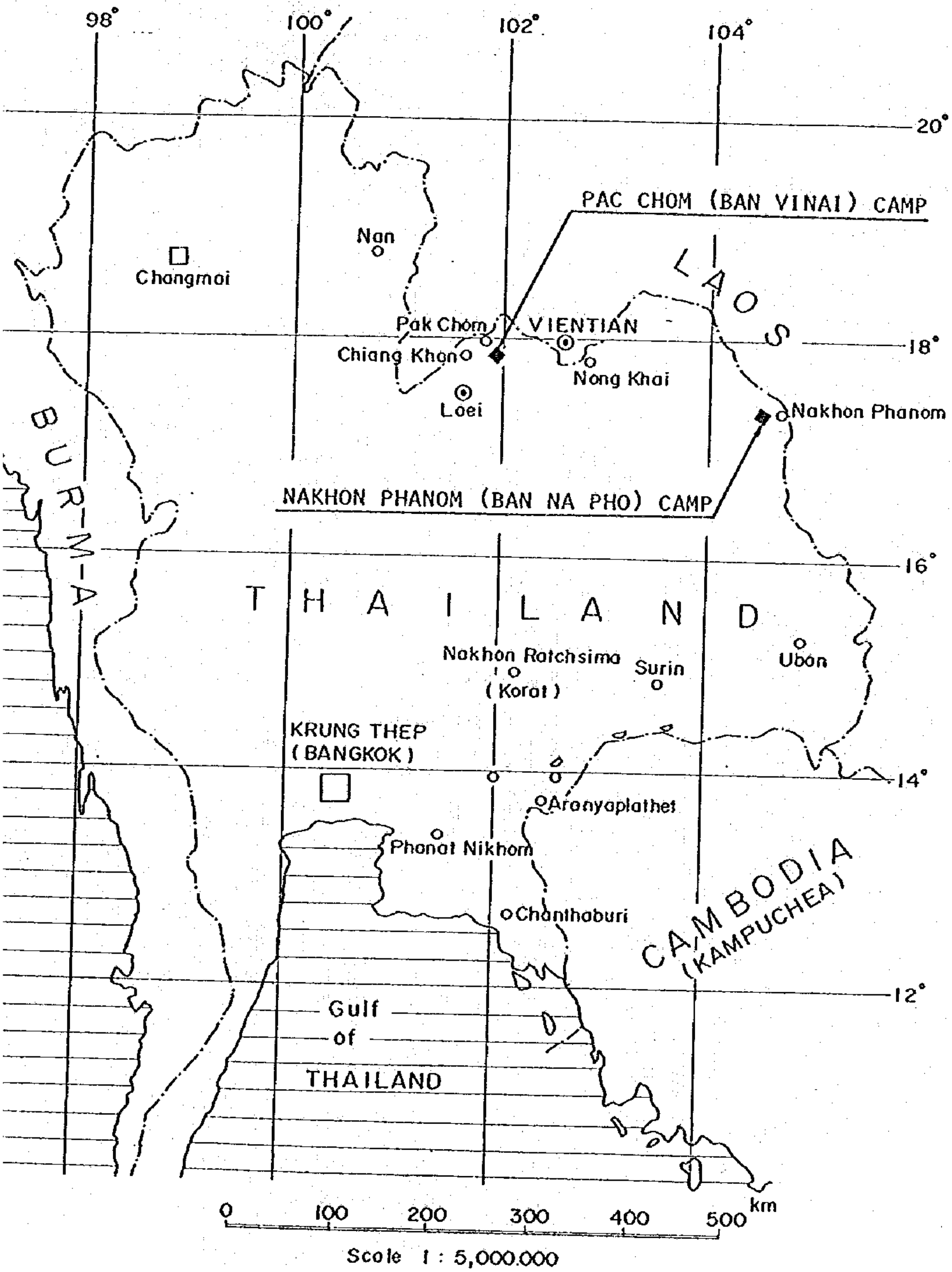
I hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the teams.

November, 1982

Keisuke Akira
President
Japan International Cooperation Agency

LOCATION MAP



WATER SUPPLY PROJECT
TO
LAOTAIN DISPLACED PERSONS
IN
THE KINGDOM OF THAILAND

NAKHON PHANOM CAMP AND PAK CHOM CAMP

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Abbreviations

DOMR	Department of Mineral Resources
JICA	Japan International Cooperation Agency
MOI	Ministry of Interior
RID	Royal Irrigation Department
UNHCR	Office of the United Nations High Commissioner for Refugees
WHO	World Health Organization

I: INTRODUCTION

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A preliminary survey was carried out with a view to water supply to camps of Laotian displaced persons located in the north-eastern and northern Thailand upon implementation of the survey for Water Supply Project for the Refugees in Thailand (Phase III) from June through August, 1981.

Taking into due consideration the report of the survey summarizing general conditions of camps for Laotian displaced persons, their future accommodation schedule and water supply plans, the Government of the Kingdom of Thailand made a request of the Government of Japan for cooperation in prompt establishment of water supply systems in Nakhon Phanom Camp and Pak Chom Camp for which there were future expansion plans.

In response to the request, the Government of Japan agreed upon the cooperation and carried out the survey in Nakhon Phanom Camp from February 4 through April 15, 1982 and in turn in Pak Chom Camp from May 20 through October 16 of the same year.

This study report presents Water Supply Project to Laotian Displaced Persons in Thailand.

II: WATER SUPPLY PROJECT TO LAOTIAN DISPLACED PERSONS IN NAKHON PHANOM CAMP (1ST STAGE)

Fig. II-1 Location of Nakhon Phanom Camp

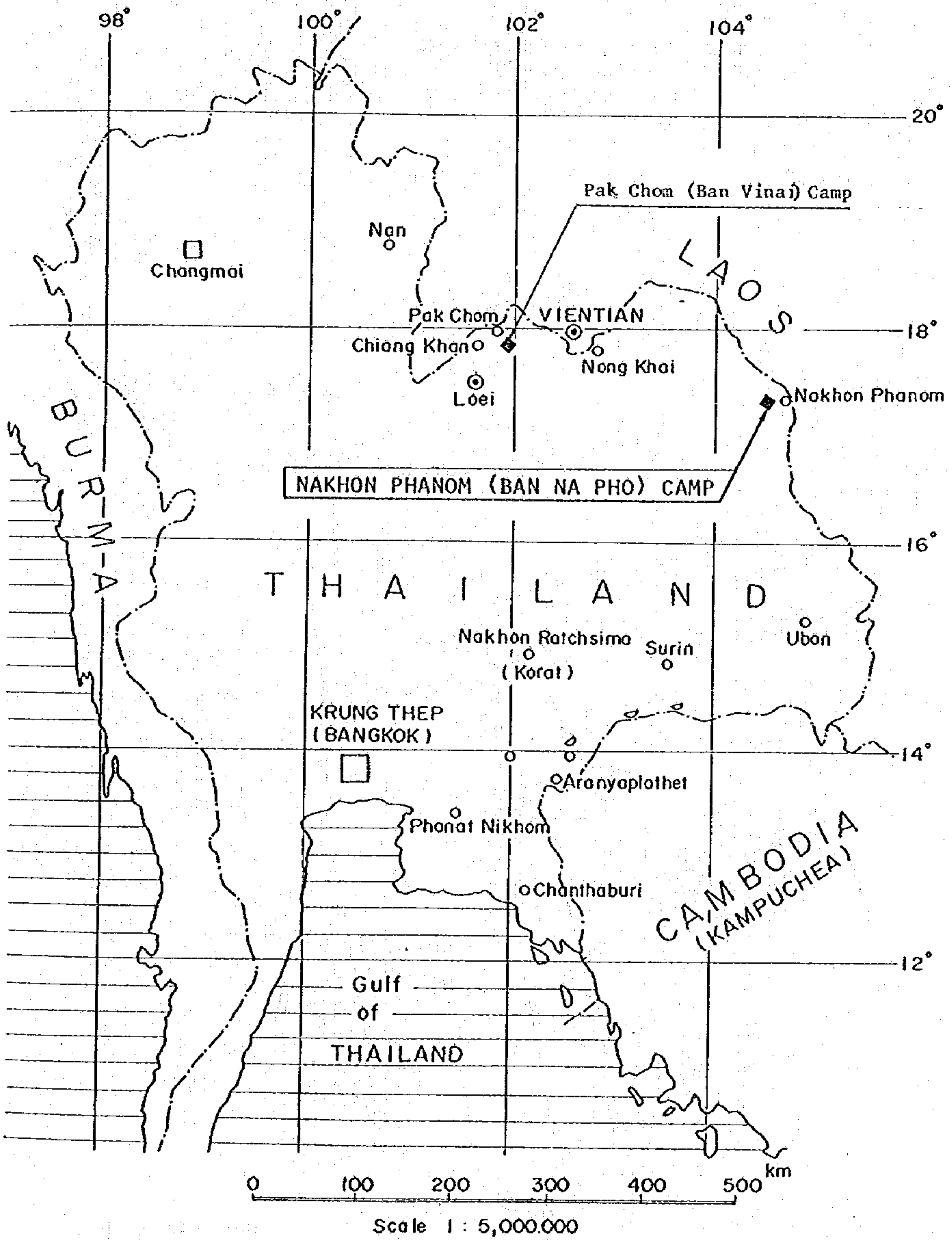
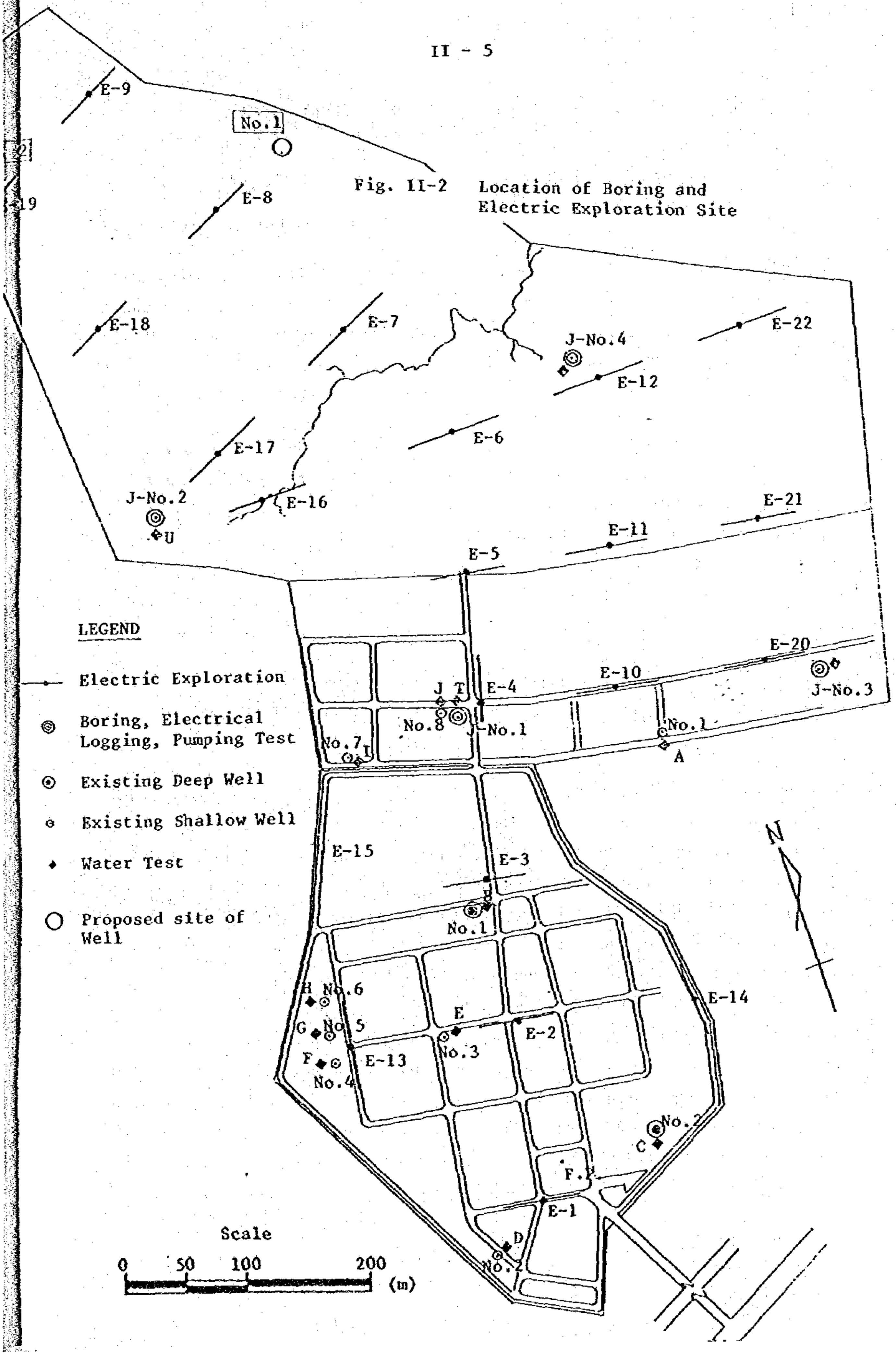


Fig. II-2 Location of Boring and Electric Exploration Site



II: WATER SUPPLY PROJECT TO LAOTIAN DISPLACED PERSONS IN NAKHON PHANOM CAMP (1ST STAGE)

1. Conclusion and Recommendation

Nakhon Phanom Camp is located about 20 km to the west of Nakhon Phanom, a north-eastern city in Thailand. The Camp, established in 1977, had a refugee population of about 7,000 at the time of the survey in early April, but its planned future population is about 20,000 which may be necessitated by closing down of Nong Khai Camp among other factors.

Field recconnaisance, electrical exploration, test boring of four holes, pumping test, electrical logging, and water quality test are the main items of the hydrogeological study conducted there. Evaluation on quantity and mode of occurrent ground-water in the Camp was made on the basis of the results of these actual observations and collected existing data. The total economic yield of ground-water in the Camp was estimated to be about 730 m^3/day totally.

Subtraction of 132 m^3/day, which is the current total pumage of the two existing deep wells, from 730 m^3/day makes 598 m^3/day as further exploitable ground-water.

Total water requirement of the Camp amounts to 700 m^3/day if 35ℓ/day/person (UNHCR plan) is supplied to the expected future population of 20,000, which is smaller than 730 m^3/day, the above estimated economic yield of ground-water in the Camp indicates ground-water is dependable as the only source of supply of subsistence water wanted in the Camp. 525 ℓ/min of ground-water can be pumped from the four bore holes made in the survey, and pumping of them for 12 hours would render 378 m^3/day. The total water supply capacity of 510 m^3/day is then obtained if this 378 m^3/day is added to 132 m^3/day, the water supply capacity of the two existing deep wells. But it is necessary to supply 190 m^3/day, which is still short, by making two more deep wells. The recommended water supply plan in the Camp contained in the present report, therefore, was written on the assumption that two more deep wells would be made making the total number of deep wells 8. The following are the detailed account on the survey.

The survey of Pak Chom Camp is scheduled for 1982 fiscal year of Japan. Location of test boring in Nakhon Phanom Camp is indicated in Fig. II-2.

2. Survey Team

The Survey Team is composed of the following five members who have experience in ground-water survey and technical assistance in Thailand.

