FEASIBILITY STUDY & MASTER PLAN

FOR

KHON KAEN MUNICIPALITY

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

7419

→ 7463
→ 9545

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Chapter 1 Introduction

1.1 Services of Japanese Experts

Under the special request from Mr. Kasian Anambutr, Director of Provincial Water Supply Division, Public & Municipal Works Department on September 17, 1971, the Japanese Experts Team have been provided for urgent need of water supply improvement of Khon-Kaen Municipality, as following dates of survey.

The 1st Trip: 22, 23, 24 September 1971
The 2nd Trip: 26, 27, 28, 29, 30 October 1971

The Japanese Experts Team consisted of following engineers under the Colombo Plan.

Chief: Sachiho Naito
Deputy Chief: Susumu Sakaguchi
Member : Koichi Degawa
" : Kenji Sugi
Counter-part: Sudhi Kornkamonphurk

1.2 Survey and Study

The Japanese Experts Team was commissioned to prepare the report under the supervision of Mr Damrong Cholvijarn, Director General, Public & Municipal Works Department, Ministry of Interior, the Government of Thailand.

The various data for the study was collected at Provincial Water Supply Division, Khon Kaen Municipality and the branch office of Royal Irrigation Department. The map and statistical data was informed from the Provincial Water Supply Division mainly It is also appreciated to Mr. I. J Silverstone that the Assignment Report on Khon-Kaen Sewerage was very much helpful for making this report.

Field survey was done, in part, by the Japanese Survey Team in leveling and plain table surveying roughly for the particular purpose, but these shall be also checked latter when detailed design would be started

1.3 Concept of Planning and Designing

Planning is interpreted in different ways by different people. The use of planning methods may be divided very broadly, among several stages of overall planning. Planning can best be done by arranging a meeting or a series of meetings at which all the interested participants can discuss the future procedures.

When any engineers would make a plan of water supply system, it is as usual that they would consider about it emphasizing on a farsighted policy. Simultaneously, it should be feasible and adaptable in actual construction from the views of not only technically but also budgetary. However, according to the condition of budgetary limitation, it is not always completely feasible even though it is adaptable technically In other word, although any one knows about what a larger container is always suited for a smaller material, a smaller container should be ready for a smaller material, due to the budgetary limitation.

On the contrary, it is absolutely necessary to plan the long range period of planning such as 20 to 30 years if some one would suppose to borrow the aids from the World Bank or Asian Development Bank although there is still doubt about it. Further among the long range of planning, it is needed to separate any programme into few stages of programme, and the first stage of this programme might be covered by detailed designing as a general rule

a) Master Planning

The time being, the word of Master Planning is not always used as it is correctly defined

There are many terms in which the word of master is used in combination with other word, such as master-key, and master-hand which are understood as it is superior wherever it goes. Following these understanding, the Master Planning might be defined as only one solution, but it may be possible after the comparative study such as feasibility study This kind of understanding is also proved by the fact that there is a sentence of "feasibility study of master planning"

On the other hand, it is not sure whether the Master Planning is always adaptable, because the scheme mentioned in Master Planning is little far from the present circumstances, even thought it will be good enough - might be best - to improve present situation In other word, the best one is not always accepted by a country which it confronted with a lack of budget Further, the best one might be extravagant from standpoint of present national economy

In occasion of Master Planning, it is required that the recommendation is done with regard to the number of phases However, although any one understand well that the first stage of Master Planning should be forwarded in order to satisfy the long range planning such as 20 to 30 years, he also has to consider about the circumstances which are confronted with strict needs of water It may say such a condition as Emergency Programme

b) Emergency Programme

It is little difficult problem whether the Emergency Programme must be prior to the first stage of Master Planning More, there are great doubts about the fact which the Emergency Programme must be considered as almost same scheme comparring with the first stage of Master Planning, although both programme should be coincided in general concept. For example, in case of planning of the Emergency Programme, any one may assume the design population in range of next decade or less, but the first stage of Master Planning may be one part of long range programme such as 20 to 30 years, even if it is least requirement of large scale of planning. More, taking the data of the water demand per capita, the Emergency Programme is limited to satisfy supplying of drinking water, but the first stage of Master Planning should be considered for not only drinking water but also fire fighting water

For example, in case of large scale of planning (Master Planning) designed by surface water utilization, cheaper deep wells would be dug in connection with smaller size of pipe line in the stage of Emergency Programme The deep wells should be scheduled in the Master Planning as supplementary intakes Besides of intakes, the distribution system should be avoided from duplex investments in pipe line In other word, the pipe line would be allowed to lay on the line from smaller size to larger size in the direction of flow More, the pipe would be temporarily allowed to set on the surface of earth, when it could not be matched on the Master Planning In any case, it is absolutely necessary to avoid from being wasted of any materials, even if it is Emergency Programme

c) Rehabilitation Work

In addition to Emergency Programme, it is also pointed out that existing facilities of water supply should be carefully improved until it would reach to normal condition for operation Abnormal condition might be caused by a lack of budget, knowledge of operator and/or supervisor and unconcerned behaviour against compulsory works, however it is absolutely necessary to emphasize promptly present capacity of water supply facilities in order to determine value and amount of extension work.

From these point of views, there is importance about Rehabilitation Work by which any equipment and apparatus shall be recovered and improved until normal capacity recognized on design criteria and standard. After the possibilities of reducing water losses and increasing own capacity by being rehabilitated, are not sufficiently explored, sometimes additional consideration would mostly taken care of it

d) Feasibility Study

It is common that comparative studies would be taken care in order to consider about overall programme including the Emergency Programme on the occasion of making Master Plan In general speaking, the preparation for fund lending from abroad has required proportionately much time and effort. The reason are not so much deficiencies in detailed design but unsatisfactory analysis of comparative studies. This refers to the identification and analysis of alternative ways under the Feasibility Study

In case of feasibility study, it is possible to study three alternative plannings which are designed by changing the period of plan and the future prospect of water demand. Thus three alternatives would be maximum and it is apparently much cost by if more than three might be thought

When it is technically difficult to compete among two alternative designs, usually economic comparative study would be done It is always clear that the comparative study has a big advantage which partial changing of step would not influence to following step in designing

Chapter 2 Summary & Recommendaion

2.1 History and Present Situation

Ever since the very beginning of the municipality planning and construction work which started on 1955 (40 m^3/hr.) and 1961 (40 m^3/hr.), the municipality had endeavoured to provide sufficient amount of water to the Khon Kaen. However, the increasing needs were so rapid that the other supply was made on 1964 (160 m^3/hr.) and 1968 (160 m^3/hr.). Furthermore, another action has been done to ensure the shortage of water on 1972 (500 m^3/hr.). These are summarized as follows.

Year	Cap.	Intake	Water Treatment Plant	Status in Future
1955	40m^3/hr.	Kut Kwang	near municipal market	going to be withdrawn
1961	40m^3/hr.	"	"	"
1964	160m^3/hr.	Kut Kwang	Nong Waeng	as Existing No. 1
1968	160m^3/hr.	"	"	"
1971	500m^3/hr.	Irrigation Canal	near Irrigation Canal	as Existing No. 2
Total	820m^3/hr. (900m^3/hr)			

As stated above, the oldest one (80 m^3/hr.) is not good enough to operate continuously as well as said capacity because of smaller size and classic style. Then, it shall be withdrawn in earliest convenience, as the result of total existing capacity as 820 m^3/hr (19,680 m^3/day).

2.2 Future Population and Water Demand

The following future projection are arrived, as a result of surveys and studies, on the water supply in Khon Kaen municipality on the basis of which the proposal for action is recommended.

1) The future population is estimated on the basis of power function's estimation in central area and geometric ratio's estimation in suburban area.

Year	Central Area	Suburban Area	Total
1980	45,600	28,100	73,700
1990	60,800	37,800	98,600
2000	76,800	50,700	127,500

2) The house connection is estimated as shown in the followings

Year	House Connection (%)
1980	65
1990	70
2000	75

3) The daily maximum consumption per capita is estimated as shown in the following.

Year	Consumption (l/c/d)
1980	250
1990	275
2000	300

4) Effective percentage is determined as 70% after allowing leakage and mastage.

5) The total water demands by year in future programs are shown as follows.

Year	1980	1990	2000
Served Population	73, 700	98, 600	127, 500
House Connection (%)	65	70	75
Maximum Daily Demand (l/c/d)	250	275	300
Total Demand (m^3/d)	12, 100	19, 100	28, 700
Average Daily * Consumption (m^3/d)	8, 067	12, 733	19, 133
Average Consumption (m^3/year)	2, 944, 455	4, 647, 545	6, 983, 545
Effective (%)	70	70	70
Yearly Consumption (m^3/year)	2, 061, 119	3, 253, 282	4, 888, 482

*: Average Daily Demand = Total Demand/1. 5

2. 3 Need and Proposed Action

Judging from present status of water supply at Khon Kaen municipality, it is fortunate that the new water intake and treatment plant have just completed in result of enough supply of treated water to the dwellings. Therefore, it is not necessary to implement urgent construction in addition to existing facilities, but the present situation of water management can be eased to great extent by rehabilitating the existing facilities.

About rehabilitation work all the leakage of pipes, valves and meters should be repaired as good as possible The next step should be to rehabilitate old purification facilities in which appropriate maintenance shall be scheduled in views of chemical dosing, sludge blow off and filter washing. And, also, all visible leakage on the distribution system should be repaired, in addition to installation of all necessary water meters.

2 4 Recommendation

2.4 1 1st Stage Works (target year 1990)

Intake Tower:	Surface Water, 820 m^3/hr at Nam Phong River
Raw Water Pump:	Mixed Flow Type, 9.97 m^3/min x 3 (including one spare)
Raw Water Main:	Cast Iron Pipe, ϕ500 - 3,200 m
Raw Water Conveyance Pump:	Volute Type, 2 67 m^3/m x 3 (including one spare)
Raw Water Conveyance Pipe:	Cast Iron Pipes, ϕ400 - 12,100 m
Distribution Pipes:	ϕ500 - ϕ150, 26,780 m

2 4 2 2nd Stage Works (target year 2,000)

Treatment Plant:	500 m^3/hr nearby irrigation canal
Clean Water Reservoir:	3,000 m^3 x 1 unit
Distribution Tank:	700 m^3 x 1 unit
Pump:	Volute Type, 5 65 m^3/min x 3 (including one spare)
Conveyance Pipe:	Cast Iron Pipe, ϕ500 - 4,100 m
Distribution Pipes:	ϕ500, 400 and ϕ200: 9,280 m

2.5 Summary of Construction Cost

The summary of construction cost is given in Table 2.1, These costs are based on following rules.

a Construction costs are calculated taking into consideration the size of the various works, based on parallel examples in Japan.

b Cost of materials, pumps, electric equipment, cast iron pipe, etc., which are imported from foreign countries include the prices CIF Bangkok, landing costs and custom duties In case the diameter of the pipe is less than 300mm asbestos cement pipe made in Thailand shall be used

c. Land costs are calculated at 20,000 Bahts per Rai, not including compensation costs.

d. Reserve funds for unforeseen costs shall be 10% of the construction cost e Expenditures are estimated to be 20% of the local currency costs for supervision, office expenses, construction site expenses, and other miscellaneous use.

f Administrative expenditures of Thai Government Agencies and its delegated representatives are estimated as 4% of total construction costs

Financial plan and water charges was based on the allocation of foreign and local currencies as follows.

a. Foreign Currency
   - Interest Rate: 4.0%
   - Term of loan: 20 years
   - Grace Period: 5 years

b Local Currency
   - Interest Rate: 8 0%
   - Term of loan: 30 years
   - Grace Period: 5 years

c. Amortization
   - Foreign currency: 15 equal annual payments
   - Local currency: equal yearly payments over a 25 years period.

d Charge for served water should be 1.5 Bahts.

Table 2 1. 1 Summary of Construction Cost (1st Stage)

(Unit: Baht)

Item	Total Cost	Foreign Currency	Local Currency
(1) Intake & Raw Water Conveyance	18, 600, 000	14, 800, 000	3, 800, 000
(2) Water Treatment Plant	950, 000	50, 000	900, 000
(3) Distribution System	14, 200, 000	7, 620, 000	6, 580, 000
(4) Electric Equipment	2, 000, 000	1, 300, 000	700, 000
Sub-Total	35, 750, 000	23, 770, 000	11, 980, 000
Engineering Fee	1, 790, 000	1, 790, 000	0
Administration Cost	1, 430, 000	0	1, 430, 000
Reserve	3, 580, 000	2, 440, 000	1, 140, 000
	42, 550, 000	28, 000, 000	14, 550, 000

Table 2. 1. 2 Summary of Construction Cost (2nd Stage)

(Unit: Baht)

Item	Total Cost	Foreign Currency	Local Currency
(1) Raw Water Conveyance & Treatment Plant	4, 800, 000	1, 888, 000	2, 912, 000
(2) Distribution System	14, 220, 000	9, 532, 000	4, 688, 000
(3) Electric Equipment	1, 000, 000	600, 000	400, 000
Sub-Total	20, 020, 000	12, 020, 000	8, 000, 000
Engineering Fee	1, 000, 000	1, 000, 000	0
Administration Cost	800, 000	0	800, 000
Reserve	2, 000, 000	1, 200, 000	800, 000
	23, 820, 000	14, 220, 000	9, 600, 000

Chapter 3 The Existing Water Works

3.1 Water Works Facilities

3.1.1 General

At 1955, the Khon Kaen municipality started the supply of water on the base of 40 m^3/hr. in which the water intake was located nearby Kut Kwang and the water treatment plant was constructed near the municipal market. However, emphasizing the center of north eastern part of Thailand, since there was almost cronic shortage of water supply all through the year, additional facilities of 40 m^3/hr. was made in 1961 as same shape and size as last one in the result of 80 m^3/hr. as total capacity.

Unfortunately, the municipality was confronted again with shortage of water, and was obliged to construct other type of water treatment plant (160 m^3/hr) in Nong Waeng having same water intake as previous facility at 1964. Only four years latter, the new water treatment plant was duplicated again because of rapid increase of water demand, in consequence of 320 m^3/hr. in Nong Waeng in addition to old water treatment plant (80 m^3/hr.) nearby municipal market at 1968. Consequently, the municipality depended upon water intake at the Kut Kwang in result of 400 m^3/hr. as total capacity.

Facing with the difficulties of water intake in Kut Kwang, the municipality decided to start epoch-making construction of new water supply system in which the water source be provided at irrigation canal of Royal Irrigation Dept. and the water treatment plant be located nearby the water intake. This system has just completed construction in the capacity of 500 m^3/hr. resulting total capacity of 900 m^3/hr.

According to present capacities of existing facilities, oldest water treatment plant located near municipal market is understood that it shall be withdrawn after completion of next extension project. This means that the concept of extension project shall be based on 820 m^3/hr.

3.1.2 Water Source

Existing facilities of water source are as follows, as shown in Fig. 3.1. There are now two water sources such as Kut Kwang River and Irrigation Canal, but the water from Kut Kwang River is now separated into two parts, one for the water treatment plant near municipal market and other for Nong Waeng. Although the water treatment plant near municipal market is going to be withdrawn in future, the capacity of water intake in Kut Kwang shall be same as before, namely 320 m^3/hr. On the other hand, the capacity of water intake in irrigation canal is called as 500 m^3/hr.

There are many problems in Kut Kwang River, one is water quality and other is water quantity As far as water quality is concerned, Fig. 3.2 shows the water quality changes throughout a year in views of oxygen consumed, turbidity, iron contents, chloride contents and so on. Judging from Fig. 3.2, it can be said that the worst quality of water is recorded around May depending upon annual conditions such as climate and crops, and it is not so serious in rainy season. This means that the any substances must be run-off by the rain fall after being accumulated in condensed condition during dry season around the catchment area of Kut Kwang, and after around May the water quality must be diluted by the amount of run-off in consequence of improving to a better quality.

Fig. 3.3 - (a) shows existing intake at Kut Kwang River.

Further study of water quality in Kut Kwang shall be considered for the reasons of existence of pollutants such as chlorides organic matter and iron contents The amount of chlorides more than 200 ppm or nearly beyond 100 ppm will be caused by rock-salt, animal and human wastes. The oxygen consumed may be caused by washing waste of jute processing (Fig. 3. 4) The iron contents nearly beyond 2 ppm may be depended on the iron ores These three items shall be given as a warning of existences of pollutants by which the water treatment becomes to be difficult to handle.

In view of water quantity, there is a big problem about fluctuation of flow through Kut Kwang. In dry season, it is difficult to pump up the water without any groin (Fig. 3. 3-b) such as wooden dam or sheet pile. On the contrary, in rainy season temporary structures at down-stream of existing intake are damaged easily by the flood However, if a permanent structures such as concrete dam would be built at down-stream of water intake, upstream can easily be flooded in result of serious damages of plant field Particularly, the railway bridge will be face with danger of scouring of foundation

From these point, it is recommended to use existing water intake as a stand-by unless permanent river improvement is done

The other intake located near irrigation canal has just completed construction under the design of 500 m^3/hr The reason why there is big artifical reservoir (Fig 3 5) nearby irrigation canal is to cover the water when no water flows through the canal in the time of repair. It seems that through there may be an adequate flow in the irrigation canal during wet season the flow during dry season may be insufficient due to operational halts for routine maintenance of canal. Analysis of the reservoir is written in following chapter

From this point of view, it is recommended to use existing intake at irrigation canal as well as design capacity, but supplementary water intake shall be located near irrigation canal, if possible, in order to cover water alternatively.

3 1. 3 Water Treatment Plant

According to the present location of water intake, there are two water treatment plants, one is in Nong Waeng (320 m^3/hr) and other is near irrigation canal (500 m^3/hr)

Routine test of raw water quality Kut Kwang has shown in Fig. 3. 2 which has already discussed Other test are shown in Table 3. 1 which are found to justify the existence of significant contamination in treated water. This is because of the chloride and iron content which are sometimes over the WHO standard (Table 3. 2).

Table 3 1 Water Analysis of Treated Water a : Turbidity in Silica Units (ppm)

Month \ Year	1964	1965	1966	1967	1968	1969	1971
Jan.	—	—	11	10. 5	25	9 6	- –
Feb.	—	—	—	—	9. 6	—	—
Mar.	—	—	25	11	9 6	5 6	4 8
Apl	—	—	11	8. 2	8. 5	11	8 8
May	—	—	25	11	9. 6	9 5	24
Jun.	—	—	91	8. 6	25	0. 5	22
Jul	—	—	—	5. 3	8 5	5. 5	4 0
Aug	—	—	25	5. 4	8 2	6. 5	—
·Sep.	—	—	11. 3	5 8	11 0	0 5	—
Oct.	—	—	—	9. 6	8 2	1. 5	—
Nov.	—	38	25	11. 0	6 4	—	—
Dec.	—	—	11	11	8 4	10	—

b : Chloride Contents

(ppm)

Year / Month	1964	1965	1966	1967	1968	1969	1971
	314 9	—	80. 0	96. 0	56. 5	212. 0	—
Feb	151. 7	161. 6	—	—	59. 5	—	—
Mar	135 2	220. 0	94. 0	123 0	67. 5	230 0	150. 0
Apl.	146. 7	169. 8	110. 0	142. 0	85. 0	256. 0	166 0
May.	159. 9	173. 1	111. 0	166 0	94 5	297. 0	181. 0
Jun.	159. 9	161. 7	90. 0	176. 0	91. 5	316. 5	173 0
Jul	148. 4	164. 0	—	167. 5	107. 0	135. 0	171. 0
Aug.	235. 7	168. 2	94. 0	159. 0	107. 0	101. 0	—
Sep	326. 4	—	79. 0	164 0	135. 0	119. 0	—
Oct.	196. 2	—	—	56 0	178. 5	—	—
Nov.	—	68 5	76. 5	40. 5	175 5	—	—
Dec	108. 8	—	91. 5	47. 5	188. 5	79. 0	—

c : Iron Contents

(ppm)

Year / Month	1964	1965	1966	1967	1968	1969	1971
Jan	0. 08	—	0. 40	0. 50	0. 50	0 30	—
Feb	0 44	0 10	—	—	0 50	—	—
Mar	0 14	0 39	0. 40	trace	0 50	0 50	0. 50
Apl	0 20	0. 08	trace	trace	trace	1. 10	0 50
May.	0 24	0. 32	0. 30	trace	1. 00	0. 30	0 80
Jun	0. 78	0 24	1. 00	trace	1. 70	0. 10	0 30
Jul	0. 04	0 42	—	0 20	trace	0. 50	0. 80
Aug.	0. 44	0 12	1 40	trace	0. 50	0. 30	—
Sep	0. 32	—	0. 20	0 40	0 80	0. 30	—
Oct.	0. 13	—	—	trace	0 50	0. 70	—
Nov	—	0 20	0. 30	trace	0. 50	—	—
Dec.	0 16	—	0. 40	1. 00	0 30	nil	—

Table 3. 2 Maximum Permissible Amount, Drinking Water Standard, WHO

Item	WHO Standard
pH	6. 5 - 9. 2
Total Hardness	100 - 500 ppm as Ca CO_3
Chloride	200 ppm
Ammonia Nitrogen	0. 5 ppm
Nitrate Nitrogen	40 ppm
Iron	0. 3 ppm
Fluoride	1. 0 ppm
Manganese	0. 1 ppm
Pnenol	0. 001 ppm
Magnesium	50 ppm
Culcium	75 ppm

The iron content can be improve by a additional equipment or method such as aeration and pre-chlorination, but the chloride is almost impossible to remote from treated water by adequate process besides of unremunerative cost. Fortunately, the chloride content is always below 200 ppm of WHO Standard, so that it may not be necessary to consider seriously about chloride at this moment. However, judging from fluctuation of chloride content shows the unreasonable circumstances around catchment area.

As far as amount of treated water is concerned, present capacity is totalized as 820 m^3/hr (19. 680 m^3/day) which is enough amount of treated water for water demand at 1990 (19. 100 m^3/day). Thus, it is not necessary to construct new water treatment plant in a hurry, besides of improvement of existing capacity.

Fig. 3. 6 shows the existing sedimentation and filtration basins located in Nong Waeng. Followings are general impressions on these facilities at present operation.

1) Chemical closing equipment shall be re-arranged by being followed on theoretical and practical consideration.

2) Water depth of rapid sand filtration is now so shallow because of heavy consumption of effluent, that at least one meter shall be kept always during normal operation.

3) Depending upon an amount of carry-over from sedimentation besins, the filter has tend to be clogged in short run of operation. Then, it is needed to wash the filter often.

