THE SOCIALIST REPUBLIC OF THE UNION OF BURMA

BASIC DESIGN STUDY

FOR

THE URBAN WATER SUPPLY PROJECT

FINAL REPORT

VOL. I MAIN TEXT

DECEMBER 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

THE SOCIALIST REPUBLIC OF THE UNION OF BURMA

BASIC DESIGN STUDY

FOR

THE URBAN WATER SUPPLY PROJECT

FINAL REPORT

VOl. I MAIN TEXT

DECEMBER 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of the Government of the Socialist Republic of the Union of Burma, the Japanese Government decided to conduct a survey on the Urban Water Supply Development Project and entrusted the survey to the Japan International Cooperation Agency. The J.I.C.A. sent to Burma a survey team headed by Mr. Kazuhisa Matsuoka from 26th July to 13th September, 1981.

The team had discussions with the officials concerned of the Government of the Socialist Republic of the Union of Burma and conducted a field survey. After the team returned to Japan, further studies were made and the present report has been prepared.

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

I wish to express my deep appreciation to the officials concerned of the Government of the Socialist Republic of the Union of Burma for their close cooperation extended to the team.

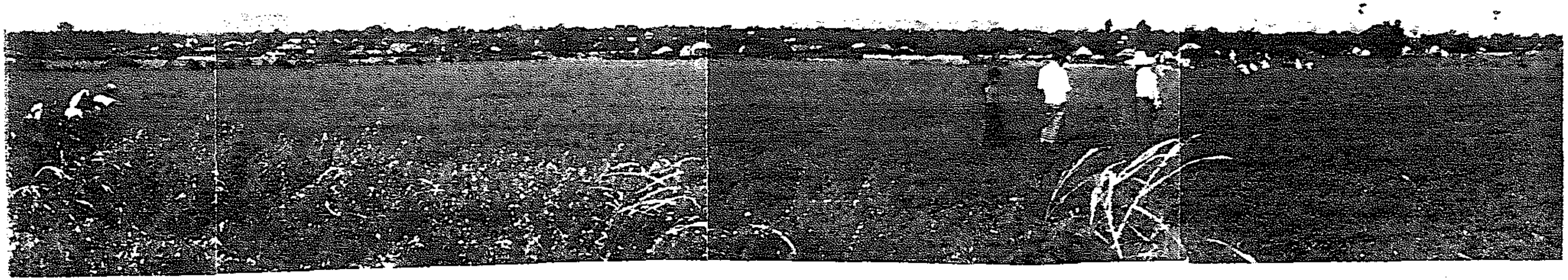
December, 1981

Keisuke Arita

President

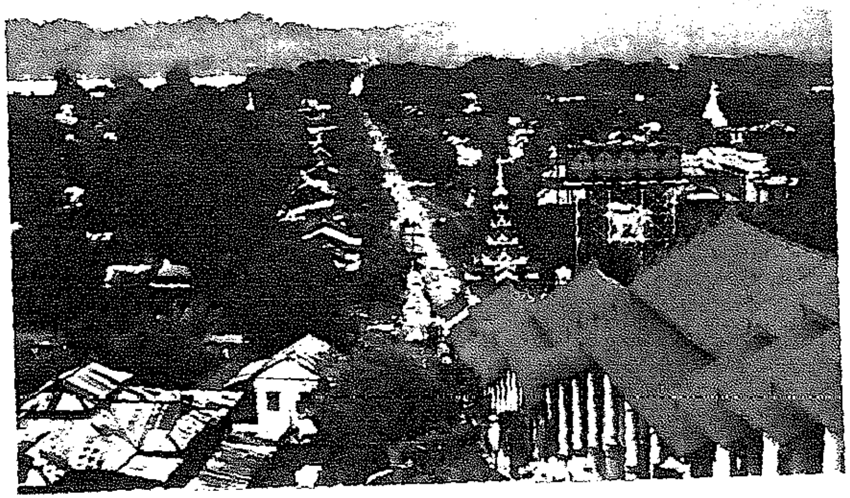
Japan International Cooperation Agency

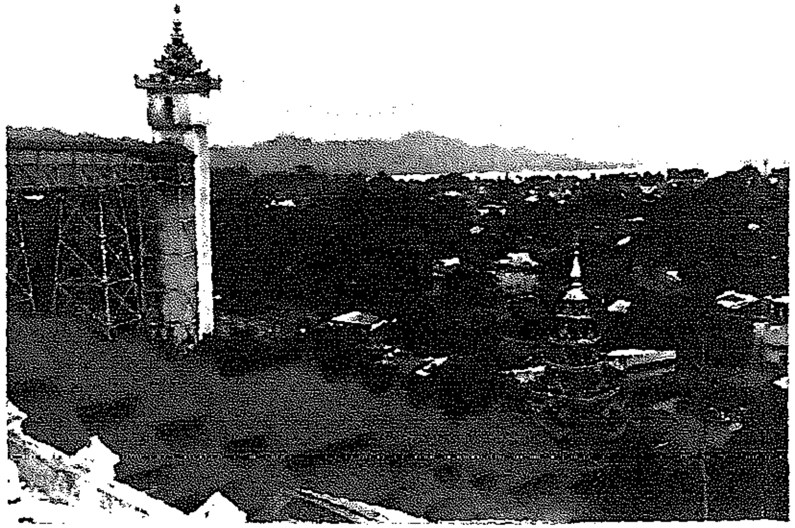
MAGWE TOWN



A view of Magwe looking from the eastern plateau to the western urban area. On the plateau (right side) electrical resitivity prospecting under way. (measuring point No. 16)
Beyond that, the pylons of a wireless station can be seen. The range of mountain in the distance is the mountainous area of the Pegu Formation distributed in the Town Minbu region lying on the opposite bank of the River Irrawaddy.

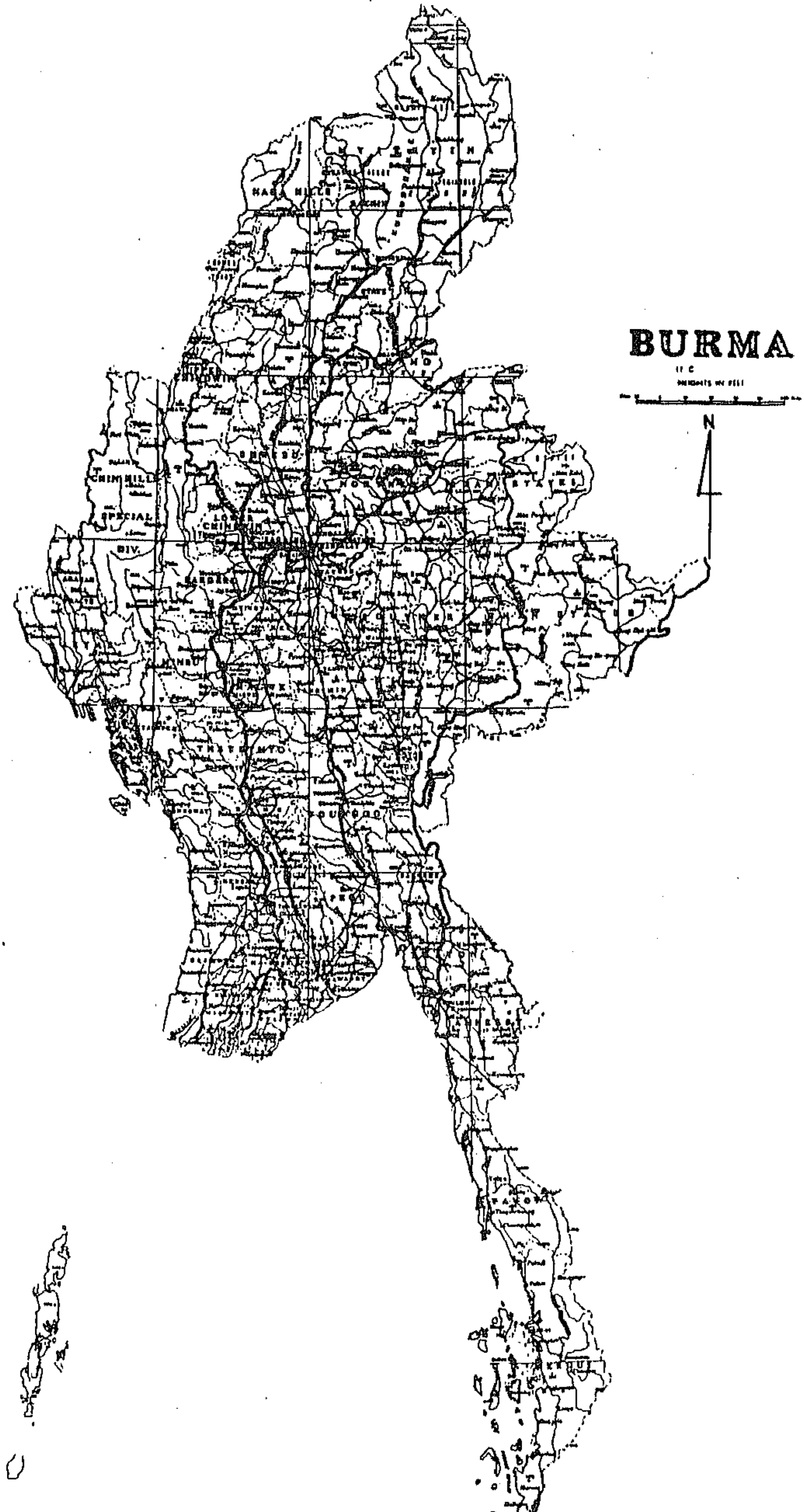
PROME TOWN

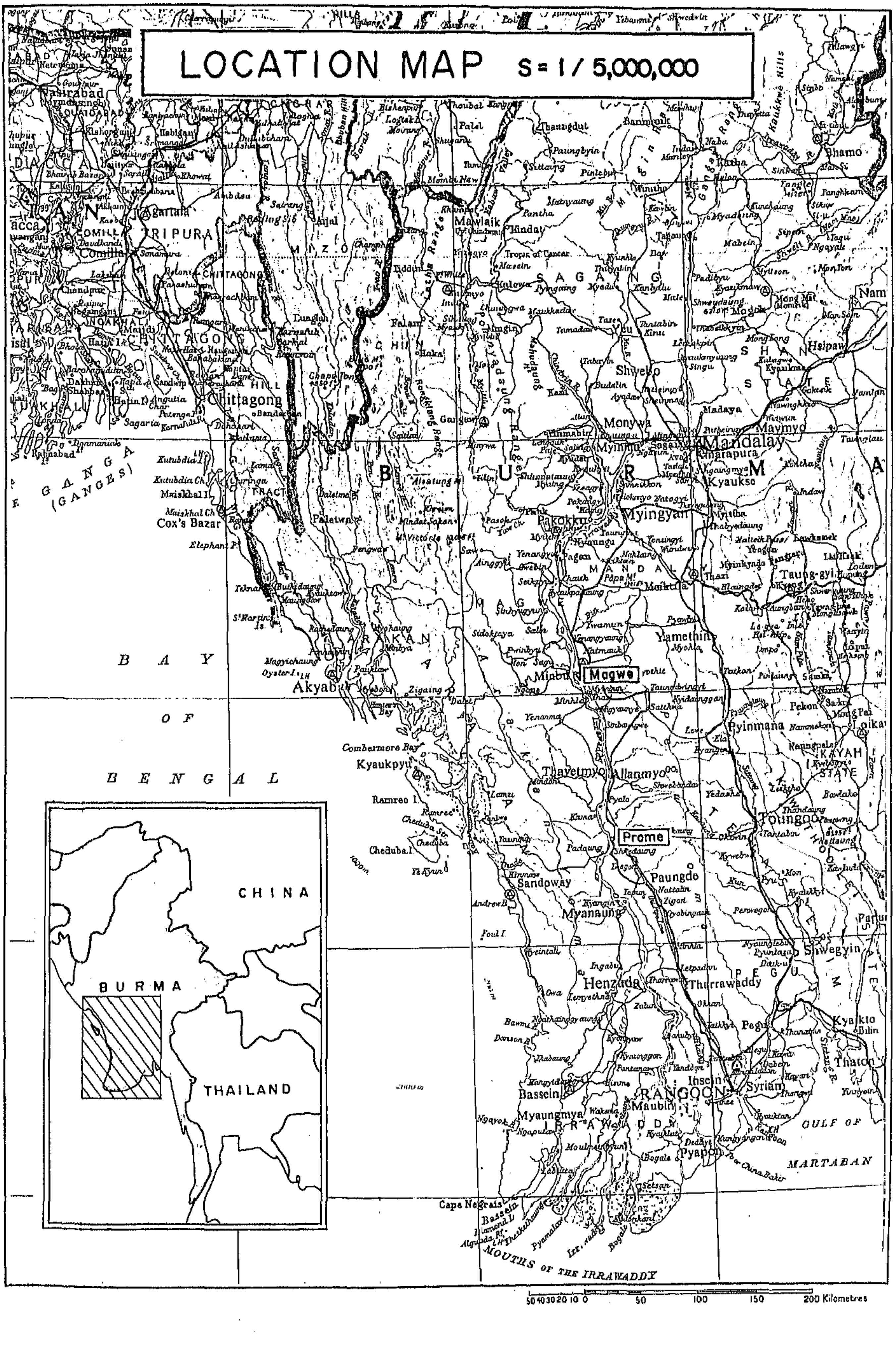




Prome Town

A view looking from the famous Shwe Sandaw Pagoda located on the southern hill of the old urban district of Prome, to the River Irrawaddy in the western side. In the central part, water distribution tanks are shown.


BURMA
N


LOCATION MAP S=1/5,000,000
CHINA
BURMA
THAILAND
BAY OF BENGAL
GULF OF MARTABAN
MOUTHS OF THE IRRAWADDY
Magwe
Prome
Mandalay
Maymyo
Monywa
Myingyan
Pakokku
Shwebo
Bhamo
Hsipaw
Kyaukse
Meiktila
Taung-gyi
Yamethin
Minbu
Akyab
Kyaukpyu
Sandoway
Thayetmyo
Allanmyo
Pyinmana
Toungoo
Paungde
Henzada
Tharrawaddy
Bassein
Myaungmya
Maubin
Pyapon
RANGOON
Insein
Syriam
Pegu
Shwegyin
Kyaikto
Thaton
Chittagong
Cox's Bazar
Comilla
Agartala
Mawlaik
Kalewa
Kindat
Haka
Falam
Nasirabad
Cape Negrais
Ramree I.
Cheduba I.
50 40 30 20 10 0 50 100 150 200 Kilometres

CONTENTS

SUMMARY

SUMMARY

1. In the Socialist Republic of the Union of Burma, the ratio of urban population to the total was nearly 10.4% in 1931 and 13.5% in 1953. Subsequently, the share rapidly increased, reaching 24% in 1981. Moreover, there are signs that there will be a further rise in the future.

However, the ratio of the population to whom water was supplied by the urban water service stood at 41% in 1977, remaining at 42% in 1981. Of 288 major towns throughout the nation, only 63 were furnished with water supply facilities. Moreover, in many towns, the facilities do not come up to their legal requirements, e.g. the water supply is extremely small in quantity and the quality is dubious. The development of urban drinking water has thus become an urgent task for the Government of Burma.

2. The Government of Burma has decided to promote a water facilities development programme for other local areas other than Rangoon, the national capital, and Mandalay, an old city. In carrying out this programme, the Government has selected the two towns of Magwe and Prome as pilot project areas and called on the Government of Japan to offer grant aid for part of the water facilities development project with the development of ground water. In response to this call, the Government of Japan decided to send this survey mission.

3. This survey was designed to carry out the following work at Magwe and Prome:

   1) Planning for the development of ground water as a water source for the water system.

   2) Formulation of a water facilities programme.

3) Evaluation of the cost-effectiveness of this project.

4) Specifications, quantity, and computation of costs, in respect of equipment and materials to be offered with grant aid.

5) Preparation of guidelines for the development of ground water with equipment and materials to be offered with grant aid.

4. The outline of Magwe and Prome and the design specifications of the ground water development programme and the water facilities programme are given below:

Outline \ Project	Magwe	Prome
Town jurisdiction (km^2)	8,614	20,719
Population (1981)	48,933	78,146
Location	560km north of Rangoon Left bank of the Irrawaddy River	250km north of Rangoon Left bank of the Irrawaddy River
Features of the town	Central town of the division as the headquarters of the Magwe division office. The town has an airport.	An important town in the north of the Pegu division and a commercial centre. Direct train services available from Rangoon.
Hydrogeology		
Annual mean precipitation (mm)	886	1,207
Annual mean evaporation (mm)	2,000	1,700
Type of zone	Semi-arid zone The entire area distributed with Irrawaddy formation.	Monsoon zone Covered with southwest Pegu formation, which in turn is covered with Irrawaddy formation.
Aquifer	Distribution of Irrawaddy formation, water permeable layer, and permeable to aquiclude as revealed by electrical prospecting. Layer thickness 20m.	Distribution the same as for Magwe. Layer thickness 30m

Outline \ Project	Magwe	Prome
Volume of ground water (m^3)	27,000,000	120,000,000
Water facilities		
Population of the target year (1991)	60,834	97,225
Population for planned water supply (persons)	60,834	67,000
Average daily water supply per person (ℓ)	150	150
Maximum daily water supply per person (ℓ)	195	195
Water supply of existing facilities (m^3/day)	1,365	3,240
Planned water supply of new facilities (m^3/day)	11,500	14,700
Water pumped per day (m^3/day 18 hrs.)	700	1,000
Average depth of production wells (m)	110	150
Average depth of exploration wells (m)	150	200
Number of production wells	17	15
Number of exploration wells	13	11
Observation wells for pumping tests	30	26
Wells for year-round observation of the water level	3	3
Submersible pumps (kW)	15	30
Total length of conduits (m)	Ductile cast iron pipes 8,700	Ductile cast iron pipes 6,900
Capacity of water tanks (m^3)	No.1 RC structure 1,400	No.1 underground RC structure 1,700
	No.2 RC structure 1,400	No.2 underground RC structure 1,600
	No.3 RC structure 1,200	No.3 elevated RC structure 290

7. The Township Development Committee (a local autonomous entity) holds itself responsible for the operation and maintenance of the water works. For this project, too, there is a need to carry out the operation and maintenance through the following system under the Township Development Committee.

1) A water works superintendent general will be assigned to take overall charge of the water works.

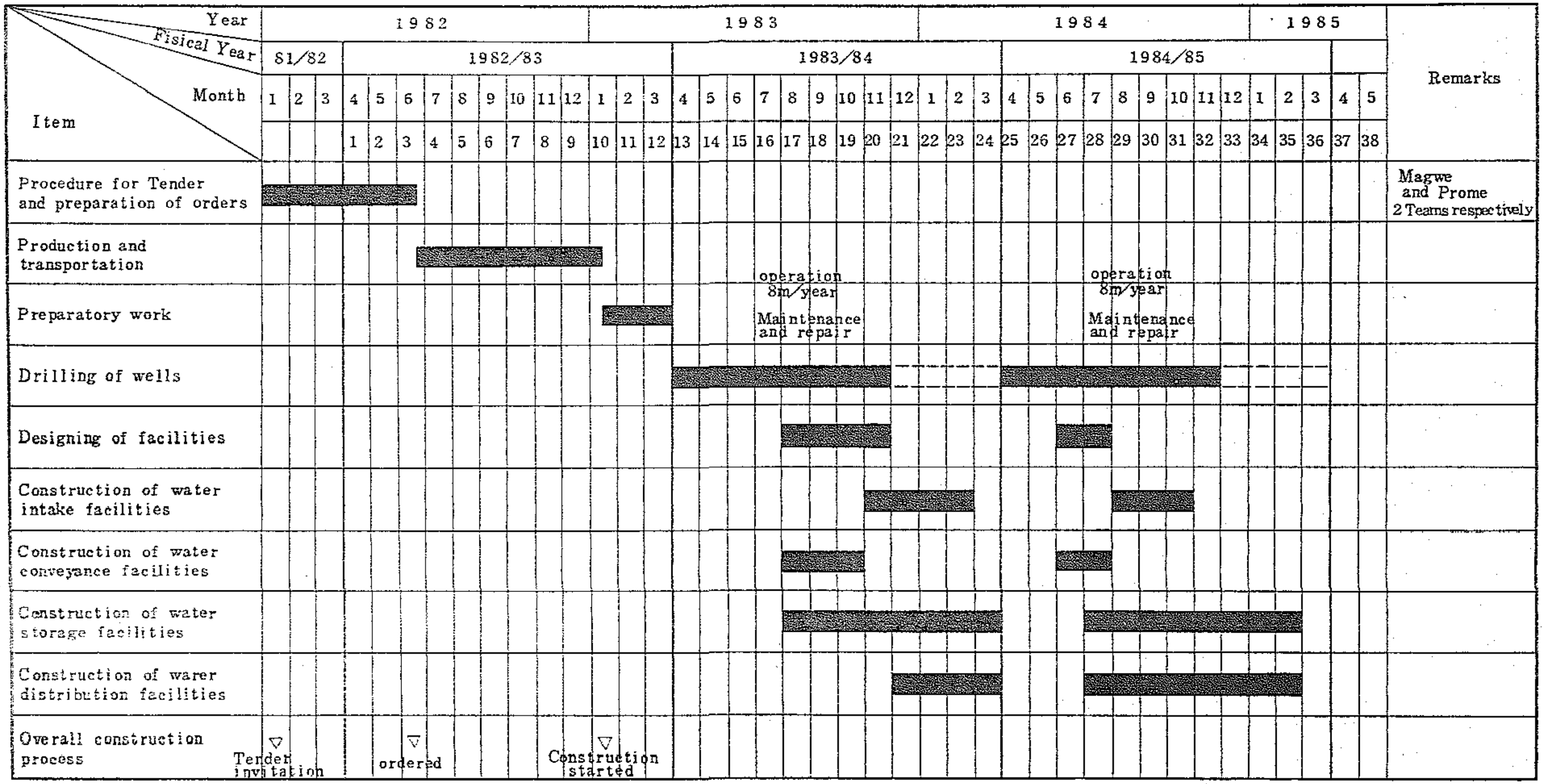
   Under this superintendent, general, a technical division director will be assigned as the person responsible for the operation and maintenance of technology. Under such director, engineering officials and water supply and distribution officials will be placed. The engineering officials will take charge of the operation and maintenance of the section from the water source to the storage tanks, whereas the water supply and distribution officials will be in charge of those of the main and branch pipes, and the faucets. In the administration sector, a division director will also be assigned. Under this director, administrative and accounts clerks will be appointed to deal with administrative matters regarding the operation and maintenance.

   Under this organization system, 21 persons will be needed for operation and maintenance except superintendent general and numbers of the administrative division.

2) The costs of operation and maintenance may be divided into the costs of operation and maintenance of the section from the water source to the storage tanks, and the costs of those associated with water supply and distribution.

   With respect to the water source wells, it will be required to set aside about 560,000 Kyats/year for Magwe and about 872,000 Kyats/year for Prome for water supply and distribution. In Magwe, an overall rough estimate for the total annual

6. The overall Imprementation schedule is shown below



5. The estimated construction cost at Magwe and Prome is given below:

Items \ Construction cost	Estimated construction cost									
	Magwe			Prome			Overall			Total
	Equipment and materials cost		Labour cost	Equipment and materials cost		Labour cost	Equipment and materials cost		Labour cost	
	Foreign	Local	Local	Foreign	Local	Local	Foreign	Local	Local	
Water intake facilities	110,801 (3,693)	40,825 (1,360)	4,956 (165)	117,466 (3,916)	37,121 (1,237)	4,505 (150)	228,267 (7,608)	77,946 (2,598)	9,461 (315)	315,674 (10,522)
Water conveyance facilities	65,536 (2,184)	-	10,920 (364)	69,370 (2,312)	-	11,707 (390)	133,013 (4,434)	-	22,627 (754)	155,640 (5,188)
Water storage facilities	-	104,200 (3,473)	26,000 (867)	-	109,900 (3,663)	27,500 (917)	-	214,100 (7,137)	53,500 (1,783)	267,600 (8,920)
Water distribution facilities	110,684 (3,689)	900 (30)	19,437 (647)	182,379 (6,074)	-	32,232 (1,074)	293,063 (9,769)	900 (30)	51,669 (1,722)	267,600 (8,920)
Total direct construction cost	285,128 (9,504)	145,925 (4,864)	61,313 (2,044)	369,215 (12,307)	147,021 (4,901)	75,944 (2,531)	654,343 (21,811)	292,946 (9,765)	137,257 (4,575)	1,084,546 (36,152)
Miscellaneous expenses	-	-	123,091 (4,103)	-	-	148,045 (4,935)	-	-	271,136 (9,038)	271,136 (9,038)
Boring machinery and accessories	234,360 (7,812)	-		234,360 (7,812)	-	-	468,720 (15,624)	-	-	468,720 (15,624)
Sea and land transport cost	-	50,183 (1,673)		-	51,415 (1,714)	-	-	101,598 (3,387)	-	101,598 (3,387)
Total	519,488 (17,316)	196,108 (6,537)	184,404 (6,147)	603,575 (20,119)	198,436 (6,615)	223,989 (7,467)	1,123,063 (37,435)	394,544 (1,315)	408,393 (13,613)	1,926,000 (64,200)
	715,596 (23,853)			802,011 (26,733)			1,517,607 (50,587)			

Note: Yen in thousands (Kyats in thousands)

As of August 1981

1 Kyat ≒ 30 yen

operation and maintenance costs is 640,000 Kyats/year, and 952,000 Kyats/year in the case of Prome.

Judging from past expenditure and the collection of fees at Magwe and Prome, the outlay will not be a burden on the local finances and will probably enrich them in the future.

8. The effects of this project are as follows:

1) About 61,000 townspeople in Magwe and about 67,000 townspeople in Prome will be supplied with sufficient drinking water.

2) The shortage of drinking water has been a major barrier to urban development, but the successful completion of this project may lead to a breakthrough.

3) The equipment and materials, which are to be supplied with grant aid, may also be used for the development of drinking water in other towns after the completion of this project.

4) Many of the occupants in both towns exist through river water in drums carried by bullock carts. The price of water to be paid by households after the laying of a water supply system is estimated at 18 Kyats on the assumption that 20 m^3/month will be consumed. This means a drastic reduction in expenditure by households from the 200 ∿ 600 Kyats/month paid for purchasing river water in drums.

5) Where ground water is used as the source, the water is hygienic, making it possible to avoid the occurrence of diseases caused by water qualitatively unsuitable for drinking.

6) The establishment of these water supply systems in Magwe and Prome will deprive water dealers of their jobs and prompt them to switch to other employment. Also, the coverage of the entire town under this system will make it necessary to retain a considerable number of full-time and part-time workers for the construction as well as its oeration and maintenance. Moreover, it should be possible to fully absorb the manpower as the climate of business will be boosted by the new water system.

9. The following problems should be considered, when this project is carried out

1) In Magwe, the existing water facilities utilize the surface water of the Irrawaddy, so that there will appear areas where this surface water, mixed with quality ground water, is distributed. Therefore, it is necessary to provide prompt treatment of the water sources of the existing water system, in order to produce water of identical quality.

   The location and number of production wells in Magwe may be changed, depending on the findings of the exploration wells. Accordingly, there may arise the necessity of preparing a detailed design.

2) In Prome, the repair and expansion of the existing water supply system will be done by the municipality, and those in other areas will be carried out under the Prome Project. For this reason, the water quality may presumably be different. There is a need therefore to process fully the water of the existing supply facilities where surface river water is used as the source, and work out a system whereby water may be mutually supplied to both areas.

Though the target year of this project is set at 1991, it is expected that there will be a sizeable concentration of population in the southern area after that year. However, the development of ground water in the southern area alone will be inadequate to cope with the increased population. There will then presumably arise a need for the development of ground water in the northern part, where the distribution of ground water conservation areas is hydrogeologically more favorable.

CHAPTER 1 INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background of the Project

There are 288 notified towns in Burma, most of them being small towns consisting of less than 60,000 population, except for the capital, Rangoon, and the old city of Mandalay.

In these urban communities (which rarely have satisfactory public water supply facilities) approximately 60% of the town dwellers are not provided with any public water service. At present, only 63 towns have public water supply systems. Furthermore, most of these public water supply facilities in these towns do not have sufficient capacity to meet the water demand of the dwellers, and the towns are obliged to provide only a limited amount of water, such as supply to only a section of the dwellers for a restricted time etc. In addition, quality of the water supplied is mostly not good enough to meet the national water quality standards (equivalent to the WHO Standards).

Therefore, the Burma Government has decided to adopt the development of drinking water resources which serve as a basic necessity for those living in towns, as one of the crucial national policies, and to promote a project for public water supply systems utilizing ground water as one of the water resources. In this project, among the 288 towns the following 10 towns have been chosen, according to their priority for drinking water development, and it aims at the construction of public water supply systems in these towns within 10 years.

Name of the town		State/division
1.	Thazi	Mandalay Div.
2.	Pakokku	Magwe Div.
3.	Prome	Pegu Div.
4.	Magwe	Magwe Div.
5.	Toungoo	Pegu Div.
6.	Monywa	Sagaing Div.
7.	Shwebo	Sagaing Div.
8.	Pegu	Pegu Div.
9.	Pyawbwe	Mandalay Div.
10.	Pyinmana	Mandalay Div.

With this background, in July 1981, the Burma Government called on the Japanese Government for grant aid to purchase the equipment and materials necessary for implementing the public water supply project by ground water development in two towns, Magwe and Prome, out of the above-mentioned 10 towns. In response to this call, the Japanese Government decided to send a mission.

1.2 Purposes of the Survey and Study

The study of the project aims at implementing the following studies:

1) Planning a ground water exploitation project as a drinking water source.

2) Planning water supply systems and estimating the cost.

3) Assessing the effects of the project.

4) Making a list of specifications and number and amount of equipment and materials expected to be required for carrying out the project and estimating the cost.

5) Making guidelines for implementation of ground water development projects which explain the implementing procedure, from electrical prospecting and well exploration, for water production and supply.

1.3 Areas Surveyed

The areas for survey were Magwe and Prome, which lie in the middle basin of the River Irrawaddy running north-south across Burma.

The water supply system plans for ground water exploitation in both towns are expected to serve as a leading pilot project for other water supply systems in the future. Therefore, from the following viewpoints, these two towns were chosen from 10 towns assigned for development of water supply systems using ground water as a source.

1) climatic condition
2) hydrological and geological condition
3) maturity of the project as a water supply system development
4) urban functions

The characteristics of the areas surveyed corresponding to the above items, are as follows;

1) Climatic condition

Magwe, of which annual average precipitation is 886 mm/year (average over 45 years), is situated in a semi-arid zone, and Prome, with annual average precipitation 1,207 mm/year (average over 71 years), lies in the monsoon region (see Fig. 2.2.1.1)

2) Hydrogeological conditions

The whole area surrounding Magwe lies in the Irrawaddy Formation (water bearing layer). The layer of the hills in the west of Prome lies in the Pegu Formation (bed rock with aquiclude layer), of which the main layer sinks towards the north and the east, and covers the region surrounded by the Irrawaddy Formation.

3) Both Magwe and Prome have already prepared New Urban Plans, which emphasize planning implementing water supply system projects based on ground water development. At the same time, extension and improvement of the existing water supply facilities in the old urban areas are included in the Fourth-Year Plan designed by the Township development Committee.

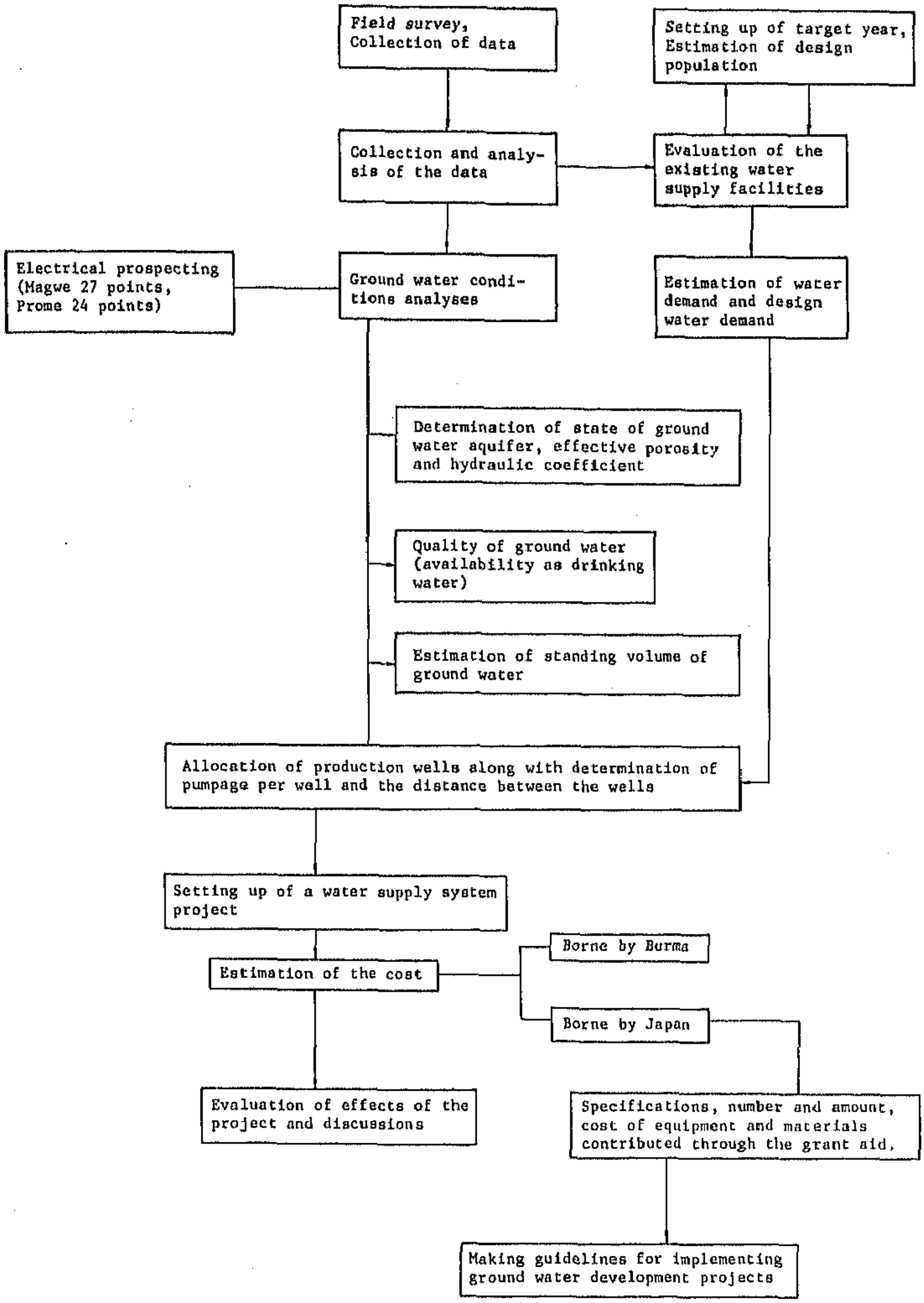
4) Magwe covers 8.614km^2 and its population amounts to 48,933 (in 1981). It lies on the east bank of the River Irrawaddy, about 560km north of Rangoon. As the capital of Magwe Division, the town is the centre of politics and economy.