Assignment	Name	Duration of Stay in Thailand
General (Team Leader)	Ko KUWATA	Feb. 4, 1982 - Apr. 15, 1982
Geology	Kinzo NARITA	Feb. 7, 1982 - Apr. 15, 1982
Drilling & Equipment	Shohachi SUZUKI	- ditto -
Drilling	Isao MAEKAWA	- ditto -
Construction Plan & Cost Estimate	Junji OHAMA	- ditto -

3. Actual Work Schedule

Date	Day	
Feb. 4	Thu.	First group arrives in Bangkok
5	Fri.	Courtesy call to MOI
6	Sat.	Preparation for study
7	Sun.	Second group arrives in Bankgok
8.	Mon.	Preparation for study
9.	Tue.	Ditto
10.	Wed.	Ditto
11	Thu.	Leaving Bangkok
12	Fri.	Arriving in Nakhon Phanom, visiting Nakhon Phanom Camp
13	Sat.	Installation of boring machine (J - No. 1)
14	Sun.	Starting boring, surface reconnaissance
15	Mon.	Meeting with Camp Commander and UNHCR officer on study shcedule
16	Tue.	Selection of J - No. 2 site, courtesy call to Governor
17	Wed.	Preparation for electric exploration, boring and electrical logging
18	Thu.	Installation of casing pipes, electrical exploration
19	Fri.	Air-lift pipe installed, electrical exploration
20	Sat.	Air-lift, electrical exploration
21	Sun.	Ditto, installation of submersible pump
22	Mon.	Pumping test, bringing boring machine to J - No. 2 site
23	Tue.	Ditto, boring started at J - No. 2
24	Wed.	Sampling water from J - No. 1 for quality test, J - No. 2 boring
25	Thu.	J - No. 2 boring
26	Fri.	J - No. 2 boring, studying collected data
27	Sat.	Ditto

Date	Day	
Feb. 28	Sun.	Electrical logging, installation of casing pipe
Mar. 1	Mon.	Installation of air-lift pipe, air-lift
2	Tue.	Air-lift
3	Wed.	Ditto, installation of submersible pump, pumping test
4	Thu.	Pumping test
5	Fri.	Survey tour to Pak Chom Camp
6	Sat.	Ditto
7	Sun.	Sampling water from J - No. 2 for quality test
8	Mon.	Descussion with Camp officer and UNHCR officer on additional study
9	Tue.	Leaving Nakhon Phanom
10	Wed.	Arriving in Bangkok
11	Thu.	Meeting with officers of Embassy of Japan
12	Fri.	Ditto
13	Sat.	Preparation of meeting minutes for additional study
14	Sun.	Meeting with JICA officers
15	Mon.	Meeting with Thai officers on additional study
16	Tue.	Leaving Bangkok
17	Wed.	Arriving in Nakhon Phanom
18	Thu.	Meeting with Camp officer on additional study
19	Fri.	Land preparation of J - No. 3 site
20	Sat.	Ditto
21	Sun.	Bringing boring machine to J - No. 3 site
22	Mon.	Setting of boring machine and starting boring
23	Tue.	Boring
24	Wed.	Ditto
25	Thu.	Ditto and electrical logging

Date	Day	
Mar. 26	Fri.	Air-lift
27	Sat.	Ditto
28	Sun.	Ditto, installation of submersible pump
29	Mon.	Pumping test, bringing boring machine to J - No. 4 site
30	Tue.	Setting boring machine at J - No. 4 site, starting drilling
31	Wed.	Boring
Apr. 1	Thu.	Ditto
2	Fri.	Installation of casing pipe, electrical logging
3	Sat.	Air-lift
4	Sun.	Ditto
5	Mon.	Ditto, installation of submersible pump
6	Tue.	Pumping test
7	Wed.	Handing over certificate submitted
8	Thu.	Leaving Nakhon Phanom
9	Fri.	Arriving in Bangkok
10	Sat.	Making report
11	Sun.	Ditto
12	Mon.	Ditto
13	Tue.	Ditto
14	Wed.	Progress report handed in
15	Thu.	Leaving Bangkok, arriving in Tokyo

4. Outline of the Study

Subjects of hydrogeological study for understanding the mode of occurrence of ground-water in a given area usually include hydrology, surface reconnaisance, electric exploration, test boring, electrical logging, pumping test, and water quality test among others. Judicious combination of these technics renders maximum information and results.

In the present study analysis in the mode of occurrence of ground-water and its quantitative evaluation in the project area was made by way of collecting existing data, surface reconnaisance, electrical exploration, test boring, electrical logging, pumping test and water quality test. The location of studied spots are as shown in Fig. 4-1 and Fig. 4-2. The scope of study is as follows.

4-1 Collecting Existing Data

Data on topography, geology, meteorology and hydrology were made available from Ministry of Interior (MOI), Department of Mineral Resources (DOMR) and Royal Irrigation Department, the major ones of which are as follows.

a) Topographical Map (1/50,000)

b) Meteorological Data (rainfall, temperature, evaporation)

c) Data on Existing Deep Wells (geological logs, record of pumping test and water quality)

4-2 Surface Reconnaissance

Surface reconnaissance was done in order to observe the present topography, geology, springing water as well as usage and water quality of existing wells, which are necessary for understanding the hydrogeological conditions of the project area.

The expanse of land within which surface reconnaissance was done is approximately 56 km^2 which lies 8 km north to south and 7 km east to west with the project area in the center and with the northernmost village of Ban Dong Sawang, southernmost Ban Nang Bua, easternmost Ban Thep Phanom and westernmost Ban Kurukhu.

Boring sites and positions of electrical exploration were selected during surface reconnaissance. Field interviews were also made concerning specifications of existing wells and their usage.

4-3 Electrical Exploration

Electrical exploration is usually performed in order to support or supplement findings from observation of geological outcrops and from test boring in hydrogeological studies of a given area. Resistivity method is frequently applied in electrical exploration.

Resistivity method is technic in which apparent electric resistivity of the ground is measured. Spacial variation in distribution of electric resistivity in the ground is studied and the geological nature is comprehensively interpreted in combination with related data from surface reconnaissance and test boring. In the present study, vertical electrical exploration (4 pole Wenner Method) was adopted for detecting the subsurface distribution of resistivity, and ρ-a curves were drawn and interpreted. Totally, 22 spots were studied. Major instrument used in it are as follows.

a) ground resistivity tester (Megger type 3244, Yokogawa Denki) 1

b) electric poles (steel, ϕ = 18 mm, l = 80 cm) 5

c) electric battery (12 V, 50 AH) 1

d) electric cable (single line, ϕ = 0.75 mm) .... 600 m

e) Measuring tape (plastic, l = 100m) 3

f) electric loud speaker 1

g) transit (with tri-pods) 1

h) level (with tri-pods) 1

i) staff and pole .... 1 set

j) tool kit for electric instrument .... 1 set

k) battery charger 1

4-4 Test Boring

Test boring was conducted for a depth of 42 m at four sites selected in the preceding surface reconnaissance in order to find out the sub-surface geological characteristics. The main machinery and equipment used in the test boring are as follows.

a) boring machine (THS-70, capacity = 150 m) 1

b) boring bits (ϕ = $8\frac{1}{2}$" tri-cone bit) 2
(ϕ = $7\frac{7}{8}$" tri-cone bit) 1
(ϕ = 9" wing bit) 1

c) pump (NAS-4B) 1

d) mixer (MCE-100) 1

e) boring rod (ϕ 75 m, l = 3 m) 15

Boring speed, water excape and water springing and the state of slime were recorded at the time of boring, on the basis of which boring logs were made (refer to Appendix H).

4-5 Electrical Logging

Electrical logging was done on completion of boring making use of the bore holes in order to survey the mode of stratification of the layers such as straigraphy, rock quality and state of fissures.

In the electrical logging which is for datecting the apparent resistivity of the bore holes, two-pole method was adopted.

The pole interval selected were 0.25 m, 0.5 m and 1.00 m and the depth surveyed was below the water level in the bore holes. The interval of the depth stages was 0.5 m.

The results of the electrical logging are as indicated in the boring logs.

The major instrument and tools used are as follows.

a) ground resistivity tester (Megger type 3244, Yokogawa Kenki) 1

b) electric pole (Model No. 3174, Oyochishitsu) .... 1 set

c) battery (12 V, 50 AH) 1

d) insulated electric cable (four cores, Oyochishitsu) ... 100 m

e) measuring tape (plastics, l = 100 m) 1

4-6 Pumping Test

Step pumping test and constant yield pumping test were conducted making use of the bore holes in order to find out the feasibility of pumping the ground-water and coefficient of acquifer in the project area. Step pumping test was done for estimating the value of critical discharge of bore holes as future wells.

The drawdown method applied in the step pumping test was to vary the rate of pumping to 4 - 5 stages at each of which drawdown was measured. Constant yield pumping test was done in order to test the relationship between drawdown of water level and time taken for it while pumping a certain volume of water and also to test the relationship between water level recovery and time taken for it after the end of pumping with a view to understanding the behavior of the ground-water.

The major instrument and tools used in pumping test are as follows.

a) pump (submersible, 3 HP, head = 50 m, Q = 40 g/m, ϕ = 2", Berkeley) 1

b) electric generator (5 KVA) 1

c) pumping pipe (ϕ = 2", l = 3.0 m) 12

d) water-level tester 1

e) circuit tester 1

f) stop watch 1

g) water tank (1.15 m x 1.15 m x 1.15 m) 1

4-7 Field Water Quality Test

Water quality test was done to surface water, springing water and ground water in and near the camp.

The data obtained from the test shall make a good contribution to understanding the quality of the ground-water yet to be exploited and to the hydrogeological study. Water quality test was done at 28 spots. The items tested and instrument used are as follows.

temperature	:	thermometer
PH value	:	PH testing paper (Toyo)
electric conductivity	:	portable electric conductivity tester (model CM-1K Tao Dempa Kogyo)

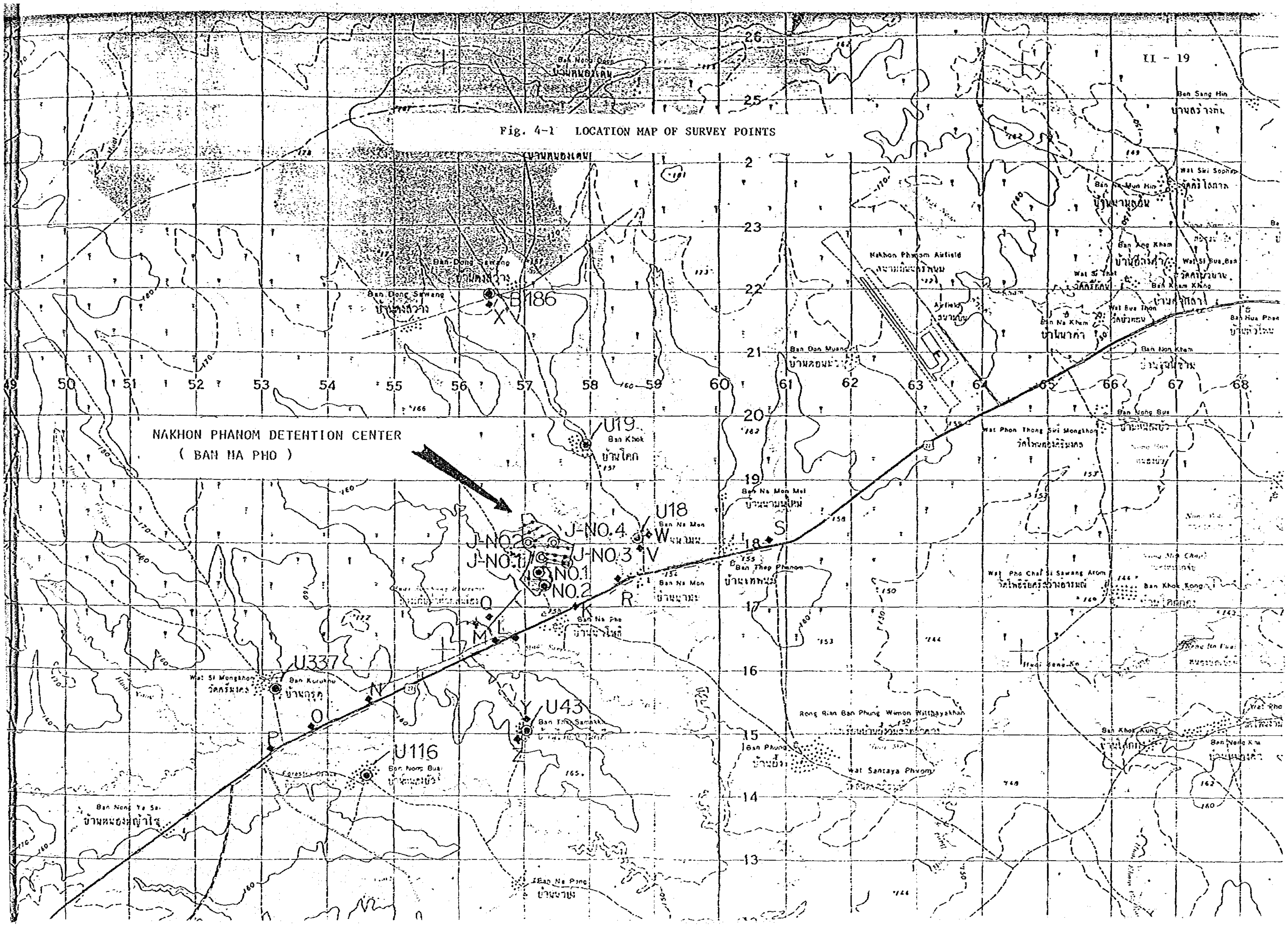
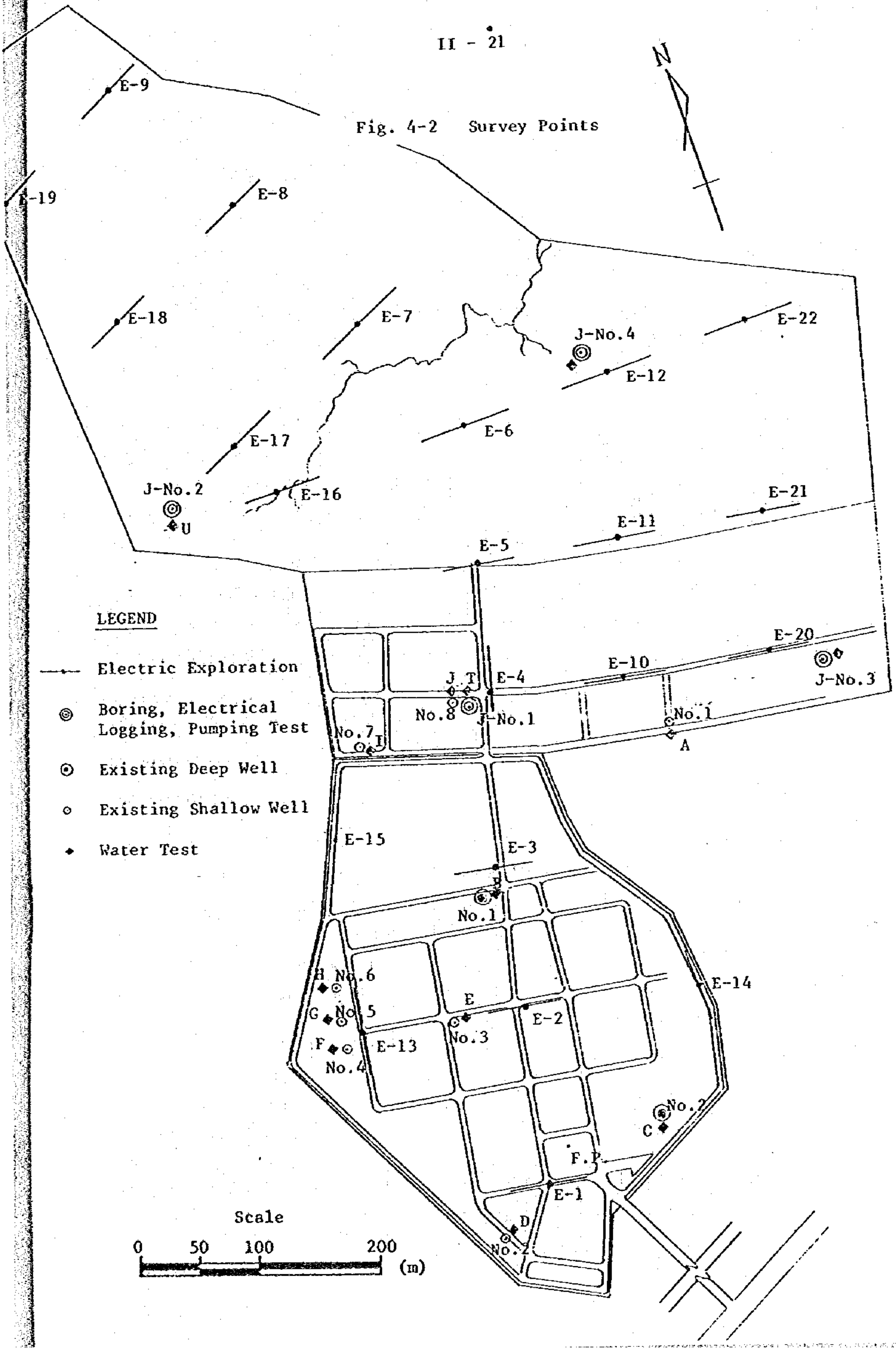


Fig. 4-1 LOCATION MAP OF SURVEY POINTS

Fig. 4-2 Survey Points



5. Results of the Study and Interpretation of Them

5-1 Topography and Geology

The studied area (Nakhon Phanom Camp) is located about 600 m to the north of the 219 km post of National Highway 22, or about 20 km to the west of the city of Nakhon Phanom. The topography of the studied area is characterized by mild slope extending toward south-east from a hill crest of about 180 m above the sea level running 6 - 7 km north of the surveyed area in the direction from north-east by east to south west by west.