Fig 3.1: Plan of Water Supply System

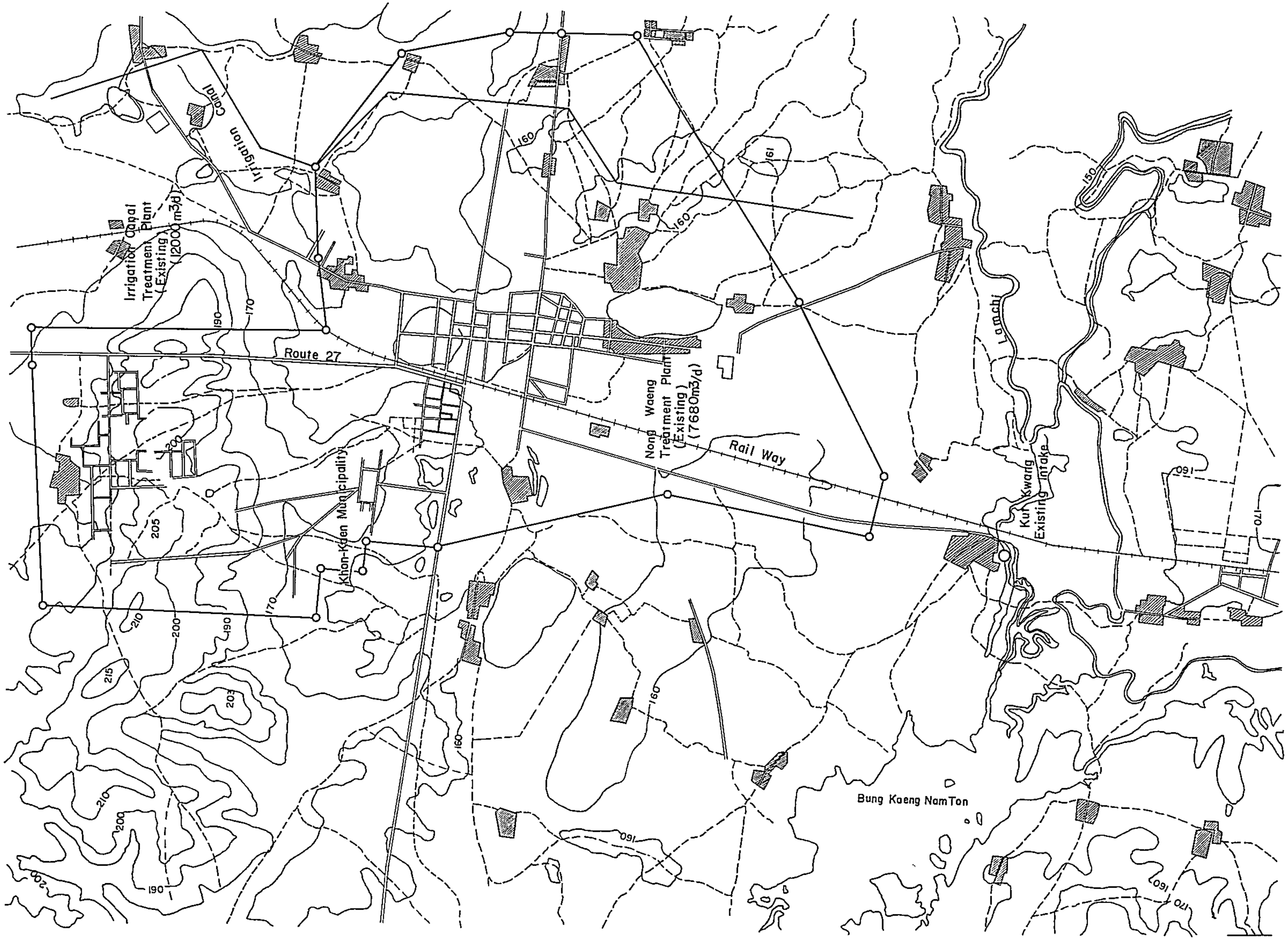
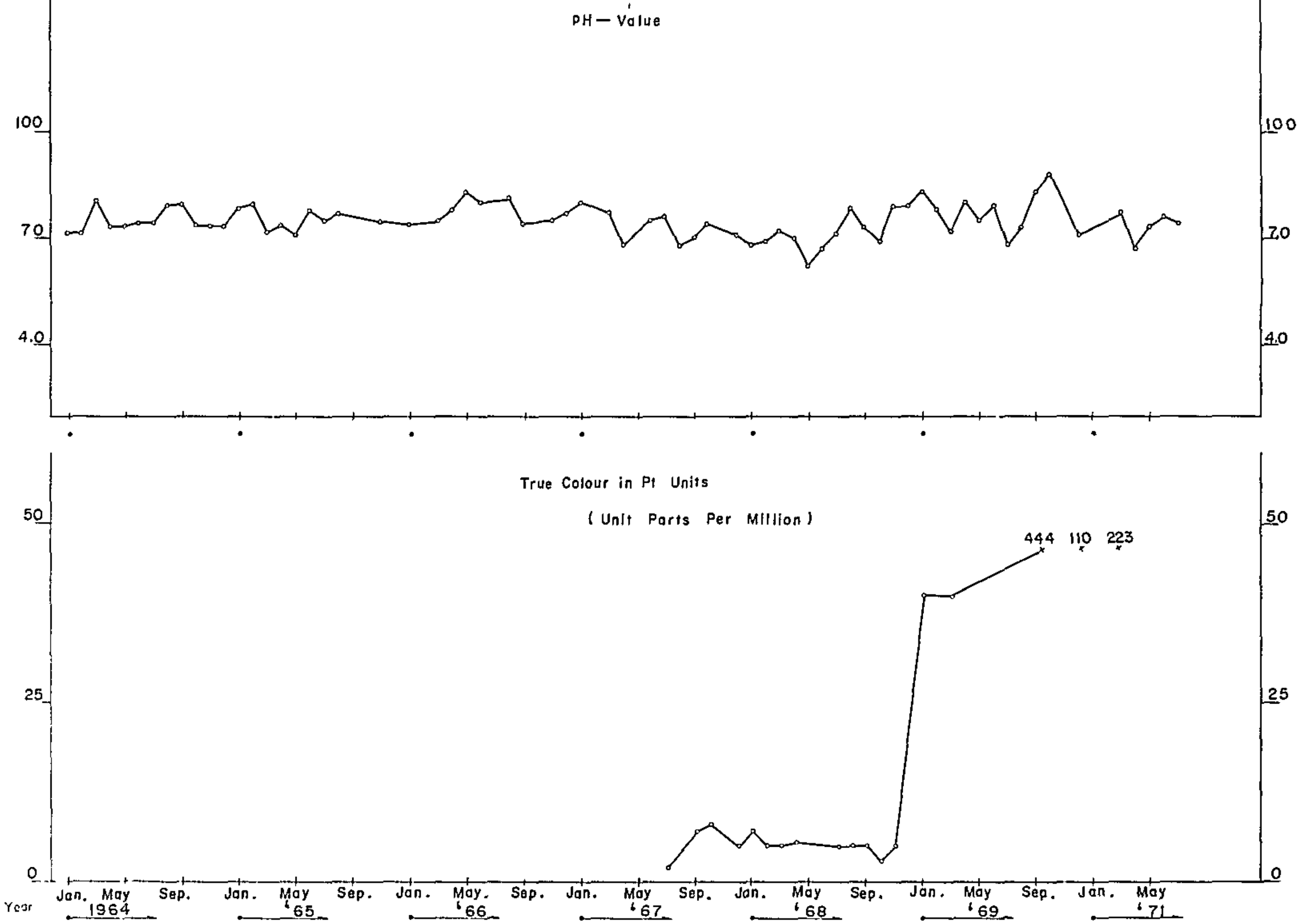


Fig. 32


PH — Value
100
70
4.0
True Colour in Pt Units
(Unit Parts Per Million)
50
25
0
444 110 223
Jan. May Sep. Jan. May Sep. Jan. May. Sep. Jan. May Sep. Jan. May Sep. Jan. May Sep. Jan. May
Year
1964
'65
'66
'67
'68
'69
'71

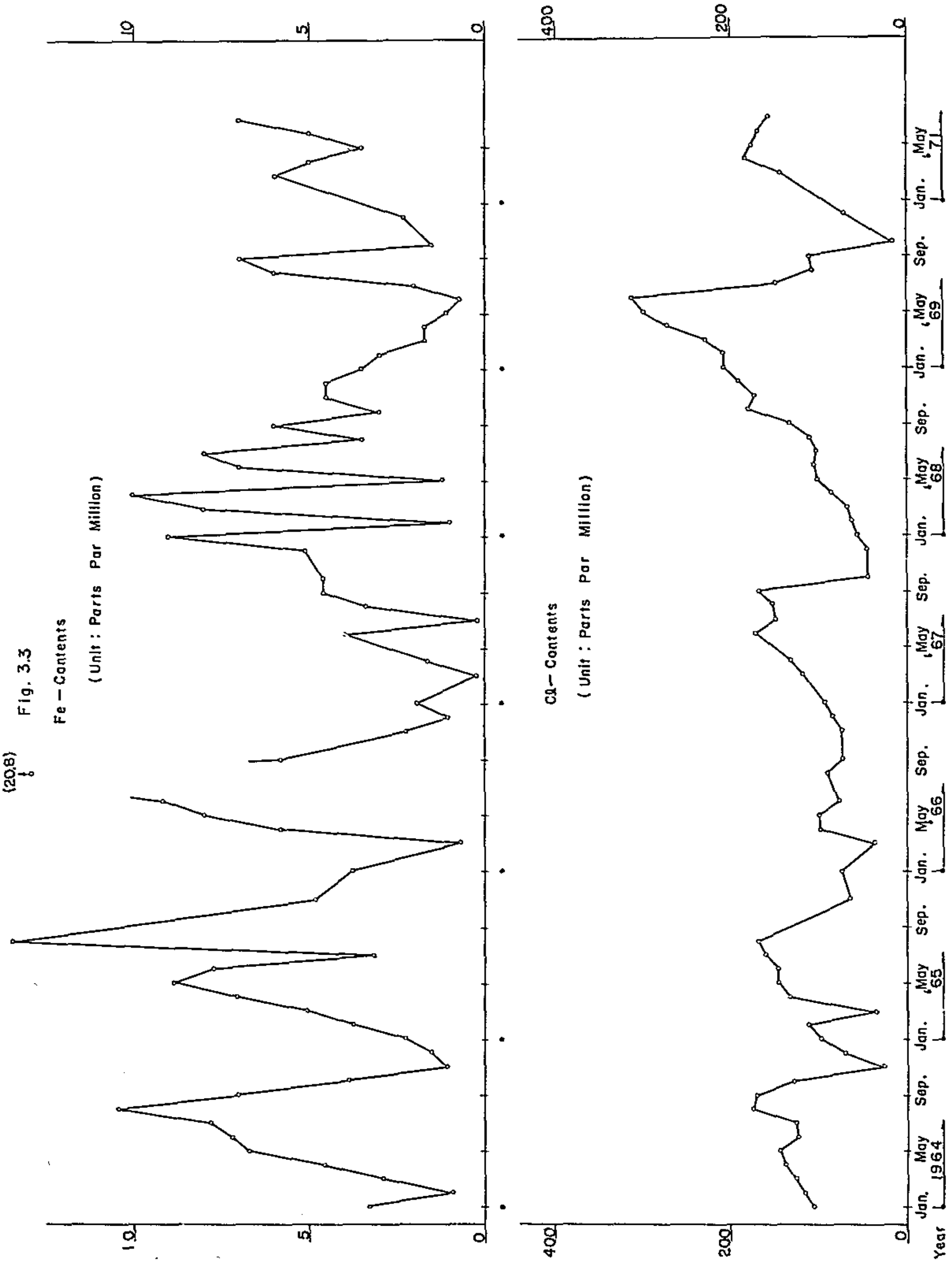


Fig. 3.3
Fe – Contents
(Unit : Parts Par Million)
(20.8)
10
5
0
Cl– Contents
(Unit : Parts Par Million)
400
200
0
Jan. 1964
May
Sep.
Jan.
May 65
Sep.
Jan.
May 66
Sep.
Jan.
May 67
Sep.
Jan.
May 68
Sep.
Jan.
May 69
Sep.
Jan.
May 71
Year

Fig 34

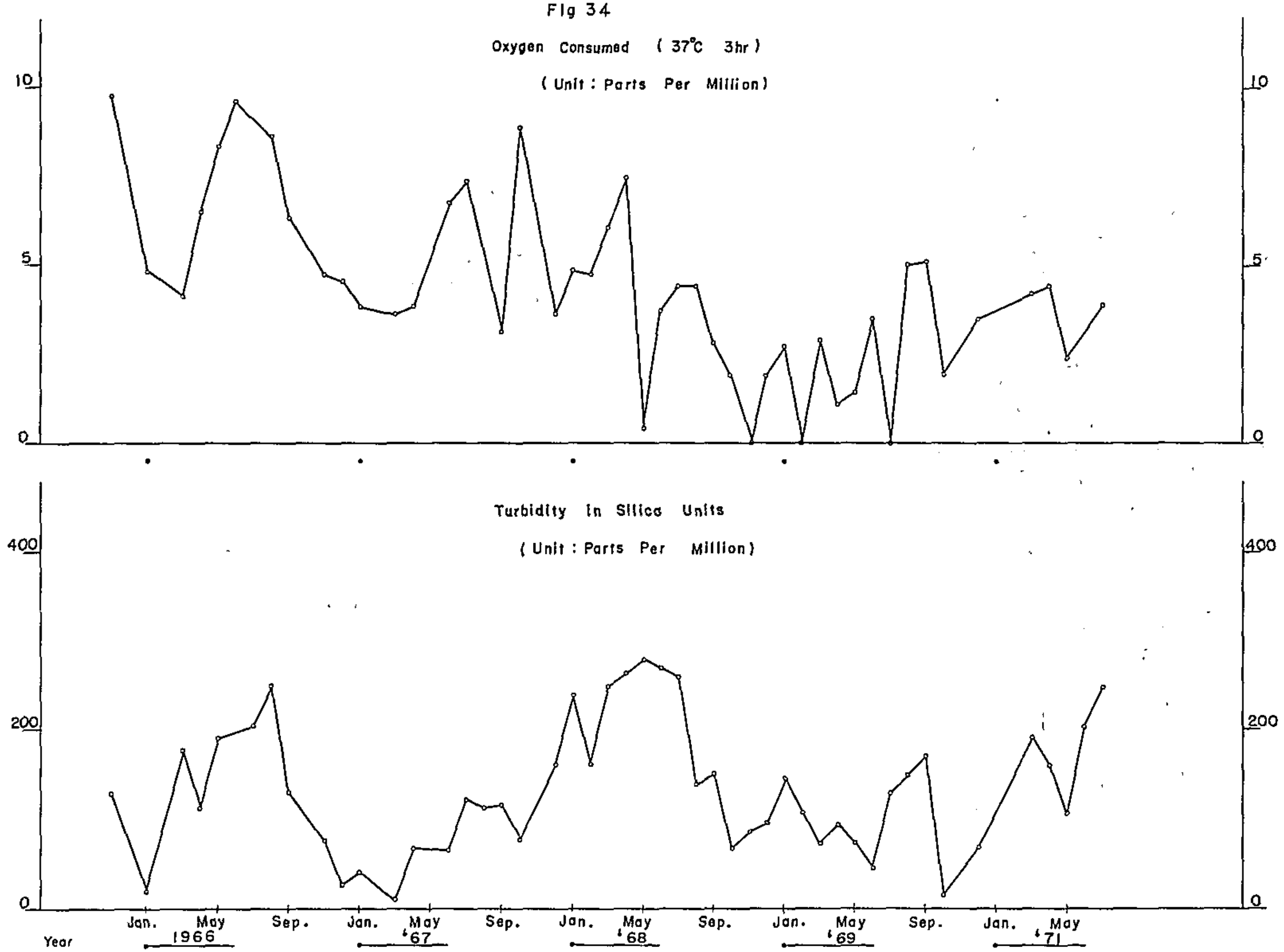

Oxygen Consumed (37°C 3hr)
(Unit : Parts Per Million)
10
5
0
Turbidity In Silica Units
(Unit : Parts Per Million)
400
200
0
Jan. May Sep. Jan. May Sep. Jan. May Sep. Jan. May Sep. Jan. May
Year
1966
'67
'68
'69
'71

Fig 3-3(a) : Intake at Kut Kwong

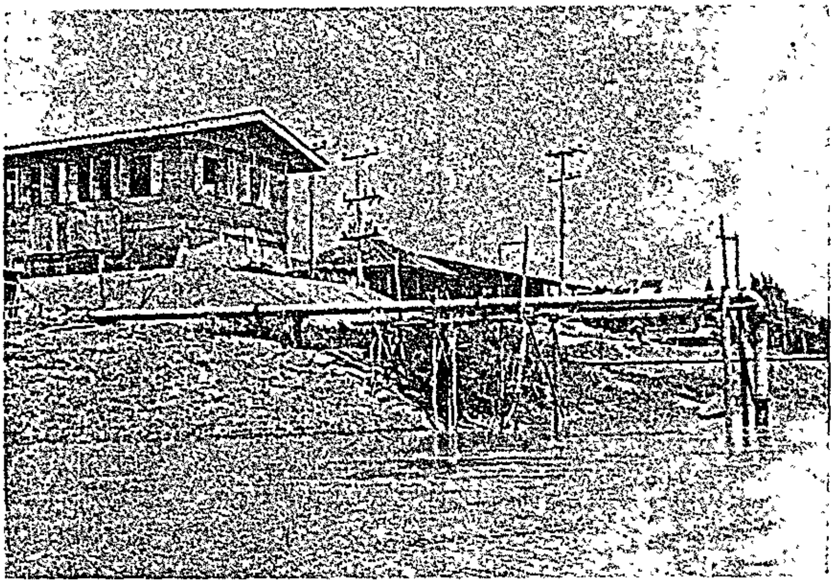


Fig. 3-3(b) : Temporary Groin at down-stream
(damaged by flood)

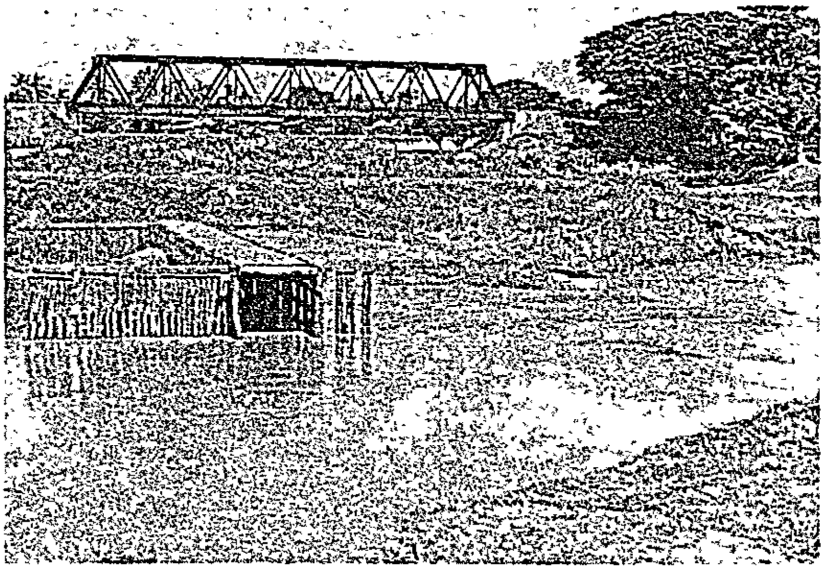


Fig. 3-4(a) : Jute Processing at Lake
(Bang Kaeng Nam Ton)

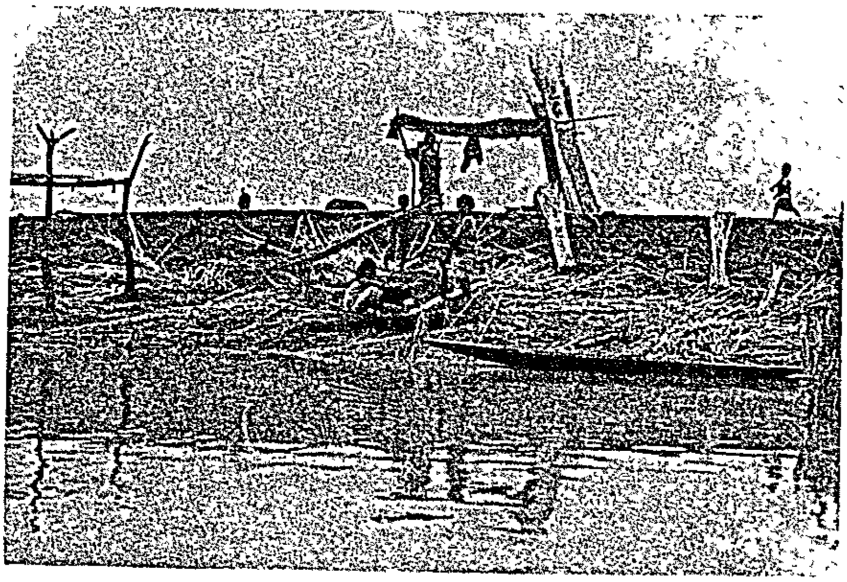


Fig. 3-4(b) : Jute Processing at River
(Nam Phong)

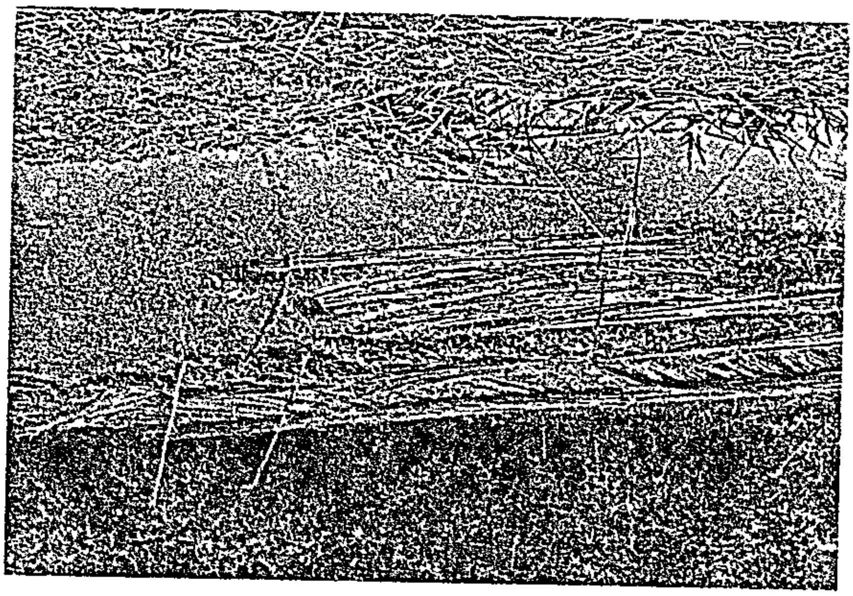


Fig. 3-5 Artificial Reservoir (near irrigation canal)

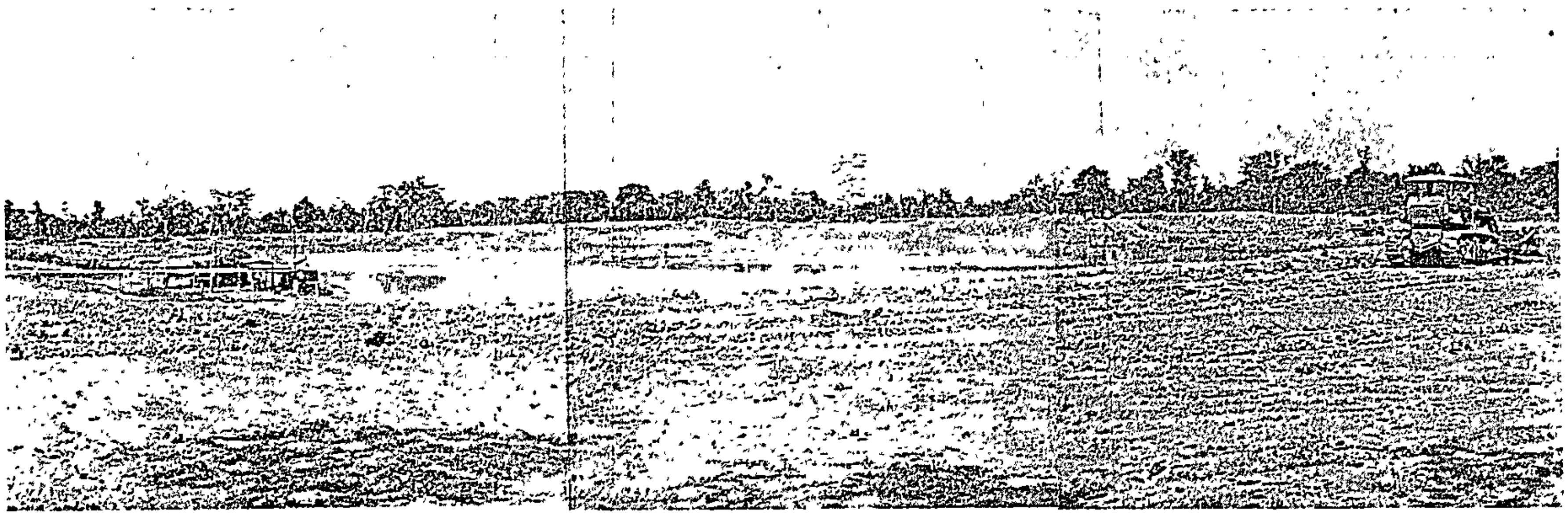


Fig. 3-6 (a) : Sedimentation Basin
(Nong Woeng)

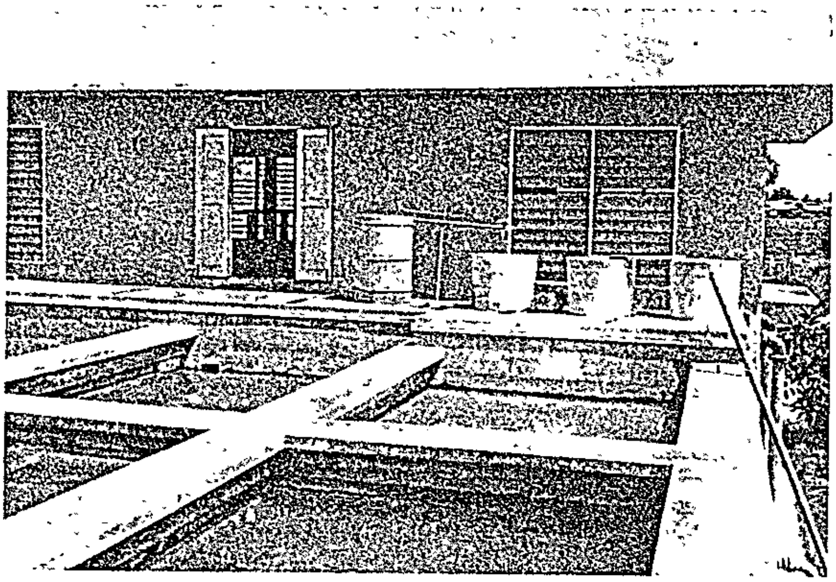
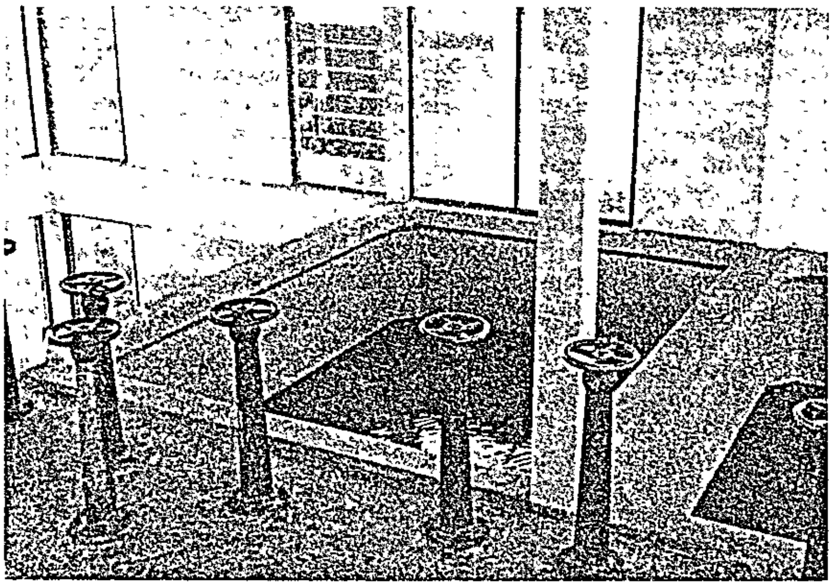


Fig. 3-6 (b) : Filtration Basin
(Nong Waeng)



Chapter 4 Population Projection

4.1 Population Projection

4.1.1 Existing Data in City Planning Dept.

a) Population and Professional

In Planning for the future of community in any places needs the consideration to the amount of population in the future of that community. Because of the personal expandi- ture of community means the increasing of demand in residences, offices, schools, food, electricity, water supply and every kinds of public utility servicing. Moreover, the appearance of the country and also the community's conditions depend on the amount of population. The country with crowded of people, of course, has more residences than the country with lower amount of people. And the conditions of economic and society have also more progress.

