e) data on existing deep wells (geological log, pumping test and water quality test)

4-2 Surface Reconnaissance

Surface reconnaissance was done in order to observe the topography, geology, surface water (water outcrips), distribution and depth of existing deep wells, going practices of utilization of them as well as their water quality in and near the camp, which were required for investigating the hydrogeological characteristics in the camp. Sites of test boring and electrical exploration were selected in the course of the reconnaissance. Field interviews were also made as to specifications of existing wells and going practices in utilization of them since there were little written records available.

4-3 Electrical Exploration

The results of electrical exploration are useful, if compaired to the known state of geology, findings from test boring and so on, for researching the hydrogeological characteristics of a given area. Electrical exploration of resistivity method was adopted in the present study. By making use of this technic, in which apparent electric resistivity of the ground is measured and its variation is analyzed, in combination with otherwise known distribution of geology and a state of deposits as well as results of test boring among other things, it is possible to indirectly find out subsurface geology, especially regarding the presence or absence of water-bearing zones. The more technical term for the electrical exploration of resistivity method adopted in the study is vertical electrical sounding (Wenner method or equi-distant four-electrode method). By this, values of resistivity (ρ - m) of the ground at different depths (a meter) from the surface were measured, according to which ρ - a curves were drawn for recognizing the subsurface hydrogeological characteristics. 34 sites were explored totally inside and along the outer peripheries of the camp.

Instrument and tools used are as follows.

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

b) electric poles (cadmium-plated-steel, Ø 18 mm, l = 80 cm) 5

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

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

e) measuring tape (plastics, l = 100 m) 4

f) electric loud speaker 1

g) transit 1

h) level 1

i) staff and pole .... 1 set

j) battery charger (AC 220V DC 12V) 1

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

4-4 Test Boring

Test boring was done at four sites in order to understand the state of subsurface geology, especially concerning the ground water.

The main machinery and equipment used in the test drilling are as follows.

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

b) boring bit (Ø 6-1/4" steel tungsten alloy) 4

c) pump (Tone NAS-4B mud-slash pump) 1

d) cement mixer (Tone MCE-100, with engine) 1

e) boring rods (Tone T73, l = 3 m) 18

Boring speed, water escape or water springing, and the state of slime (mud-carried sludge of pulverized rock) were observed and recorded during the boring, and boring logs were drawn later.

4-5 Electrical Logging

Apparent resistivity of layers at varying depths was measured immediately after completion of test boring, by lowering an electrode and cable for electrical logging into bore holes. It is useful to detect the characteristics of rocks and state of fissures in each layer and the results of electrical logging are as indicated in boring logs. The major instrument and tools used are as follows.

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

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

c) battery (12V, 50AH) 1

4-6 Pumping Test

Step drawdown pumping test and constant yield pumping test were done by making use of bore holes in order to find out pumping conditions and coefficients of aquifers in the camp. Step drawdown pumping test, in which quantity of pumped water is varied by stages, is designed for finding the critical discharge of a well, whereas constant yield pumping test, in which relationship between drawdown caused by pumping a constant volume and time taken for it and also relationship between water level recovery and time taken for it after pumping is stopped are measured, is designed to obtain data for interpreting subsurface hydrogeology.

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

a) pump (submersible motor pump, Ebara 40BHS 13-2-2 for 4" pipe 140 l/min. at 50 m, 2.2 KW, 380 Volt 3 phase 50 cycle) ... 1

b) electric generator (7.5 KVA, with gasoline engine, TECUMSEN OH-160, 38 Volt, 3 Phase, 50 cycle) 1

c) pumping pipe (Ø = 40 mm, l = 3 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

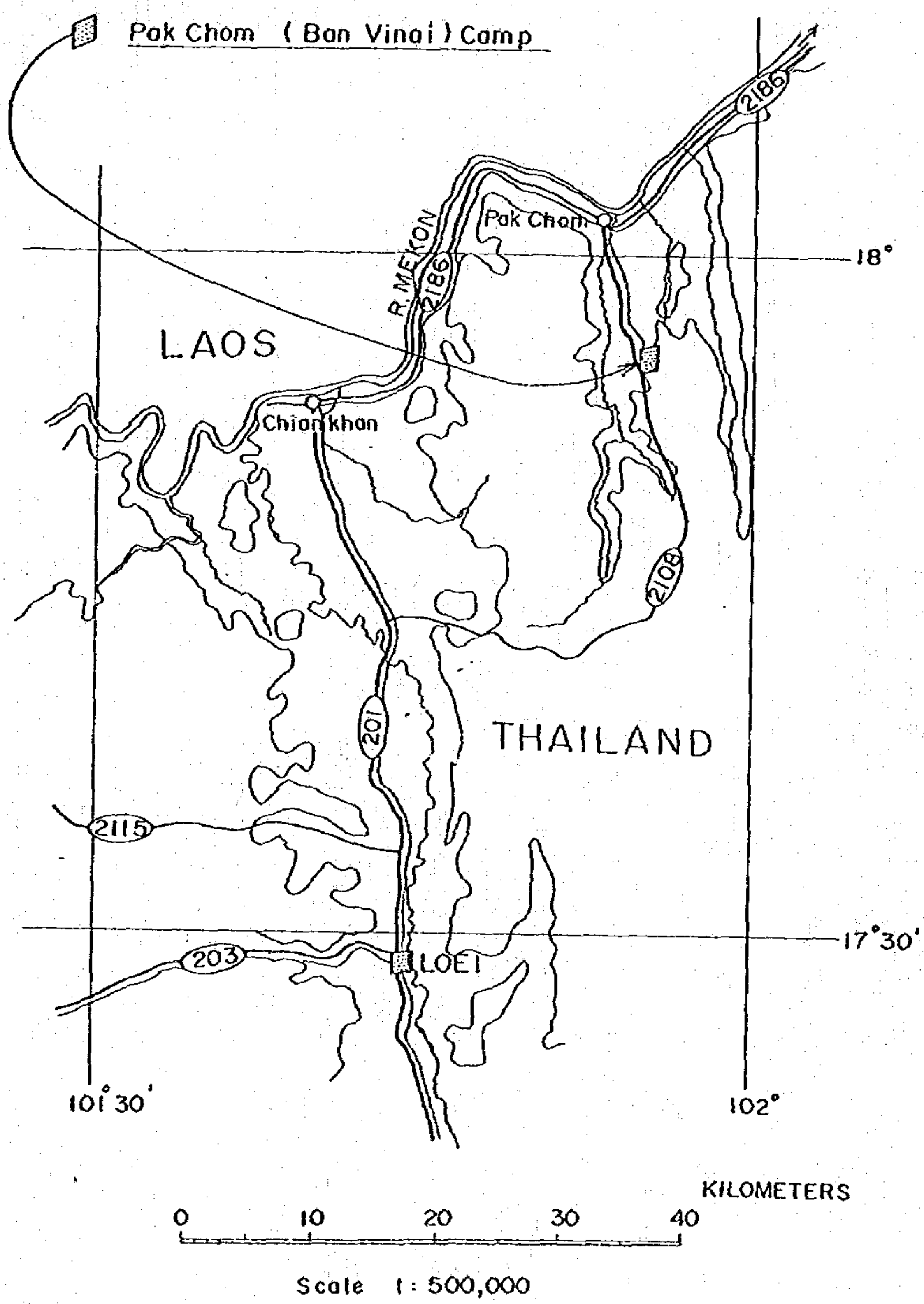
4-7 Water Quality Test

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. The test was done at 50 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, Toa Dempa Kogyo)

Fig. 4-1 Location Map



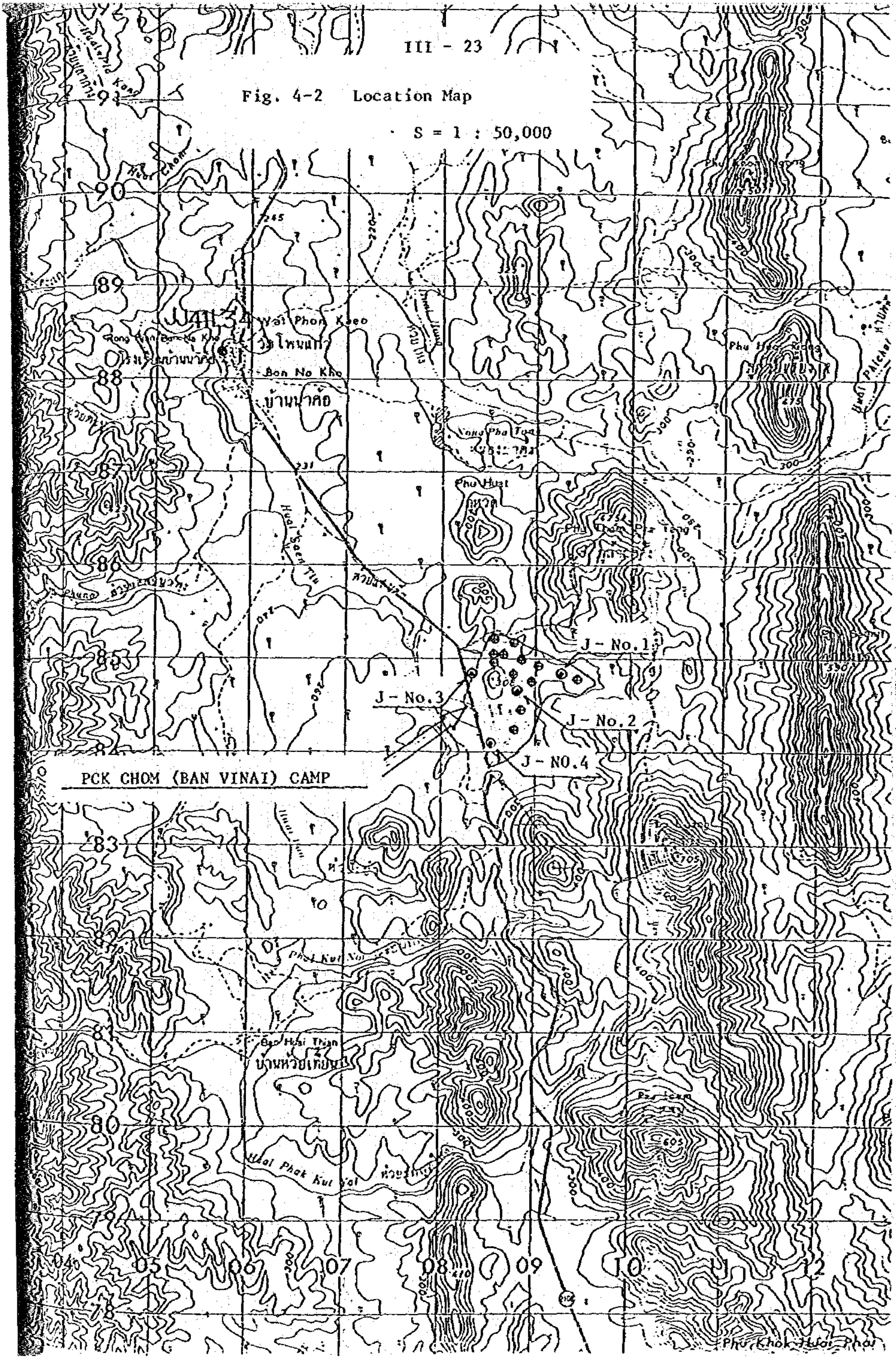
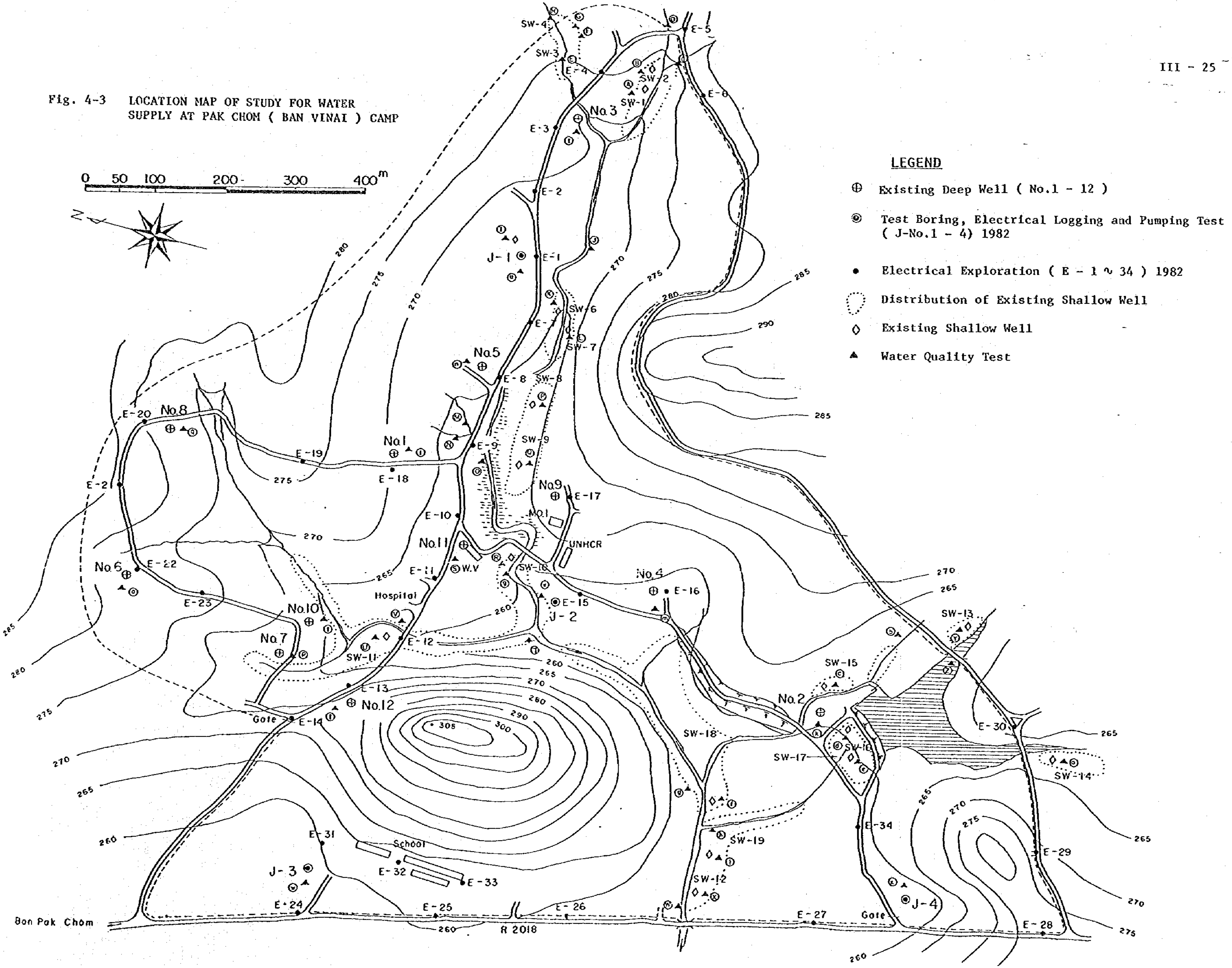


Fig. 4-2 Location Map

S = 1 : 50,000

Fig. 4-3 LOCATION MAP OF STUDY FOR WATER SUPPLY AT PAK CHOM (BAN VINAI) CAMP



5. Results of the Study and Interpretation of Them

5-1 Topography and Geology

The topography of Pak Chom Camp and its neighborhood is characterized by mountain ranges and river systems of various scales running almost north to south. The elevation of the entrance into the playground of the primary school located on the provincial highway 2108 which runs on the southern edge of the camp is 260 m above sea level, and the elevation of the summit of the hill on the south of the camp with north-to-south oriented crest which is fairly separate from other hills is 308 m.

The topography of the northeastern part of the camp is either mountain slope or piedmont of about 280-300 m above sea level over which the summits rise at the altitude of about 400 m above sea level. The piedmont topography of the same extent prevails also from the eastern side to the southern side of the camp, whereas its western side is on a hillside slope of altitude of about 280 m above sea level.

As main surface water, the camp has small streams in its northern and western valleys and a reservoir in the southern part of it.

The water discharged from the reservoir also flows as another stream. The three streams meet together inside the camp and then goes west out of it passing under a bridge of the provincial highway 210 till it joins with Saen Tiu River. Saen Tiu River flows north almost along the provincial highway and confluence with Chom River. Chom River flows into Mekong River at the eastern part of Pak Chom Village which is located about 10 km (in straight line) to the north-west by north of Pak Chom Camp. The houses of the displaced persons are built on the lower slopes of the hills in a crowded manner looking as if plastered there. The camp premises have little forestsand cultivated land.

Old and hard rocks of Silurian, Devonian, Carboniferous, Permian, Triassic and Jurassic periods prevail in this region, but there is little distribution of the Quaternary layers as shown in the geological map of Fig. 5-1 and Table 5-1.

Igneous rocks are also distributed in places.

Thick water-born deposits of silt, clay, sand and gravel of alluvium are found only along the discharge basin of Loei River.

Flat terraces of sand and gravel are formed on the both sides of other rivers of various scales. Micaceous shale of mainly dark brown, grayish brown and red colors, which is from Jurassic period of Mesozoic era is distributed over the stretch of land from the neighborhood of Tha Li located to the west of Muang District of Loei to the eastern and western part of the Muang District. Mudstone, sandstone and conglomarate are interbodded in the shale. This layer is known in Thailand as Phu Kradung formation.

The expanse of land from 10 km to 30 km to the east of the Muang District and the hills on the west of it are composed of massive or slabby limestone of light gray color from Carboniferous to Permian periods. Shale, mudstone, coglomerate and tuffs are frequently observed to be interbedded in the limestone. It is called Ratburi formation.

Thick layers of greywacke, slate, mudstone and siltstone of Silurian, Devonian and Carboniferous periods of Palaeozoic era are distributed over the stretch of land on the right bank of Mekong River, from a point of about 10 km to the east of the town of Chiang Khan to a point of about 15 km to the east of Pak Chom. Limestone is interbedded at places. Also, veins of quartz are observed in a threadlace state or running along lines of bedding. Black or gray shale and light gray sandstone often containing pebbles of quartz, quartzite, slate and grainte are present at places. These layers are grouped in Thailand as Kaeng Krachan Formation.

Inside or in the vicinity of the Kaeng Krachan Formation there are intrusions of granite or granodiorite which are exposed at mountain tops or sometimes forming fairly separate mountains. These rocks are suspected to have been formed in Triassic period.

Triassic quartzite is also distributed over the land from 5 km to 15 km to the east of the town of Tha Li.

Carboniferous mafic rocks and ultramafic rocks are slightly distributed in the area about 20 km to the east of village of Pak Chom.

Kaeng Krachan Formation is distributed in and around Pak Chom Camp.

Observation of outcrops and boring slime (pulverized rock) revealed the presence of greywacke, as a major component, slate, siltstone, mudstone, shale, sandstone and limestone. Most of these rocks have a north-to-south strike and eastward dips of 30^o-70^o. But some are dipped toward west at about 40^o indicating the record of highly irregular, wild and localized folding.

It was suspected that strike faults of various scales exist in the layers.

Test boring was done at four sites in the camp in order to confirm the mode of occurrence of fissure water supposedly present in cracks of these rocks.

It was as a result of the test boring that highly resistant greywacke and slate were recognized both with numerous veins of quartz. The maximum time which it took the tungsten-alloy steel tri-cone drilling bits for advancing one meter was 15 hours and 45 minutes. Normal time taken for a meter is 4-6 hours.

5-2 Hydrology and Climate

(1) River Systems

There are two major river systems by Pak Chom Camp, which are Pichai River and Saen Tiu River running on the eastern and western sides, respectively, of a hill range of about 300-700 m above sea level lying north to east.

These water systems flow NE to NW gathering tributaries on their courses. Pichai River flows into Nam Ngao River and Saen Tieu River flows into Chom River before the water of the both eventually flows into Mekong River near the village of Pak Chom.

Even though Pichai River and Chom River both have water in the dry season, the amount then is fairly small and the flow is slow. Pak Chom Camp which is the site of the present study, is located near the origin of Saen Tiu River which has a discharge basin of about 5.11 km^2.

(2) Precipitation

The climate of Loei can be divided into the dry season from October through April and the rainy season from May through September. About 80% of the annual rainfall occurs during the rainy season making the rest of the year very dry.

The four months period from November through February, especially, has no rainfall in some years.

Annual and monthly rainfall is as shown in Tables 5-2 and Fig. 5-2 ∿ 4.

maximum annual rainfall in 27 years (1978);	1,687.2 mm
average annual rainfall in 27 years (1954-1980);	1,236.2 mm
maximum monthly rainfall in 27 years (Sep. 1967);	527.8 mm
maximum average monthly rainfall (Sep.);	247.0 mm

(3) Air Temperature

Air temperature in Loei is highest in April, after which it gradually lowers until October when the lowering rate begins to quicken before the minimum temperature occurs in January.

Annual and monthly air temperature is as shown in Table 5-2 and Fig. 5-4.

average annual temperature (1954-1975);	25.9°C
maximum average monthly temperature (Apr.);	28.9°C
minimum average monthly temperature (Jan.);	21.7°C

(4) Evaporation and Transpiration

Evaporation is observed in class A Pan. As shown in Table 5-2 and Fig. 5-4, evaporation is small during the rainy period from May through November and is large during the dry period of December though April.

average annual evaporation (1954-1975);	801.2 mm
maximum average monthly evaporation (Mar.);	107.4 mm
minimum average monthly evaporation (Sep.);	34.7 mm

(5) Runoff

Even though there is no record of runoff, it is roughly estimated at about 45% of annual rainfall because of the hilly topography of the Camp and its neighborhood in spite of the rich vegitation suggesting otherwise, a relatively high water holding capacity of the area. There is no runoff during the six months' period from November through April when evaporation exceeds precipitation.

5-3 Geological Structure

(1) Comparison of Electrical Exploration and Test Drilling

Electrical exploration of resistivity method (Wenner's 4-pole, vertical sounding) was performed in 34 lines inside and along the periphery of the camp. ρ-a curves were prepared by plotting depth (a-meter) in relation to the value of resistivity of the ground (ρ - Ωm). ρ-a curves of these sites of electrical exploration are shown in Appendix I.