This mild slope descending toward south-east has dissected valleys running in the same direction. The low land formed as result of advanced dissection is cultivated as rice fields and the land remaining undissected lies as long strips of wooded monadnocks or is partly cultivated for upland crops.

Nakhon Phanom Camp rests on one of the long strips of monadnocks of about 160 m above sea level, which is about 10 m higher in elevation than the neighboring dissected lowland.

The River Khom Yai flows on the north eastern side of the premises of the Camp. There is Somhong Reservoir (storing 2,430,000 m^3) made by damming Somhong River serving agriculture and subsistence to the south-west of the Camp.

The origins of Khom Yai and Somhong Rivers are tracted to the hilly land of about 180 m above sea level located about 6 - 7 km to the north of the Camp. These hills are wooded at the altitude of about 170 m above sea level or higher. Somhong River joins Khom Yai River at a point about 3.5 km south-east of the Camp. Kom Yai River, in its turn, joins Bang Ko River at a point about 6 km south-east of the Camp.

Bang Ko River, after confluencing with Khom Yai River, swerves itself toward north-east by east and flows into the Mae Khong River. The National Highway 22, running across the dissected valleys and monadnocks, is full of vertical undulations.

Geology of the studied area and its neighborhood is basically Phu Phan and Phra Whan formation of Mesozoic Jurassic Khorat formation overlain by Cretaceous Salt and Khok Kruat formation which, in its turn, is capped with relatively new deposits of alluviam and diluvium of the Quartenary period. Phu Phan and Phra Whan formation is composed of sandstone, siltstone, shale and conglomerate among others. This formation widely distributed through the hills located to the south of Sakhon Kakhon City, running from north-west to north-east, is not found on the surface near the studied area. The layer predominant in and near the studied area is the Cretaceous Salt and Khok Kruat formation composed of sandstone, siltstone and shale. The thickness of shale is especially great in the Camp and its vicinity. The upper part of the shale there has undergone advanced weathering. Observation of outcrops along the National Highway 22 and in some sites of earth-moving revealed that the upper part of the layer to the depth of about 5 m has been argilized and the deeper part has highly grown fissures and joints.

As for the relatively new deposits, there are terrace deposits remarkable along the Mae Khong River, alluvial deposits in minor rivers and streams as well as in the dissected lowland, and washed out deposits at slopes between the hill and lowland.

The terrace deposits observed along the Mae Khong River is composed of clay, silt, sand and gravel. The City of Nakhon Phanom is located on the terrace. The components of the river deposits are found to vary depending on the size of the rivers and steams. Whereas the riverbed of the Mae Khong River is formed by sand and gravel, the riverbeds of other rivers are mainly formed by clay, silt and sand with only marginal presence of gravel especially smaller in diameter than 10 mm. It is safe to state, in this connection, that the smaller the rivers and streams are so is the particle size of their deposits.

The washed out deposits formed by clay, silt, sand, and pebbles are unconsolidated and in a loose state.

5-2 Hydrology and Climate

(1) River System

The river system in the vicinity of the Camp can be divided into that of Khom Yai River and Somhong River, both originating in the hilly zone of about 180 m above sea level lying 6 - 7 km to the north of the Camp in NEE-SWW orientation and flowing in the direction of south-west dissecting the surface. These river systems, gathering tributaries in the course of their flow, meet together at a point of about 3.5 km to the south-east of the Camp.

The stream, after the confluence, continues the south-east bound flow until it joins Bang Ko River at a point about 6 km to the south-east of the Camp. Bang Ko River, after the confluence, swerves toward north-east and flows into the Mae Khong River on the south of the City of Nakhon Phanom.

Khom Yai River, flowing on the south-west of the Camp, has a very slight gradient and its flow is very slow. It has some surface discharge even in the dry season, but the volume is very small. Somhong River, flowing on the south-west of the Camp, flows into and then out of Somhong Reservoir (storage volume 2,430,000 m^3, dam length 900 m, area of water surface 40 ha) located on the west of the Camp, which is used for irrigation and drinking.

Somhong Reservoir, constructed by RID in 1956, has the flood water level of 155.3 m above sea level and is equiped with intake gates, one on the right bank and another on the left, from which irrigation canals of 8 km and 6.3 km, respectively, extend, covering the total area of about 1,760 ha.

Electric pumping was started in 1979 at the reservoir for supplying a nearby military base with subsistence water.

An officer of RID in charge of operation and maintenance of the reservoir commented that the volume of the water stored there is not sufficient.

(2) Precipitation

The climate of Nakhon Phanom can be roughly divided into the dry season from October through April and the rainy season from May through September. About 90 % of the total annual rainfall concentrates in the rainy season and there is very little rainfall for the rest of the year. The four months from November through February are especially dry, even without any rainfall in some years.

Data of precipitation around Nakhon Phanom were obtained from Bangkok office of MOI in Nakhon Phanom office of RID.

The data of monthly and annual rainfall obtained from MOI are as shown in the Table 5-1. And on the basis of these data the annual average rainfall and the monthly average rainfall are shown in Fig. 5-2 and Fig. 5-3, respectively.

Maximum annual rainfall for the period of 28 years; 2,836.0 mm (1961)

Average annual rainfall for the period of 28 years; 2,278.9 mm (1953 - 1980)

Maximum monthly rainfall for the period of 28 years; 1,232.9 mm (Aug. 1975)

Average maximum monthly rainfall for the period of 28 years; 592.6 mm (Aug.)

(3) Air Temperature

Air temperature in Nakhon Phanom and its neighborhood, as shown in the Table 5-2 and Fig. 5-4, rises highest in April and then slowly lowers till October. The rate of drop in air temperature in October and afterward is faster until the lowest is recorded in January. In Februaly and afterwards, air temperature rises fast until its peak in April.

Average annual temperature; 26°C(1952 - 1975)

Average monthly maximum temperature; 29°C (April)

Average monthly minimum temperature; 22.1°C (January)

(4) Evaporation and Transpiration

The atomometer used for guaging evaporation is a "Class A Pan". Its record is as shown in the Table 5-2 and Fig. 5-4.

Average annual evaporation; 872.4 mm (1951 - 1975)

Average monthly maximum evaporation; 107.4 mm (March)

Average monthly minimum evaporation; 34.2 mm (August)

Average monthly evaporation is small during the rainy period from May through October and is great during the dry period from November through April.

Even though no record of transpiration is available, a rough estimation of it on the basis of the observed state of vegitation could be about 70 % (annual average) of the recorded evaporation.

(5) Runoff

Even though no record of average annual runoff is available, its value roughly estimated from the known change in water storage in Somhong Reservoir and precipitation is about 40 %. However, there is no runoff in the period from November through March during which evaporation exceeds precipitation.

5-3 Geology

(1) Comparison of Electrical Exploration and Test Boring

The topography where the Camp is located is a long strip of monadnock and its general geology is characterized by extensive distribution of shale corresponding to Salt and Khök Kruat formation of the Cretaceous period, which is overlain by hard clay and laterilized sandy gravel.

The electric resistivity of the formation known from electrical exploration was compared with findings from test boring at the four spots (J - No. 1 ∿ J - No. 4). The comparison reveals the presence of the quarternary layers as follows.

top layer	ρ = 100 ∿ 1700 Ω-m,	gravelly soil
second layer	ρ = 12 ∿ 110 Ω-m,	hard clay
third layer	ρ = 5 ∿ 10 Ω-m,	highly weathered shale
fourth layer	ρ = 10 ∿ 17 Ω-m,	shale (with well developed joints and fissures)

The state of distribution of the quarternary layers of the Camp area is as shown in the sectional chart of resistivity distribution in Fig. 5-6. It is considered that the third and fourth layers correspond to Ks formation (Salt and Khok Kruat formation).

The top and second layers are considered to be diluvial deposits (medium or high terrace deposits), but the top layer is absent at places.

(2) Geological Formation

The geological formation (Ks formation, or Salt and Khok Kruat formation) of the Camp and its vicinity is characterized by the anticilinal axis oriented in the direction NW-SE running on the southern side of the City of Sakon Nakhon whose north-eastern side is dipped in the north-east. Observation of outcrops in the nighborhood of the Camp reveals a monocline with the strike of the shale (Ks formation) in NW-SE and the dip in the direction of north-east at a gradient of about 10 degrees.

As schematic sectional chart of the geological formation along the line connecting between Sakon Nakhon City and Nakhon Phanom City is as shown in Fig. 5-8.

5-4 Hydrogeology

(1) Mode of Occurrence of Ground-water

The bedrock in and near the Camp is shale which is overlain by hard clayey soil and sandy gravel which are considered to be medium or high terrace deposits at monadnocks, any by the river deposits of mainly clay, silt and sand at dissected valleys (lowland).

It was found out in the field survey of shallow wells in and near the Camp that the level of the ground-water is 2 - 3 m from the surface at the lowland, and 2 - 6 m at monadnocks. The ground-water is free water and it is present near the boundary between the bedrock and the relatively new deposits. The estimated volume of the water is very small.

The depth of existing deep wells is 30 - 61 m and the source of the yield is the shale layer (Ks layer) which is the bedrock. The shale layer, even with fairly highly advanced weathering at the upper part, is sufficiently consolidated as a bedrock.

So it has no aquifer with great thickness and continuity. Rather, what is pumped by deep well is fissure water in the bedrock. The level of the fissure water in the shale layer is at the range of 142.5 m - 146.9 m above sea level according to testing in the bore holes (J - No. 1 ∿ J - No. 4) made in the present study. It is bout 10 m lower than the water level of the shallow wells.

(Table 5-3) mode available say that the deep wells are 30 - 50 m deep and have the yield capacity of 135 ℓ/min - 520 ℓ/min and that pumping for 10 hours a day would yield 81 - 312 m^3/day, but current actual pumpage is only 6 - 20 m^3/day.

In the Camp with a population of 6,770 (as of Feb. 15, 1982), water is obtained from 8 shallow wells and two deep wells (Table 5-3 and 5-4). The shallow wells, privately made and used by the occupants of the Camp, are mostly used for non-drinking miscellaneous porposes, but the quality and quantity of the water is low. Drinking water is obtained only from the two deep wells and the shallow well No.1. The total yield from these three wells is about 143 m^3/day, which is equivalent to a per capita rationing rate of 21 ℓ/day/person.

(3) Pumping Test

Step-drawdown pumping test and constant yield pumping test were done in the bore holes (J - No. 1 ∿ J - No. 4) made in the Camp.

a) Step Drawdown Pumping Test

Step drawdown pumping test was done for 4 - 5 steps. At each step the requlating valve was given a certain extent of opening and water was pumped until the water level stabilized at a certain depth, which was measured and recorded.

The results of the pumping test are as shown in Fig. 5-9, and they indicate the critical discharge at each bore holes is as follows.

Result of Step Drawdown Test

Drill Hole No.	Critical Discharge Q(ℓ/mm)	Drawdown s (m)	Specific Yield m^3/day/m	Drawdown (m)
J - No. 1	120 (172.8 m^3/day)	15.5	11.1	30.9
J - No. 2	100 (144.0 m^3/day)	20.0	7.2	33.3
J - No. 3	160 (230.4 m^3/day)	20.1	11.5	33.6
J - No. 4	500 (720.0 m^3/day)	14.0	51.4	19.5

The economic yield should be below critical discharge. Even though economic yield is usually supposed to be about 80 % of critical discharge, the figure does not always fit specific factors like well diameter, pumping hours, well to well interval and hydrogeological conditions. Performance of plural wells in a common neighbourhood should be studied, treating them as mutually influencing members of a group located in the area where a certain comprehensive pumping plan is required.

b) Constant Yield Pumping Test

The record and the derivative result of computation of constant yield test at each bore hole are as shown in Appendix G. Trasmissibility coefficient and storage coefficient were obtained by applying to the pumping record "non-equillibrium formula of Theis" and "Jacob's formula". The results are as follows.

Results of Constant Yield Pumping Test

Drill Hole No.	Permeability Coefficient T (m^3/sec)		Storage Coefficient S		Pumpage (m^3/sec)
	Theis' Formula	Jacob's Formula	Theis' Formula	Jacob's Formula	
J - No. 1	1.026×10^{-4}	3.833×10^{-5}	3.569×10^{-3}	2.887×10^{-1}	0.00202
J - No. 2	6.100×10^{-4}	1.800×10^{-5}	1.924×10^{-3}	2.294×10^{-1}	0.00173
J - No. 3	1.266×10^{-4}	3.937×10^{-5}	1.519×10^{-3}	2.395×10^{-1}	0.00258
J - No. 4	7.730×10^{-4}	3.965×10^{-5}	7.027×10^{-3}	3.520×10^{-1}	0.00407
Average	6.95×10^{-4}	1.23×10^{-5}	2.44×10^{-3}	2.77×10^{-1}	

As shown in the table, transmissibility coefficient T and storage coefficient S are valued different in "Theis' formula" and "Jacob's formula". They also differ from bore hole to bore hole. Even though the groundwater from J - No.1 to J - No.4 is all fissure water present in shale, the critical discharge and specific yield from J - No.4 are much larger than those of the three others. It would be safe to place the average coefficients of aquifer for J-No.1 ∿ J-No.3 as $T = 9.7 \times 10^{-5}$ m^2/sec for transmissibility and $S = 50 \times 10^{-2}$ for storage.

(4) Water Quality Test

The results of the water quality test done at water outcrops mainly by checking electric conductivity are classified as follows. The details of them are shown in Table 5-5.

Water Quality

Type of Water		Location	Water Temperature	PH	Electric Conductivity at 25°C (μ℧/cm)
Surface Water		River	25° - 27°	5.4 - 6.0	19.8 - 460.4
		Canal	26° - 27°	5.4 - 5.6	20.1 - 27.2
		Dam	25°	5.6	22.5
Ground-water	Shallow Well	In the Camp	24° - 30°	5.0 - 6.8	13.3 - 6,875.0
		Near the Camp	27° - 29°	6.8 - 7.0	62.6
	Deep Well	In the Camp	28° - 30°	6.6	484.5 - 719.0
		Near the Camp	29° - 30°	6.8 - 7.0	404.8 - 488.8

The tabulated result of the test reveal that quality of surface water and quality of the shallow wells are fairly similar to each other while being different quality of water of the deep wells. In many cases, the surface water and the water of shallow wells show the temperature of 24°C - 30°C, PH value of 5.4 - 5.6 and electric conductivity of 20 - 63 μ℧/cm, whereas the water of the deep wells shows the temperature of 28°C - 30°C, PH value of 6.6 - 7.0 and electric conductivity of 400 - 500 μ℧/cm. This supports the earlier statement on the suspected close relationship between the surface water and the water of the shallow wells and the separability of the deep wells in water quality and other aspects.

As a reference, the results of the water quality test conducted for the existing deep wells near the Camp are shown in Table 5-7.

It is noteworthy that in some wells CaCo3 and Fe exceeds the water quality standard of Thailand. The results of the water quality test conducted in the new bore holes are as shown in Appendix - D and Table 5-7. The results of the quality test of the water from J - No.1, J - No.2, J - No.3 and J - No.4 show that turbidity and total hardness exceed the water quality standard of Thailand. Also, total solids and sodium chloride are relatively great in the water from J - No.3 and J - No.4. Of these impurities, total solids and turbidity are expected to diminish as pumping is continued and these values for new wells are not necessarily unusual.

The above mentioned value of total hardness is permissible under the standard of WHO or other international standards. It is judged, therefore the ground-water pumped from J - No.1, N - No.2, J - No.3 and J - No.4 is fit to drink without any precessing.

(5) Quanitiative Evaluation of Ground-water Refill

As was mentioned in the section for "Mode of Occurrence of Ground Water", the hilly area near the Camp would be where there is the source of the ground water refill in the Camp and its neighborhood. The season of refill is considered to be the five months from May through September during which precipitation is greater than evaporation.

Since the Camp is located on a monadnock surrounded by the rivers of Khom Yai and Somhong. So the ground water refill is originating in thought to be originated in these river courses.

The annual volume of ground-water refill can be obtained by the following equation.

$$Qr = \{P - (D + E)\} \times Ar$$

where, Qr : volume of ground-water refill

P : precipitation

D : runoff

E : evaporation

Ar : area of drainage basin

The ground water refill of Khom Yai and Somhong river basins obtained from the above equation is as follows.