Prome covers 20.719km^2, has a 78,146 population (in 1981), and lies on the east bank of the River Irrawaddy, 250km north of Rangoon. The town is included in the Pegu Division and serves as a politically and economically important place in the north region.

1.4 Outline of the Project

The Study of the Project took place from the end of July 1981 to the end of December 1981 (including a field survey from 28 Jul. 1981 to 12 Sep. 1981). The following flow chart 1.4.1 illustrates its procedure. List of The Mission Members and the Minutes during the process of the Survey are given in Appendix.

Fig. 1.4.1 Flow Chart of Survey



CHAPTER 2 DEVELOPMENT OF GROUND WATER SOURCES AND URBAN WATER SUPPLY IN BURMA

CHAPTER 2 DEVELOPMENT OF GROUND WATER SOURCES AND WATER SUPPLY IN BURMA

2.1 Outline of Burma

Burma covers 678.000km^2 in the monsoon area, and her population is approximately 34,000,000, consisting of many national races. Her geographical characteristics are; Chin Hills in the northwest, the Shan Highlands in the east, the Arakan Mountains in the west, and the central part consist of lowlands, where the River Irrawaddy runs from the north towards the south, forming a vast delta at its downstream area. Along the border between Thailand in the east of the River Irrawaddy, the River Salween runs.

The hydrology, geology and other natural conditions which form the basics for the development of ground water in Burma will be elucidated later. Here, our attempt will be confined to a general view of the economic situation which creates the basic social conditions of Burma, and the economic outlook.

As to the current economic policy of Burma, the Third Four-year Plan, starting in the 1978∿79 FY, is under way, and is due to expire in the 1981∿82 FY. Subsequently, the Fourth Four-Year Plan has been made for the four years from 1982∿83 FY and is due to be implemented. In the meantime, the economy has grown at a relatively smooth pace, in parallel with evolution of the policy.

The trend of the economy of the last four years has shown an annual growth rate of 6.7% in terms of Gross Domestic Production (GDP). The proposed growth rate and the actual growth rate of GDP are shown in Table 2.1.1.

Table 2.1.1 Growth Rate by Year

Fiscal year	Proposed growth rate	Actual growth rate
1978∿'79	5.9%	6.5%
1979∿'80	5.9%	5.4%
1980∿'81	6.9%	8.3%

Source: Burma Government

The economic structure of Burma is such that the share of the agricultural, forestry and fishery sectors in gross national product, is high. The economic infrastructure is founded on agriculture and, in terms of development, priority is given to agriculture.

The economic growth rate of the major industries is shown in Table 2.1.2. Notably, agriculture in the 1980∿'81 FY grew at a rapid pace.

Table 2.1.2 Growth Rate in Main Economic Sectors

Sector \ Fiscal year	1978 ∿ 1979	1979 ∿ 1980	1980 ∿ 1981
Agriculture	7.7%	5.2%	14.6%
Fishery and domestic	6.0%	6.1%	1.4%
Forestry	14.3%	6.9	2.4%
Mining	7.7%	12.4%	3.3%
Production and processing	2.5%	4.0%	11.3%

Source: Burma Government

2.2 Hydrogeology of Burma

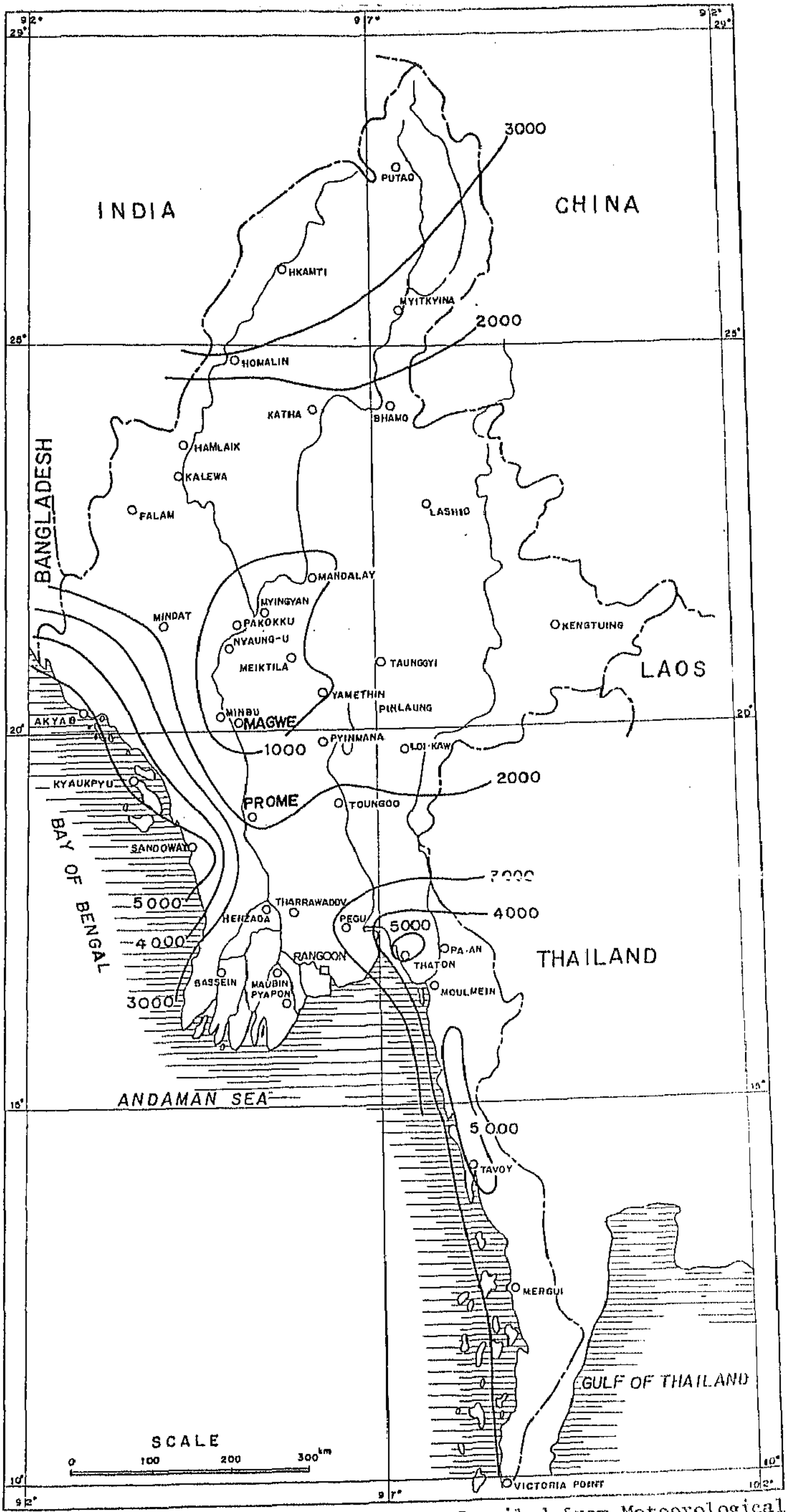
2.2.1 Precipitation and Evaporation

Precipitation and evaporation in Burma, which is within the monsoon area, varies considerably, owing to specific conditions, such as effects of the location, ocean, geography, and trade winds.

The Burmese Meteorological Agency's hydrology department issues a yearly hydrological report. On the basis of this report, an annual mean precipitation chart is prepared and given in Fig. 2.2.1.1, with the location of weather stations and the annual mean precipitation being documented and given as a supplement.

Evaporation is higher in the inland area and lower in the north and the south. The Table 2.2.1.1 shows the precipitation and evaporation in Mandalay and Pegu, which typify the semi-arid area climate and monsoon area climate, respectively.

Fig. 2.2.1.1 Rainfall Distribution in Burma (in millimeter)



Compiled from Meteorological Department Data

Table 2.2.1.1 Precipitation and Evaporation in Semi-arid and Monsoon Area (1974)

in mm

Name of city and town	Item \ Month	1	2	3	4	5	6	7	8	9	10	14	12	Total
Mandalay (semi-arid area)	Precipitation	0	0	17	60	203	132	79	93	287	76	87	0	1,034
	Evaporation	90.6	157.9	215.3	239.7	239.5	205.6	212.2	177.9	168.1	159.5	90.8	83.8	2,040.9
Pegu (monsoon area)	Precipitation	0	0	26	44	547	702	814	709	561	315	46	0	3,770
	Evaporation	117.8	122.0	159.9	146.1	131.7	88.7	96.6	103.7	129.6	140.9	97.8	111.4	1,446.2

Source: Burma Meteorological Department

2.2.2 Hydrogeology

A general view on the geological structure of Burma is; the east is covered by the Shan Highlands mainly consisting of old bed rock, and in the west the Arakan Upheavals, consisting of the Palaeogene and the Cretaceous strata, runs north-south. The Central Lowlands between them is cut at both sides by a north-south tectonic line, forming a graben, and is called the Central Cenozoic belt. The bedrock of this stratum consists of the Oligocene and the middle and lower Miocene Formations (Pegu formation), the upper Miocene or the Pliocene Formations being distributed on them. The plains are covered by alluviums. A general tectonic map is shown in Fig. 2.2.2.1.

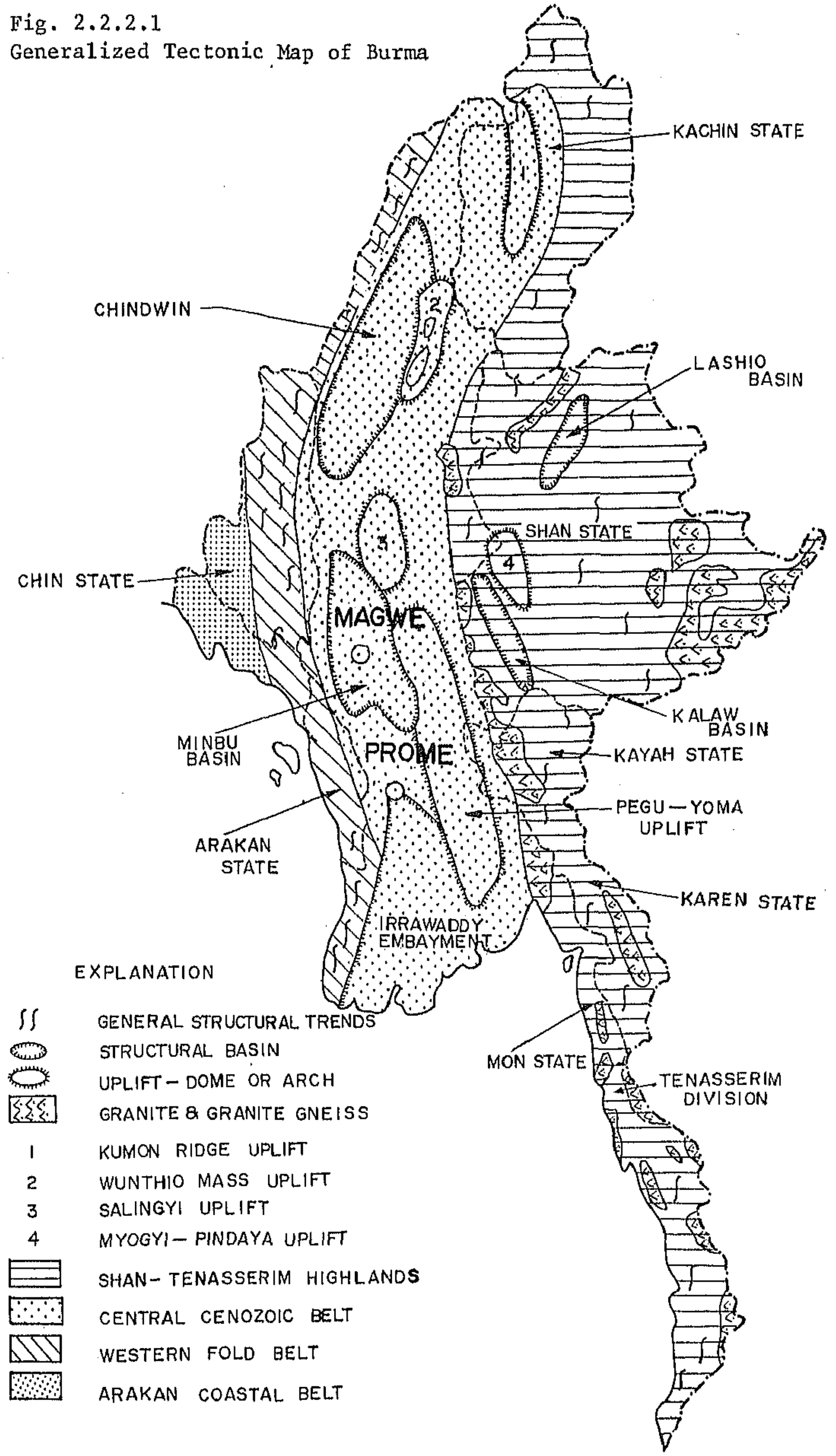
The Irrawaddy formation is a main water bearing formation. It is extremely difficult to take ground water from the layer placed in a level lower than this formation, except for special cases, such as in fissures and faults.

Thickness of the Irrawaddy formation is presumed approximately as 3,000m (The Geological Map of Burma, Explanatory Brochure). This formation forms a layer consisting of sand and clay alternately, but sand is more dominant. It is characterized by predominant middle or coarse sand particles and, in some cases, by ferruginous sandstone with quartz pebbles. In addition, it contains many silicified fossil woods as well as many fossils of terrestrial and aquatic vertebrates, mostly mammalian, by which geological age can be determined. The geological age of the Irrawaddy formation mostly falls in the Pliocene era, covering partly the Quaternary period, but a part of it belongs to the upper Miocene. This formation, which is always uncomformity with the lower layers, covers them.

As to development of aquifer, the layers of coarse sand mixed with gravel lying in the south of the Irrawaddy embayment area form aquifers. The layer components change to alternate

formations with clay or sand towards the north, and in the Prome area lying in the north end of the Irrawaddy embayment, and in the Magwe area lying in the central part of the Minbu Basin, alternate layers are formed. Therefore, development of aquifer in these areas is inferior to that in the Rangoon area in the south.

Fig. 2.2.2.1
Generalized Tectonic Map of Burma



Source: THE GEOLOGICAL MAP OF BURMA (EXPLANATORY BROCHURE)

2.3 *Existing Conditions of Urban Water Supply System*

The first water supply system in Burma started in Rangoon in 1879. Since then, many towns in Burma have been equipped with water supply systems. The urban population in Burma is about 8,340,000 in 1981, which accounts for 24% of the total population. Of this population, a total of 3,500,000 are in receipt of a water supply, about 42.0% of the entire population.

As is shown in Table 2.3.1, the urban water supply system in Burma has been in the doldrums for the past few years. In the change of water supply systems in both urban and rural districts between 1977 and 1981, the water-supplied population was almost the same in both areas in 1977, but in later years, the number of those people in urban areas failed to show any increase, being half that of the rural water-supplied population in 1981.

Also, the development of water supply systems in urban areas has been reduced over the last five years. Subsequently, only 63 of the 288 major Burmese towns are now equipped with water-supply facilities.

The average per-capita volume of water supply a day differs largely from one urban area to another. It is 5-10 litres per day in semi-arid zone dried districts, and 115 litres per day in small-and medium-sized towns of the other areas. In the capital city of Rangoon, the average per-capita water-supply volume stands at 270 litres per day.

As for details of the water supply, some towns have no total water-supply system covering all their areas, and others have differences in the volume of supplied water, regarding different sections within them, or restricted supply is being made only for several hours a day or for every two days.

At the same time, there exist many problems as to the quality of the supplied water, because the water has its source in surface river water.

Table 2.3.1 Water Supply, Urban and Rural (Country Report on Water Supply and Sewerage Sector; R.C.D.C.)

	1977	1978	1979	1980	1981
1. Population (in millions)					
Urban	7.53	7.72	7.91	8.11	8.34
Rural	24.11	24.64	25.18	25.74	26.33
Total	31.64	32.36	33.09	33.85	34.67
2. Population Served (Existing systems)					
Urban	3.10(.45)	3.15(.46)	3.24(.48)	3.31(.51)	3.50(.52)
Rural	3.35(-)	4.37(-)	5.41(-)	6.45(-)	7.48(-)
Total	6.43(.45)	7.52(.46)	8.65(.48)	9.76(.51)	10.93(.52)
3. Population Served (New Projects)					
Urban	-	-	0.02(-)	0.10(-)	0.15(-)
Rural	-	-	-	-	-
Total	-	-	0.02(-)	0.10(-)	0.15(-)
4. Total Population Served					
Urban	3.10(.45)	3.15(.46)	3.26(.48)	3.41(.51)	3.65(.52)
Rural	3.33(-)	4.37(-)	5.41(-)	6.45(-)	7.48(-)
Total	6.43(.45)	7.52(.46)	8.67(.48)	9.86(.51)	11.13(.52)
5. Percent Served					
Urban	41.2(6.0)	40.8(6.0)	41.2(6.1)	42.0(6.3)	43.8(6.3)
Rural	13.8(-)	17.7(-)	21.5(-)	25.1(-)	28.4(-)
Total	20.3(1.4)	23.2(1.4)	26.2(1.5)	29.1(1.5)	32.1(1.5)

Source: R.C.D.C.

2.4 Administration of Urban Water supply System

2.4.1 Present Situation of Urban Water supply Administration

The water supply in Burmese urban areas is being administered by the General Affairs Department of the Ministry of Home and Religious Affairs, an organization of which is given in Fig. 2.4.1.

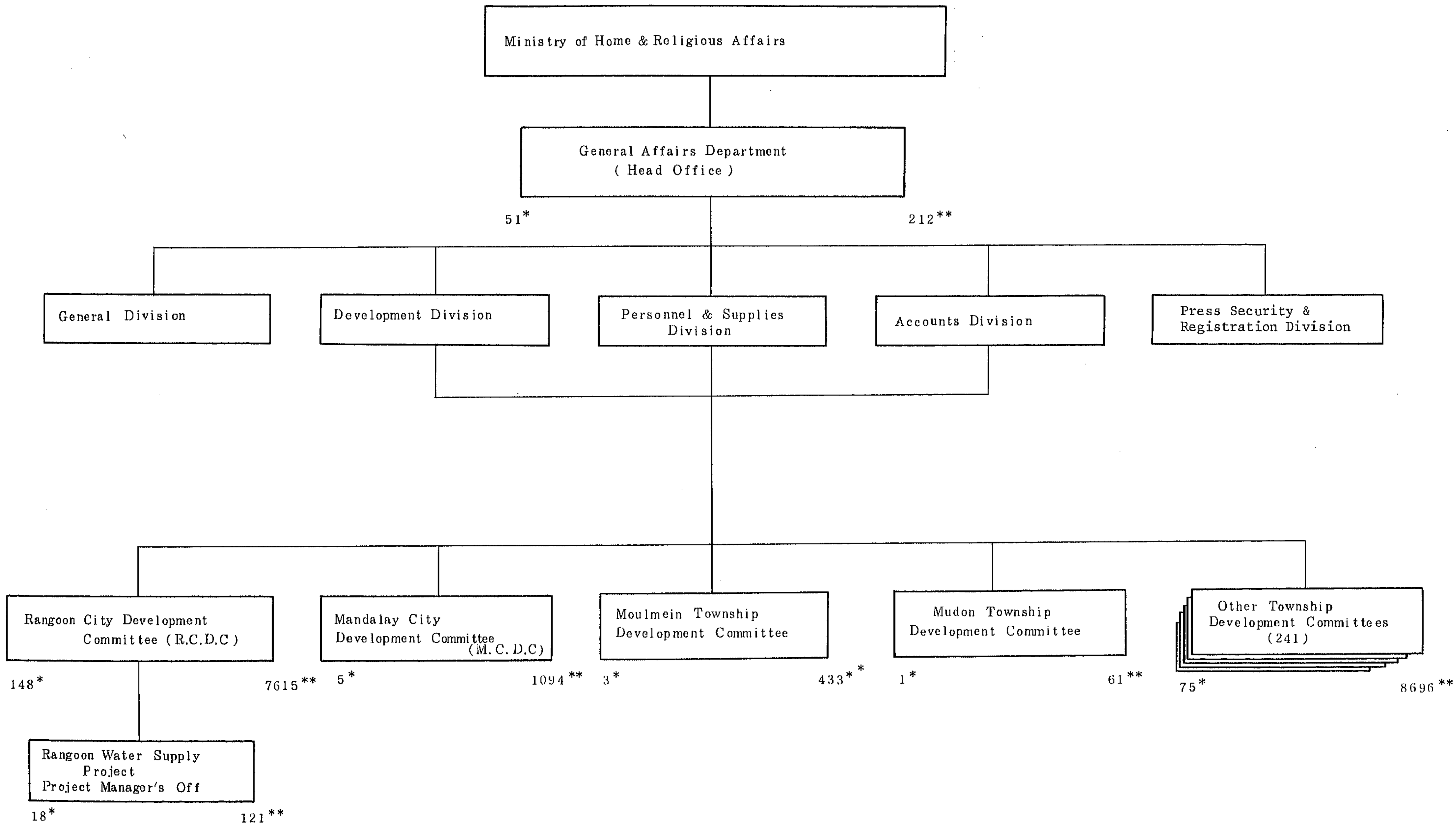
The three divisions -- Development Division, Personnel and Supplies Division, and Accounts Division -- under the General Affairs Department, are directly responsible for supervising water supply affairs in urban areas. Associated with these three divisions are the Rangoon City Development Committee (R.C.D.C), Mandalay City Development Committee (M.C.D.C), and other township development committees.

A total of 245 township development committees, including those in Rangoon and Mandalay, are all under the supervision of the Ministry of Home and Religious Affairs, and water supply is one of the ministry's administrative duties.

Any township development committee should report to the general affairs department, when it plans to construct a water-supply system or improve existing water supply system. The General Affairs Department then calls for the Ministry of Housing Department of the Construction to conduct related feasibility studies. If the General Affairs Department concludes through those studies that the construction project cannot be financed exclusively by the regional development committee, the department requests the national Myanma Economic Bank to extend loans to the regional development committee.

Construction works will be conducted by the construction corporation for the township development committee. The completed facilities are to be under the control of the township development committee, and the committee will be responsible for operation and maintenance.

Fig. 2-4-1 Organizational Chart of the General Affairs Department



Note * Officers
** Other Ranks

Source : General Affairs Department

The committee also will collect water supply taxes and charge from the users, and apply them to reimburse the costs mentioned above and the loans from the national bank.

These are the basic procedures, through which a township development committee constructs a water supply system.

2.5 Foreign Aid to Urban Water supply Systems

Burma needs assistance from overseas countries for its internal development. The same is true of urban water supply system construction, to which diverse kinds of aid are being extended by many international organizations and governments.

The concentration of population in urban areas has recently become severe in Burma, and among various urban development projects, water supply system construction has attracted special attention.

Burma now receives foreign aid for its urban water supply facility constructions in Rangoon and other cities in the following way.

The Pugyi Project in Rangoon City, one of the water supply development projects in urban areas, which is supported by a loan from the Asian Development Bank (A.D.B.) and a fund from OPEC, is now under construction with the prospect of completion in 1984. Technical studies on improvement and examination of the Rangoon City Water Distribution System initiated in Jul. 1979 by a fund from ADB, has already been completed. On the recommendation of a consulting company which participated in the project, a loan from ADB is likely to be granted for this project, too.

The Mandalay City Water Supply Project has finished its feasibility study, in joint collaboration with ADB and UNDP. Consultants started the study in 1979, and released an interim report. This project, covering the whole city, has been supported by ADB in the form of a loan.

In appreciation of the necessity of a feasibility study on water supply system projects in other towns, UNDP is ready to contribute for a feasibility study towards these projects.

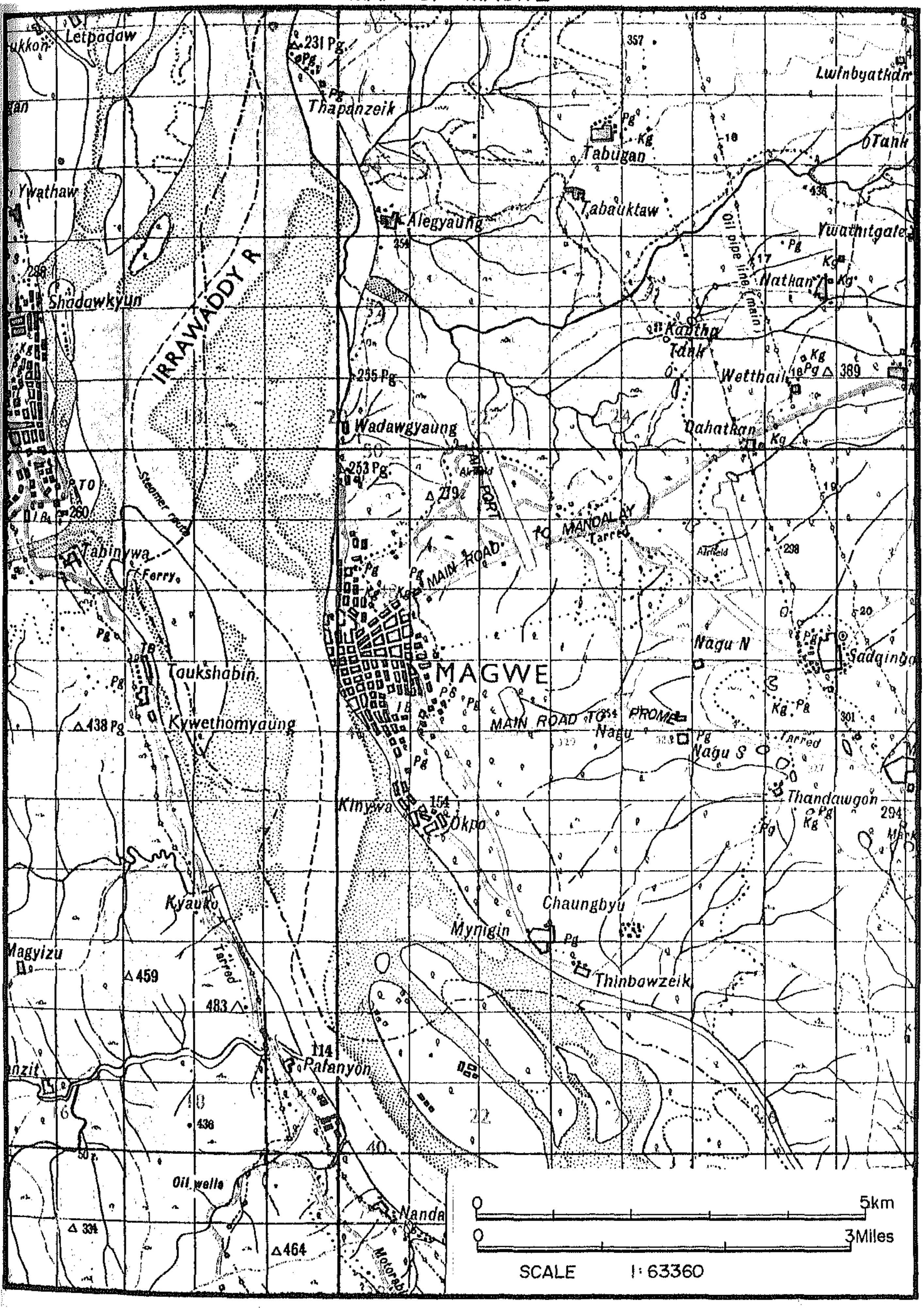
In addition to the afore-mentioned technical aid, feasibility studies on water supply development, conducted by UNDP/ADB are provided for five towns (Moulmein, Akyab, Bassein, Sagaing, and Minbu).

There are plans at the moment to supply water from the Azin dam near Mudon in Mon State, to Moulmein and Mudon towns. The Azin dam project is being financed by a loan from the World Bank to the Irrigation Department. Out of the total volume of water from Azin dam, 60% will be used by the Irrigation Department for agricultural purposes and the remaining 40% will be made available for Moulmein and Mudon town water supply. The financing of the water supply project does not include the distribution system in the two towns.

This project, supported by a grant aid from the Japanese Government, is regarded as one of the foreign aid programmes.

CHAPTER 3 MAGWE PROJECT

MAP OF MAGWE


Letpadaw
Thapanzeik
Tabugan
Lwinbyathar
Tank
Ywathaw
Alegyaung
Tabauktaw
Ywathitgale
IRRAWADDY R
Oil pipe line (main)
Nathan
Shadawkyun
Kadtha
Tank
Wetthail
389
Wadawgyaung
Dahatkan
Steamer route
Airfield
AIR PORT
TO MANDALAY
Tarred
MAIN ROAD
Tabinywa
Ferry
Airfield
Nagu N
Sadqinga
Taukshabin
MAGWE
Kywethomyaung
MAIN ROAD TO PROME
Nagu
Nagu S
Tarred
438
Thandawgon
Kinywa
Okpo
Chaungbyu
Kyauko
Mynigin
Magyizu
459
Tarred
483
Thinbawzeik
Pafanyon
Oil wells
Nanda
334
464
0
5km
0
3Miles
SCALE 1:63360

CHAPTER 3 MAGWE PROJECT

3.1 Outline of the Area

Magwe, lying in the central part of the Central Lowlands inland, belongs to the semi-arid zone. Its average annual precipitation (over 45 years) was 886mm, the maximum precipitation was 1,406mm (1938) and the minimum was 539mm (1972). The highest temperature was 108°F (42.4°C) and the lowest 57°F (13.8°C).

Magwe is placed on the east bank of the River Irrawaddy, its west side faces the river, and the north and the northeast form a mountainous district more than 80 metres above sea level. This mountainous district runs along the river, falling sharply to the river at the north end of the town, and on the plateau at the east of the mountainous district, the Magwe Airport is situated. This mountainous land reaches the town in a gradual descent to the southwest. The altitude of the old sections of the town is 50m to 60m above sea level, and the land slopes gradually southeast, reaches the River Irrawaddy in the west, falling sharply to the river cliffs of about 10 metres in height.

The history of Magwe shows that the town was once a small port town during the feudal era. During the period when England ruled, the town still maintained urban functions, but it was a relatively quiet local town which had no transportation except river transportation. Since independence in 1948, however, Magwe has developed gradually as a core town in the central part of Burma, and construction of river transportation facilities, principal roads to Rangoon and Mandalay, and the airport, have stimulated further development as the divisional headquarters of Magwe Division and the centre of politics and economy, especially commerce. Table 3.1.1 demonstrates the drastic increases in households, population and area, between 1972 and 1978.

Table 3.1.1 Number of Households, Population, and Area Assimilated, by Year

Year	Households	Population	Area (km^2)
1972	7,629	30,058	3.12
1975	9,629	45,158	8.61
1978	10,305	45,845	8.61

Source: Burma Government

The estimated population in recent years and annual increases are shown in Table 3.1.2.

Table 3.1.2 Estimated Population and Annual Increase

Year	Estimated population	Year Increase (%)
1977 ∿ 1978	40,460	4.7
1978 ∿ 1979	42,725	4.2
1979 ∿ 1980	44,733	3.5

Source: Burma Government

(Compared with the average increase over the whole country, 2.2%, and urban population increase, 2.5%, the figures in this table show a greater increase)

Administratively, Magwe consists of nine wards, and new sections of the town are placed in KANTHA-MYNTHA. The area and population of each ward in 1981 are represented in Table 3.1.3.

Table 3.1.3 Area and Population of each Wards in 1981

No.	Name of wards	Area (ha.)	Population (1981)
1	MYOHAUNG	0.2511	4,680
2	SONEHTANA	0.1735	2,263
3	ZAYLESO	0.4556	2,181
4	MYOMAOBO	0.1864	1,804
5	SARSHWEKIN	0.6084	5,156
6	YWATHIT-PWEKYO	2.3869	5,410
7	THEINGAGIRI	0.9113	11,266
8	KANTHA-MYNTHA	2.8426	11,532
9	SOEKAWMIN	0.7948	4,611
	Total	8.6106	48,933

Source: Burma Government

(While new sections of the town cover 33% of the total area, the population accounts for about 23.6%.)

The Fourth Four-Year Plan prepared by the Magwe Township Development Committee which starts in 1982, shown in Table 3.1.4.

Table 3.1.4 Fourth Four-Year Plan of Magwe Township Development Committee

(Kyats in thousands)

	Thousand Kyats / Description	1982~1983		1983~1984		1984~1985		1985~1986		1982~1983 to 1985~1986	
		Total	FE comp	Total	FE comp	Total	FE comp	Total	FE comp	Total	FE comp
1	Improvement of existing water supply system	-	-	-	-	200	100	-	-	200	100
2	New water supply system (Japanese Grant Aid Project)	100	40	300	120	50	20	50	20	500	200
3	Road construction	90	90	-	-	-	-	200	100	290	190
4	Other construction	1,000	-	150	-	150	-	-	-	1,300	-
5	Water disposal	-	-	-	-	-	-	110	-	110	-
6	Office equipment	-	-	-	-	20	-	-	-	20	-
	Total	1,190	130	450	120	420	120	360	120	2,420	490

Source: Burma Government

The financialy condition of Magwe, as shown in Table 3.1.5, maintains a relatively stable equilibrium between revenue and expenditure.

Table 3.1.5 Balance of revenue and expenditure

Year	Revenue (Kyats)	Expenditure (Kyats)	Balance (Kyats)
1978 ∿ 1979	988,590	606,503	+382,080
1979 ∿ 1980	1,152,546	752,986	+399,560
1980 ∿ 1981	1,267,306	957,050	+310,256

Source: Burma Government

3.2 History of Waterworks

Before the Second World War, water supply in Magwe was managed by the small-scale facility utilizing several dug wells along the riverside of Irrawaddy as the source of water. This facility was destroyed during the War, and over the next 20 years there was no water supply system available.

After the War, in 1961 in order to cope with increasing water demand accompanied by population expansion, Burma directed TAHAL LTD. of Israel to make a feasibility study on a water supply plan for this town. (TAHAL Water Planning Ltd. Report)

In this report, two alternatives were studied, that is, using ground water and surface water of the River Irrawaddy as a water source, and a water supply plan by ground water exploitation was recommended, for economic and hygienic reasons.

However, this plan failed to be implemented, then due to national budgetary problems. The town then planned to construct a water supply system using the River Irrawaddy as the source, and installed, between 1964 and 1965, one motor pump, one water collecting tank (11,260 gallons) and a slow sedimentation tank with a 125,000 gallon capacity, and this state remains, up to now.

Since this facility was constructed 17 years ago, its supply can no longer satisfy the necessary water demand due to a rapid increase in population, caused by an inflow from surrounding areas in recent years.

Currently, the existing facility can provide water only to 16,000 dwellers, which accounts for only 30% of the population of 48,000. Furthermore, water is supplied only for one hour in the morning or the evening every other day, because of shortage of the exact amount of water. Even in the areas where water is served, a higher region in the north cannot be served satisfactorily for one hour, owing to insufficient water head.

In the areas with no facilities or insufficient supply, they depend on rain water or surface water of the river, which is pumped, stored in drums and sold, or from privately owned tube wells of small diameter. Since, in case of fire, sufficient water for fire-fighting cannot be provided, and fire could cause wide spread damage. It should be pointed out that the dwellers are very apprehensive of fires.