The forcasting of the amount of people in any occations which will be increase in the future is necessary to survey the amount of people in that location both in the past and present. By means of the amount of people, we are able to forcast the amount of people in the future by using the truth that "increasing the amount of people in future is the proportion or relation to the increasing of amount of people in the past for that area", This is to say that, number changing from the natural and usual conditions in that area. However, the important aims of the government, developing of working system, conditions of economic and society including to environment conditions during forcasting relate to the increasing or decreasing of amount of people in the community too.

b) Forecasting the population in the future

In forcasting the amount of people in the future for small community such as, population within Khon-Kaen city which is the area for planning has a chance to be mis- taken very easily. Because, any changing may be happened in that area, even quite little change, for example, new factories or industries have been constructed, new roads or lacking of water in agriculture. These caused the amount of people increase or de- crease rapidly. And moreover, the statistics related to the rate of birth and dead, moving in and out, age and sex of the people in that area have small in number and missing which make the difficulty for forcasting and for from the correct way. However, although risk to the missing, estimation or forcasting necessary to do. Because, the amount of people in the future is the most important in planning the city. The number of field's area which will become the residences, trading, industries, number and size of schools, size of government offices, types of public servicing such as watersupply, electricity, roads must depends on the amount of peopl e in the future which has forcasted.

The main thing use inforcasting in amount of people within Khon-Kaen city which increase in the future is the increasing the amount of people in small area relate in pro- portion to increasing the amount of people in the bigger area. Thus, we might be have a theory that " increasing the amount of people in Khon-Kaen City which is the area for planning is the proportion to increasing the amount of people of the whole Khon-Kaen province", in the same time between Khon-Kaen province and north east, and also the whole country. (Plan 2) So, the consideration of the increasing people of the country and of north east is the first necessary in calculation the amount of people of Khon-Kaen city, as following consideration : -

1. Population of the country: It appeared that the number of population in the whole country is 26,257,916 when compare the statistic with the first collec- tion in 1919, only 9,207,355 or means that the population increased 17 millions

within only 41 years. If consider to the increasing rate of number of population, we will see that in the last decade (between 1947 - 1959) people of country increased 3.2% which the highest rate when compare with the next year. And when compared with the increasing rate of people in this stage with another countries such as Burma and Philippines. The increasing rate of people in Thailand is higher than those countries in low percentage.

In forcasting the number of people of the country in the future. In here, regarding the calculation from the report of city planning expand which arrange the Bangkok & Thonburi city plan and has forcasted 1982. Population of the whole country is about 43,525,000 by assuming the average rate of increasing people of the country in next 20 years which equal the increasing rate in year 1947 to 1959.

2. North-East part: The increasing rate of people of north-east which has been averaged every year in every decade showed that the gradually increasing rate up to the highest during the last decade between 1947 to 1959. It means that the rate of increasing up to 2.76% when compare with the increasing rate of country.

   In 1960, the population in North-East is about 8.9 million more than 1/3 of the the population of the whole country. It distributed to the village. Then, the crowded people conditions have not much with average density only 53 per square km.

   The regular increasing rate of people and planning for developing the country are stimulate to increasing the population in North-East very rapidly. From year 1952, the increasing rate of people up to present increase about 5%. (Table 4.2)

3. Number of population in Khon-Kaen: Khon-Kaen province is one in the 15 provinces of Northern part of Thailand. The area and population of this province are the third of this part from Ubol and Nakorn-Rajasima provinces. But the increasing rate of people is high in the second from Nakorn-Rajasima province. The average density about 63 per square km.

   Distribution of population in Khon-Kaen is the same as other provinces of North-East. It means that, the distribution has come to the villages. The increasing rate of number of population in Khon-Kaen which has calculated in percentages in every ten years (Table 4.1) showed that the increasing rate of population 1919 is 3.73%. And gradually decrease until 1959, then again gradually increase

   In increasing the number of population in each Amphur in Khon-Kaen province, those are Pol, Ban Pai, Nam Pong, Chum Pair, Pun Kaeud, Munja-Kiri, Kra-nuan and sub-amphur Nhong Reer showed the trend in increasing in every Amphurs. Amphur which has the highest increasing rate in during 1960 - 1961 is Nam Pong.

   Because of, the government has planned to develop Khon-Kaen is the central province of North East, and central of education, and the economic of this part according to North East developing plan. We can regard that the increasing rate of this province which has increased recently. It still keep this level and have a trend in higher. From the forcasting of population in Khon-Kaen in next 20 years (1982) showed about one time of population in the present.

4. Number of population in planning area: The area has considered for project planning of Khon-Kaen is Khon-Kaen city in the present which is in the municipality and it is the site for town hall and Khon-Kaen central development.

Table 4. 1 Population in Country, North East and Khon-Kaen Province

Year	Country	Increasing from past statistics		North East	Increasing from past statistics		Khon-Kaen	Increasing from past statistics		Khon-Kaen Municipal	Increasing from past statistics	
		Qua.	Av. /%		Qua.	Av. /%		Qua.	Av. /%		Qua.	Av. /%
1919	9, 207, 355	—	—	3, 253, 411	—	—	235, 682	—	—	—	—	—
1929	11, 506, 207	2, 298, 852	2. 16	3. 887, 165	633, 754	1. 80	399, 679	103, 997	3. 73	—	—	—
1937	14, 464, 105	2, 957, 898	2. 90	4, 952, 288	1, 065, 123	3. 07	475, 516	135, 837	3. 44	—	—	—
1947	17, 442, 689	2, 978, 584	1. 89	6, 169, 881	1, 217, 593	2. 23	590, 638	115, 112	2. 19	—	—	—
1957	23, 669, 459	857, 758	3. 19	8, 097, 216	232, 701	2. 76	774, 662	21, 412	2. 75	15, 853	—	—
1958	24, 311, 556	642, 097	2. 71	8, 266, 598	169, 382	2. 10	789, 618	14, 956	1. 94	16, 724	871	5. 51
1959	24, 979, 096	667, 540	2. 74	8, 441, 406	174, 808	2. 11	809, 738	20, 120	2. 55	17, 475	751	4. 49
1960	26, 257, 916	1, 278, 820	5. 11	8, 991, 543	550, 137	6. 52	884, 075	34, 337	4. 24	19, 548	2, 073	11. 86

Table 4. 2 Population of Country and rate of number of population in north east, Khon-Kaen province and municipality

	Population in Country	Rate of population between maximum and minimum								Remarks
		North East	%	Khon-Kaen	%	3 districts	%	municipality	%	
1919	9, 207, 355	3, 253, 411	33. 59	235, 682	7. 24	—	—	—	—	Increasing the
1929	11, 506, 207	3, 887, 165	33. 78	339, 679	8. 74	—	—	—	—	population in
1937	14, 464, 105	4, 952, 288	34. 24	475, 516	9. 60	—	—	—	—	municipality
1947	17, 442, 684	6, 169, 881	35. 60	590, 638	9. 57	—	—	—	—	more than
1957	23, 669, 450	8, 097, 216	34. 21	774, 662	9. 57	33, 504	4. 20	15, 853	48. 7	surrounded,
1960	26, 257, 916	8, 991, 354	34. 24	844, 075	9. 39	36, 090	4. 27	19, 548	51. 2	inclusion,
1962	26, 400, 000	9, 626, 000	36. 45	914, 500	9. 50	40, 800	4. 46	21, 600	52. 9	municipality
1967	29, 530, 000	11, 623, 000	37. 80	1, 104, 000	9. 50	52, 000	4. 71	29, 600	56. 9	expanditure and
1972	33, 600, 000	12, 835, 000	37. 20	1, 222, 000	9. 52	60, 700	4. 97	36, 900	60. 8	population nearly
1977	38, 245, 000	14, 877, 000	38. 90	1, 417, 000	9. 53	74, 000	5. 22	48, 000	64. 9	village moved in
1982	43, 525, 000	17, 062, 000	39. 20	1, 629, 000	9. 55	89, 300	5. 48	61, 300	68. 7	City.

Besides, this present city has fall of residences and people in area 3, 000 Rai.

In forcasting the number of population for planning area in the future is easily mistaken, because of it is small community area. So, in forcasting have to consider in increasing the number of population in the wide area before. In this case, has considered the whole population in 3 districts first, those are Sila, Pra-Lub and Kao district by thinking that the planning project area is one of these areas. And any in fluence of changing in Khon-Kaen municipality may be covered to these 3 districts. When considered the correlation rate of Khon-Kaen population in 3 districts, in 1960 the number of population is about 4. 27% of the province. But in the municipality, number of population was 19, 548 which more than 51. 2% of number of population in 3 districts.

From the forcasting by using the correlation rate(Fig. 4. 1) showed that the number of population in 3 districts increased from 4. 27% in the present to 5. 48% in 1982 when compared with Khon-Kaen province. In year 1982, it will have population about 85, 300 in these 3 districts. And in this number, about 61, 300 will be in planning program.

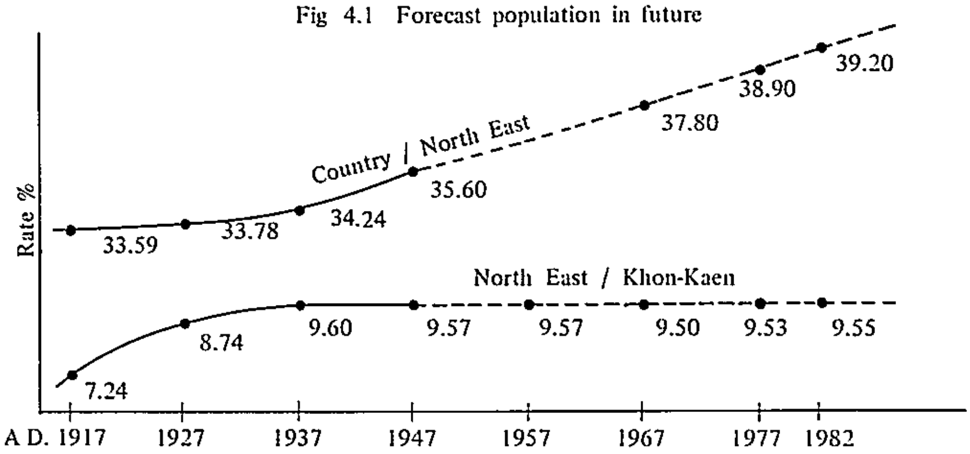
c) Conditions of living and career

Most of people in North East has the career in agriculture, for instance, planting rice or growing other crops such as kenaf and cotton etc. There are several size of villages which people in that village has the career in agriculture also.

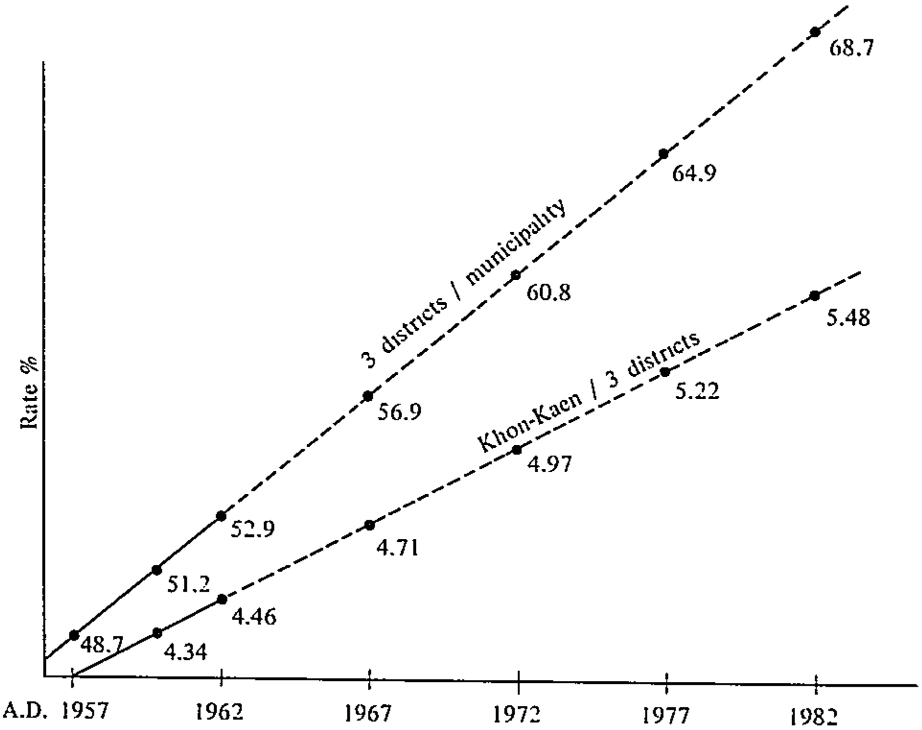
In Khon-Kaen city which is the central of economic, society and execution of Khon-Kaen has a conditions of living and career similar to the big villages. Most of population is farmers or agriculturer. Because the city has the important communication, especially the railway, it made the increasing of transportation. So, the conditions of living and career of population inside the city must higher than the people outside the city.

In plan number 6 has shown the expansion of number of population within the planning area. Showing the comparision of distribution of population.

Fig 4.1 Forecast population in future



Stage 1 Rate of population between country, North East and Khon-Kaen Province



Stage 2 Rate of population in Khon-Kaen, 3 districts around the city and present city

4.1.2 Existing Data in PMWD

According to the statistics of Statistical Sub-Section, Provincial Water Supply Division, PMWD, Table 4.3 shows the past records of population and consumer.

Regarding to the increase of population, there were comprehensive rule throughout the country such as "rate of population growth of Thailand between 1968 to 1983 in estimated 3.2% per year". This is too high rate of population increase. Thus, at the beginning of 1972 fiscal year, the Govt. of Thailand has decided the Third Five Years Program in which the rate of population growth has been reduced to 2.5% per year. If these rules will be applied to the duration from 1956 to 1970 in Table 4.3, the population in 1970 must be calculated as follows.

$$P = 21,537 \times 1.025^{14} = 21,537 \times 1.413 = 30,432$$

$$P = 21,537 \times 1.032^{14} = 21,537 \times 1.554 = 33,468$$

Judging from actual population as 31,625 at 1970, these rule are not so different from the fact, but not followed by the geometric increase of population.

4.1.3 Future Population

a) General Discussion

There are several methods of determination of planned population to be supplied such as arithmetical, geometric, logistic curve's and power function's increase. However, either one has only the meaning of mathematical consolidation, because vital statistics are not so simple knowledge which can be easily calculated on the mathematical equation. Population increase must be renewed by industrial growth, human revolution, industrialization, modernization of life, urbanization, innovation and so on.

The developing country always uses the way of five year program which has good sounds of emergency planning. However, it shall always be renewed again after two to three years. This is proved what how the future estimation is difficult or how so complex the fact is.

There will never be an accurate forecast of population over the next thirty years. This is caused by the reason that economic pressure, accelerated Government transfers, the attraction to the capital tend to increase the population during the early years of the city's growth. A knowledge of the municipality and its surburbs, whether or not its industries are expanding, the state of development will enter into the estimation of future population.

The ultimate figures arrived by this planning are to be said as tentative and will have to be further refined by undertaking a more detailed study in future and a continuous watch over the growth of population will have to be kept so as to enable precise and accurate forecast for the future.

b) Population in Existing Municipal Area

Fig. 4.2 shows the past data for 13 years from 1957 to 1970, which may identify the social factors rather than natural population increase as 3% per year throughout Thailand. This is same tendency as Korat Municipality, so that it is reasonable way to estimate future population by a power function method as shown in Table 4.4 and Table 4.5.

Table 4.3 Past Records of Statistics

Khon-Kaen Water Works — Source of Water Huay Kud Kwang

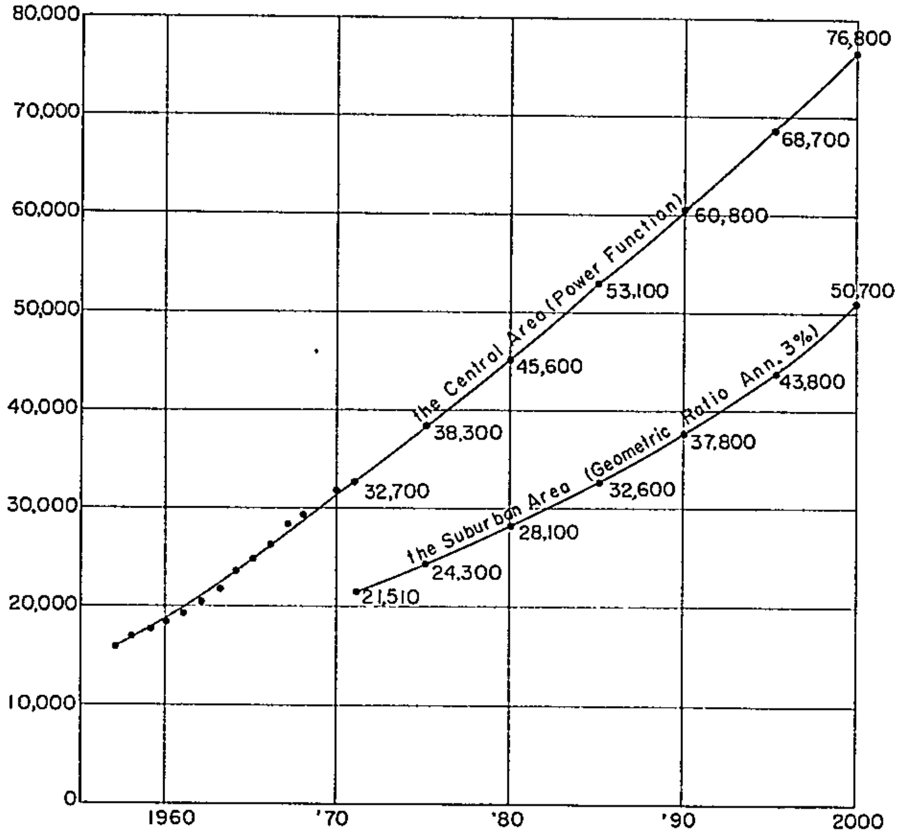
Starting Construction Expenditure 4,39,000 Baht

Started on 1 March 1955 — Capacity per day 8,000 m³ (1971)

Year	Population (person)	Increased+ Decreased−	Area (k.m)²	Density n of pop/km²	House hold	Average person/ House	Consumer			
							Consumer	Consumer (meter) Household	Consumer (Head) (7)/(9)	% of Consumer (11)/(2)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1956	21,537		4.301	5,007	3,263	7.0	315	9.65	2,205	10.2
1957	15,758		4.301	3,664	3,437	5.0	499	14.51	2,495	16.0
1958	16,724	+ 966	4,301	3,888	3,117	5.3	593	19.02	3,143	19.0
1959	17,475	+ 751	4,301	4,063	3,324	5.2	625	18 80	3,250	19.0
1960	18,495	+1,020	4.301	4,300	3,512	5.2	766	21.81	3,983	21.5
1961	19,261	+ 766	4.301	4,478	3,648	5.2	933	25.57	4,852	25.1
1962	20,445	+1,184	4.301	4,754	3,781	5.4	1,197	29.28	5,978	29.2
1963	21,687	+1.242	4.301	5,042	4,026	5 3	1,269	31.52	6,726	31.0*
1964	23,575	+1,888	4.301	5,481	4,119	6.0	1,365	33.14	8,190	35.0
1965	14.945	+1,370	4.301	5,799	4,404	6.0	1,659	37.65	9,954	40.0
1966	26,050	+1,105	4.301	6,057	4,371	6 0	2,118	48.45	12,708	49.0
1967	28,437	+2,387	4.301	6,612	4,844	6.0	2,654	54.79	15,924	56.0
1968	29,267	+ 830	4.301	6.805	5,169	6.0	2,944	56.95	17.664	60.3
1969	30,247	+ 980	4 301	7,033	5,372	6.0	3.385	63 01	20,310	67.1
1970	31,625	+1,378	4 301	7,353	5,511	6.0	3,736	67.79	22,416	71.0

*rate of growth = 5.4% per year (R = 1.054)

Fig 4.2 · Population Estimation



$$Pn = Po + An^{a}$$

$$a = \frac{N\Sigma XY - \Sigma X \Sigma Y}{N\Sigma X^2 - \Sigma X \Sigma Y}$$

$$= \frac{12 \times 12.242952 - 8.71509 \times 14.946733}{12 \times 7.54050 - (8.71509)^2}$$

$$= \frac{16.653301}{14.533206} = 1.146$$

$$b = \frac{\Sigma X^2 \Sigma Y - \Sigma X \Sigma XY}{N\Sigma X^2 - \Sigma X \Sigma X}$$

$$= \frac{7.54050 \times 14.946733 - 8.71509 \times 12.242952}{12 \times 7.54505 - (8.71509)^2}$$

$$= \frac{6.007412}{14.533206} = 0.4133576$$

$b = \log A \qquad \therefore A = 2.590$

$Pn = 49.83 + 2.590 \times n^{1.146}$

Table 4.4 Population Estimations Using a Power Function Method.

Year	n	X = logn	X^2	Population	Pn	Pn-Po	Y = log (Pn-Po)	XY
1957	0	——	——	15,758	49.83	——	——	——
1958	1	0	0	16,724	52.88	3.05	0.484300	0
1959	2	0.30103	0.09062	17,475	55.26	5.43	0.734800	0.221197
1960	3	0.47712	0.22764	18,495	58.48	8.65	0.937016	0.447069
1961	4	0.60206	0.36248	19,261	60.90	11.07	1.044148	0.628640
1962	5	0.69897	0.48856	20,445	64.65	14.82	1.170848	0.818388
1963	6	0.77815	0.60552	21,687	68.58	18.75	1.273001	0.990586
1964	7	0.84510	0.71419	23,575	74.55	24.72	1.393049	1.177266
1965	8	0.90309	0.81557	24,945	78.88	29.05	1.463146	1.321353
1966	9	0.95424	0.91057	26,050	82.37	32.54	1.512418	1.443210
1967	10	1.00000	1.00000	28,437	89.92	40.09	1.603036	1.603036
1968	11	1.04139	1.08449	29,267	92.54	42.71	1.630530	1.698018
1970	13	1.11394	1.24086	31,625	100.00	50.17	1.700441	1.894189
	——	8.71509	7.54050	——	——	——	14.946733	12.242952

N = 12, $\Sigma X = 8.71509$, $\Sigma X^2 = 7.54050$, $\Sigma Y = 14;946733$, $\Sigma XY = 12.242952$

Table 4.5 Population Estimation in Future.

	n 1.146	x 2.590	Pn	Population
1971 (n = 14)	20.58	53.30	103.13	32,700
1975 (n = 18)	27.45	71.10	120.93	38,300
1980 (n = 23)	36.35	94.15	143.98	45,600
1985 (n = 28)	45.55	117.97	167.80	53,100
1990 (n = 33)	54.98	142.40	192.23	60,800
1995 (n = 38)	64.63	167.39	217.22	68,700
2000 (n = 43)	74.47	192.88	242.71	76,800

c) Population in Suburban Municipal Area

There are no data about population increase of enlarged suburban municipal area which has just been approved by the Cabinet. However, suburban area must be followed by natural increase of population as 3% per year.

$Pn = Po\ (1 + r)^n$ here, $r = 3\%$

1971 : 21,510 present population
1980 : $Pn = 21,510 \times 1.03^9 = 28,100$
1990 : $Pn = 21,510 \times 1.03^{19} = 37,800$
2000 : $Pn = 21,510 \times 1.03^{29} = 50,700$

4.1.4 Percentage of House Connection

Percentage of house connection is same meaning as propagation ratio. In general, the water supply area shall be determined by the municipality itself within the administrative area. In other word, the water supply area is up to 100 percent of administrative area depending upon the local condition of housing location of the inhabitants. It is easy to determine the water supply area on the map of the administrative area, but it has no significant if the population in the water supply area cannot be definitely determined. If the vital statistics are completely arranged in some office, it can be done. However, it is almost impossible to determine peoples those who are living in the water supply area under present data concerned.

From these viewpoints, the percentage of house connection shall be determined with reference to the records of water supply of a municipality with similar characteristics and developing situation. And then, the increase of house connection after the completion of construction will depend on the needs of drinking water, progress of new cultural life, improvement of social life, condition of environmental sanitation and so on. According to several data in the past records, the first year after the completion of construction is determined as 60%. Further, 75% is determined as final goal of percentage of house connection, as shown in Table 4.6.

Table 4.6 Percentage of House Connection

Year	%
1970	60
1971	60.5
1975	62.5
1980	65
1985	67.5
1990	70
1995	72.5
2000	75

4.2 Water Demand

4.2.1 Average daily consumption

a) Histogram

Since 1959, the daily consumption of water per capita (Xi) has been reported for seventeen municipalities (n), in addition to the arithmetic total mean (m) as Σ^{x_i}/n. Getting deviation from the mean, the histogram can be figured.

b) Computation of standard deviation

By way of the square root of the mean square of deviation'ssquare in each year, the standard deviation (σ) can be defined as $\sigma = \sqrt{\frac{\Sigma(m-x_i)^2}{n}}$ Therefore, statistically significant value can be shown as, $m-\sigma \leq$ water consumption $\leq m+\sigma$ as listed in Table 4.7.