The four electrodes were placed at equal distances (a meter) from each other, which are equivalent to the depth of sounding where resitivity (ρ) of the ground was measured.

The value of ρ alone is logarythmically represented in the figure.

It was attempted to interpret the ρ-a curves by standard curves after logarithmically plotting both a and ρ, but fluctuation of ρ-a curves were so wild that it was difficult to obtain results at a high level of precision.

Even though the comparison of boring logs and ρ-a curves of the vicinity of the site of test boring did not indicate much clear-cut tendency or relationship, it served as a guidepost for the hydrogeological study. Especially it was useful in differentighting solid part of the bedrock with relatively high resistivity from soft or cracked part of it containing fissure water with relatively small value of resistivity.

(2) Geological Formation

Top soil in and near the camp, formed as a result of weathering of the bedrock, contains sandy and clayey soil as well as rock masses and pieces. Its thickness is very small. The thickest of the top soil in the sites of test boring was about 6 m and the thinnest was about 0.5 m. Outcrops of the bedrock is observed in almost all places. Weathered part of graywacke, slate, and siltstone of about 2 m. in thickness lie under the top soil.

Fresh and resistant bedrock lies under the weathered part.

The ground water termed fissure water is present in the zone of the bedrock where cracks are well grown. What is pumped from deep wells is this kind of water. Cracks in bedrocks are developed by orogenic folding or by occurrence of faults.

Cracks, if filled with minute pieces or pulverized rocks and clay, frequently block the flow of ground water or hot spring, but this probably, does not happen in this region where earthquakes of any remarkable extent, supposedly, do not occur.

Over 200 manually made shallow wells are distributed along the streams which flow through the lowland in the camp.

They are all about 3.5 m deep. Ground water is present in the weathered part of the bedrock with cracks and in the transitional part between the rockbed and the top soil. The wells not deeper than the weathered part of the rockbed go waterless in the dry season.

Fig 5-5 indicates an east-west geological section (E-W) of a central part of the camp.

The strike of the layers, in many places, is oriented in south-east and the dip is about 70° toward east.

But the strike and dip of some parts were observed to be varied due to localized foldings.

Even though faults are not apparent on the surface, it is presumable that small-scale subsurface faults oriented north to south exist near the site of test boring J-No.2. Also, it is considered presence of south-east oriented faults along the provincial highway 201 in the line connecting J-No.3 and J-No.4.

Smaller-scale faults are also suspected to exist in parallel lines to these faults.

A flat lowland with an east to west width of about 3 km lies north to south, along the southern part of which the river system of Huay Chom runs north to south. The mountain ranges on the eastern and western side of the river system lie also in north to south direction.

It indicates that there could be subsurface faults of a large scale along the north-to-south stretched lowland.

5-4 Hydrogeology

The geology of the northern part of Loei Province, as mentioned earlier, is characterized by predominant old rocks from Mesozoic Juraissic and Triassic periods and Palaeozoic Silurian, Devonian, Carboniferous and Permian periods. Distribution of Quaternary alluvium and diluvium is extremely narrow. (Fig. 5-6, Table 5-4)

The area along the discharge basin of Loei River, corresponding to the alluvium, has thick deposites of sand and gravel forming acquifers. Large quantities of groundwater, therefore, can be obtained from relatively shallow zones there, and the quality of the water is mostly good.

The area extending southward from nearly 40 km to the east of Pak Chom has a peneplain-type topography which is formed by shale, sandstone, siltstone and some conglomerate. Fissure water is obtained from the zones of the rocks where joints are well developed. The quality of the water is good in most wells. Mudstone, siltstone, sandstone graywacke, and limestone with occasional interbeddings of phyllite, shale, quartzite and quarty veins in the area from Chiang Khan to Pak Chom. Intrusions of granite are also known there.

According to the record of a well 'JJ41L34' excavated in the village of Na Kho located about 4 km to the northwest of the camp, the depth of drilling was 33 m, ground water level about 5 m and yield was about 32.14 gpm. The ground water there, probably, is fissure water from cracks developed in granite and slate interbedded by quartz veins.

The total daily pumpage from the 12 existing deep wells of Pak Chom Camp is about 560 m^3, which is all fissure water from the bedrock.

There is a chain of mountains with steep slopes in the eastern part of Loei stretched north-to-south which is formed with limestone frequently interbedded with shale or chert. Some of the cavities of various scales formed in the limestone store water and others discharge water.

The granitic rocks distributed in the south-eastern part of. Chiang Khan and in the eastern part of Pak Chom have well developed joints, so presence fissure water there is worth expecting.

(1) Mode of Occurrence of Ground Water

Ground water is present in the subsurface sandy soil containing breccia and rock pieces of various scales made as a result of weathering and in the weathered zone of the bed-rock. The mannually made shallow wells in the lowland of the camp are for making use of this type of ground water. The depth of the shallow wells range from about 1.8 m to about 4.7 m.

Most of these shallow wells, being fed by percolated rainfall and surface streams, run dry in the dry season during which there is not such recharge. But some shallow wells reaching the weathered zone of the bedrock can escape the seasonal depletion since the ground water contained in the cracks of weathered zone of the bedrock comes out.

The ground water of deep wells corresponds to the water held in the fissure zone with numerous fissures made as a result of strain exerted to the bed rock by occurrence of faults and foldings due to orogenic movement or crustal deformation. Much ground water is held in large-scale fracture zones of faults or in accompanying smaller-scale faults.

Deep wells are made with a view to utilize the fissure water present in the fissures, zones of well developed joints characteristic of rocks and in faults.

(2) Current Situation of Ground Water Utilization

a) Shallow well

There are over 200 shallow wells in the Camp concentrated in some lowlands.

The results of survey on the main well groups of them are as shown in Table 5-5.

The depth of them varies from 1.78 - 4.70 m, the water level from 0.35 - 2.20 m and the diameters from 1.0 - 1.2 m.

The minimum amount daily usage of water from a shallow well is 0.5 m^3 and the maximum is 5 m^3. About 40% of the shallow well water is used for drinking and the remaining 60% is used for miscellaneous purposes such as laundering, bathing and washing.

b) Deep well

There are twelve existing deep wells in the camp, of which one is pumped by submersible motor pump, another by hand-pump and the remaining 10 by gear pump. The total pumpage of these wells, if operated normally, would be 560,160 litres (about 560 m^3) (Table 5-6). Since the population of the displaced persons in the camp is 33,381 (as of September, 1982), these deepwells have potentials of yielding a rationing rate of 16.78 l/day/person.

However, all these wells can not be put into service alike every day in the present circumstances.

For instance, two deep well pumps No.6 and No.8 have been left out of service since May, 1982 with no immediate prospect of repairing, which would otherwise be lifting 90,700 litres (about 90 m^3) water a day. Therefore, the actual daily per capital supply now is only 14 litres.

Pumping from these deep wells are done two times a day; one-time in the morning and another in the afternoon, operating at the rate of 11 - 17 hours a day. It is thought that excessive pumping is done from all the wells.

Since there was little written record available concerning the deep wells, interviews were made with persons in charge of pump operation and maintenance, as a result of which it was learned No.1 is 42.3 m deep and No.4 is 40.5 m deep and No.12 is 52.5 m deep as shown in Table 5-7. The depth of the rest of the deep wells are still unknown, but it may range from 24 m to 42 m.

Even though the level of the ground water has not been measured, it, presumably, is 6 - 18 m. The diameter of well casings vary from 4 inches to 6 inches. The position of screened casings is unknown.

Lithologic character of the rocks into which the existing deep wells were made is not known either.

(3) Pumping Test

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

a) Step Drawdown Pumping Test

In the step drawdown pumping test, the rate of pumping was controlled by a valve at 4-5 steps during each of which pumping was continued until water level stabilized.

The relationship between pumping rate (Q) and drawdown (S) is as shown in Fig. 5-7, from which critical discharge of the drill holes is judged to be as shown in the following table.

Economic critical discharge should be lower than the critical discharge.

Result of Pumping Test

Bore Hole Number	Critical discharge ℓ/min.	drawdown (m)	specific m^3/day/m	water level after drawdown GL
J-No.1	78.0 (112.3 m^3/day)	23.0	4.88	25.95
J-No.2	190.0 (2,736 m^3/day)	25.4	10.77	27.00
J-No.3	195.0 (280.8 m^3/day)	16.5	17.02	21.00
J-No.4	200.0 (288.0 m^3/day)	16.5	17.45	19.55

Even though economic critical discharge is set at about 80 % of critical discharge in many cases, the evaluation may differ from case to case depending on the well diameter, hours of continued pumping, well-to-well distance and subsurface hydrological conditions. Economic critical discharge of a given well should be arrived at on the basis of its pumping schedule treating it as a member of a group of wells located in a given area which are necessarily mutually influential.

b) Constant Yield Pumping Test

The record and the derivative results of computation of constant yield test at each bore hole are as shown in Appendix G. Transmission 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 shown in Appendix F.

Result of Constant Yield

Bore hole	Transmission coefficient (m^2/sec)		Storage coefficient		Test Yield (m^3/sec)
	Theis	Jacob	Theis	Jacob	
J-No.1	$5,594 \times 10^{-5}$	$1,860 \times 10^{-5}$	$7,459 \times 10^{-4}$	$5,190 \times 10^{-1}$	0.00131
J-No.2	$1,821 \times 10^{-4}$	$5,072 \times 10^{-5}$	$3,642 \times 10^{-5}$	$4,290 \times 10^{-1}$	0.00277
J-No.3	$1,408 \times 10^{-4}$	$1,190 \times 10^{-4}$	$9,011 \times 10^{-1}$	$1,494 \times 10^{0}$	0.00260
J-No.4	$2,195 \times 10^{-4}$	$1,198 \times 10^{-4}$	$2,156 \times 10^{-1}$	-	0.00242
Average	$1,496 \times 10^{-4}$	$7,703 \times 10^{-5}$	-	-	-

As shown in the table, transmission coefficient T and storage coefficient S are valued different in "Theis' formula" and "Jacob's formula". They also differ from drill hole to bore hole. Even though the ground water from J-No.1 to J-No.4 is all fissure water present in sandstone and slate, the critical discharge and specific yield from J-No.3 are much greater than those of the three others. It would be safe to place the average coefficients of acquifer for J-No.1 - J-No.2 as $T = 1.5 \times 10^{-4}$ m^2/sec. for transmission coefficient, as storage coefficient about $S = 4.00 \times 10^{-3}$ judging from drawdown.

(4) Water Quality Test

Temperature, PH value and electric conductivity of surface water (river, dam) and ground (deep wells, shallow wells) water were measured.

The results of the test are tabulated in following Table. The details of the test are shown in Table 5-8.

Results of Water Quality Test

type of water	sub-classification	temperature	PH	electric conductivity at 25°C 1μʊ/cm
surface water	river	31.0-35.0	6.6-6.8	320-797
	reservoir	37.0	6.6	540
ground water	shallow well	28.0-30.0	6.6-6.8	580-885
	existing deep well	27.0-30.0	7.2-7.4	380-795
	holes of test drilling	27.0-28.0	6.9-7.4	475-780.7

The water temperature is lower in the order of deep wells, shallow wells, rivers and the reservoir. PH values of the surface water and the water of shallow wells are similar to each other both indicating slight acidity, whereas the PH values of the water of deep wells are PH=7.2-7.4 indicating slight alkalinity. The value of electric conductivity is greatest in the water of shallow wells and then in the water of deep wells and surface water in the descending order.

It is judged that the surface water and the water of shallow wells are fairly similar in quality and rather different from the water of deep wells.

Also, the similarity and difference apply in the mode of occurrence of these types of water.

The results of laboratory quality analysis of the water from the bore holes are as shown in Appendix-D. They are also summarized in Table 5-9.

It is shown that the amount of total solids of the water from all the bore holes exceeds the Thai standard of water quality. Also the total hardness, iron content and turbidity of J-No.2 and J-No.3 exceeds the Thai Standards, of which the values of total solids and turbidity, plausible immediately after the completion of drilling, are considered to reduce as pumping is continued. The value of total hardness is below the dangerous level of the international water quality standards of

World Health Organization.

The water from the bore holes is judged to fit to drink by the results of the laboratory analysis according to which the toxic substances of lead and arsenic are undetected or very weak in concentration.

But iron, present in excess in the water of J-No.2 and J-No.3, should be removed.

(5) Quantitative Evaluation of Ground Water Refill

The camp is located near the origin of Saen Tiu River shose discharge basin is about 5.11 km^2. The zone of recharge storage of the ground water obtained in the camp, as mentioned in "The Mode of Ground Water Occurrence", is the hills located upstreams. The period of refill is considered to be the six month from May through October during which rainfall exceeds evaporation. Here is a quantitative evaluation of ground water refill in the discharge basin where the camp is located.

The annual ground water refill can be obtained by the following formula.

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

where,

- Qr : ground water refill
- P : precipitation
- D : runoff
- E : evaporation
- Ar : area of discharge basin

The ground water refill arrived at from the above formula is as follows.

Ground Water Refill

discharge basin Ar (km^2)	precipitation P (mm/yer)	runoff D (mm/yer)	evaporation E (mm/yer)	infiltation G=P-(D+E)	recharge storage Qr=ArxG
5.11	1,236.2	494.48	560.84	180.88	924.297

The computed quantity of ground water refill is about 920,000 m^3/year.

The current total quantity of exploited ground water is about 200,000 m^3/year from deep wells, which is equivalent to approximately 22% of the total annual refill.

This evaluation arrived at mostly according to existing data, however, might desirably be refined in the future by more actual observation.

(6) Pumping Conditions and Influence Area

There is a few pumping test record of existing deep wells in the camp.

Therefore pumping conditions and radius of influence area shall be treated here on the basis of the pumping test conducted in the bore holes made by the study team in the camp.

.coefficients of acquifer

$T = 1.50 \times 10^{-4}$ m^2/sec

$S = 0.004$

.pumping conditions

Qc = 156 ℓ/m (average critical discharge of J-No.1, J-No.2 .....)

Q = 112.3 m^3/day (operating 12 hrs/day)

T = 6.48 m^2/day (1.5×10^{-4} m^2/sec x 43,200 sec)

S = 0.004

From the above conditions, s and u are as follows.

$$s = \frac{Q}{4\pi T} W(u)$$

$$= 1.38\ W(u) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

$$u = \frac{S \cdot r^2}{4Tt}$$

$$= 1.543 \times 10^{-4} \frac{r^2}{t} \quad \ldots\ldots\ldots\ldots \quad 2$$

where,

Q : yield (m^3/day)

T : transmission coefficient (m^2/day)

S : storage coefficient

W(u), u : well function

s : draw down

r : radius of influence area

t : time of continuous pumping

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

time of continuous pumping	draw down (m)	radius of influence
1 day	19.04	58
30 days	23.32	380
120 days	26.22	680
365 days	27.46	1,400

It is concluded now, the theoretical radius of influence area of a well in the camp, if it is pumped 112.3 m^3/day for a year, is 1,400 m, which means that a given pair of wells should be about 2,800 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 300 - 400 m is fairly safe provided that pumping takes place intermittently, since the volume of pumpage at the beginning of pumping is relatively greater than it at the routine pumping time, and intermittent pumping procedure may contribute to shortening of pumping time, thus enabling faster recovery of the water level of well.

The appropriate number of deep wells (40 m deep, 4" diameter) to be made in the Camp and the total economic yield of them are 13 wells and 1,460 m^3/day, respectively, on the conditions that the total land area of the camp is 113 ha and minimum well-to-well distance is 300 m.

The existing deep wells (24 m - 52.5 m deep) in the Camp, incidentally, are operated under rather poor pumping efficiency, especially so, in the case of No.7 and No.10 (Hospital) located 65 m apart from each other, since the well-to-well distance of them is 65 m - 200 m which causes excessive mutual influence in the event of simultaneous pumping.

(7) Recommended Future Development of Ground Water

It has been estimated that the quantity of ground water refill is about 920,000 m^3/day, appropriate number of wells (40 m deep, 4" diameter) 13, and total economic discharge 1,460 m^3/day (about 52.3 m^3/year).

The evalue of the economic discharge is equivalent to about 56.6% of the quantity of ground water refill.

On the other hand, the total water requirement, if the benefied population is 50,000 and per capita rationing rate is UNHCR's 35 ℓ/day/person, 1,750 m^3/day (about 640,000 m^3/year).

So, the required amount of water exceeds the economic critical discharge. Therefore, it is impossible to depend solely on the ground water from the Camp area for catering to the total requirements, but what is short should be supplied from outside.

In making a comprehensive pumping plan of the wells, it is necessary to be fully cautions to secure sufficient potential of ground water refill. Excessive pumpage from a certain well, or exploitation of ground water in excess of the total economic critical discharge frequently give rise to ground water pollution.

Since, at present, there are twelve deep wells (24 - 52.5 m deep, well-to-well distance 65 m - 200 m), yielding tally 560 m^3/day and the total economic discharge in the Camp area is 1,460 m^3/day, the quantity of ground water exploitable to the future is 900 m^3/day.

The total critical discharge from the drill holes made in the present study is 663 ℓ/min, which is equivalent to 477 m^3/day if they are pumped 12 hours a day.

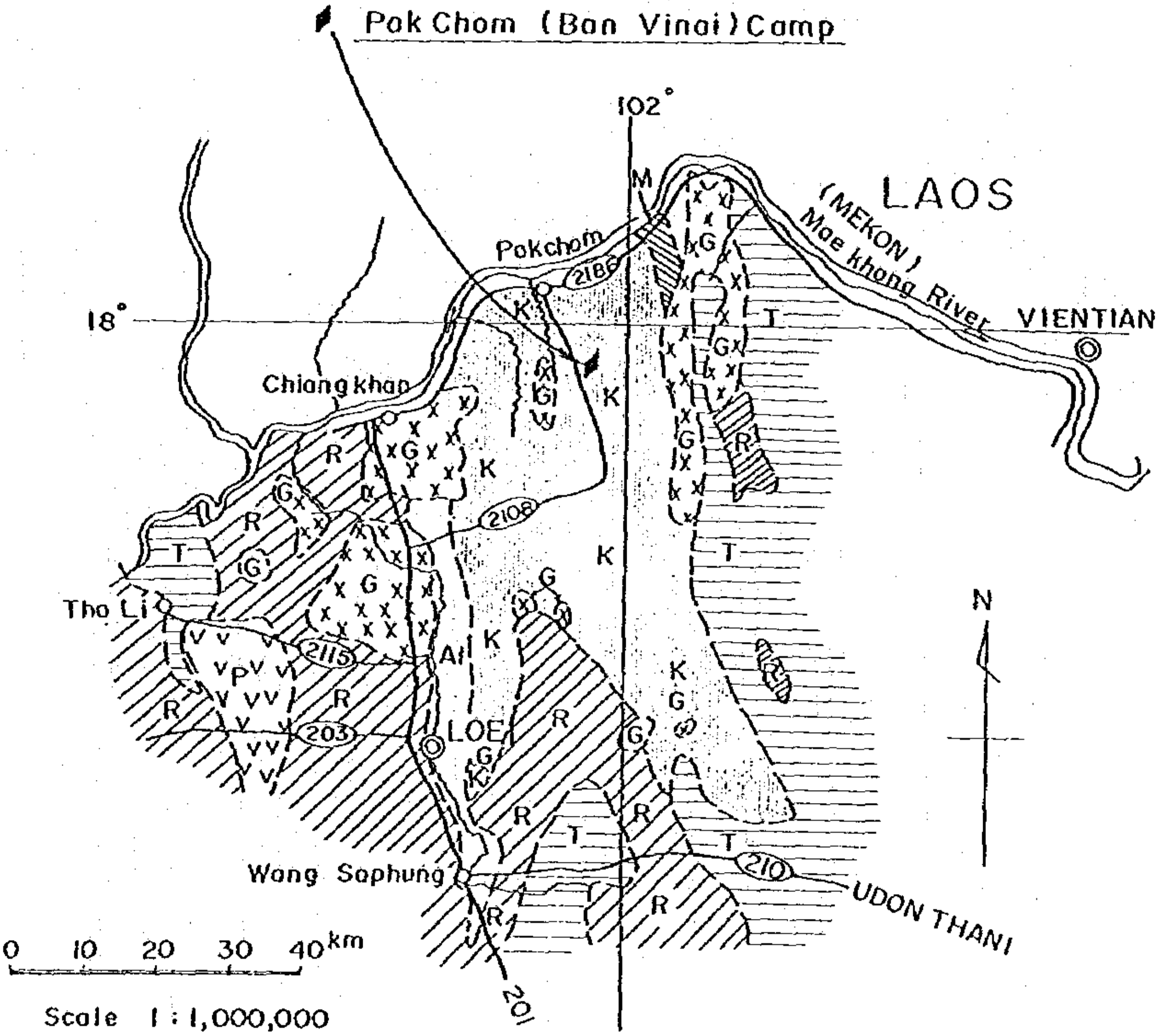
So, the total quantity of water, in addition to the quantity obtainable from the bore holes, is 423 m^3/day.

This additionally obtainable quantity of ground water, in the light of the average discharge of the bore holes (m^3/day), is equivalent to three wells.

But the practical number of additional wells (40 m deep, 4" diameter) should be two, considering the location of the existing deep wells and the prevailing hydrogeological conditions.

Recommended areas and sites of deep wells to be made additionally are shown in Fig. 5-9.