Ground-water Refill

River Basin	Area Ar km^2	Precipitation P mm/y	Discharge D mm/y	Emporation E mm/y	Percolation G = P - (D+E) mm/y	Refill Q = Ar x G m^3/y
Somhong	16.26	2,278.9	911.56	610.7	756.64	12,302,966
Khom Yai	21.7	2,278.9	911.56	610.7	756.64	16,419,088
Total	37.96	2,298.9	911.56	610.7	756.65	28,722,054

As shown in the table, the ground-water refill from the river basins of Somhong and Khom Yai is about 12,300,000 m^3/y and 16,420,000 m^3/y respectively, making the total of 28,720,000 m^3/y.

Estimated volume of the ground water exploited in the Camp and its neighborhood surrounded by these water ways is 75,000 m^3/y and 50,000 m^3/y, respectively, totaling to 125,000 m^3/y, which is less than 1 % of the estimated volume of the ground-water refill.

However, since the evaluation so far arrived at has been based on rather rough computation of some existing data, it is advisable to make use of actually observed values to enhance the precision of evaluation.

(6) Pumping Conditions and Influence Area

Estimated cirtical discharge and specific yield of wells located on the river baisns are 140 - 150 m^3/day and 7.0 - 120 m^3/day/m, respectively, but actual pumpage and observed specific capacity of many of the wells are 140 - 250 m^3/day and about 10 m^3/day/m, respectively.

Pumping conditions and influence area shall now the studied on the basis of the results of pumping test done in the Camp.

coefficients of aquifer

$T = 9.7 \times 10^{-5}$ m^2/sec

$S = 0.05$

pumping conditions

$Qc = 127$ ℓ/min	(average critical pumpage of J - No.1, J - No.2 and J - NO.3)
$Q = 91.4$ m^3/day	(assuming 12 hours operation a day)
$T = 4.19$ m^3/day	(9.7×10^{-5} $m^2/sec \times 43{,}300$ sec)
$S = 0.05$	

From the above conditions the values of s and u will be as follows.

$$s = \frac{Q}{4 \cdot \pi \cdot T} W(u) = 1.74\, W(u) \quad \cdots\cdots\cdots\cdots \quad \langle 1 \rangle$$

$$u = \frac{S \cdot r^2}{4 \cdot T \cdot t} = 2.98 \times 10^{-3} \frac{r^2}{t} \quad \cdots\cdots\cdots\cdots \quad \langle 2 \rangle$$

where,
- Q : pumpage (m^3/day)
- T : permeability coefficient (m^2/day)
- S : storage coefficient
- W(u), u : well function
- s : drawdown (m)
- r : radius of the influence area (m)
- t : time of continous pumping (day)

The relationship between the radius of the influence are (r) and drawdown (s) is obtained from <1> and <2> for the four stages of continous pumping, namely t = 1 day, 30 days, 120 days and 365 days and shown in Fig. 5-10 and Table 5-8.

From Fig. 5-10, the relationship between drawdown and rodius of the influence area at a pumpage of 91.4 m^3/day can be summarized as tabalated below.

Time of continuous pumping	Drawdown (m)	Radius of the influence area (m)
1 day	16.9	15.5
30 days	22.6	83.0
120 days	24.7	165.0
365 days	27.0	290.0

It is concluded now, the theoretical radius of the influence area of a well in the Camp, if it is pumped for 91.4 m^3/day a year, is 290 m, which means that a given pair of wells should be about 600 m or more apart from each other if mutual influence is to be avoided.

However, in actual practice, it is considered that the well-to-well distance of about 300 m is fairly safe, considering that the level of the ground-water may rise somewhat in thr rainy season and the volume of pumpage is relatively great at the beginning of pumping which contributes to shortening of pumping time, thus enabling faster recovery of the water level of the well.

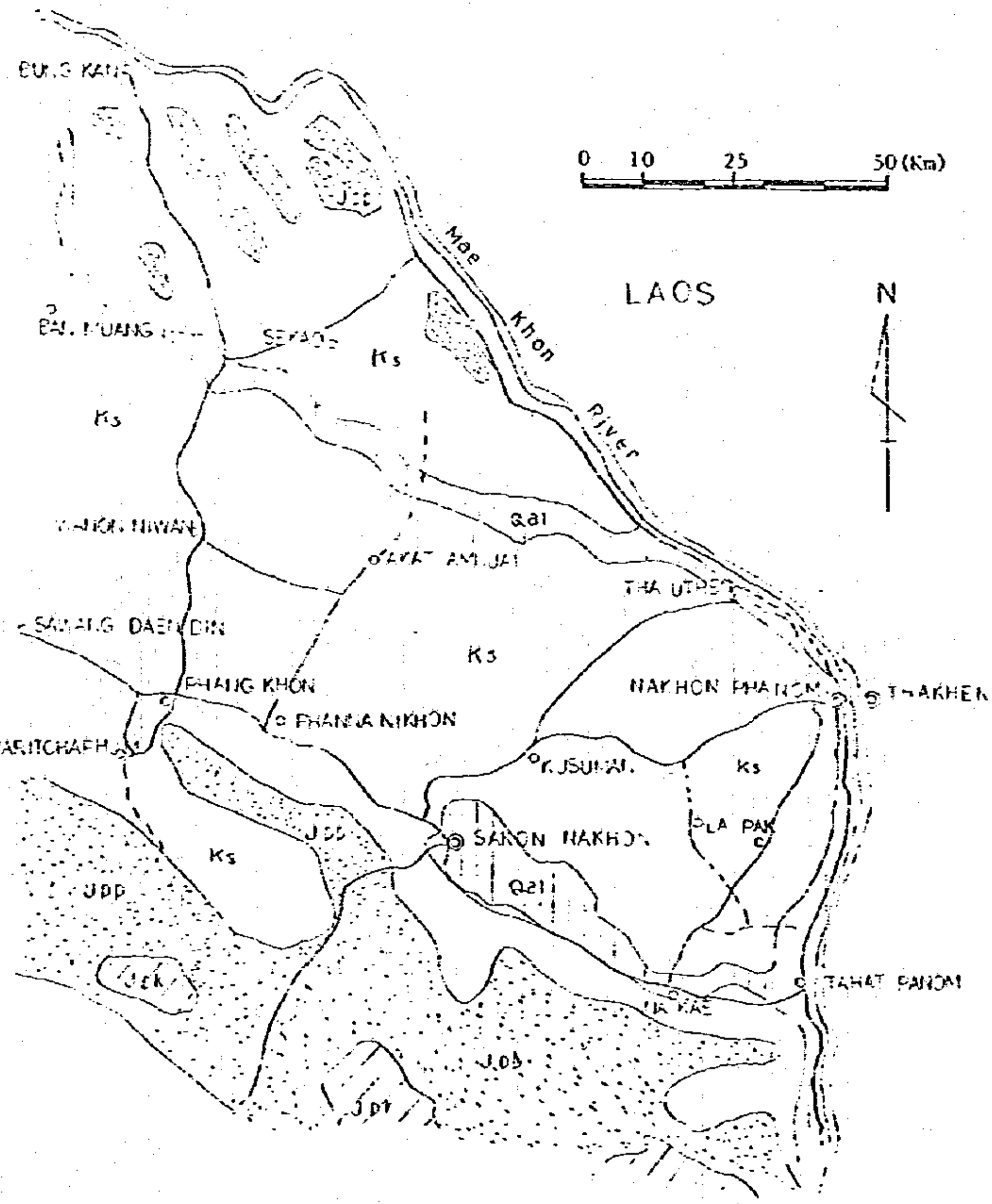
The appropriate number of deep wells to be made in the Camp and the total economic yield of them are 8 wells and 730 mm^3/day, respectively on the conditions that the Camp has a total land area of 41.2 ha and minimum well-to-well distance is 300 m and also considering the location of existing wells.

The total economic yield of 730 m^3/day is equivalent to a rationing rate of 36.5 ℓ/day/person for the projected future Camp population (20,000), which well satisfies the UNHCR's planned rationing rate of 35 ℓ/day/person.

Now, it is judged that two more deep wells can be made in the Camp in addition to the existing ones including the bore holes made by the study team.

As for the sites of the additional wells, vicinity of the sites of electrical exploration E-8 and E-19 is recommendable (refer to Fig. 5-5).

Fig. 5-1 Geological Map



Qal	Alluvium, Diluvium Valley fill and river gravel			Quarternary to Recent
Ks	Sandstone, Siltstone, Shale	Salt and Khok Kruat Formation		Cretaceous
Jpp	Sandstone, Corglomerate Shale and Siltstone	Phu Phan and Phra Whan Formation	Khorat Group	Jurassic
Jpk	Shale, Siltstone, Sand- stone and Conglomerate	Phu Kradung Formation		Jurassic and Triassic