Figures 3.2.1 and 3.2.2, and Table 3.2.1 roughly illustrate the state of the existing water supply systems and facilities.

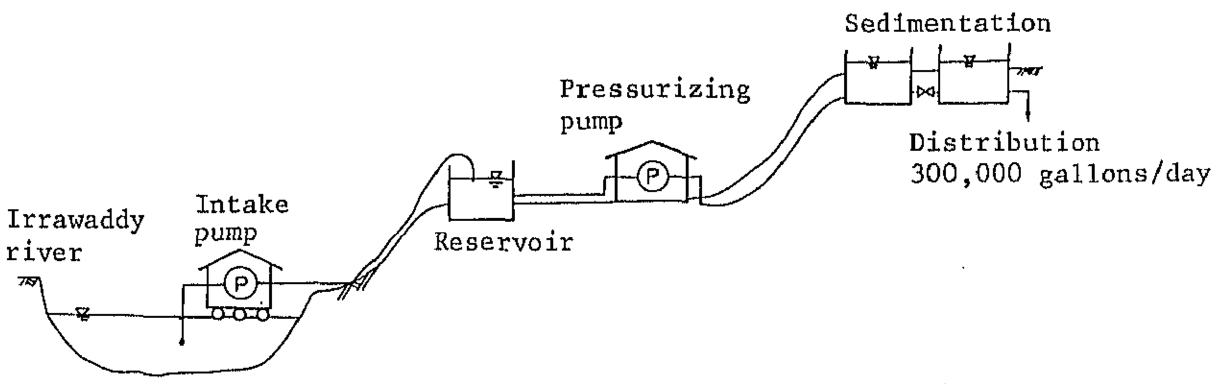
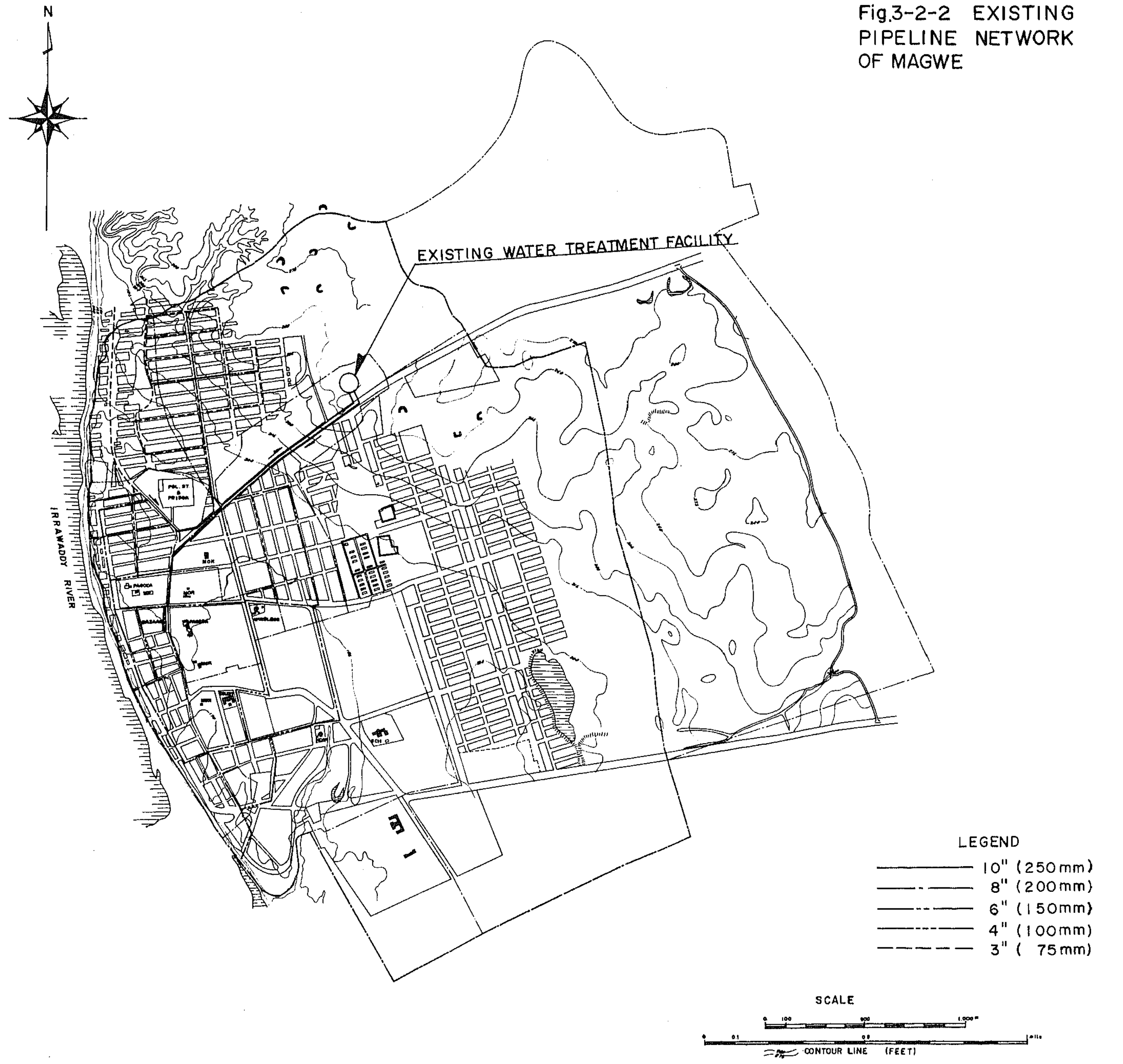


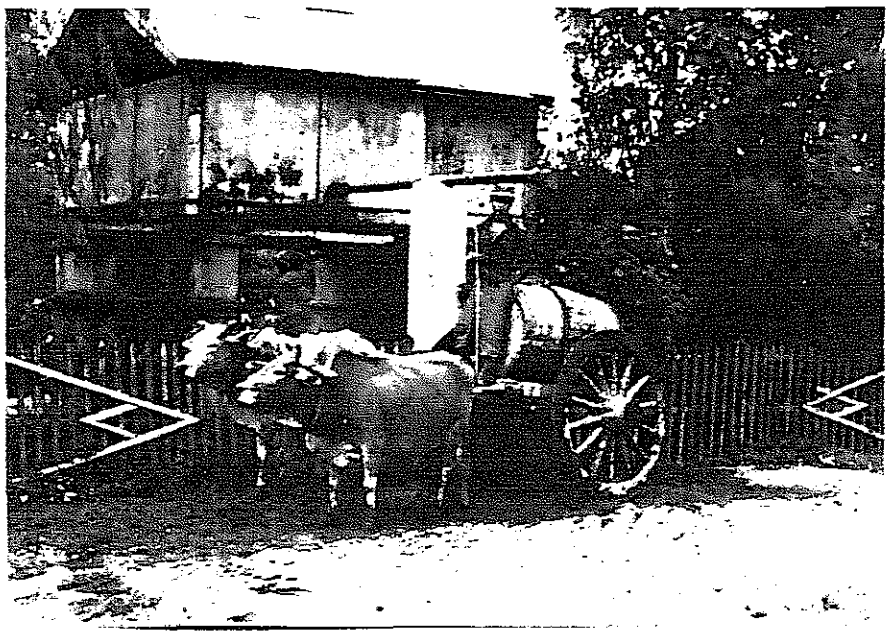
Figure 3.2.1 Rough Sketch of Existing Water Supply Systems

Table 3.2.1 Situation of Existing Facility (1980)

Item	Details	Remarks
Existing town area	3.32 $miles^2$	8.61 km^2
Population	47,882	
Supply water gal/day	300,000 gallons	1,365m^3
Free supply for public facilities and water losses	50,000 gallons	228m^3
Effective population	16,000	
Effective water gal/day	250,000 gallons	1,137m^3
Effective water gal/day/person	15.62 gallons	71ℓ
Public stand pipe	130	
Fire hydrants	50	
Water tax/month		
Percentage of building costs	4%	(Percentage per annual rental charge)
1/2"φ house connections	12 Kyats/month	360 yen/month
Incomes from water	130,928 Kyats/year	3,930 thousand yen/year
Salaries and other costs	101,332 Kyats/year	3,040 thousand yen/year
Net profit	29,596 Kyats/year	890 thousand yen/year
Existing pipelings		
C.I Pipe 10"(φ250mm)	8,574ft	2,600m
" 8"(φ200mm)	1,843ft	600m
" 6"(φ150mm)	18,205ft	5,500m
" 4"(φ100mm)	12,462ft	3,800m
" 3"(φ75mm)	13,602ft	4,100m
Total	54,686ft	22,600m

Fig.3-2-2 EXISTING PIPELINE NETWORK OF MAGWE





Upper left : The surface water of the Irrawaddy is collected into 40-gallon drums for sale by bullock cart.

Lower left : The surface water of the Irrawaddy is stored before it is sold by bullock cart.

Upper right: Water is sold at remote places by tank lorry.

Fig. 3.2.3

3.3 Planning of Water System

3.3.1 Projected Area

To solve one of the main problems in the central part of Magwe, which is the population inflow from the periphery, new urban areas are now under construction with the aim of dispersing population to the east.

According to the Land Use Plan Map released by the Magwe Development Committee, the land is categorized into three groups by land use purposes; (see Figure 3.3.1.1)

A Area ;	existing residential area
B Area ;	agricultural area with a low population density, including storehouses.
C Area ;	planned residential area including the new residential district.
D Area ;	Non-residential area

From the viewpoint of water consumption, A and C Areas are massive consumption areas and B Area is lower consumption area.

Of the nine wards, the area under the Magwe project encompasses Area A, B, and C, and excludes Area D, as indicated in the Classification Chart by Land Use Purposes (Figure 3.3.1.2).

Figure 3.3.1.1 and Table 3.3.1.2 depict the ratio of areas by land use purposes, a sectional map, and population and area by section, respectively.

Fig.3-3-1-1 AREAS DIVIDED BY POPULATION DENSITY FOR LAND USE OF MAGWE

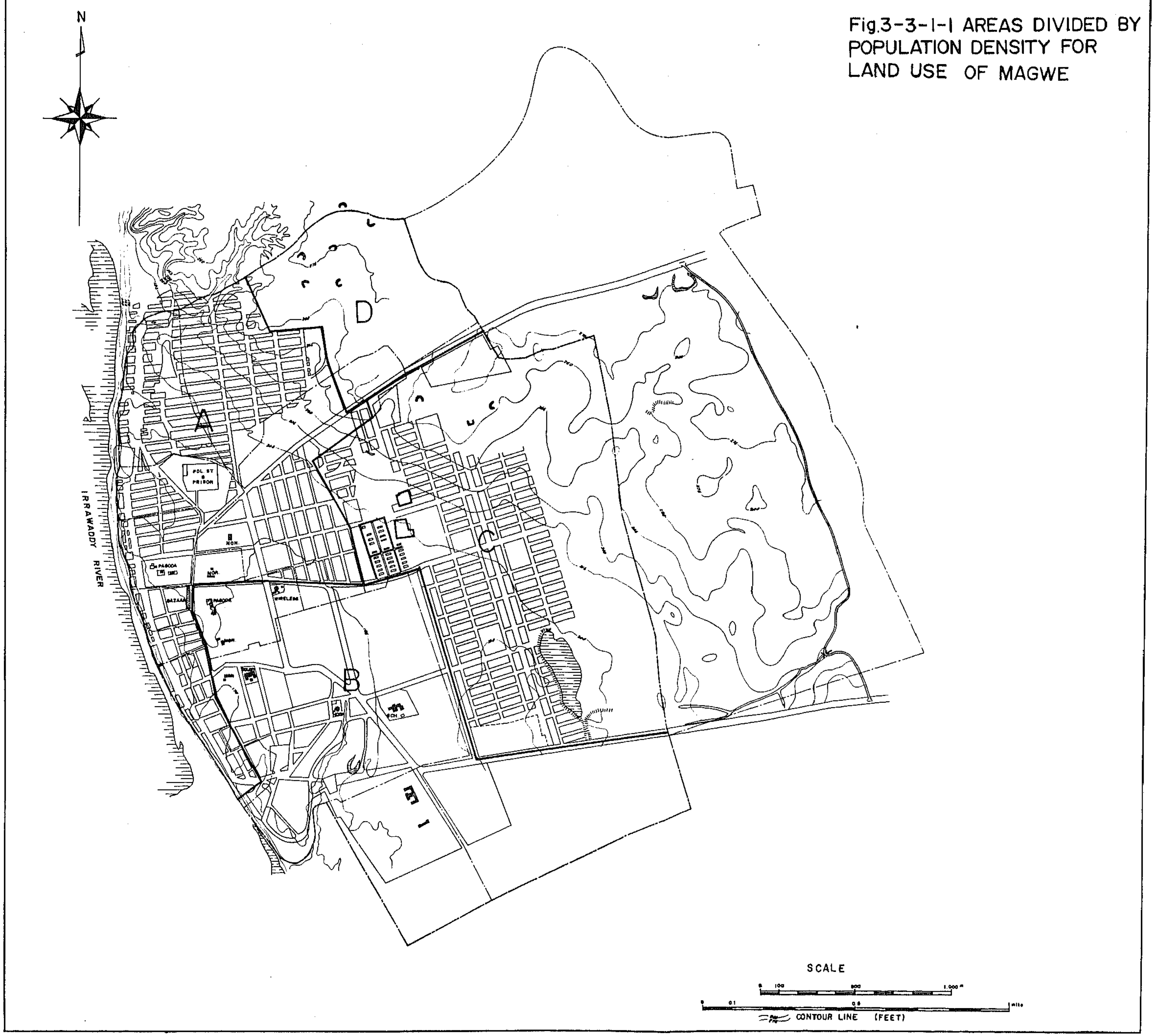
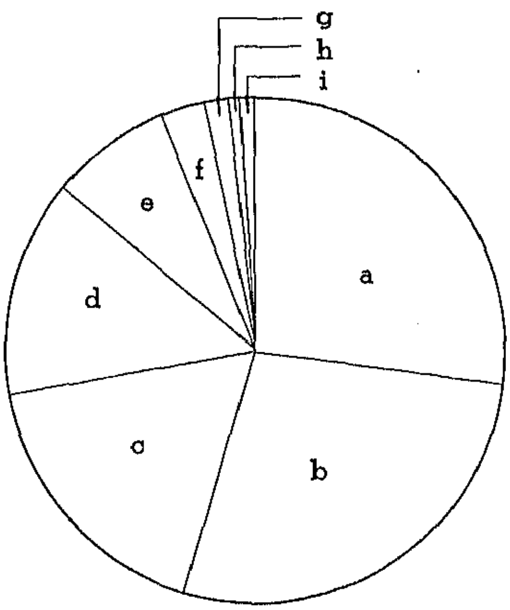


Fig. 3.3.1.2 Ratio of Areas by Land Use Purposes of Magwe



a)	Rice and Sesame field, etc.	28.38 %
b)	Residential Area	27.42 %
c)	Godown	17.39 %
d)	Cemetery, Garden and Park	14.32 %
e)	Religious Center	6.28 %
f)	Commercial Places	3.29 %
g)	Industrial Areas	2.19 %
h)	Governmental Buildings (Offices, School, Hospital and Governmental Buildings)	0.45 %
i)	Pond and Creeks	0.27 %

3.3.2 Designed Population

The target year is set at 1991.

The designed water supply population of Magwe is 60,834, and Magwe is divided into wards, shown in Table 3.3.2.1, Figure 3.3.2.1. This figure is estimated on the basis of the National Census in 1978. Regarding the data to which the survey team had access, it was difficult to compute the growth rate of Magwe, so that computation was made with the average national growth rate set at 2.2%.

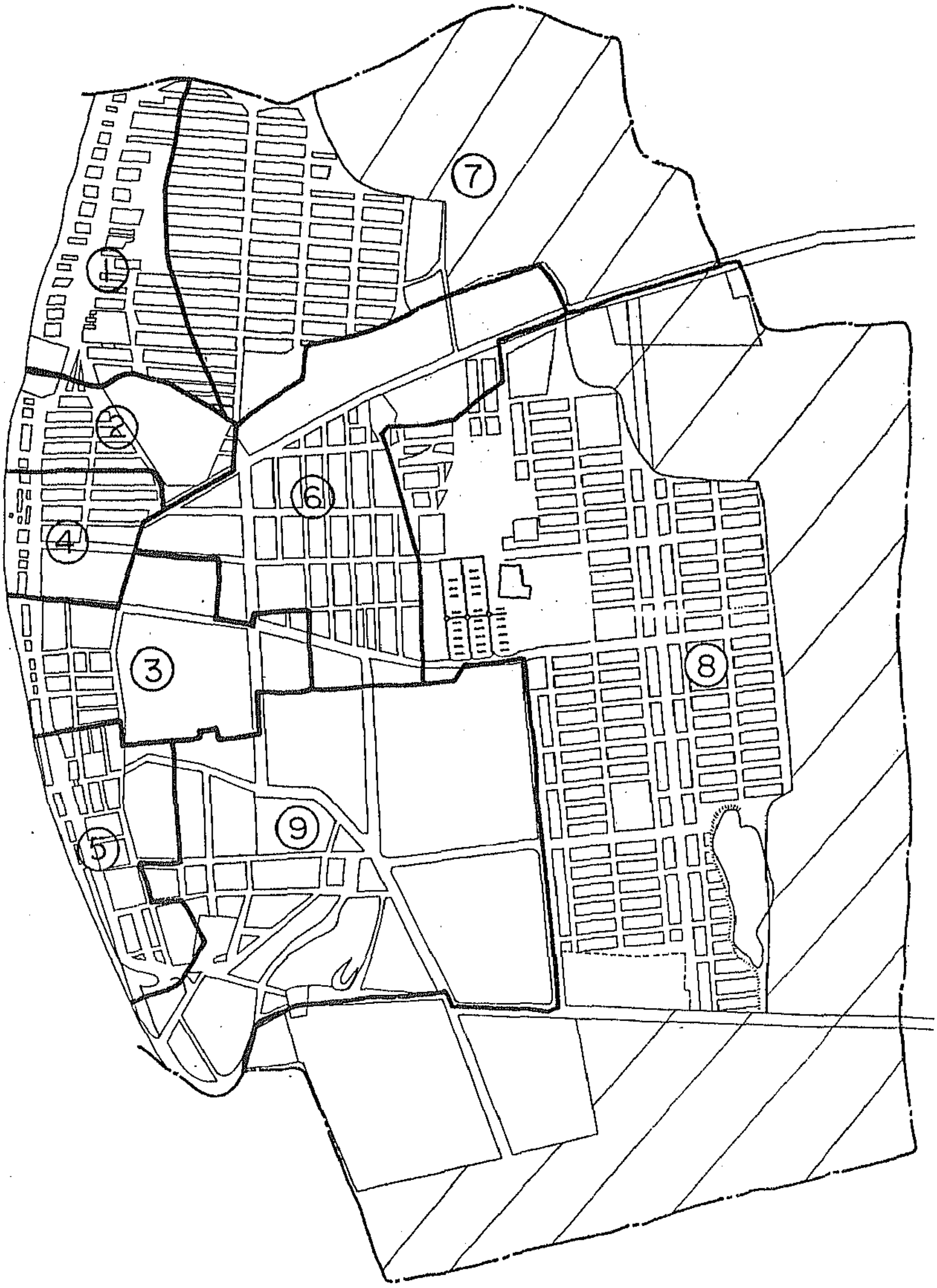
Table 3.3.2.1 Estimate of Designed Water Supply Population

Wards \ Year		Population		
		1978	1981	1991
1.	Myohaung	3,488	4,680	
2.	Sonyat	2,120	2,263	
3.	Zaylesoe	2,043	2,181	
4.	Obomyoma	1,690	1,804	
5.	Sarshwekin	4,830	5,156	
6.	Ywathitpwekyo	5,068	5,410	
7.	Theingagiri	10,555	11,266	
8.	Kantha Myintha	10,803	11,532	
9.	Soekawmin	4,348	4,461	
	Total	45,845	48,933	60,834

Source: Trail computation made on the basis of data from the Burmese Government.

$$45,845 \text{ persons} \times (1.022)^{13} = 60,834 \text{ persons}$$

Fig. 3.3.2.1 Magwe Divided into Wards



3.3.3 Designed Water Demand

The designed water supply, as referred to here, is the total water demand for domestic, commerce, fire-fighting and others, of the target year.

It is considered possible to supply water under the Magwe project from the existing facilities for which the surface water of the Irrawaddy is used as the water source. It was decided to incorporate this water in the programme.

The breakdown of the water demand is shown below. The design specifications and water supply are shown in Table 3.3.3.1

a) Domestic water

Domestic water = Maximum design water supply per person per day × design population = 0.195 m^3/person/d × 60,834 persons = 11,863 m^3/d.

b) Water for commerce, industry, and fire-fighting

At present, there exists practically no industry of a massive water consuming type. The planned land utilization programme does not indicate any possible future of these types of development, either. Given this factor, the quantity of water for commerce, industry, and fire-fighting, is set at 1,000 m^3/d, of which 144 m^3/d is set aside for fire-fighting.

(20 ℓ/s × 2 hrs. × 1 time/d)

c) Maximum daily water supply

$a + b = 11,863 + 1,000 = 12,863\ m^3/d$

d) Water supply by existing facilities

1,365 m^3/d (from Table 3.3.3.1)

e) Design water supply by new facilities

$$12,863\ m^3/d - 1,365\ m^3/d = 11,498\ m^3/d$$

approx. 11,500 m^3/d

Table 3.3.3.1 Design Data and Design Demand of water supply

Items	Details	Remarks
① Existing population (1981)	48,933 persons	
② Designed population (1991)	60,834 persons	
③ Average amount of design water supply per person per day	150ℓ	
④ Maximum design water supply per person per day	195ℓ	③ × 1.3*
⑤ Maximum design amount of water supply per day	12,863 m^3/d	
Drinking water	11,863 m^3/d	
Others	1,000 m^3/d	
⑥ Amount of water supply by existing system	1,365 m^3/d	
⑦ Design water supply amount by new system	11,500 m^3/d	

* 1 , 3 are the load ratio compared with a average amount of design water supply per person per day.

3.3.4 Proposed Water Source

Surface water of the River Irrawaddy and ground water can possibly serve as water sources for the proposed water supply. The TAHAL Report has recommended ground water as a source. Because surface water of the river contains abundant suspended solids, and the flow rate is liable to seasonal fluctuations, neither stable intake of water nor perfect water treatment can be expected. Many problems can be pointed out in this project;

according to this water supply project, a huge amount of water, 11,500 m^3/day (8.4 times of the existing water supply), and huge cost for operation and maintenance are required.

On the other hand, quality of the ground water lying in the water bearing layers of the Irrawaddy formation is suitable for tap water and is advantageous to operation and maintenance of facilities. It also allows possible extension of the water supply system, including water sources corresponding to a future population increase, and can provide flexible systems.

This project has started with a series of surveys, including a field study, and a ground water development plan has been made.

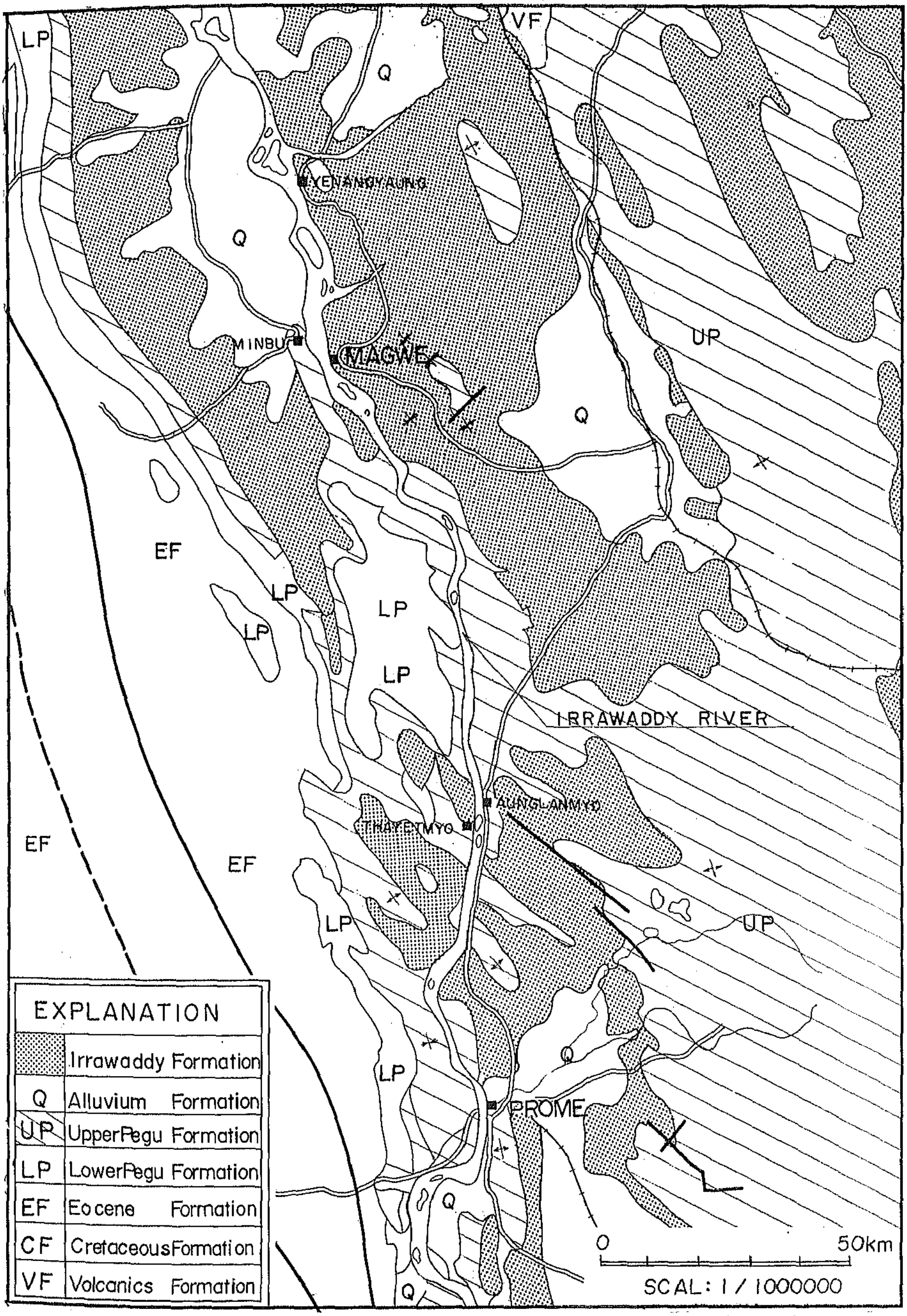
3.4 Ground Water Development Plan

3.4.1 Outline of Hydrogeology

Tectonically, Magwe lies in the central part of the Minbu tectonic basin in a distribution zone of the Central Cenozoic Belt Tertiary period. The Pegu Formation, which consists of aquicludes or impermeable layers, is spread over the Minbu basin, and the Irrawaddy Formation is distributed on the upper part. An anticline runs along the west bank of the River Irrawaddy and in the east of Magwe, in the distribution belt of the Pegu Formation. In the east of Magwe, a syncline runs north-north-west. A hydrogeological map of Magwe is shown in Figure 3.4.1.1.

From a broad viewpoint, the deepest section of the Minbu Tectonic Basin is placed near the syncline in the east of Magwe. As the Irrawaddy Formation lies in the central part of the basin, and the Pegu Formation is distributed in the west and the east, the distribution of water bearing layers is limited only to the area of the Irrawaddy Formation. As development of the aquifers and recharge of ground water greatly depend on the Irrawaddy Formation, the aquifers are

Fig. 3.4.1.1 Hydrogeological Map of Magwe & Prome



Source: Burma Government

rather undeveloped and narrow from the viewpoint of ground water recharge, and can hardly be regarded as bearing abundant ground water.

3.4.2 Aquifer

Of the water containing layers, the layer which particulary excels in water permeability is adopted for the pumping-up of water and called an aquifer. In order to come to grips with the water preservation of this layer, or the depth, thickness, breadth and continuity of this layer, existing data were analyzed, the existing wells were surveyed, and an electrical prospecting was conducted.

An electrical prospecting was described in the TAHAL Report and also conducted by our team. In the TAHAL Report typical ρ - a curves at four points out of 42 points measured were shown, but any resistivity cross section map was not prepared.

We conducted electrical prospecting on three measuring lines and 27 points in the east-west direction (distance between the points is 400m) by a vertical survey based on the Wenner's quadopolar method. The location of the measuring points is shown in Figure 3.4.2.1. The distance between electrodes is as follows:

a	1∿10m	10∿32m	32∿72m	72∿152m	152∿200m
Distance of electrode	1m	2m	4m	8m	16m

The result is expressed by ρ-a curves and resistivity cross-sections, as shown in Figures 3.4.2.2 and 3.4.2.3.

These results show that the resistivity layers can be grouped into four groups.

First layer; resistivity is 10∿200Ω-m, and sediments mainly consisting of surface soil with non-aquifer, sand, and clay.

Second layer; resistivity is 100∿200Ω-m, permeable layer mainly consisting of small gravel and intercalating clay layers.

Third layer; resistivity 50∿100Ω-m. Alternate layer with sand, fine gravel, and clay. Permeable bed to aquiclude. However, according to this classification, there are some layers with a resistivity of 10-30Ω-m (A-A' and E-E' sections), where the ratio of clay admixed is slightly higher, and they are aquicludes bearing little water.

Fourth layer; resistivity 10∿20Ω-m. Aquiclude to impermeable bed mainly consisting of clay.

Water bearing strata in these layers are assumed to exist in the layers with a resistivity higher than 50Ω-m.

Nevertheless, even in the layers with a low resistivity stated as aquiclude, there are some cases where existence of water-bearing strata is recognized and ground water is pumped, according to the columnar section and well data (Appendix; Well No. 4, Magwe College) compiled from other sources.

The collected data on the existing wells are shown in Table 3.4.2.1. According to the data, ground water is pumped at a depth lower than 100m, and the depth of the layers classified as aquiclude to impermeable bed is approximately 100m in general.

When water is pumped up from an aquifer, there are many cases in which the ground water of the shallow layers contains much salt, as Magwe is situated in a semi-arid zone, so that ground water at depths of less than 30m will not be pumped up, in principle.

It was assessed that the thickness of the aquifer stood at 10∿20m in existing wells. In the case of existing wells deeper than these wells, the aquifer must accordingly be thicker. The thickness of the aquifer in this area was estimated at 20m.

The aquifer constant was not yet known, due to no pumping test of the existing wells, an estimation was made with reference to the results of the pumping tests carried out in the north of Rangoon where the Irrawaddy Formation is spread.

The results of the pumping tests and the aquifer constants are represented in Table 3.4.2.2.

Magwe and Rangoon belong to the same Irrawaddy Formation, as shown in the Burma Tectonic Map (Figure 2.2.2.1), but their sedimentation environment differs considerably owing to a distance of 350km between them. In general, fine sediment tends to increase towards the centre of a subsided basin. Therefore, the layer of Magwe contains more fine particles and becomes less permeable. However, the coefficient of permeability ranges from 8.78×10^{-3} to 1.73×10^{-2} cm/s as shown in Table 3.4.2.1, and the average value is 1.06×10^{-2} cm/s. This value, which is considerably high as a sand layer in the Tertiary period, is rather close to one of a diluvial formation in Japan and reaches ten times the value of the Tertiary formation, 1×10^{-3} cm/s.

Under this project, the distribution of Irrawaddy formation, conditions of the aquifers, and the draw down of the water

level in this area, were compared with those in Rangoon. Taking into consideration the fact that the Irrawaddy formation belong to the Tertiary formation, the intermediate water permeability coefficient between that of the Tertiary formation in Rangoon and that of Japan was taken up, and the water permeability coefficient of Magwe was set at 5×10^{-3} cm/s.

From the above point of view, the area where considerable quantities of ground water could be collected, judging from the thickness of the aquifer and the water permeability and continuity, were designated as areas for the drilling of production wells and called production well areas. In such areas, the lower borderline was estimated at 110m on the average, the thickness at 20m and the water permeability coefficient at 5×10^{-3} cm/s.