Fig. 5-1 Geological Map



LEGEND

Al	Alluvium eluvium valley fill and river gravel
T	Micaceous shale with some siltstone micaceous sandstone and conglomerate
R	Limestone interbeded shale, mudstone conglomerate and tuff
K	Greywacke, mudstone and siltstone. Shale with pebbles of quartz, quarzite slate and granite
G	Granite and granodiorite
P	Porphyry
M	Mafic and ultromafic

Fig. 5-2 Annual Rainfall at Loei for the Period 1954 - 1980

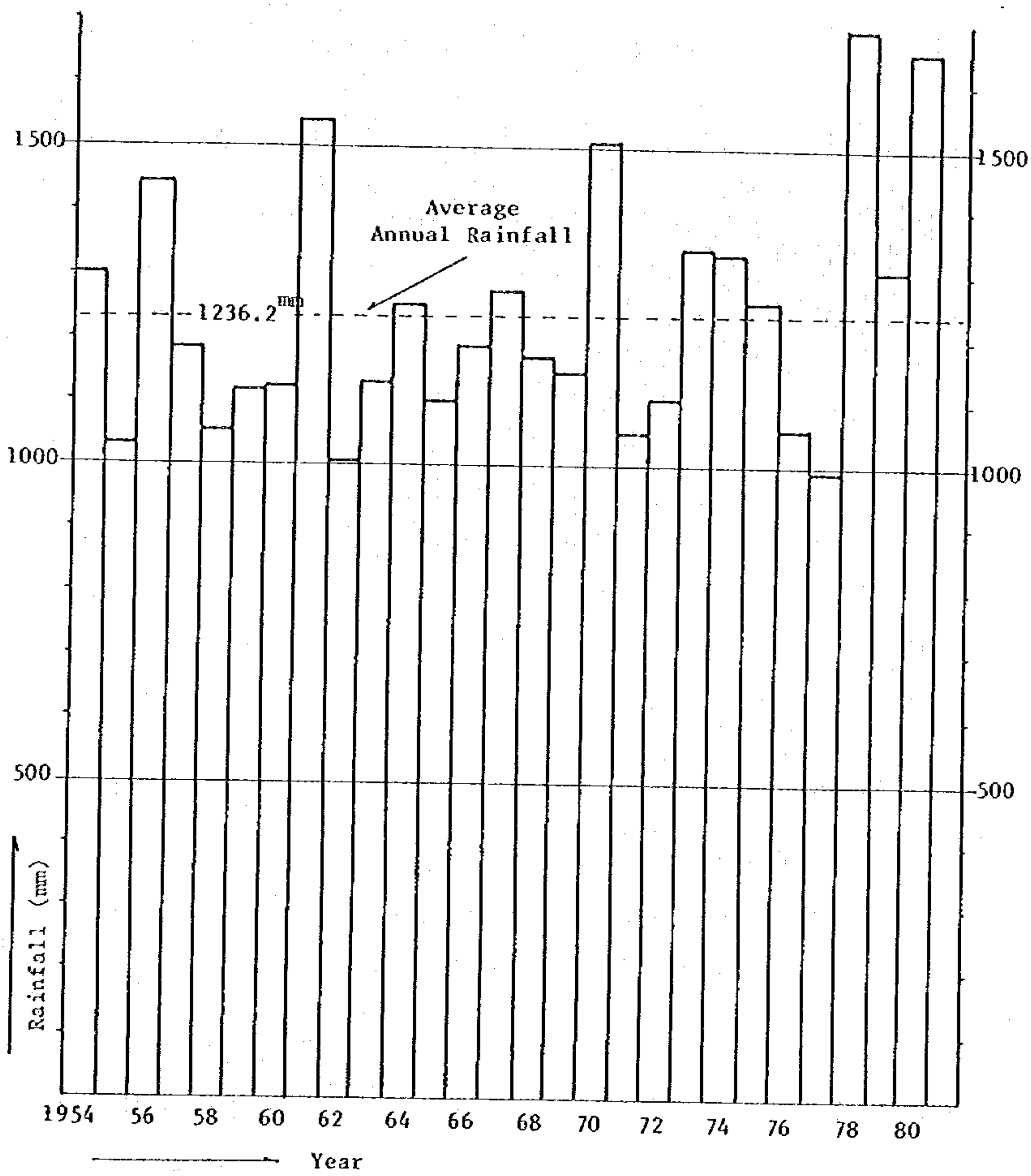


Fig. 5-3 Average Monthly Rainfall at Loei for the Period 1954 - 1980

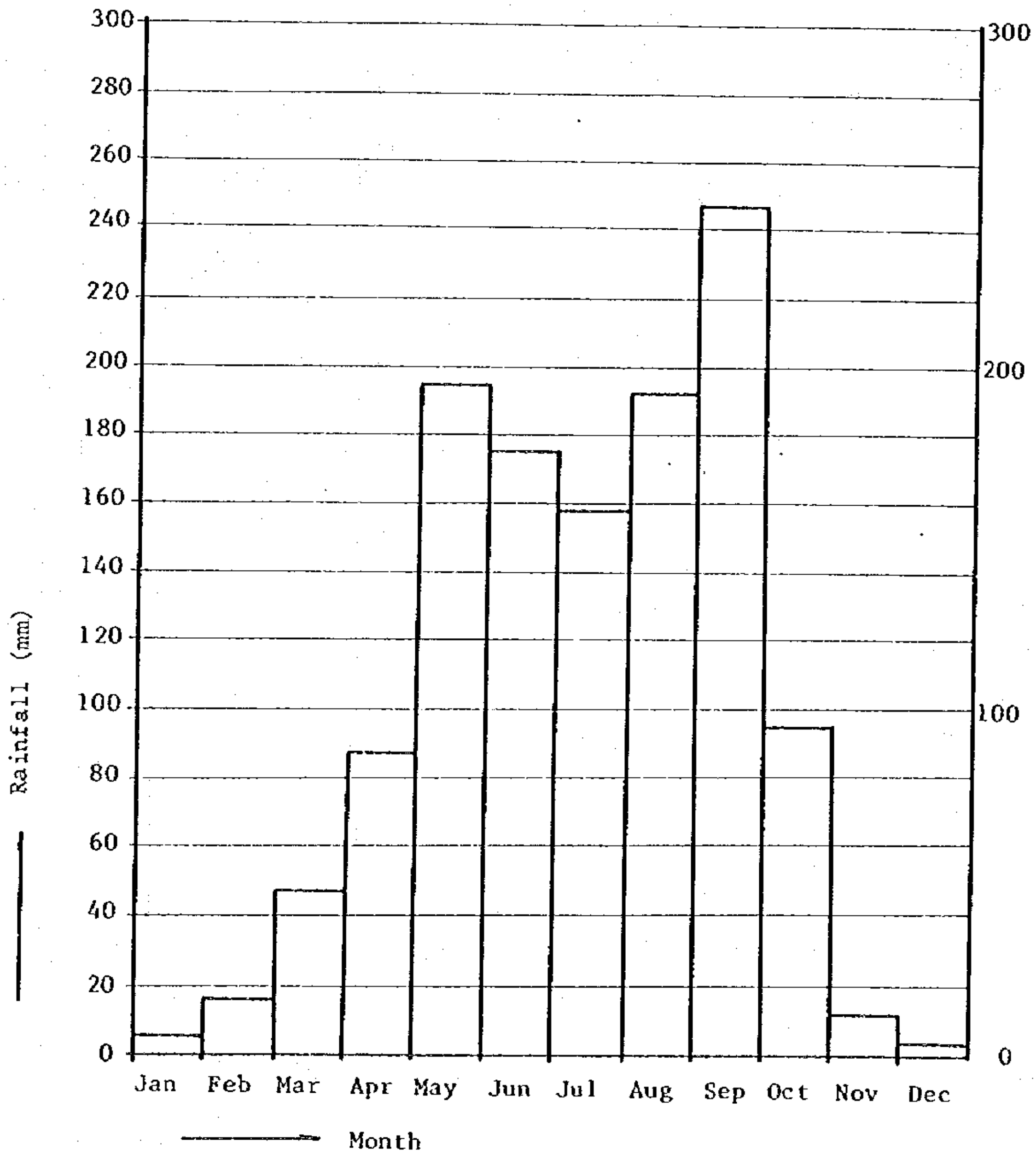


Fig. 5-4 Monthly Mean Rainfall, Evaporation and Temperature at Loei

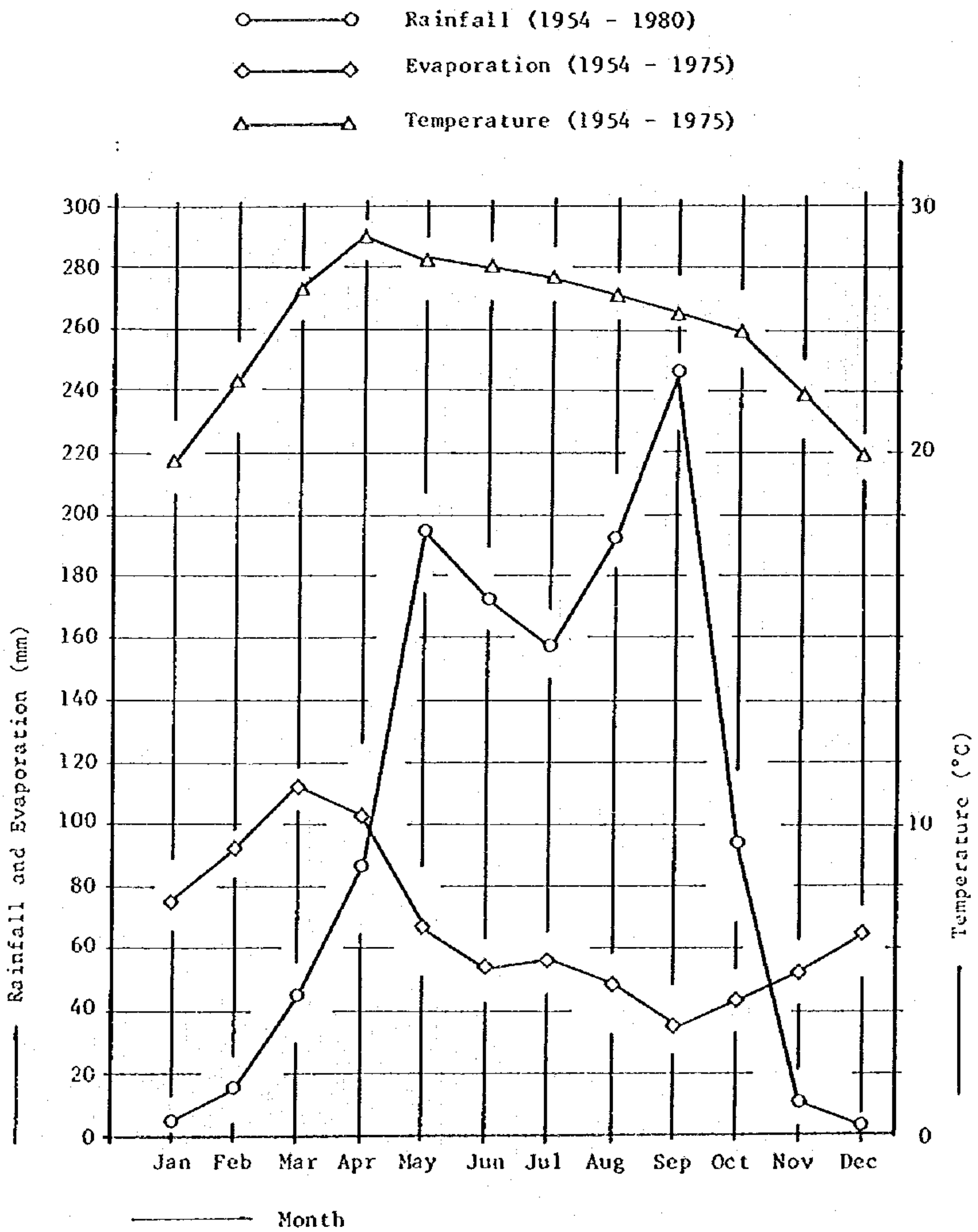


Fig. 5-5 E-W Geological Section (Pac Chom Camp)

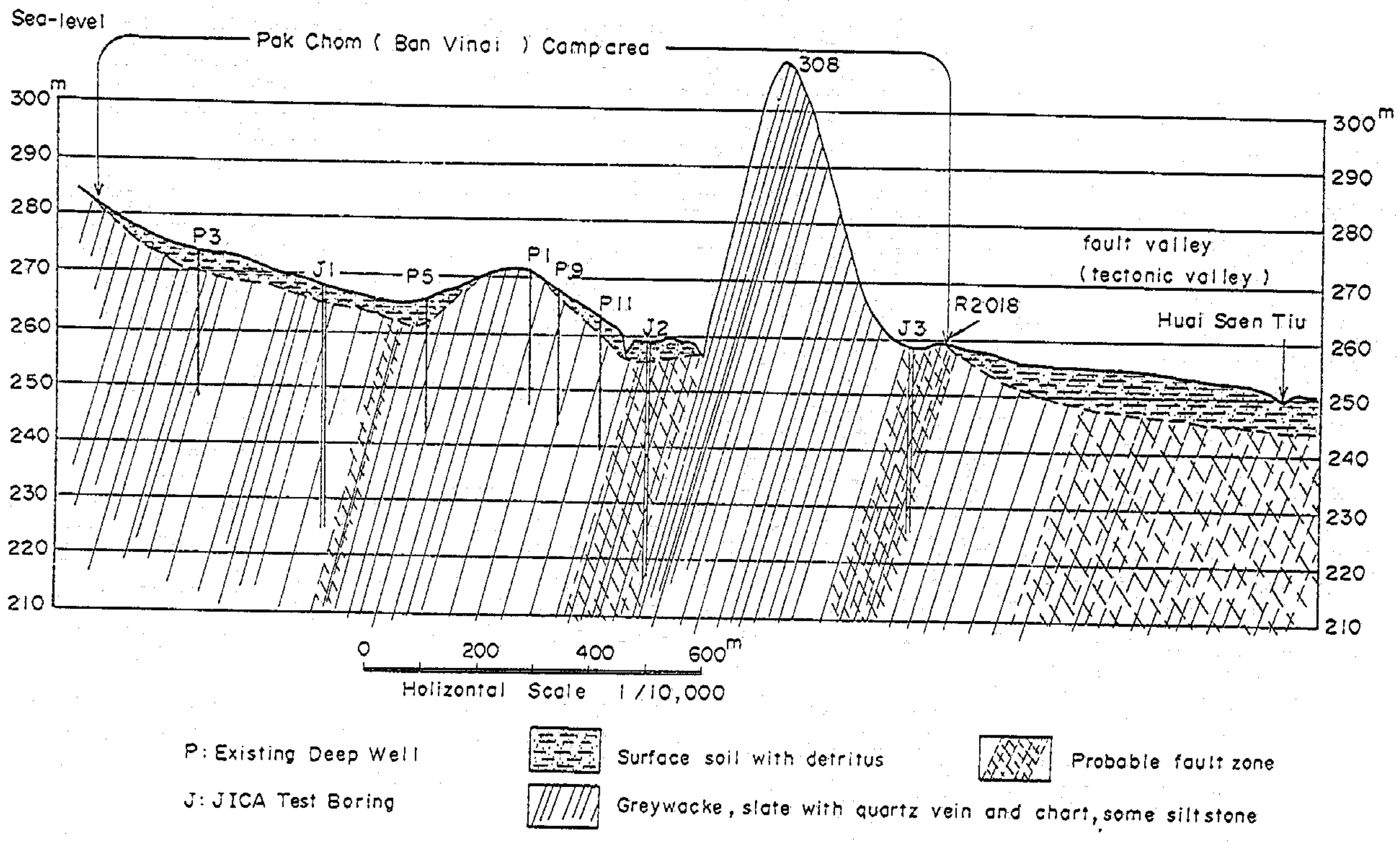


Fig. 5-6 Hydrogeological Map

by Dept. of Mineral Resources,
Ministry of Industry, Thailand, 1973

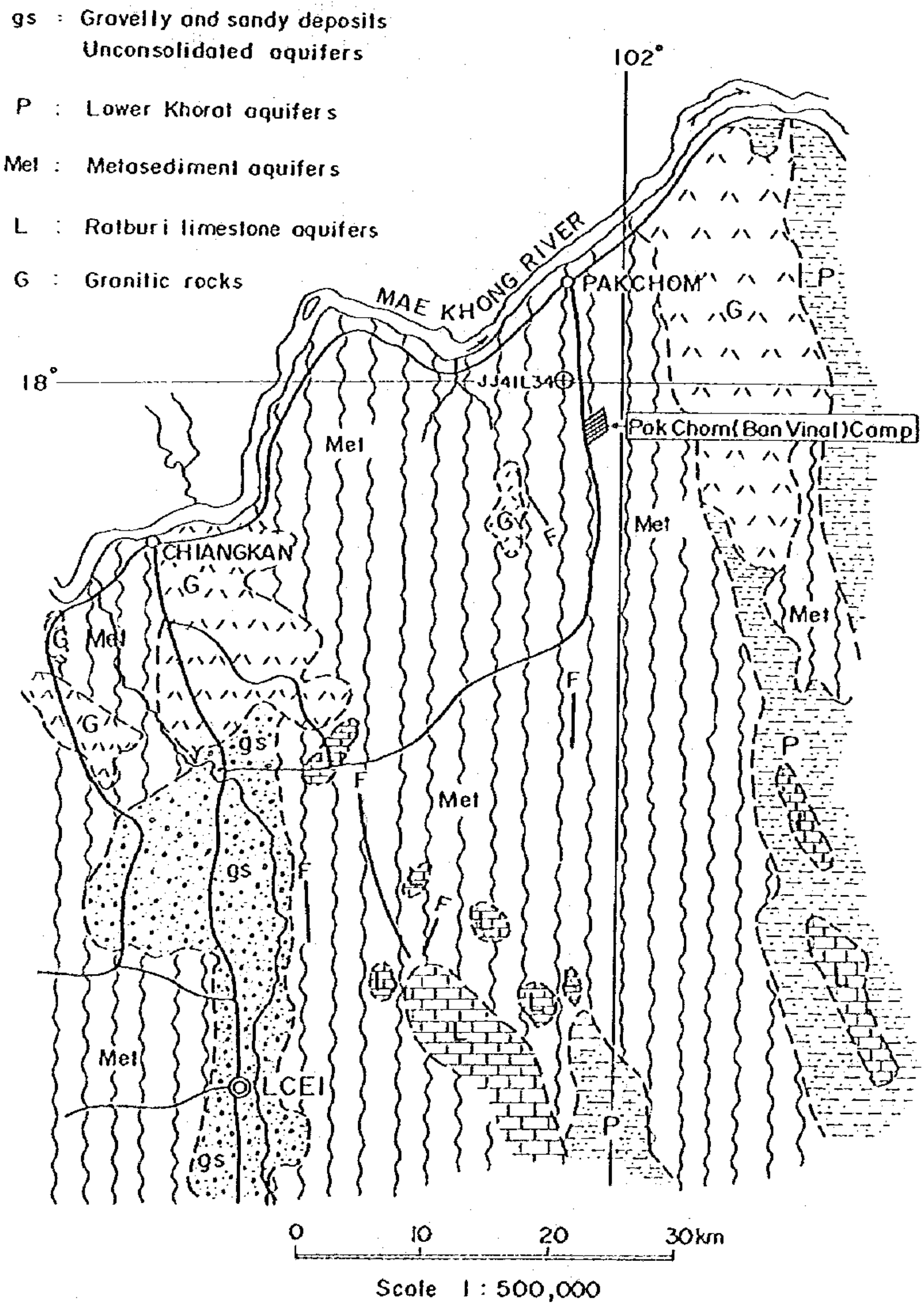
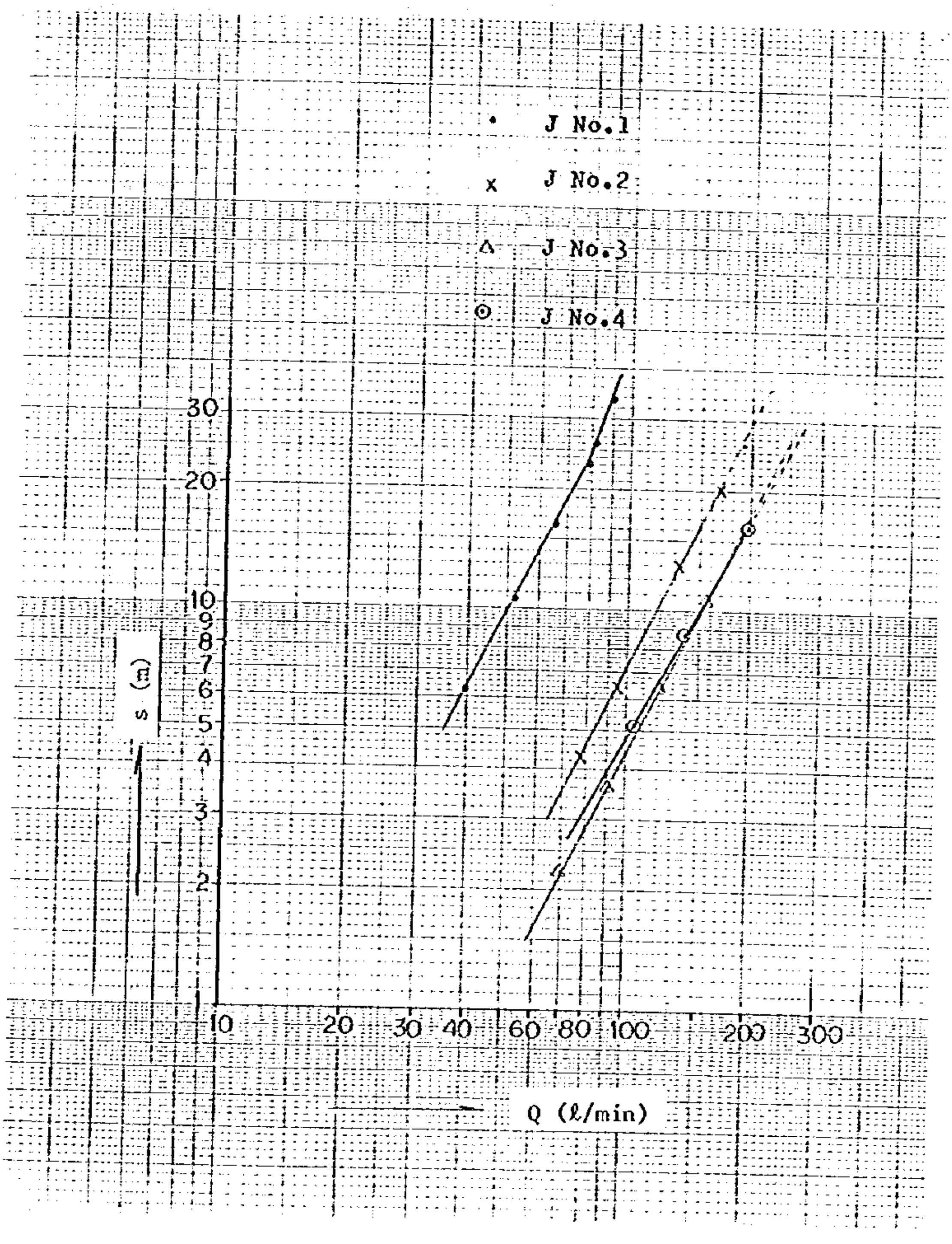