Fig. 5-2 Annual Rainfall at Nakhon Phanm for the Period 1953 - 1980

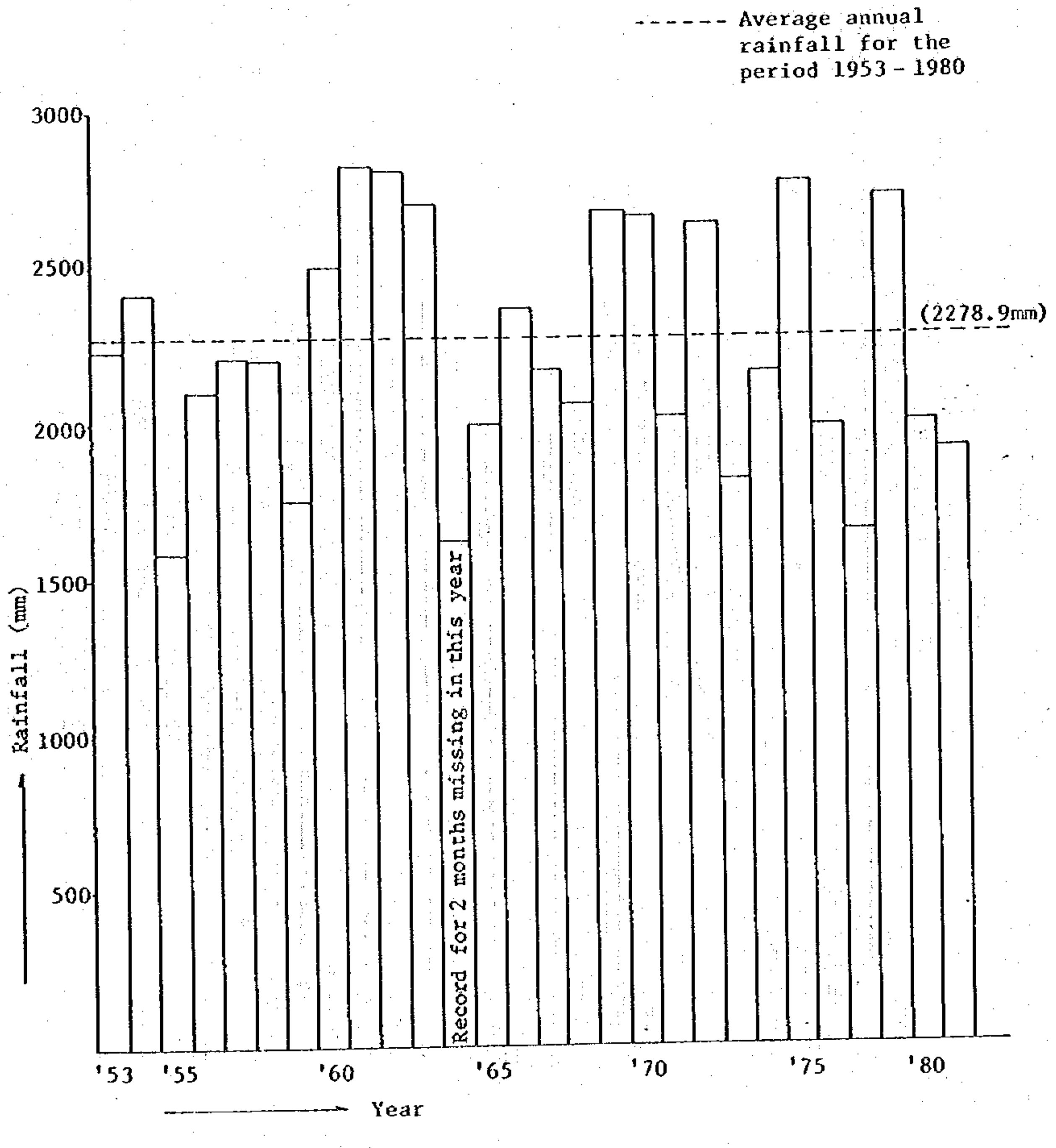


Fig. 5-3 Average Monthly Rainfall at Nakhon Phanom for the Period 1953 - 1980

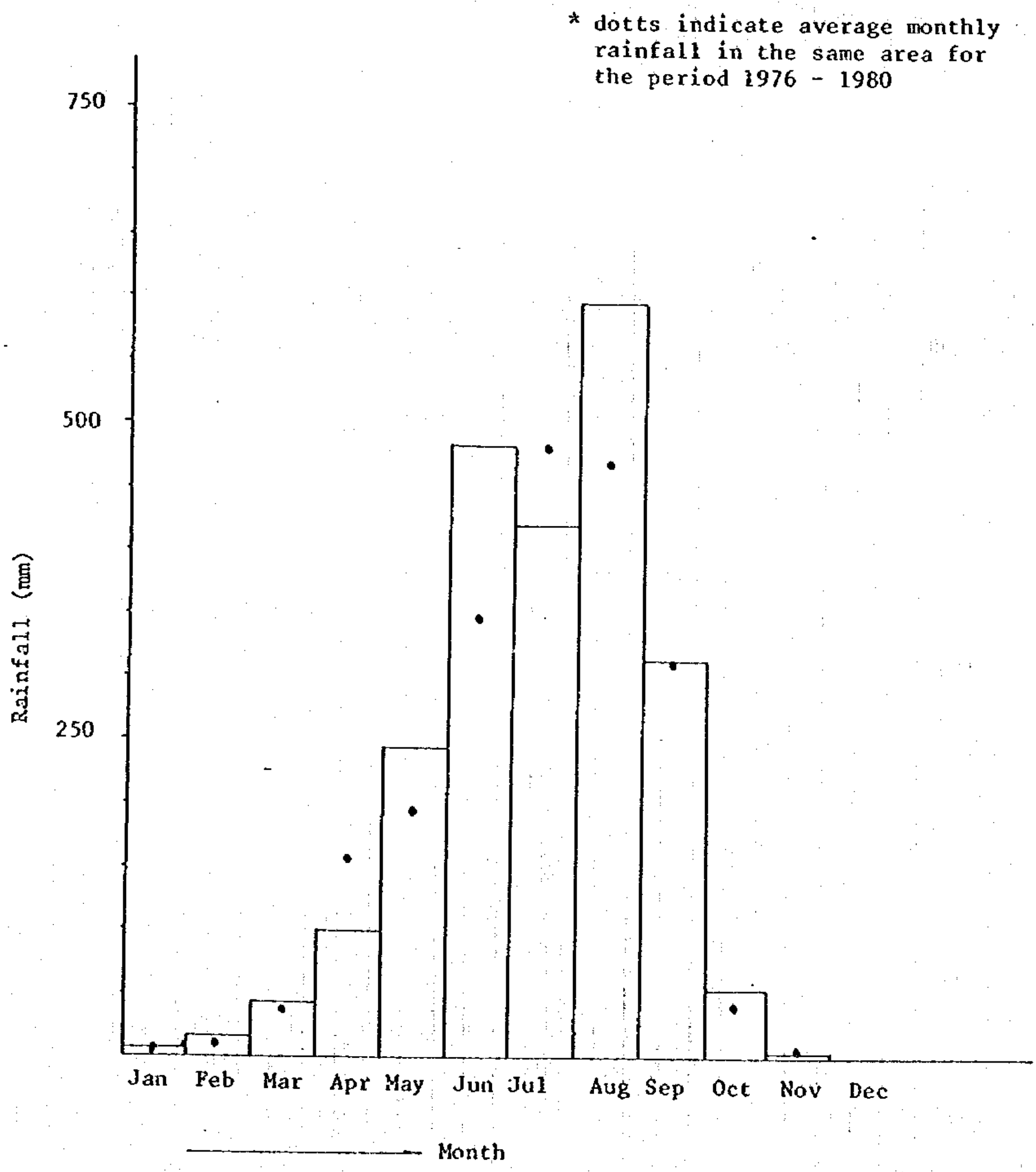


Fig. 5-4 Monthly Mean Rainfall, Evaporation and Temperature at Nakhon Phanom

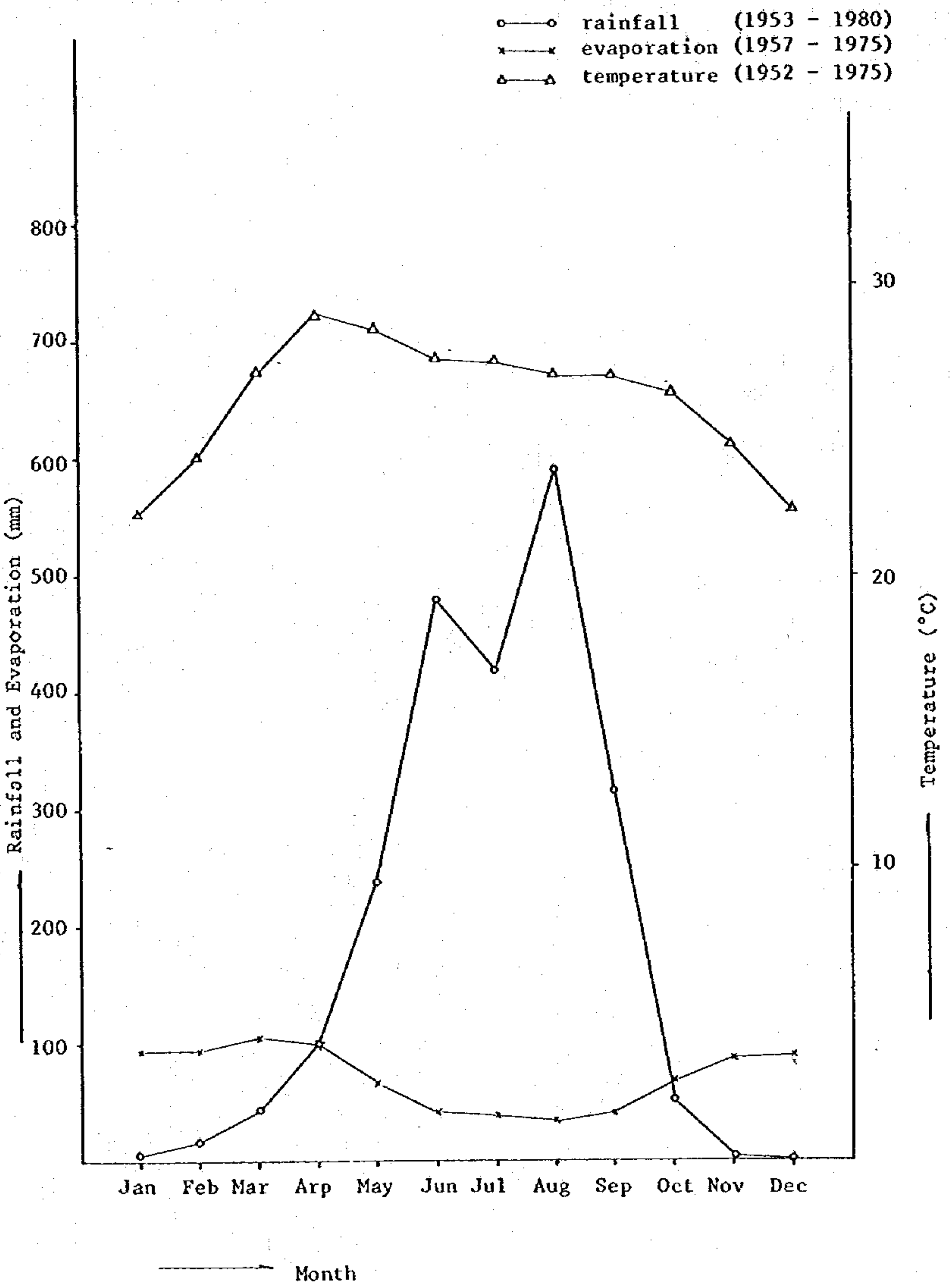


Fig. 5-5 Location Map of Survey Points in the Nakhon Phanom Camp

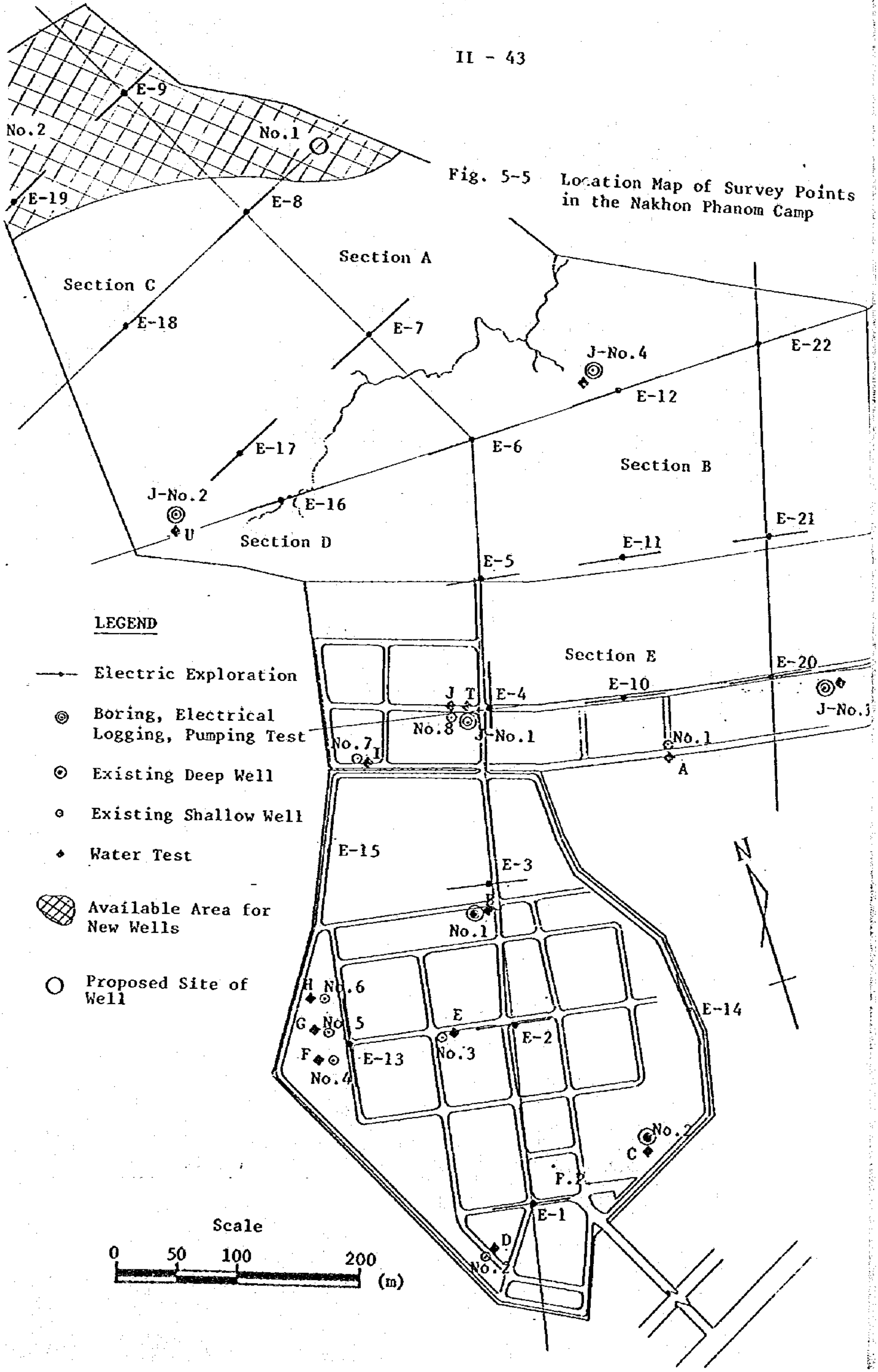


Fig. 5-6 Cross Section of Nakhon Phanom Camp (After Electrical Explorations)

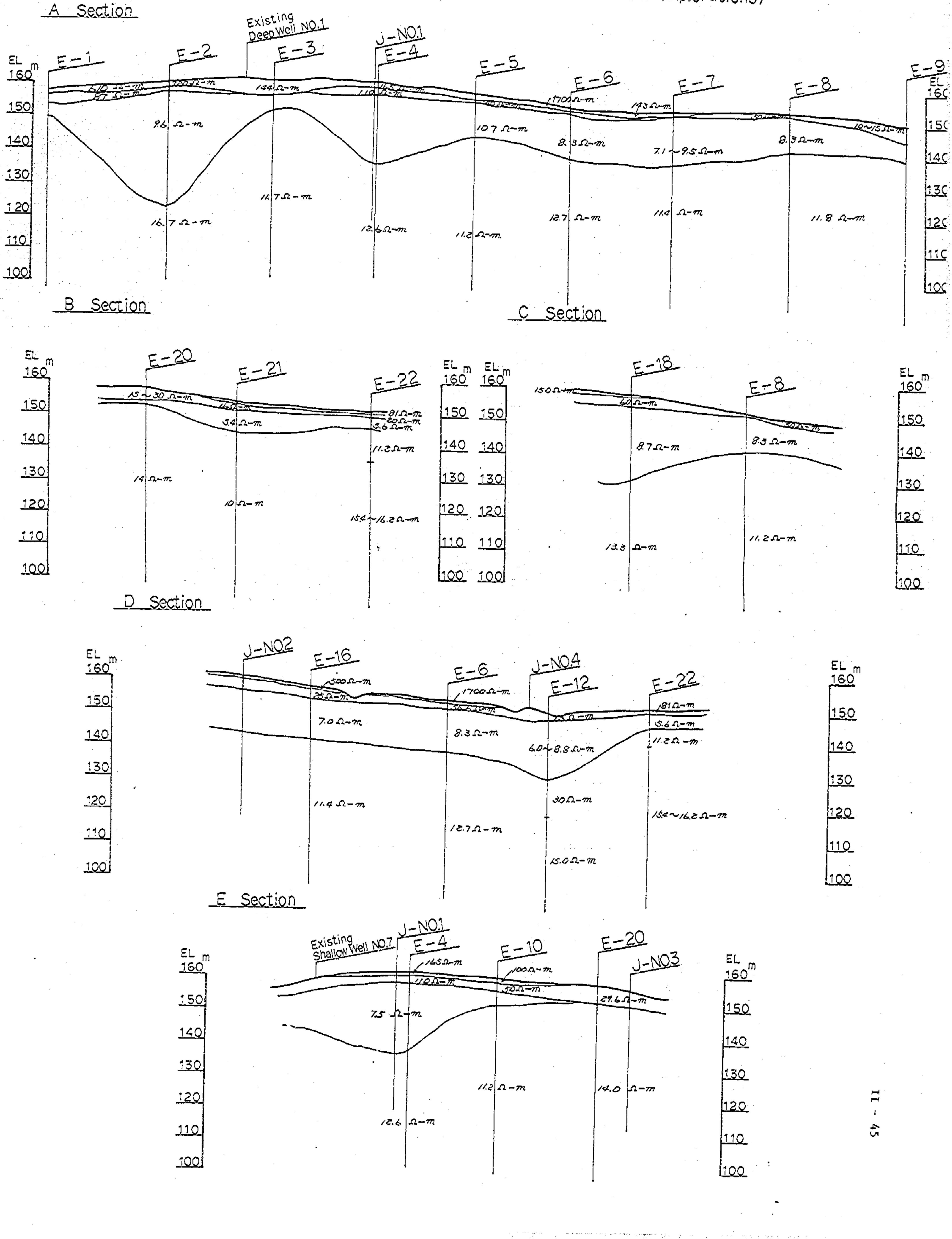


Fig. 5-7 Contour Line of Base Rock

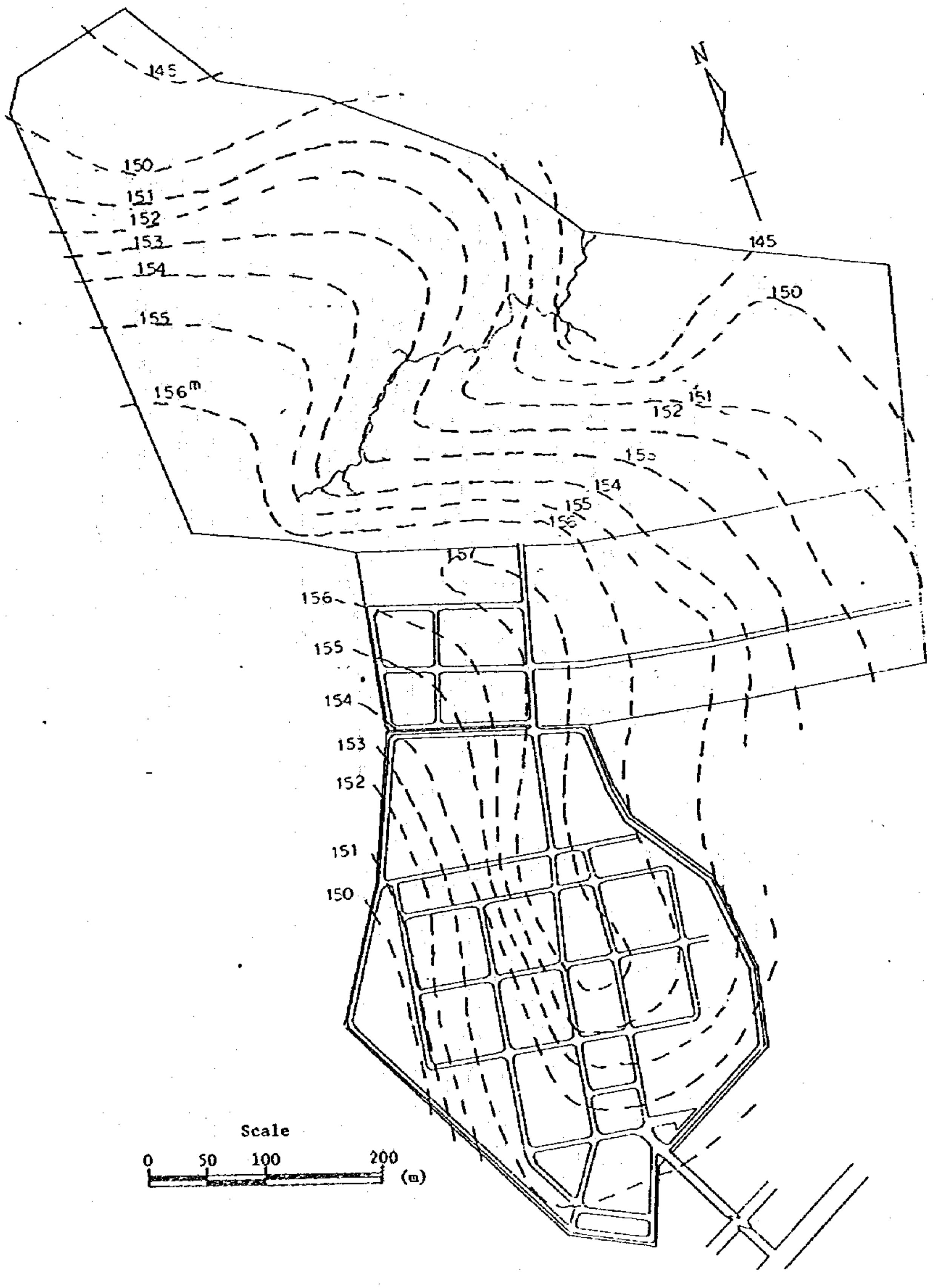
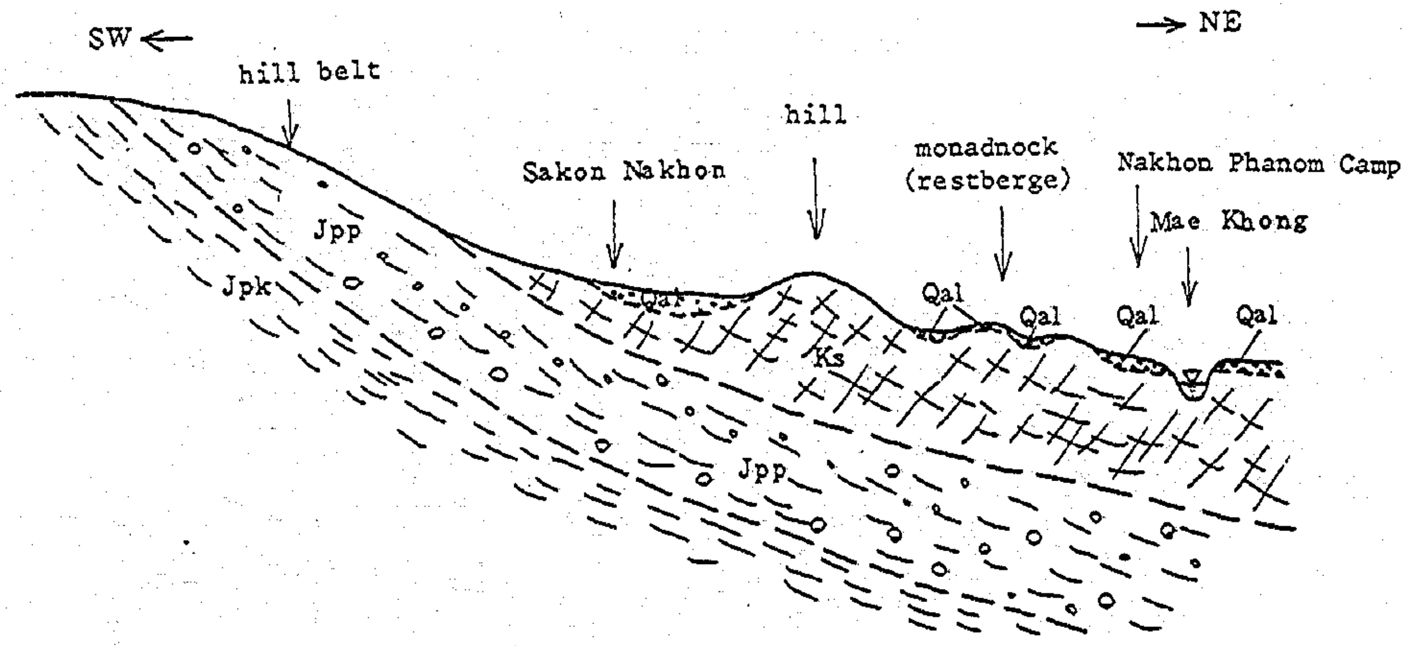