Fig.3-4-2-1 ELECTRICAL SURVEY & EXISTING WELLS OF MAGWE

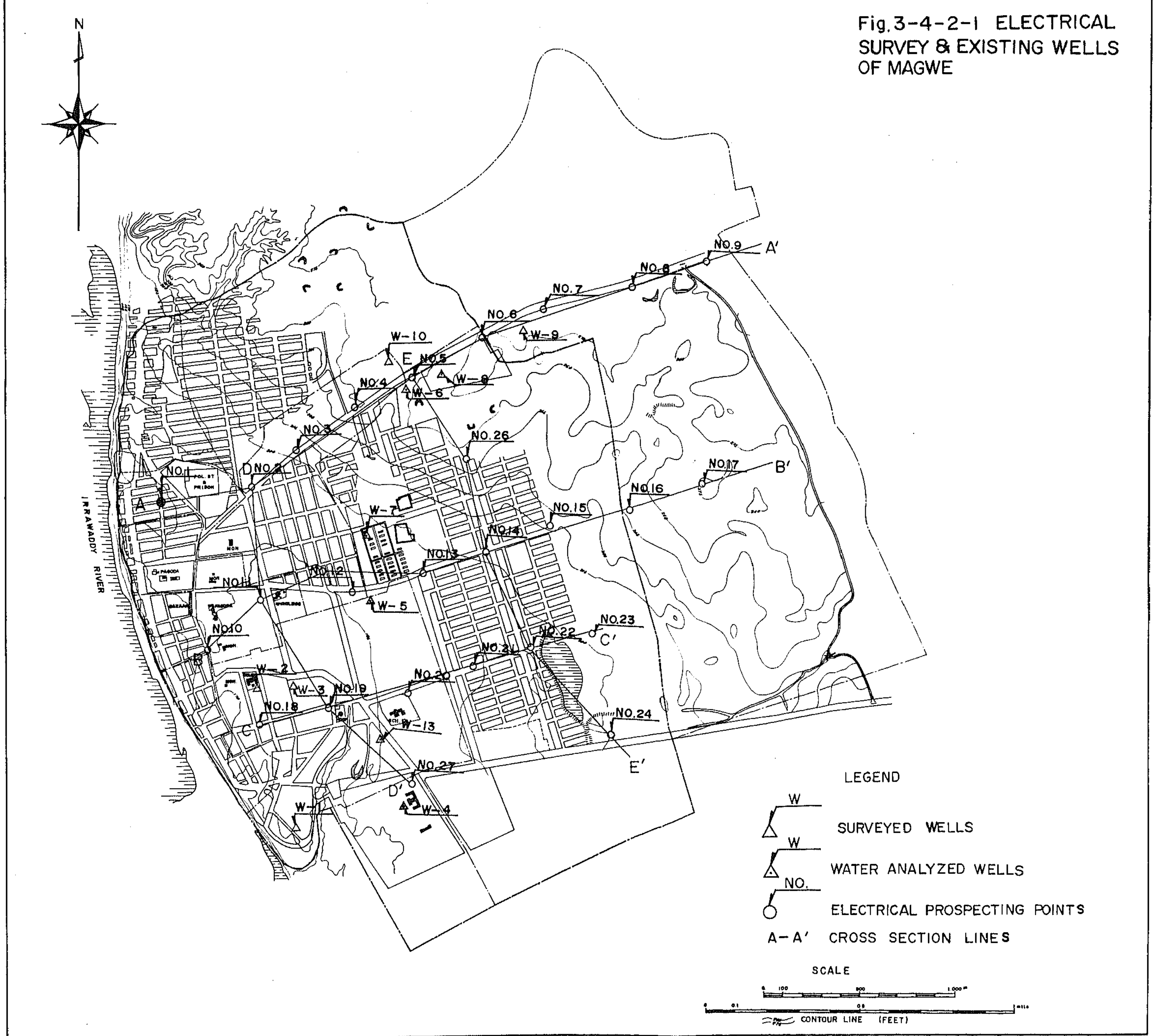
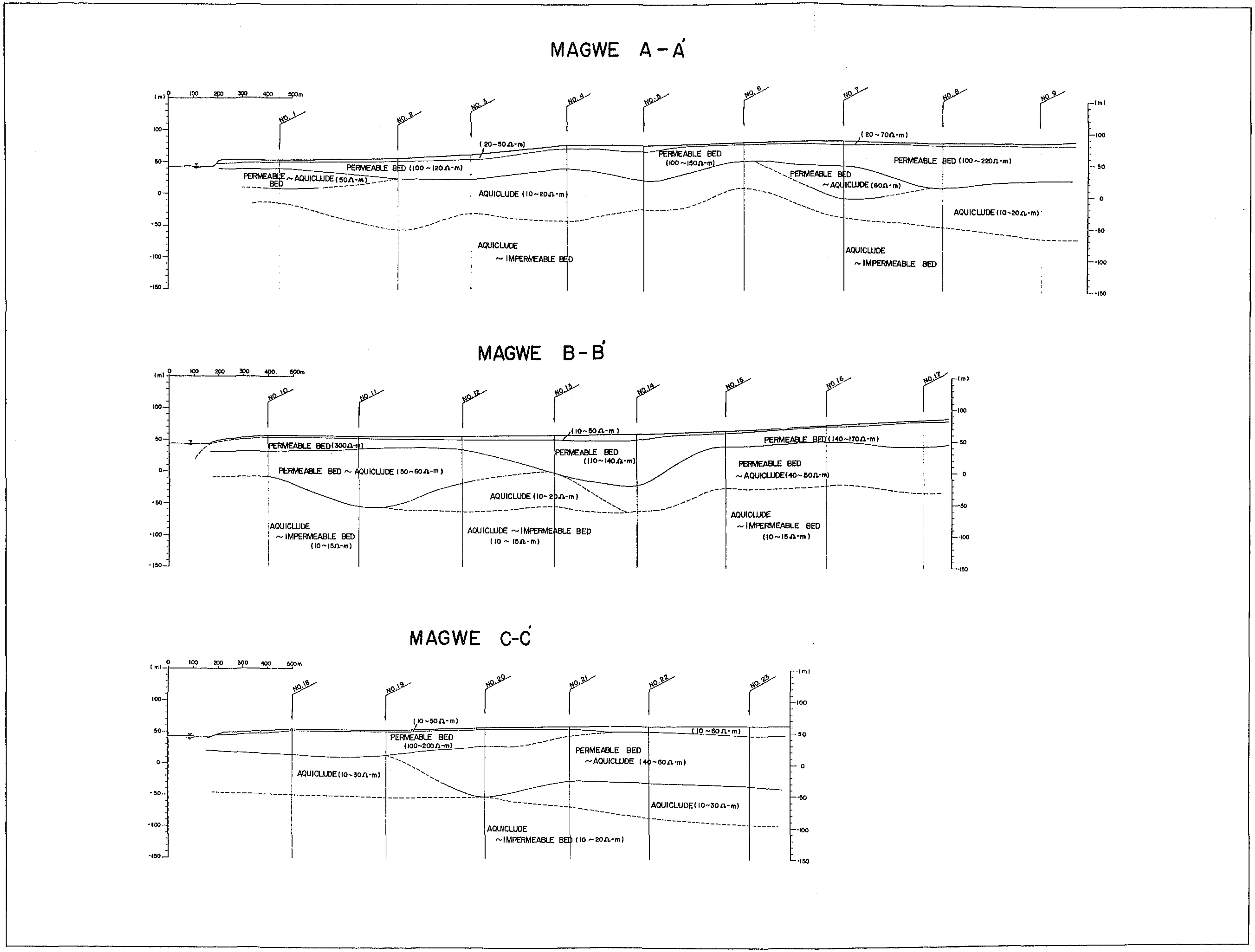
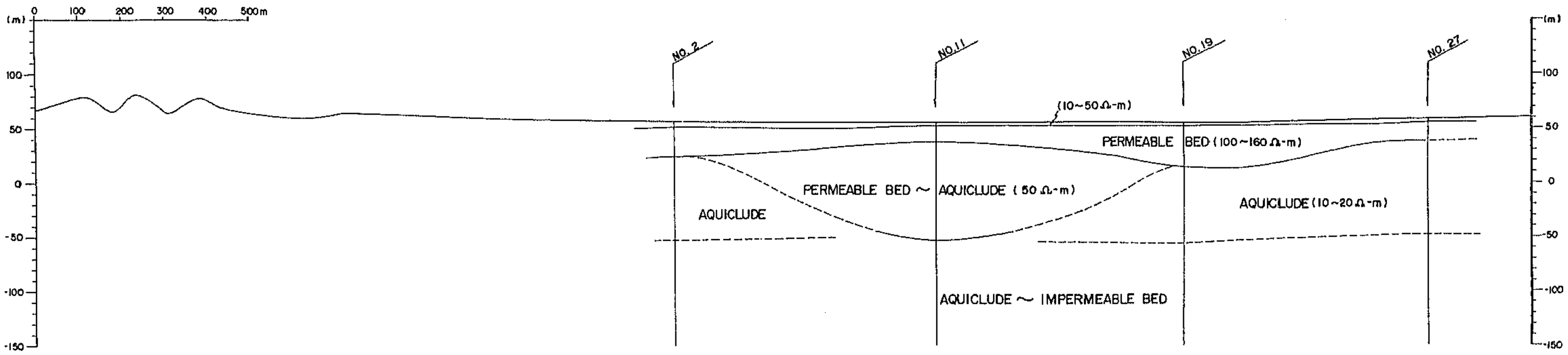


Fig.3-4-2-2
RESISTIVITY PROFILES OF MAGWE



MAGWE D-D'



MAGWE E-E'

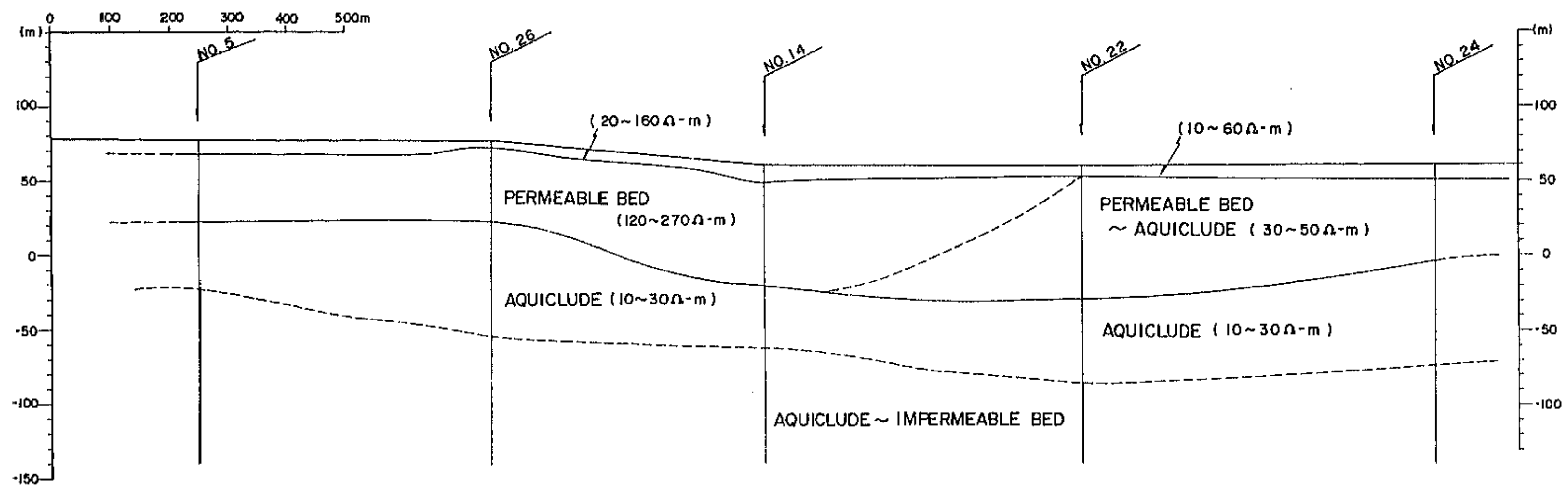


Table 3.4.2.1 LIST OF ARTESIAN WELLS

IN MAGWE

No:	Location	No. of wells	Dia-meter mm	Depth of wells m	Depth of Eduction pipes m	Yield m^3/h	Remarks
1.	Divisional Regional Party Committee	1	100	87.4	79.2	56.16	
2.	Divisional People's Council	1	150	102.9	104.4	18.2	
3.	Divisional Sports and Physical Education Department	1	150	83.2	49.7	56.16	
4.	Magwe College	1	150	65.3	57.9	28.5	
5.	Magwe Hospital	1	150	61.7	45.7	45.46	
6.	Divisional Township Co-operative Society	1	150	98.0	88.4	16.36	
7.	Pyidawtha East Area	2	200	66.7	41.1	10.9	
			200	72.2	41.1	10.9	
8.	Agricultural Corporation (Farm)	1	150	113.5	82	25.5	
9.	Ist Burma Rifles	1	150	110.3	109.7	16.36	
10.	Ist Kayah Rifles	1	150	133.1	132.9	18.2	
11.	Garrison Engineer (Near the Irrawaddy River)	2	150	37.4	32.3	36.8	
12.	Telegraph Office Compound	1	100	86.5	79.2	18.2	
13.	Agricultural Mechanization Department (Water Supply)	1	150	69.3	62.8	51.5	

Table 3.4.2.2 Pumping Test and Aquifer Coefficient in the North of Rangoon

No. of wells	Depth of wells (m)	Dia-meter (mm)	Thick-ness of aquifer (m)	Hydro-static level (m)	Pumpage (m^3/min)	Draw-down (m)	Specific yield	Coefficient of permea-bility (cm/sec)	Granular size
1	102	200	20	16.5	0.909	3.45	19	8.38×10^{-3}	Coarse sand
2	138	200	20	16.5	0.818	1.32	45	1.19×10^{-2}	Coarse sand mixed with gravel and fine gravel
3	102	200	20	16.1	1.136	1.65	50	1.73×10^{-2}	"
4	69	200	14	3.1	1.363	6.25	15.7	1.2×10^{-2}	Fine particles mixed with coarse sand

Source: R.C.D.C.

3.4.3 Quality of Ground Water

The ground water samples from seven points were analyzed to judge suitability for tap water. The location of sampling wells is shown in Figure 3.4.2.1. Chemical analysis was requested of the Burma National Health Laboratory.

The following items were analyzed.

1. Total solids
2. Total hardness, as $CaCO_3$
3. Permanent hardness, as $CaCO_3$
4. Calcium, as Ca
5. Magnesium, as Mg
6. Iron, as Fe
7. Manganese, as Mn
8. Zinc, as Zn
9. Chloride, as $C\ell$
10. Sulphate, as SO_4
11. Nitrate, as N
12. Carbonate, as CO_3
13. Bicarbonate, as HCO_3
14. Free & saline ammonia, as NH_3
15. Albuminoid ammonia, as NH_3
16. PH

The results of this chemical analysis are included in the Appendix.

As regards the water quality criteria of Burma, the water system of Rangoon follows the criteria of WHO and AWWA. This criteria is also followed in other city and towns.

When the findings of an analysis in Magwe are analyzed according to these criteria, the PH value stands at $7.6 \sim 8.4$, suggesting that the water is alkaline, containing less soluble

components. In terms of water quality, there are no significant features, so the quality of its water may be considered suitable.

3.4.4 Ground Water Storage

Before computing the standing volume of ground water, the area which was to be computed was confined to the jurisdiction of the entire town, which included the sections which had been newly incorporated into the town. The whole town was divided into a production area (3.4.2) and other areas.

Judging from an electrical survey and from data on wells, this production well area features a high ground water developability. "Other areas" are those sections of the entire town from which this area is excluded. (Figure 3.4.4.1)

Standing volume of ground water within a definite area at the present is calculated as follows;

$$V = A \times S \times E$$

where V = standing volume of ground water (m^3)
A = area (m^2)
S = thickness of aquifer (m)
E = effective porosity (%)

A; area is divided into the afore-mentioned two categories,

i) production well area = $3,821,499m^2 \fallingdotseq 3,822,000m^2$

ii) others = $8,484,903m^2 \fallingdotseq 8,485,000m^2$

S; thickness of aquifer is 20m in accordance with "3.4.2 Aquifer)

E; effective porosity is 13% in the production well area, and 10% in others.

(Note) Experts in Burman ground water development have assumed that the effective porosity of the aquifer in the Irrawaddy Formation is 15∿20%. Taking the regional difference in development of aquifer and the sedimentation environment into consideration, we assumed 13% and 10%.

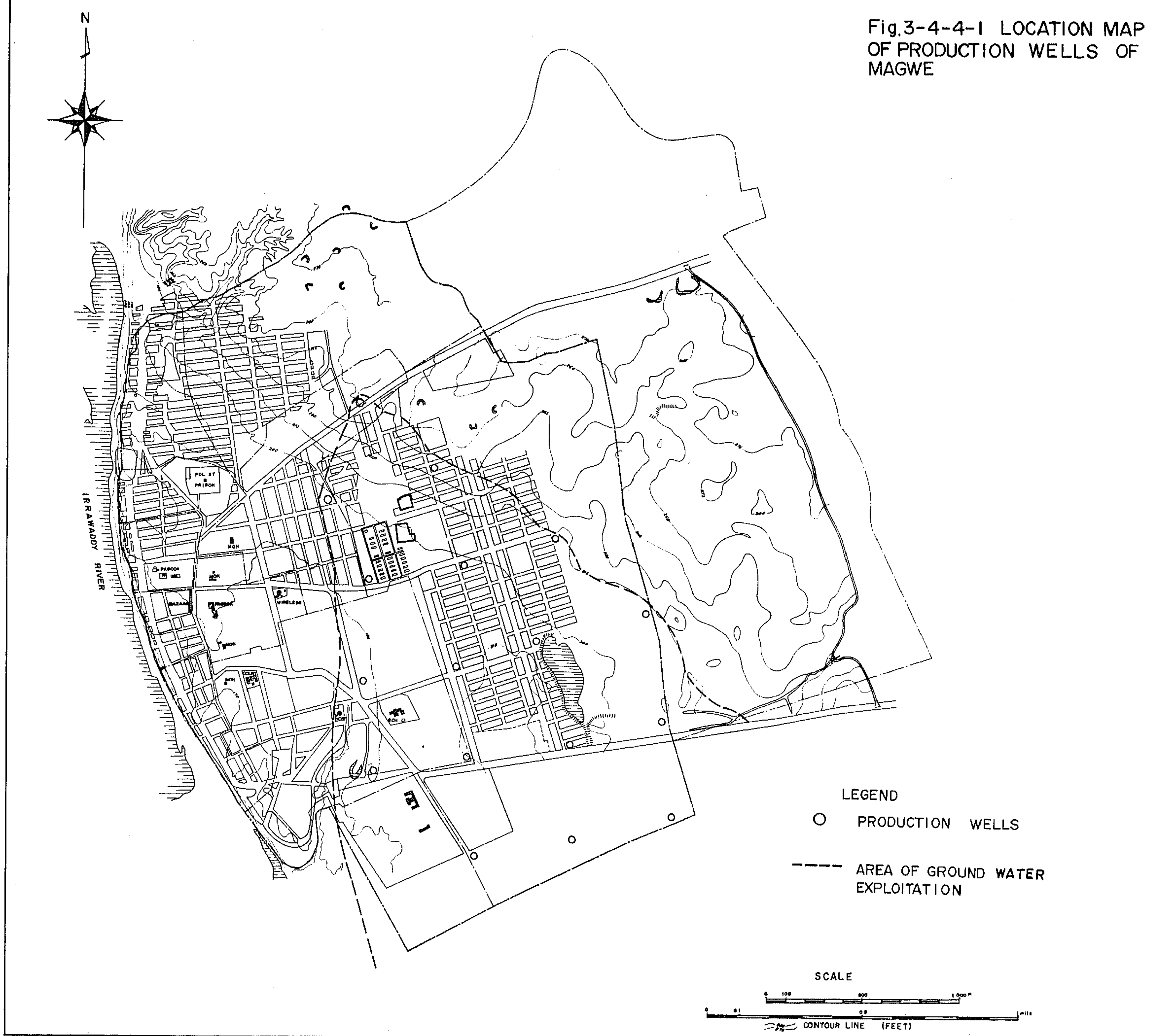
$$\therefore \quad V = (3{,}822{,}000 \times 20 \times 0.13) + (8{,}485{,}000 \times 20 \times 0.10$$

$$= 9{,}937{,}000 + 16{,}970{,}000 = 26{,}907{,}000 \doteqdot 27{,}000{,}000 m^3$$

This figure shows the present volume of ground water in disregard of ground water recharge or movement.

While this area faces the River Irrawaddy, it is assumed from the piezometric level based on the well data that movement of the ground water flows from the mountain side towards the river in gentle descent. Therefore, in normal conditions, ground water cannot be supplied from the river, but the production well area is supplied with water from mountains in the east. Therefore, it is possible to assure a full standing volume for pumping-up as a water source for the water system.

Fig.3-4-4-1 LOCATION MAP OF PRODUCTION WELLS OF MAGWE



3.4.5 Pumping Quantity per Well, Distance and Depth

The data on the wells in Magwe are shown in Figure 3.4.2.1.

Of these data on the wells, the pumping volume of each well excluding those away from the project area, is shown in Table 3.4.5.1.

Table 3.4.5.1 The Pumping Volume of each Well

No. of wells	Depth of wells (m)	Pumping quantity (m^3/h)	P.Q.m^3/18h
1	87.4	56.16	1,010.88
*2	102.9	18.2	327.6
3	83.2	56.16	1,010.88
4	65.3	28.5	513.0
5	61.7	45.46	818.28
7	66.7	10.9	196.2
*12	86.5	18.2	327.6
13	96.3	51.5	927.0

*; Outside the production well area

The pumping-up of water in the production well area averages 746.04 m^3/18 hrs./day. The average pumping volume of the wells, including two nearby wells outside the production well area, stands at 641.43 m^3/18 hrs./day.

The production wells under this project are deeper than those in the upper layer, and it is possible to select favourable aquifers and pump up water. It is fully possible to pump up 700 m^3/18 hrs./day per well in the production well area, and the volume is set at 700 m^3/day as water is pumped for 18 hours a day.

The interval between wells prevents drops in pumping quantity and water level. The interval between wells should be long enough to prevent any interference by neighbouring wells.

When the conditions of the geology and aquifers in this area, and the drops in pumping quantity and draw down water level on the basis of existing data are taken into consideration, it is necessary to set the interval between wells at more than 500m. The interval here is set at a minimum of 500m.

Now that the lower depth of the standing volume of an aquifer is in the neighbourhood of 100m, the average depth of production wells is set at 110m and that of exploration wells, for which a survey has to be made at depths greater than for production wells, to some extent, is set at 150m. Pumping test observation wells were made the same in depth as the main wells, whereas water level observation wells are of the same depth as production wells.

3.4.6 Well Construction

At the outset of the implementation of the ground water exploitation, the number of wells required was estimated as follows; as daily average pumping volume is 700 m^3/day, the number of wells required is $11,500 \div 700 = 16.4 \doteqdot 17$. Hence, 17 production wells lead to a pumping quantity per day of 17×700 m^3/day $= 11,900$ m^3/day.

As the standing volume of aquifers in the Magwe area is not known exactly, it is made a principle to drill exploration wells before production wells. However, at the sites where the result of electrical survey or the data from the existing wells ensure that pumping quantity is more than the average quantity, no exploration well is tried. The four sites in point are shown in Figure 3.4.6.1.

In the remaining 13 wells, first, an exploration well is drilled. Then, when the site is found to be unsuitable for a production well from the result of the previous exploration well, an adjacent site is selected for the exploration well. An observation well for the pumping test is drilled at each production and exploration well, and, in addition, three observation wells for secular monitoring of water level are drilled.

i) Production well

The proposed sites for production wells are shown in Figure 3.4.6.1. Because of relatively great pumping quantity and pumping height, installation of a large submersible pump is required. For this reason, the structure of the pump is designed to apply a pump housing casing with a 250mm diameter from the surface to 40m depth, and a casing with a 200mm diameter and screen in the lower depth.

The structure of the production wells for this project is illustrated in Figure 3.4.6.2.

The operation procedure for production wells is as follows;

1) well drilling
2) after completion of drilling, electrical logging by means of resistivity (normal type), SP logging, γ-ray logging and thermal logging.
3) From the results of the logging and coring, determining the position of the screen.
4) casing and arranging the screen
5) gravel packing
6) discharging mud
7) drilling an observation well

8) Setting the screen and casing at the same level as the production well.

9) discharging mud (observation well)

10) pumping test (by submersible pump)

(More details about the operation are described in the guideline)

Operation procedure and the period required are as follows;

Operation	Period
Arrangement	2
Surface drilling (maximum 10m)	0.5
Setting up of mouth pipe	0.5
Drilling 110m (25m/day)	4
Electrical logging	1
Casing 90m and screening 20m	0.5
Gravel packing	0.5
Mud discharge	2
Pumping test	2
Movement and removal site clearance and removal	2
Total	15 days

Drilling personnel are assigned in the following manner:

Taking the actual conditions in Burma into consideration, well drilling of one shift for 8∿10 hours is acceptable.

Crew composition per drilling machine (2 groups)

Boring chief,	1
Assistant	2
Mechanic	1
labour (including a watchman)	3
Driver (seconding as a crane man)	1
Total	8 persons

In addition to these, the following personnel are deemed necessary:

Transporation staff	2	Construction staff	2
Driver	1	Pump setting	1
labour	1	Water tank operator	1

Since these staff members are not regular, and some of them hold another post concurrently, the personnel have to be properly disposed.

ii) Exploration well

The exploration well structure is shown in Figure 3.4.6.2. The diametre of the casing pipe is 100mm. The operating procedure for an exploration well is carried out in the way described in "production well". Working days are as follows;

The organization of a working group otherthan a drilling crew follows the same structure as that of "production well".

Operation	Period
Arrangement	2
Surface drilling (*maximum* 10m)	0.5
Setting up of mouth pipes	0.5
Drilling 140m 35 m/day	4
Electrical logging	1
Casing 130m, and Screening 20m	1
Air lift (pumping test)	2
Site clearance and removal	2
Total	13 days

iii) Observation well

There are two kinds of observation well; one, which accompanies production and exploration wells, monitors water level drop in a pumping test, and the other monitors the trend of water level over the area throughout the year.

a) Observation well for pumping test

The observation well for a pumping test is drilled at a point 5m distant from the main well, and at the same depth and position as the screen of the production well. Diameter of the pipe is 50mm, and its structure is shown in Figure 3.4.6.2.

The working procedure and arrangement of the personnel followings the system for "production well".

	Production well (110m)	Exploratory well (150m)
Arrangement	2	2
Surface drilling	0.5	0.5
Setting up of mouth pipes	0.5	0.5
Drilling	3	4
Casing and screening the strainer	0.5	0.5
Site clearance and removal	2	2
Total	8.5 days	9.5 days

b) Observation well for water level monitoring

Three observation wells are needed for water level monitoring, one being required on the mountain side and are on the flatland side, respectively. Figure 3.4.6.1 shows the location. The depth of the observation wells is the same as that of the production well, its diameter is 100mm and a strainer is equipped in a main aquifer. A one-month hydrograph is used. The working procedure and the arrangement of the personnel follow the system for "observation well for pumping test".

iv) Transformer and pumping facility

Electricity for the submersible pump, transmitted at high voltage (11,000V), is lowered to 400V by a transformer. The submersible pump has a capacity of 0.65 m^3/min pumping quantity, corresponding to an average pumping quantity of 700 m^3/day, a pumping height of 50∿77m and output of 15 KW.

After completion of the production well construction, the submersible pump is installed in parallel with equipment of the transformer facility and the water supply and discharge pipes.

v) Total working days needed for production well construction

In a case where it takes for two years from initiation of drilling operation to completion of production well construction, the following working days are scheduled;

a) Durations calculated for construction term:

1. Construction: 2 years

2. Months in which work is possible: 8 months/year × 2 years = 16 months.

3. Operational days: 25 days/month × 16 months = 400 days

4. Days of work is possible, using 2 drilling rigs: 400 × 2 = 800 days.

b) The duration calculated from construction process requirements is equal to the total number of days required to production, exploration and observation wells.

Production wells: (15 days/well + 8.5 days/well) × 17 wells = 399.5 days.

Exploration wells: (13 days/well + 9.5 days/well) × 13 wells = 292.5 days.

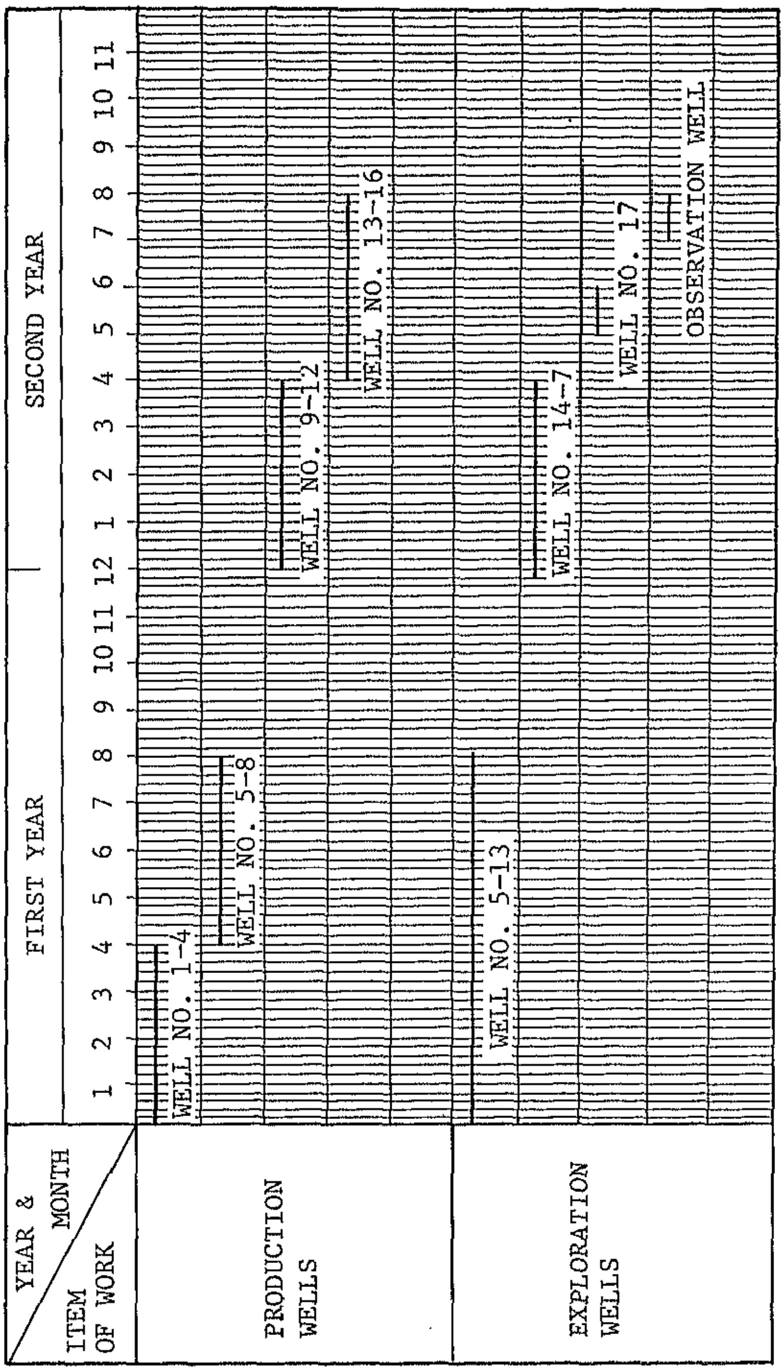
Water level observation wells: 8.5 days × 3 wells = 25.5 days

Total 717.5 days.

The number of days required calculated from the construction process requirements is smaller than that calculated from the construction term, so a wide margin exists for the construction process.

The work schedule is shown as below.

Table 3.4.6.1 Work Schedule in Magwe



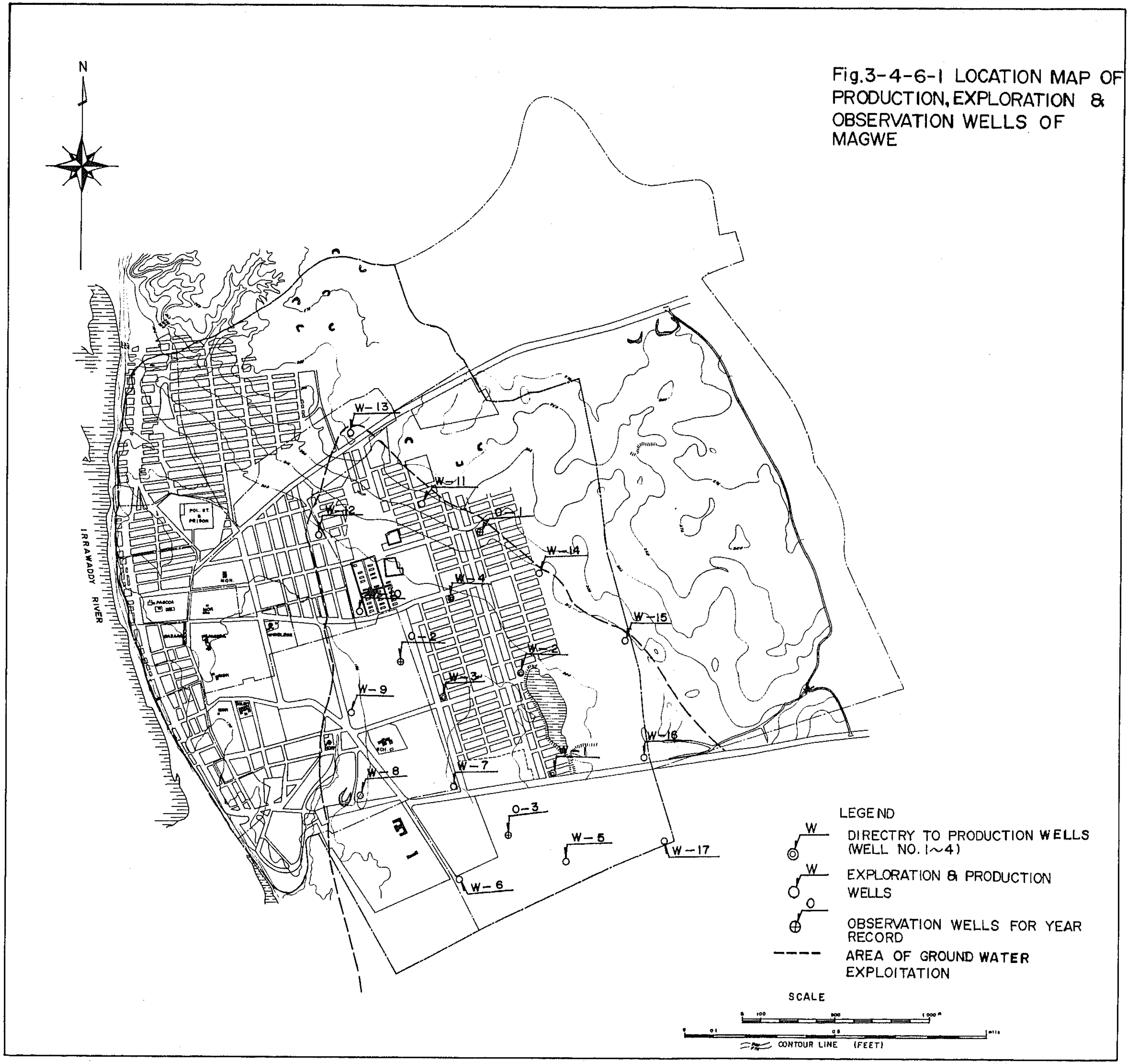
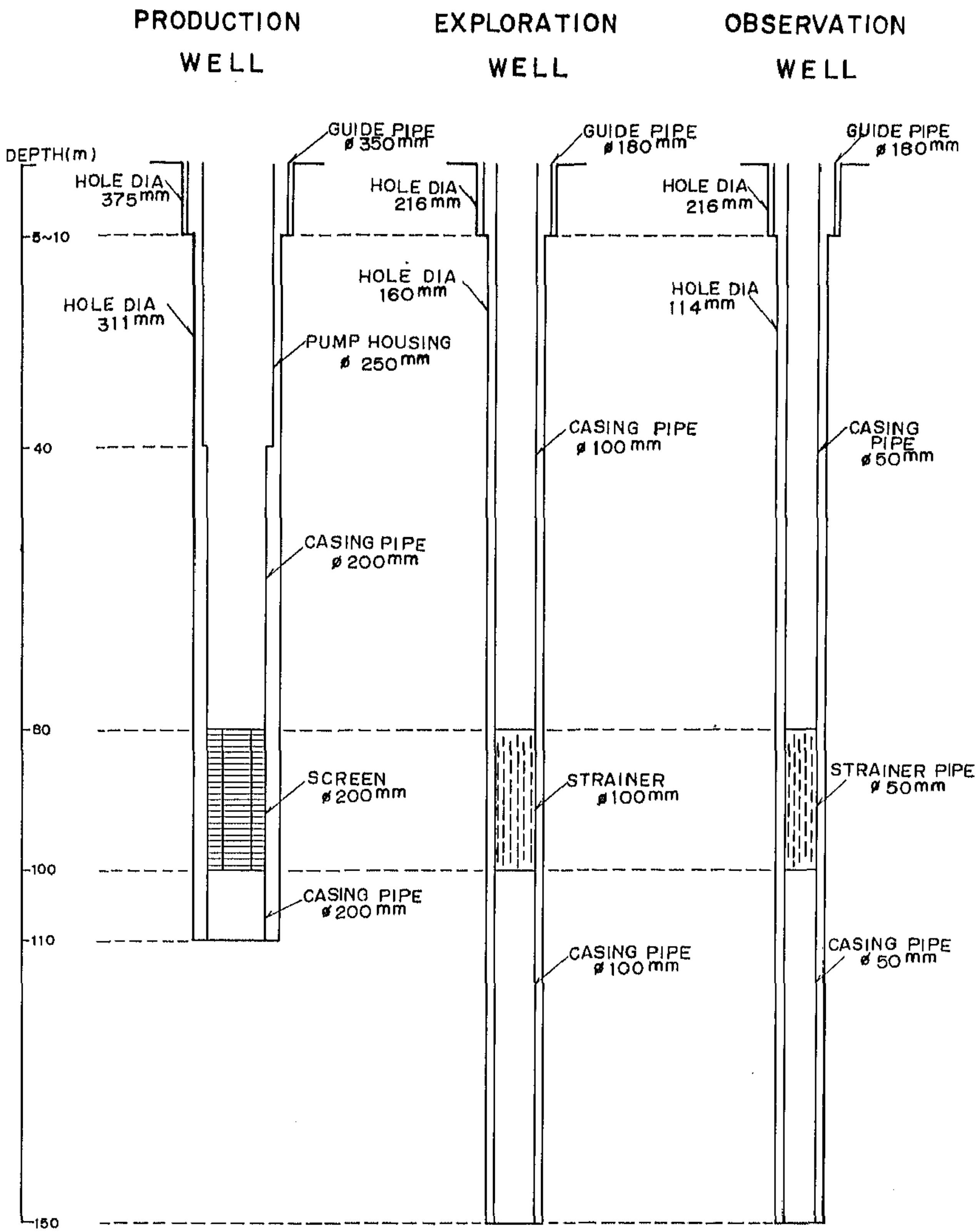


Fig.3-4-6-1 LOCATION MAP OF PRODUCTION, EXPLORATION & OBSERVATION WELLS OF MAGWE

Fig. 3.4.6.2 Design of Wells in Magwe



3.5 Water Facility Planning

3.5.1 Design Criteria

The design criteria related to this project follows "Design Criteria for Towns Water Supply" (See Appendix) ordered by the Rangoon City Development Committee (R.C.D.C.). Through the information obtained from the field survey and the results of consultation with R.C.D.C., the elements for the project was set as follows;

i) Target year; 1991 (ten years later)

ii) Unit water quantity
Average water supply per person per day 150ℓ/d
Maximum water supply per person per day $150 \times 1.3 = 195$ℓ/d

iii) Hourly maximum water supply $195 \times 1.5 = 292.5$ ℓ/d

iv) Water head; Deep well (more than 100m)

v) Pumping facility; Submersible pump

vi) Duct and conduit; Ductile cast iron pipe

vii) Storage facility; Under ground tank (RC structure)
Storage capacity; Equivalent to a six hour volume of daily water supply.
Elevated water tank (RC structure) equivalent to a 2 hour volume of daily water supply.