Fig. 5-7 s - Q



• J No.1
x J No.2
Δ J No.3
⊙ J No.4
30
20
10
9
8
7
6
5
4
3
2
1
s (m)
10
20
30
40
60
80
100
200
300
Q (ℓ/min)

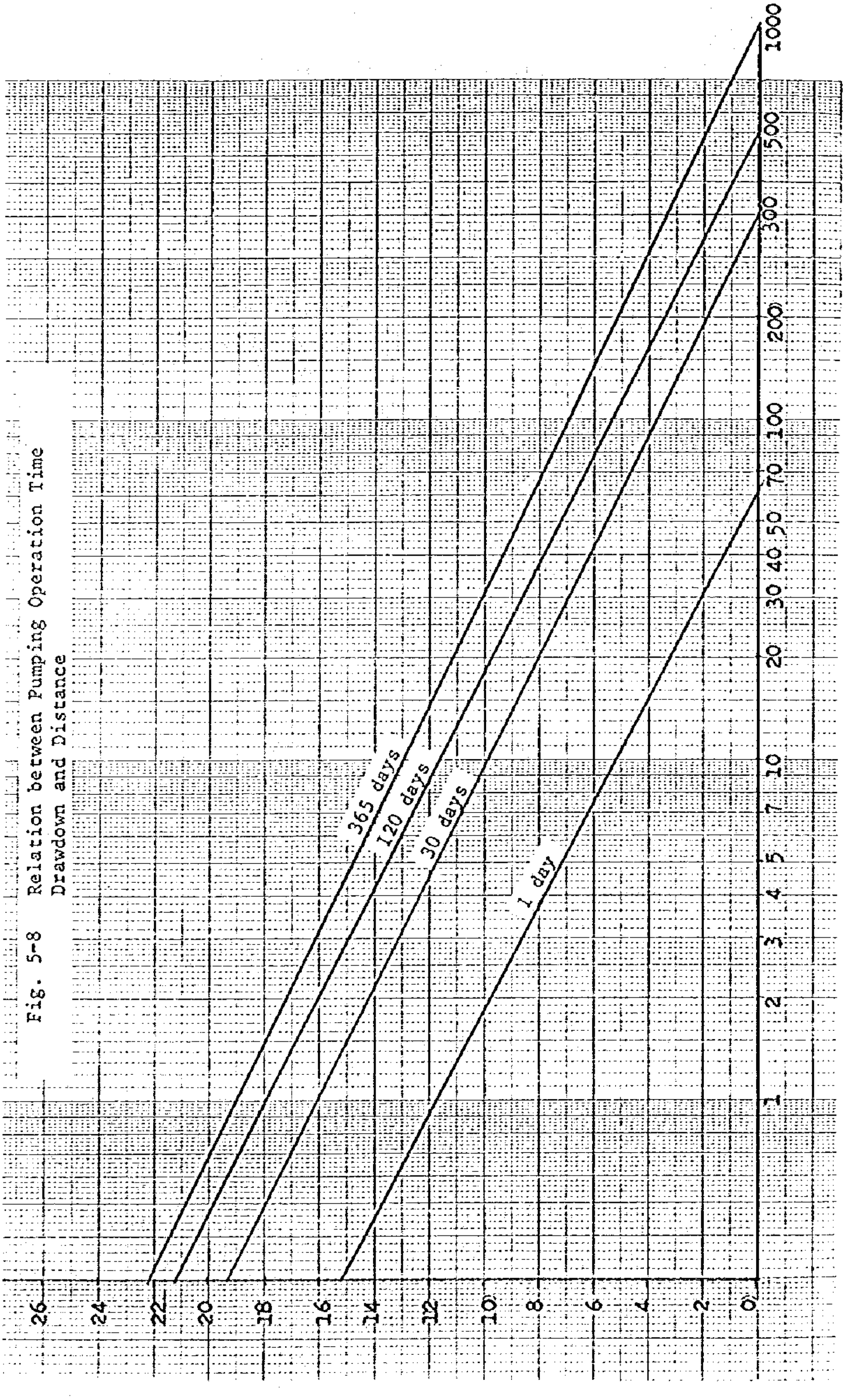
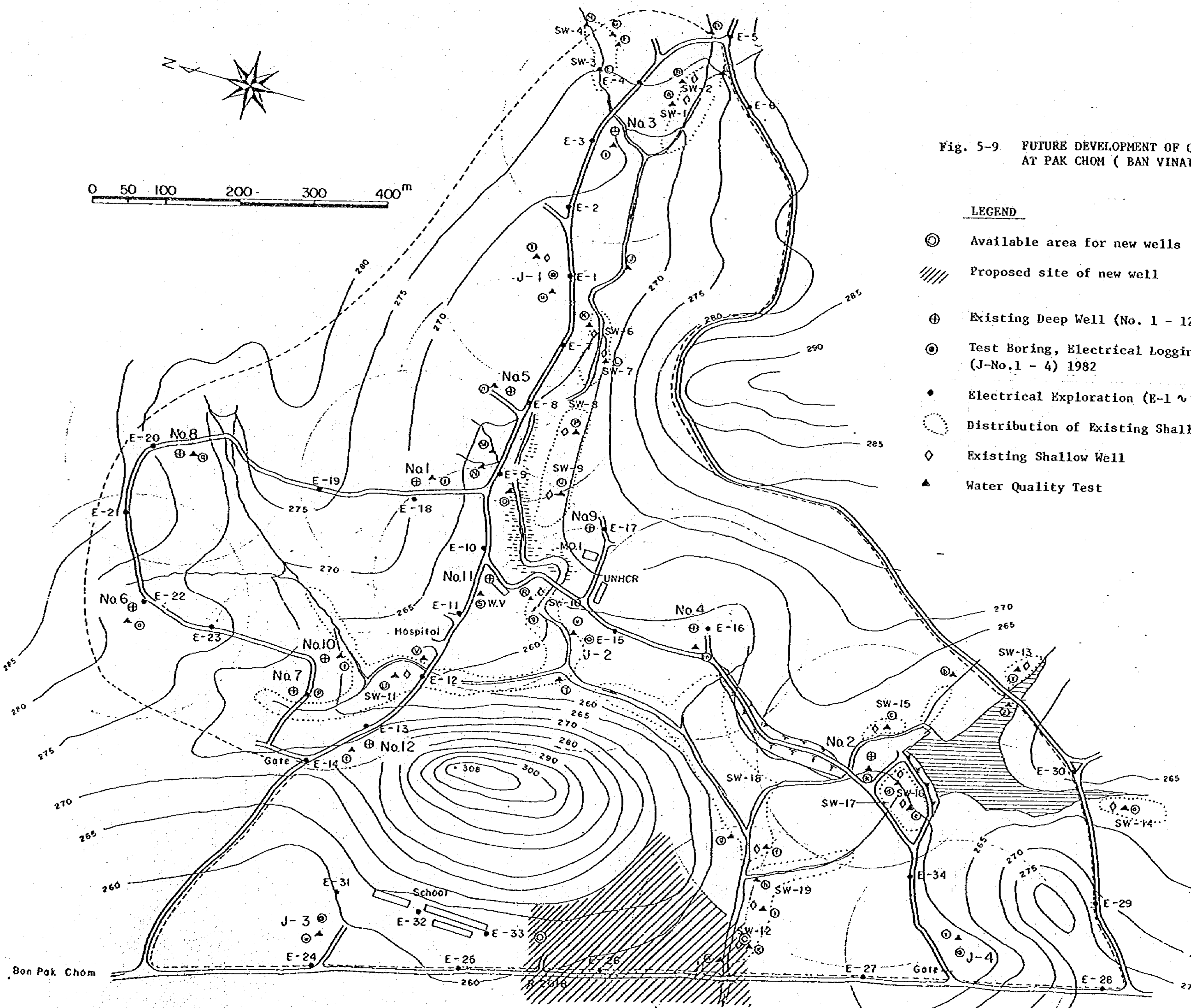


Fig. 5-8 Relation between Pumping Operation Time Drawdown and Distance

Fig. 5-9 FUTURE DEVELOPMENT OF GROUNDWATER AT PAK CHOM (BAN VINAI) CAMP



LEGEND

- ◎ Available area for new wells
- //// Proposed site of new well
- ⊕ Existing Deep Well (No. 1 - 12)
- ⊙ Test Boring, Electrical Logging and Pumping Test (J-No.1 - 4) 1982
- • Electrical Exploration (E-1 ∼ E-34) 1982
- ⁘ Distribution of Existing Shallow Well
- ◇ Existing Shallow Well
- ▲ Water Quality Test

Table 5-1 Stratigraphic Classification

Symbol	Sedimentary and Metamorphic Rocks	Age
Al	Alluvium, eluvium, vaileyfill and river gravel	Quaternary to Recent
	PHU KRADUNG FORMATION	
T	Predominantly dark brown, grayish brown, red micaceous shale with some siltstone, micaceous sandstone and conglomerate	Jurassic and Triassic
	RATBURI FORMATION	
R	Massive light gray limestone inter-bedded with shale, sandstone, mudstone, conglomerate and volcanic tuff	Carboniferous and Premian
	KAENG KRACHAN FORMATION	
K	A thick sequence of poorly bedded greywacke, mudstone and siltstone. Limestone occurs locally. A group of well bedded black and gray shale and light coloured sandstone with pebbles of quartz, quarizite, slate and granite	Carboniferous Devonian and silurian

Symbol	Igneous Rocks	Age
G	Granite and granodiorite	Triassic
P	Porphyry	Pre-triassic
M	Mafic and ultramafic	Carboniferous

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

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Evaporation (mm) 1954 - 1975	75.7	92.2	111.9	102.8	66.9	53.9	56.4	49.0	34.7	43.8	51.0	62.9	801.2
Temperature (°C) 1954 - 1975	21.7	24.3	27.2	28.9	28.2	27.9	27.6	27.1	26.5	25.8	23.9	21.9	25.9
Rainfall (mm)	5.8	16.4	47.2	87.6	195.3	174.7	159.0	193.0	247.0	94.8	11.7	3.7	1,236.2

Table 5-3 Monthly and Annual Rainfall for the Period 1951 - 1980

Station : Loei
Index Station 48: 353
Latitude : 17° 27' N.
Loongitude : 101° 44' E.

Elevation of station above MSL: 252.52 meters
Height of raingauge : 1.00 meters
(Above MSL : 253.52 meters)

YEAR	JAN	FEB	MAR	ARP	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1951	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	-	-	-	-	-	-	-	-	-	-	-	-	-
1954	0.0	2.3	47.3	67.8	228.5	124.2	65.4	225.9	336.5	196.6	4.9	2.0	1301.4
1955	0.0	9.7	116.7	119.2	95.9	302.9	92.4	146.9	138.7	6.5	5.9	0.0	1034.8
1956	0.0	42.4	56.9	83.5	190.8	141.1	401.0	211.9	248.6	70.6	2.5	0.5	1449.8
1957	10.3	5.2	134.1	98.7	146.6	214.4	106.3	188.6	242.2	38.9	0.0	0.0	1185.3
1958	14.2	13.9	25.1	8.6	48.4	171.8	77.4	420.4	158.5	116.3	0.9	0.0	1055.5
1959	7.5	19.1	60.6	34.8	170.3	170.5	164.2	74.8	403.4	10.7	3.8	0.1	1119.8
1960	2.9	0.3	51.0	101.2	198.8	70.6	195.9	127.0	209.0	154.2	9.6	0.5	1121.1
1961	1.6	32.3	48.2	130.0	252.1	179.8	111.0	174.0	418.9	192.8	2.0	0.0	1542.5
1962	0.8	0.0	20.9	70.7	203.0	93.3	112.3	223.5	145.4	131.8	1.7	4.4	1007.8
1963	0.0	0.5	63.3	52.6	98.7	140.3	122.4	262.3	192.7	150.9	41.9	2.3	1127.9
1964	8.1	5.2	35.9	129.7	298.3	54.4	166.6	159.1	162.9	210.6	6.5	4.1	1251.4
1965	0.0	25.3	31.7	75.2	176.7	101.2	90.2	300.3	216.5	48.7	34.8	0.0	1100.6
1966	4.4	11.1	43.4	69.6	388.8	82.0	126.8	192.6	131.2	72.9	21.4	39.9	1184.1
1967	3.3	38.3	1.1	102.2	120.4	135.5	171.1	110.3	527.8	31.4	33.1	0.0	1274.5
1968	0.2	0.4	19.7	168.4	241.9	187.8	193.6	172.3	137.7	48.8	0.5	0.0	1171.3
1969	36.8	0.0	29.0	87.1	157.4	193.9	187.8	102.7	212.9	85.9	53.8	0.0	1147.3
1970	4.2	4.4	55.0	166.7	277.9	388.9	52.0	264.1	296.3	41.5	5.8	2.0	1508.8
1971	0.8	8.3	30.8	20.1	158.1	151.0	98.1	248.9	225.3	102.8	3.4	5.3	1052.9
1972	0.0	24.7	27.9	73.1	77.5	211.7	88.8	119.6	245.9	189.2	21.8	33.8	1114.0
1973	0.0	0.0	62.0	48.8	185.6	242.4	158.8	158.1	465.2	20.2	0.6	0.0	1340.6
1974	3.1	4.6	67.1	178.3	152.8	49.3	120.2	350.7	197.8	163.5	45.1	1.9	1334.4
1975	43.1	32.0	52.8	31.9	304.2	135.1	176.6	103.0	263.5	117.6	1.3	0.0	1261.1
1976	0.0	53.1	4.5	67.0	165.5	144.5	162.4	150.3	178.5	123.5	8.4	0.0	1057.7
1977	12.0	0.0	42.2	153.0	106.5	66.1	173.5	179.1	165.8	85.8	4.1	2.0	990.1
1978	3.0	7.9	71.4	52.2	228.1	199.6	508.5	381.4	293.2	41.9	0.0	0.0	1687.2
1979	0.0	79.6	8.3	68.4	272.7	442.2	121.3	142.2	165.3	5.4	0.0	0.0	1305.4
1980	0.0	23.3	67.4	106.8	329.1	363.1	247.1	121.1	289.8	100.4	2.7	0.0	1650.8
AVERAGE	5.8	16.4	47.2	87.6	195.3	174.7	159.0	193.0	247.0	94.8	11.7	3.7	1236.2

Remarks: - = no report

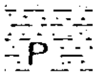
Table 5-4 Legend of Hydrogeological Map

Unconsolidated Aquifers (Alluvium, Holocene)

Gravelly or sand deposites.

Consisted of older and younger alluviums in river terraces and active flood plains.

Almost 100% of wells have good quality water.



Lower Khorat Aquifers (Upper Traissic to Jurassic)

Consisted of shale, sandstone and siltstone, some conglomerate.

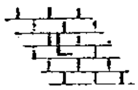
Peneplain-type topography. Mostly dissected mountainous region.

Almost 100% of wells have good quality water.

Metasediment Aquifers (Devonian to Permian)

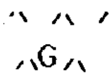
Consisted of shale, siltstone, sandstone, greywacke and limestone; in place phyllite, shale and quartzite.

Ground water in jointed massive rocks.



Ratburi Limestone Aquifers (Permocarboniferous)

Consisted mainly of cavernous limestone; with interbedding shale or chert beds.



Granitic Rocks (Trassic and Tertiary)

Consisted of older granite and granodiorite, and younger diorite.

Ground water yields mainly from jointed in volcanic rocks.

Fault

Table 5-5 Existing Shallow Wells in the Camp

Location No.	Depth (m)	Water level (m)	Diameter (m)	Amount of Pumped Water (m^3/day)	Remarks	
					Drinking Water	Un-drinking Water
SW-1	2.75	1.35	1.0	4.00	o	o
2	3.45	1.10	1.2	5.00	o	o
3	1.78	0.80	1.0	0.50	o	o
4	3.00	1.50	1.0	4.80	o	o
5	4.70	2.20	1.0	4.80	o	o
6	2.90	0.20	1.0	0.55	x	o
7	3.20	1.45	1.0	1.00	x	o
8	4.48	2.17	1.0	1.20	x	o
9	4.06	0.86	1.0	2.40	x	o
10	4.20	0.73	1.0	0.50	x	o
11	4.10	0.35	0.0	1.00	x	o
12	3.58	1.02	1.0	0.80	x	o
13	2.50	0.90	1.0	0.50	o	o
14	2.87	1.10	1.0	0.50	o	o
15	4.10	1.40	1.0	0.50	x	0
16	3.40	1.10	1.0	0.90	x	o
17	3.85	0.75	1.0	0.60	x	o
18	1.85	0.50	1.0	0.50	x	o
19	4.70	1.03	1.0	4.80	x	o

Table 5-6 Water Pump Working of The Deep Wells
Pak Chom Camp (June 1982)

Well-Pump No.	Amount Liter	Pump work (minutes)	Yield* (liter/min)	Pumping work schedule	
				Morning	Afternoon
1	69,920	900	77.69	01:00-09:00	13:00-20:00
2	48,640	720	67.56	02:00-08:00	13:00-19:00
3	48,640	660	73.69	02:00-08:00	13:00-18:00
4	88,160	1020	86.43	01:00-09:00	12:00-21:00
5	33,440	540	61.93	03:00-08:00	13:00-17:00
6	33,440	660	50.67	02:00-08:00	13:00-18:00
7	51,680	660	78.30	02:00-08:00	13:00-18:00
8	57,760	790	73.11	01:00-08:00	12:00-18:10
9 Headquarter	42,560	720	59.11	02:00-08:00	13:00-19:00
10 Hospital	42,560	660	64.48	02:00-07:00	11:00-19:00
11 Police	27,360	660	41.45	02:00-08:00	13:00-18:00
12 Hand-pump	16,000			anytime	
TOTAL	560,160				

* Yield: Actual pumping up capacity

Table 5-7 List of Existing Deep Wells in the Camp

Location	Depth	Water Level	Yield	Diameter	Amount of Pumped Water	Actual Pumping rate	Actual draw down	Columnar section
	m	m	l/min	inch	m^3/day	l/min	m	
No.1	42.3	3.6 (6.0)	170.1	6	69.92	77.69	(21.0)	o
No.2	(36.0)	- (15.0)		6	48.64	67.56	(12.0)	x
No.3	(24.0)	- (15.0)		6	48.64	73.69	(6.0)	x
No.4	40.5	2.1 (6.0)	158.8	4	88.16	86.43	(12.0)	o
No.5	(24.0)	- (6.0)		6	33.44	61.93	(15.0)	x
No.6	(42.0)	- (18.0)		6	33.44	50.67	(18.0)	x
No.7	(37.5)	- (12.0)		5	51.68	78.30	(12.0)	x
No.8	(24.0)	- (9.0)		6	57.76	73.11	(12.0)	x
No.9 Headquarter	(24.0)	- (9.0)		6	42.56	59.11	(12.0)	x
No.10 Hospital	(24.0)	- (12.0)		6	42.56	64.48	(9.0)	x
No.11 Police	(24.0)	- (12.0)		6	27.36	41.45	(9.0)	x
No.12 Hand pump	52.5	9.0 (-)	94.6	4	16.00	22.22	-	o

Remarks: ( ) Numerical value by informed persons or estimation.