Fig. 5-8 Schematic Profile of Geological Structure



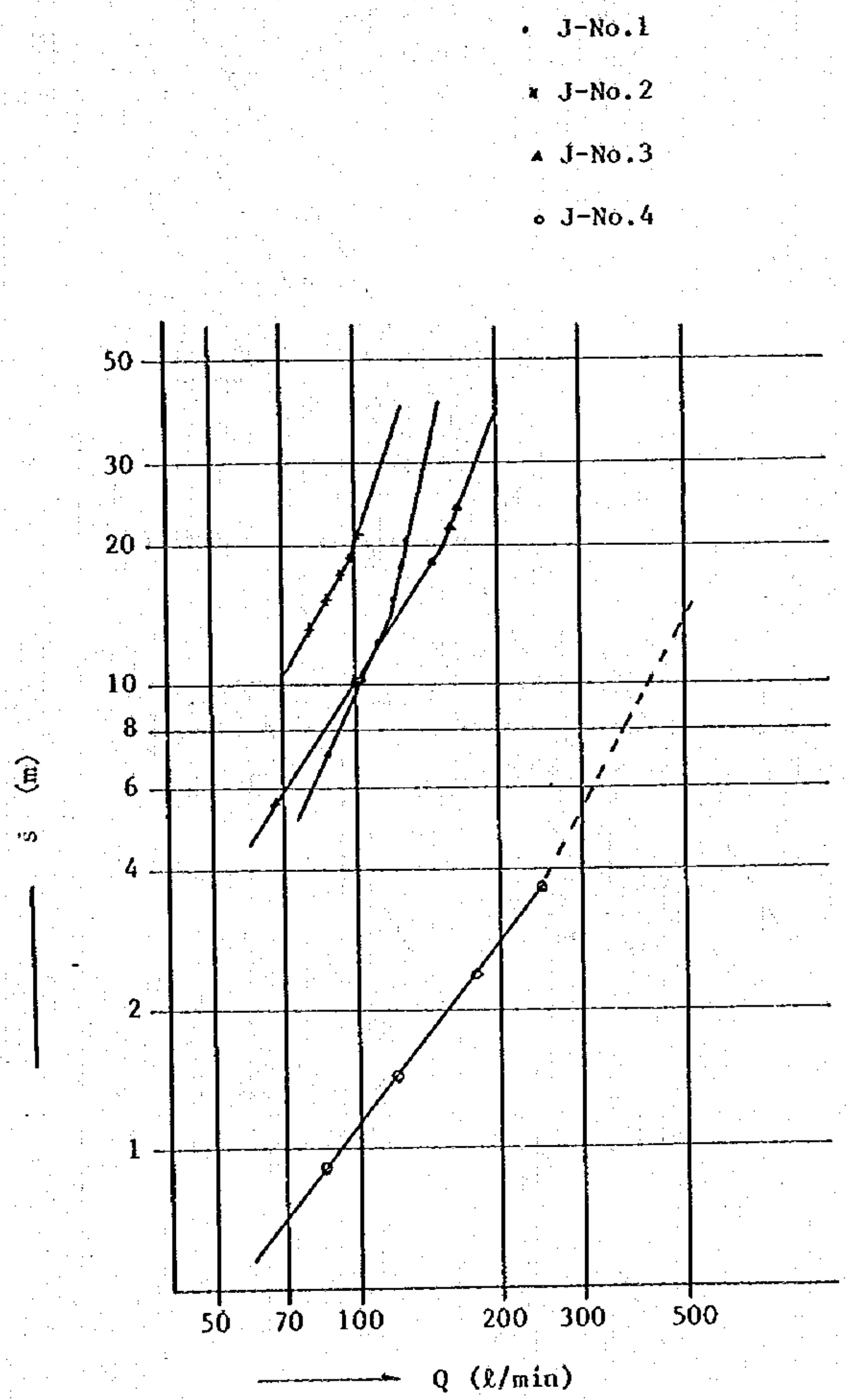
Qal : Alluvium. Diluvium

Ks : Salt and Khok Kruat Formation

Jpp : Phu Phan and Phra Whan Formation

Jpk : Phu Kradung Formation

Fig. 5-9 s - Q


• J-No.1
× J-No.2
▲ J-No.3
o J-No.4
50
30
20
10
8
6
4
2
1
s (m)
50
70
100
200
300
500
Q (ℓ/min)

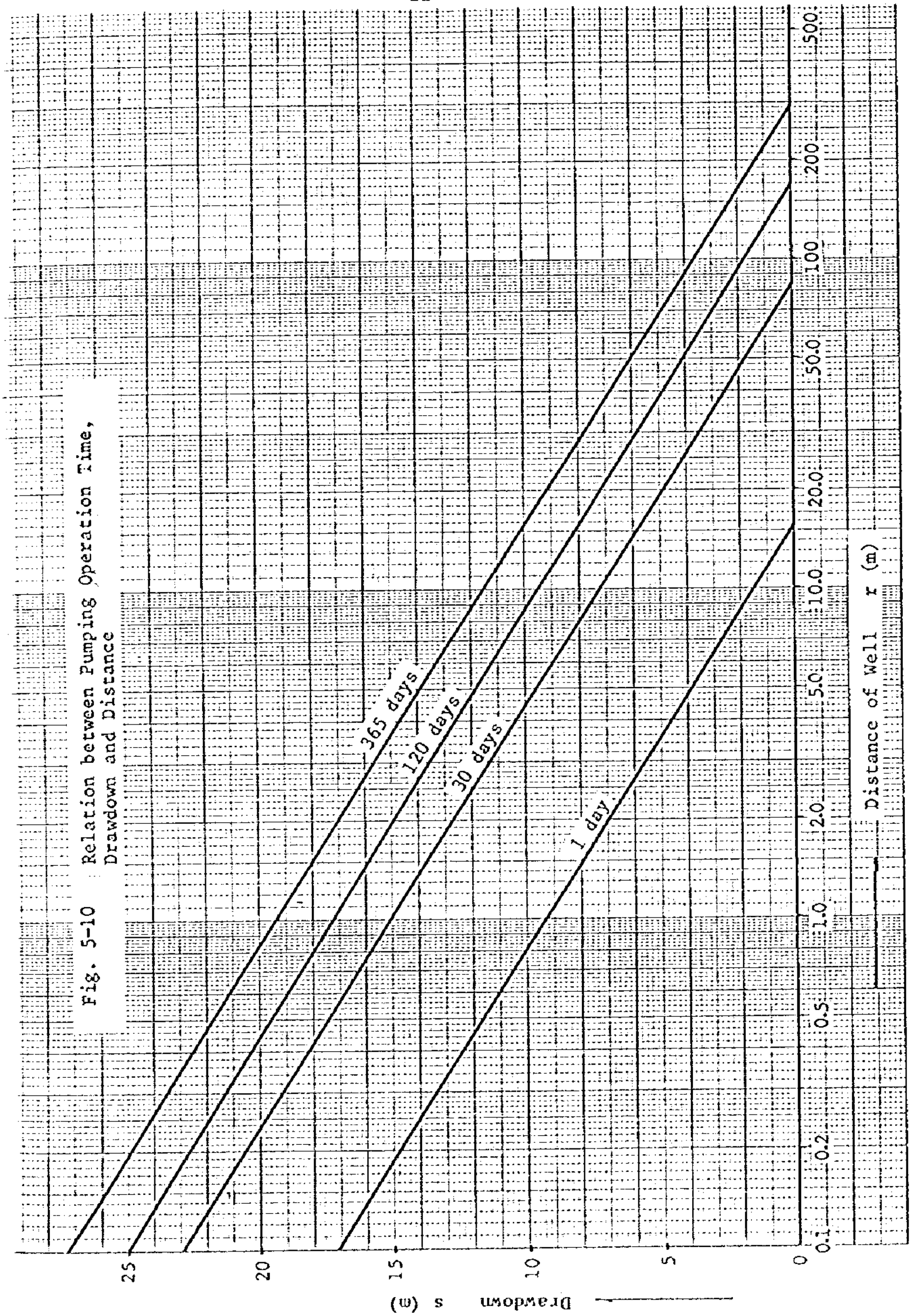


Fig. 5-10 Relation between Pumping Operation Time, Drawdown and Distance

Table 5-1 Monthly and Annual Rainfall for the Period 1951 - 1980

Station: Nakhon Phanom
Index Station 48: 357
Latitude: 17°25' N.
Longitude: 104°47' E.

Elevation of station above MSL: 140.00 Meters
Height of raingauge: 0.80 Meters
(Above MSL: 140.80 Meters)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1951	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	33.4	37.4	22.2	52.8	398.7	550.3	306.0	619.0	159.5	48.2	10.4	0.0	2239.9
1954	82.8	72.9	4.2	119.7	172.1	553.4	312.5	522.0	486.0	94.3	0.0	0.0	2419.9
1955	0.0	0.0	24.6	77.4	190.6	379.2	283.3	292.5	334.9	12.9	1.6	0.0	1597.0
1956	0.0	48.7	41.0	128.3	241.8	210.3	398.1	644.5	355.4	37.1	0.0	0.0	2105.2
1957	0.0	0.0	46.3	111.3	214.4	409.3	374.4	635.8	374.8	40.6	5.7	0.0	2212.6
1958	20.9	65.5	49.3	40.0	178.2	601.4	466.1	368.1	357.7	46.5	0.0	0.0	2211.7
1959	0.0	14.2	11.1	60.1	205.6	76.1	390.7	544.4	457.1	0.3	0.0	0.0	1759.6
1960	0.0	16.7	117.6	9.0	198.6	344.3	297.6	1088.3	315.5	116.0	0.4	0.0	2504.0
1961	0.0	0.0	58.9	72.5	266.2	760.3	270.8	764.9	586.8	56.3	0.0	0.0	2836.7
1962	0.0	0.0	40.8	166.3	328.5	1032.8	408.7	526.0	297.1	21.6	1.2	0.0	2823.0
1963	0.0	0.0	114.2	58.4	164.2	900.5	485.6	508.9	367.8	68.8	45.1	0.0	2713.5
1964	0.0	0.0	38.3	72.5	334.8	x	x	575.1	318.9	290.5	3.0	0.0	(1633.1)
1965	0.0	17.7	24.0	92.9	236.3	775.9	301.0	273.9	261.5	18.7	2.7	0.0	2004.6
1966	0.0	49.4	96.9	204.3	259.4	396.7	324.6	842.1	159.2	32.9	8.5	0.0	2374.0
1967	0.0	8.7	49.6	185.3	249.7	375.8	396.1	483.9	403.7	6.8	7.0	0.0	2186.6
1968	2.0	31.0	71.9	13.4	239.0	424.1	356.9	644.3	230.9	57.3	0.0	0.0	2070.8
1969	10.3	0.5	15.9	115.7	281.0	643.6	770.6	503.7	305.3	42.6	0.0	0.0	2689.2
1970	0.0	0.3	6.4	76.3	442.5	497.8	414.2	745.1	468.7	21.3	0.7	0.0	2673.3
1971	2.7	23.0	5.7	30.6	295.8	371.4	532.1	315.4	375.3	42.1	0.3	28.5	2022.9
1972	0.0	17.1	83.3	107.2	254.4	706.1	493.1	761.7	101.6	126.5	0.5	0.0	2651.5
1973	0.0	0.9	9.8	71.0	214.9	288.4	472.2	430.9	307.5	24.8	0.1	0.0	1820.5
1974	7.8	2.9	24.7	76.8	190.1	418.7	434.8	864.6	97.3	36.4	15.7	0.8	2170.6
1975	2.8	31.1	58.8	76.8	190.5	499.8	515.1	1232.9	140.3	32.5	3.2	0.0	2783.8
1976	0.0	3.6	64.2	101.1	169.8	320.5	546.5	377.7	285.5	128.0	0.0	0.0	1996.9
1977	13.9	0.0	1.3	117.1	109.0	265.2	380.8	348.7	381.5	11.6	21.7	1.2	1652.0
1978	19.2	52.5	96.0	284.4	256.4	400.5	592.1	750.2	278.7	4.9	3.4	0.0	2738.3
1979	2.4	6.9	17.2	123.9	290.0	494.5	434.5	522.8	200.2	0.0	0.0	0.0	2092.4
1980	0.0	27.8	36.1	159.6	139.1	254.9	450.9	387.6	426.5	41.6	0.1	0.0	1924.2
AVERAGE	7.1	18.9	43.9	100.2	239.7	480.4	422.6	592.6	315.5	52.2	4.7	1.1	2276.9

Table 5-2 Monthly and Annual Mean Evaporation Temperature and Rainfall at Nakhon Phanom

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANNUAL
Evaporation (mm) (1957-1975)	95.0	95.4	107.4	100.4	66.9	43.1	39.2	34.2	42.4	69.5	88.2	90.7	872.4
Temperature (°C) (1952-1975)	22.1	24.2	27.1	29.0	28.5	27.5	27.4	26.9	26.9	26.3	24.6	22.4	26.0
Rain fall (mm) (1953-1980)	7.1	18.9	43.9	100.2	239.7	480.4	422.6	592.6	315.5	52.2	4.7	1.1	2,278.9

Table 5-3 List of Existing Deep Wells

Location	Locality	Depth (m)	Yield (ℓ/min)	Amount of pumped water (m^3/day)	Water level (m)	Draw down (m)	Columnar section	Pomping test	Water analysis	Remarks
No.1	Ban Na Pho (camp)	-	-	40.0	-	-	x	x	x	Drinking Water
No.2	Ban Na Pho (camp)	-	-	92.0	-	-	x	x	x	Drinking Water
U19	Ban Khok	-	-	6.0	-	-	x	x	o	Miscellaneous Water
U18	Ban Na Mon	30.5	520	10.0	3.26	6.26	x	o	o	Miscellaneous Water
U43	Ban Na Phung	48.8	-	10.0	4.70	-	o	x	o	Drinking Water
U337	Ban Khurukhu	30.5	135	6.0	3.05	4.36	o	o	o	Drinking Water
U116	Ban Neng Bua Khurukhu	30.5	176	18.0	3.76	-	o	o	o	Miscellaneous Water
B186	Ban Dan Sawang	38.7	-	20.0	4.50	-	o	x	x	Drinking Water

Table 5-4 . List of Existing Shallow Well in Camp

Location	Depth (m)	Water Level (m)	Diameter (m)	Yield (ℓ/min)	Amount of pumped water (m^3/day)	Remarks
No.1	37	12.0	0.05	15.0	10.8	Drinking Water
No.2	10	2.0	2.0	-	0.5	Miscellaneous Water
No.3	5.7	5.0	0.9	-	0.4	Miscellaneous Water
No.4	6.6	6.0	1.6	-	0.3	Miscellaneous Water
No.5	6.45	6.3	1.0	-	0.15	Miscellaneous Water
No.6	2.7	2.5	0.9	-	0.15	Miscellaneous Water
No.7	7.0	4.6	1.2	-	0.3	Miscellaneous Water
No.8	7.0	4.50	1.3	-	0.3	Miscellaneous Water