3.5.2 Outline of Facility

The ground water is judged suitable for drinking from the results of chemical analysis, and so, principally, purification of water is not conducted. The basic system is, pumping → conveyance → storage → distribution → supply (see Figure 3.5.2.1)

The layout of the facility is briefly shown in Figure 3.5.2.2. and Figure 3.5.2.3. To determine the conditions, the following are taken into consideration.

i) Intake per well and well distance

Intake per well	$700m^3/d$
Minimum well distance	500m

ii) Division of supply area

The supply area is divided into three blocks according to local conditions, and in each block independently block systems are planned, which are linked to each other by connecting pipes.

iii) Application of geographical conditions

Water supply and distribution are conducted by gravity, and the storage facility is built at a reasonably high level in each supply block.

iv) Utilization of the existing facilities

The existing facilities are utilized as much as possible, and integrated with the new facilities.

v) Of the existing water intake, treatment, and distribution facilities, those which are usable at present will be put to use as they are. However, some problems are posed as to the water treatment facilities, and they are to be taken up in Chapter 8.

Fig. 3.5.2.1 Proposed Flow Chart for Waterworks Facilities *of Magwe*

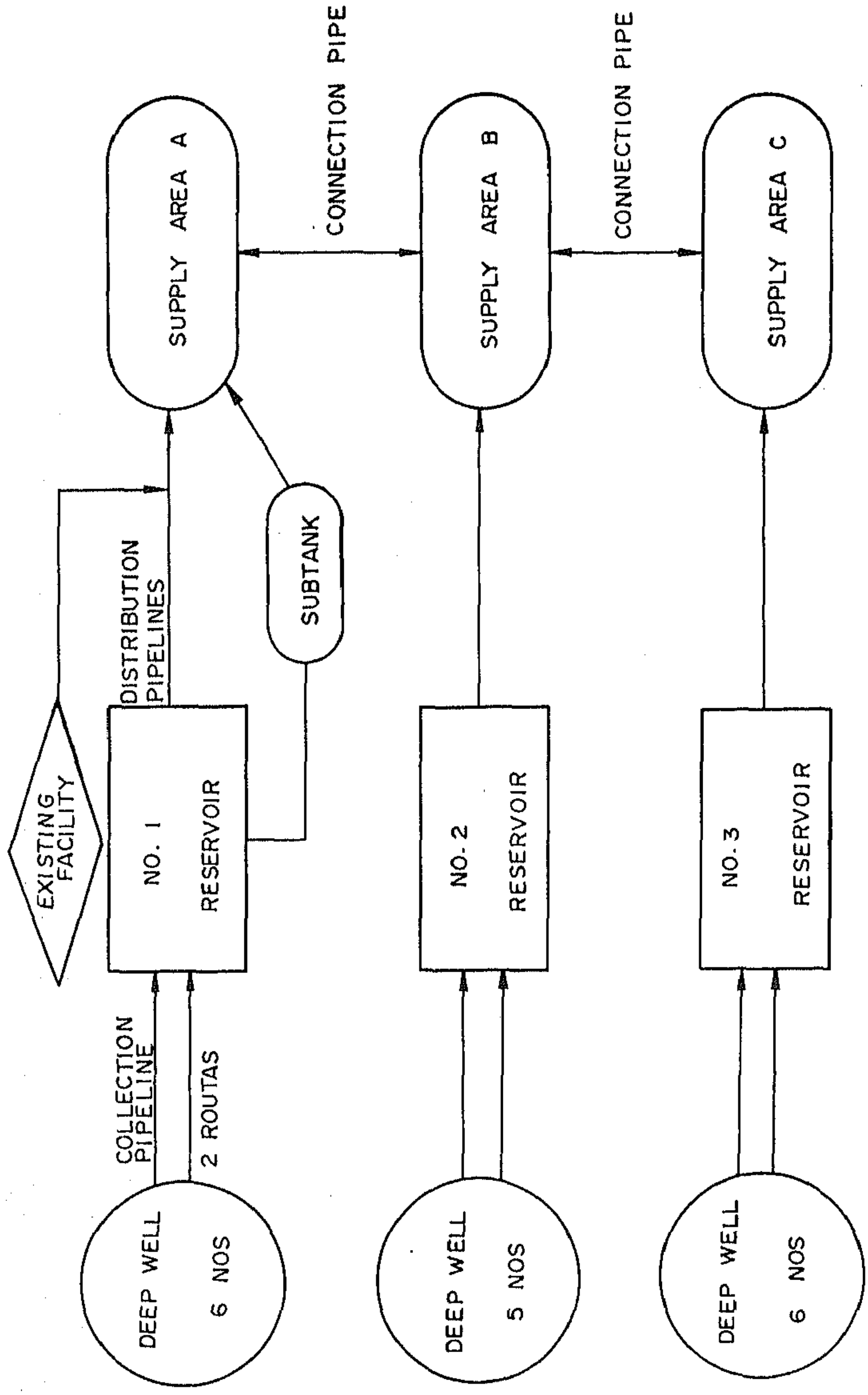


Fig.3-5-2-2 LAYOUT OF FACILITIES(I) WELLS, COLLECTION PIPELINES AND RESERVOIRS OF MAGWE

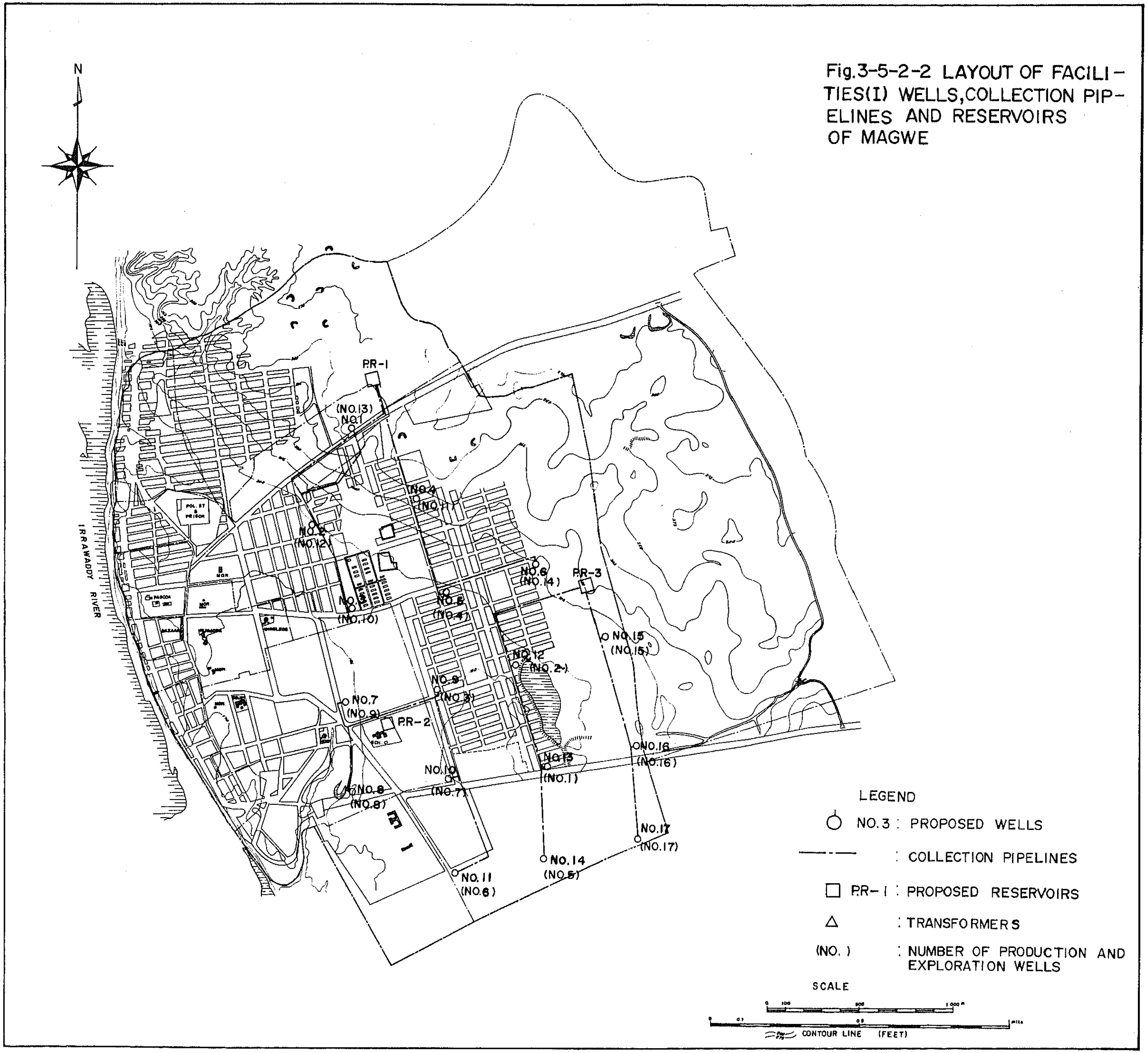
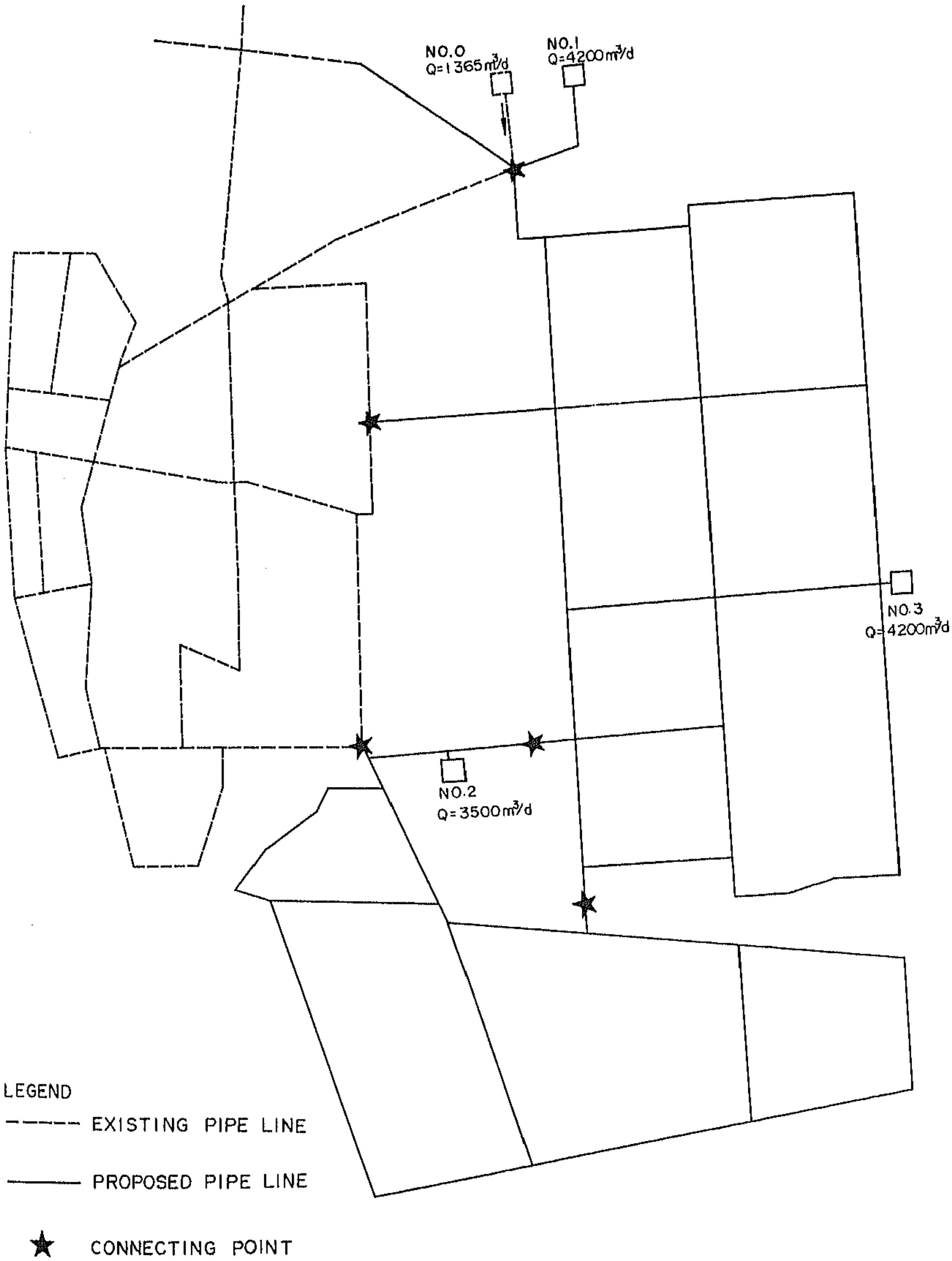


Fig. 3.5.2.3 Layout of Facilities(II) Water Supply Pipelines of Magwe



3.5.3 Proposed Facilities

Considering the calculation results (3.5.4) and others the scale of each facilities was determined as follows.

i) Intake facility

a) Production well

Discharge	700m^3/d/well
Number of wells	17 Nos.
Depth	Ave. 110m
Diameter of Borehole	
Upper part	375mm
Lower part	311mm
Diameter of pump housing	250mm
Diameter of casing	200mm
Gravel wall (gravel size)	ϕ3mm ∿ ϕ10mm

b) Pump room

Structure	Brick construction 4.0m×4.0m
Number of pump room	17 nos.

c) Well pump

Output	15kW 17 nos.

ii) Water conveyance facility

- Collecting pipes (ductile cast iron pipe type I)

Diameter of pipe	Length
ϕ150mm (ϕ6")	3,200m
ϕ200mm (ϕ8")	3,100m
ϕ250mm (ϕ10")	2,400m

- Specials 1 set
- Air valve 10 units
- Sluice valve 19 units

iii) Distribution reservoir

Name	Structure	Capacity
P.R. No. 1	Reinforced concrete	1,400m^3
P.R. No. 2	"	1,400m^3
P.R. No. 3	"	1,200m^3

iv) Distribution facility

- Auxiliary tank for P.R. No. 1

  Elevated tank 50m height

(auxiliary tank for ensuring water head to distribute water to the higher areas in the north-east of the town)

- Distribution pipes (ductile cast iron pipe type I)

Diameter of pipe	Length
φ75mm (φ3")	- (5,460)
φ100mm (φ4")	4,570m (4,410)
φ150mm (φ6")	20,900m (6,200)
φ200mm (φ8")	2,660m (620)
φ250mm (φ10")	2,550m (1,770)

Parenthesis contain the length of the existing pipes.

- Specials 1 set
- Air valve 20 units
- Sluice valve 50 units
- Stand pipe 50 units
- Fire Hydrant 50 units

3.5.4 Calculations

i) Intake and water conveyance facilities

List of Intake Pump

Number of wells	Actual pumping head	Friction loss of head by pipeline	Residual head required	Other head losses	Total head	Output of motor
No. 1	44(m)	1.1(m)	5.0(m)	2.0(m)	52.1(m)	9.8(kW)
No. 2	61	3.5	"	"	71.5	13.4
No. 3	64	5.6	"	"	76.6	14.4
No. 4	51	2.3	"	"	60.3	11.3
No. 5	61	4.2	"	"	72.2	13.4
No. 6	58	6.3	"	"	71.3	13.4
No. 7	46	1.3	"	"	54.3	10.2
No. 8	45	2.2	"	"	54.2	10.2
No. 9	41	0.9	"	"	48.9	9.2
No.10	40	2.5	"	"	49.5	9.3
No.11	45	5.2	"	"	57.2	10.7
No.12	52	2.5	"	"	61.5	11.5
No.13	52	4.6	"	"	63.6	11.9
No.14	49	6.7	"	"	62.7	11.8
No.15	49	0.9	"	"	56.9	10.7
No.16	48	3.0	"	"	58.0	10.9
No.17	49	5.1	"	"	61.1	11.5

Collection Main Pipelines

Line	Distance (L.M.)	Dia.	Quantity (m^3/min.)	Hydraulic gradient (%)	Velocity (m/sec)
No.3∿No.2	500	150(6")	0.7	4.2	0.61
No.2∿No.1	700	200(8")	1.4	3.5	0.67
No.1∿R.V.	350	250(10")	2.1	3.1	0.72
No.6∿No.5	550	150(6")	0.7	4.2	0.61
No.5∿No.4	550	200(8")	1.4	3.5	0.67
No.4∿R.V.	650	250(10")	2.1	3.1	0.72
No.8∿I.C.	350	150(6")	0.7	4.2	0.61
No.7∿I.C.	150	150(6")	0.7	4.2	0.61
I.C.∿R.V.	200	200(8")	1.4	3.5	0.67
No.11∿No.10	650	150(6")	0.7	4.2	0.61
No.10∿No.9	450	200(8")	1.4	3.5	0.67
No.9∿R.V.	300	250(10")	2.1	3.1	0.72
No.14∿No.13	500	150(6")	0.7	4.2	0.61
No.13∿No.12	600	200(8")	1.4	3.5	0.67
No.12∿R.V.	800	250(10")	2.1	3.1	0.72
No.17∿No.16	500	150(6")	0.7	4.2	0.61
No.16∿No.15	600	200(8")	1.4	3.5	0.67
No.15∿R.V.	300	250(10")	2.1	3.1	0.72

* Calculated using the Hazen-Williams formura.

Hazen Williams Formula

Hydraulic gradient

$$I = 10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85}$$

Velocity

$$V = 0.35464 \times C \times D^{0.63} \times I^{0.54}$$

where I: hydraulic gradient ($^0/_{00}$)

C: coefficient of velocity

D: internal diameter of pipe (m)

Q: flow rate (m^3/sec.)

V: average velocity (m/sec.)

Table of Pumping Head

Number of wells	Ground level		H.W.L. of reservoir (m)	Actual pumping head (m)
	Feets	Metres		
No. 1	257	78	82	42
No. 2	199	61	"	61
No. 3	189	58	"	64
No. 4	233	71	"	51
No.5	199	61	"	61
No. 6	209	64	"	58
No. 7	181	55	61	46
No. 8	185	56	"	45
No. 9	197	60	"	41
No.10	199	61	"	40
No.11	185	56	"	45
No.12	197	60	72	52
No.13	196	60	"	52
No.14	205	63	"	49
No.15	206	63	"	49
No.16	209	64	"	48
No.17	206	63	"	49

Pump diameter

$$D = 146\sqrt{\frac{Q}{V}}$$

$$= 146 \times \sqrt{\frac{0.7}{3.0}}$$

$$= 70.5(\text{mm}) \rightarrow \phi 80\text{mm}.$$

where V = Velocity in suction pipe (m/s)

Q = Discharge (m^3/min).

Pump output

$$pm = \frac{16.3\gamma.Q.H.}{y}(1+\alpha)$$

$$= \frac{16.3 \times 1.0 \times 0.65 \times 1.15}{65} \times H$$

$$= 0.187 \times H \text{ (kW)}.$$

where γ = specific weight of water (kg/ℓ)

Q = discharge (m^3/min)

H = total head (m)

y = pump efficiency (%)

α = margin of error

ii) Storage reservoir

Capacity of the reservoir is equivalent to a six-hours volume of the daily maximum water supply plus water for fire-fighting.

No. 1 Reservoir (P.R. No. 1)

$$6 \text{ wells} \times 700 \text{ m}^3/\text{well} \ \frac{6}{24} + 350\text{m}^3 = 1,400\text{m}^3$$

No. 2 Reservoir (P.R. No. 2)

$$6 \text{ wells} \times 700 \text{ m}^3/\text{well} \ \frac{6}{24} + 350\text{m}^3 = 1{,}400\text{m}^3$$

No. 3 Reservoir (P.R. No. 3)

$$5 \text{ wells} \times 700 \text{ m}^3/\text{well} \times \frac{6}{24} + 300\text{m}^3 = 1{,}175\text{m}^3$$

Approx. $1{,}200\text{m}^3$

iii) Distribution facility

The designed supply area is grouped into three districts. Population density in each district is set as follows:

A District; existing urban area with a design population density of 90 person/ha.

B District; light-industrial area with design population density of 50 person/ha.

C District; Proposed residential area with a design population density of 90 person/ha.

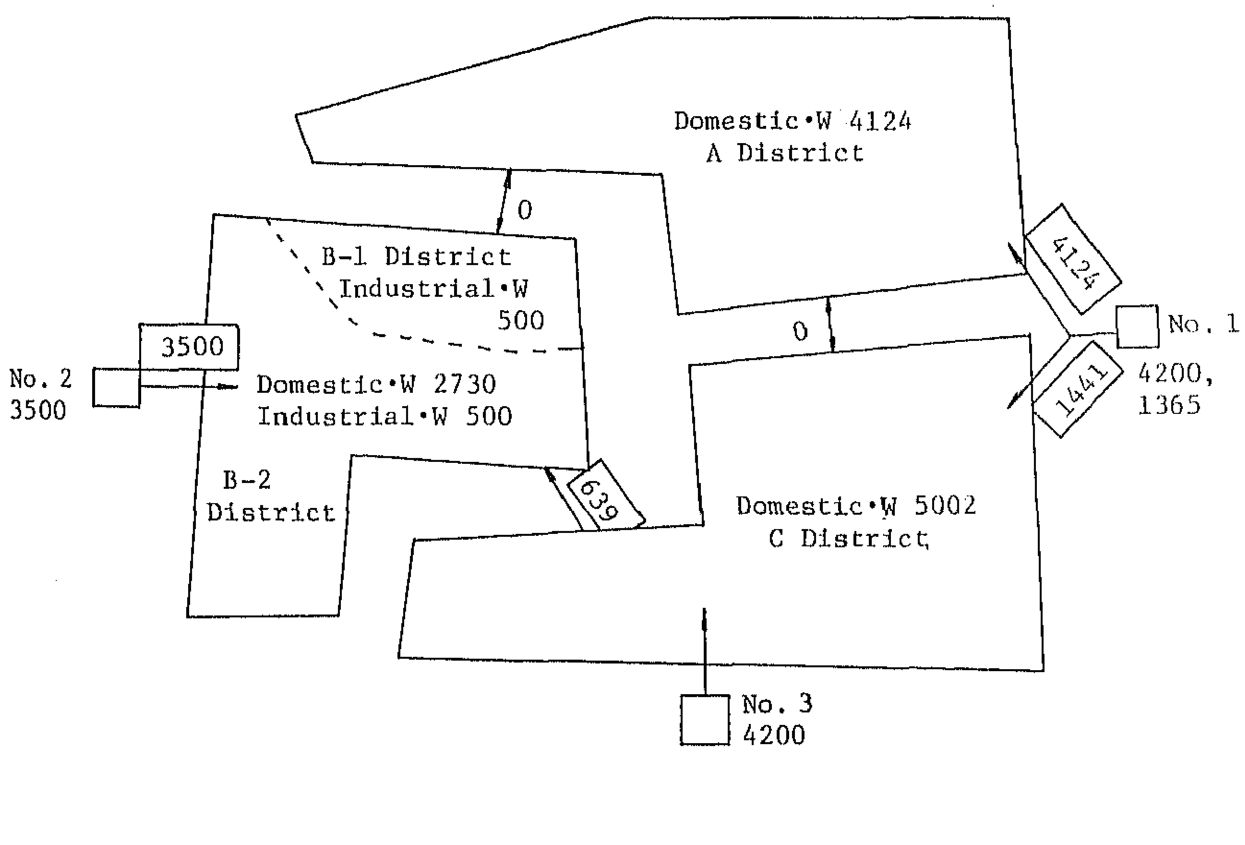
a) Designed water supply

With the designed daily water supply set at 292.5 ℓ/day, an additional 1,000 tons will be supplied to the light industry area. Water distribution facilities will be determined with the designed maximum water supply per hour set at 1.5 times this water supply. Specifications for water distribution are given in Table 3.5.4.1.

Table 3.5.4.1 Specifications for water distribution

District / Water supply		Existing residential	Light-industrial area		Proposed residential area	Total
		A District	B-1 District	B-2 District	C District	
Water supply		Existing	Existing	Proposed	Proposed	
Designed population		21,150	14,000		25,650	60,800
			4,200	9,800		
Area		235 ha	280 ha		285 ha	861 ha
			84 ha	196 ha		
Planned water demand	Domestic water	4,124 m³/d	2,730 m³/d		5,002 m³/d	11,856 m³/d
			819 m³/d	1,911 m³/d		
	Industrial water	-	500 m³/d	500 m³/d		1,000 m³/d
Max. water supply per hour		71.6 ℓ/sec	22.9 ℓ/sec	41.9 ℓ/sec	86.8 ℓ/sec	222.2 ℓ/sec

b) Design flow scheme



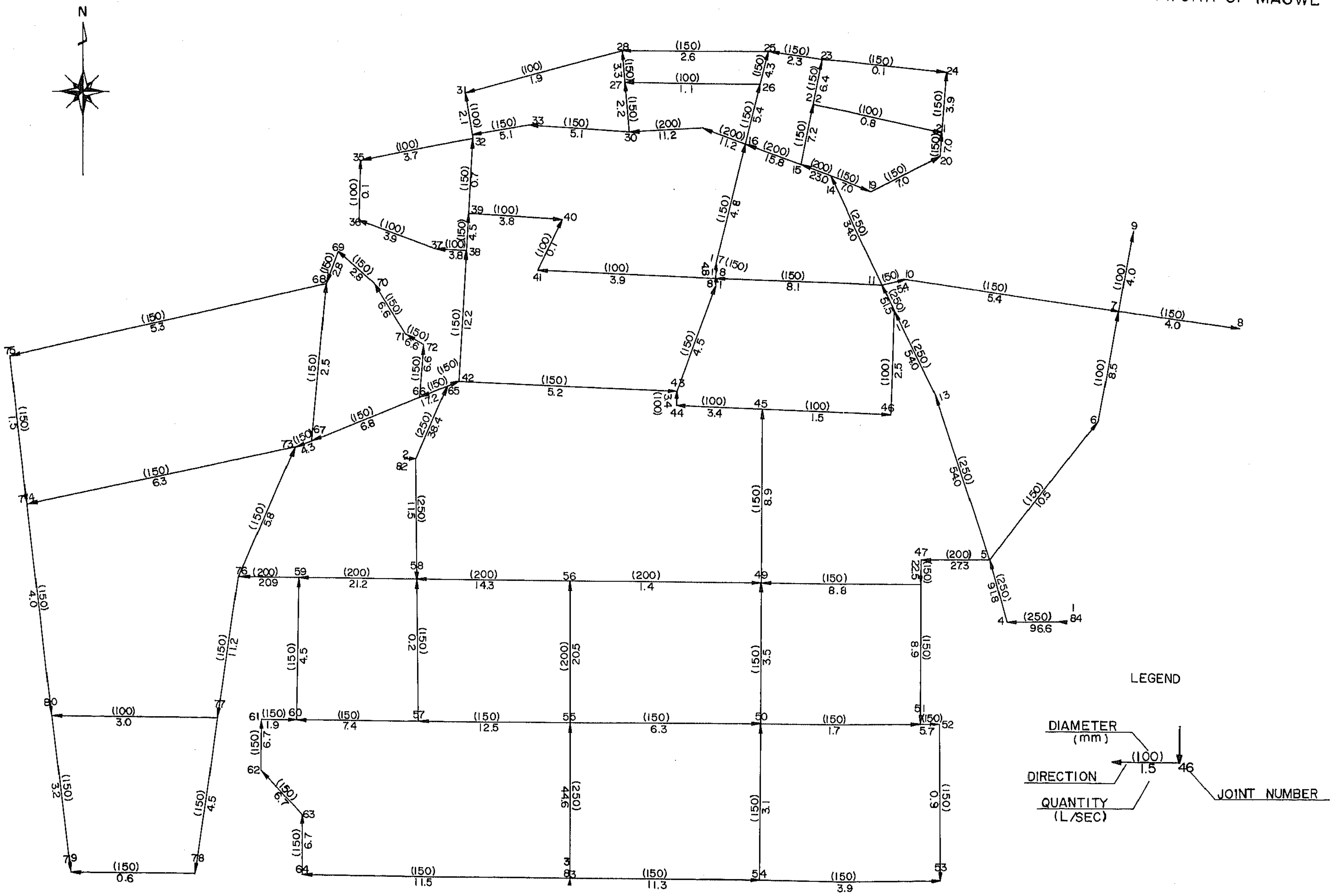
c) Pipe line planning

In principle, water is supplied independently from three sources to each district. For provision against any trouble at the sources, pipes connecting each district are designed to form a pipe line system.

d) Calculation of pipe line

Calculation of pipe line is based on the Hardy-Cross method, and Output Data obtained by computing are recorded in the Appendix. Diagramming of the results are shown in Figure 3.5.4.1.

Fig. 3-5-4-1 DISTRIBUTION PIPELINE NETWORK OF MAGWE



CHAPTER 4 PROME PROJECT

CHAPTER 4 PROME PROJECT

4.1 Outline of the Area

Prome is located on the northern edge of the southern Burma plain and comes within the monsoon area. The annual average precipitation is 1,207mm (over 71 years), with a maximum of 1,749mm (1973) and a minimum of 816mm (1972).

Prome is located on the east bank of the Irrawaddy River, the town being situated on a plain approximately 30m above sea level, so there is no great difference in elevation between the land and the Irrawaddy River. The water level of the Irrawaddy River varies according to season, being low in the dry season and high in the rainy season. Table 4.1.1 shows the monthly average water level of the Irrawaddy River in 1974.

Table 4.1.1 Monthly Average Water Level

Month	1	2	3	4	5	6	7	8	9	10	11	12
Monthly average water level (m)	18.35	17.56	17.33	18.03	19.65	21.70	27.22	28.56	27.23	24.84	20.96	19.69

Source: Burma Meteorological Department

The recorded maximum level was 30.25m (15th August 1974), and this flooded the town. In the northern part of the town, the River Nawin Chaung runs along the northern boundary. Downstream, the river is meandering and has left crescent lakes or swampy areas. Therefore, an embankment was built and the nearby areas are now swampy areas. To the south of the town, there are hills 45m to 90m above sea level. These hills run along the left bank of the Irrawaddy River and face the river with steep cliffs. The

district of Prome consists of the present town, with hills to the south and hills stretching towards the east.

Summarizing the topography, the south is an area of rather higher hills becoming lower towards the north, where the Nawin Chaung lowland is located. The arterial roads and railways run E-W governed by the topography, and the road divides at the eastern edge of the town, leading to Mandalay in the north and Rangoon in the south. The railways connect Rangoon and Prome directly.

At one time in the past, Prome was the capital of Burma, and the magnificent Shwe Sandaw Pagoda indicates its former prosperity. Now, Prome is an important town in the northern Pegu Division, and is a centre of commerce. The population of Prome increased rapidly between 1959 and 1970 and the town became over-populated resulting in fear of fire. Thus, 1,550 households moved to a new town being constructed east of Prome town. Table 4.1.2 shows the number of households and population, since 1972.

Table 4.1.2 Annual Number of Households, Population, and Area

Year	House holds	Population	Area (km^2)
1972	14,316	60,284	20.72
1975	14,954	71,810	20.72
1978	15,120	73,125	20.72
1981		78,146	20.72

Source: Burma government

Administratively, Prome consists of 7 wards and the estimated population for 1981 is 78,146.

Table 4.1.3 Population of each Wards and Area (1981)

Name of wards	Area (ha)	Population
① NAWIN	569.6	16,288 persons
② SHWEGU	28.5	5,012
③ KYAUNGGYI	41.4	5,658
④ SANDAW	69.9	12,412
⑤ SINZU	181.2	6,078
⑥ YWABAI	768.4	16,730
⑦ KHITTAYA-MYOTHIT	411.6	15,968
⑧ New Boundary Area	934.4	0
Total	3,005.0 ha	78,146 persons

* ①,⑥,⑦,⑧ are project areas Source: Burma government

Table 4.1.4 shows the fourth four year plan commencing 1982 made by the Prome Town ship Development Committee.

In the fourth four year plan, Prome is planning to provide a complete water supply system in the old town, and this is to be carried out in conjunction with this project. As a result, the whole of Prome, including the newly expanded area, is to have a complete water system.

Table 4.1.4 Fourth Four Year Plan of Prom Township Development Committee

(*Kyats in thousands*)

Description \ Thousand Kyats		1982∿83		1983∿84		1984∿85		1985∿86		1982∿83 to 1985∿86	
		Total	FE comp	Total	FE comp	Total	FE comp	Total	FE comp	Total	FE comp
1	Extension of existing water supply system	1,200	300	1,000	300	400	100	455	150	3,055	850
2	New Water supply system (Japanese Grant Aid Project)	200	80	500	200	100	40	100	40	900	360
3	Improvement of existing water supply system	-	-	-	-	-	-	100	100	100	100
4	Road construction	250	250	180	150	-	-	100	100	530	500
5	Other construction	75	-	400	-	195	-	210	-	880	-
6	Drainage	650	200	400	100	1,000	150	750	250	2,000	700
7	Sewerage	200	200	-	-	-	-	-	-	200	200
8	Waste disposal	-	-	-	-	350	200	200	200	550	400
9	Office equipment	10	-	20	-	5	-	-	-	35	-
10	Miscellaneous	120	60	100	-	-	-	-	-	220	60
	Total	2,705	1,090	2,600	750	2,050	490	1,915	840	9,270	3,170

Source: Burma Government

The economy of the town, as shown in Table 4.1.5, shows a relatively well balanced revenue and expenditure.