Table 4 7

Year	average (m) (1/c/d)	σ (1/c/d)	$m-\sigma$ (1/c/d)	$m+\sigma$ (1/c/d)
1959	59.6	22.9	36.7	82.5
1960	74.7	29.5	44.2	104.2
1961	63.1	19.0	44.1	82.1
1962	91.8	36.6	55.2	128.4
1963	60.4	18.9	41.5	79.3
1964	107.5	57.3	50.2	164.8
1965	103.7	53.0	50.7	156.7
1966	118.8	65.1	53.7	183.9

c) Differences between municipalities

Table 4.7 shows that the standard deviation tends to increase year by year, which means that the differences of water consumption are increasing between municipalities consumed large amount of water and small amount of water. This means that the water consumption shall be depended on the scale of municipalities (particularly population), and shall not be one value throughout country.

d) Determination of daily consumption

As mentioned above, it is recommended that the past data shall be separated into three groups of which each group is classified on the population less than 50,000, between 50,000 and 100,000, and more than 100,000 respectively at AD 2000

From this step, any data has been arranged in each group for each year respectively and a mean value has been calculated among the data taking off the eccentric maximum and minimum values. As the result, the average value can be used for further step as the typical data of each year.

e) Municipality populated less than 50,000

Regarding the municipalities populated less than 50,000 at AD 2000 as listed as Table 4.8, the mean value per each year is shown as Y, in addition to other value such as X, X^2 and XY.

Table 4.8 Daily Consumption, mean value per each year

Year	x	Y	$X = \sqrt{x}$	X^2	XY
1959	0	53	0	0	0
1960	1	62	1.000	1	62.00
1961	2	62	1.414	2	87.67
1962	3	72	1.732	3	124.70
1963	4	71	2.000	4	142.00
1964	5	84	2.236	5	187.82
1965	6	88	2.449	6	215.51
1966	7	98	2.645	7	259.21
1967	8	99	2.828	8	279.97
Total	-	689	16 304	36	1,358.88

Considering about parabolic curve is one of the best solution to determine the future estimation of the daily consumption, the least square method is applied for $Y = a\sqrt{x} + b$ as follows.

$$a = \frac{n\Sigma XY - \Sigma X \cdot \Sigma Y}{n\Sigma X^2 - \Sigma X \cdot \Sigma X} = \frac{9 \times 1,358.88 - 16.304 \times 689}{9 \times 36 - (16.304)^2} = 17.1 \quad \text{say } 17$$

$$b = \frac{\Sigma X^2 \cdot \Sigma Y - \Sigma X\,\Sigma XY}{n\Sigma X^2 - \Sigma X\,\Sigma X} = \frac{36 \times 689 - 16.304 \times 1,358.88}{9 \times 36 - (16.304)^2} = 45.5 \quad \text{say } 45$$

In consequence, equation $Y = 17\sqrt{x} + 45$ is determined as basic equation for future estimation of daily consumption. Then, Table 4.17 can be obtained.

Daily Consumption of Municipalities
Table 4.17 Populated less than 50,000 (l/cap.)

Year	Average, from equation	Average, determine	Maximum, Average x 1.5
1970	101	117	175
1980	123	127	190
1990	140	137	205
2000	155	147	220

f) Municipalities populated more than 50,000

Because of lack of data, it can not be satisfied to apply same idea into other municipalities populated more than 50,000. Then, according to experimental data, following equation is defined respectively.

Population between 50,000 and 100,000:
$Y = 17\sqrt{x} + 65$ (Table 4.9)

Population more than 100,000:
$Y = 17\sqrt{x} + 90$ (Table 4.10)

Daily Consumption of Municipalities
Table 4.9 Populated between 50,000 to 100,000 (l/cap.)

Year	Average, from equation	Average, determine	Maximum, Average x 1.5
1970	121	127	190
1980	143	140	210
1990	159	153	230
2000	175	167	250

Daily Consumption of Municipalities
Table 4.10 Populated more than 100,000 (l/cap.)

Year	Average from equation	Average, determine	Maximum, Average x 1.5
1970	146	150	225
1980	168	167	250
1990	185	183	275
2000	200	200	300

4.2.2 Maximum daily consumption

a) General

In order to plan a satisfactory water supply system, it is imperative that we should know exact seasonal, daily and hourly variation of demand. However, since the condition of water supply is such that it has never met the full demand of the people, it is not possible to have the exact idea of such a variation specifically.

b) Other country

Examples of other country are helpful for estimation of variation in demand and given below in Table 4.11.

Table 4.11 Example of Ratio of Daily Maximum over Daily Average in other countries.

Name	Population (1,000)	Ratio	Year
London	6,132	1.28	1969
Stockholm	923	1.27	1968
Paris	2,760	1.17	1967
Zurich	435	1.54	1968
Rome	2,682	1.20	1968
Chicago	4,703	1.63	1968
Tokyo	8,246	1.25	1967
Average of 1504 Municipalities in Japan	—	1.28	1967

c) Field study

To comply shortage of data, several types of field study has been performed throughout developing countries. Unfortunately, however, since the water supply has been limited and restricted due to shortage of water, it is not possible to ascertain the actual consumption per house or capita. This tendency is always emphasized in a municipality in which such study is needed.

In any how, the Second Colombo Plan Experts have tried field study in Sri-racha. This municipality is now developing by commercial activities such as oil refinery and fishery, and it has great advantage in compact and independent shape of municipality as far as domestic water supply is concerned. Table 4.12 shows the montly variation of water used, depending upon money collection of water rate.

Table 4.12 Water Consumption in Sri-racha

*: Assuming 7 families/meter

Month	No. Meter 1969	No. Meter 1970	Amount of Water 1969 (m^3/min)	Amount of Water 1970 (m^3/min)	Population* 1969	Population* 1970	Amount of Water 1969 (m^3/day)	Amount of Water 1970 (m^3/min)	1/c/d 1969	1/c/d 1970	Ratio 1969	Ratio 1970
1	1,252	1,443	45,351	49,272	8,764	10,101	1,511.7	1,642.4	172.5	162.6		
2	1,265	1,458	50,662	65,873	8,855	10,206	1,688.7	2,195 8	190.7	215.1		
3	1,269	1,476	45,019	59,609	8,883	10,332	1,500.6	1,987.0	168.9	192.3		
4	1,289	1,490	54,690	58,171	9,023	10,430	1,823.0	1,919.0	202.0	185.9		
5	1,297	1,513	47,925	64,452	9,079	10,591	1,597.5	2,148.4	176.0	202.9		
6	1,308	1,524	49,633	53,298	9,156	10,668	1,654.4	1,776,6	180.7	166.5		
7	1,328	1,566	51,506	60,505	9,296	10,962	1,716.8	2,016.8	184.7	184.0		
8	1,337	1,628	46,113	60,318	9,359	11,396	1,537.1	2,010.6	164.2	176.4		
9	1,350	1,635	46,964	58,243	9,450	11,445	1,565.5	1,941.4	165.7	169.6		
10	1,383	1,654	44,933	50,617	9,681	11,578	1,497.8	1,687.2	154.7	145.7		
11	1,399	1,683	44,041	67,714	9,793	11,781	1,468.0	2,257.1	149.9	191.6		
12	1,414	1,699	63,302	61,462	9,898	11,893	2,110.1	2,048.7	213.2	172.3		
Total									2,123.2	2,164.9		
Max.									213.2	215.1	1.21	1.19
Min.									149.9	145.7	0.85	0.81
Aver.									176.9	180.4	1.00	1.00

According to Table 4.12, it can be said that the maximum consumption are recorded on December or February under about 20% over the average consumption throughout year. This may show typical variation in especially the water being used for domestic purpose. Therefore, when a commercial use would be expected in future, the ratio between average and maximum may show more larger than 1.20.

d) Determination of maximum daily demand

On the basis of the above conclusion, it is consequently determined that the ratio between average daily demand and maximum daily demand is given in 2.2. This ratio has been used since few years ago throughout Thailand, so it has no more doubt about this determination.

4.2.3 Hourly water consumption

a) Other country

It is known that the maximum hour demand in smaller municipalities is much higher than that of the larger one. It is interested in Pakistan that the World Bank has ever approved the ratio of 2.0 or 2.25 between average daily and hourly demand. Further, in design criteria of Japan Waterworks Association, maximum hourly flow over daily maximum demand is 30% up for large municipality, 50% up for middle sized municipality, and 100% up for small municipality.

b) Field study

As well as daily maximum demand, the Second Colombo Plan Experts have checked the hourly variation of water consumption in Sri-racha, as shown in Table 4.13 Hourly maximum is recorded on 7.00 pm afternoon as 17.13/13.97 = 1.23

Table 4.13 Hourly Variation of Water Consumption
(Mean Value for three days in Jan. 1971)

Time	Q(m^3/hr.)	Time	Q(m^3/hr.)
1	10.94	14	15.43
2	10.58	15	14.73
3	10.30	16	14.83
4	10.40	17	15.85
5	10.58	18	16.73
6	11.54	19	17.13
7	12.98	20	16.13
8	15.40	21	14.75
9	16.23	22	13.95
10	16.45	23	11.34
11	16.38	24	10.66
12	16.33	Total	335.39
13	15.75	Average	13.97

c) Determination of hourly water consumption

Taking into account the above facts and data it has come to the conclusion that the ratio between daily maximum and hourly maximum is given in 2.2 which has been used in Thailand since few years ago.

4.2.4 Water Demand

a) General

Following by the conclusion above mentioned, the quantity of water required for thirty year's program will be summarized as shown as Table 4.14.

Table 4.14 Summary of Population and Water Demand in Future

Population

Year	the Central Area (person)	the Suburban Area (person)	Total (person)
1971	32,700	21,510	54,210
1975	38,300	24,300	62,600
1980	45,600	28,100	73,700
1985	53,100	32,600	85,700
1990	60,800	37,800	98,600
1995	68,700	43,800	112,500
2000	76,800	50,700	127,500

Coefficient of Water Demand

Year	House Connection (%)	Supply Unit (1/c/d)	Supply Coef. ($m^3/c/d$)
1971	60.5	227.5	0.138
1975	62.5	237.5	0.148
1980	65.0	250.0	0.163
1985	67.5	262.5	0.177
1990	70.0	275.0	0.193
1995	72.5	287.5	0.208
2000	75.0	300.0	0.225

Water Demand

Year	Population (person)	Supply Coef. ($m^3/c/d$)	Demand (m^3/d)
1971	54,210	0.138	7,500
1975	62,600	0.148	9,300
1980	73,700	0.163	12,100
1985	85,700	0.177	15,200
1990	98,600	0.193	19,100
2000	127,500	0.225	28,700

b) <u>Water for fire fighting</u>

In addition to the water demand listed on Table 4.14, it is necessary to consider about water for fire fighting. It is reported that the big fire incident took place last year when the Japanese Experts visited at site. According to the unfortunate experience, the Experts was known about the fact that the water pressure and amount were not enough to extinguish the fire although there are good arrangement of fire hydrants connected with the main pipe.

The standard rate of discharge of fire fighting water per hydrant shall be more than 1 m^3/min., and the discharge rate from a hydrant shall be assumed to be more than 500 1/min. when small fire pumps are used. There is a design rule about the amount of water in distribution system, in which a larger amount would be adopted among hourly maximum and daily maximum plus fire fighting water comparatively. In other word, in larger municipality, hourly maximum amount of water is always more than a sum of daily maximum and fire fighting water. On the contrary, small municipality has a chance that a sum of daily maximum and fire fighting is always over the hourly maximum amount.

However, if this rule is unconsiously applied to small municipality the distribution system is obliged to come into greater size than normal diameter. For developing country like Thailand, an economical design shall be prior to a perfect design in order to save the budget. When a fire would be occured, all people is better to save the use of tap water, emphasizing mutual cooperation against fire fighting. From these standpoint, it is concluded that the hourly maximum is a base of designing of distribution system.

4.3 Consideration of Alternatives

4.3.1 Design Criteria

Any water supplied by a water supply system must conform to the established standards of water quality. Simultaneously, the water supply system must have facilities and equipment confortable to the standards stipulated for the class of facilities.

From these standpoints, there is important need of design criteria and water quality standard. However, it shall be recommended that any criteria which have been prescribed in rich country with a shortage of labor and with a sophisticated technology should be carefully reviewed, and if necessary modified, before applying them to projects under different climatological, social and economic environments. It is absolutely necessary to determine design criteria as soon as possible, if otherwise, the desire to design a technically perfect scheme, using the most advanced techniques normally leads into the wrong direction. It is always necessary to attack an enemy who would let the design drive into excess free employing sophisticated devices.

The rationality of design will be started from points of segragation and standardization of design and will reach finally to the automatization. In general theory, there are plenty of work to be done as, connection between planning and economy; research for newly developed technology; preparation of standardization and criteria; speed up with higher accuracy of design and so on. It is easy to just list up such a plenty of work, but as a matter of fact there is not so many items which have been fixed in routine work. For instance, it can be listed only for pipe, valve, hydrant, section of excavation, pavement of road and so forth. Simple structure and piping may be possible to standardize, but it shall be even changeable depending upon different conditions. Piping also seems to be a simple work, but it would be changed awfully by an obstacle under the road.

There are many safety factors which should be included in the designing, such as qualitative, quantitative and structural factors in technical viewpoint. In the quantitative safety, it should be noticed that the drinking standard had been made on the condition of natural contamination itself. In another word, it is necessary to consider about artificial pollution such as heavy metals from industry. No men have been known whether safety factor of drinking water standard has been involved, even though it has been decided by ways of health hazard and utility demage.

For structural analysis, it has been recently well-known that there is a word of "scrap & build" in industrial field. However, although supposing the safety factor is rather smaller value than usual, economical merit would not be expected too much under the condition of little smaller size of structure, because water supply facilities should have some minimum size by which no water would be leaked.

There is very difficult problem concerning to the concept of relationship between safety and economy. In general, both concepts shall be opposed each by each, but it depends upon individual appraisal which may be explained differently by human, generation and environment. For example, although future prospect would be little larger than usual in the demand of water, it would be unable to criticize the design as extravagant scale, because it is easy to expect the increasing amount of income by water rate and to be able to eliminate the social unwillingness caused by shortage of water.

4.3.2 General Consideration

a) First Stage Works (completed at end of 1980)

When existing water intake at irrigation canal is not operated normally at the time of repair of canal, water shall be covered by other source. From this point of view, new water intake at Nam Phong shall be installed as soon as possible. However, supposing existing water intake as normal capacity throughout year, the new water intake at Nam Phong shall be completed at end of 1980. The capacity of new water intake is installed as many as the demand of 2000 A.D., namely 28,700 m^3/day

Distribution main shall be completed at the end of 1980 to supply enough water to existing system.

b) Second Stage Works (completed at end of 1990)

At end of 1990, there is till enough treated water, but the construction schedule of water treatment plant shall be completed at end of 1990 as usual extension scheme. The capacity of new water treatment plant is installed as many as the existing capacity nearby irrigation canal, using existing specification and blue-print in order to save the time of detailed design.

Additional distribution main shall be completed at the end of 1990 to supply enough water to existing system.

c) Existing capacity

According to the Chapter 3, existing capacity can be defined as follows.

Water Intake

320 m^3/hr	Kut Kwang: as stand-by
500 "	Irrigation Canal: as usual
Total	500 m^3/hr. = 12,000 m^3/day

Water Treatment

320 m^3/hr.	Nong Waeng: as usual
500 "	Near Irrigation Canal: as usual
Total	820 m^3/hr. = 19,680 m^3/day

d) Extension schedule

Judging from existing capacity of water intake and treatment, extension project must be scheduled as shown as Table 4.15.

Table 4. 15 Extension Schedule

	Water Intake					Water Treatment			
Year	Demand (m^3/d)	Existing (m^3/d)	Balance (m^3/d)	Need for extension (m^3/d)	Capacity of extension (m^3/d)	Existing (m^3/d)	Balance (m^3/d)	Need for extension (m^3/d)	Capacity extension (m^3/d)
1971	7,500	12,000	+ 4,500	0	0	19,680	+12,180	0	0
1975	9,300	12,000	+ 2,700	0	0	19,680	+10,380	0	0
1980	12,100	12,000	− 100	28,700	28,700	19,680	+ 7,580	0	0
1985	15,200	12,000	− 3,600	28,700	0	19,680	+ 4,480	0	0
1990	19,100	12,000	− 7,100	28,700	0	19,680	+ 580	9,020	12,000
2000	28,700	12,000	−16,700	28,700	0	19,680	− 9,020	9,020	0

Chapter 5 Consideration of Alternatives

5.1 Possibility of Underground Water

There is valuable report named "Ground Water Resources Development of Northeastern Thailand" in events leading up to exploration for ground water in northeastern Thailand, under the cooperation with USA.

Results of the drilling by Jeep Mounted Auger drills were much less satisfactory. This was due primarily to the fact that the drills were placed in operation without assignment of drilling instructors to train new drilling personnel, failure to assign groundwater hydrologists or geologists to the project, and concentration of drilling in relatively small areas where salt water has since been shown to prevalent at shallow depths in the majority of wells.

Table 5.1 Wells drilled in Khon-Kaen

Item	1952 – 1954	1955 – 1958	1958 – 1961	1961 – 1963
No. of wells drilled	26	15	33	33
Total length of drilling (ft)	-	1,868	12,404	4,550
Production wells, good water	14	8	20	26
Production wells, brakish water	2	2	3	0
Unsatisfactory wells	10	5	10	2

According to water analysis of drilled wells, there are many possibilities of having high chloride contents as shown as Table 5.2.

Table 5.2 Result of Water Quality

Location	Depth (ft)	Chloride (ppm)	Total Dissolved solids (ppm)	Total Hardness as $CaCO_3$ (ppm)
Muang Phon Municipality Compound	540	—	—	—
Muang Phon Public Compound	121	600	1,300	570
Muang Phon 300 m NW	115	566	3,617	732
Ban Phai Power Plant	121	745	1,430	250
Nong Song Hong Police Station	47	840	1,785	1,590
King Amphoe, Nong Song Hong	155	2,125	4,428	3,900

Also, it has been understood that there are many rock salts around Lake Thung Sang.

In addition to the chloride contents, heavy iron contents have been reported in the range of up to 100 ppm.

Consequently, it is concluded to consider the possibilities of underground water as unreasonable source.

5.2 Possibilities of Surface Water

a) Lake Thung Sang (Fig 5. 1)

According to the report by Mr. I. J. Silverstone, it is proposed to treat the sewage in two oxidation or stabilization pond. These ponds will take up a small corner of Lake Thung Sang, diked off and excavated to the required level.

There is small possibility to use other small corner of Lake Thung Sang, but it shall be withdrawn from decision of adoption in views of water quality caused by sewage effluent and chloride contents.

b) Nam Phong Diversion Dam (Fig 5.2)

Royal Irrigation Department built the diversion dam in Nam Phong in order to catch the water for irrignation purpose . Simultaneously, PMWD has just completed water intake upstream of diversion dam for supplying water to Nam Phong.

There is no difficulty of either water quality or quantity in the diversion dam without budgetary consideration. Fig 5.3 shows the general idea of alternates of Nam Phong Diversion Dam, in which raw water is transmitted from Nam Phong to existing storage pond nearby irrigation canal through asbestos cement pipe 600 mm in dia. Since whole amount of raw water is depended on Nam Phong diversion dam, a part of water shall be transfered to existing treatment plant from storage pond through asbestos cement pipe 400 mm in dia.

From the standpoint of permanent use of water point, this water reconnaisance has big advantage rather than the other. However, unfortunately, this is costly compared with other alternates (see Table 5.3).

c) Kut Kwang Development

Existing intake is located in Kut Kwang River which has been depended on Rung Kaeng Nam Ton (Fig 5.4). When it is further expected to take water from Kut Kwang River, it is needed to improve existing river and to set new water point upstream of existing intake.

It has been written in Chapter 3 that the water quality of Kut Kwang River has become worse and worse day after day.

As shown as Fig 5. 5, the raw water will be transmitted from new water point to existing treatment plant, besides of existing facilities at irrigation canal.

d) New intake at Nam Phong

Judging from present circumstances around Kut Kwang, it may be recommended to withdraw existing intake at Kut Kwang. In this case, whole amount of water shall be depended upon other source which is recommended to set new water intake nearby existing storage pond.

Flow of Nam Phong has been improved since completion of Nam Phong diversion dam According to living farmers near existing storage pond, no flow of river has been reported even in dry season. Then, it is recommended to locate new water intake about 3.2 km far from existing storage pond, as shown as Fig 5.6.

Fig 5.7 shows the Nam Phong River which is about 15 km downstream of proposed intake. Even in downstream, it has been reported that enough water has flowed in dry season. Accrding to the check of Japanese Survey Team, it is estimated as about 15 m^3/sec in October 1971.

e) Cost Comparison

Among three alternates, Table 5.3 shows the cost comparisons from the standpoints of intake and transmission line except treatment plant.

Table 5.3 Cost Comparison

Unit: Baht

Alter-nates	Intake-Facility	Pump	Piping (A.C.P.)	Other	Total	Remarks
b)	850,000 (at Diver-sion Dam)	1,700,000	ϕ600 (31.0 Km) ϕ400 (9 4 Km) 24,040,000	Relay Pumping Facility. 402,000	26,992,000	too ex-pensive
c)	1,200,000 (at Kut Kwang)	500,000	ϕ400 (6.2 Km) 3,610,000	River Improve-ment 270,000	5,580,000	not be adopted
d)	1,250,000 (at Nam Phong)	1,000,000	ϕ500 (3.2 Km) ϕ400 (9.4 Km) 5,350,000	Relay Pumping Facility 105,000	7,705,000	be adopted

5.3 Effect of Existing Storage (near irrigation canal)

a) Capacity of storage (Fig 5.8)

Maximum surface area impounded: 89,000 m^2
Bottom area of storage pond: 77,000 m^2
Mean water surface: 83,000 m^2
Maximum depth: 3.5 m

Rough calculation: $= \frac{3.5}{2}$ (89,000 + 77,000) = 290,000 m^3

Effective capacity = say 270,000 m^3

b) Evaporation rate can be gained about 70% of Daily Evaporation Record in simple calculation. The Records are given from Hydrologic Data, Volume II, 1966 (Table 5.4) in which monthly maximum data of evaporation is 247.7 mm (say 250 mm) in March, so that,

Maximum monthly evaporation rate
= 250 x 0.7 = 175 mm ≑ 6 mm/day

Maximum volume of evaporate
= 0.006 x 83,000 ≑ 500 m^3/day

c) Relation between evaporation and storage

Table 5.5 shows the relationship between evaporation and storage, since no additional water is assumed to supply into storage under the annual water demand.

Table 5.4 Daily Evaporation in Millimeters for Calendar Year 1966 (Khon-Kaen)

Days	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.0	5.6	7.7	3.4	7.6	5.1	4.0*	6.2	1.9	8.0	2.0	8.0
2	4.0	7.0	7.9	3.8	6.4	7.7	4.6	1.6	4.9	4.0	6.0	7.0
3	7.0	4.4	7.0	7.5	6.2	5.6	4.3	3.0	4.6	6.2	7.5	3.7
4	5.0	4.0	9.6	6.4	6.1	6.6	4.1	4.7	6.0	8.0	5.0	4.5
5	6.0	4.7	7.5	10.6	6.8	3.2	7.9	4.2	4.0	9.9	7.0	8.0
6	5.0	5.0	8.7	8.0	8.2	4.0	7.0	5.5	3.1	3.4	3.5	4.5
7	6.0	5.0	9.4	9.6	4.5	7.0	7.1	6.6	3.5	6.5	4.8	5.0
8	5.0	8.0	5.7	7.7	4.3	5.0	7.2	5.3	2.8	3.0	8.0	8.0
9	5.5	6.0	5.2	6.0	10.5	5.2	9.0	3.1	2.8	4.7	5.0	5.0
10	6.0	6.0	7.8	9.0	8.1	8.8	7.1	0.6	3.2	1.5	5.0	4.5
11	5.0	5.1	6.0	6.5	8.0	7.5	8.6	4.0	4.3	6.0	6.0	8.0
12	5.0	7.0	6.0	8.2	10.6	8.6	5.3	5.1	2.9	6.0	4.0	5.5
13	8.0	8.0	8.2	12.3	9.1	8.5	8.5	4.7	2.0	7.5	4.5	5.0
14	6.0	4.3	6.5	10.2	5.0	6.1	7.6	7.2	4.5	9.0	6.3	7.5
15	7.0	6.0	9.8	9.0	4.2	6.5	7.4	6.3	3.5	5.0	5.5	3.1
16	7.0	7.8	8.1	4.5	5.8	4.0	6.8	2.5	1.2	7.5	6.0	3.9
17	5.0	5.3	5.2	10.6	3.4	8.0	4.5	7.2	3.2	7.0	8.0	5.5
18	6.0	7.0	8.6	6.3	4.9	2.9	4.8	7.0	5.0	4.5	6.1	4.5
19	7.0	6.3	7.1	1.8	7.2	6.5	4.5	5.0	4.5	6.0	7.5	4.2
20	7.0	4.3	7.5	6.4	3.4	4.5	2.2	5.5	7.0	9.5	7.0	5.3
21	10.0	9.2	8.3	6.0	1.3	6.0	5.8	2.2	6.5	4.5	8.0	4.4
22	7.0	5.5	10.2	6.1	1.3	6.7	3.8	4.8	8.0	6.0	7.2	5.0
23	5.0	3.7	9.5	10.2	6.3	5.0	5.6	4.5	3.0	6.5	5.0	6.0
24	6.0	4.3	12.2	6.5	0.7	5.6	5.4	3.5	5.0	2.4	3.0	3.6
25	6.5	2.0	11.3	8.6	4.9	4.2	7.0	3.8	8.0	0.8	5.0	6.5
26	6.0	6.1	8.0	10.2	0.1	7.0	5.0	4.3	6.0	4.6	4.5	5.5
27	7.0	7.5	9.2	10.9	5.4	5.2	7.0	1.6	7.4	3.0	8.6	11.8
28	5.0	6.5	7.6	9.2	4.4	7.2	2.5	5.0	5.0	7.5	4.5	6.5
29	4.0		8.0	12.1	7.2	4.8	5.3	4.7	6.0	5.0	8.0	6.0
30	7.0		7.8	7.9	3.5	5.0	8.0	3.4	7.2	5.0	7.0	6.0
31	6.0		6.1		7.4		6.9	0.5		2.1		5.0
Total	188.0	161.9	247.7	235.5	172.8	179.3	185.1	133.6	137 0	170.6	180.5	177.0

Annual Evaporation = 2,169.0 mm * Estimated

Table 5.5 Relationship between evaporation and storage

Year	Effective Capacity of Storage Pond	Consumption			Storage Capacity
		Water Demand	Evaporation	Total	
		m3/d	m3/d	m3/d	days
1975	27,000 m^3	9,300	500	9,800	27.6
1980		12,100	"	12,600	21.4
1985		15,200	"	15,700	17.2
1990		19,100	"	19,600	13.8
1995		23,400	"	23,900	11.3
2000		28,700	"	29,200	9.2

d) Consideration

According to same Hydrologic Data, daily precipitation of 1966 in shown in Table 5.6. From November to January, namely about 3 months, there is almost no precipitation, and this is the time of repairing of irrigation canal. The repair of irrigation canal takes sometimes few months because of concrete work of lining, and it will be commenced without previous notice. Then supposing no supply water into storage during repair of canal, it is needed to restrict the plenty use of tap water, referring the water balance listed in Table 5.5.