Table 5-5 Measurement of Water Quality

No.	Location	Kind of Water	Water Temperature (°C)	Specific Conductivity at 25°C (μ v/cm)	pH
A	SW - No. 1 (Camp)	Shallow well	28	608.0	6.8
B	No. 1 (Camp)	Deep well	28	484.5	6.6
C	No. 2 (Camp)	Deep well	30	719.0	6.6
D	SW - No. 2 (Camp)	Shallow well	30	13.3	5.4
E	SW - No. 3 (Camp)	"	29	41.4	5.4
F	SW - No. 4 (Camp)	"	27	41.4	5.4
G	SW - No. 5 (Camp)	"	24	63.2	5.6
H	SW - No. 6 (Camp)	"	24	6,875.0	5.0
I	SW - No. 7 (Camp)	"	25	6,250	5.6
J	SW - No. 8 (Camp)	"	27	6,419	5.6
K	Ban Na Pho	Canal	26	27.2	5.4
L	Huai Samrong	River	26	19.8	5.4
M	Ban Na Pho	Canal	27	20.1	5.6
N	Ban Kurukhu	River	26	99.0	5.6
O	Huai Noi	River	26	128.7	5.6
P	Huai Bang Ko	River	26	460.4	6.0
Q	Huai Somhong Reservoir	Dam	25	22.5	5.6
R	Huai KHam Yai	River	27	65.3	5.4
S	Huai PHoug	River	25	66.5	5.6
T	J - No. 1 (Camp)	Deep well	30	455.4	6.8
U	J - No. 2 (Camp)	Deep well	30	515.2	6.8
V	Ban Na Mon	Shallow well	29	-	7.0
W	U18	Deep well	30	-	6.8
X	Ban Dong Sa Wang	Deep well	30	404.8	6.8
Y	U43	Deep well	29	488.8	7.0
Z	Ban Thai Samakku	Shallow well	27	62.6	5.6
a	J - No. 3	Deep Well	30	1,840	5.8~6.0
b	J - No. 4	Deep Well	30	736	6.4~6.6

Table 5-6 Water Quality of Existing Deep Wells

Constituents	Well Number U18	U19	U43	U116	U337	Thai Standard of Drinking Water
PH	8.1	7.9	7.5	8.2	7.9	6.5 - 8.5
Specific conductance (microm	-	-	345	322	328	
Turbidity (silica scale)	-	-	-	2	-	57
Tru colour (platium - cobalt scale)	-	-	-	1	-	20
Calcium (Ca)	-	-	42	18	28	
Magnesium (Mg)	-	-	7.1	9.5	16	
Sodium (Na)	-	-	16	-	16	
Potassium (K)	-	-	1.7	-	-	
Iron-dissolved (Fe)	-	-	-	0.00	-	
Iron-total (Fe)	1.2	4.4	1.0	0.12	0.17	0.5
Manganese (Mn)	-	-	0.06	0.00	-	0.05
Chloride (Cl)	8.6	5.2	11	15	5.8	25.0
Sulfate (So_4)	4.8	1.6	2.0	32	0.8	
Nitrite (NO_2)	-	-	0.00	0.00	0.00	
Nitrate (NO_3)	-	-	0.3	0.0	0.0	4.0
Carbonate (Co_3)	-	-	0	0	0	
Bicarbonate (HCO_3)	-	-	172	134	195	
Fluoride (F)	-	-	0.0	0.0	0.0	1.5
Phosphate-total (Po_4)	-	-	-	-	-	
Carbon dioxide (Co_2)	-	-	8.6	1.3	3.9	
Hydrogen sulfide (H_2S)	-	-	-	-	-	
Dissolved solids	-	-	152	203	208	500
Total hardness as $CaCo_3$	285	176	134	84	134	100
Noncarbonate hardness	-	-	0	0	0	
Copper (Cu)	-	-	0.00	-	0	1.0
Zinc (Zn)	-	-	0.11	-	-	5.0

Table 5-7 Result of Water Quality Analysis

Constituents	J-No. 1	J-No. 2	J-No. 3	J-No. 4	Thai Standards	WHO*
Colour, in terms of Hazen units	Less than 5	less than 5	less than 5		20	
Turbidity in terms of Silica scale	17.0	6.6	8.0		5	
pH value	8.4	8.3	8.0		6.5 ~ 8.5	7.0~8.5
Total solids	371	385	2,422		500	500
Total hardness ($CaCo_3$)	134	142	484		100	500
Chlorides, (NaCℓ)	6.6	nil	514.4			
Saline ammonia	0.004	0.02	0.02			
Albuminoid ammonia	0.07	0.07	0.07		0.1	
Nitrates (No. 3)	0.07	0.07	0.07		4.0	
Nitrites (No. 2)	nil	nil	0.005			
Iron (Fe)	0.20	0.25	0.14		0.5	0.3
Load (Pb)	0.01	0.002	0.01		0.1	
Arsenic (As)	0.003	not found	not found		0.05	

*WHO : Water Quality Standards by WHO

Table 5-8 Relation between Time of Pumping Operation and Drawdown

t (day)	r (m)	u	W(u)	s (m)
1	$r_0 = 0.10795$	3.47×10^{-5}	9.70	16.88
	$r_1 = 5.0$	7.45×10^{-2}	2.15	3.74
	$r_2 = 7.0$	1.46×10^{-1}	1.55	2.70
30	$r_0 = 0.10795$	1.16×10^{-6}	13.00	22.62
	$r_1 = 10$	9.93×10^{-3}	4.20	7.31
	$r_2 = 40$	1.59×10^{-1}	1.46	2.54
120	$r_0 = 0.10795$	2.89×10^{-7}	14.20	24.71
	$r_1 = 30$	2.24×10^{-2}	3.40	5.92
	$r_2 = 80$	1.59×10^{-1}	1.47	2.56
365	$r_0 = 0.10795$	9.51×10^{-8}	15.50	26.97
	$r_1 = 60$	2.94×10^{-2}	3.01	5.24
	$r_2 = 130$	1.38×10^{-1}	1.61	2.80

6. Recommended Water Supply Project

6-1 Basic Conditions for Planning

(1) Population

The assumptive benefited population is 20,000, taking into account the future plan of the Camp.

(2) Rationing Rate

Rationing rate of 35 ℓ/day/person from UNHCR is adopted.

(3) Total Requirement of Water Supply

From (1) and (2) above, the total volume of water required a day is 700 m^3/day

6-2 Pumpage of Wells and Shortage

(1) Results of the Study

The critical discharge from the existing wells and new bore holes confirmed by the present study is as follows.

existing wells No.1 Q = 40 m^3/day
No.2 Q = 92 m^3/day
new drill holes J-No.1 Q = 120 ℓ/min, Ha = 30.9 m
J-No.2 Q = 100 ℓ/min, Ha = 33.3 m
J-No.3 Q = 160 ℓ/min, Ha = 33.6 m
J-No.4 Q = 500 ℓ/min (estimate), Ha = 19.5 m

(2) Recommended Pumpage of Existing Wells and New Bore Holes

Recommended pumpage is studied on the basis of the results of the study in the preceeding section.

It is assumed, in this connection, that the existing wells with their completed water servicing facilities now in operation shall not be changed, while the new bore holes (J-No.1 ∿ J-No.4) and future wells shall be equipped with water tanks for realizing well controlled water distribution practice.

The capacity of submersible pumps installed in the new bore holes is shown in Fig. 6-1. Pumpage from these bore holes on the assumption that the height of the water tanks is about 15 m. is as follows.

bore holes	water level	height of water tank	piping loss of head	total head	pumpage
J-No.1	30.9 m	15 m	3 m	48.9 m	165 ℓ/min
J-No.2	33.3 m	15 m	3 m	51.3 m	150 ℓ/min
J-No.3	33.6 m	15 m	3 m	51.6 m	150 ℓ/min
J-No.4	19.5 m	15 m	3 m	37.5 m	215 ℓ/min

The recommended pumpage of J-No.1 and J-No.2 whose pumping capacity exceeds the critical discharge shall be obtained according to the critical discharge. Also, the recommended pumpage of J-No.3 whose pumping capacity is slightly below the critical discharge shall be obtained on the basis of the critical discharge, in the case of J-No.4, the pumping capacity is much lower than the critical discharge, but it is possible and more efficient to make pumpage done near the level of critical discharge by replacing the pumping system with another one.

Even though it would be theoretically possible to pump the water at critical discharge, it is desirable to make the actual pumpage at about 80% of that rate for safety (economic yield).

So the recommended pumpage from the new bore holes shall be as follows.

bore hole	critical discharge	recommended pumpage
J-No.1	120 ℓ/min.	100 ℓ/min
J-No.2	100 ℓ/min	80 ℓ/min
J-No.3	160 ℓ/min	130 ℓ/min
J-No.4	500 ℓ/min	215 ℓ/min
Total	880 ℓ/min	525 ℓ/min

(by the pumping system installed in the course of the study)

If the time of operation of each pump is 8 hours a day, total pumpage will be 378 m^3/day from the new bore holes, which, combined with the pumpage from the existing deep wells, will make 510 m^3/day altogether.

(3) Shortage

The projected total water requirement of the Camp is 700 m^3/ day, while the total expected pumpage from the existing deep wells and the new bore holes is 510 m^3/day. So the difference of 190 m^3/day will be short.

6-3 Recommended Water Service Facilities

(1) Well

The shortage of 190 m^3/day for satisfying the projected water requirement of the Camp is equivalent to 246 ℓ/min if the time of pumping is 12 hr/day. It is assumed, here, that the shortage will be supplied by additional wells. The area of feasible sites for additional wells is as shown in Fig. 5-5, within which two wells can be made.

Supposing the two additional wells are made, one near the site of electrical exploration of E-8 and the other near E-19, possible pumpage is estimated.

The study of the bore holes J-No.1 ∿ J-No.4 revealed the estimated specific capacity is about 10 m^3/day/m. (6.94 ℓ/min/ m) and drawdown about 20 m.

So, if the depth of the new wells is 40 m, the average critical discharge of each well is 139 ℓ/min and the economic critical discharge 111 ℓ/min, which means daily pumpage from one new well is estimated to be 80 m^3/day. The volume is made 160 m^3/day with two wells. Even though this still falls short by 30 m^3/day, it could be compensated for by longer pumping time or by proper management of water distribution facilities. Since further addition of a well is not recommendable in the light of technical judgement on appropriate number and location of wells in the Camp and also in terms of cost incurred, it is recommended that two wells only shall be made.

(2) Water Tank

The volume of water supply from the existing deep wells and the new bore holes if the time of operation is 12 hours/day is as follows.

well and bore hole	daily supply
No.1	40 m^3/day (existing)
No.2	92 m^3/day (existing)
J-No.1	72 m^3/day (new)
J-No.2	58 m^3/day (new)
J-No.3	94 m^3/day (new)
J-No.4	154 m^3/day (new)
Total	510 m^3/day (new)

If water consumption takes place during the same 12 hours as the time of pumping at a constant rate, there might not be need of water tanks. But storage of a certain amount in water tanks is planned here with a view to meeting the change in the demanded volume of water in a day and possible emergency like malfunction of pumps.

The designed capacity of each water tank shall be based on the criterion practiced in water supply system in Japan, which is "storing the volume equivalent to 1-3 hours of full pumping operation".

Since the operating time for supplying the above-tabulated daily supply is 12 hours a day, about a quarter of the volume shall be adopted as the capacity of storage tanks.

Excluding the existing deep wells with water tanks already in operation from the plan, the capacity of the water tanks of the new and future wells shall be made as follows.

well	daily supply (m^3/day)	capacity of water tank
J-No.1	72	18 m^3 (20 m^3 x 1)
J-No.2	58	15 (20 m^3 x 1)
J-No.3	94	24 (30 m^3 x 1)
J-No.4	154	39 (20 m^3 x 1)
proposed No.1	80	20 (30 m^3 x 1)
No.2	80	20 (30 m^3 x 1)

Champaign glass type water tower (Fig. 6-2) which is easy to build and durable is adopted. The proposed sites of the water tanks are at the four locations of the test boring by the study team and two future well sites as shown in Fig. II-2.

(3) Hydrant

The number of hydrants required depends on the discharge volume from one. The average size of hydrants in water distribution system at a washing room in Japan is as follows.

Water consumption	Size of hydrant
12 - 40 ℓ/min.	13 - 20 mm.

If the water consumption is about 25 ℓ/min which is about the average of the above, and time spent is 12 hours a day, water discharge from a tap a day is 18.00 m^3. Here, the number of water taps required for each well can be obtained according to its planned volume of water supply.

well	daily supply		number of hydrants
	well	hydrant	
J-No.1	72 m^3/day	18 m^3/day	4
J-No.2	58	18	4
J-No.3	94	18	5
J-No.4	154	18	9
proposed No.1	80	18	5
No.2	80	18	5

For the sake of standardization, J-No.1 ∿ J-No.3 and proposed No.1 and No.2 shall be equipped with the water distribution systems having five hydrants each, and in the case of J-No.4, two water tanks shall be made, each with five hydrants.

Quantities of materials required for each of such water tanks and related facility is as follows.

◦ Concrete

$1.40 \times 3.30 \times 0.10 = 0.462\ m^3$

$0.80 \times 0.25 \times 3.30 = 0.660\ m^3$

$0.15 \times 0.10 \times (3.30 + 0.82 \times 2) = 0.074\ m^3$

Total $= 1.196 \doteqdot 1.2\ m^3$

◦ SG pipe

3/4" : $0.25/2 \times 5 + 2.40 + 0.8 + 0.8 = 4.625 \doteqdot 5$ m

2" : 5 m, assuming the distance of water tank from the well is about 5 m.

4" : 5 m, assuming the distance between water tank and hydrants is about 5 m.

◦ Water tap 3/4" 5 pieces

◦ Gravel $1.5 \times 3.40 \times 0.05 \doteqdot 0.255 \doteqdot 0.3\ m^3$

6-4 Estimated Project Cost

(1) Total Project Cost

unit : baht

well No.	well work	pumping facility	water tank	hydrant	total
J-No.1	-	-	400,000	20,000	420,000
J-No.2	-	-	400,000	20,000	420,000
J-No.3	-	-	500,000	20,000	520,000
J-No.4	-	-	800,000	40,000	840,000
proposed No.1	500,000	100,000	500,000	20,000	1,120,000
No.2	500,000	100,000	500,000	20,000	1,120,000
Total	1,000,000	200,000	3,100,000	140,000	4,440,000

(2) Breakdown of Estimated Construction Cost

(i) Well 500,000 baht/well

drilling Ø 8", casing Ø 6"
depth 40 m x about 12,000 baht/m

(ii) Pumping Facility 100,000 baht/set

submersible motor pump Ø 50 mm (2") with water proof 50,000 baht

cable control box, accessories, pumping pipe Ø 50 mm (2") x 4 m. power generator 5 KVA, accessories 30,000 baht

valves and miscellaneous works 20,000 baht

(iii) Water Tower

Champaign glass type 30 m^3	500,000 baht/set
Champaign glass time 20 m^2	400,000 baht/set

(iv) Hydrant

Concrete	3,850 baht	x 1.2 m^3	= 4,620 baht
cobble stone	550	x 0.3 m^3	= 165
pipe (3/4")	290	x 5 m	= 1,450
pipe (2")	580	x 5 m	= 2,900
pipe (4")	1,100	x 5 m	= 5,500
water tap	450	x 5 pieces	= 2,250
miscellaneous work			3,115
Total			20,000 baht/set