Table 4.1.5 Balance of revenue and Expenditure

Year	Revenue (Kyats)	Expenditure (Kyats)	Balance (Kyats)
1978 - '79	2,698,270	1,941,900	+1,056,370
1979 - '80	2,665,775	1,975,690	+ 690,085
1980 - '81	2,808,544	2,270,523	+ 538,021

Source: Burma Government

4.2 History of Water-works

The water-works in Prome were started in 1883, during the British Colonial Era.

The facilities at that time collected water through a filtration system set at the bottom of the Irrawaddy River, and, by use of a steam piston pump, lifted it up to a raised tank from which water was supplied to the town, but almost all of these facilities were destroyed in World War II.

In 1961, TAHAL (water planning) Ltd. of Israel carried out a feasibility study for a water supply project in Prome

According to this report, surveys were carried out on two cases where water sources were investigated in ground water and the Irrawaddy River. For economic and hygienic reasons, a water supply system from ground water was recommended.

However, this project was not executed due to the national budget, so the town planned a water system with the Irrawaddy River as its source, and in 1975 a filtration facility was built.

This facility takes water from three motor pumps set on the Irrawaddy River bank, through a receiving tank, sterilization and sedimentation equipment. The water is fed to raised tanks, from which water is supplied through booster pumps.

Table 4.2.1 Situation of Existing Facility (1980)

Item	Details	Remarks
Existing town area	8.00 miles^2	20.72 km^2
Population	76,527	
Supply water gal/day	720,000 gallons	3,240m^3
Free supply for public facilities and water loses	210,000 gallons	956m^3
Effective population	30,000	
Effective water gal/day	510,000 gallons	2,284m^3
Effective water gal/day/person	17 gallons	77ℓ
Public stand pipe	148	
Fire hydrants	50	
Water tax/month Percentage of buildings cost	 5%	
1/2ϕ house connections	20 Kyats/month	600 yen/month
Incomes from water	408,476 "	12,250 thousand yen/year
Salaries and other costs	221,077 "	6,630 "
Net profit	187,390 "	5,620 "
Existing pipelines C.I pipe 10" (ϕ250mm) " 8" (ϕ200mm) " 6" (ϕ150mm) " 4" (ϕ100mm)	 2,290ft 10,161ft 13,327ft 7,064ft	 700m 3,100m 4,100m 2,200m
Total	32,842ft	10,100m
Water levels difference in the Irrawaddy River	40.21 ft	12m

The available water supply amount from this facility is 720,000 gallons (3,276m^3) per day, supplying about 30,000 people, 40% of the present population of 76,000.

For areas other than that supplied by the existing water supply facility, drinking water relies on rainwater, Irrawaddy River water, private small diameter tube wells, or water bought from such tube wells, and a early start on public water-works is expected.

Figure 4.2.1 and Table 4.2.1 show the present situation of existing water supply facilities.

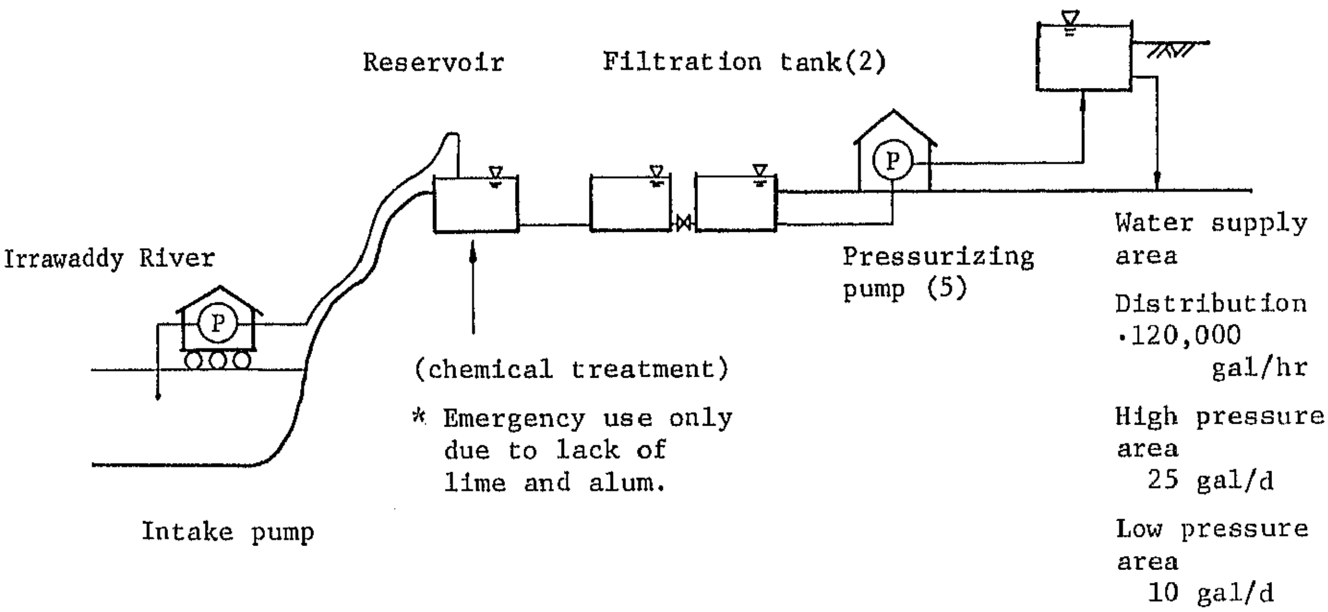


Figure 4.2.1 Rough Sketch of Existing Water Supply Systems

4.3 Planning of Water System

4.3.1 Definition of the Design Area

Prome consists of 8 wards: Nawin, Shwegu, Kyaungyi, Sandaw, Sinzu, Ywabai Khittaya-Myothit, and the New Boundary Area integrated into the old town in 1981. The whole of Shwegu, Kyaungyi, Sandaw, Sinzu, and parts of Nawin, and Ywabai are areas supplied by the existing water system and an expansion project is being carried out by the Housing Department. The design area for this project is limited to the whole of Khittaya-Myothit, the New Boundary Area and parts of Nawin, and Ywabai. Figure 4.3.1.1 shows the wards and design areas and Table 4.3.1.1 shows the population in each ward and area.

When the design area is classified according to topography, the following three areas can be recognized: (See Figure 4.3.1.2).

A: Hills stretching from the centre and south.
B: Low area stretching E-W along the northern boundary
C: Plain area other than the above-mentioned.

According to the future Land Use Plan proposed by Prome, the present residential, industrial, and proposed residential areas, colleges, and airports, are all in area C and this area is the water demand design area for this project.

Fig. 4-3-1-1 AREA AND WARDS FOR PROME PROJECT

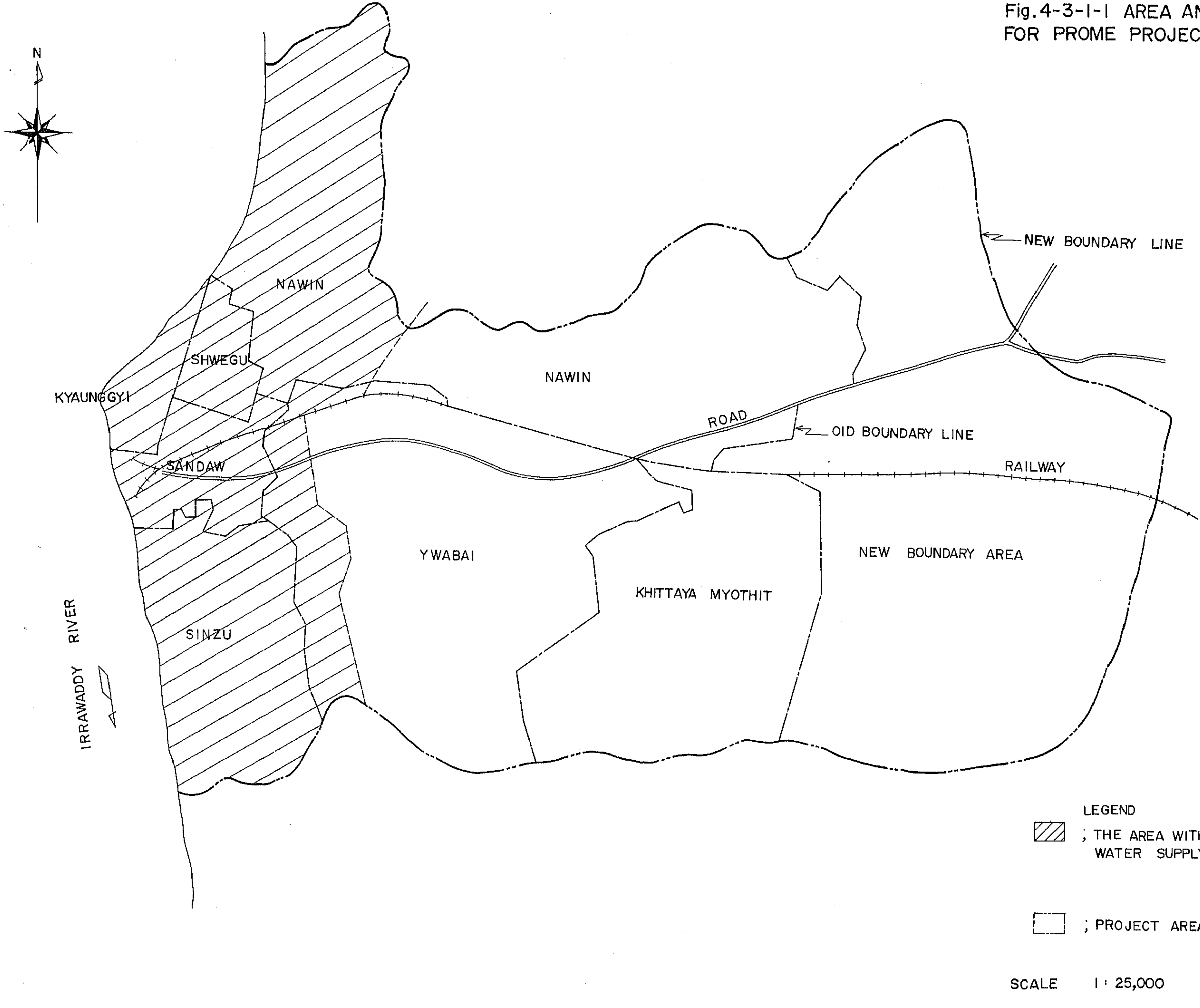
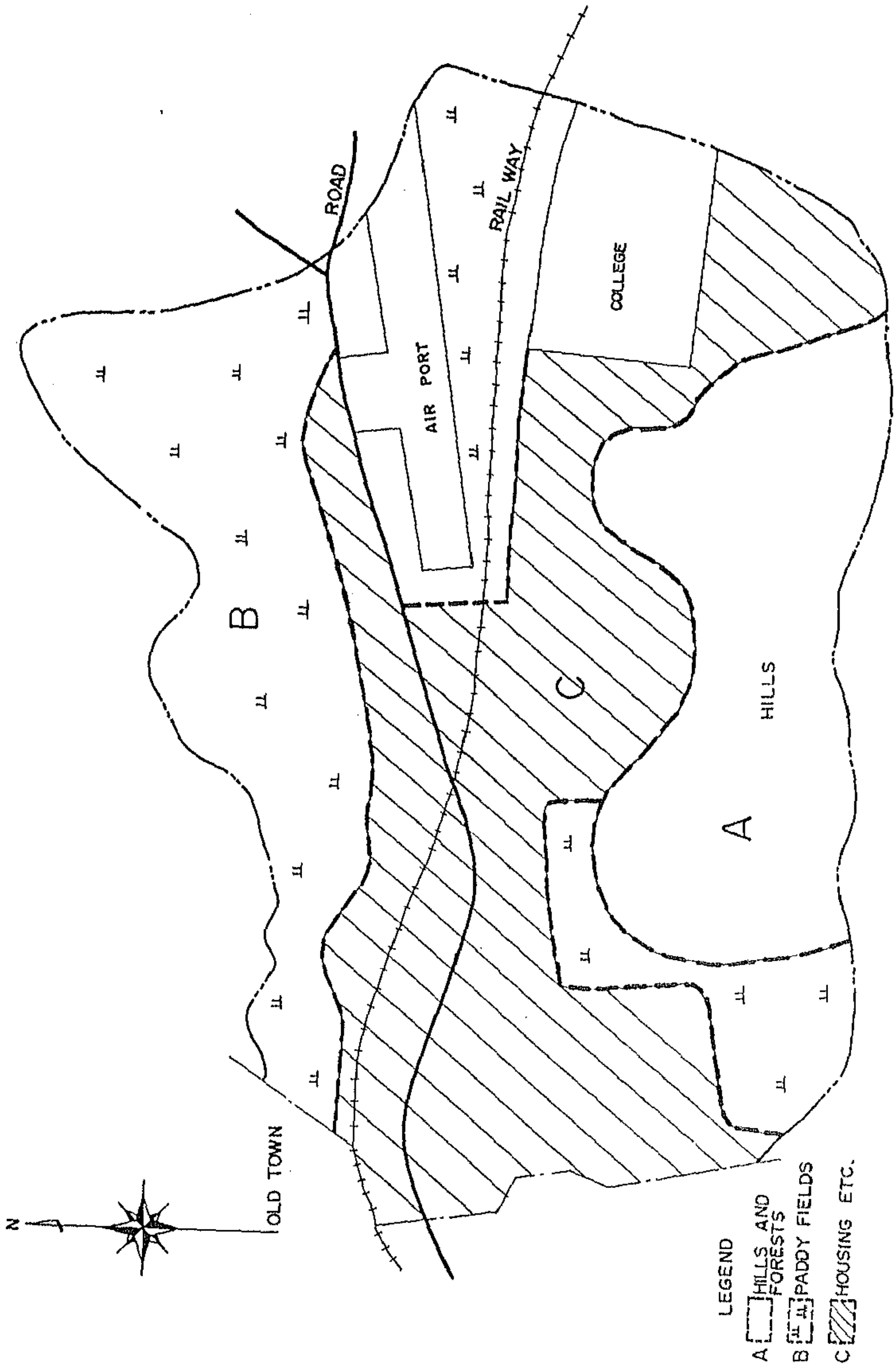


Fig. 4.3.1.2 Land Use Plan of Prome



4.3.2 Designed Population

The target year is set at 1991.

The designed population, as indicated in Table 4.3.2.1, is 97,225. This population was estimated on the basis of the National Census conducted in 1978. As it was difficult to estimate the rise in the population of Prome on the basis of the data to which the survey team had access, computation was made on the basis of the national average growth rate of 2.2%.

Table 4.3.2.1 Estimate of Designed Population

District \ Year	Population 1978	1981	1991
1. Nawin	15,228	16,288	
2. Shwegu	4,678	5,102	
3. Kyaunggyi	5,286	5,658	
4. Sandaw	11,670	12,412	
5. Sinzu	5,682	6,078	
6. Ywabai	15,643	16,730	
7. Khittaya-Myothit	14,929	15,968	
8. New Boundary Area	-	-	
Total	73,152	78,146	97,225

Source: Trial computation made on the basis of data from the Burmese Government

(73,152 persons × $(1.022)^{13}$ = 97,225 persons)

However, as a future supply of water to 30,000 persons is assured under the programme which is being carried out by the Housing Department for an expansion of the existing water

supply system, the designed population under this project in the target year will be 67,000 persons, estimated by deducting 30,000 persons from the total population.

4.3.3 Designed Water Demand

The designed water supply, as referred to here, is the total demand of water for domestic, commerce and industry, a college, and fire fighting.

The breakdown of the demand of water is shown below. The designed water supply is shown in Tables 4.3.3.1 and 4.3.3.2.

a. Domestic water

Domestic water = designed maximum water supply per person per day × designed water supply population
= $0.195m^3$/person/day × 67,000 persons
= $13,065m^3$/day

b. Water for commerce and industry

At present 70,000 gallons/day (about $320m^3$/day) of water is used for commerce and industry. As it is surmisable that there would be extremely little progress in commerce and industry under future land utilization programmes, the quantity of water for commerce and industry, including the airport, is set at $1,000m^3$/day.

c. College

Under the programme, the capacity of the college is considered at 3,000 persons, including the teaching staff.

If the maximum water supply per person per day is set at $50\ell/d$, the water supply to the college will be $150m^3/d$.

d. Water for fire fighting

20ℓ/s × 2 hours × 1 time/day × 3 districts = $432m^3/d$

(Refer to the appendix of the R.C.D.C. Design Criteria)

e. Designed water supply

a + b + c + d = 13,065 + 1,000 + 150 + 432

= $14,647m^3/d$

Approx. $14,700m^3/d$

Table 4.3.3.1 Designed Specifications and Designed Water Supply (Water Supply Area)

Items	Details	Remarks
① Designed population for the whole town in the target year.	97,225 persons	
② Future water supply population by the expansion of existing systems	30,000 "	
③ Designed water supply population	≒67,000 "	①-②
④ Average amount of water supply per person per day	150ℓ	
⑤ Maximum amount of water supply per person per day	195ℓ "	④ × 1.3
⑥ Maximum designed water supply per day	$14,647m^3/d$	
Water for daily living requirements	13,065 "	
Others	1,582 "	
⑦ Designed water supply amount	$14,700m^3/d$	

Table 4.3.3.2 Designed Specifications and Designed Water Supply (Whole Town)

Items	Details	Remarks
① Existing population (1981)	78,146 persons	
② Designed population (1991)	97,225 persons	
③ Average amount of water supply per person per day	150ℓ	
④ Maximum water supply per person per day	195ℓ	③ × 1.3
⑤ Maximum designed water supply per day	20,959m^3/d	
Water for daily living requirements	18,959 "	② × ④
Others	2,000 "	
⑥ Amount of water supply by existing system	3,240 "	
⑦ Designed water supply amount	17,719 "	⑤ - ⑥

4.3.4 Proposed Source Programme

The proposed project area is the area from which the section where the existing water facilities indicated in Fig. 4.3.1.1 are situated, is excluded.

Most of the project area is included in the "Well Field" area incorporated in the TAHAL report. The findings of the latest electrical prospecting and various other data suggest that it has a good supply of ground water.

This area is far from the Irrawaddy, so that if plans are worked out to use the surface water of the Irrawaddy as the water source, it will disadvantageously require huge amounts of money for its facilities and their operation and maintenance

As at Magwe, therefore, it was decided to use the ground water abundantly available in this area, instead of the surface water of the Irrawaddy.

4.4 Ground Water Development Plan

4.4.1 Summary of Hydrogeology

Geologically speaking, Prome belongs to the Central Cenozoic Belt, being located on the northern edge of the Irrawaddy Embayment. (See Figure 2.2.2.1, Figure 3.4.1.1 shows the hydrogeological map of Magwe and Prome) The hills south of the old city, where Shwe Sandaw Pagoda is located, consist of Pegu Formation, and this is a stratum belonging to Miocene to Oligocene, having hard gravel sandstone, and is a stratum forming an aquiclude or impermeable beds. The structure of this stratum forms a dip structure having a N-S axis. To the north and east, the Irrawaddy formation covers this extensively, the lowlands being covered with alluvium.

To the east of the hills where Shwe Sandaw Pagoda is located, hills stretching NW-SE are distributed, surrounding lowland in the middle, the strata belonging to the Irrawaddy Formation.

Judging from the fact that Prome is located on the north edge of the Irrawaddy Embayment, and the Pegu Formation is distributed in the south-west of the area, Geologically, it appears that the Irrawaddy formation distributed here are deposited in the shallow sea, and that the lateral changes in the layers are considerably severe and the layers are not so thick.

4.4.2 Aquifer

With regard to the survey methods used to extract the characteristics of the aquifer in this area, electrical prospecting and data collection from existing wells were carried out.

Along the railways stretching E-W, an electrical prospecting was carried out on line A-A' with 13 survey points (survey point interval 500m) to the north, and line B-B' with 14 survey points (survey point interval 500m) to the south. Using the wenner 4 electrode method, a vertical survey was carried out. Figure 4.4.2.1 shows the lines and survey points. Electrode intervals are as follows:

a	1∿10m	10∿32m	32∿72m	72∿152m	152∿200m
Distance of electrode	1m	2m	4m	8m	16m

The survey results are shown in Figure 4.4.2.2 with ρ ∿ a curves and resistivity cross sections.

From these results, the resistivity of formations are classified into five strata along the A-A' line, and four strata along the B-B' line.

A-A' line

First layer ; This is a surface sand and clay layer, giving resistivity values of 10 ∿ 20Ω-m

Second layer; This gives resistivity values of 80∿120Ω-m and is considered to consist of sand small gravel and to be a permeable bed, and is considered to be fully saturated.

Third layer ; Distributed around survey points Nos. 5∿11 giving resistivity values of 20 ∿ 50Ω-m, and is considered to be aquiclude ∿ impermeable.

Fourth layer ; This gives resistivity values of 40∿70Ω-m and consists of alternating layers of sand or small gravel and clay, and is considered to be permeable ∿ aquiclude. In parts around survey points

Nos. 1 ∿ 4, resistivity was recorded as smaller, at 20 ∿ 30Ω-m, but in comparison with the strata above and below, but it is considered to be permeable ∿ aquiclude.

Fifth layer ; Around survey points Nos. 1∿4, resistivity values of about 10Ω-m were recorded, indicating an aquiclude ∿ impermeable bed, but it is estimated to be a clayey sandstone of the Pegu Formation.

B-B' line

First layer ; This gives resistivity values of 40∿250Ω-m and is a non-saturated surface sand and clay layer.

Second layer; This gives resistivity values of 20∿50Ω-m and is considered to be an aquiclude consisting mainly of clay. Around survey point Nos 17, at some places, high resistivity values of 200Ω-m were recorded, and this is considered to indicate a permeable zone formed by the concentration of large quantities of sand and small gravel at these particular places.

Third layer ; This gives resistivity values of 60∿80Ω-m and, as in line A-A', this is considered to be aquiclude ∿ impermeable. At some places around survey points Nos. 12 ∿ 13 and Nos 19 ∿ 20, an aquiclude bed was indicated.

Fourth layer; Around survey points Nos.12∿16, the resistivity was measured at 20 ∿ 40Ω-m and, as in line A-A'. This is considered to be a clayey sandstone of the Pegu Formation.

From the above results, the main staturated strata lies along line A-A', second layer in the west and third layer in the east, which are permeable ∿ aquiclude beds.

Along line B-B', the major saturated stratum lies between second layer and third layer. With regard to the aquiclude ∿ impermeable beds these are generally foundation rock, or beds generally belonging, geologically, to the foundation rock. The upper surfaces of these strata are undulating, and lie at about 100m depth in the western area, and about 150m or more to the east of the level crossing of the railway and arterial road, which indicates the lower limit of the saturated strata. Table 4.4.2.1 shows the data collected from existing wells.

The well columns are given in the Appendix. The depths of the wells are 30 ∿ 50m and the wells were not used to check the aquifer.

However, from the well at the National Cattle Breeding and Research Centre about 10kms north of Prome, gravel and sand strata mixed with fine gravel was found between 104.6 ∿ 148.5m depth, and this bed is a good aquifer.

Judging from the data, the results of the electrical survey, and the conditions of the saturated strata of the Irrawaddy Formation, it is estimated that a saturated stratum from which pumping is possible exists at depths between 40 ∿ 150m, and the thickness of the stratum is estimated as 30m.

Therefore, for this project, the aquifer in Prome was assumed to be 30m.

With regard to the constant for the aquifer, because no pumping tests have been carried out in existing wells, the pumping test results obtained from the north of Rangoon were used as a standard value, as was the case in Magwe. (See Table 3.4.2.2).

As can be seen from the geological structure map of Burma (Figure 2.2.2.1), both Prome and Rangoon are situated on the same Irrawaddy Formation, but they are 200kms apart. Furthermore, when the conditions of sedimentation for each location are considered, the coefficient of permeability for the aquifer in Prome is estimated to be smaller than that of the Rangoon Stratum. Generally, the Prome coefficient is considered to be between the Magwe coefficient value, 5×10^{-3} cm/s, and the value for well Nos 1 in Table 3.4.2.1, 8.38×10^{-3} cm/s, thus giving a figure of 7×10^{-3} cm/s.

At Prome, aquifers are distributed in the area from which the section where Pegu formation are exposed or distributed in the shallow layers are excluded. The aquifers' lower depth exceeds 150m in some places, but this depth is estimated as 150m on the average, the thickness of the aquifers being estimated at 30m.

Fig.4-4-2-1 LOCATION MAP

ELECTRICAL SURVEY & EXISTING WELLS OF PROME

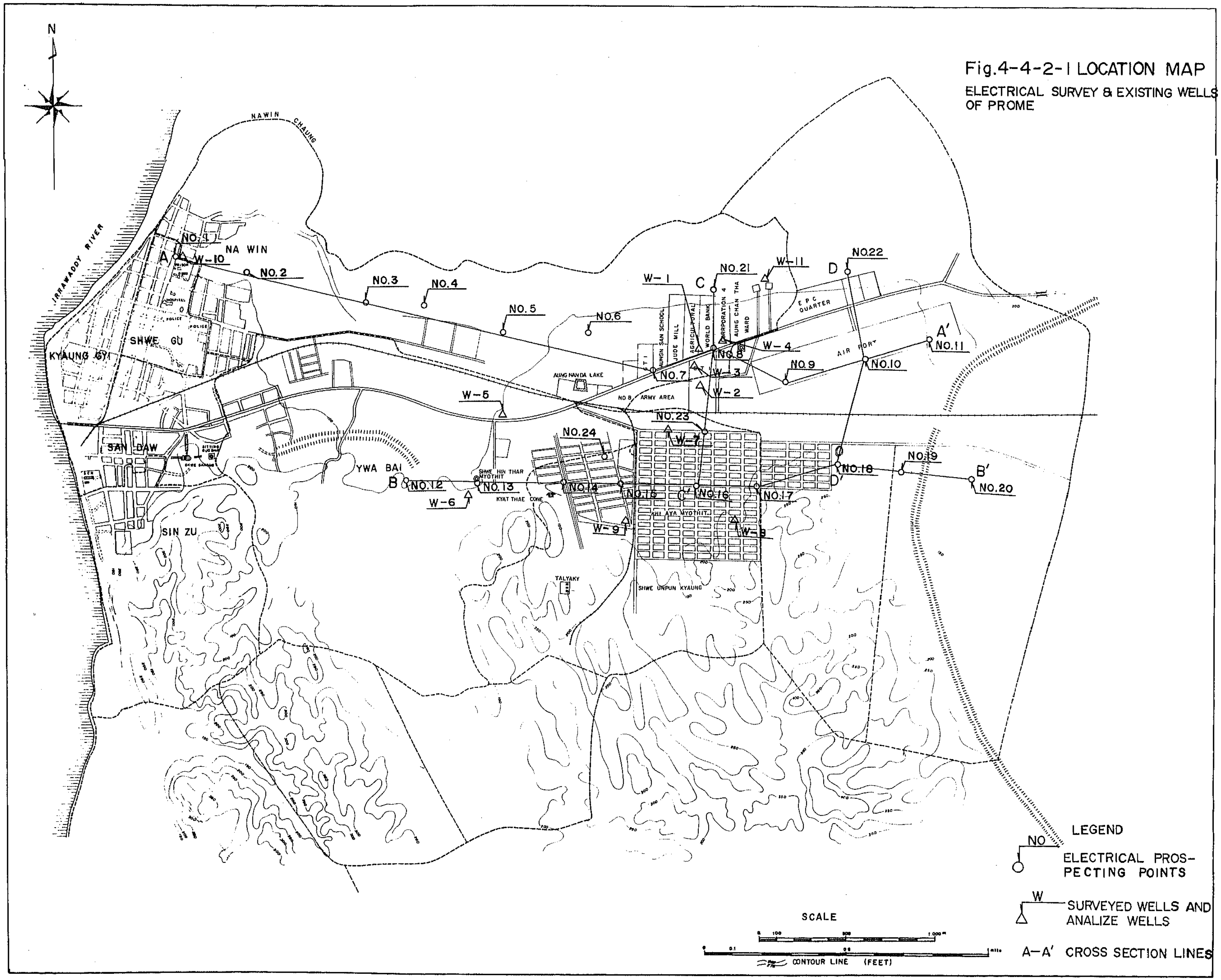


Fig.4-4-2-2
RESISTIVITY PROFILES OF PROME

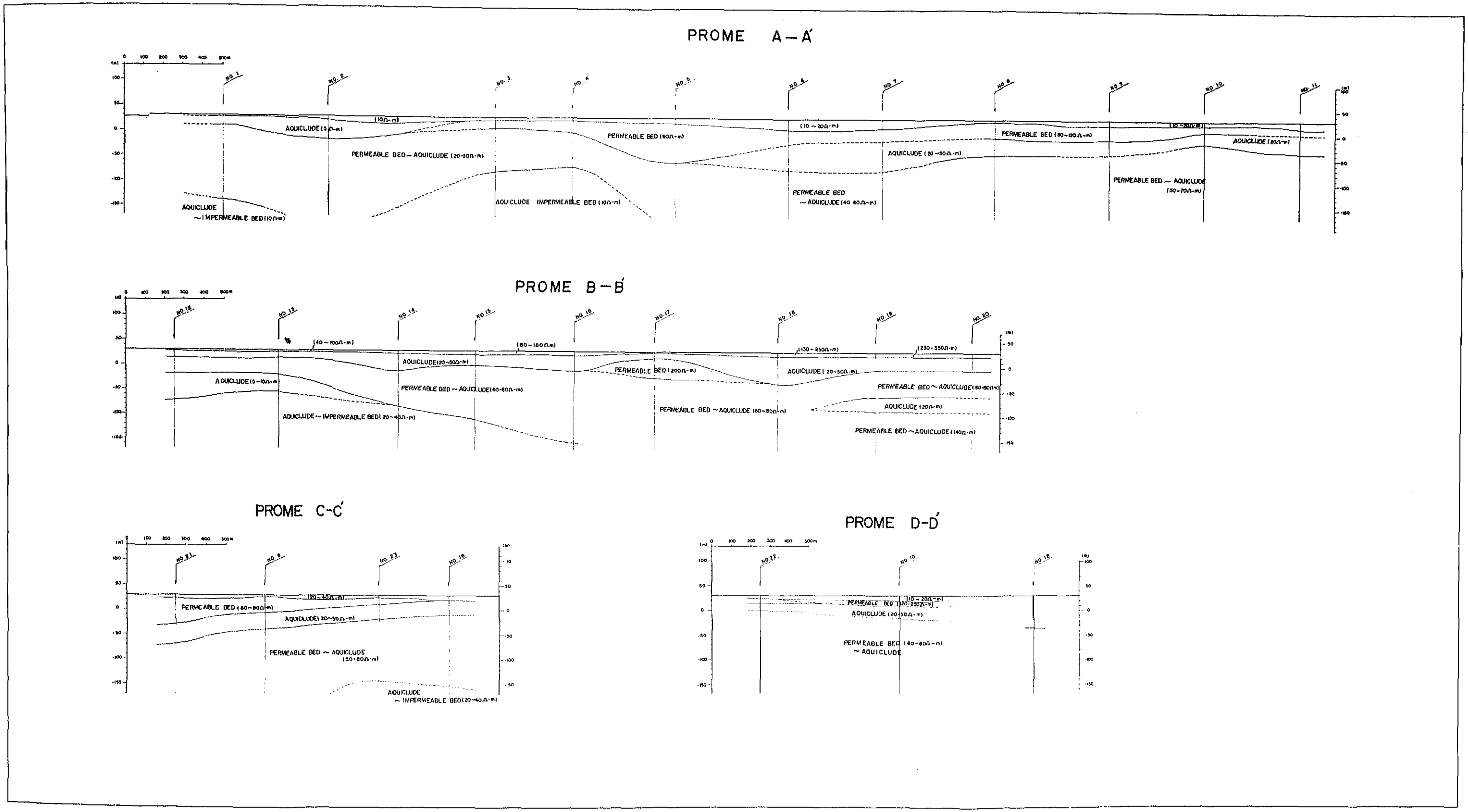


Table 4-4-2-1 LIST OF EXISTING WELLS IN PROME

No.	Name of well & situation.	Static water level (m)	Pumping water level (m)	Screen length (m)	Casing length (m)	Total length (m)	Casing diameter (m)	Water temperature (°C)	Yield m^3/hr	Well depth (m)	Remarks
1.	Timber Corporation	1.8288	1.9812	6.096	30.48	36.576	0.2032	29.7	45.46	36.576	
2.	G.T.I No. 1	5.1816		6.096	30.48	36.576	0.2032	28.5	45.46	36.576	
3.	G.T.I No. 2	4.8768		6.096	28.042	34.1376	0.1524	28	13.638	36.576	
4.	C.C Divisional Stores	5.1816				32.9184	0.1016	29	18.184	36.576	
5.	Khittayar Garden Tubewell	4.8768				33.8328	0.0762	28	27.276	35.052	
6.	Shwehintha Qr.	6.096		6.096		48.768	–	28.25	–	48.768	
7.	Thayaykhittayar Newtown	9.4488		1.8288		27.432	0.0508	28.5	5.4552		
8.	Municipal well Newtown	10.668		3.048		33.528	0.1016	28	8.1828		
9.	Irrigation compound.	13.716	16.3068	1.8288		67.056	0.1016	28.25	4.546		
10.	Jail (Prison)	1.524		1.524	47.548	49.073	0.2032	33.5	22.73		
11.	Hot Spring (Hand dug well)										

SOURCE: MINISTRY OF HOME AND RELIGIOUS AFFAIRS

4.4.3 Ground Water Quality

With regard to ground water quality, this was analysed from water collected at 11 existing wells. Regarding laboratory and analysis methods, these were the same as in Magwe, and the analysis results are shown in the Appendix.

Locations of water sampling wells are shown on Fig. 4.4.2.1.

Except well Nos 11, the temperature of the water was 28 ∿ 29.7°C, and with regard to pH value, except in well Nos 10, it was a weak alkali of 6.6 ∿ 7.8.

Except for the wells having high iron and manganese content, generally speaking, the water proved to be suitable for tap water.

Wells Nos. 1, 2, 3 and 4 are located close to each other and contain a large quantity of iron and manganese. Therefore, if production wells are to be drilled near here, it will be necessary to check the iron content amount. Well Nos 11 is a spring well and it has the special characteristic of having a remarkably large quantity of calcium and magnesium, and a high water temperature (33.5°C).