Furtunately, the proposed water point in Nam Phong is located nearby the storage pond, so that the proposed water point can supply water into storage pond during no supply water from irrigation canal. However, in consequence of the discussion above-mentioned, it is recommended to reconsider an installation of storage pond as well as this case in future.

Table 5.6 Daily Precipitation in Millimeters for Calendar Year 1966 (Khon -Kaen)

Days	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec
1		6.6	T	1.6	1.6		30.8	T	0.9			
2			2.9	0.1		T	T	0.6	T			
3		63.4				0.6	T	T	11.6			
4					1.1	9.1	1.3	0.4	T	T		
5		0.3			15.8	53.2		T	29.5	7.9		
6						24.0		7.2	T	3.4		
7					1.3	T		1.6	1.5			
8			0.2		2.3		T	41.3	11.3			
9			T		38.4	5.2		1.0	3.8	39.7		
10					0.6	T		4.6	2.2	18.0		
11				36.7						2.0		
12				0.2	0.4			T	1.4			
13								13.7	57.0			
14					0.5		9.4	3.2	41.5		0.3	
15			4.8		T		31.4		2.5			7.1
16			14.1		61.8		2.8	22.5	3.8			2.9
17			0.2	T	5.4		13.5	0.6				
18			T	0.3	5.4	25.7	14.4	T		T		
19		0.2	T				T	T				
20		0.5		2.4	26.4		1.9			T		8.3
21		2.7			24.3	0.5	3.8	24.2				0.1
22		1.0		0.6	14.8		13.4	0.8		T		
23		1.5			58.3		0.6	25.5		T		
24		0.3			31.7	4.6	1.4	T	T	5.4		
25					19.9	0.2	T	7.8		16.6		
26					25.1	1.4		1.3		7.1	T	
27				0.1	0.4		T	36.6				
28					9.4		T	21.0				
29					1.3	3.8	27.8	7.7				
30			17.8	16.0	7.0	8.8		2.4			11.0	
31			16.1		1.4			4.5		6.1		
Total	0.0	76.5	56.1	58.0	354.6	137.1	152.5	228.5	167.0	106.2	11.3	18.4

Annual Precipitation = 1,366.2 mm

T = Trace

Fig 5.1 Lake Thung Sang

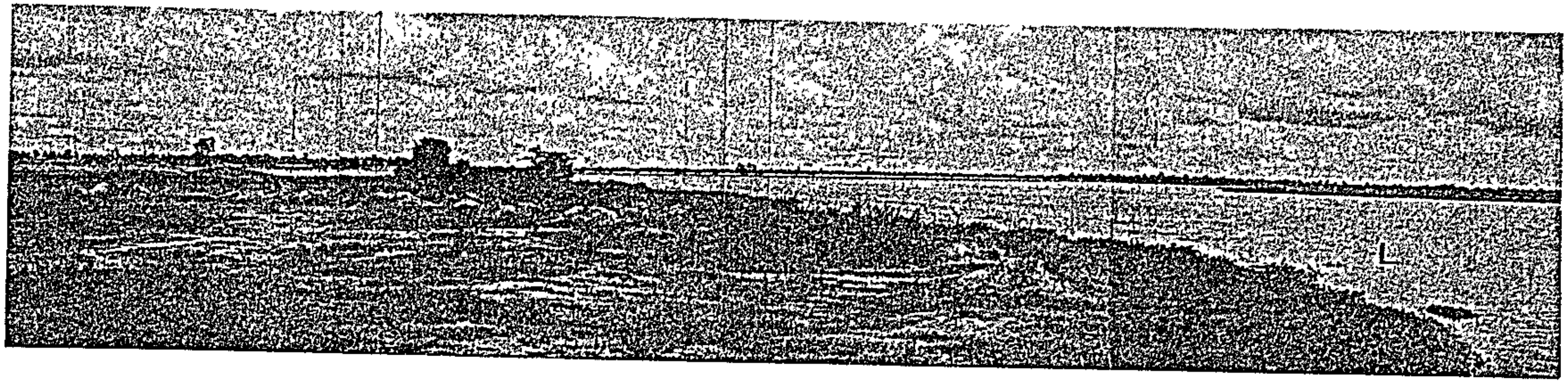


Fig 5.2 Nam Phong Diversion Dam

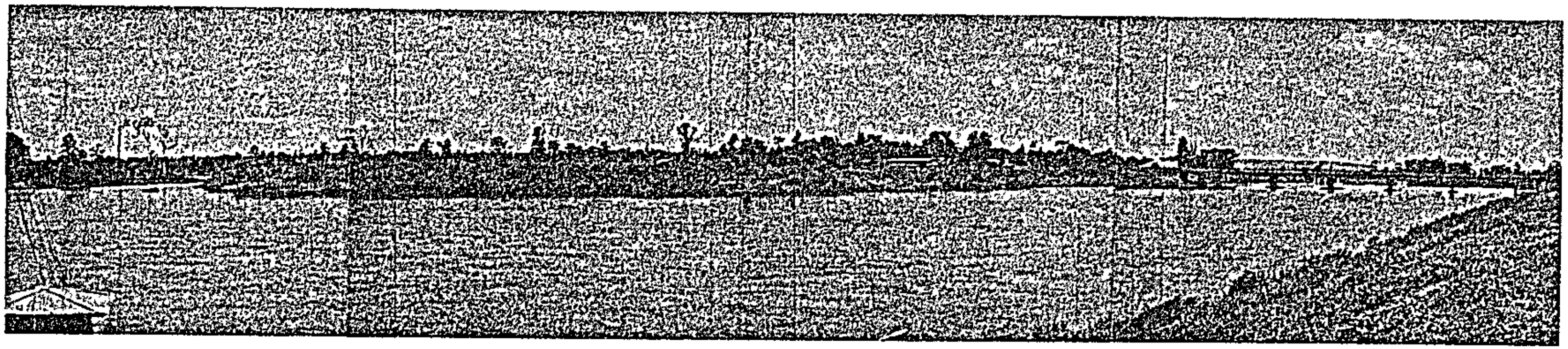


Fig 5.3 Alternates of Nam Phong Diversion Dam

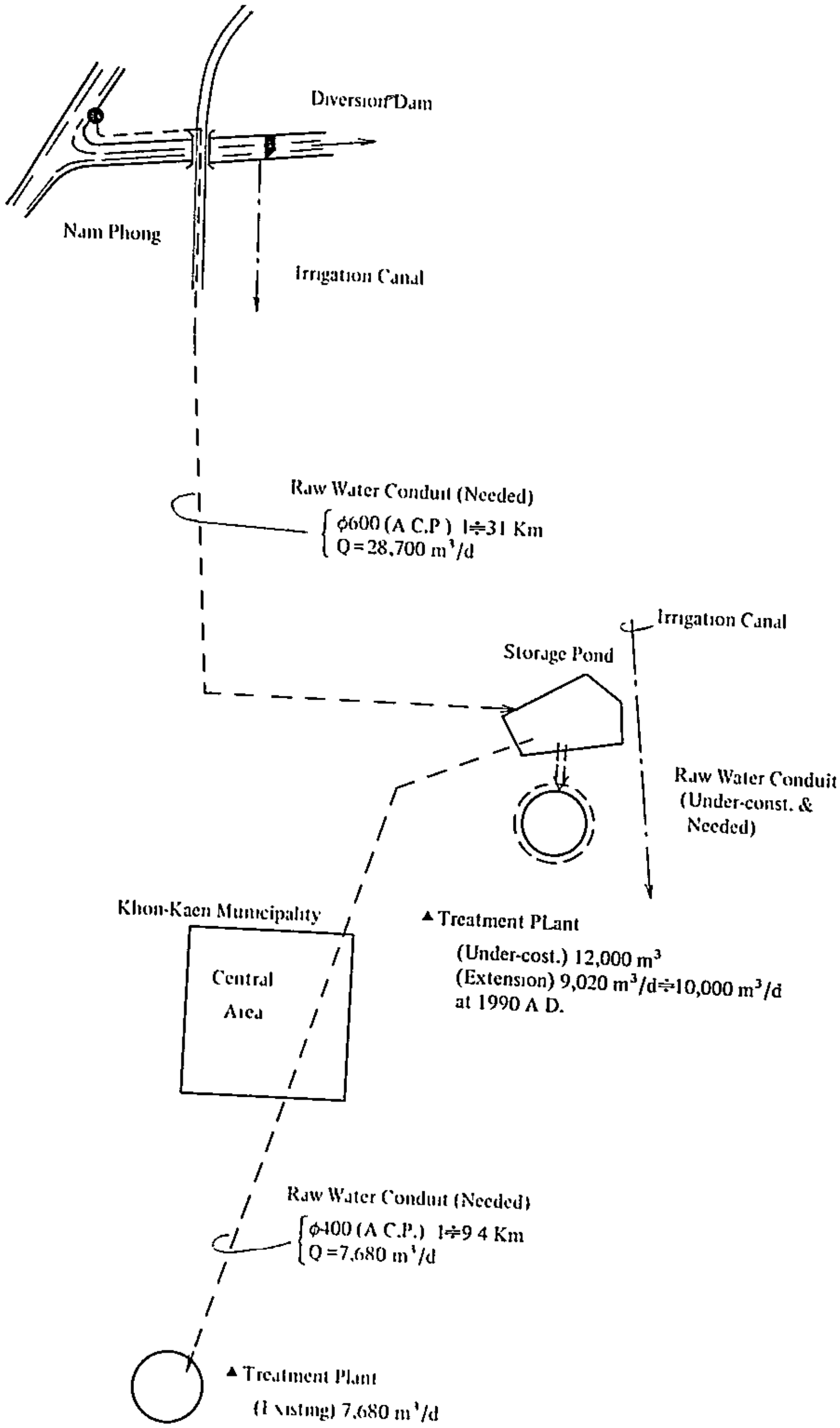


Fig 5.4 Rung Kaeng Nam Ton

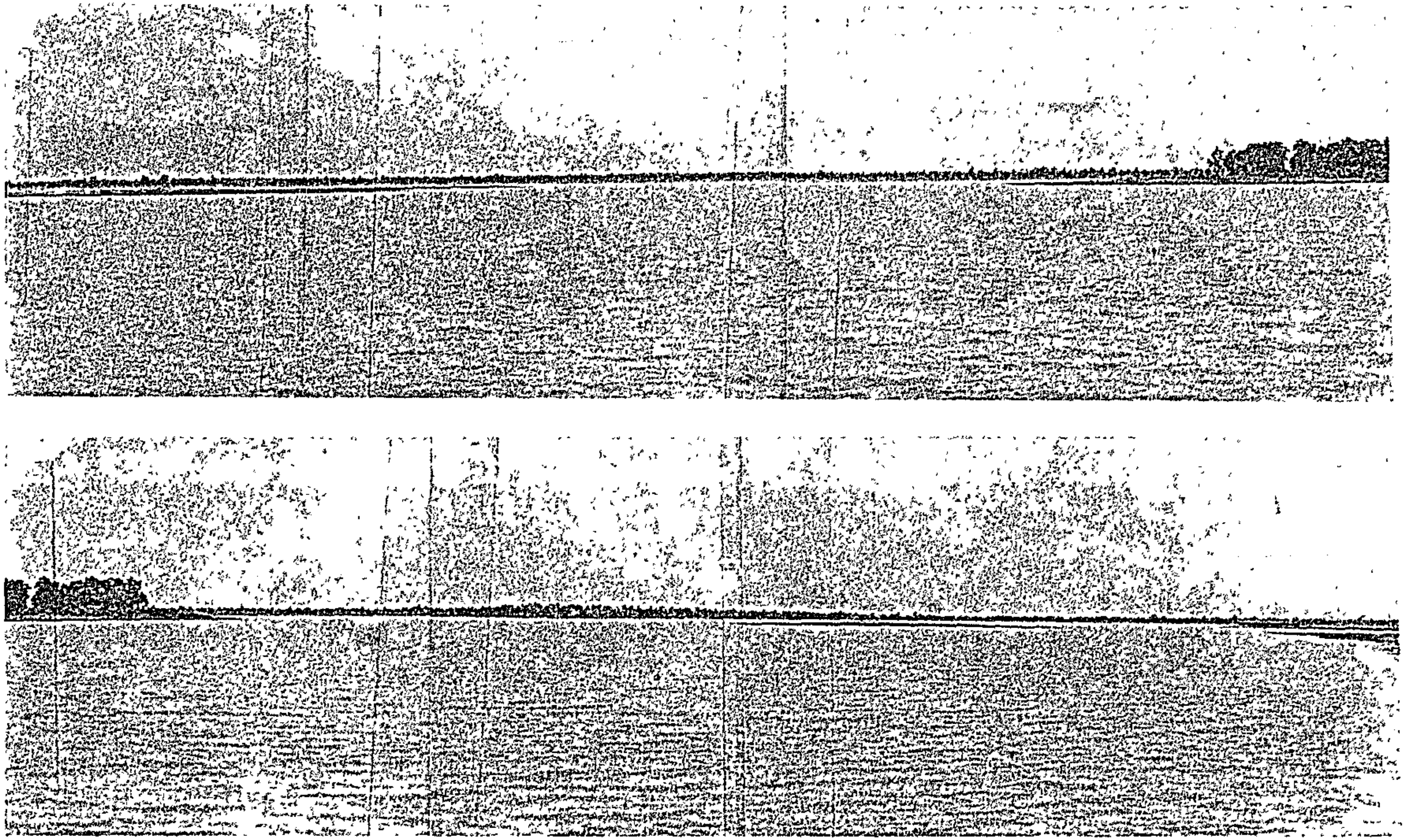


Fig 5. 5 Kut Kwang Development

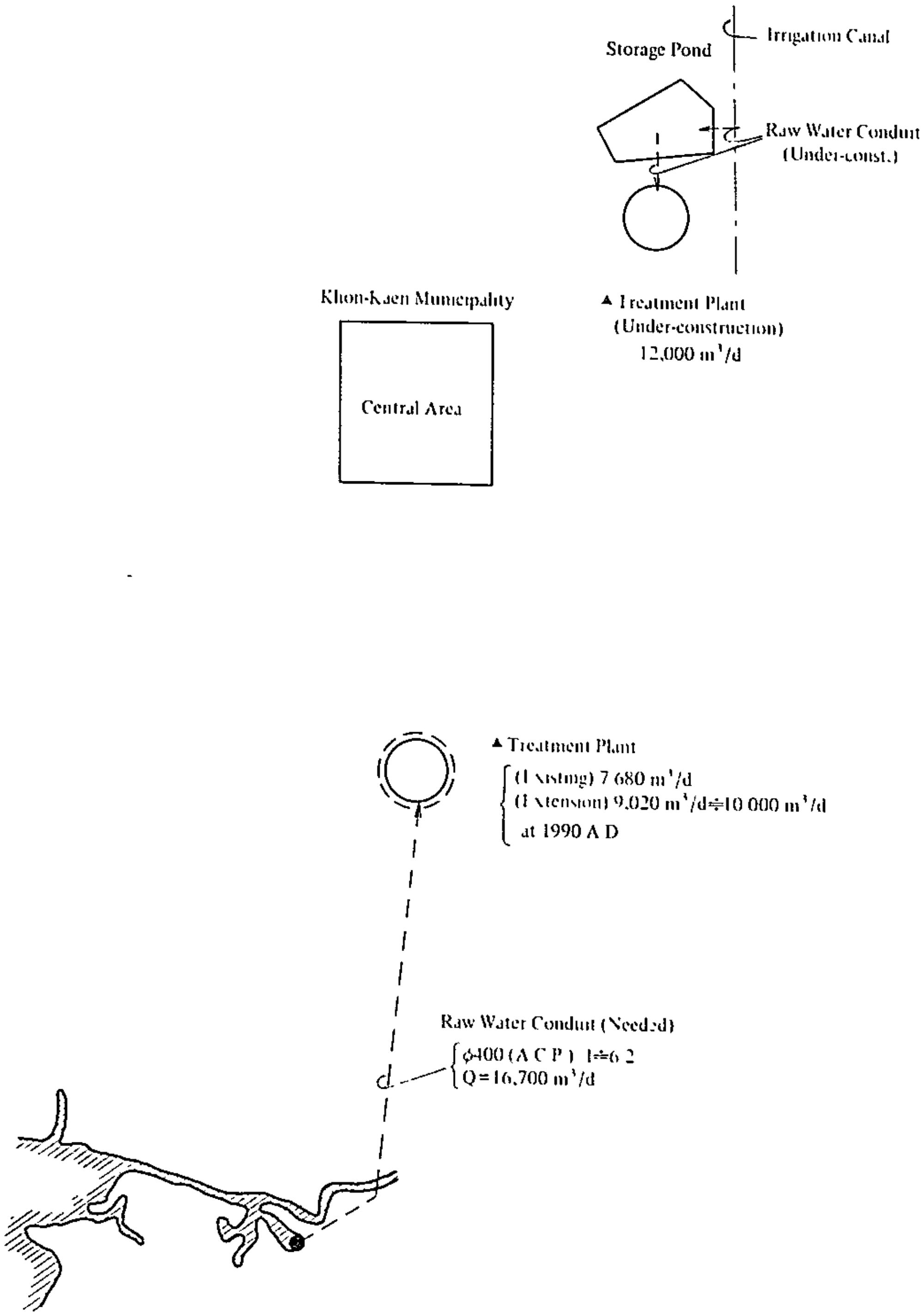


Fig 5. 6 New intake at Nam Phong

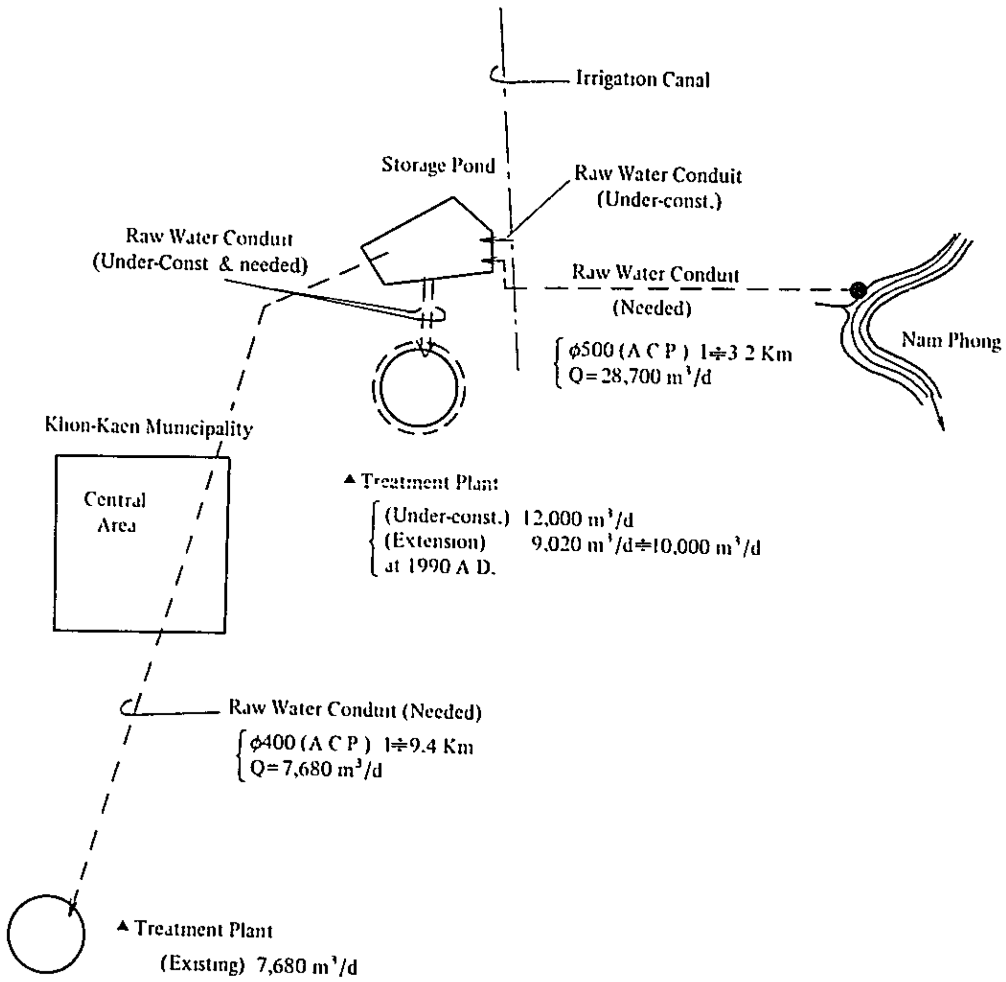


Fig 5.7 Nam Phong (along High-Way)

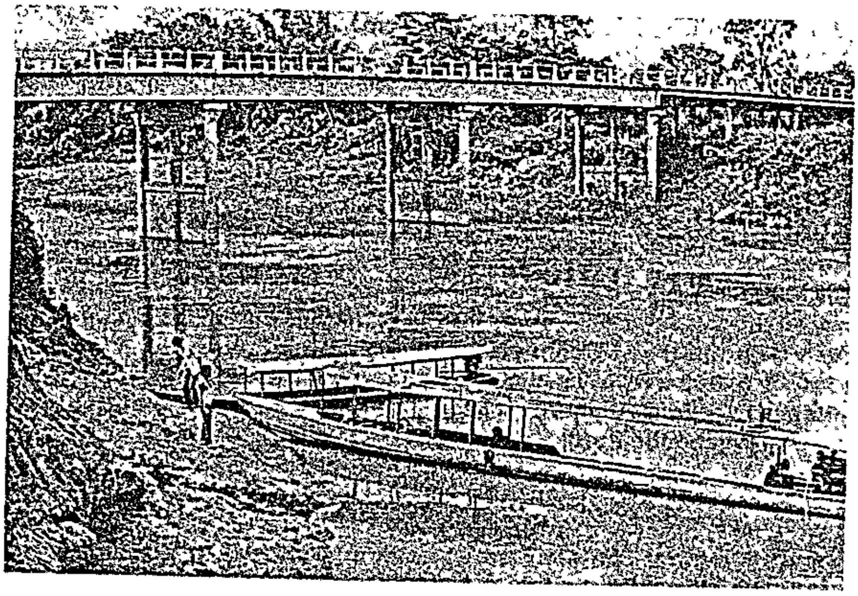
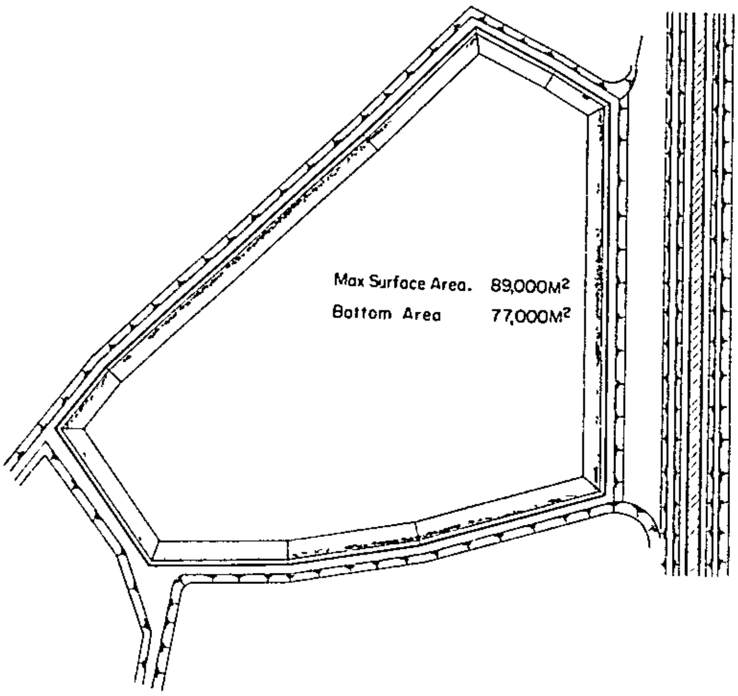


Fig 5.8 Existing storage pond



Chapter 6 Proposed Plan of Extension Project

6.1 Proposed Plan (excluding distribution system)

6.1.1 Water Demand

As far as the extension project is concerned, water demands have been decided in ultimate conclusion, as shown as Table 4.15.