Fig. 6-1 Pump Performance Curve

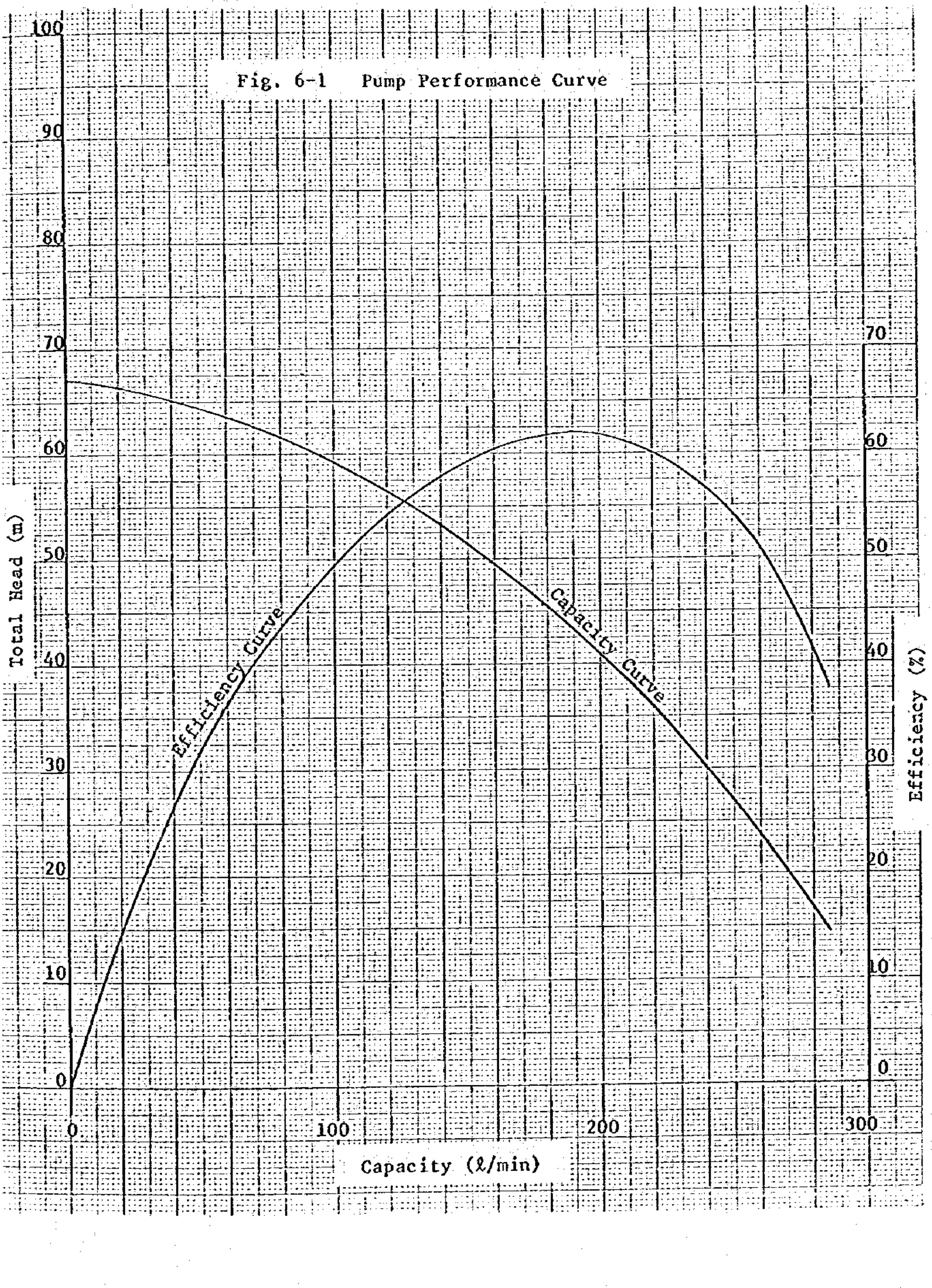
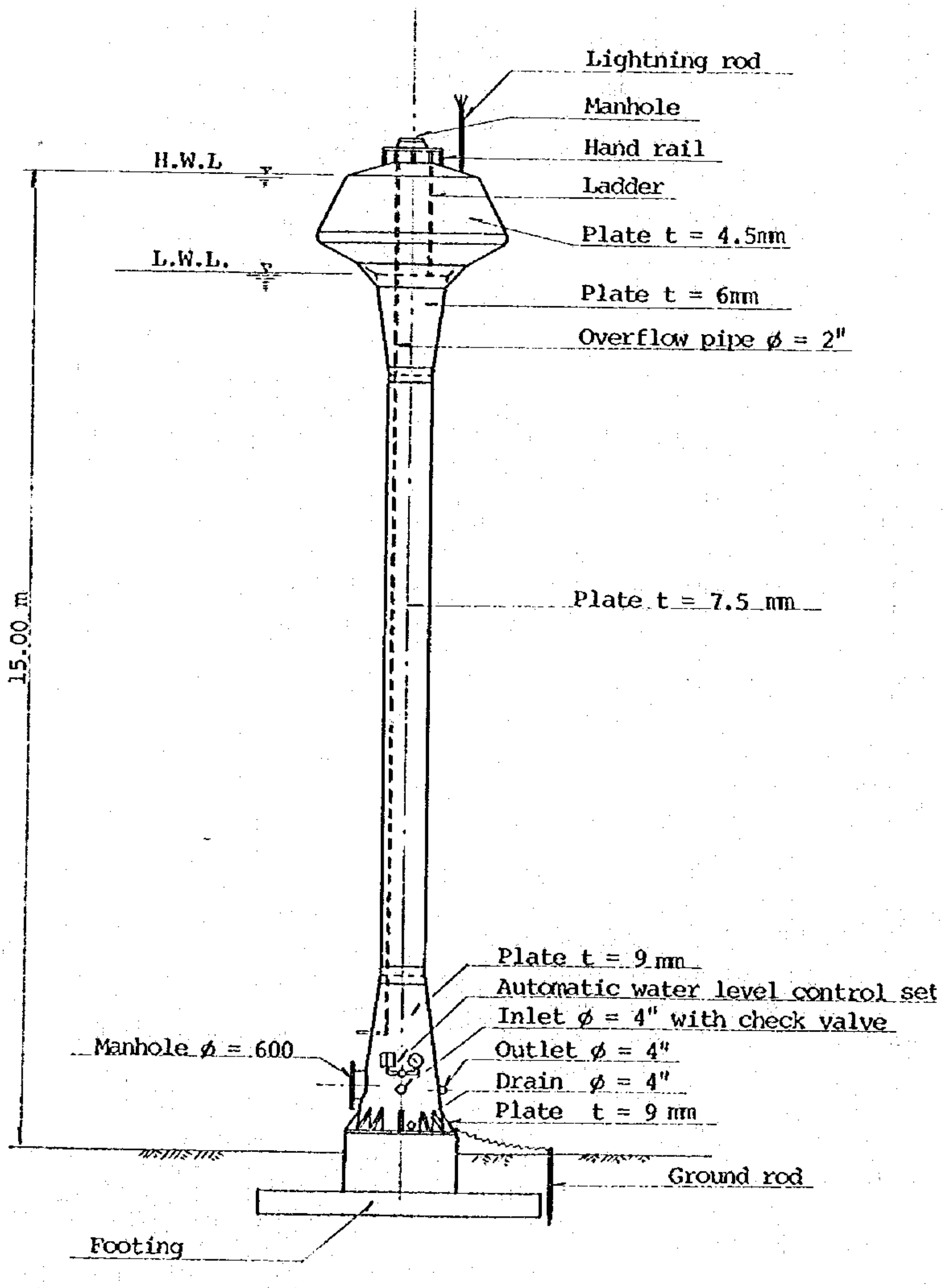
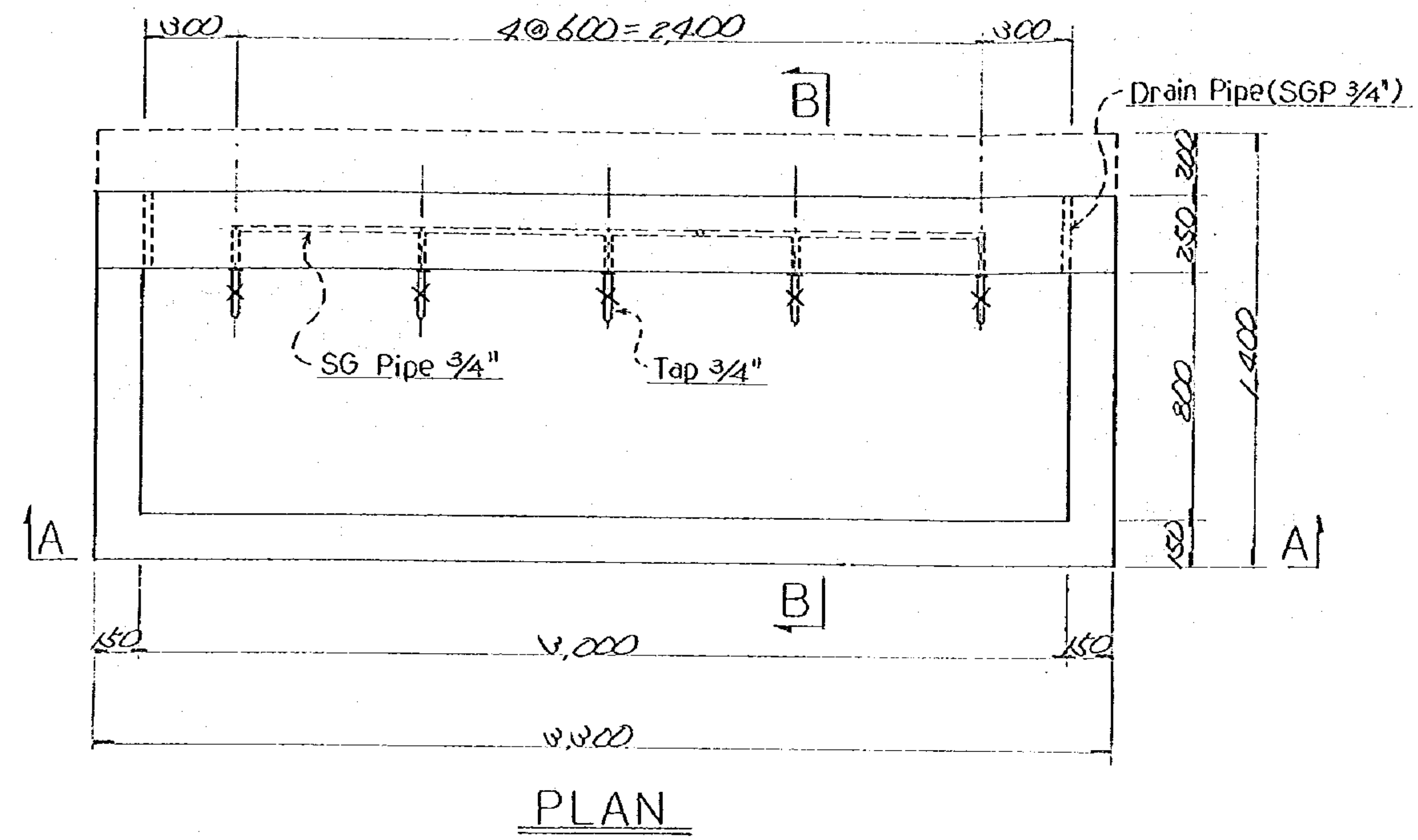
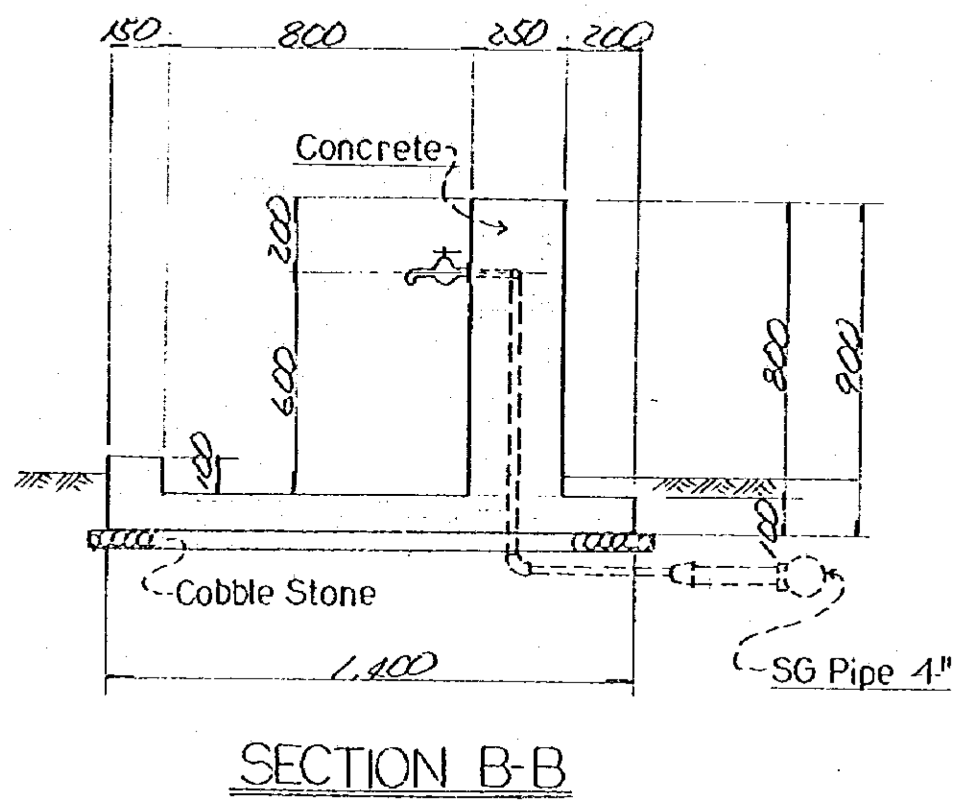


Fig. 6-2 Water Tank







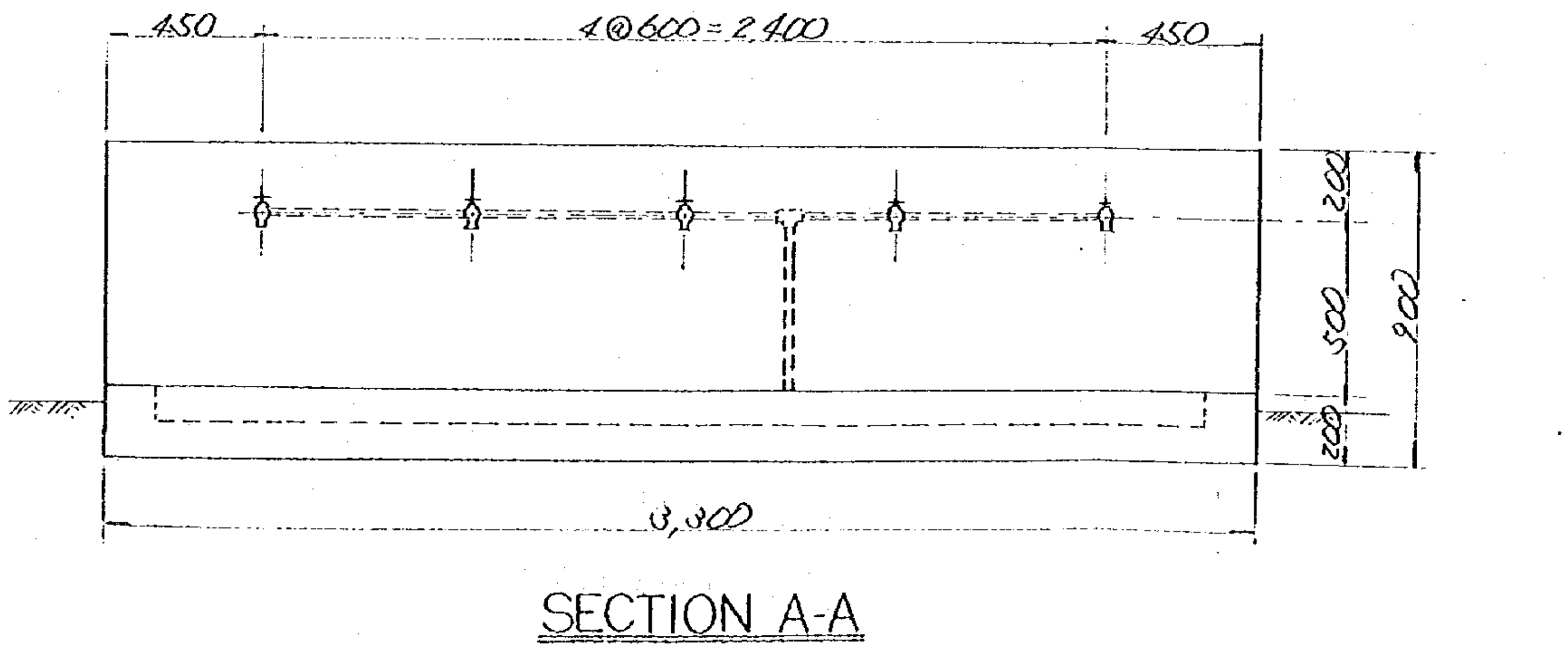


Fig. 6-3 Detail of Water Service Facilities