4.4.4 Ground Water Storage

The amount of ground water storage in Prome was obtained by the same method as in Magwe.

$$V = A \times S \times E$$

where,

V: Ground water storage (m^3)

A: Area (m^2)

S: Aquifer thickness (m)

E: Effective porosity (%)

A: Areas are classified as follows:

i) Areas where the Pegu Formation is exposed or shallower than 50m are not included here.

ii) Area where it was deduced from the region: $24,800,000m^2$

S: 30m from "4.4.2 aquifer"

D: The estimation of the effective porosity was as estimated in Magwe, and the component in aquifer and degree of compaction is estimated to be between the value for Magwe (13%) and Rangoon (15 ∿ 20%), and was made to be 16%.

$\therefore V = 24,800,000 \times 30 \times 0.16 = 119,040,000 \fallingdotseq 120,000,000m^3$

This storage amount is the present water amount which does not include ground water supply of flow.

For the ground water supply, there is rainfall and in the northern Nawin Chaung catchment area, plus rivers and swampy fields. With regard to the total annual inflow and discharge, evaporation exceeds precipitation, but in the rainy season, precipitation is two or three times the evaporation.

Here, the area is limited to the town, but where the water table is lower, there is inflow from surrounding areas, so the ground water storage is considered sufficient as the source of water.

4.4.5 Pumping Quantity per Well, Distance and Depths

Table 4.4.2.1 shows the data for wells in Prome.

The pumping quantity from the existing wells varies considerably, between 45.46 ∿ $4.55m^3/hr$, so it is difficult to establish the potential pumping rate. Therefore, at Timber Corporation well (well Nos 1 in Table 4.4.2.1) continuous pumping was carried out for two hours. As a result, the pumping rate was $145m^3/hr$, and the normal water level depth of 1.82m increased to 1.98m after

pumping, showing a 16cm draw down in water level.

Well Nos 1 has a depth of 36.57m, diameter 200mm, and is much shallower than the wells planned in the Prome project, but where the aquifer is good it is considered that a potential pumping rate of 1,000m^3/day is possible with little drop in water level. Thus, the average pumping rate per well was determined as 1,000m^3/18 hours.

With regard to well distance, based on the same premises as at Magwe, the minimum distance was determined as 500m.

The average well depth was fixed as 150m, based on "4.4.2 saturate strata".

4.4.6 Well Construction

The design water demand for Prome is 14,700m^3/day. The average pumping rate per well is 1,000m^3/day. Therefore, the number of production wells needed is 15 to produce 15,000m^3/day.

As in Magwe, for ground water development, four wells have been drilled without prior survey whereas, for the remaining 11 wells, exploration wells should be drilled first. With regard to the first four wells, these were drilled at locations for which average pumping quantity had already been checked. The total number wells is as follows:

- Production wells: 15 (four already drilled)
- Exploration wells: 11
- Observation wells (for pumping tests): 26
- Observation wells (for water elevel observation): 3

With regard to the production wells, in order to match the requirements of the water demand quantities for each ward, these are distributed among the wards as follows:

Number of wells / Area	Production wells	Number of production wells drilled without prior survey	Number of exploration wells
Area A	6	(1)	5
Area B	7	(1)	6
Area C	2	(2)	0
Total	15	(4)	11

With regard to the siting and development sequence of production wells 1 ∿ 15 and exploration wells 5 ∿ 15, these are shown in Figure 4.4.6.1 with the location of water level observation wells.

(i) Production wells

The structure of the production wells is the same as for the wells in Magwe and the depth is 150m.

The construction process is the same as for the wells in Magwe, and the required times are as follows:

Arrangement	2 days
Surface drilling (maximum depth 10m)	0.5
Setting up of mouth pipe	0.5
Drilling 140m	5
Electrical logging	1
Casing 130m and screening 20m	0.5
Gravel packing	0.5
Mud discharge	2
Pumping tests	2
Site clearance and removal	2
Total	16 days

Each well construction crew consists of 8 people, as in Magwe.

Structural diagrams for production, exploration and observation wells are given in Figure 4.4.6.2.

(ii) Exploration wells

The planned locations for exploration wells are those for the production wells, the drilling sequence being given in Figure 4.4.6.1. The drilling depth is deeper than that of the production wells, being on average 200m. In cases where depths exceeding 200m are required, drilling accessories are prepared to provide for depths of up to 250m.

The construction process is the same as for the Magwe wells, and the required times are as follows:

Arrangement	2 days
Surface drilling (maximum depth 10m)	0.5
Setting up of mouth pipe	0.5
Drilling 190m	6
Electrical logging	1
Casing 180m and screening 20m	1
Air lift (pumping test)	2
Site clearance and removal	2
Total	15 days

(iii) Observation wells

As in Magwe, there is a total of 29 observation wells, of which 26 are for pumping tests, and three are for water level observations.

With reagard to the pumping test wells, these are drilled 5m distant from production and exploration wells. The location of the water level observation wells are shown in Figure 4.4.6.1.

The construction process is the same as for the Magwe wells, and the required times are as follows:

Observation wells / Work	Production wells (150m) Water level observation	Exploration wells (200m)
Arrangement	2 day	7 day
Surface drilling	0.5	0.5
Setting up of mouth pipes	0.5	0.5
Drilling	4	5
Casing and screening	0.5	1
Site clearance and removal	2	2
Total	9.5	11.0

(iv) Transformer and pumping facilities

The voltage must be transformed from the supplied high voltage (11,000V) to 400V and pumping motors must be submersible pumps. The capacity of the submersible pumps is $0.95m^3$/min, the pumping head is 74 ∿ 86m, and a 30kW pump is required.

(v) Total operation time required for production well installation

If, as in Magwe, the start and completion dates are fixed to give a two year work period, the timing is as follows:

a) Durations calculated for construction term:

1. Construction: 2 years
2. Months in which work is possible: 8 months/year × 2 years = 16 months
3. Operational days: 25 days/month × 16 months = 400 days

4. Days of work is possible, using 2 drilling rigs:
   400 × 2 = 800 days

b. The duration calculated from construction process requirements is equal to the total number of days required to production, exploration and observation wells.

   Production wells: (16 days/well + 9.5 days/well) × 15 wells = 382.5 days

   Exploration wells: (15 days/well + 11.0 days/well) × 11 wells = 286.0 days

   Water level observation wells : 9.5 days × 3 wells = 28.5 days

   TOTAL 697 days

   The number of days required calculated from the construction process requirements is smaller than that calculated from the construction term, so a wide margin exists for the construction process.

   Table 4.4.6.1 shows the construction process duration of production, exploration and observation wells.

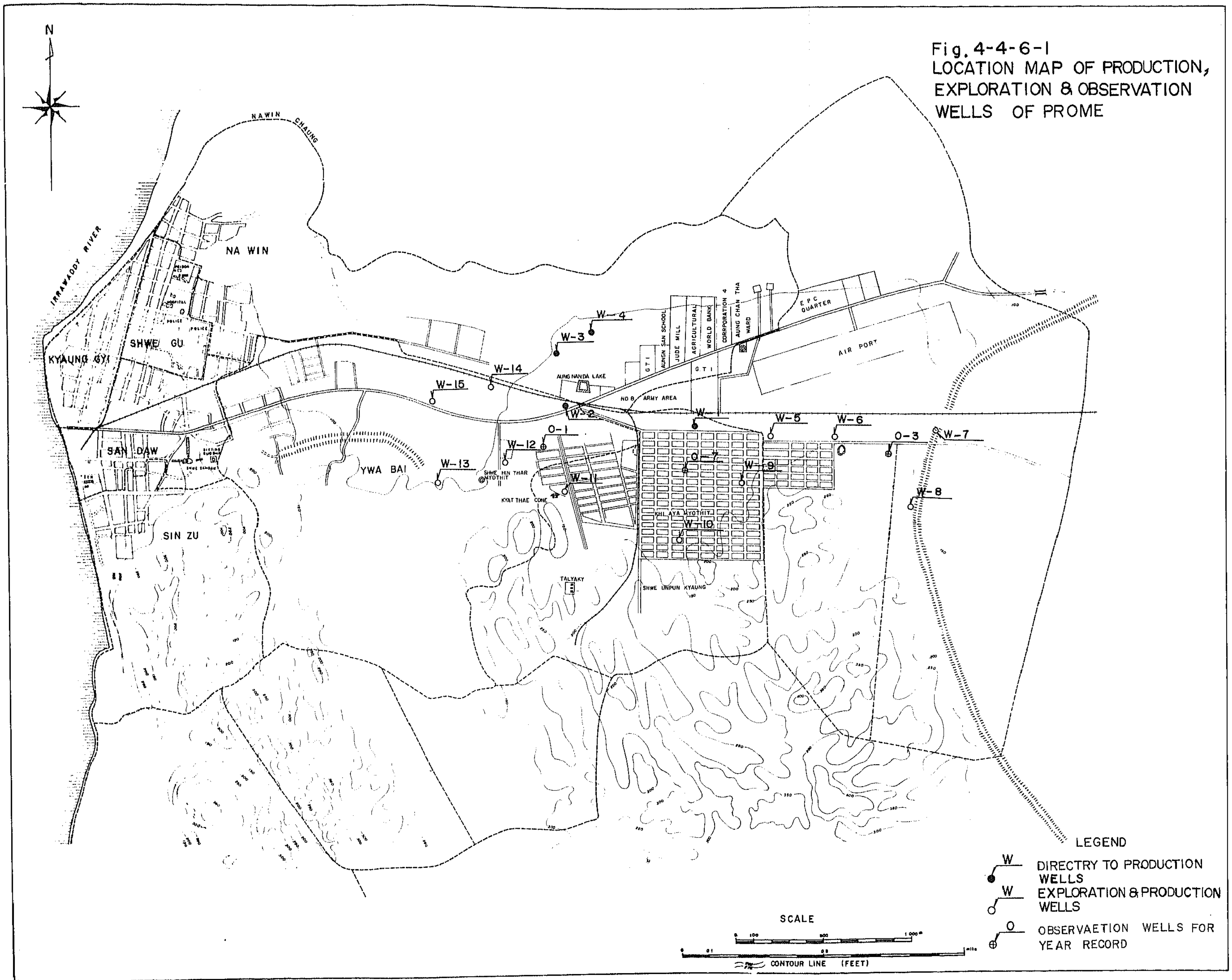


Fig. 4-4-6-1
LOCATION MAP OF PRODUCTION, EXPLORATION & OBSERVATION WELLS OF PROME

Fig. 4.4.6.2 Design of Wells in Prome

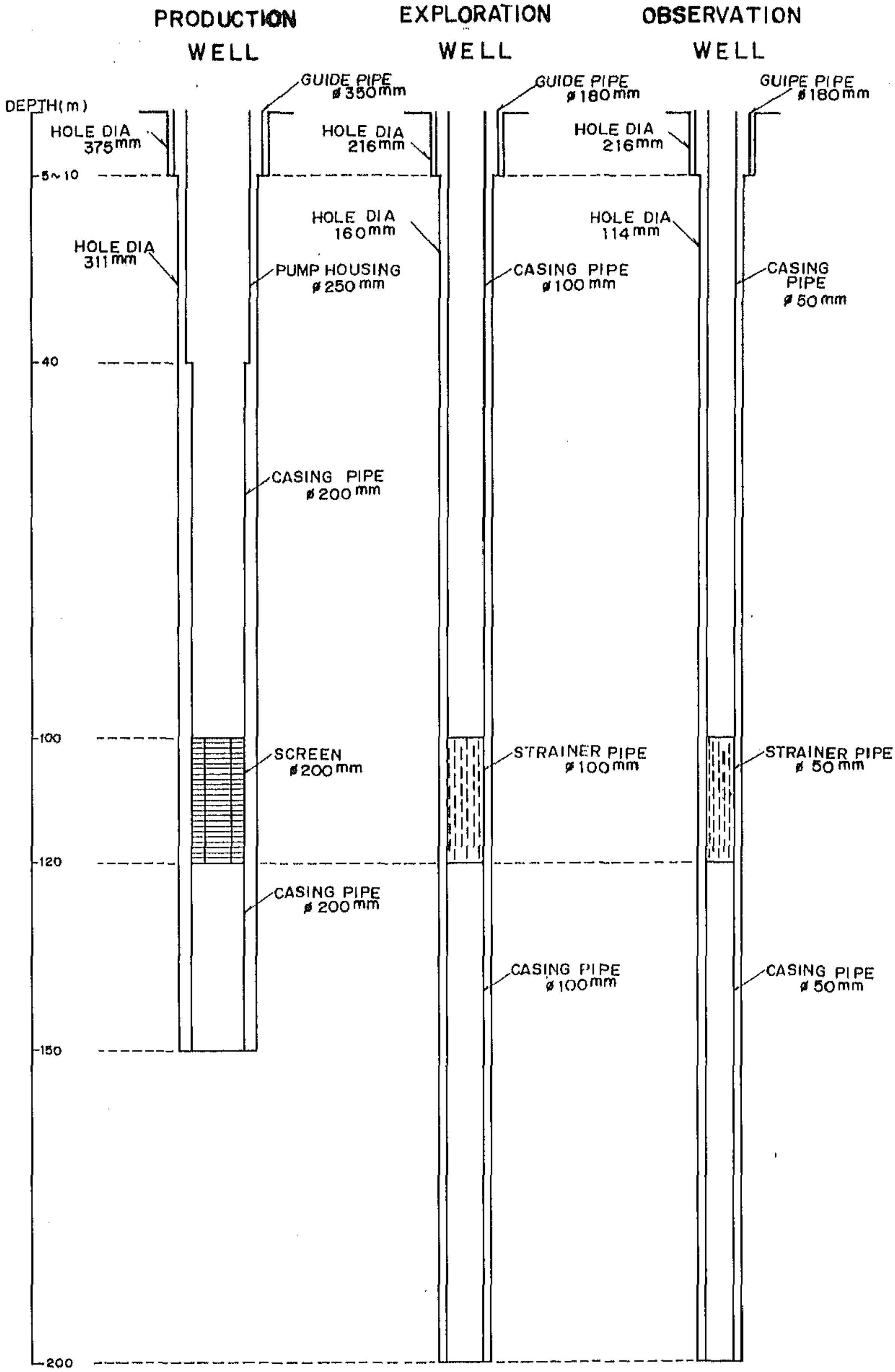
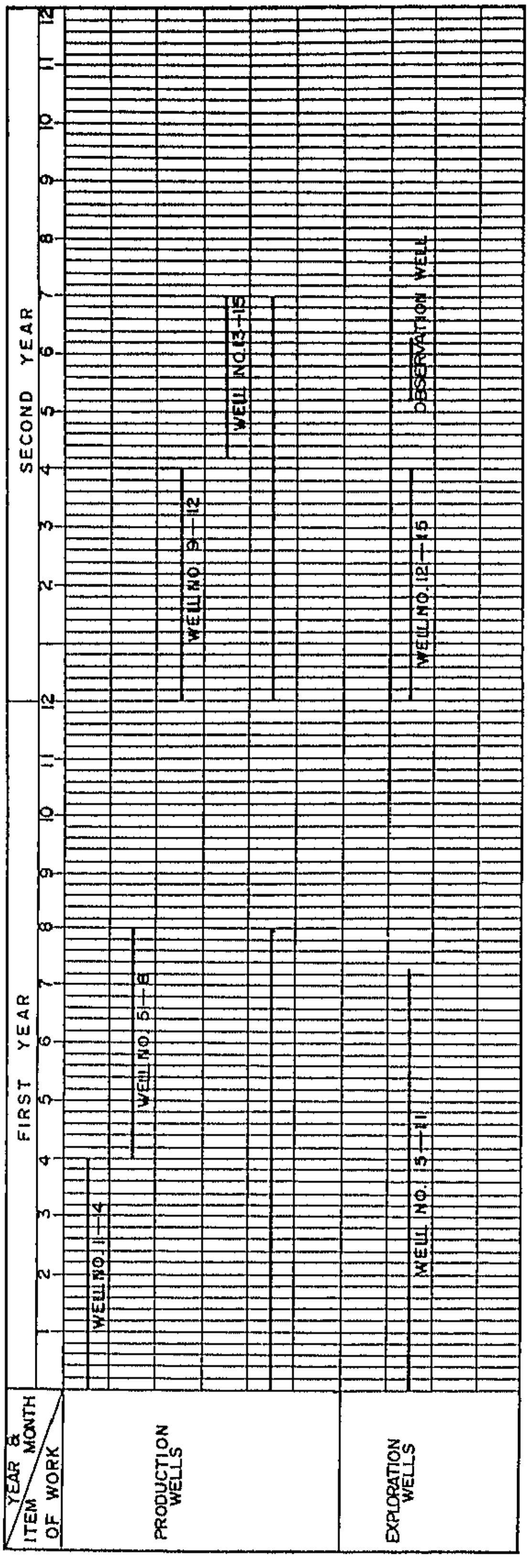


Table 4.4.6.1 Work Schedule in Prome



4.5 Water Facility Planning

4.5.1 Design Criteria

This project's design criteria are based on the R.C.D.C. "Design Criteria for Town Water Supply". From information obtained from field surveys and results of discussions with R.C.D.C., the following criteria for this project's planning were adopted:

i) Target year: 1991

ii) Unit water quantity

Average demand per person per day 150ℓ/d

Maximum demand per person per day 150 1.3 = 195ℓ/d

iii) Maximum hourly demand 195 1.5 = 292.5 "

iv) Water source: deep wells over 100m.

v) Intake facilities: submersible motor pump

vi) Piping: ductile cast iron pipes.

vii) Storage facilities: ground water tank (R C structure). storage capacity 6 hrs. of daily demand.
raised tank (R C structure). storage capacity 6 hrs. of daily demand.

4.5.2 Outline of Facilities

From the water quality test results, the water is considered suitable for drinking water, so this project does not require water purification facilities and the basic system consists of: pumping → transfer → storage → water supply → feeding.

The layout of the facility is shown in Figure 4.5.2.1 and in deciding the layout, the following were taken as criteria:

i) Intake per well and well spacing

Intake per well	1,000m^3/d
Minimum well spacing	500m

ii) Conduits

The conduits from the wells to the water tanks will be of two systems with the breakdown of wells and pipe routes.

iii) Classification of water demand area

The water demand area was divided into three types according to population density and site conditions, and each type is provided with an independent, block system, water supply, although they are connected by pipes (see Figure 4.5.2.2.).

iv) Usage of topography

With regard to feeding and water supply, the gravity method is used, and storage facilities are sited on relatively close hills. However, with regard to Area C, an elevated tank should be used, due to the generally flat topography.

Fig. 4.5.2.1 Proposed Flow Chart for Waterworks Facility of Prome

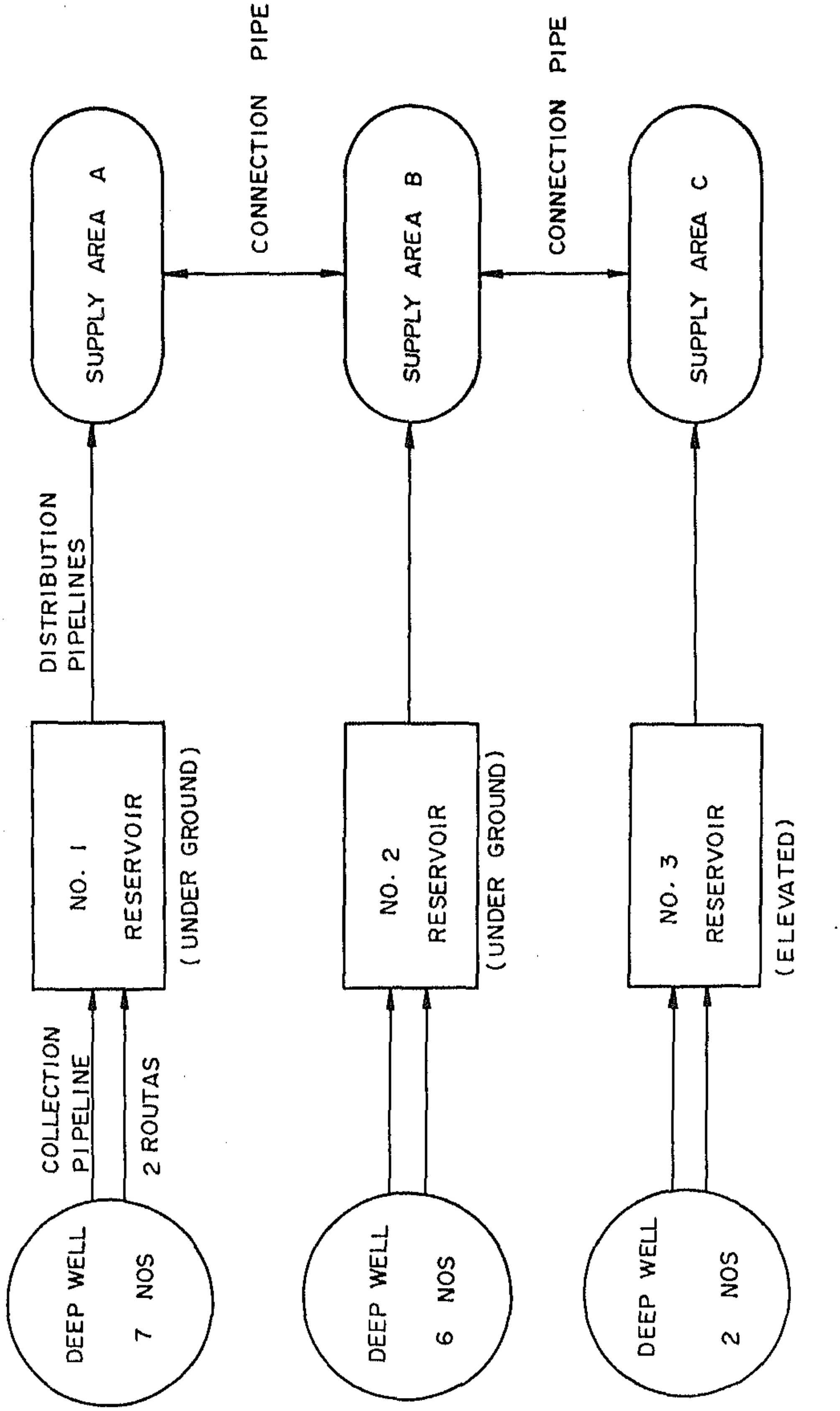


Fig.4-5-2-2 LAYOUT OF FACILITIES(I) WELLS,COLLECTION PIPELINES AND RESERVOIRS IN PROME

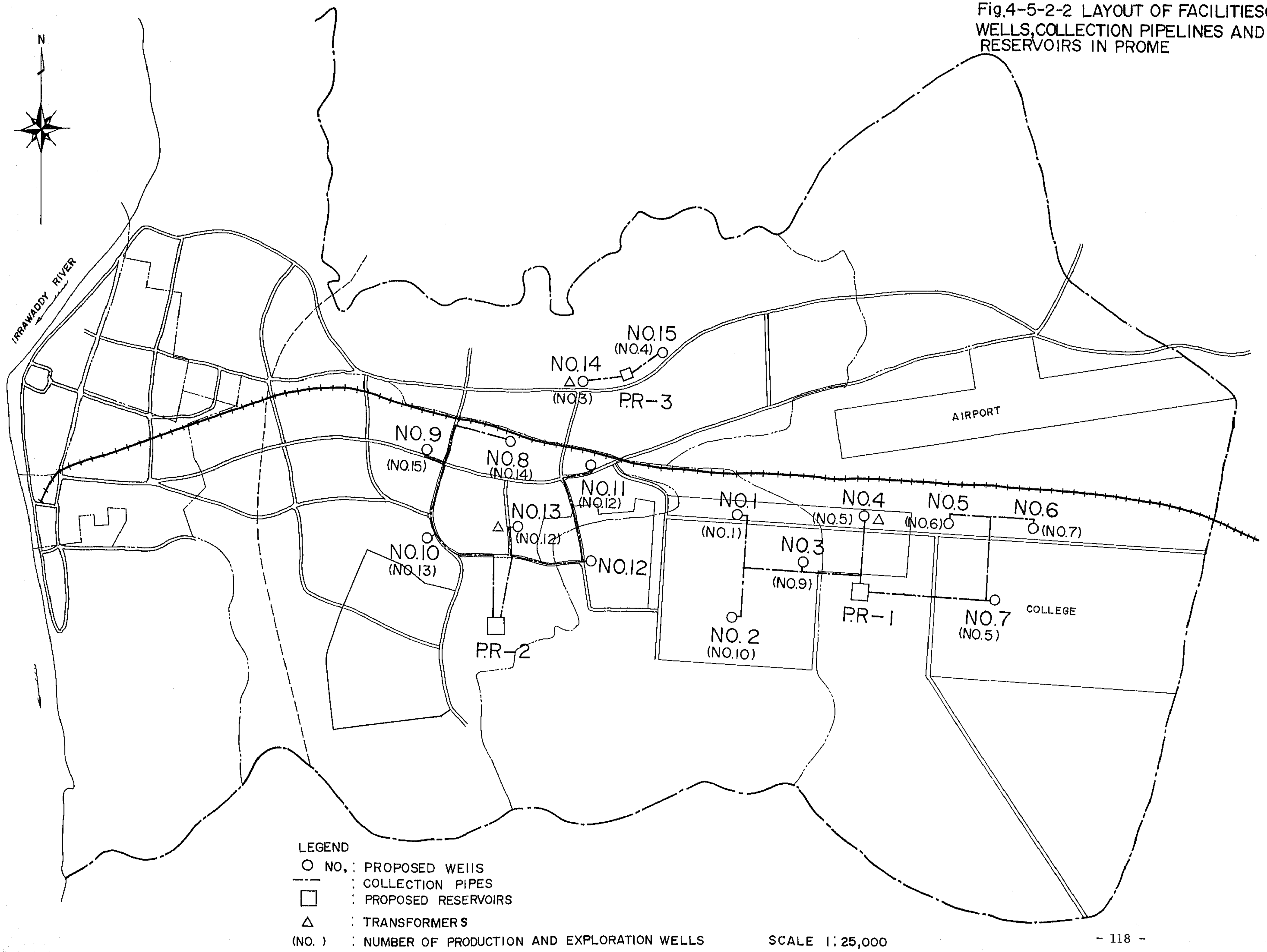
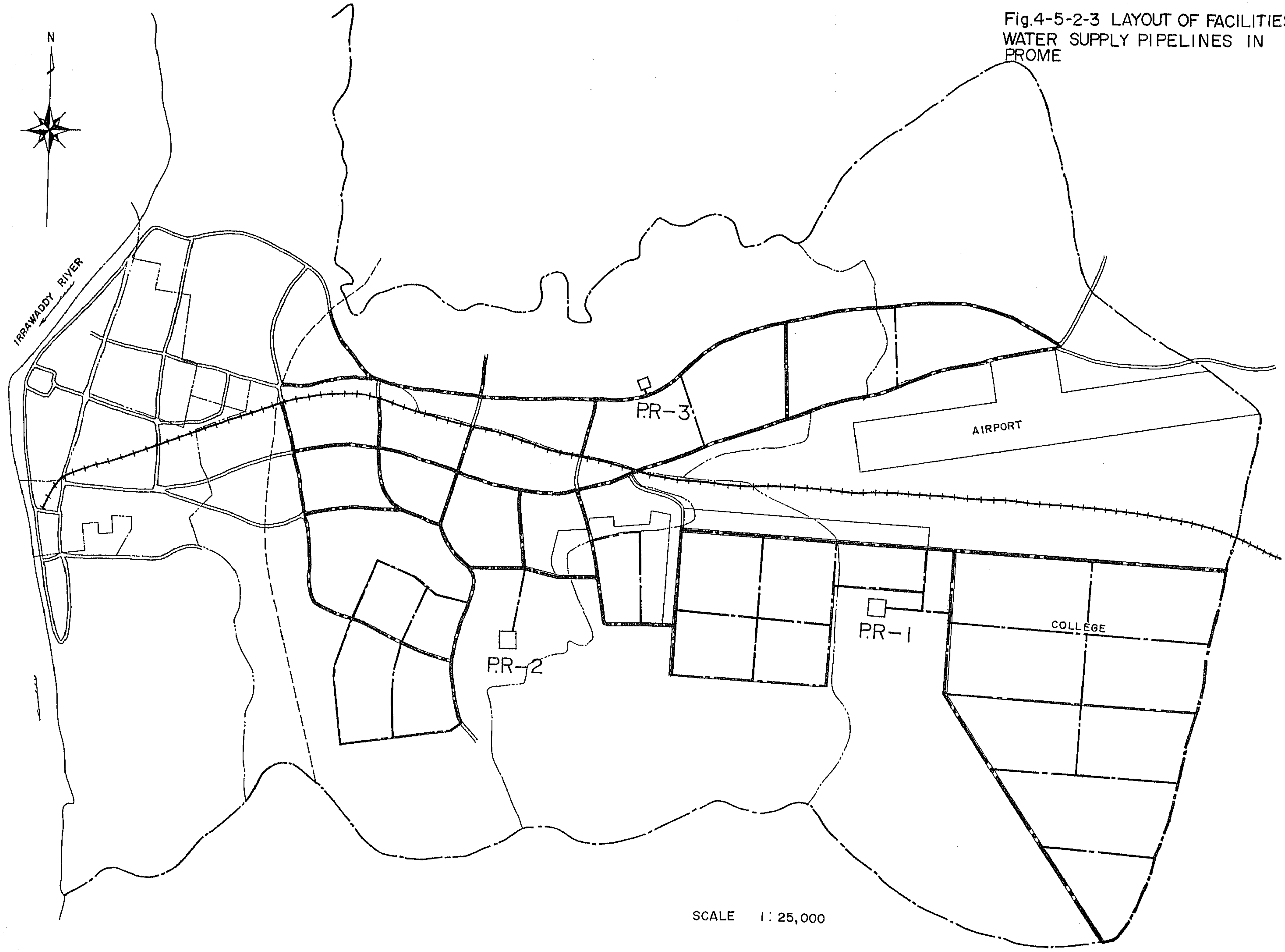


Fig.4-5-2-3 LAYOUT OF FACILITIES(II) WATER SUPPLY PIPELINES IN PROME



4.5.3 Proposed Facilities

Considering the calculation results (4.5.4) and others the scale of each facilities was determined as following.

i) Intake facility

a) Intake well

Designed intake	1,000m^3/d per well
Number of wells	15
Depth	150m average
Diameter of borehole upper	375mm
Diameter of borehole lower	311mm
Pump housing diameter	
Casing diameter	200mm
Gravel wall	φ3mm ∿ φ10mm

b) Intake pump room

Structure	brick 4.0m × 4.0m
Site	16m^2
Number	15

c) Intake pump

Motor output	30kW	15 units

ii) Water conveyance facility

- Collecting pipes (ductile cast iron pipe Type I)

diameter of pipe	length
φ200mm(φ8")	3.650m
φ250mm(φ10")	1.750m
φ300mm(φ12")	2.250m
φ350mm(φ14")	100m

· Specials	1 set
· Air valve	10 units
· Sluice valve	17 units

iii) Storage reservoir

Name	Structure	Capacity
P.R. No. 1	Reinforced concrete (underground)	$1,700m^3$
P.R. No. 2	Reinforced concrete (underground)	$1,600m^3$
P.R. No. 3	Reinforced concrete (elevated)	$290m^3$

iv) Distribution facility

- Distribution pipes (ductile cast iron pipe type I)

Diameter of pipe	Length
φ150mm (φ6")	30,500m
φ200mm (φ8")	400m

· Specials	1 set
· Air valve	30 units
· Sluice valve	82 units
· Stand pipe	50 units
· Fire-Hydrant	50 units

4.5.4 Calculations

i) Intake and water conveyance facility

Table of Pumping Head

Number of wells	Ground level		H.W.L. of reservoir (m)	Actual pumping head (m)
	Feets	Metres		
No. 1	130	40	76	76
No. 2	145	44	"	72
No. 3	145	44	"	72
No. 4	145	44	"	72
No. 5	150	46	"	70
No. 6	140	43	"	73
No. 7	155	47	"	69
No. 8	95	29	64	75
No. 9	90	27	"	77
No. 10	95	29	"	75
No. 11	110	34	"	70
No. 12	130	40	"	64
No. 13	110	34	"	70
No. 14	100	30	45	55
No. 15	100	30	"	55

Collection Main Pipe Lines

Line	Distance (L.M.)	Dia.	Quantity (m^3/min.)	Hydraulic gradient (%)	Velocity (m/sec)
No.1-I.C.	300	200(8")	1.0	2.4	0.6
No.2-I.C.	300	200(8")	1.0	2.4	0.6
I.C.-No.3	350	250(10")	2.0	2.8	0.7
No.3-I.C.	350	300(12")	3.0	2.5	0.8
No.4-I.C.	350	200(8")	1.0	2.4	0.6
I.C.-R.V.	100	350(14")	4.0	2.0	0.7
No.5-I.C.	250	200(8")	1.0	2.4	0.6
No.6-I.C.	250	200(8")	1.0	2.4	0.6
I.C.-No.7	500	250(10")	2.0	2.8	0.7
No.7-R.V.	700	300(12")	3.0	2.5	0.8
No.11-No.12	700	200(8")	1.0	2.4	0.6
No.12-I.C.	450	250(10")	2.0	2.8	0.7
No.13-I.C.	200	200(8")	1.0	2.4	0.6
I.C. - R.V.	400	300(12")	3.0	2.5	0.8
No.8-I.C.	550	200(8")	1.0	2.4	0.6
No.9-I.C.	150	200(8")	1.0	2.4	0.6
I.C.-No.10	450	250(10")	2.0	2.8	0.7
No.10-R.V.	800	300(12")	3.0	2.5	0.8
No.14-R.V.	300	200(8")	1.0	2.4	0.6
No.15-R.V.	300	200(8")	1.0	2.4	0.6

* Calculated using the Hazen-Williams formula.

List of Intake Pump

Number of wells	Actual pumping head	Friction loss of head by pipe line	Residual head required	Other head losses	Total head	Output of motor
No. 1	76 (m)	2.8 (m)	5 (m)	2 (m)	85.8 (m)	24.7 (kW)
No. 2	72	2.8	"	"	81.8	23.6
No. 3	72	1.1	"	"	80.1	23.1
No. 4	72	1.0	"	"	80.0	23.0
No. 5	70	3.8	"	"	80.8	23.3
No. 6	73	3.8	"	"	83.8	24.1
No. 7	69	1.8	"	"	77.8	22.4
No. 8	75	4.6	"	"	86.6	24.9
No. 9	77	3.6	"	"	87.6	25.2
No. 10	75	2.0	"	"	84.0	24.2
No. 11	70	3.9	"	"	80.9	23.3
No. 12	64	2.3	"	"	73.3	21.1
No. 13	70	1.5	"	"	78.5	22.6
No. 14	55	0.7	"	"	62.7	18.1
No. 15	55	0.7	"	"	62.7	18.1

Pump diameter

$$D = \sqrt{146 \frac{Q}{V}} = 146 \times \sqrt{\frac{1}{3.0}}$$

$$= 84(\text{mm}) \rightarrow \phi 100\text{mm}$$

where V: velocity in suction pipe (m/s)

Q: discharge (m^3/min)

Pump output

$$P_m = \frac{16.3 \cdot \gamma \cdot Q \cdot H}{y} (1 + \alpha) = \frac{16.3 \times 1.0 \times 1.0 \times 1.15}{65} \times H$$

$$= 0.288 \times H \text{ (kW)}$$

where γ: specific weight of water (kg/ℓ)

Q: discharge (m^3/min)

H: total head (m)

y: pump efficiency (%)

α: margin of error

ii) Storage reservoir

Six hours of maximum daily demand plus fire fighting requirements.