Table 5-8 Measurement of Water Auality

Location No.		Kind of Water	Water Temperature (°C)	Specific Conductivity at 25°C (μV/cm)	PH
A	(SW-1)	Shallow well	30.0	611.2	6.8
B	(SW-2)	Shallow well	28.5	653.2	6.8
C		River	31.0	473.2	6.8
D		River	32.0	489.5	6.6
E		River	33.5	352.6	6.6
F	(SW-3)	Shallow well	28.0	601.6	6.8
G	(SW-4)	Shallow well	30.0	727.4	6.8
H		River	33.5	460.1	6.6
I	(SW-5)	Shallow well	28.0	658.0	6.8
J		River	34.0	510.0	6.6
K	(SW-6)	Shallow well	28.5	589.1	6.6
L	(SW-7)	Shallow well	28.0	864.8	6.8
M		River	34.0	340.0	6.6
N		River	33.0	516.0	6.8
O		River	35.0	797.4	6.8
P	(SW-8)	Shallow well	28.5	883.6	6.8
Q	(SW-9)	Shallow well	30.0	677.1	6.4
R	(SW-10)	Shallow well	29.0	668.0	6.4
S		River	35.0	739.2	6.6
T		River	35.0	768.2	6.8
U	(SW-11)	Shallow well	29.0	823.5	6.6
V		River	36.0	492.0	6.4
W		River	35.0	520.8	6.6
X	(SW-12)	Shallow well	29.0	581.0	6.6
Y	(SW-13)	Shallow well	30.5	782.6	6.6
Z		Dam	37.0	539.4	6.6
a	(SW-14)	Shallow well	29.0	828.1	6.6
b		River	31.0	320.4	6.6
c	(SW-15)	Shallow well	29.0	414.0	6.6
d	(SW-16)	Shallow well	30.0	677.1	6.6

Location No.		Kind of Water	Water Temperature (°C)	Specific Conductivity at 25°C (μν/cm)	PH
e	(SW-17)	Shallow well	28.0	374.0	6.6
f	(SW-18)	Shallow well	29.5	878.4	6.6
g		River	35.0	425.0	6.8
h		River	32.0	445.0	6.6
i	(SW-19)	Shallow well	30.0	618.8	6.0
j	(No.1)	Deep well	28.0	752.0	7.4
k	(No.2)	Deep well	27.0	384.0	7.4
l	(No.3)	Deep well	28.5	795.0	7.2
m	(No.4)	Deep well	27.0	672.0	7.2
n	(No.5)	Deep well	30.0	549.0	7.2
o	(No.6)	Deep well	-	420.0	7.2
p	(No.7)	Deep well	29.0	736.0	7.4
q	(No.8)	Deep well	29.0	460.0	7.4
r	(Hospital)	Deep well	30.0	778.0	7.2
s	(Police)	Deep well	28.0	608.0	7.2
t	(Hand pump)	Deep well	27.5	480.0	6.6
u	(J-No.1)	Bore hole	28.0	710.0	7.4
v	(J-No.2)	Bore hole	28.0	780.0	7.3
w	(J-No.3)	Bore hole	27.0	475.0	6.9
x	(J-No.4)	Bore hole	27.0	800.0	6.8

Table 5-9 Result of Water Quality Analysis

Constituents	J-No.1	N-No.2	J-No.3	J-No.4	Thai Standards	* WHO	
						tolerance	harmful level
Colour, Hazen units	less than 5	less than 5	less than 5	less than 5	20		
Turbidty, Silica scale	4.6	23	25	2.7	5		
PH Value	7.4	7.3	6.9	7.6	6.5-8.5	7.0-8.5	6.5-9.2
Total solids, ppm	563	741	612	556	500	500	1,000
Total hardness ($CaCo_3$), ppm	277	535	474	425	100	500	1,500
Chlorides, (NaCl), ppm	87.4	46.2	11.5	37.9			
Free and saline ammonia (NH_3), ppm	0.03	0.07	0.006	0.006			
Albuminoid ammonia (NH_3), ppm	0.12	0.08	0.004	0.06	0.1		
Nitrate (No_3), ppm	0.06	0.02	0.289	0.02	4.0	10.2	
Nitrite (NO_2), ppm	0.05	0.002	0.003	0.001			
Iron (Fe), ppm	0.36	1.15	1.1	0.039	0.5	0.3	1.0
Lead (Pb), ppm	not found	0.002	not found	not found	0.1		
Arsenic (As), ppm	0.001	0.001	not found	not found	0.05		

* WHO: Water Quality Standards by WHO

Table 5-10 Relation between pumping Operation Time and Drawdown

Pumping Operation Time	Distance from the Well (m)	u	W (u)	s (m)
1 day	0.0508	3.98×10^{-7}	13.8	19.04
	1	1.54×10^{-4}	8.5	11.73
	5	3.86×10^{-3}	5.1	7.04
	7	7.56×10^{-3}	4.4	6.07
30 days	0.0508	1.33×10^{-8}	16.9	23.32
	1	5.14×10^{-6}	11.6	16.01
	10	5.14×10^{-4}	7.2	9.94
	40	8.23×10^{-3}	4.4	6.07
120 days	0.0508	3.32×10^{-9}	19.0	26.22
	1	1.29×10^{-6}	13.0	17.94
	30	1.16×10^{-3}	6.4	8.83
	80	8.23×10^{-3}	4.3	5.93
365 days	0.0508	1.09×10^{-9}	19.9	27.46
	1	4.23×10^{-7}	13.8	19.04
	60	1.52×10^{-3}	6.1	8.42
	130	7.14×10^{-3}	4.5	6.21

6. Recommended Water Supply Project

6-1 Basic Conditions for Planning

(1) Population (Envisaged)

The benefited population envisaged in the present study is 50,000, taking into account the future expansion plan of the Camp.

(2) Rationing Rate

UNHCR's daily per capita rationing rate of 35 ℓ/day/person is adopted.

(3) Total Water Supply Requirement

From (1) and (2) above, the total daily water supply requirement is 1,750 m^3/day (638,750 m^3/year).

6-2 Pumpage of Wells and Shortage

(1) Results of the Study

The critical discharge and Ha (water level) of the existing wells and the study team's bore holes are as follows.

existing deep wells	No.1	Q = 69.92 m^3/day
	No.2	Q = 48.64
	No.3	Q = 48.64
	No.4	Q = 88.16
	No.5	Q = 33.44
	No.6	Q = 33.44
	No.7	Q = 51.68
	No.8	Q = 57.76
	Head quarter	Q = 42.56
	Hospital	Q = 42.56
	Police	Q = 27.36
	Hand pump	Q = 16.00

drill holes	J-No.1	Q = 78.0 ℓ/min,	Ha = 25.95 m
	J-No.2	Q = 190.0 ℓ/min,	Ha = 27.00 m
	J-No.3	Q = 195.0 ℓ/min,	Ha = 21.00 m
	J-No.4	Q = 200.0 ℓ/min,	Ha = 19.55 m

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

On the basis of surveys and pumping test, pumpage from each existing deep well and drill hole is planned.

There shall not be any new undertakings made to the existing deep wells since they are equipped with complete water service facilities, but any additional well to be made from now on shall be with a water tank in order to secure well controlled water servicing practice.

The capacity of the submersible motor pumps installed in the drill holes is as shown in Fig. 6-1. The delivery rate of the pumps will be as follows, if a water tank of about 15 m above the ground level is built for each of them.

bore hole	water level	height of water tank	piping loss in head	total head	yield
J-No.1	25.95	15 m	3 m	43.95 m	166 ℓ/min
J-No.2	27.00	15 m	3 m	45.00 m	163 ℓ/min
J-No.3	21.00	15 m	3 m	39.00 m	178 ℓ/min
J-No.4	19.55	15 m	3 m	37.55 m	180 ℓ/min

Since the pump capacity exceeds the critical discharge in the case of J-No.1, its planned pumpage could be the critical discharge, while, in the case of J-No.2 - No.4, the pump capacity is slightly lower than the critical discharge, so, the planned pumpage could be the pump capacity.

The economic discharge, however, according to customary practice, is usually about 80% of critical discharge.

The advisable discharge in the present case shall be made about 75% of the critical discharge, in the light of the fact that the studies were made during the rainy season, and there could be some mutual interference among wells sometimes located so close to one another as 150 m - 200 m.

So the recommended discharge of the bore holes shall be as follows.

bore hole	critical discharge	recommended pumpage
J-No.1	78 ℓ/min	55 ℓ/min
J-No.2	163 ℓ/min	120 ℓ/min
J-No.3	178 ℓ/min	130 ℓ/min
J-No.4	180 ℓ/min	135 ℓ/min
Total	599 ℓ/min	440 ℓ/min

If the daily operating time of each pump is 12 hours, the total daily pumpage will be 316.8 m^3/day addition of which to the pumpage of the existing deep wells of 560 m^3/day will make the total pumpage 876.8 m^3/day.

(3) Shortage (of Water)

The total water supply requirement of the Camp is 1,750 m^3/day whereas the combined pumpage of the existing deep wells and the bore holes is 876.8 m^3/day indicating that 873.2 m^3/day of water is short.

6-3 Recommended Water Service Facilities

(1) Well

The shortage of 837.2 m^3/day for satisfying the projected water requirement of the Camp is equivalent to 1,213 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. 5-9, within which two wells can be made.

Supposing the two additional wells are made, one near the site of electrical exploration of E-33 and the other near a bridge on prefectural road, possible pumpage is estimated.

The study of the bore holes J-No.1 ∿ J-No.4 revealed the estimated specific capacity is about 12.5 m^3/day/m. (8.68 l/min./m) and drawdown about 16 m.

So, if the depth of the new wells is 40 m, the average critical discharge of each well is 138.9 l/min. and the economic critical discharge 104.2 l/min, which means daily pumpage from one new well is estimated to be 75.0 m^3/day. The volume is made 150 m^3/day with two wells. Even though this still falls short by 723.2 m^3/day. It is necessary to supplement the shortage from water sources (ground water, surface water) outside the Camp.

(2) Water Tank

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

well and drill hole	daily supply
Existing 12 wells	560 m^3/day
J-No.1	40 m^3/day (new)
J-No.2	86 m^3/day (new)
J-No.3	93 m^3/day (new)
J-No.4	97 m^3/day (new)
Total	876 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 Japank 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 12 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	40	10 m^3 (20 m^3 x 1)
J-No.2	86	21 m^3 (30 m^3 x 1)
J-No.3	93	23 m^3 (30 m^3 x 1)
J-No.4	97	24 m^3 (30 m^3 x 1)
proposed No.1	94	23 m^3 (30 m^3 x 1)
No.2	94	23 m^3 (30 m^3 x 1)

Champaing glass type water tower which is easy to build and durable is adopted (Fig.6-2). The proposed sites of the water tanks are at the four locations of the test drilling by the study team and two future well sites as shown in Fig. 5-9.

(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 (Fig. 6-3).

well	daily supply well	daily supply hydrant	number of hydrants
J-No.1	40 m^3/day	18 m^3/day	3
J-No.2	100	18	6
J-No.3	104	18	6
J-No.4	108	18	6
proposed No.1	94	18	6
No.2	94	18	6

For the sake of standardization, J-No.1 ∿ J-No.4 and proposed No.1 and No.2 shall be equipped with the water distribution systems having six hydrants each.

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

◦ Concrete

1.40 x 3.90 x 0.10	= 0.546 m^3
0.80 x 0.25 x 3.90	= 0.780 m^3
0.15 x 0.10 x (3.90 + 0.82 x 2)	= 0.083 m^3
Total	= 1.409 ≑ 1.5 m^3

◦ SG pipe

3/4" : 0.25/2 x 6 + 3.00 + 0.8 + 0.8 = 5.35 ≑ 6 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" 6 pieces

◦ Gravel 1.5 x 4.00 x 0.05 ≑ 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	0	0	400,000	22,000	422,000
J-No.2	0	0	500,000	22,000	522,000
J-No.3	0	0	500,000	22,000	522,000
J-No.4	0	0	500,000	22,000	522,000
proposed No.1	500,000	100,000	500,000	22,000	1,122,000
No.2	500,000	100,000	500,000	22,000	1,122,000
Total	1,000,000	200,000	2,900,000	132,000	4,232,000

(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 40 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^3 400,000 baht/set

(iv) Hydrant

Concrete	3,850 baht	x 1.5 m^3	= 5,775.-
Cobble stone	550	x 0.3 "	= 165.-
pipe (3/4")	290	x 6 m	= 1,740.-
pipe (2")	580	x 5 m	= 2,900.-
pipe (4")	1,100	x 5 m	= 5,500.-
water tap	450	x 6 pieces	= 2,700.-
miscellaneous work			3,220.-
Total			22,000 baht/set

Fig. 6-1 Pump Performance Curve

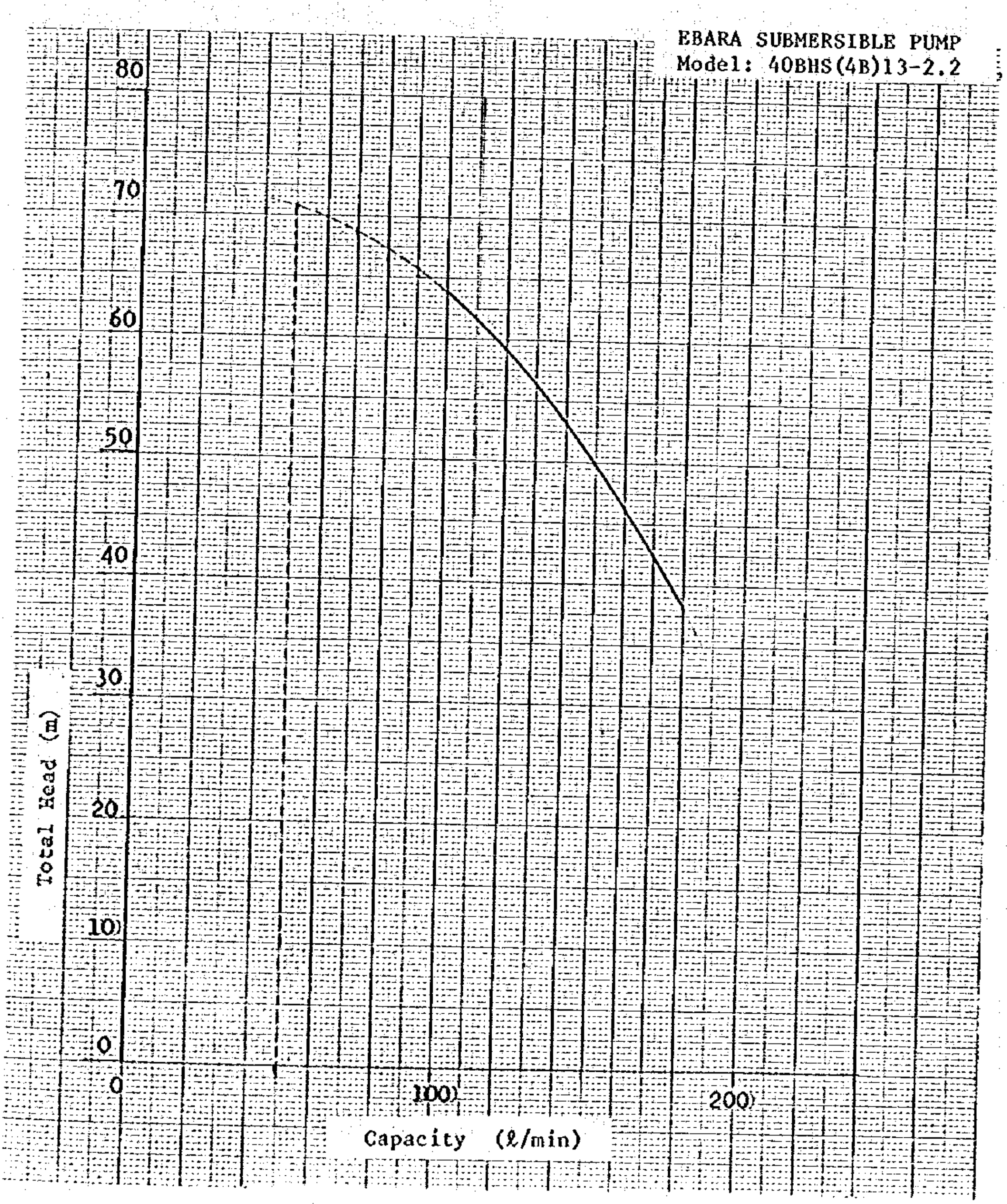
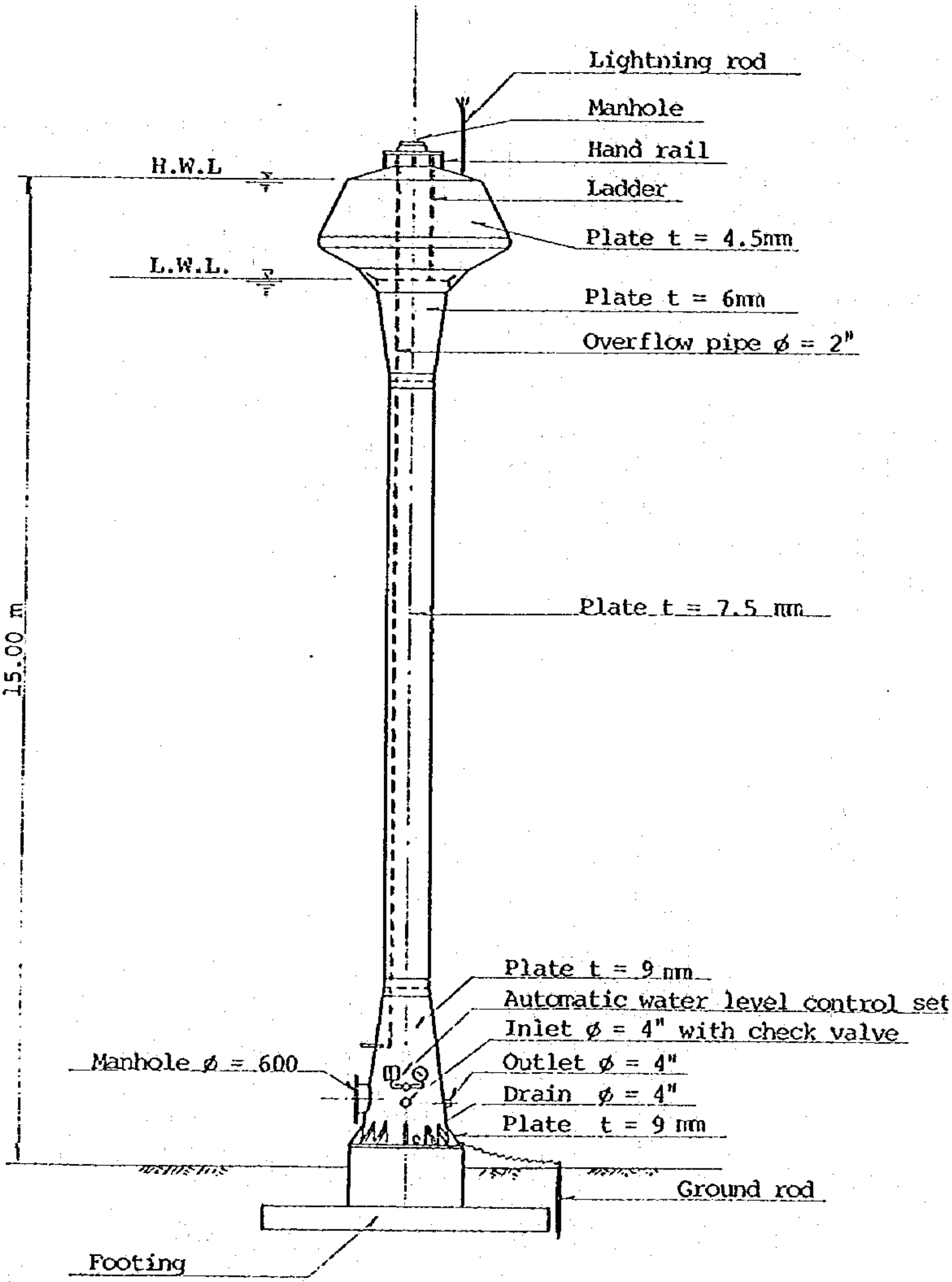


Fig. 6-2 Water Tank



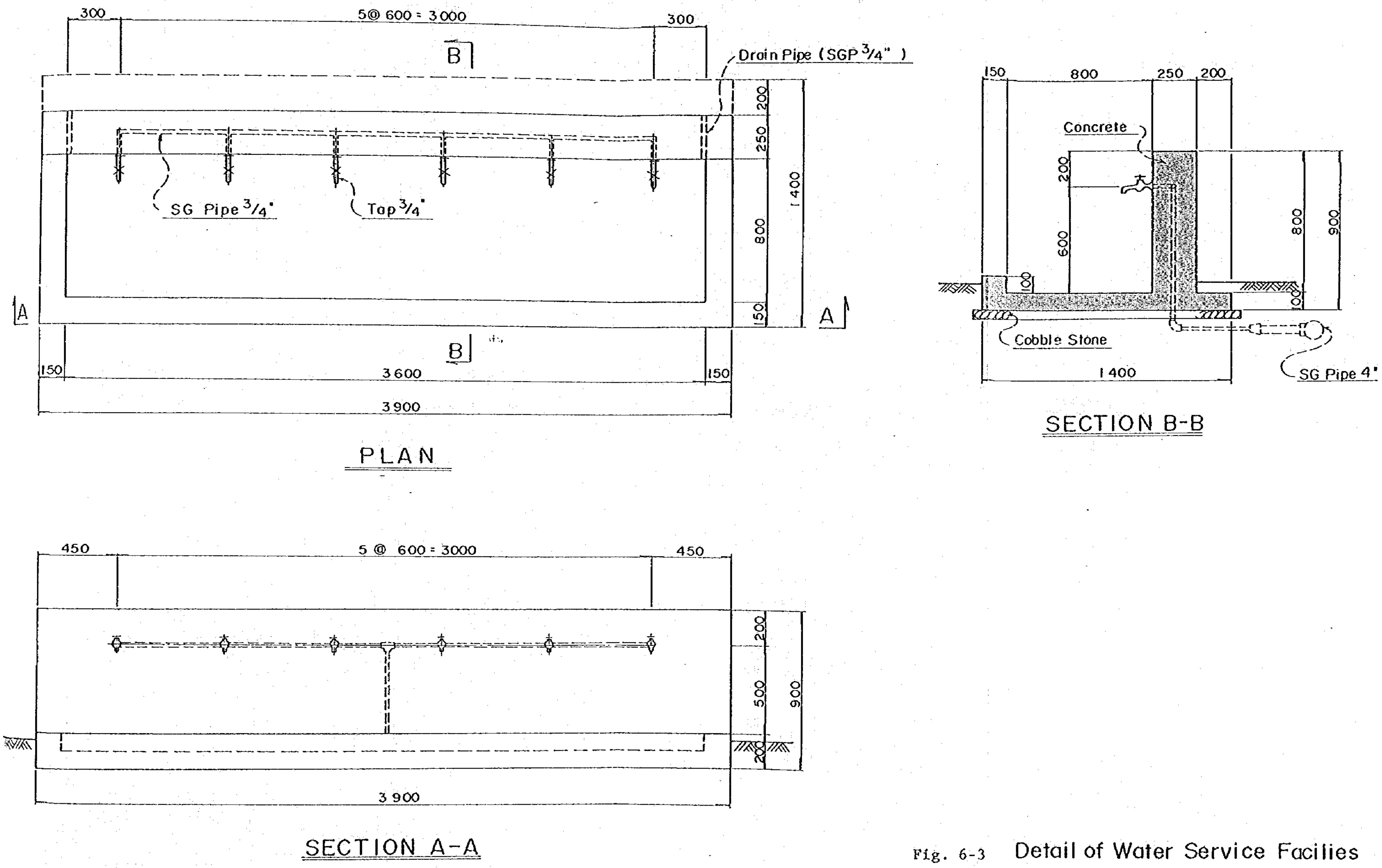


Fig. 6-3 Detail of Water Service Facilies

APPENDIX

MINUTES OF DISCUSSION

ON

STUDY OF WATER SUPPLY PROJECT TO THE LAOTIAN DISPLACED PERSONS

IN THE KINGDOM OF THAILAND

(STAGE II)

I. INTRODUCTION

In response to the request made by the Government of Thailand, the Government of Japan has made the dicision to provide a study on Water Supply Project to the Laotian displaced persons in accordance with laws and regulations in force in Japan.