6.1.2 1st Stage Works

1) Intake Tower

Structure:	Reinforced Concrete
Dimension:	5.0 m (W) x 12.0 m (L) x 12.0 m (H)
Accessories:	Suluce Gate, 1.0 m (W) x 1.0 (H)
	Aqueduct Bridge, 3.0 m (W) x 18.0 (L)

2) Raw Water Pump

Type:	Vertical Shaft Mixed Flow Pump
Capacity:	9.97 m^3/m x 44 m x 1,450 rpm x 150 HP
Number:	3 sets (Including 1 spare)

3) Diesel Engine

Type:	Water-Cooled 4-cycle, 6-cylinder
Capacity:	180 PS x 1,500 rpm
Number:	3 sets (Including 1 spare)

4) Raw Water Main (From Intake Tower to Storage Reservoir)

Meterial:	C.I.P.
Diameter:	ϕ 500
Length:	3,200 m

5) Raw Water Conveyance from Storage Reservoir to the Old Treatment Plant.

a. Pump Station at the Reservoir.

Structure:	Reinforced Concrete
Dimension:	6.3 m (W) x 6.8 m (L) x 6.6 m (H)

b. Raw Water Conveyance Pump

Type:	Horizontal shaft single suction Volute Pump
Capacity:	2.67 m^3/min x 33 m x 1,450 rpm x 45 HP
Number:	3 sets (including one spare)

c. Raw Water Conveyance Pipe

Material:	C.I.P.
Dimension:	ϕ 400 mm
Length:	12,100 m

6) Office & Pump Room

Structure:	Reinforced Concrete

Construction Areas: 12 m x 24 m = 288 m^2

6.1.3 2nd Stage Works

1) Purification Facilities

Capacity as same as the Existing Plant nearby irrigation Canal.

6.2 Proposed Plan(Distribution System)

6.2.1 General

In general, the distribution area is covered by gravity flow from the elevated tanks located respectively in No. 1, No. 2 and No. 3 distribution network. At present, the municipality has distributed the filtered water by gravity from three elevated tanks located respectively in three plants. They have not been operated systematically because of shortage of capacity, different height of elevated tank and so on. From this point of view, the distribution system has been composed in three networks, neglecting the existing elevated tank (120 m^3) located nearby municipal market.

6.2.2 Distribution Program at 2000AD

There will be three networks at 2000 AD throughout municipal area in which No.1 network will be distributed for western part of area beyond railway and almost all municipal area belonged to old Khon-Kaen (Fig 6.6). No.2 and No.3 network will be distributed for a part of old Khon-Kaen and eastern part of area beyond old Khon-Kaen (Fig 6.7).

All pipes have selected asbestos cement pipe throughout all area as shown as Fig 6.8, in which hydraulic gradient lines are figured in Fig 6.9 and 6.10.

6.2.3 Distribution Program at 1990 AD

Until ultimate program of distribution system at 2000 AD, existing pipes shall be used as far as possible in consequence of normal progress of new distribution line. Namely, showing as Fig 6.11, No.1 network will be temporarily connected with distribution main from water treatment plant nearby irrigation canal. Remainder of all networks will be distributed from Nong Waeng treatment plant.

6.2.4 Transmission Pumps

There are three pumps located in water treatment plant nearby irrigation canal as following specifications.

Pump No.1: 400 m^3/hr x 40 m x 100 HP
" No.2: 400 m^3/hr x 40 m x 100 HP
" No.3: 200 m^3/hr x 40 m x 60 HP

These pumps will be used for not only pumping to elevated tank but also direct-pumping to distribution system. When the pumps are used for direct-pumping, hydraulic pressures in each point through network are shown as Fig 6.11, supposing hourly maximum consumption at 1990.

6.2.5 Reservoirs

Fig 6.12 and 6.13 shows respectively the relationship between capacity of water plant and distributing amount of water, in which it is not needed to install any clear water reservoir or distribution reservoir till 1990 AD. However, at 2000 AD, a clear water reservoir (3,000 m^3) and a distribution tank (700 m^3) is respectively needed.

6.2.6 1st Stage

Distribution Pipes (Cast Iron Pipe)	ϕ 500	3,350 m
	ϕ 400	3,810 m
Asbestos Cement	ϕ 300	4,710 m
	ϕ 250	7,290 m
	ϕ 200	3,950 m
	ϕ 150	3,670 m
	Total	26,780 m

6.2.7 2nd Stage

Clear Water Reservoir (designed already by PMWD)

Structure: Reinforced Concrete
Capacity: 3,000 m^3
Unit: one

Distribution Tank

Structure: P.C. Concrete
Size: Effective dia (ϕ 15 m) x depth (4 m)
Capacity: 700 m^3
Unit: one

Pump (Treatment Plant to Distribution Tank)

Type: Horizontal-shaft Double Suction Volute Pump
Capacity: 5.65 m^3/min. x 58 m x 1,450 rpm x 130 HP
Unit: 3 sets (including one spare)

Conveyance Pipe

Cast Iron Pipes	ϕ 500	4,100 m

Distribution Pipes

Cast Iron Pipes	ϕ 500	2,600 m
	ϕ 400	1,580 m
Asbestos Cement Pipes	ϕ 200	5,100 m

Fig. 6.1 Intake Point & Raw Water Main

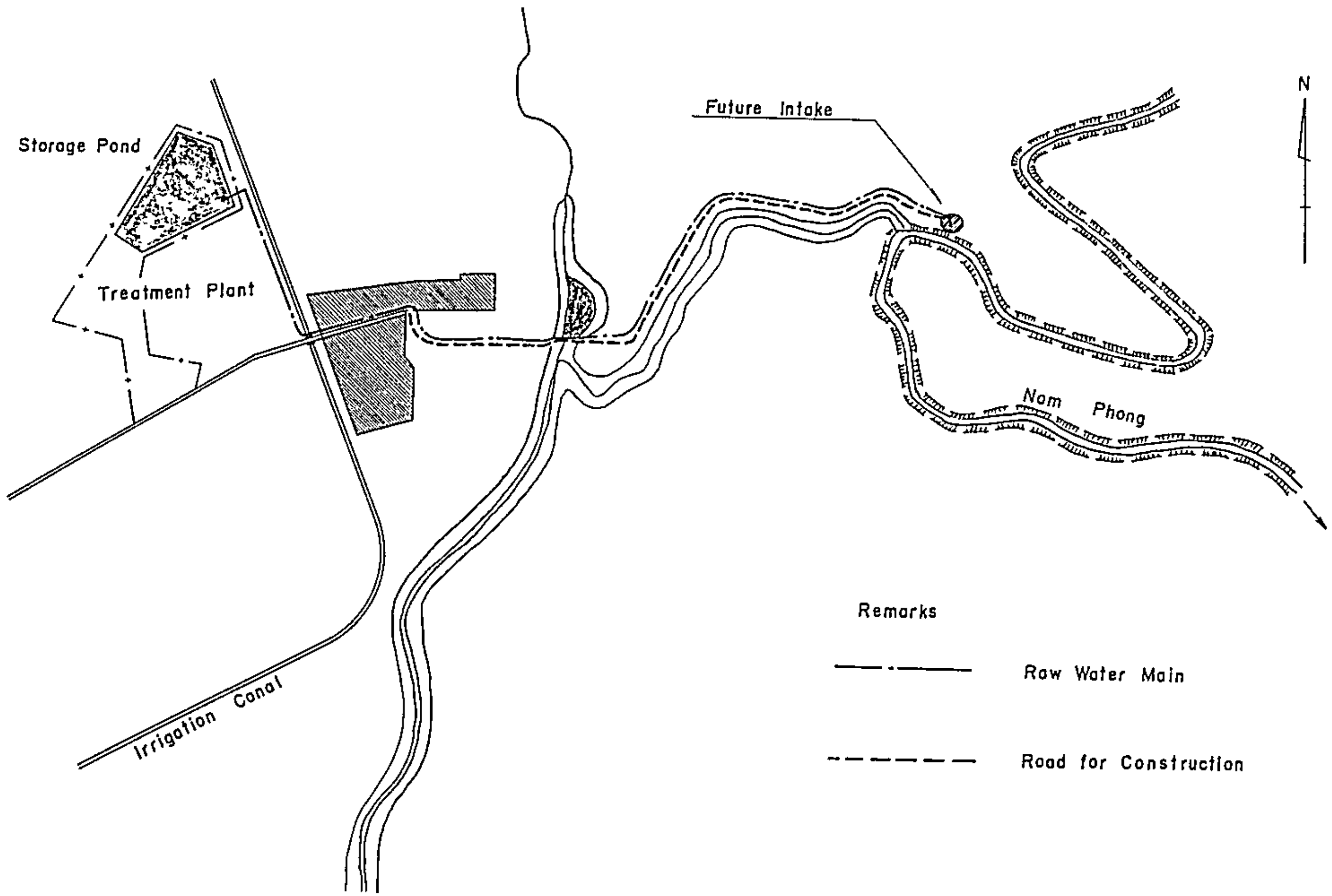


Fig. 6.2 Intake Tower

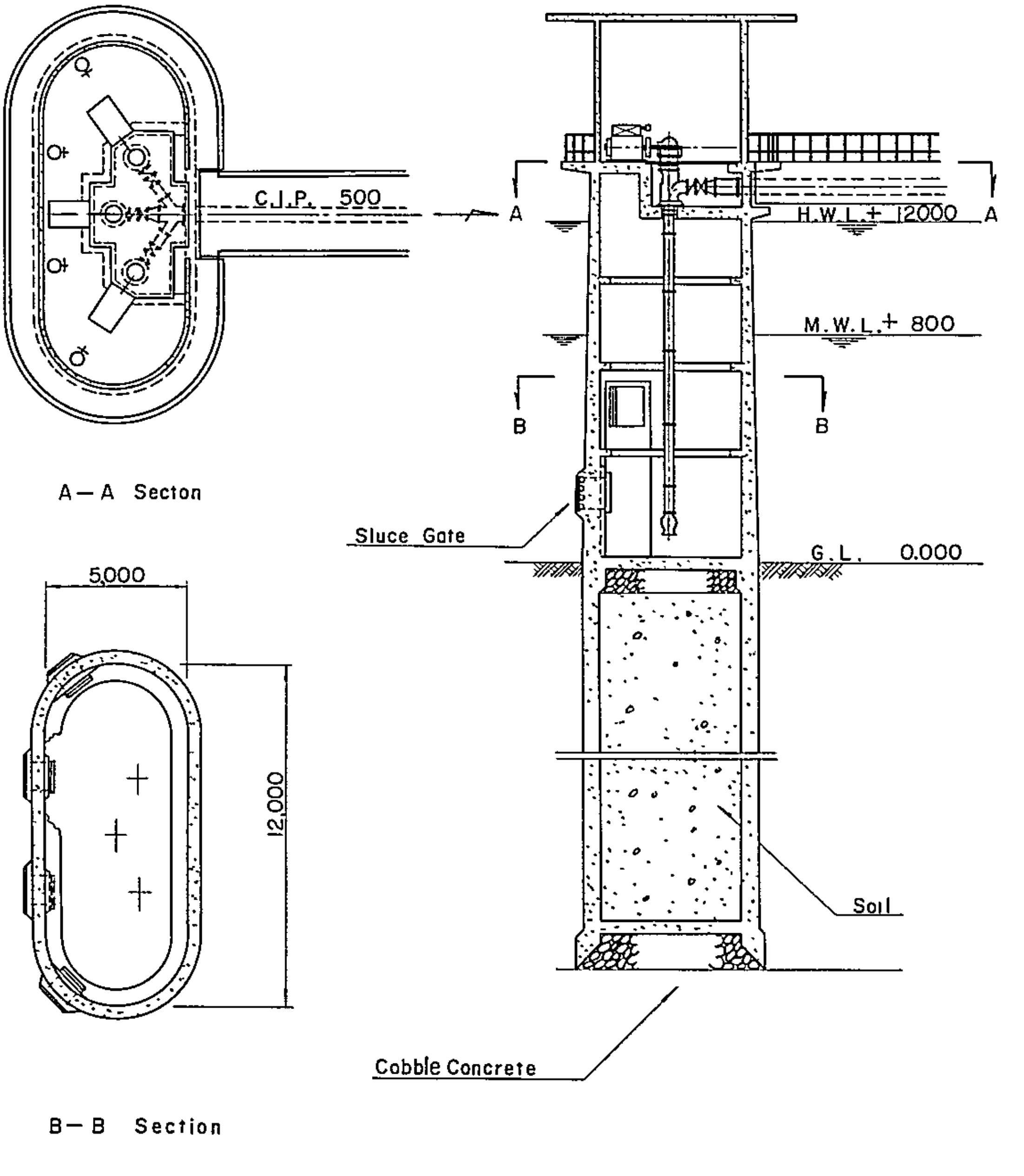


Fig. 6.3 Pumping Station at Storage Reservoir

Plane

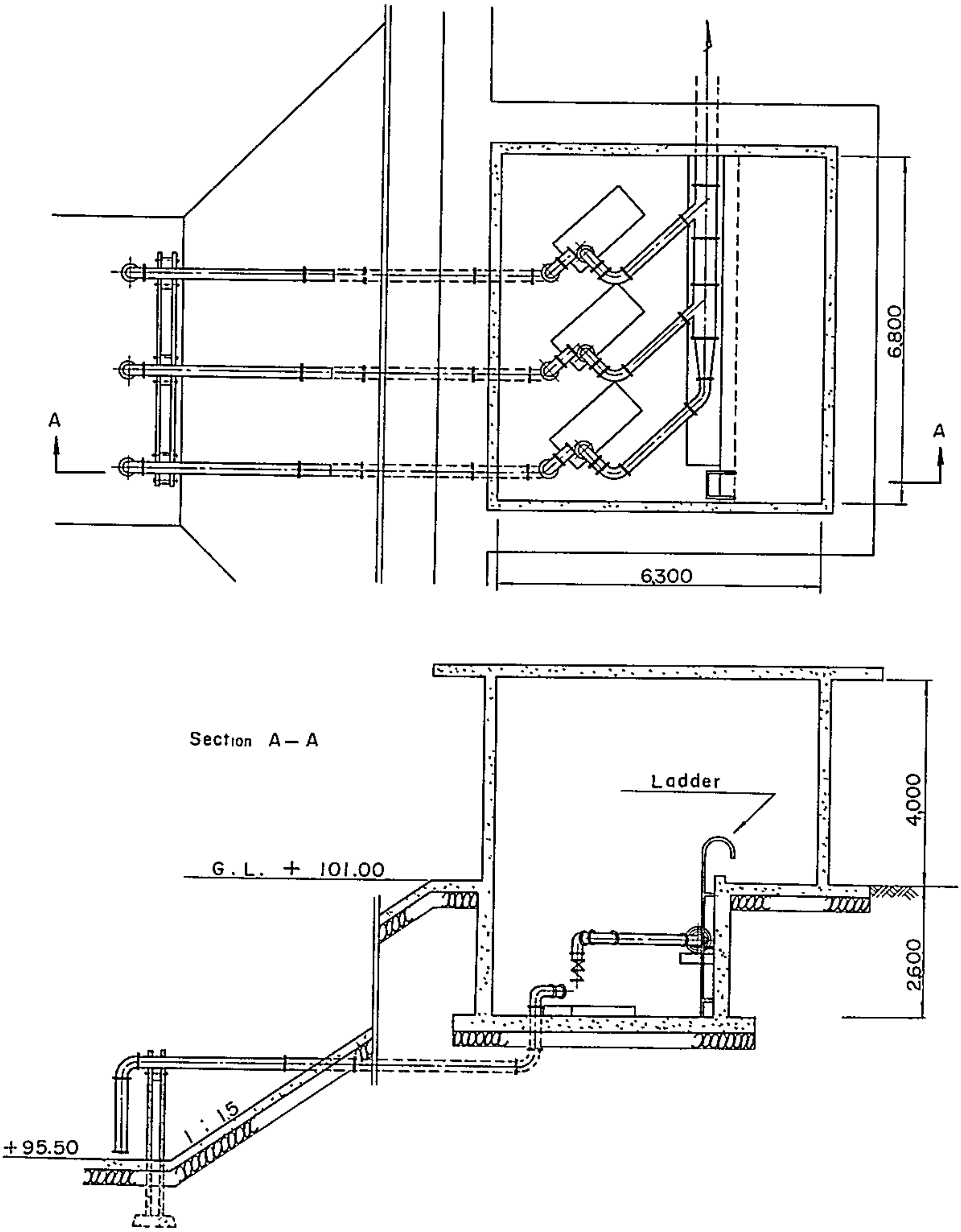


Fig 6 4 Khon Kaen Water Works

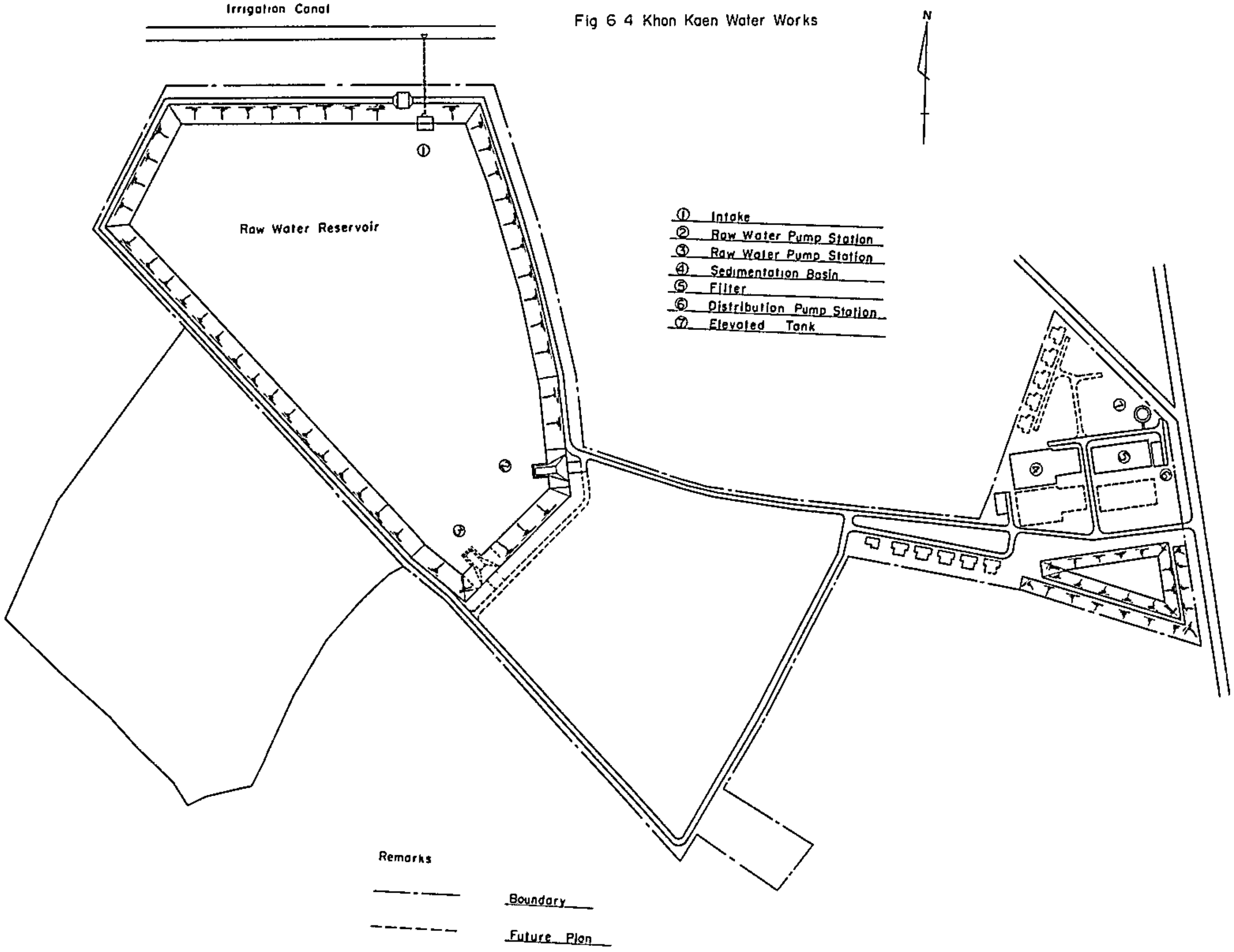


Fig. 6.5 Head Office

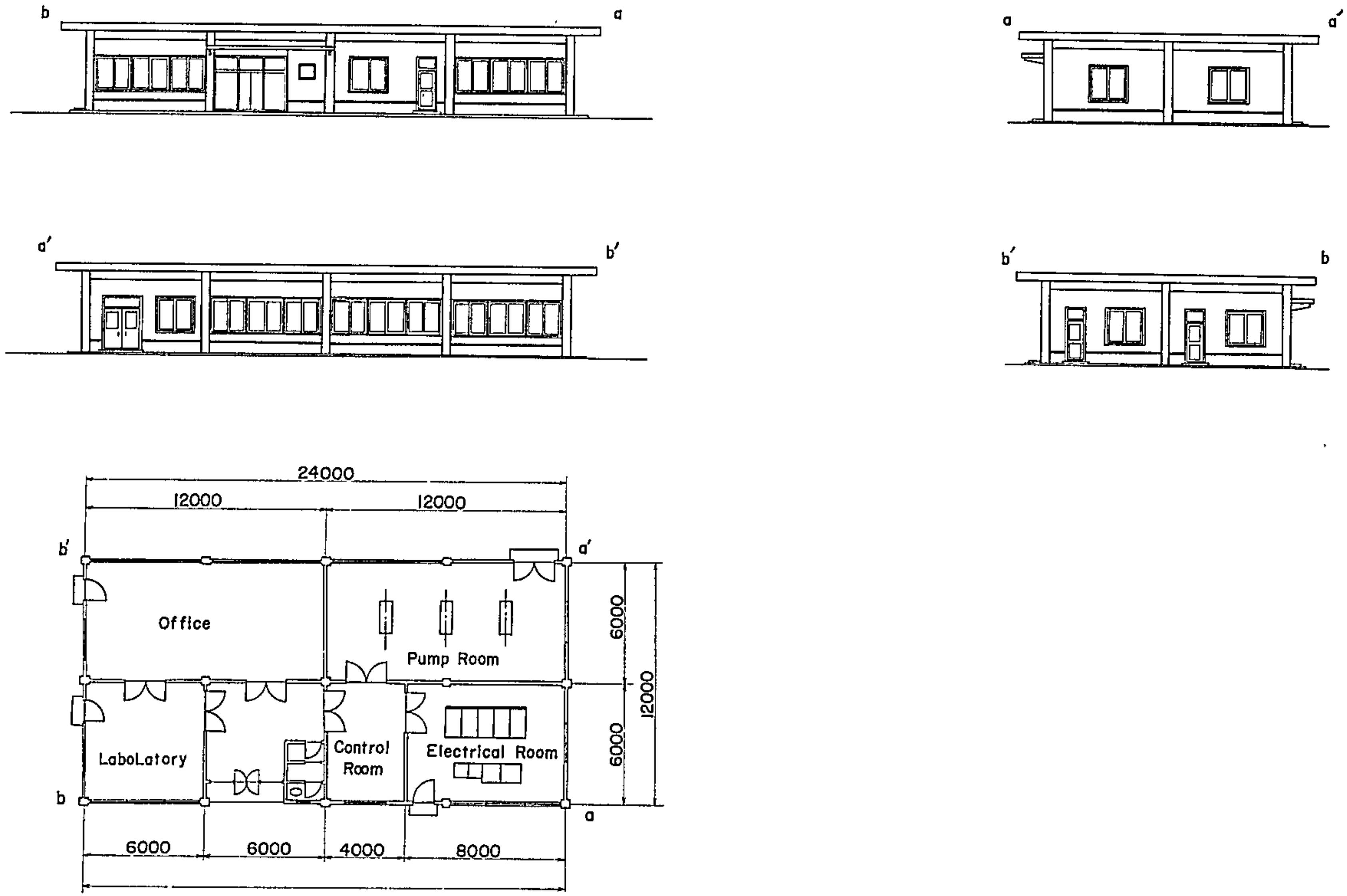


Fig 6.6: No.1 Distribution Network (2000 A D)