The Japan International Cooperation Agency(JICA), an official agency responsible for implementation of technical cooperation programs of the Government of Japan, carried out the underground water survey for the Nakhom Phanom Camp from February 4 to April 15 1982, as the STAGE I.

I. SCOPE OF WORK

2.01 The objective of the study is to formulate an underground water development plan at the Pak Chom Camp.

2.02 The survey will be carried out from May 20 to October 1, 1982.

2.03 The survey consists of three steps as follows.

Step 1

1. Preparation of an inception report
2. Preparation of necessary equipment and materials for the field survey.

Step 2

1. Submission and explanation of the inception report
2. Collection of data
3. Field reconnaissance
4. Electrical exploration
5. Test boring, 4 holes
6. Electrical logging, pumping test, water quality test and etc, on above bored holes

Step 3

1. Technical analysis of underground water condition
2. Planning of underground water exploitation for water supply
3. Preparation and submission of the final report

2.04 Reports

Inception Report (15 copies in English) will be prepared until May 24, 1982 and Progress Report (15 copies in English) will be prepared and submitted until October 1, 1982. Final Report (15 copies in English) will be prepared and submitted within two months after the field survey.

2.05 Undertakings of the Government of Thailand:

1. Provision of Data for Ground Water Exploitation
   (1) All drilling data in and around area of the Camp

(2) Hydrogeological data on existing wells within the Camp

(3) The camp's facilities' layout

2. Security Services for the Survey Team

(1) Permits/Licenses for free passages (personnel and cargo)

(2) Security measures in the survey areas

3. Local Inhabitants Agreement for Execution of the Work

(1) Drilling at site

(2) Topographical survey

(3) Field investigation on irrigation and water supply

4. Arrangement of Local Labourers

5. Procurement of Local Materials (by UNHCR's support)

6. Tax-exemption in the articles to be carried in and out of Thailand for execution of the Work

2.06 Schedule

The work schedule is shown in Table I.

Kamol Prachuabmoh

(Lt.Col.Kamol Prachuabmoh)

Deputy Director

Operation Centre for Displaced Persons

Ministry of Interior

(Mr. AKIRA KASAI)

Resident Representative of JICA

BANGKOK Office

APPENDIX B

TECHNICAL DATA

1) Geological Map of Thailand (S : 1/1,000,000)
   Department of Mineral Resources, Ministry of National Development, 1969

2) Hydrogeological Map of Northeastern Thailand (S : 1/500,000)
   Department of Mineral Resources, Ministry of Industry, 1973

3) Climatological Data of Thailand; 25 Year Period (1951 - 1975)
   Meteorogical Department, Ministry of Communications

4) Electric Sounding Method, Printed by Shokodo (in Japanese)
   K. Simura (1965)

5) Pumping Test and Well Management, Printed by Shokodo (in Japanese)
   S. Yamamoto (1979)

APPENDIX C

LIST OF COLLECTION DATA

1) Monthly and Annual Rainfall for the Period 1953 - 1980
   Meteorological Department, Ministry of Communication

2) Pumping Test Records (Well No.JJ 41 L34)
   Department of Mineral Resources

3) Water Analysis Report (Well No.JJ 41 L34)
   Department of Mineral Resources

4) Well Log (Well No.JJ 41 L34)
   Department of Mineral Resources

5) Standard of Drinking Water (The Ministry of Public Health No.61-1981)
   Ministry of Public Health

6) Topographical Map (Scale 1:50,000)
   Royal Irrigation Department

7) Outline Plan of Pak Chom Camp (Scale about 1:2250)
   Pak Chome Camp Office, MOI

8) Outline Plan of Ban Vinai Camp (Scale-unknown-aout 1:2250)
   Ban Vinai Camp Office, UNHCR

9) Highway Map Central Region - Northeastern, Thailand (Scale 1:1,000,000)

10) Well Logs (No.1, 2 and Hand-pump wells at Ban Vinai Camp) 1980
    Ban Vinai Camp Office, World Vision

11) Well Logs (No.1 and 2 wells at Nong Daeng Agricultural Training Center)
    Ban Vinai Camp Office, World Vision

12) Information on Water Well Pumps in Ban Vinai Camp, March 1982
    Development Section, World Vision

APPENDIX D. WATER QUALITY TEST

COPY

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APPENDIX D - 1

DEPARTMENT OF SCIENCE SERVICE
RAMA VI ROAD, BANGKOK 4, THAILAND

17672

Our Ref. No. 0304/

18 August 1982

Mr. T. Hagiwara
JICA-J.E.C.
No.2-6, Okubo, 2-Chome,
Shinjuku-ku, Tokyo, Japan

Dear Sir,

With reference to your request of 5 August 1982, Ref. No.4080, we are pleased to send you the following report on the sample/s of "Deep well for Pak-Chom Camp. Muang Loei" received on 5 August 1982.

Yours truly,

Usa Antarikananda

(Mrs. Usa Antarikananda)
Director, Division of Chemistry
for Director-General

REPORT

On the sample/s of Deep well for Pak-Chom Camp. Muang Loei

Laboratory number/s

KY.263 : J-No.1

	KY.263
Colour, Hazen units	less than 5
Turbidity, silica scale	4.6
pH value	7.4
Total solids, ppm	563
Total hardness as $CaCO_3$, ppm	277
Chloride as NaCl, ppm	87.4
Free and saline ammonia as NH_3, ppm	0.03
Albuminoid ammonia as NH_3, ppm	0.12
Nitrate as N, ppm	0.06
Nitrite as N, ppm	0.05
Iron, ppm	0.36
Lead	not found
Arsenic, ppm	0.001

(Sgd.) Nopporn Rochananonda
(Mrs. Nopporn Rochananonda)
Scientist 7

The above report is valid for the received sample/s only, and does not guarantee any such material of the same brand or marking which may be sold in the market.

THIS REPORT IS NOT TO BE USED FOR ADVERTISING PURPOSES.

Certified true copy

A. Mekanontchai

(Mrs. Amphi Mekanontchai)
Chief, Registration and Statistics Section

COPY

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.........หัวอย่าง
.........รายการ

APPENDIX D - 2

DEPARTMENT OF SCIENCE SERVICE
RAMA VI ROAD, BANGKOK 4, THAILAND

Our Ref. No. 0304/ 17673

18 August 1982

Mr. T. Hagiwara
JICA-J.E.C.
No.2-6 Okubo, 2-Chome,
Shinjuku-ku, Tokyo, Japan.

Dear Sir,

With reference to your request of 5 August 1982, Ref. No.4060, we are pleased to send you the following report on the sample/s of "Deep well for Pak-Chom Camp, Muang Loei" received on 5 August 1982.

Yours truly,

Usa Antarikananda

(Mrs. Usa Antarikananda)
Director, Division of Chemistry

for Director-General

REPORT

On the sample/s of Deep well for Pak-Chom Camp, Muang Loei

Laboratory number/s/

KY.264 : J-No.2

	KY.264
Colour, Hazen units	less than 5
Turbidity, silica scale	23
pH value	7.3
Total solids, ppm	741
Total hardness as $CaCO_3$, ppm	535
Chloride as NaCl, ppm	46.2
Free and saline ammonia as NH_3, ppm	0.07
Albuminoid ammonia as NH_3, ppm	0.08
Nitrate as N, ppm	0.02
Nitrite as N, ppm	0.002
Iron, ppm	1.15
Lead, ppm	0.002
Arsenic, ppm	0.001

(Sgd.) Nopporn Roshananonda
(Mrs. Nopporn Roohananonda)
Scientist 7

The above report is valid for the received sample/s only, and does not apply to any such material of the same brand or marking which may be sold in the market.

THIS REPORT IS NOT TO BE USED FOR ADVERTISING PURPOSES.

Certified true copy

A. [illegible]

(Mrs. Angkana M.[illegible])
Chief, Registration and Statistics Section

III-A-13

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.....รายการ

APPENDIX D - 3

DEPARTMENT OF SCIENCE SERVICE
RAMA VI STREET, BANGKOK 4

Our Ref. No. 0304/18072

30 August 1982

Mr. T.Hagiwara
JICA-J.E.C.
No. 2-6-2 Okubo,Shinjuku-ku
Tokyo, Japan

Dear Sir,

With reference to your request of 17 August 1982, Ref. No.4210, we are pleased to send you the following report on the water sample/s received on 17 August 1982.

Yours truly,

Usa Antarikananda
(Mrs. Usa Antarikananda)
Director, Division of Chemistry
for Director General

Division of Chemistry
Tel. 817444 Ext. 02

REPORT ON PHYSICAL AND CHEMICAL EXAMINATIONS

The report is valid for the received sample/s only and is not to be used for advertising purposes.

Laboratory No.	Sample	Collected from	By	Date	Time
KY.590	Deep well water J-No.3	Pok-Chom Camp. Huang Looi	the dondor	-	-

	KY.590
Colour, in terms of Hazen units	less than 5
Odour	-
Taste	-
Turbidity, in terms of Silica scale	25
pH value	6.9
Electrical conductivity at 20°C, micromhos/cm	-
	parts per million
Total solids	612
Loss on ignition	-
Suspended solids	-
Dissolved solids	-
Total hardness, expressed as calcium carbonate	474
Temporary hardness, ———do.———	-
Permanent hardness, ———do.———	-
Residual alkalinity, ———do.———	-
Chlorides, expressed as chlorine	-
Chlorides, expressed as sodium chloride	11.5
Free and Saline ammonia, expressed as ammonia	0.006
Albuminoid ammonia, expressed as ammonia	0.004
Nitrates expressed as nitrogen	0.289
Nitrites, expressed as nitrogen	0.003
Iron	1.1
Lead	not found
Arsenic	not found

Certified true copy

(Sgd.) Nopporn Rochananonda
(Mrs. Nopporn Rochananonda)
Scientist 7

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APPENDIX D - 4

DEPARTMENT OF SCIENCE SERVICS
RAMA VI STREET, BANGKOK 4

Our Ref. No.0304/ 1434

26 October 1982

Mr.T.Hagiwara
JICA-J.E.C.
No.2-6-2 OKUBO, SHINJUKU-KU
TOKYO, JAPAN

Dear Sir,

With reference to your request of 4 October 1982, Ref. No.22, we are pleased to send you the following report on the water sample/s received on 4 October 1982.

Yours truly,

Usa Antarikanonda

(Mrs. Usa Antarikanonda)
Director, Division of Chemistry
for Director General

Division of Chemistry
Tel. ~~817444 Ext. 02~~
282-7294

REPORT ON PHYSICAL AND CHEMICAL EXAMINATIONS

The report is valid for the received sample/s only
and is not to be used for advertising purposes.

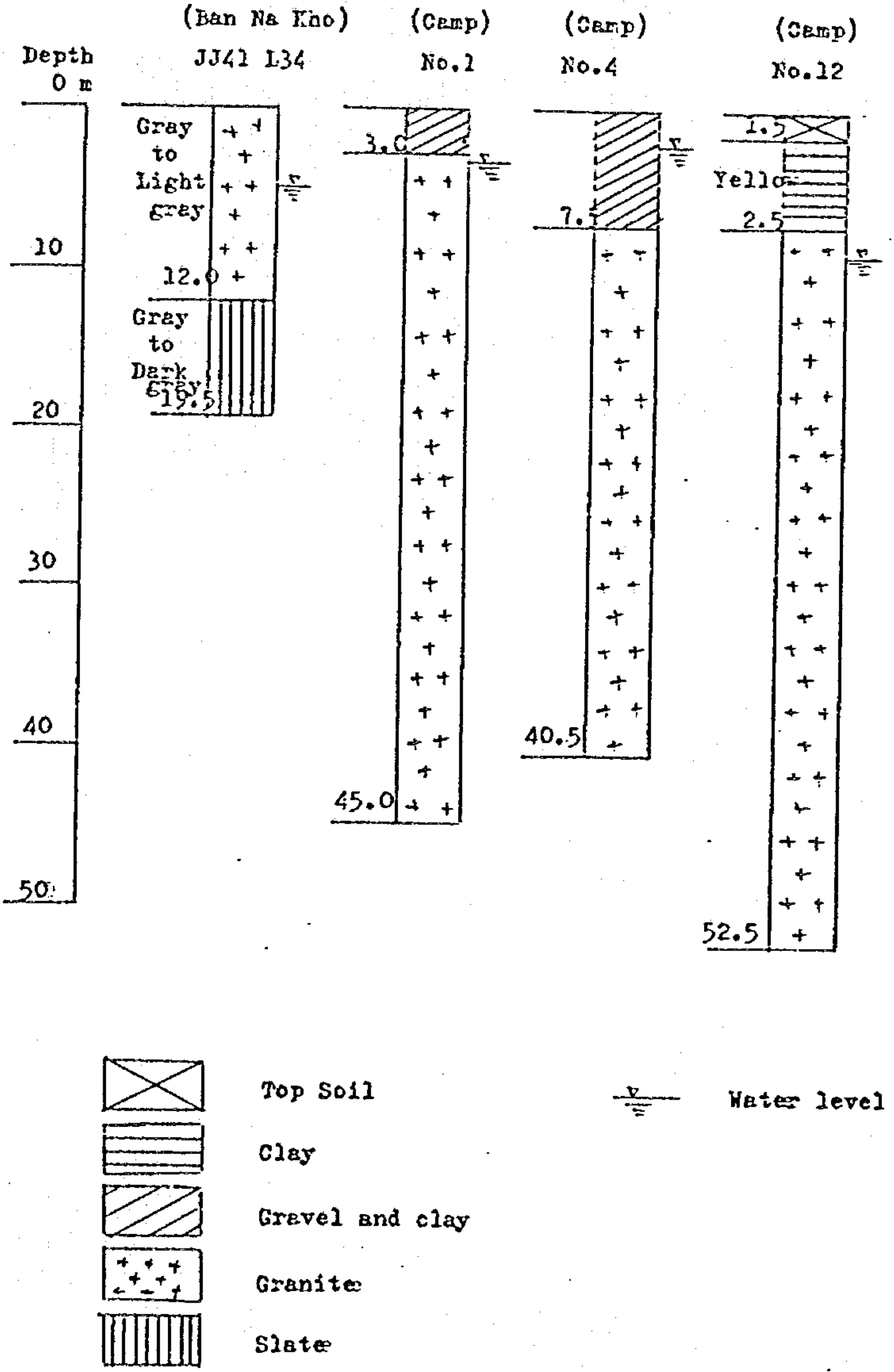
Laboratory No.	Collected from	By	Date	Time
KZ.892	J-NO-3 PAK CHOM CAMP MUANG LOEI	The sender	-	-
KZ.893	J-NO-4 PAK CHOM CAMP MUANG LOEI	The sender	-	-

	KZ.892	KZ.893
Colour, in terms of Hazen units	Less than 5	Less than 5
Odour	-	-
Taste	-	-
Turbidity, in terms of Silica scale	10.2	2.7
pH value	7.6	7.6
Electrical conductivity at 20°C, micromhos/cm	850	800
	parts per million	
Total solids	575	556
Loss on ignition	-	-
Suspended solids	-	-
Dissolved solids	-	-
Total hardness, expressed as calcium carbonate	440	425
Temporary hardness, ——do.——	-	-
Permanent hardness, ——do.——	-	-
Residual alkalinity, ——do.——	-	-
Chlorides, expressed as chlorine	-	-
Chlorides, expressed as sodium chloride	13.2	37.9
Free and Saline ammonia, expressed as ammonia	0.006	0.004
Albuminoid ammonia, expressed as ammonia	0.06	0.06
Nitrates expressed as nitrogen	0.23	0.02
Nitrites, expressed as nitrogen	0.01	0.001
Iron	0.72	0.39
Lead	not found	not found

Viriya Chulamok

(Miss Viriya Chulamok)
Scientist 6

COLUMNAR SECTION



APPENDIX F. DATA OF PUMPING TEST

APPENDIX F - 1

Data of Pumping Test (J.- No. 1)

June 24, 1982

Time (hr min sec)	Time after Pumping Started t (sec)	Time after Pumping Stopped t' (sec)	Water Level (m)	Draw-down s(m)	t/t'	Log t/t'	Radius of Well r (m)	r^2/t	Pumping Rate $Q(m^3/sec)$	Remarks
11 31 50	0		3.018	0.000			0.0508		0.0013115	pumping started
	30		8.710	5.692			0.0508	8.602×10^{-5}		
	60		9.822	6.804			0.0508	4.301×10^{-5}		
	90		10.764	7.746			0.0508	2.867×10^{-5}		
	120		11.565	8.547			0.0508	2.151×10^{-5}		
	150		12.450	9.432			0.0508	1.720×10^{-5}		
	180		13.082	10.064			0.0508	1.434×10^{-5}		
	210		13.759	10.777			0.0508	1.229×10^{-5}		
	240		14.393	11.375			0.0508	1.075×10^{-5}		Q = 78.689 ℓ/min
	270		15.082	12.064			0.0508	9.558×10^{-6}		
	300		15.661	12.634			0.0508	8.602×10^{-6}		
	360		16.759	13.741			0.0508	7.168×10^{-6}		
	420		17.578	14.560			0.0508	6.144×10^{-6}		
	480		18.391	15.373			0.0508	5.376×10^{-6}		
	540		19.000	15.982			0.0508	4.779×10^{-6}		
	600		19.549	16.531			0.0508	4.301×10^{-6}		
	660		20.099	17.081			0.0508	3.910×10^{-6}		
	720		20.565	17.547			0.0508	3.584×10^{-6}		
	780		20.968	17.950			0.0508	3.309×10^{-6}		
	840		21.330	18.312			0.0508	3.072×10^{-6}		
	900		21.680	18.662			0.0508	2.867×10^{-6}		
	1200		22.915	19.897			0.0508	2.151×10^{-6}		
	1500		23.646	20.628			0.0508	1.720×10^{-6}		
	1800		24.059	21.039			0.0508	1.434×10^{-6}		
	2100		24.280	21.262			0.0508	1.229×10^{-6}		
	2400		24.459	21.441			0.0508	1.075×10^{-6}		
	2700		24.560	21.542			0.0508	9.558×10^{-7}		
	3000		24.745	21.727			0.0508	8.602×10^{-7}		
	3300		24.809	21.791			0.0508	7.820×10^{-7}		
	3600		24.920	21.902			0.0508	7.168×10^{-7}		
	4200		25.115	22.097			0.0508	6.144×10^{-7}		
	4800		25.272	22.254			0.0508	5.376×10^{-7}		
	5400		26.324	23.308			0.0508	4.779×10^{-7}		
	5700		27.317	24.299			0.0508	4.527×10^{-7}		
	6000		27.624	24.606			0.0508	4.301×10^{-7}		
	6300		27.639	24.621			0.0508	4.096×10^{-7}		
	6600		27.600	24.582			0.0508	3.910×10^{-7}		
	6900	0	27.554	24.536	0		0.0508	3.740×10^{-7}		pumping stopped
	6930	30	24.970	21.952	231	2.364	0.0508			
	6960	60	22.390	19.372	116	2.064	0.0508			
	6990	90	20.230	17.212	77.667	1.890	0.0508			
	7020	120	18.273	15.255	58.5	1.767	0.0508			
	7050	150	16.722	13.704	47	1.672	0.0508			
	7080	180	15.105	12.087	39.333	1.595	0.0508			
	7110	210	13.713	10.695	33.857	1.530	0.0508			
	7140	240	12.648	9.630	29.75	1.473	0.0508			
	7170	270	11.628	8.610	26.556	1.424	0.0508			
	7200	300	10.825	7.807	24	1.380	0.0508			
	7260	360	9.446	6.428	20.167	1.305	0.0508			
	7320	420	8.472	4.454	17.429	1.241	0.0508			
	7380	480	6.305	3.287	15.375	1.187	0.0508			
	7440	540	5.647	2.629	13.778	1.139	0.0508			
	7500	600	5.217	2.199	12.5	1.097	0.0508			
	7560	660	4.878	1.860	11.455	1.059	0.0508			
	7620	720	4.655	1.637	10.583	1.025	0.0508			
	7680	780	4.477	1.459	9.846	0.993	0.0508			
	7740	840	4.342	1.324	9.214	0.964	0.0508			
	7800	900	4.292	1.224	8.667	0.938	0.0508			
	8100	1200	3.940	0.922	6.75	0.829	0.0508			
	8400	1500	3.805	0.787	5.6	0.748	0.0508			
	8700	1800	3.687	0.669	4.833	0.684	0.0508			
	9000	2100	3.618	0.600	4.286	0.632	0.0508			
	9300	2400	3.565	0.547	3.875	0.588	0.0508			
	9600	2700	3.525	0.507	3.556	0.551	0.0508			
	9900	3000	3.494	0.476	3.3	0.519	0.0508			

Data of Pumping Test (J - No. 2)

July 17, 1982

Time hr min sec	Time after Pumping Started t (sec)	Time after Pumping Stopped t' (sec)	Water Level (m)	Draw-down s(m)	t/t'	Log t/t'	Radius of Well r (m)	r^2/t	Pumping Rate $Q(m^3/sec)$	Remarks
11 30 00	0		1.6	0			0.0508		0.00278	pumping started
	60		-	-			0.0508	$4.301x10^{-5}$		
	120		12.53	10.93			0.0508	$2.151x10^{-5}$		
	180		14.01	12.41			0.0508	$1.434x10^{-5}$		
	240		15.55	13.95			0.0508	$1.075x10^{-5}$		
	300		16.55	14.95			0.0508	$8.602x10^{-6}$		
	360		17.31	15.71			0.0508	$7.168x10^{-6}$		
	600		19.01	17.41			0.0508	$4.301x10^{-6}$		
	900		19.83	18.23			0.0508	$2.867x10^{-6}$		
	1200		20.15	18.55			0.0508	$2.151x10^{-6}$		
	1500		20.37	18.77			0.0508	$1.720x10^{-6}$		
	1800		20.44	18.84			0.0508	$1.434x10^{-6}$		
	2400		20.73	19.13			0.0508	$1.075x10^{-6}$		
	3000		20.87	19.27			0.0508	$8.602x10^{-7}$		
	3600		20.96	19.36			0.0508	$7.168x10^{-7}$		
	4200		21.09	19.49			0.0508	$6.144x10^{-7}$		
	4800		21.24	19.64			0.0508	$5.376x10^{-7}$		
	5400		21.25	19.65			0.0508	$4.779x10^{-7}$		
	6000		21.35	19.75			0.0508	$4.301x10^{-7}$		
	6600		21.41	19.81			0.0508	$3.910x10^{-7}$		
	7200		21.51	19.91			0.0508	$3.584x10^{-7}$		
13 40 00	7800	0	21.57	19.97			0.0508	$3.308x10^{-7}$		pumping stopped
	7860	60	-	-	131	2.117				
	7920	120	9.89	8.29	66	1.820				
	7980	180	6.77	5.17	44.33	1.647				
	8040	240	5.53	3.93	33.50	1.525				
	8100	300	4.85	3.25	27	1.431				
	8160	360	4.33	2.73	22.67	1.355				
	8220	420	4.01	2.41	19.57	1.291				
	8280	480	3.78	2.18	17.25	1.237				
	8340	540	3.59	1.99	15.44	1.189				
	8400	600	3.42	1.82	14	1.146				
	8460	660	3.28	1.68	12.82	1.108				
	8520	720	3.19	1.59	11.83	1.073				
	8580	780	3.05	1.45	11	1.041				
	8640	840	2.99	1.39	10.29	1.012				
	8700	900	2.90	1.30	9.67	0.985				
	8760	960	2.81	1.21	9.13	0.960				
	8820	1020	2.80	1.20	8.65	0.937				
	8880	1080	2.71	1.11	8.22	0.915				
	8940	1140	2.68	1.08	7.84	0.894				
	9000	1200	2.63	1.03	7.50	0.875				
	9060	1260	2.59	0.99	7.19	0.857				
	9120	1320	2.54	0.94	6.91	0.839				
	9180	1380	2.53	0.93	6.65	0.823				
	9240	1440	2.50	0.90	6.42	0.808				
	9300	1500	2.46	0.86	6.20	0.792				
	9600	1800	2.33	0.73	5.33	0.727				
	9900	2100	2.25	0.65	4.71	0.673				
	10200	2400	2.20	0.6	4.25	0.628				
	10500	2700	2.15	0.55	3.89	0.590				
	10800	3000	2.10	0.5	3.60	0.556				
	11100	3300	2.07	0.47	3.36	0.526				
	11700	3900	2.00	0.4	3	0.477				
	12300	4500	1.96	0.36	2.73	0.436				
	12900	5100	1.94	0.34	2.53	0.403				
	14700	6900	1.88	0.28	2.13	0.328				

APPENDIX F - 3

Data of Pumping Test (J - No. 3)

August 11, 1982

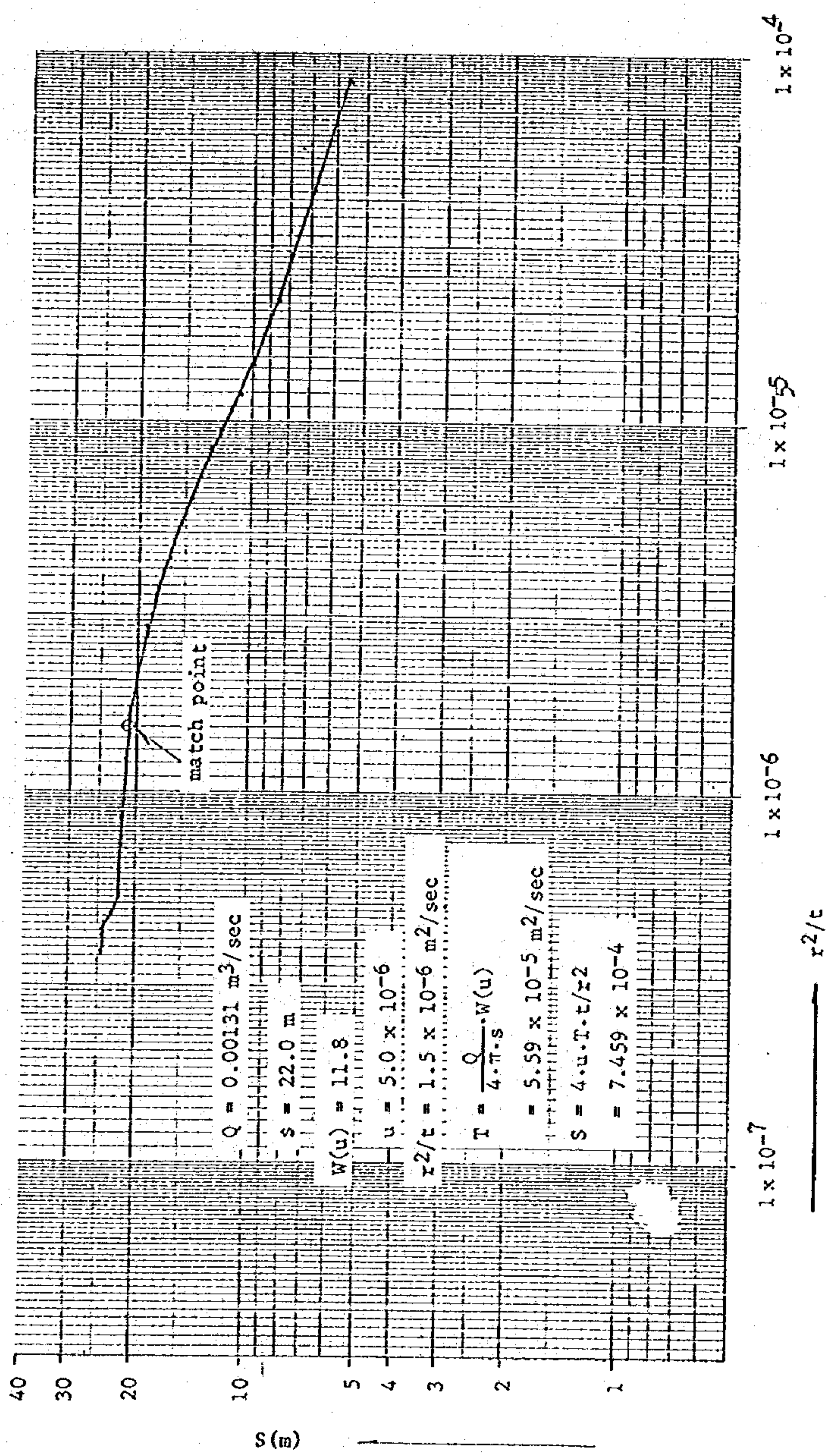
Time hr min sec	Time after Pumping Started t (sec)	Time after Pumping Stopped t' (sec)	Water Level (m)	Draw-down s(m)	t/t'	Log t/t'	Radius of Well r (m)	r^2/t	Pumping Rate Q(m^3/sec)	Remarks
13 30 00	0		3.905	0			0.0508		0.0026	pumping started
	60		7.27	3.365			0.0508	4.301×10^{-5}		
	120		8.09	4.185			0.0508	2.151×10^{-5}		
	180		8.65	4.185			0.0508	1.434×10^{-5}		
	240		9.1	5.195			0.0508	1.075×10^{-5}		
	300		9.4	5.495			0.0508	8.602×10^{-6}		
	360		9.67	5.765			0.0508	7.168×10^{-6}		
	420		9.91	6.005			0.0508	6.144×10^{-6}		
	480		10.1	6.195			0.0508	5.376×10^{-6}		
	540		10.29	6.385			0.0508	4.779×10^{-6}		
	600		10.41	6.505			0.0508	4.301×10^{-6}		
	900		11.02	7.115			0.0508	2.867×10^{-6}		
	1200		11.46	7.555			0.0508	2.151×10^{-6}		
	1500		11.83	7.925			0.0508	1.720×10^{-6}		
	1800		12.1	8.195			0.0508	1.434×10^{-6}		
	2400		12.62	8.715			0.0508	1.075×10^{-6}		
	3000		13.01	9.105			0.0508	8.602×10^{-7}		
	3600		13.34	9.435			0.0508	7.168×10^{-7}		
	5400		14.1	10.195			0.0508	4.779×10^{-7}		
	7200		14.48	10.575			0.0508	3.584×10^{-7}		
	9000		14.77	10.865			0.0508	2.867×10^{-7}		
	10800		15.05	11.145			0.0508	2.389×10^{-7}		
17 00 00	12600	0	15.29	11.385			0.0508	2.048×10^{-7}		pumping stopped
	12660	60	12.17	8.265	211	2.324				
	12720	120	11.61	7.705	106	2.025				
	12780	180	11.24	7.335	71	1.851				
	12840	240	10.98	7.075	53.5	1.728				
	12900	300	10.78	6.875	43	1.633				
	12960	360	10.61	6.705	36	1.556				
	13020	420	10.44	6.535	31	1.491				
	13080	480	10.30	6.395	27.25	1.435				
	13140	540	10.17	6.265	24.333	1.3862				
	13200	600	10.06	6.155	22	1.342				
	13500	900	9.61	5.705	15	1.176				
	13800	1200	9.26	5.355	11.5	1.061				
	14100	1500	8.98	5.075	9.4	0.973				
	14400	1800	8.71	4.805	8	0.903				
	15000	2400	8.36	4.455	6.25	0.796				
	15600	3000	8.07	4.165	5.2	0.716				
	16200	3600	7.82	3.915	4.5	0.653				

Data of Pumping Test (J - No. 4)

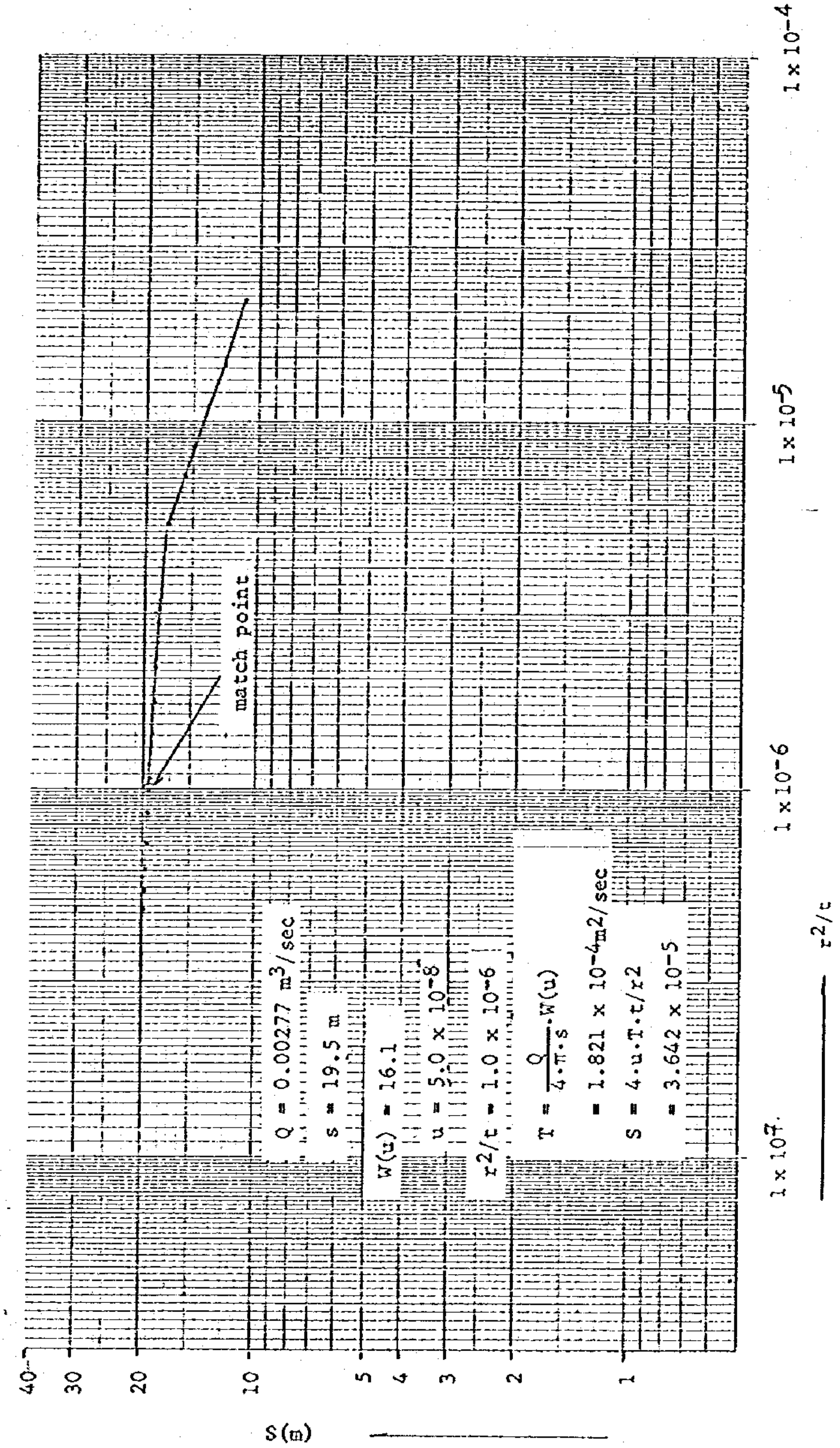
October 7, 1981

Time hr min sec	Time after Pumping Started t (sec)	Time after Pumping Stopped t' (sec)	Water Level (m)	Draw-down s(m)	t/t'	Log t/t'	Radius of Well r (m)	r^2/t	Pumping Rate $Q(m^3/sec)$	Remarks
11 05 00	0		2.86	0			0.0508		0.00242	pumping started 145ℓ/min
	30		5.05	2.19			0.0508	8.602×10^{-5}		
	60		5.34	2.48			0.0508	4.301×10^{-5}		
	90		5.52	2.66			0.0508	2.867×10^{-5}		
	120		5.64	2.78			0.0508	2.151×10^{-5}		
	150		5.77	2.91			0.0508	1.720×10^{-5}		
	180		4.89	3.03			0.0508	1.434×10^{-5}		
	210		6.00	3.14			0.0508	1.229×10^{-5}		
	240		6.08	3.22			0.0508	1.075×10^{-5}		
	270		6.14	3.28			0.0508	9.558×10^{-6}		
	300		6.24	3.38			0.0508	8.602×10^{-6}		
	360		6.38	3.52			0.0508	7.168×10^{-6}		
	420		6.51	3.65			0.0508	6.144×10^{-6}		
	480		6.64	3.78			0.0508	5.376×10^{-6}		
	540		6.74	3.88			0.0508	4.779×10^{-6}		
	600		6.86	4.00			0.0508	4.301×10^{-6}		
	900		7.34	4.48			0.0508	2.867×10^{-6}		
	1200		7.71	4.85			0.0508	2.151×10^{-6}		
	1500		8.00	5.14			0.0508	1.720×10^{-6}		
	1800		8.30	5.44			0.0508	1.434×10^{-6}		
	2400		8.76	5.90			0.0508	1.075×10^{-6}		
	3000		9.15	6.29			0.0508	8.602×10^{-7}		
	3600		9.46	6.60			0.0508	7.168×10^{-7}		
	5400		10.09	7.23			0.0508	4.779×10^{-7}		
	7200		10.53	7.67			0.0508	3.584×10^{-7}		
	9000		10.80	7.94			0.0508	2.867×10^{-7}		
	10800		11.00	8.14			0.0508	2.389×10^{-7}		
	12600		11.15	8.29			0.0508	2.048×10^{-7}		
14 35 00	12900		11.40	8.54			0.0508	2.000×10^{-7}	0.00265	159ℓ/min
	13200		11.45	8.59			0.0508	1.955×10^{-7}		
	13800		11.60	8.74			0.0508	1.870×10^{-7}		
	15000		11.71	8.85			0.0508	1.720×10^{-7}		
	16200		11.82	8.96			0.0508	1.593×10^{-7}		
15 35 00	16500		12.05	9.19			0.0508	1.564×10^{-7}	0.00275	165ℓ/min
	17400		12.185	9.325			0.0508	1.483×10^{-7}	"	
16 05 00	18000	0	12.26	9.40			0.0508	1.434×10^{-7}	"	pumping stopped
	18180	180	8.77	5.91	101.0	2.004				
	18360	360	8.23	5.37	51.0	1.708				
	18540	540	7.82	4.96	34.3	1.535				
	18900	900	7.16	4.30	21.0	1.322				
	19080	1080	6.89	4.03	17.7	1.248				
	19260	1260	6.63	3.77	15.3	1.185				

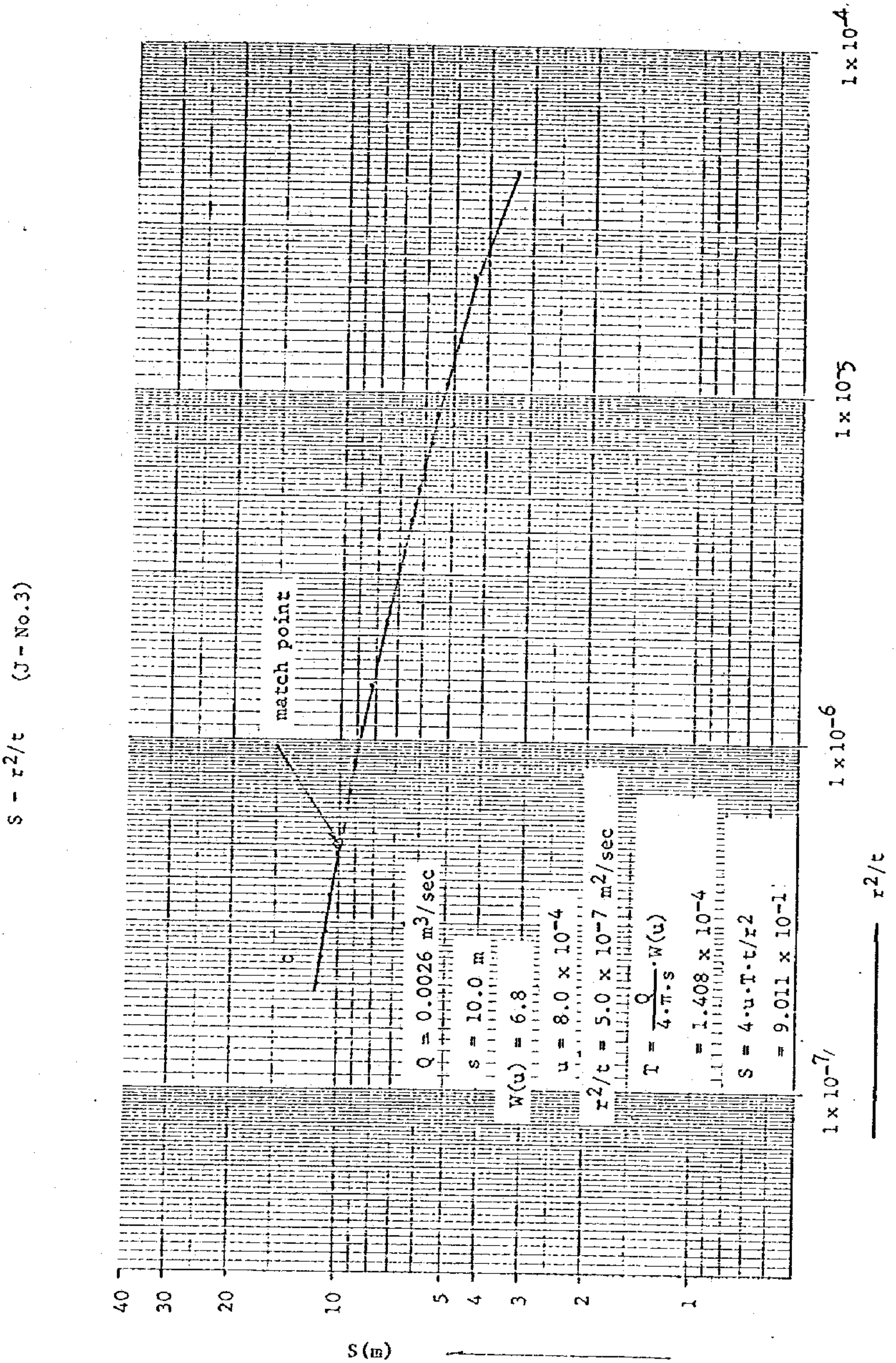
S - r^2/t (J - No.1)