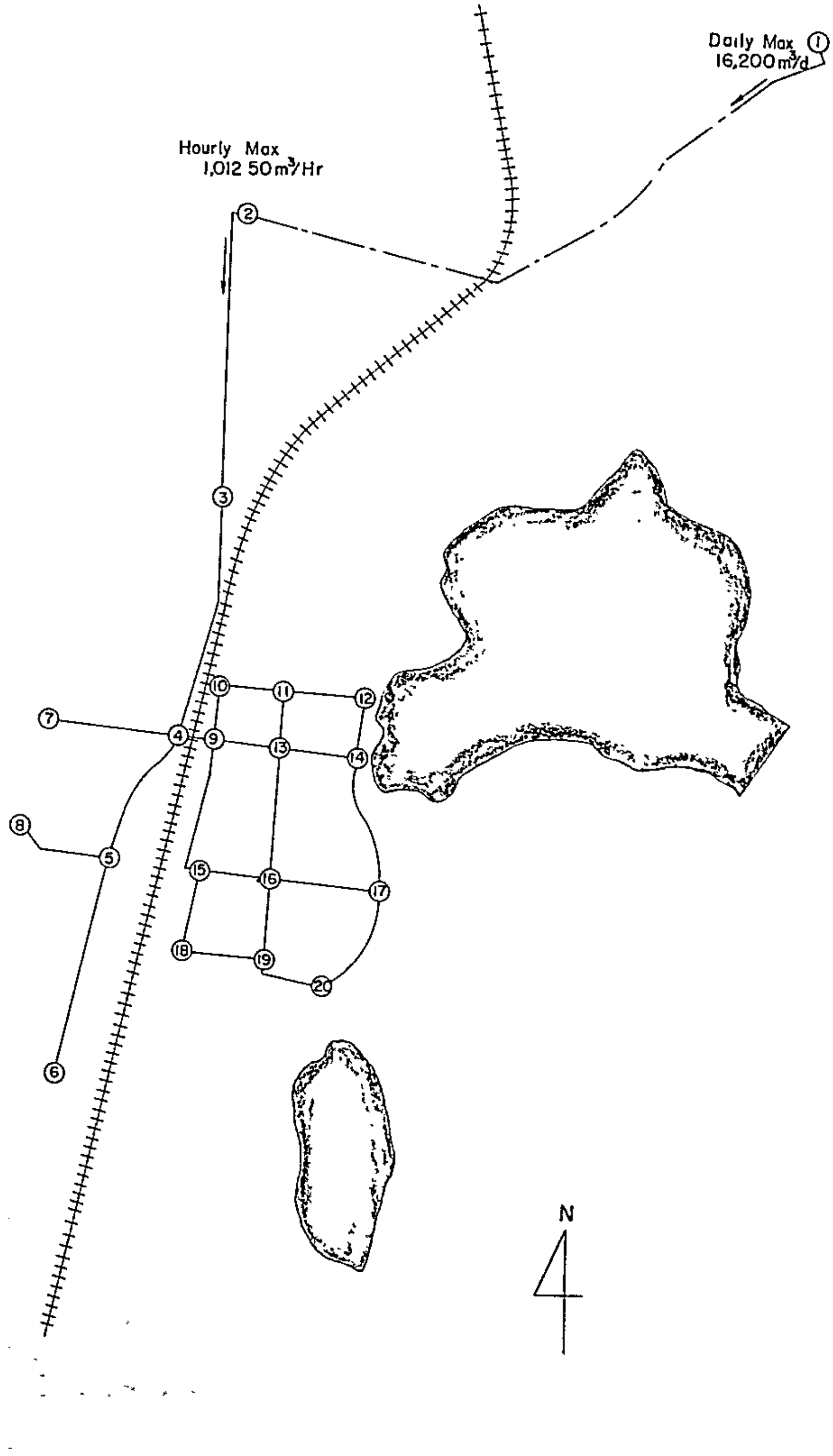


Fig 6.7: No.2 and No.3 Distribution Network (2000 AD)

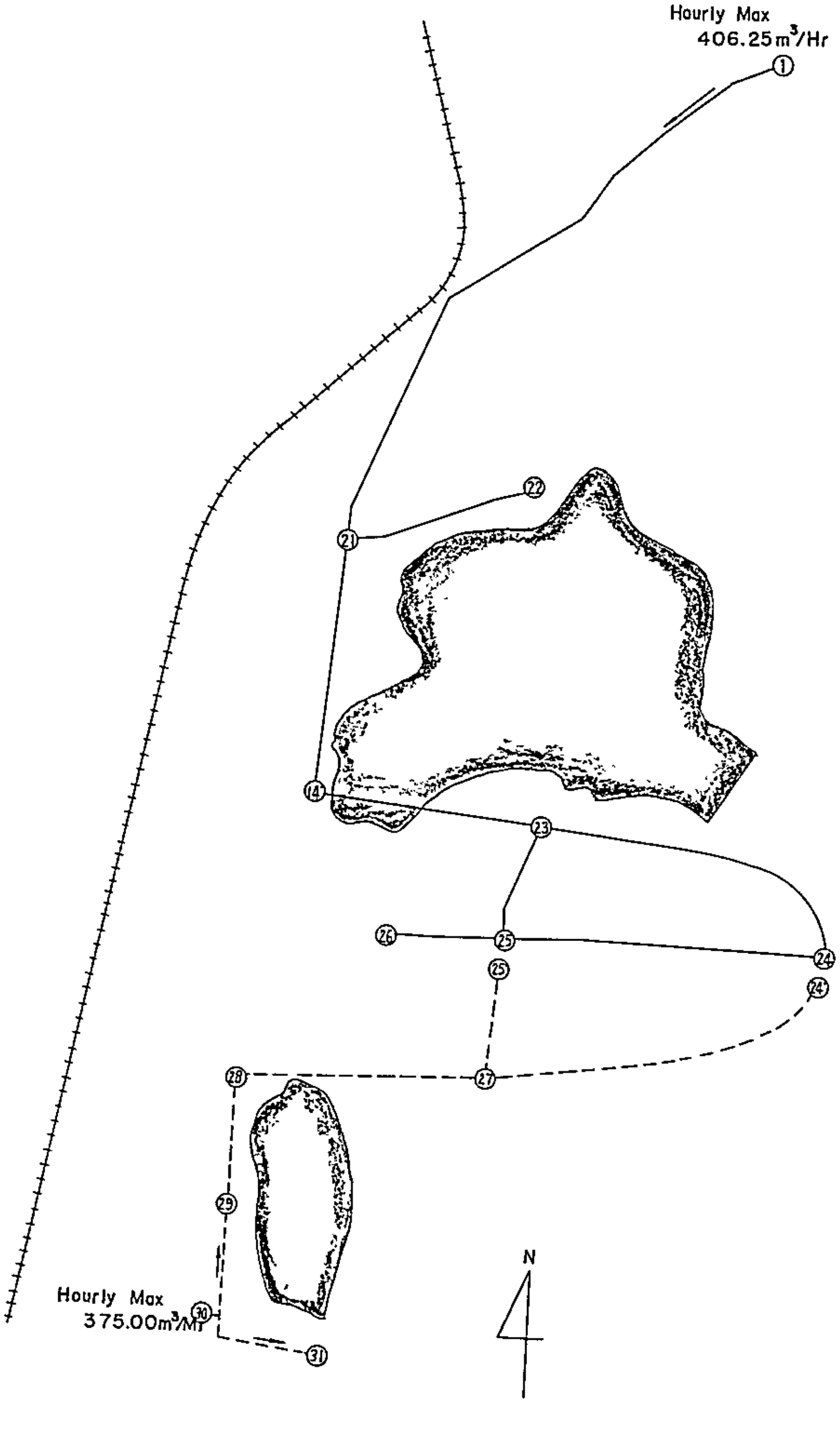


Fig 6.8 · Conveyance & Distribution Pipes At 2000

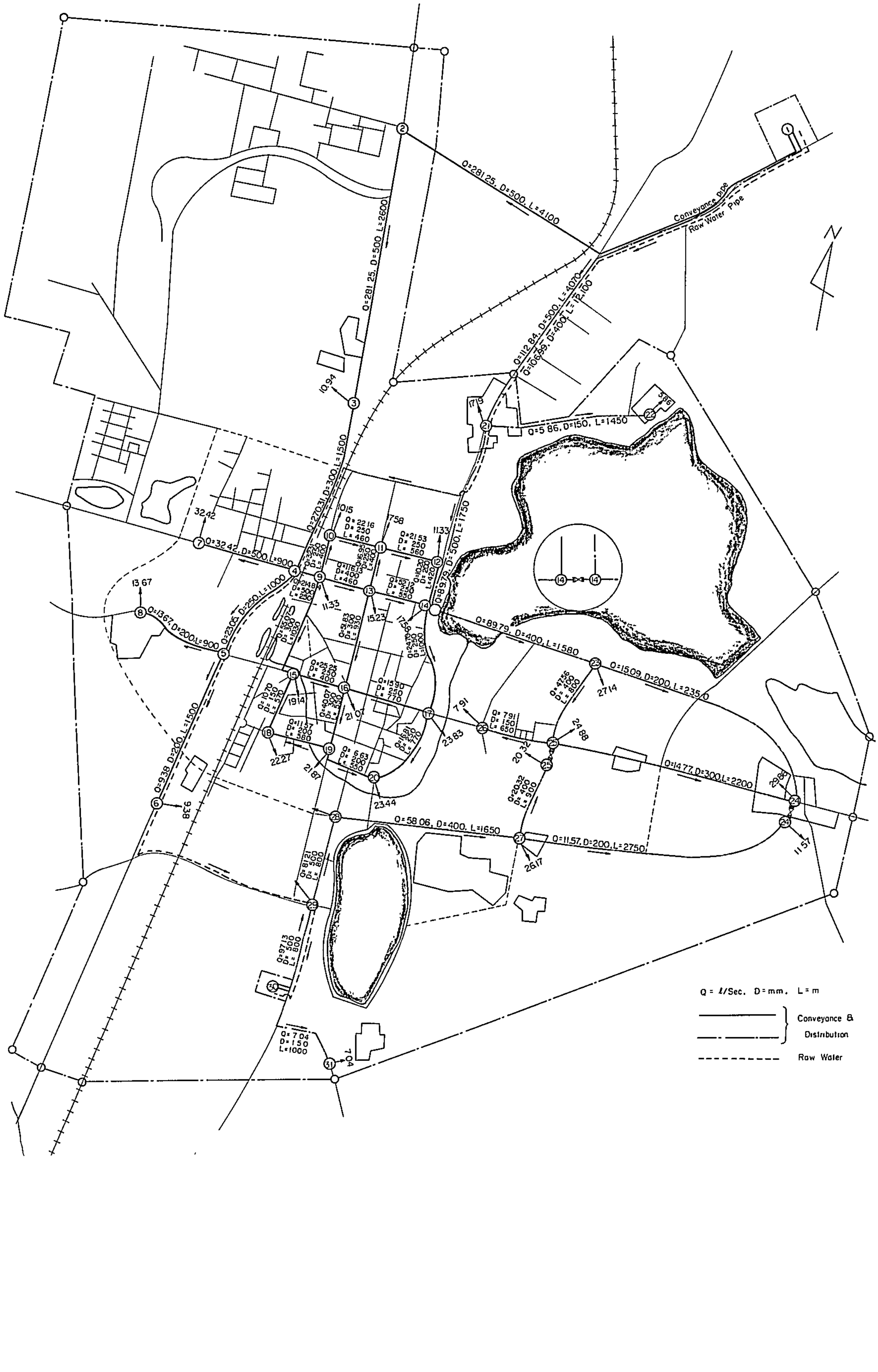


Fig 6.9: Hydraulic Gradients At 2,000

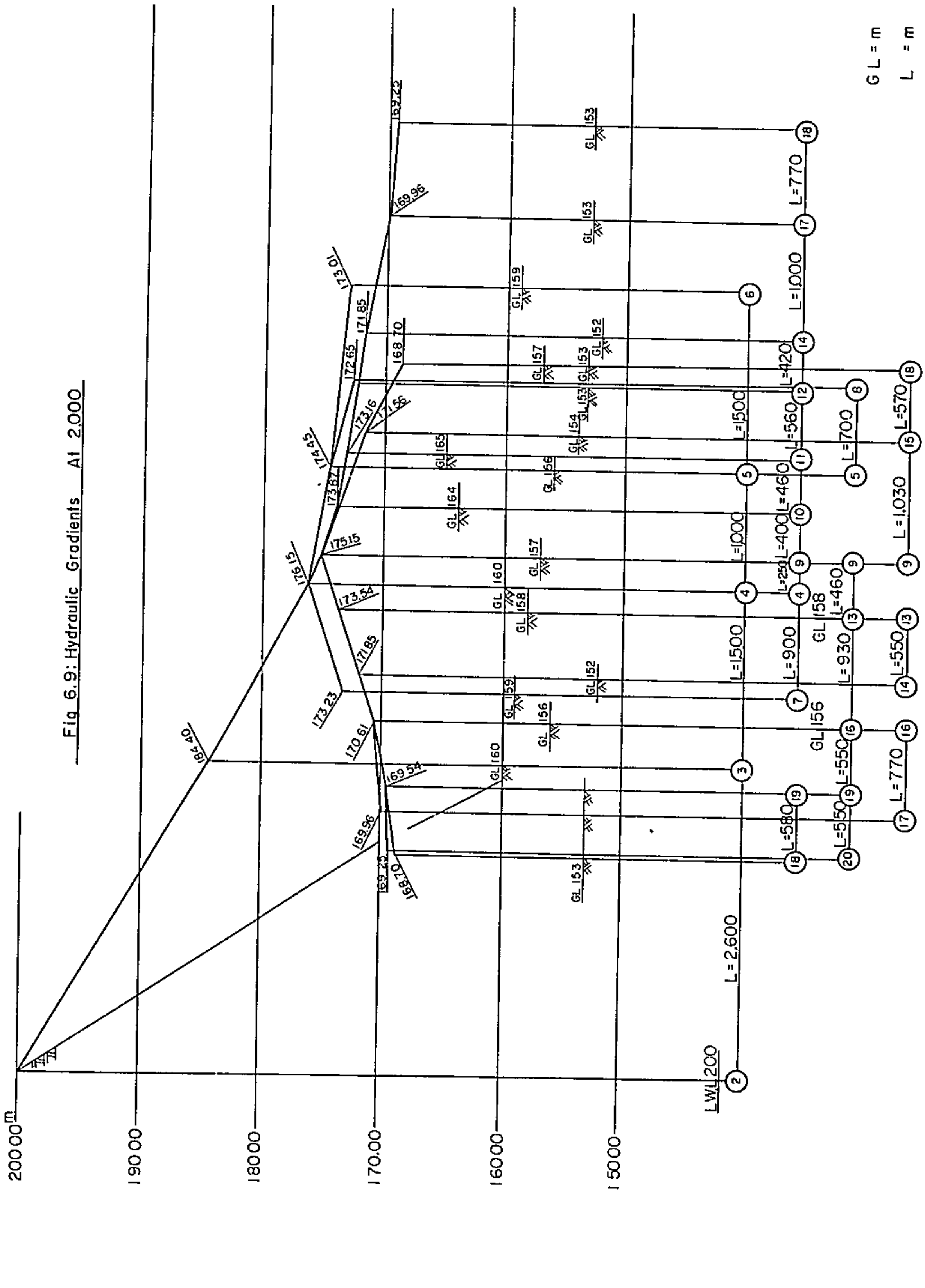


Fig 6.10' Hydraulic Gradients At 2000

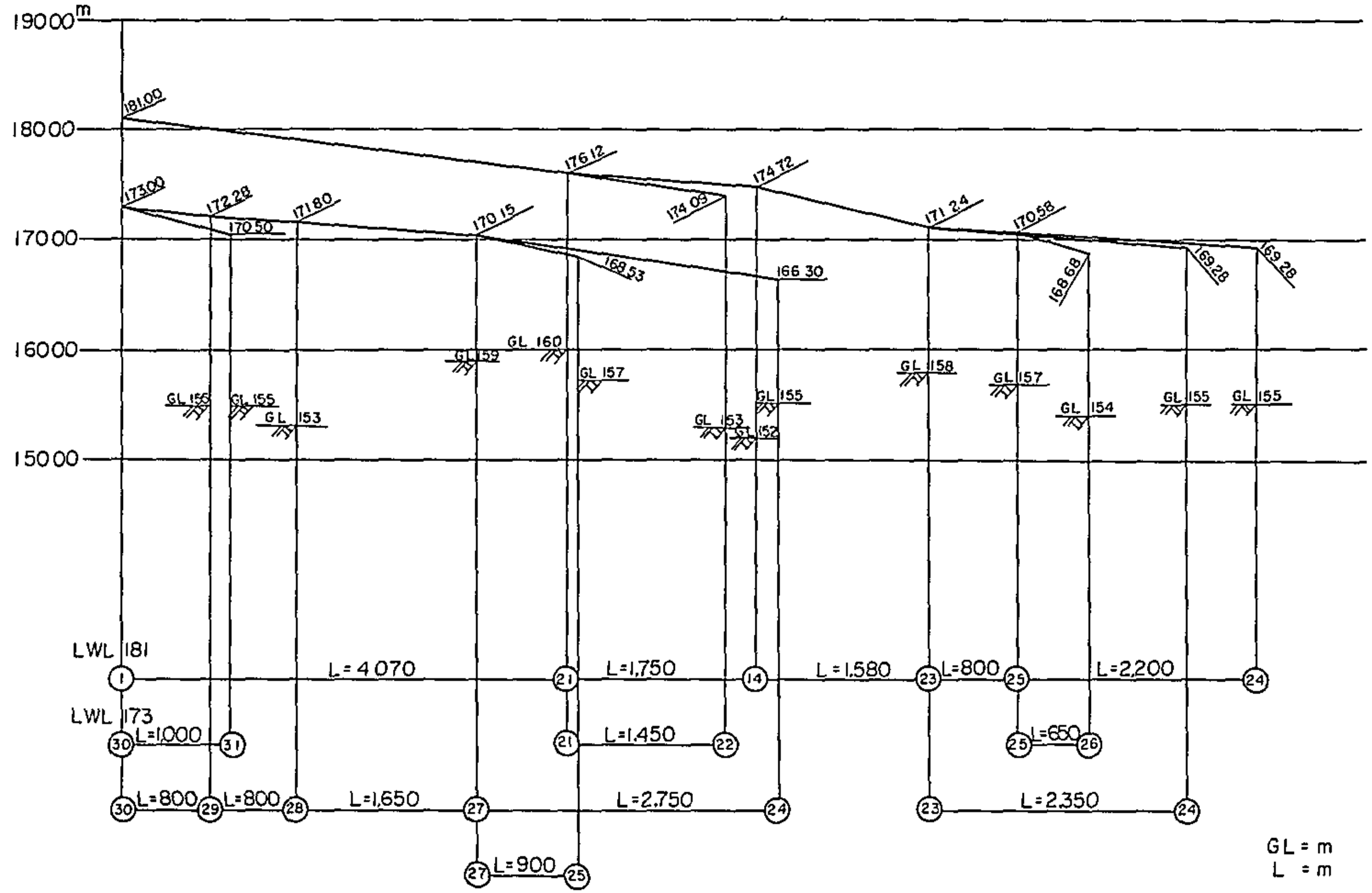


Fig 6 11: Temporary Method of Distribution

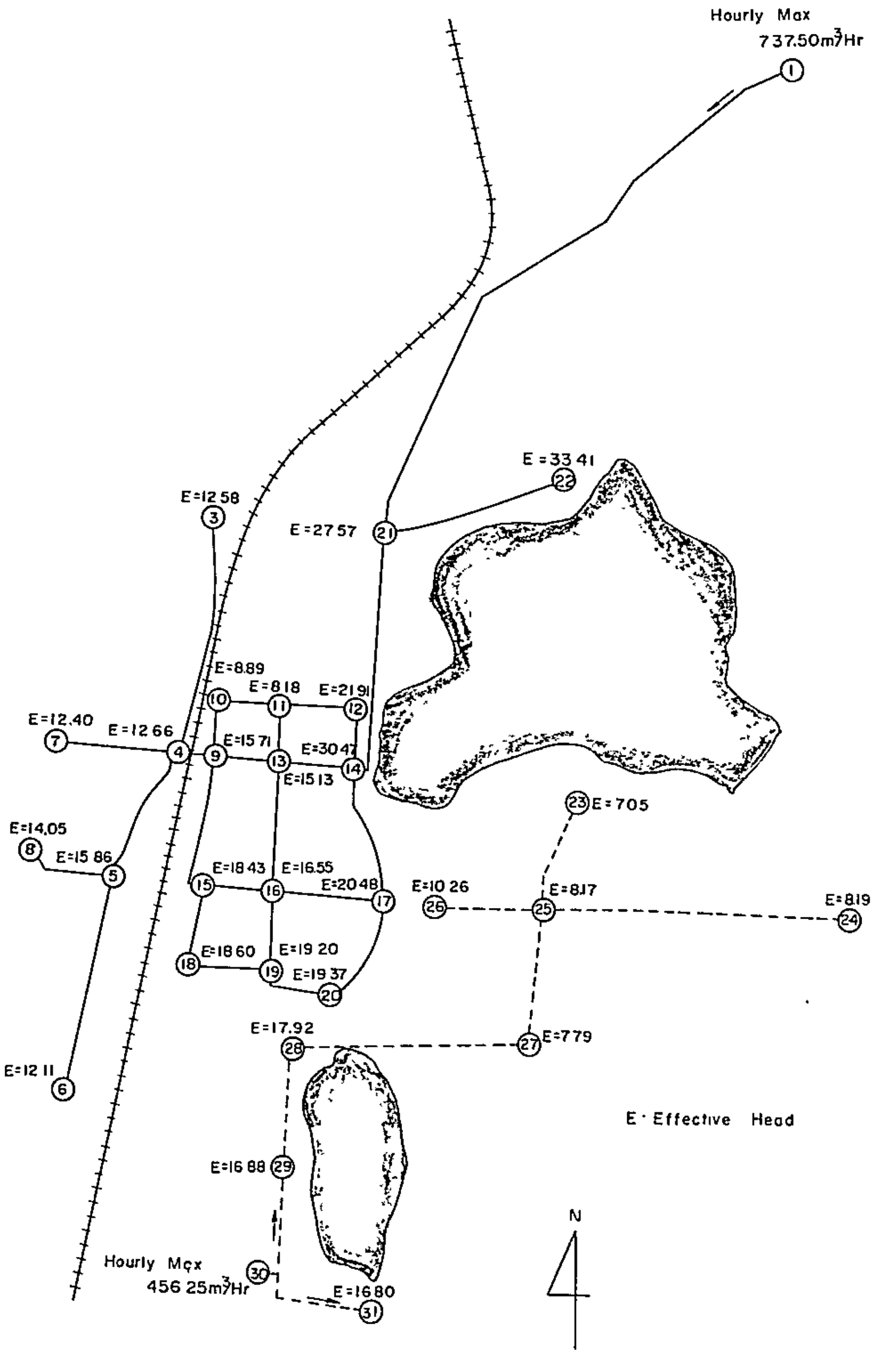


Fig 6. 12 Relation between old and new plant

For till A D. 1990

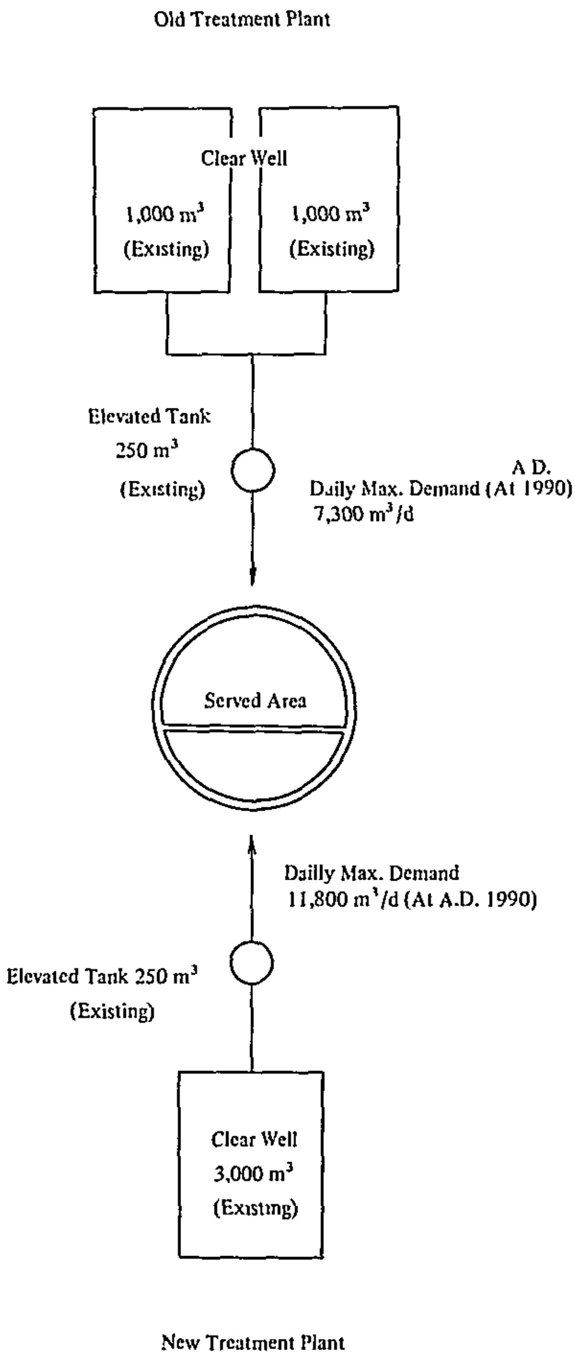


Fig 6. 13 Relation between old and new plant

For till A.D. 2000

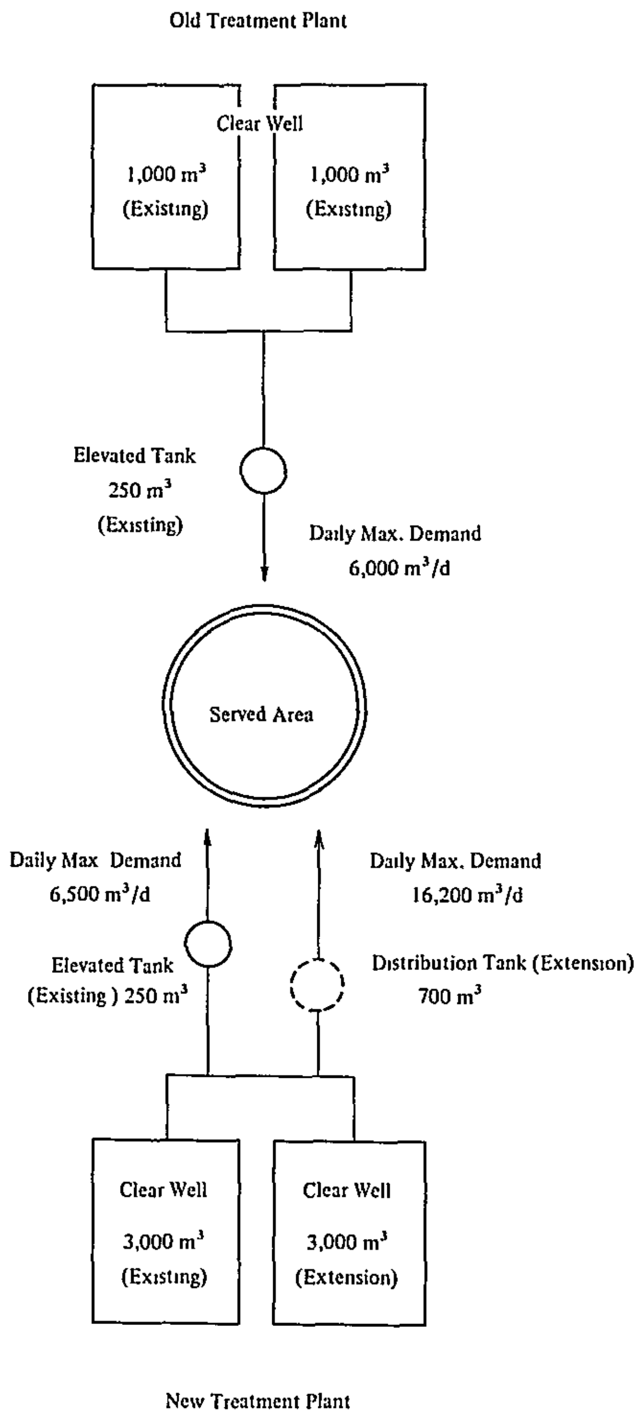


Fig. 6. 14 Pump Room in Head Office

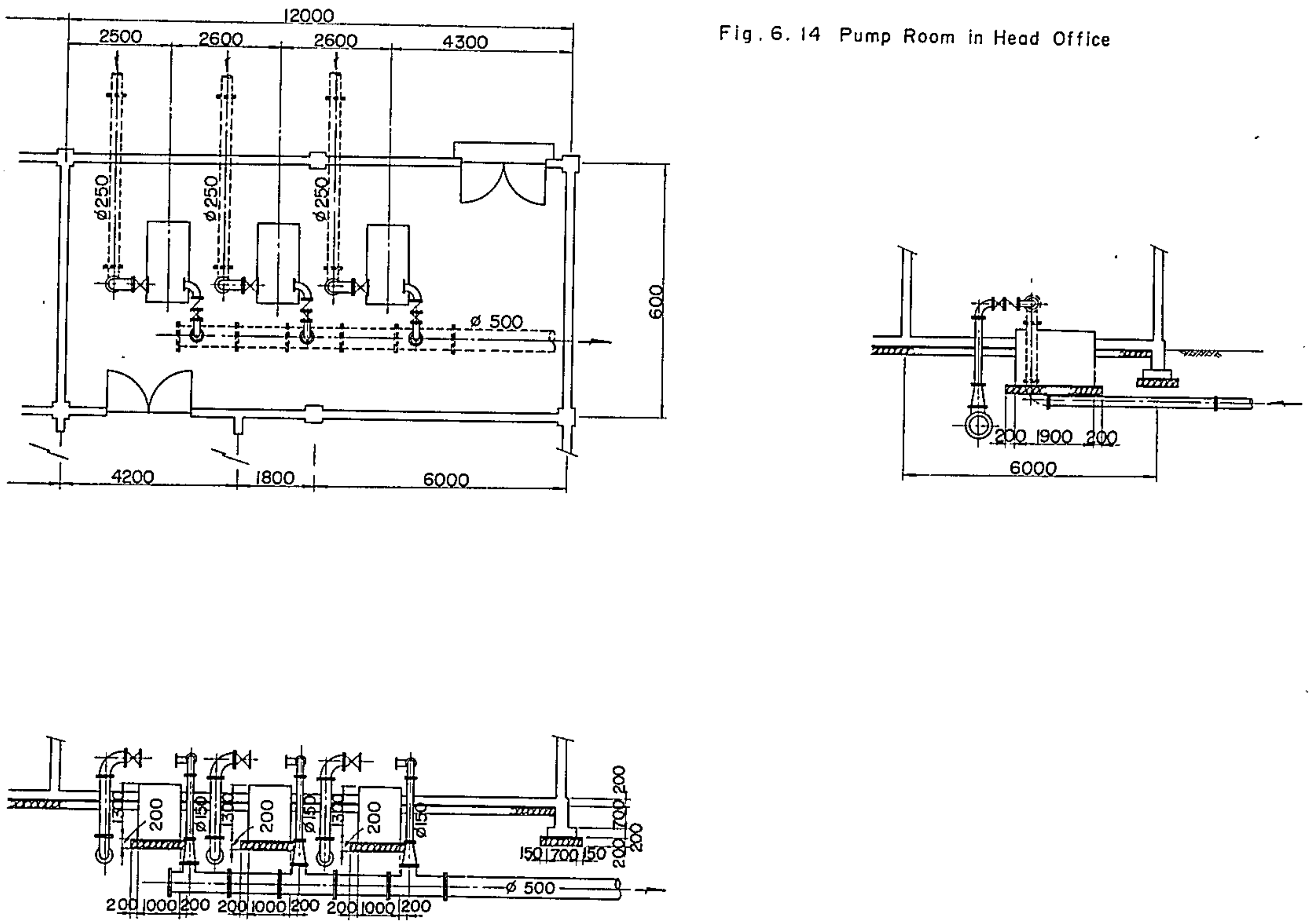
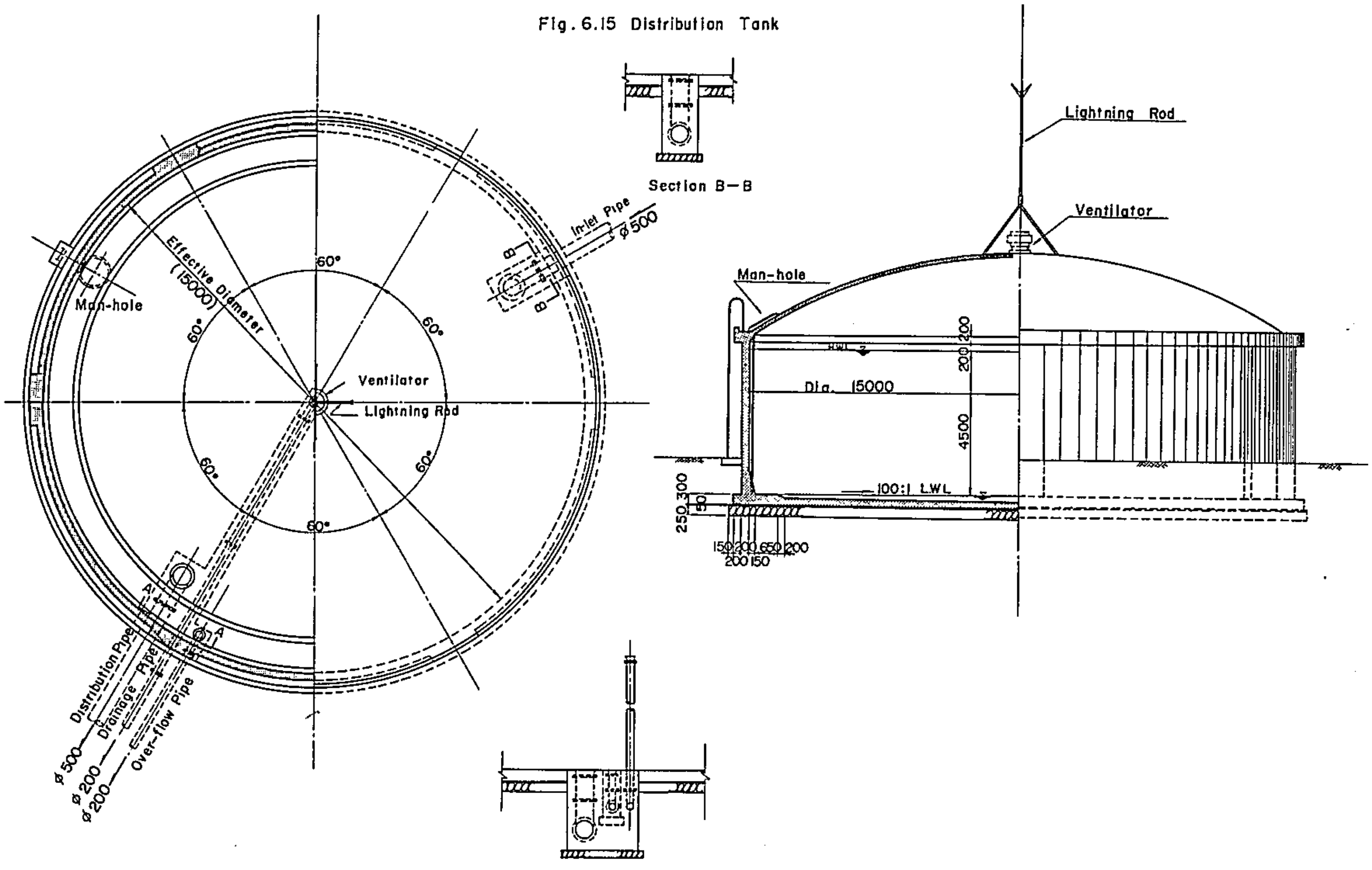


Fig. 6.15 Distribution Tank



Chapter 7 Cost of Construction

7.1 Breakdown of Construction Cost (1st Stage)

Item	Quantity	Total	Foreign Currency	Local Currency
1. Raw Water Intake & Conveyance				
1-1 Land Cost	5,000 m^2	100,000	0	100,000
1-2 Intake Tower	1 unit	1,320,000	100,000	1,220,000
1-3 Construction Road	1,715 m^2	60,000	0	60,000
1-4 Raw Water Main (φ500 C.I.P.)	3,200 m	3,790,000	3,410,000	380,000
1-5 Pump Equipment & Diesel-Engine	3 sets	1,796,000	1,620,000	176,000
1-6 Raw Water Branch (φ400 C.I.P.)	12,100 m	9,445,000	8,500,000	945,000
1-7 Pumping House		130,000	0	130,000
1-8 Pump Equipment	3 sets	528,000	475,000	53,000
1-9 Pavement	12,100 m	546,000	0	546,000
1-10 Miscellaneous (5.00%)		885,000	695,000	190,000
Sub-Total		18,600,000	14,800,000	3,800,000
2. Water Treatment Plant				
2-1 Head House	288 m^2	910,000	46,000	864,000
2-2 Miscellaneous (4.40%)		40,000	4,000	36,000
Sub-Total		950,000	50,000	900,000
3. Distribution System				
3-1 Distribution Pipe				
C.I.P. φ500	3,350 m	3,527,550	3,174,795	352,755
" φ400	3,810 m	2,823,210	2,540,889	282,321
A.C.P. φ300	4,710 m	1,172,790	0	1,172,790
" φ250	7,290 m	1,436,130	0	1,436,130
" φ200	3,950 m	584,600	0	584,600
" φ150	3,670 m	367,000	0	367,000
3-2 Sluice Valve				
φ500	8	277,632	277,632	0
φ400	8	171,056	171,056	0

Item	Quantity	Total	Foreign Currency	Local Currency
ϕ300	9	97,416	97,416	0
ϕ250	15	122,085	122,085	0
ϕ200	10	57,350	57,350	0
ϕ150	10	38,110	38,110	0
3-3 Hydrant				
Double	63	373,401	373,401	0
Single	78	389,220	389,220	0
3-4 Pavement	26,780 m^2	1,205,110	0	1,205,100
3-5 Expenditure (20% of Local)	-	839,000		839,000
3-6 Miscellaneous (5.33%)	-	718,350	378,046	340,304
Sub-Total		14,200,000	7,620,000	6,580,000
4. Electric Equipment	-	2,000,000	1,300,000	700,000
Sub-Total		2,000,000	1,300,000	700,000
Grand-Total		35,750,000	23,770,000	11,980,000
Engineering Fee	5%	1,790,000	1,790,000	0
Administration Cost	4%	1,430,000	0	1,430,000
Reserve	10%	3,580,000	2,440,000	1,140,000
Total		42,550,000	28,000,000	14,550,000

7.2 Summary of Construction Cost (1st Stage)

(Unit: Baht)

Item	Total Cost	Foreign Currency	Local Currency
(1) Intake & Raw Water Conveyance	18,600,000	14,800,000	3,800,000
(2) Water Treatment Plant	950,000	50,000	900,000
(3) Distribution System	14,200,000	7,620,000	6,580,000
(4) Electric Equipment	2,000,000	1,300,000	700,000
Sub-Total	35,750,000	23,770,000	11,980,000
Engineering Fee	1,790,000	1,790,000	0
Administration Cost	1,430,000	0	1,430,000
Reserve	3,580,000	2,440,000	1,140,000
	42,550,000	28,000,000	14,550,000

7.3 Breakdown of Construction Cost (2nd Stage)

Item	Quantity	Total	Foreign Currency	Local Currency
1. Raw Water Conveyance & Treatment Plant (Designed already by P.M.W.D.)				
1-1 Raw Water Pump	1 set	500,000	450,000	50,000
1-2 Sedimentation Basin	1 unit	3,200,000	800,000	2,400,000
1-3 Filter	1 unit			
1-4 Chemical Feeder	4 sets	200,000	180,000	20,000
1-5 Chlorine Feeder	2 sets	100,000	90,000	10,000
1-6 Piping System	-	300,000	270,000	30,000
1-7 Sludge Drainage System	-	250,000	0	250,000
1-8 Miscellaneous (5.49%)	-	250,000	98,000	152,000
Sub-Total		4,800,000	1,888,000	2,912,000
2. Distribution System				
2-1 Land Cost	1,000 m²	20,000	0	20,000
2-2 Distribution Tank	1 unit	733,000	166,000	567,000
2-3 Clear Well (Designed already by P.M.W.D.)	1 unit	1,450,000	72,000	1,378,000
2-4 Pump Equipment		972,000	875,000	97,000
2-5 Conveyance & Distribution Pipe				
C.I.P. ϕ500	6,700 m	7,055,100	6,349,590	705,510
ϕ400	1,580 m	1,170,780	1,053,702	117,078
A.C.P. ϕ200	5,100 m	754,800	0	754,800
2-6 Sluice Valve				
ϕ500	9	312,336	312,336	0
ϕ400	1	21,382	21,382	0
ϕ200	6	34,410	34,410	0
2-7 Hydrant				
Double	20	118,540	118,540	0
Single	24	119,760	119,760	0
2-8 Pavement	13,380 m²	602,100	0	602,100
2-9 Expenditure (20% of Local)		315,000	0	315,000

Item	Quantity	Total	Foreign Currency	Local Currency
2-10 Miscellaneous (5.15%)		540,792	409,280	131,512
Sub-Total		14,220,000	9,532,000	4,688,000
3. Electric Equipment		1,000,000	600,000	400,000
Sub-Total		1,000,000	600,000	400,000
Grand-Total		20,020,000	12,020,000	8,000,000
Engineering Fee	5%	1,000,000	1,000,000	0
Administration Cost	4%	800,000	0	800,000
Reserve	10%	2,000,000	1,200,000	800,000
		23,820,000	14,220,000	9,600,000

7.4 Summary of Construction Cost (2nd Stage)

(Unit: Baht)

Item	Total Cost	Foreign Currency	Local Currency
(1) Raw Water Conveyance & Treatment Plant	4,800,000	1,888,000	2,912,000
(2) Distribution System	14,220,000	9,532,000	4,688,000
(3) Electric Equipment	1,000,000	600,000	400,000
Sub-Total	20,020,000	12,020,000	8,000,000
Engineering Fee	1,000,000	1,000,000	0
Administration Cost	800,000	0	800,000
Reserve	2,000,000	1,200,000	800,000
	23,820,000	14,220,000	9,600,000

Chapter 8 Financial Prospect

8.1 Financial Prespect

In the preceding Chapters, existing facilities and future water demand were studied and analyzed. And as a result of these studies and analyzes, a construction program was drawn out. The construction of new facilities require a sizable amount of funds in both local and foreign currencies. Avalability of funds may necessitate modification of construction schedule. For one thing, the amount of available funds must be made sure before everything. For second, terms and conditions of funds must be acceptable to this project. When these are not satisfied, the schedule of construction must be accordingly changed.

In general, it is desirable for water supply projects with slow speed of capital rotation to be carried out using long-term, low-interest fund. However, since it is difficult to procure such long-term, low-interest funds in domestic financial market of a developing country, it was assumed that for this water supply system foreign currency fund requirements would be met by foreign loans and local currency requirements by Thai Government funds.

Example of loans obtained from foreign countries of this type in Thailand currently are the World Bank loan, Asian Development Bank, Yen-Credit and so forth. However, this project of water supply in pattani municipality is probable financed by loan from the Japanese Government Economic Cooperation Fund with the terms contemplated to be an interest rate of 4% and amortization periods 20 years including a grace of 5 years, but it cannot be concluded that loans in the future can be secured at such terms.

8.2 General Consideration & Water Rate

Financial plan has been made by following conditions partionly as stated as before.

Table 8.1 Amortization Schedule

	Foreign Fund	Local Fund
Iterest	4 %	8 %
Term of Loan	20 years	30 years
Grace Period	5 years	5 years
Annual Rate of Amortization	0.0899414	0.0936787

Cost of maintenance and management has been calculated as shown as Table 8.2, and effective rate of water supply is as shown as Table 8.3.

Table 8.2 Cost of Maintenance & Management

Unit: Baht

	(1) Personnel Expenditure	(2) Miscellaneous (1) x 20%	(3) Repair Expenditure (1) x 10%	(4) Chemical Cost	(5) Power Cost	(6) Total
1972	198,904	39,781	19,890	134,956	380,343	773,874
1973	207,000	41,400	20,700	149,468	402,937	821,505
1974	215,280	43,056	21,528	162,858	421,052	863,774
1975	223,744	44,749	22,374	178,868	443,646	913,381
1976	232,760	46,552	23,276	196,069	466,237	964,894
1977	241,960	48,392	24,196	214,239	488,898	1,017,685
1978	251,712	50,342	25,171	235,856	516,037	1,079,118
1979	261,648	52,330	26,165	258,661	543,177	1,141,981
1980	272,136	54,427	27,214	283,065	570,332	1,207,174
	2,105,144	421,029	210,514	1,814,040	4,232,659	8,783,386
1981	282,992	56,598	28,299	306,508	785,556	1,459,953
1982	294,400	58,880	29,440	334,048	821,869	1,538,637
1983	306,176	61,235	30,618	365,846	864,264	1,628,139
1984	318,320	63,664	31,832	396,775	900,576	1,711,167
1985	331,016	66,203	33,102	432,489	942,878	1,805,688
1986	345,000	69,000	34,500	471,534	985,274	1,905,308
1987	358,800	71,760	35,880	515,054	1,033,660	2,015,154
1988	373,152	74,630	37,315	558,126	1,076,055	2,119,278
1989	388,056	77,611	38,806	607,087	1,124,441	2,236,001
1990	403,512	80,702	40,351	662,495	1,178,909	2,365,959
Σ	3,401,424	680,283	340,143	4,649,952	9,713,482	18,785,284

Table 8.3 Effective Rate of Water Supply

Year	Population (person)	House Connection (%)	Max. Daily Demand	Average Demand*		Effective Quantity for Revenue	
			(m3/d)	(m3/d)	(m3/yr.)	Effective Ratio(%)	(m3/yr.)
1972	56,200	61.0	7,900	5,267	1,922,455	70	1,345,719
1973	58,200	61.5	8,400	5,600	2,044,000	70	1,430,800
1974	60,300	62.0	8,800	5,867	2,141,455	70	1,499,019
1975	62,600	62.5	9,300	6,200	2,263,000	70	1,548,100
1976	64,700	63.0	9,800	6,533	2,384,545	70	1,669,182
1977	66,900	63.5	10,300	6,867	2,506,455	70	1,754,519
1978	69,100	64.0	10,900	7,267	2,652,455	70	1,856,719
1979	71,400	64.5	11,500	7,667	2,798,455	70	1,958,919
1980	73,700	65.0	12,100	8,067	2,944,455	70	2,061,119
—	—	—	—	—	—	—	15,160,096
1981	76,000	65.5	12,600	8,400	3,066,000	70	2,146,200
1982	78,400	66.0	13,200	8,800	3,212,000	70	2,248,400
1983	80,800	66.5	13,900	9,267	3,382,455	70	2,367,719
1984	83,200	67.0	14,500	9,667	3,528,455	70	2,469,919
1985	85,700	67.5	15,200	10,133	3,698,545	70	2,588,982
1986	88,200	68.0	15,900	10,600	3,869,000	70	2,708,300
1987	90,800	68.5	16,700	11,133	4,063,545	70	2,844,482
1988	93,300	69.0	17,400	11,600	4,234.000	70	2,963,800
1989	96,000	69.5	18,200	12,133	4,428,545	70	3,099,982
1990	98,600	70.0	19,100	12,733	4,647,545	70	3,253,282
—	—	—	—	—	—	—	26,691,066

*: Average Daily Demand = Max. Daily Demand/1.5

8.3 Financial Plan

Financial plan has been shown in Table 8.4 for the period of 1972 to 1980, in which profit would be expected at end of 1980 if wupposing water rate as 1.50 Bahts per cubic meters. This profit shall be transfered to the financial plan for the period of 1981 to 1990 as shown as Table 8.5.

Portion of currency is as follows:

(1)	Construction Cost	42,550,000.00	Baht
	{Foreign Currency	28,000,000.00	Baht
	{Local Currency	14,550,000.00	Baht
(2)	Balance brought forward	Profit 13,956,757.50	Baht
(3)	Borrowing for Construction	28,593,242.50	Baht
	{Foreign Currency	28,000,000.00	Baht
	{Local Currency	593,242.50	Baht

Table 8. 4 Financial Plan for 1972 - 1980 Water Charge 1. 50 Baht/m^3 (Unit: Baht)

Year	Income				Expenditure				Balance
	Balance brought forward	Borrowing	Water Charge	Total	Construction Cost	Management Cost	Amortization	Total	
1972	0	0	2,018,578.50	2,018,578.50	0	773,874.00	0	773,874.00	1,244,704.50
1973			2,146,200.00	2,146,200.00		821,505.00	0	821,505.00	1,324,695.00
1974			2,248,528.50	2,248,528.50		863,774.00	0	863,774.00	1,384,754.50
1975			2,376,150.00	2,376,150.00		913,381.00	0	913,381.00	1,462,769.00
1976			2,503,773.00	2,503,773.00		964,894.00	0	964,894.00	1,538,879.00
1977			2,631,778.50	2,631,778.50		1,017,685.00	0	1,017,685.00	1,614,093.50
1978			2,785,078.00	2,785,078.00		1,079,118.00	0	1,079,118.00	1,705,960.00
1979			2,938,378.50	2,938,378.50		1,141,981.00	0	1,141,981.00	1,796,397.50
1980			3,091,678.50	3,091,678.50		1,207,174.00	0	1,207,174.00	1,884,504.50
–	0	0	22,740,143.50	22,740,143.50	0	8,783,386.00	0	8,783,386.00	13,956,757.50

Table 8. 5 Financial Plan for 1981 - 1990 Water Charge 1. 50 Baht/m^3 (Unit: Baht)

Year	Income				Expenditure				Balance
	Balance brought forward	Borrowing	Water Charge	Total	Construction Cost	Management Cost	Amortization	Total	
(1960)	13,956,757.50	28,593,242.50		42,550,000.00	42,550,000.00			42,550,000.00	
1981			3,219,300.00	3,219,300.00		1,459,953.00	1,167,459.40	2,627,412.40	591,887.60
1982			3,372,600.00	3,372,600.00		1,538,637.00	1,167,459.40	2,706,096.40	666,503.60
1983			3,551,578.50	3,551,578.50		1,628,139.00	1,167,459.40	2,795,598.40	755,980.10
1984			3,704,878.50	3,704,878.50		1,711,167.00	1,167,459.40	2,878,626.40	826,252.10
1985			3,883,473.00	3,883,473.00		1,805,688.00	1,167,459.40	2,973,147.40	910,325.60
1986			4,062,450.00	4,062,450.00		1,905,308.00	2,573,933.39	4,479,241.39	△ 416,791.39
1987			4,266,723.00	4,266,723.00		2,015,154.00	2,573,933.39	4,589,087.39	△ 322,364.39
1988			4,445,700.00	4,445,700.00		2,119,278.00	2,573,933.39	4,693,211.39	△ 247,511.39
1989			4,649,973.00	4,649,973.00		2,236,001.00	2,573,933.39	4,809,934.39	△ 159,961.39
1990			4,879,923.00	4,879,923.00		2,365,959.00	2,573,933.39	4,939,892.39	△ 59,969.39
	13,956,757.50	28,593,242.50	40,036,599.00	82,586,599.00	42,550,000.00	18,785,284.00	18,706,963.95	80,042,247.95	2,544,351.05

Remarks △ .... deficit