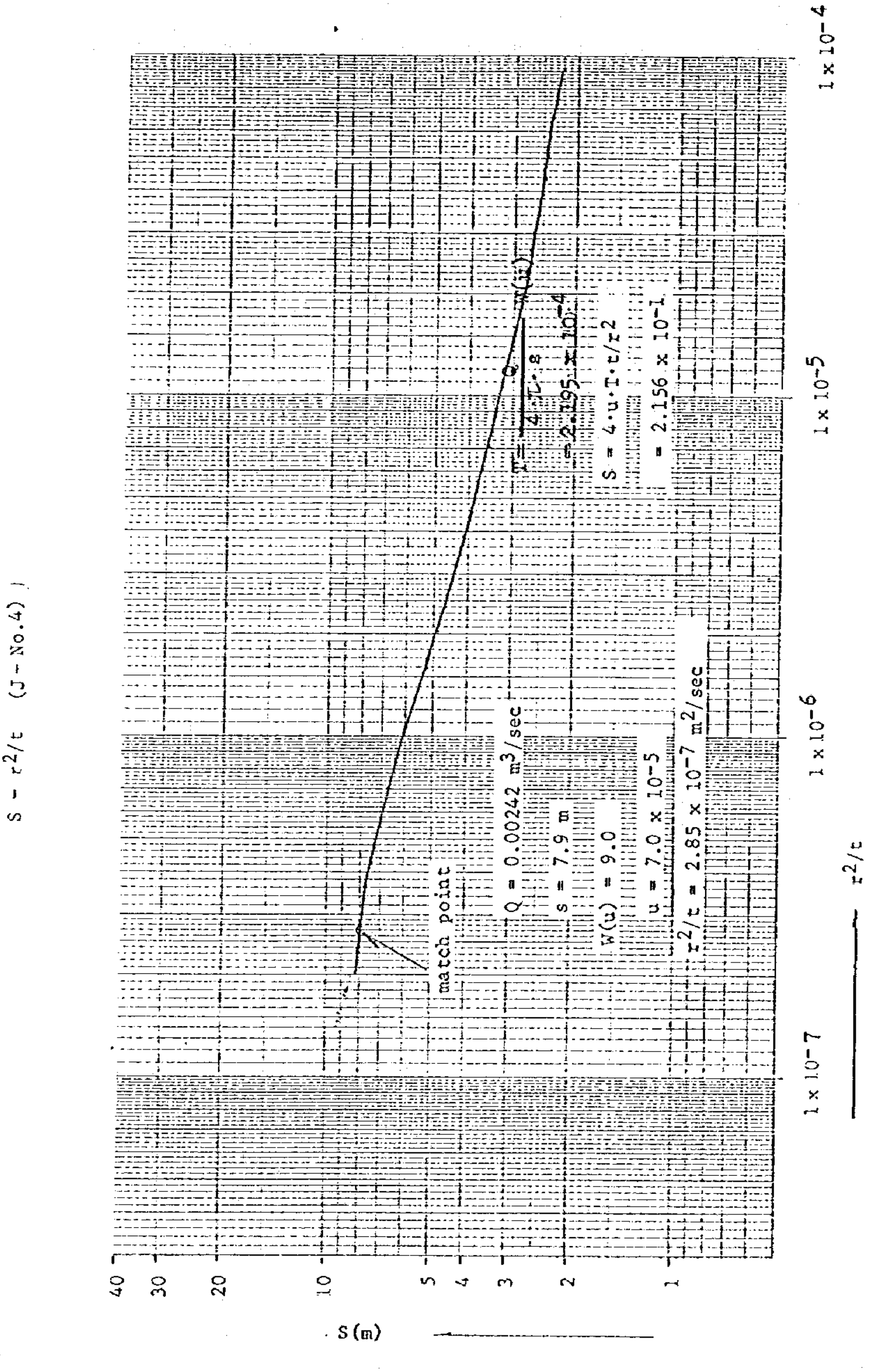

match point
Q = 0.00131 m³/sec
s = 22.0 m
W(u) = 11.8
u = 5.0 x 10⁻⁶
r²/t = 1.5 x 10⁻⁶ m²/sec
T = Q/(4·π·s)·W(u)
= 5.59 x 10⁻⁵ m²/sec
S = 4·u·T·t/r2
= 7.459 x 10⁻⁴
1 x 10⁻⁷
1 x 10⁻⁶
1 x 10⁻⁵
1 x 10⁻⁴
r²/t
40
30
20
10
5
4
3
2
1
S(m)

S - r²/t (J - No.2)

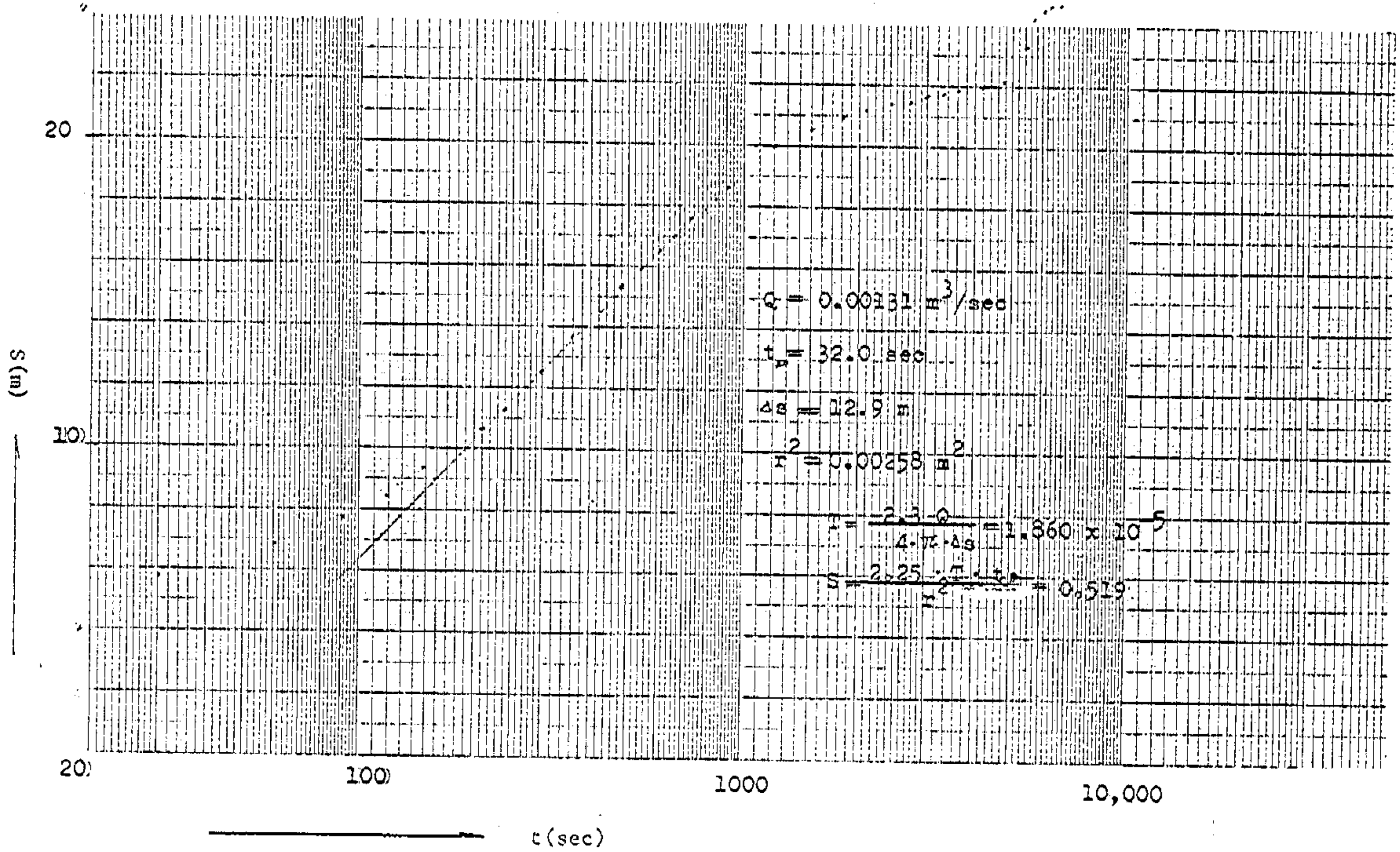


match point
Q = 0.00277 m³/sec
s = 19.5 m
W(u) = 16.1
u = 5.0 x 10⁻⁸
r²/t = 1.0 x 10⁻⁶
T = Q/(4·π·s)·W(u)
= 1.821 x 10⁻⁴ m²/sec
S = 4·u·T·t/r2
= 3.642 x 10⁻⁵
1 x 10⁻⁷
1 x 10⁻⁶
1 x 10⁻⁵
1 x 10⁻⁴
r²/t
40
30
20
10
5
4
3
2
1
S(m)


S - r²/t (J - No.3)
match point
Q = 0.0026 m³/sec
s = 10.0 m
W(u) = 6.8
u = 8.0 x 10⁻⁴
r²/t = 5.0 x 10⁻⁷ m²/sec
T = Q/(4·π·s)·W(u)
= 1.408 x 10⁻⁴
S = 4·u·T·t/r²
= 9.011 x 10⁻¹
1 x 10⁻⁴
1 x 10⁻⁵
1 x 10⁻⁶
1 x 10⁻⁷
r²/t
40
30
20
10
5
4
3
2
1
S(m)

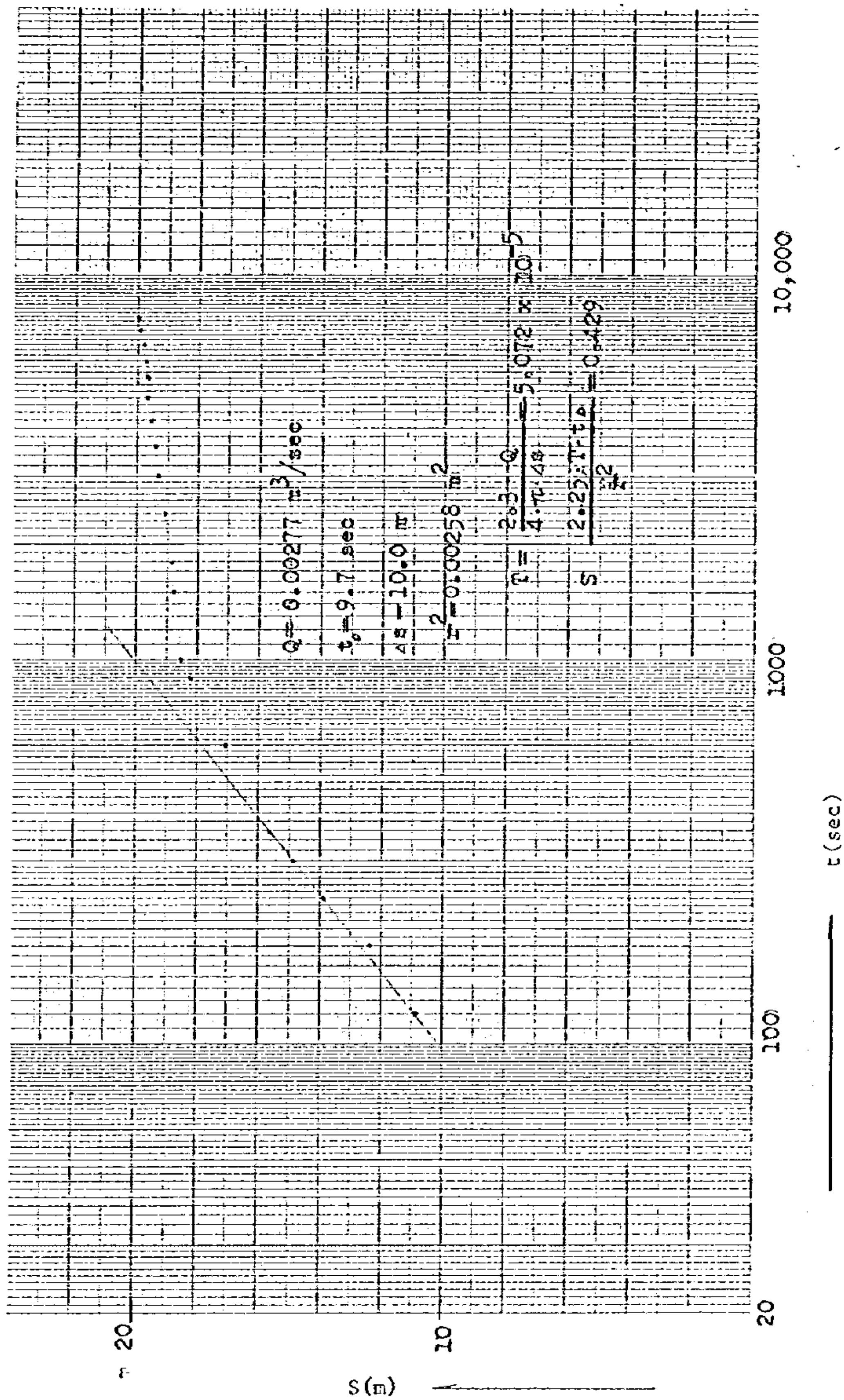

S - r2/t (J - No.4)
match point
Q = 0.00242 m3/sec
s = 7.9 m
W(u) = 9.0
u = 7.0 x 10-5
r2/t = 2.85 x 10-7 m2/sec
T = Q / 4·π·s · W(u)
= 2.195 x 10-4
S = 4·u·T·t/r2
= 2.156 x 10-1
1 x 10-7
1 x 10-6
1 x 10-5
1 x 10-4
r2/t
40
30
20
10
5
4
3
2
1
S(m)

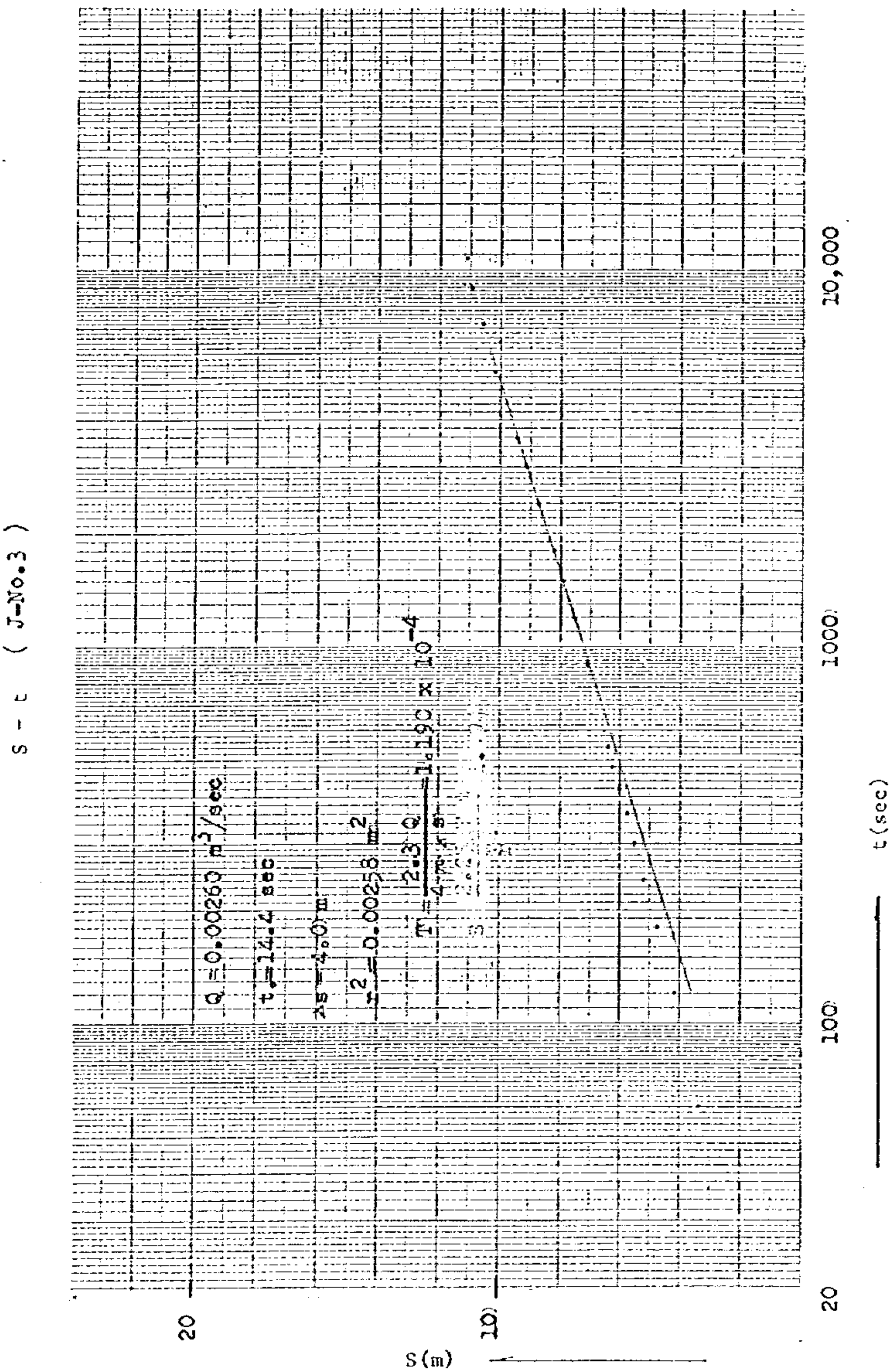
S - t (J-No.1)


Q = 0.00131 m3/sec
tR = 32.0 sec
Δs = 12.9 m
r2 = 0.00258 m2
T = 2.3 Q / 4·π·Δs = 1.860 x 10-5
S = 2.25·T·t0 / r2 = 0.519
20
10
20
100
1000
10,000
S(m)
t(sec)

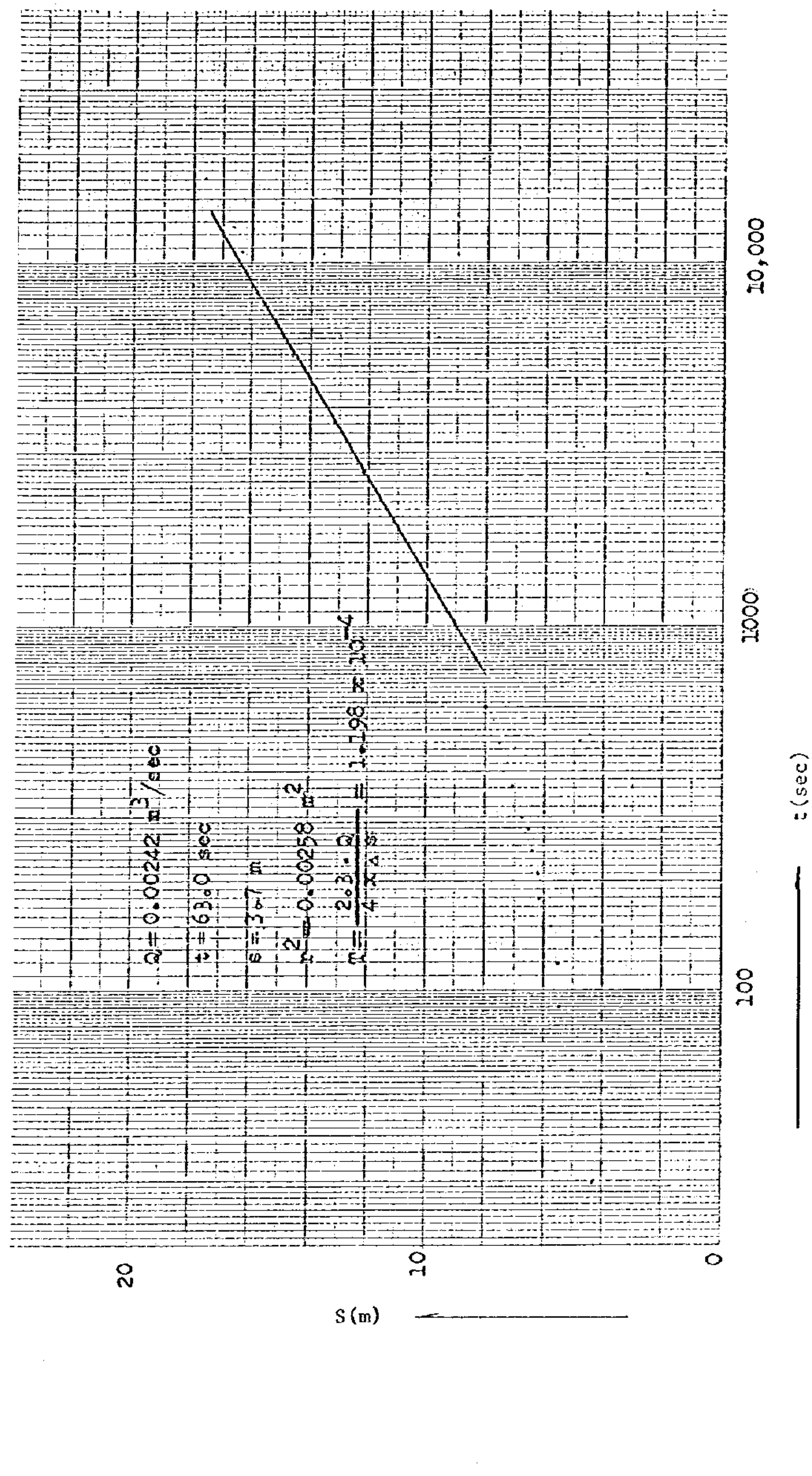
APPENDIX F - 10

S - t (J-No.2)




S - t (J-No.3)
Q = 0.00260 m3/sec
t = 14.4 sec
Δs = 4.0 m
r2 = 0.00258 m2
T = 2.3 Q / 4πΔs = 1.190 x 10-4
20
100
1000
10,000
t(sec)
20
10
S(m)

S - t (J-No.4)


Q = 0.00242 m³/sec
t = 63.0 sec
s = 3.7 m
r² = 0.00258 m²
u = 2.3·Q / 4π·Δs = 1.98 x 10⁻⁴
10,000
1000
100
t (sec)
20
10
0
S (m)

APPENDIX G

THAI STANDARD OF DRINKING WATER

(The Ministry of Public Health No.61, 1981)

1) Physical Properties

. Colour	not more than 20
. Ordor	not other ordor (not incl. chlorine)
. Turbidity	not more than 5
. PH value	between 6.5 - 8.5

2) Chemical Properties

. Total solid	not more than 500 mg/kg
. Total hardness	not more than 100 mg/kg
. Arsenic	not more than 0.05 mg/kg
. Barium	not more than 1.0 mg/kg
. Cadmium	not more than 0.01 mg/kg
. Chloride (expressed as chlorine)	not more than 250 mg/kg
. Chromium	not more than 0.05 mg/kg
. Copper	not more than 1.0 mg/kg
. Iron	not more than 0.5 mg/kg
. Lead	not more than 0.1 mg/kg
. Managanese	not more than 0.05 mg/kg
. Mercury (Hg)	not more than 0.002 mg/kg
. Nitrates (expressed as nitrogen)	not more than 4.0 mg/kg
. PL	not more than 0.001 mg/kg
. Silver	not more than 0.01 mg/kg
. Sulfate	not more than 250.0 mg/kg
. Zine	not more than 5.0 mg/kg
. Fluoride (express as fluorine)	not more than 1.5 mg/kg

3) Baetrial Properties

. Most probable number of coliform organism per 100 mℓ (m.p,n.) less than 2.3

. Free from Eschericha coli type I

. There are not bacterial for illness