However, with respect to elevated tanks, from the structural and economic point of view, capacity is determined according to two hours of maximum daily demand plus fire fighting requirements.

P.R-1

Designed demand population: 33,000 (includes 3,000 at college)

Maximum daily demand per person

Consumers	195 ℓ/c/d
College	50 ℓ/c/d

Maximum daily demand

30,000 × 195ℓ/c/d + 3,000 × 50ℓ/c/d = 6,000m^3/d

Storage capacity

$$6{,}000m^3/d \times \frac{6}{24} + 144m^3/d = 1.644m^3 \fallingdotseq 1{,}700m^3$$

P.R-2

Designed demand population 28,000

Maximum daily demand per person 195ℓ/d

Maximum daily demand

$$28{,}000 \times 195\ell/c/d = 5{,}460m^3/d$$

Storage capacity

$$5{,}460m^3/d \times \frac{6}{24} + 144m^3/d = 1{,}509m^3/d \fallingdotseq 1.600m^3$$

P.R-3 (Elevated tank)

Designed demand population 9,000

Maximum daily demand per person 195ℓ/d

Maximum daily demand

$$9{,}000 \times 195\ell/c/d = 1{,}755m^3/d$$

Storage capacity

$$1.755m^3/d \times \frac{2}{24} + 144m^3/d = 290$$

iii) Water distribution facilities

On the basis of the Chart of Apportionment of Water Supply Areas and Distribution of Population in Figure 4.5.4.1, a network of pipes is hypothesized and prescribed quantities of water will be fed from the water distribution ponds erected in three places.

Water will be separately distributed through the network of pipes, in principle. With the possible breakdown of each water distribution taken into account, a connecting pipe will be laid between areas, and one network of pipes will be planned, in Figure 4.5.4.2.

The network of pipes was planned with a computer, according to the Hardy-Cross method. The conditions were set forth as follows:

i. Minimum water pressure: $0.5kg/cm^2$

ii. Designed minimum pipe diameter: ϕ150mm(ϕ6")

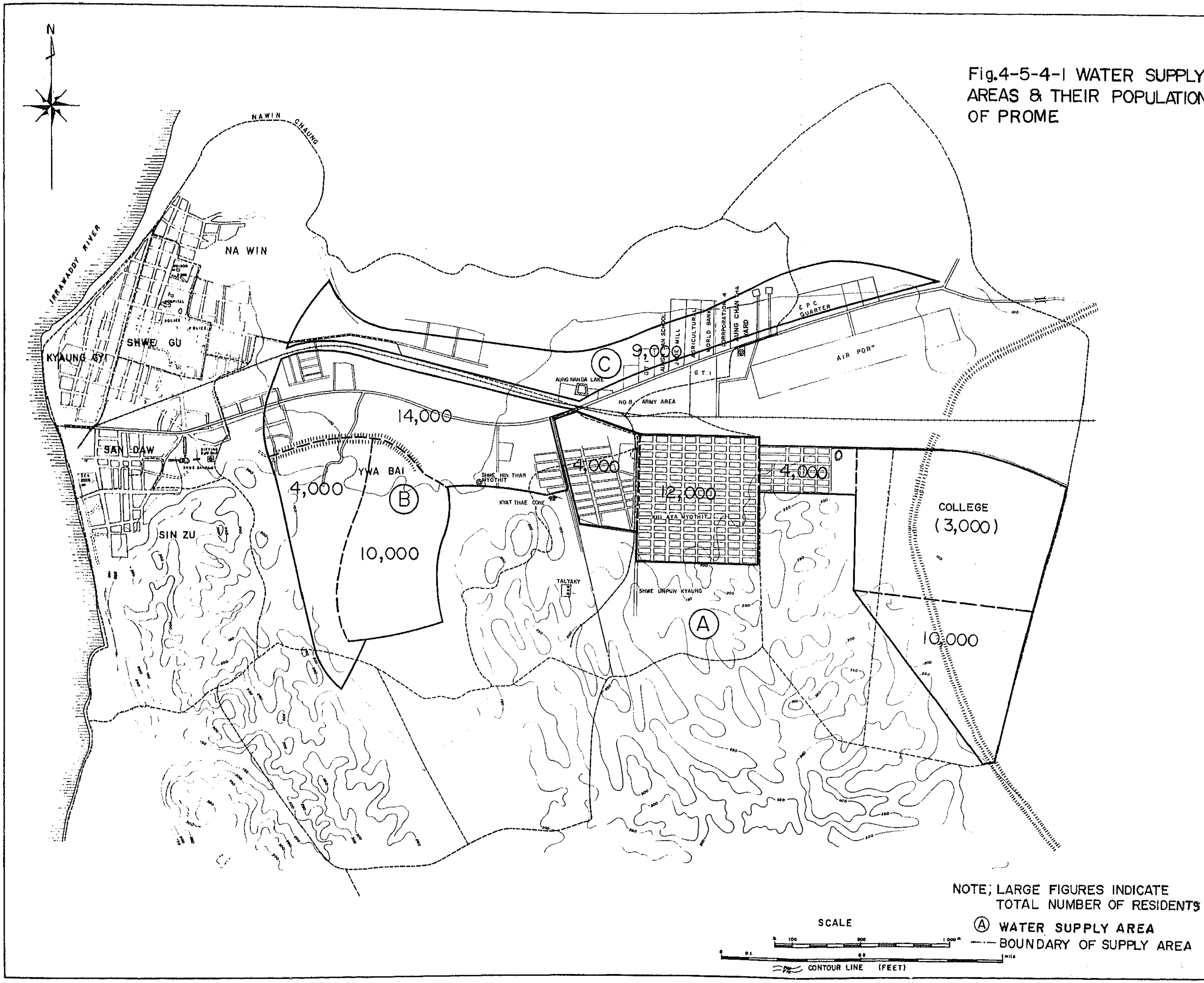
iii. Designed water distribution quantity: Designed maximum water supply per hour - water for consumption. However, the designed maximum water supply per hour is 1.5 times the maximum daily water supply. Specifications for water distribution are given in Table 4.5.4.1.

Table 4.5.4.1 Specifications for water distribution

Area		A area	B area	C area	Total
Water supply population		30,000	28,000	9,000	67,000
Designed water supply (m^3/d)	For domestic	5,850	5,460	1,755	13,065
	For commerce and industry	-	-	1,000	1,000
	College	150	-	-	150
	Subtotal	6,000	5,460	2,755	14,215
	For fire fighting	144	144	144	432
Maximum water supply per hour (ℓ/h)		105.8	96.5	49.5	251.8

CHAPTER 5 CONSTRUCTION OPERATION AND MAINTENANCE

Fig.4-5-4-1 WATER SUPPLY AREAS & THEIR POPULATIONS OF PROME



NOTE; LARGE FIGURES INDICATE TOTAL NUMBER OF RESIDENTS

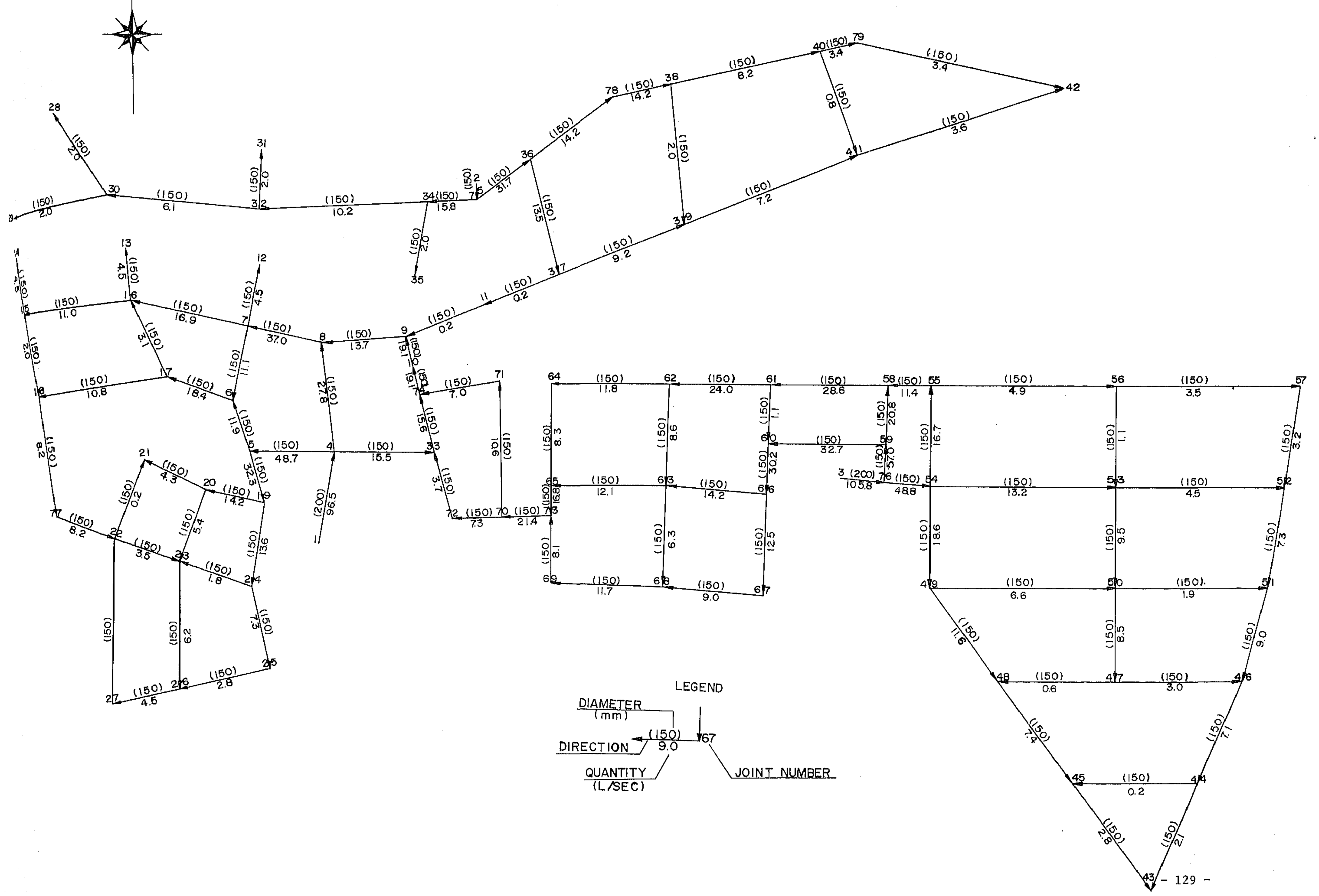
SCALE

Ⓐ WATER SUPPLY AREA

BOUNDARY OF SUPPLY AREA

CONTOUR LINE (FEET)

Fig.4-5-4-2 DISTRIBUTION PIPELINE NETWORK OF PROME



CHAPTER 5 CONSTRUCTION, OPERATION AND MAINTENANCE

5.1 Construction Cost

On the basis of the facilities programme given in the previous chapter, the construction cost is estimated in terms of prevailing prices (October 1981). The results are shown in Tables 5.1.1 through 5.1.3.

As for the breakdown of the construction cost, it is divided into the cost for construction equipment and materials and the labour cost. It is also divided into the cost for foreign goods and the cost for local goods.

The foreign goods, among others, include casings and screens as materials for wells, transformers and cables as power facilities, pumps as pumping facilities, pipes as water distribution facilities, and drilling machinery (including spare parts).

The local goods, among others, include cement, frames, crushed stone and timber, which are raw materials in the sector of equipment and materials. The labour cost and the sea and land transportation cost are included in the cost for domestic cargoes.

The total construction cost is 1,926 million yen (64 million Kyats) as indicated in Table 5.1.3. The Japanese share is 43% or 830 million yen, and the Burmese share is 57% or 1,096 million yen. (37 million Kyats)

* 1 Kyat ≒ 30 yen (As of August 1981)

Table 5.1.1 Construction Cost of Magwe

Facilities	Type of construction	Q'ty	Unit	82/83 ~ 84/85 (Total construction cost) Construction cost: Equipment and materials Foreign	Equipment and materials Local	Labour cost Local	Total	82/83 Construction cost: Equipment and materials Foreign	Equipment and materials Local	Labour cost Local	Total	83/84 Construction cost: Equipment and materials Foreign	Equipment and materials Local	Labour cost Local	Total	84/85 Construction cost: Equipment and materials Foreign	Equipment and materials Local	Labour cost Local	Total
Intake facilities	1-01 Construction of production wells	17	Ea	52,853 (1,762)	10,744 (358)	833 (28)	64,430 (2,148)	52,853 (1,762)	-	-	52,853 (1,762)	-	5,372 (179)	417 (14)	5,789 (193)	-	5,372 (179)	416 (14)	5,788
	1-02 Construction of exploration wells	13	"	6,462 (215)	7,501 (250)	559 (19)	14,522 (484)	6,462 (215)	-	-	6,462 (215)	-	3,751 (125)	280 (9)	4,031 (134)	-	3,750 (125)	279 (9)	4,029
	1-03 Construction of observation wells	33	"	5,378 (179)	13,200 (440)	1,254 (42)	19,832 (661)	5,378 (179)	-	-	5,378 (179)	-	6,600 (220)	627 (21)	7,227 (291)	-	6,600 (220)	627 (21)	7,227
	1-04 Construction of intake pump facilities	17	"	26,816 (894)	1,700 (37)	510 (17)	29,026 (968)	26,816 (894)	-	-	26,816 (894)	-	850 (28)	255 (9)	1,105 (39)	-	850 (28)	255 (9)	1,105
	1-05 Construction of intake pump rooms	17	"	-	3,740 (125)	850 (28)	4,590 (153)	-	-	-	-	-	1,870 (62)	425 (14)	2,295 (77)	-	1,870 (62)	425 (14)	2,295
	1-06 Installation of suspended electric power wires	1	Job	19,292 (643)	3,940 (131)	950 (32)	24,182 (806)	19,292 (643)	-	-	19,292 (643)	-	1,970 (66)	475 (16)	2,445 (82)	-	1,970 (66)	475 (16)	2,445
	Subtotal			110,801 (3,693)	40,825 (1,360)	4,956 (165)	156,582 (5,219)	110,801 (3,693)	-	-	110,801 (3,693)	-	20,413 (680)	2,479 (83)	22,892 (763)	-	20,412 (680)	2,477 (83)	22,889
Conduit facilities	2-01 Installation of conduits	8,700	m	63,463 (2,115)	-	10,920 (364)	74,563 (2,485)	63,463 (2,115)	-	-	63,463 (2,115)	-	-	5,460 (182)	5,460 (182)	-	-	5,460 (182)	5,460
	Subtotal			63,463 (2,115)	-	10,920 (364)	74,563 (2,485)	63,463 (2,115)	-	-	63,463 (2,115)	-	-	5,460 (182)	5,460 (182)	-	-	5,460 (182)	5,460
Water storage facilities	3-01 Construction of reservoirs	3	pond	-	104,200 (3,473)	26,000 (867)	130,000 (4,340)	-	-	-	-	-	52,100 (1,737)	13,000 (433)	65,100 (2,170)	-	52,100 (1,737)	13,000 (433)	65,100
	Subtotal			-	104,200 (3,473)	26,000 (867)	130,200 (4,340)	-	-	-	-	-	52,100 (1,737)	13,000 (433)	65,100 (2,170)	-	52,100 (1,737)	13,000 (433)	65,100
Distribution facilities	4-01 Construction of auxiliary tanks	1	Ea	-	900 (30)	225 (9)	1,125 (38)	-	-	-	-	-	450 (15)	123 (4)	573 (19)	-	450 (15)	122 (4)	572
	4-02 Installation of distribution pipes	17,700	m	110,684 (3,689)	-	19,212 (640)	129,896 (4,330)	-	-	-	-	36,844 (1,229)	-	6,404 (213)	43,288 (1,443)	73,800 (2,460)	-	12,808 (427)	86,608
	Subtotal			110,684 (3,689)	900 (30)	19,437 (648)	131,021 (4,367)	110,684 (3,689)	-	-	110,684 (3,689)	36,884 (1,229)	450 (15)	6,527 (217)	43,861 (1,462)	73,800 (2,460)	450 (15)	12,930 (431)	87,180
Total direct construction cost		1	Job	285,128 (9,504)	145,925 (4,864)	61,313 (2,044)	492,366 (16,412)	174,444 (9,504)	-	-	174,444 (9,504)	36,884 (1,229)	72,963 (2,432)	27,466 (916)	137,313 (4,577)	73,800 (2,460)	72,962 (2,432)	33,867 (1,129)	180,629
Miscellaneous expenses		1	"	-	-	123,091 (4,103)	123,091 (4,103)	-	-	50,000 (1,667)	50,000 (1,667)	-	-	23,091 (770)	23,091 (770)	-	-	50,000 (1,667)	50,000
Boring machinery		1	"	234,360 (7,812)	-	-	234,360 (7,812)	234,360 (7,812)	-	-	234,360 (7,812)	-	-	-	-	-	-	-	-
Maritime and overland transport cost		1	"	-	50,183 (1,673)	-	50,183 (1,673)	-	50,183 (1,673)	-	50,183 (1,673)	-	-	-	-	-	-	-	-
Total				519,488 (1,732)	196,108 (6,537)	184,404 (6,147)	900,000 (30,000)	408,804 (13,627)	50,183 (1,673)	50,000 (1,667)	508,987 (16,966)	36,884 (1,229)	72,963 (2,432)	50,557 (1,685)	160,404 (5,347)	73,800 (2,460)	72,962 (2,432)	83,867 (2,800)	230,629 (7,688)
				715,596 (2,385)				458,987 (15,300)				109,847 (3,662)				146,762 (4,892)			

Note: Yen in thousands As of August 1981

(Kyats in thousands) 1 Kyat ≒ 30 yen

Table 5.1.2 Construction Cost of Prome

Fiscal year / Facilities	82/83 ~ 84/85 (Total construction cost)							82/83				83/84				84/85			
Facilities	Type of construction	Q'ty	Unit	Construction cost				Construction cost				Construction cost				Construction cost			
				Equipment and materials		Labour cost	Total	Equipment and materials		Labour cost	Total	Equipment and materials		Labour cost	Total	Equipment and material		Labour cost	Total
				Foreign	Local	Local		Foreign	Local	Local		Foreign	Local	Local		Foreign	Local	Local	
Intake facilities	1-01 Construction of production wells	15	Ea	54,236 (181)	9,765 (326)	750 (25)	64,752 (2,158)	54,237 (181)	-	-	54,237 (181)	-	4,883 (163)	375 (13)	5,258 (175)	-	4,882 (163)	375 (13)	5,257 (175)
	1-02 Construction of exploration wells	11	"	6,839 (228)	6,776 (226)	495 (17)	14,100 (470)	6,839 (228)	-	-	6,839 (228)	-	3,388 (113)	248 (8)	3,636 (121)	-	3,388 (113)	247 (8)	3,635 (121)
	1-03 Construction of observation wells	29	"	5,738 (191)	12,180 (406)	1,160 (39)	19,078 (636)	5,738 (191)	-	-	5,738 (191)	-	6,090 (203)	580 (19)	6,670 (222)	-	6,090 (203)	580 (19)	6,670 (222)
	1-04 Construction of intake pump facilities	15	"	32,166 (1,072)	1,500 (50)	450 (15)	34,116 (1,137)	32,166 (1,072)	-	-	32,166 (1,072)	-	750 (25)	225 (8)	975 (33)	-	750 (25)	225 (8)	975 (33)
	1-05 Construction of intake pump rooms	15	"	-	3,300 (11)	750 (25)	4,050 (1,352)	-	-	-	-	-	1,650 (55)	375 (13)	2,025 (168)	-	1,650 (55)	375 (13)	2,025 (68)
	1-06 Installation of suspended electric power wires	1	Job	18,486 (616)	3,600 (120)	900 (30)	22,986 (766)	18,486 (616)	-	-	18,486 (616)	-	1,800 (60)	450 (15)	2,250 (75)	-	1,800 (60)	450 (15)	2,250 (75)
	Subtotal			117,466 (3,916)	37,121 (1,237)	4,505 (150)	159,092 (5,303)	117,466 (3,916)	-	-	117,466 (3,916)	-	18,561 (619)	2,253 (175)	20,814 (694)	-	18,560 (619)	2,252 (75)	20,812 (694)
Conduit facilities	2-01 Installation of conduits	2,750	m	69,370 (2,312)	-	11,707 (290)	81,077 (270)	69,370 (2,312)	-	-	69,370 (2,312)	-	-	5,854 (195)	5,854 (195)	-	-	5,853 (195)	5,853 (195)
	Subtotal			69,370 (2,312)	-	11,707 (290)	81,077 (270)	69,370 (2,312)	-	-	69,370 (2,312)	-	-	5,854 (195)	5,854 (195)	-	-	5,853 (195)	5,853 (195)
Water storage facilities	3-01 Construction of reservoirs	3	Pond	-	109,900 (3,663)	27,500 (917)	137,400 (4,580)	-	-	-	-	-	54,950 (1,832)	13,750 (458)	68,700 (2,290)	-	54,950 (1,832)	13,750 (458)	68,700 (2,290)
	Subtotal			-	109,900 (366)	27,500 (917)	137,400 (4,580)	-	-	-	-	-	54,950 (1,832)	13,750 (458)	68,700 (2,290)	-	54,950 (1,832)	13,750 (458)	68,700 (2,290)
Distribution facilities	4-01 Construction of auxiliary tanks			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4-02 Installation of distribution pipes	30,900	m	182,379 (6,079)	-	32,232 (1,094)	214,611 (7,154)	-	-	-	-	60,793 (2,026)	-	10,744 (358)	71,537 (2,385)	121,586 (4,053)	-	21,488 (716)	143,074 (4,769)
	Subtotal			182,379 (6,079)	-	32,232 (1,074)	214,611 (7,154)	-	-	-	-	60,793 (2,026)	-	10,744 (358)	71,537 (2,385)	121,586 (4,053)	-	21,488 (1,716)	143,074 (4,769)
Total direct construction cost		1	Job	369,215 (12,307)	147,021 (4,901)	75,944 (2,531)	592,180	186,836 (6,228)	-	-	186,836 (6,228)	60,793 (2,026)	73,511 (2,450)	32,601 (1,087)	166,905 (5,564)	121,586 (4,053)	73,510 (2,450)	43,343 (1,445)	238,439 (7,948)
Miscellaneous expenses		1	"			148,045 (4,935)	148,045 (4,935)	-	-	50,000 (1,667)	50,000 (1,667)	-	-	48,045 (1,602)	48,045 (1,602)	-	-	50,000 (1,667)	50,000 (1,667)
Boring machinery		1	"	234,360 (7,812)	-	-	234,360 (7,812)	234,360 (7,812)	-	-	234;360 (7,812)	-	-	-	-	-	-	-	-
Maritime and overland transport cost		1	"	-	51,415 (1,715)	-	51,415 1,715)	-	51,415 (1,715)	-	51,415 (1,715)	-	-	-	-	-	-	-	-
Total				603,575 (20,119)	198,436 (6,615)	223,989 (7,466)	1,026,000 (34,200)	421,196 (14,040)	51,415 (1,715)	50,000 (1,667)	522,611 (17,420)	60,793 (2,020)	73,511 (2,450)	80,646 (2,688)	214,950 (7,165)	121,586 (4,653)	73,510 (2,450)	93,343 (3,111)	288,439 (9,615)
				802,011 (26,734)				472,611 (15,754)											

Note: Yen in thousands (Kyats in thousands) As of August 1981

1 Kyat ≒ 30 yen

Table 5.1.3 Overall Construction Cost

Fiscal year / Facilities				82/83 ∿ 84/85 (Overall construction cost)				82/83				83/84				84/85			
				Construction cost				Construction cost				Construction cost				Construction cost			
				Equipment and materials		Labour cost	Total	Equipment and materials		Labour cost	Total	Equipment and materials		Labour cost	Total	Equipment and materials		Labour cost	Total
Facilities	Type of construction	Q'ty	Unit	Foreign	Local	Local		Foreign	Local	Local		Foreign	Local	Local		Foreign	Local	Local	
	1-01 Construction of production wells	32	Ea	*107,090 (3,636)	20,509 (684)	1,583 (53)	129,182 (4,306)	*107,090 (3,636)	-	-	107,090 (3,636)	-	10,255 (342)	792 (26)	11,047 (368)	-	10,254 (342)	791 (26)	11,045 (368)
	1-02 Construction of exploration wells	24	"	*13,300 (443)	14,277 (476)	1,054 (25)	28,631 (954)	*13,300 (443)	-	-	13,300 (443)	-	7,139 (238)	527 (18)	7,667 (256)	-	7,138 (238)	526 (18)	7,664 (256)
	1-03 Construction of observation wells	62	"	*11,116 (371)	25,380 (846)	2,414 (80)	38,910 (1,297)	*11,116 (371)	-	-	11,116 (371)	-	12,690 (423)	1,207 (40)	13,897 (463)	-	12,690 (423)	1,207 (40)	13,891 (403)
Intake facilities	1-04 Construction of intake pump facilities	32	"	*58,982 (1,966)	3,200 (107)	960 (32)	63,142 (210)	*58,982 (1,966)	-	-	58,982 (1,966)	-	1,600 (53)	480 (16)	2,080 (69)	-	1,600 (53)	480 (16)	2,080 (69)
	1-05 Construction of intake pump rooms	32	"	-	7,040 (235)	1,600 (53)	8,640 (288)	-	-	-	-	-	3,520 (117)	800 (27)	4,320 (144)	-	3,520 (117)	800 (27)	4,320 (144)
	1-06 Installation of suspended electric power wires	2	Job	*37,778 (1,260)	7,540 (251)	1,850 (62)	47,168 (1,572)	*37,778 (1,260)	-	-	37,778 (1,260)	-	3,770 (126)	925 (31)	4,695 (157)	-	3,770 (126)	925 (31)	4,695 (157)
	Subtotal			*228,267 (7,609)	77,946 (2,598)	9,461 (315)	315,674 (10,522)	*228,267 (7,609)	-	-	228,267 (7,609)	-	38,974 (1,299)	4,732 (158)	43,706 (1,457)	-	38,972 (1,299)	4,729 (158)	43,701 (1,457)
Conduit facilities	2-01 Installation of conduits	16,450	m	*133,013 (4,434)	-	22,627 (754)	155,640 (5,188)	*133,013 (4,434)	-	-	133,013 (4,434)	-	-	11,314 (377)	11,314 (377)	-	-	113,133 (377)	113,133 (377)
	Subtotal			*133,013 (4,434)	-	22,627 (754)	155,640 (5,188)	*133,013 (4,434)	-	-	133,013 (4,434)	-	-	11,314 (377)	11,314 (377)	-	-	113,133 (377)	113,133 (377)
Water storage facilities	3-01 Construction of reservoirs	6	Ea	-	214,100 (7,137)	53,500 (1,783)	267,600 (8,920)	-	-	-	-	-	107,050 (3,568)	26,750 (892)	133,800 (4,460)	-	107,050 (3,568)	26,750 (892)	133,800 (4,460)
	Subtotal			-	214,100 (7,137)	35,500 (1,783)	267,600 (8,920)	-	-	-	-	-	107,050 (3,568)	26,750 (892)	133,800 (4,460)	-	107,050 (3,568)	26,750 (892)	133,800 (4,460)
	4-01 Construction of auxiliary tanks	1	Ea	-	900 (30)	225 (8)	1,125 (38)	-	-	-	-	-	450 (15)	123 (4)	573 (19)	-	450 (15)	122 (4)	572 (19)
Distribution facilities	4-02 Installation of distribution pipes	48,600	m	293,063 (9,769)	-	51,444 (1,715)	344,507 (11,484)	-	-	-	-	97,677 (3,256)	-	17,148 (572)	114,825 (3,828)	195,386 (6,513)	-	34,296	229,682 (7,656)
	Subtotal			293,063 (9,769)	900 (30)	51,669 (1,715)	345,632 (11,521)	-	-	-	-	97,677 (3,256)	450 (15)	17,223 (574)	115,350 (3,845)	195,386 (6,513)	450 (15)	34,446 (1,148)	230,282 (768)
Total direct construction cost		2	Job	654,343 (21,811)	292,946 (9,765)	137,257 (4,575)	1,084,546 (36,152)	*361,280 (12,043)	-	-	361,280 (12,043)	97,677 (3,256)	146,474 (4,882)	60,019 (2,000)	304,170 (10,139)	195,386 (6,513)	146,472 (4,882)	77,238 (2,575)	419,096 (13,970)
Miscellaneous expenses		2	"	-	-	271,136 (9,038)	271,136 (9,038)	-	-	100,000 (3,333)	100,000 (3,333)	-	-	71,136 (2,371)	71,136 (2,371)	-	-	100,000 (3,333)	100,000 (3,333)
Boring machinery		2	"	*468,720 (15,624)	-	-	468,720 (15,624)	*468,720 (15,624)	-	-	468,720 (15,624)	-	-	-	-	-	-	-	-
Maritime and overland transport cost		2	"	-	101,598 (3,387)	-	101,598 (3,387)	-	101,598 (3,367)	-	101,598 (3,367)	-	-	-	-	-	-	-	
Total				1,123,063 (37,435)	394,544 (13,151)	408,393 (13,613)	1,926,000 (64,200)	*830,000 (27,667)	101,598 (3,387)	100,000 (3,333)	1,031,598 (34,387)	97,677 (3,256)	146,474 (4,882)	131,203 (4,373)	375,354 (12,512)	195,386 (6,513)	146,472 (4,882)	177,238 (5,908)	519,096 (17,303)
				1,517,607 (50,587)				931,598 (31,053)				244,151 (8,138)				341,858 (11,395)			

Note: Yen in thousands As of August 1981

(Kyats in thousands) 1 Kyat ≒ 30 yen

* Japan Grant Aid

5.2 Construction Schedule

The construction schedule of this programme is shown in Table 5.2.1.

The specifications for orders will be prepared by the Burmese Government three months after the exchange of E/N (30 october 1981) In the subsequent six months, orders will be placed. Production and transportation will be made with in seven months subsequently.

After the arrival of equipment and materials in Burma, a period of above three months will be set aside to make preparations for construction. After the lapse of this period, drilling will be conducted. Midway in the course of this drilling, the actual pumping quantity per well and the number and position of wells will be finally determined. With this in mind, the detailed designing of facilities will be set aside four months after the drilling is started.

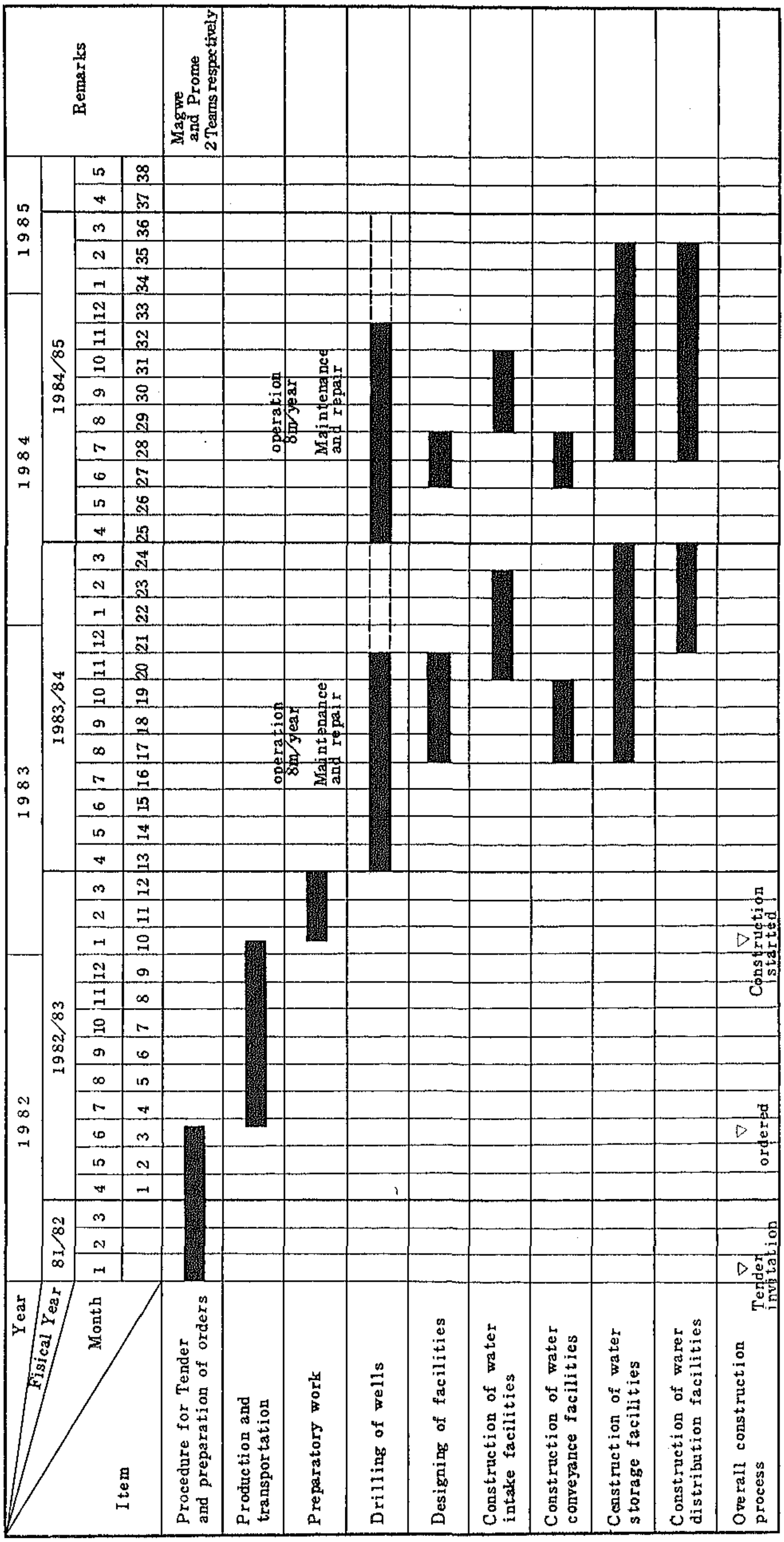
With the meteorological conditions taken into account, the number of workable months is set at eight a year.

The progress of construction depends on the way the Burmese Governments a budget during the construction period. According to the basic policy presented by the R.C.D.C. it is enfasized that the construction be brought to completion in two or three years. With this in mind, the entire construction period is set at about three years from the procedure for tender.

5.3 Implementation

For the new water supply projects in Magwe and Prome, the construction corporation will not be commissioned by the Township Development Committee to carry on the implementation of construction works, unlike with the previous similar projects. The new water supply project is to be done by the General

6. The overall Imprementation schedule is shown below



Management Office, Magwe•Prome, as it is temporarily named, and will soon go into operation.

The General Affairs Department and the Rangoon City Development Committee (R.C.D.C.) at present are discussing a plan to create the above-mentioned office under the General Affairs Department, along with the R.C.D.C. and M.C.D.C. controlled by the department's three divisions, and then assign the department to supervise it. (Refer to Fig. 5.3.1)

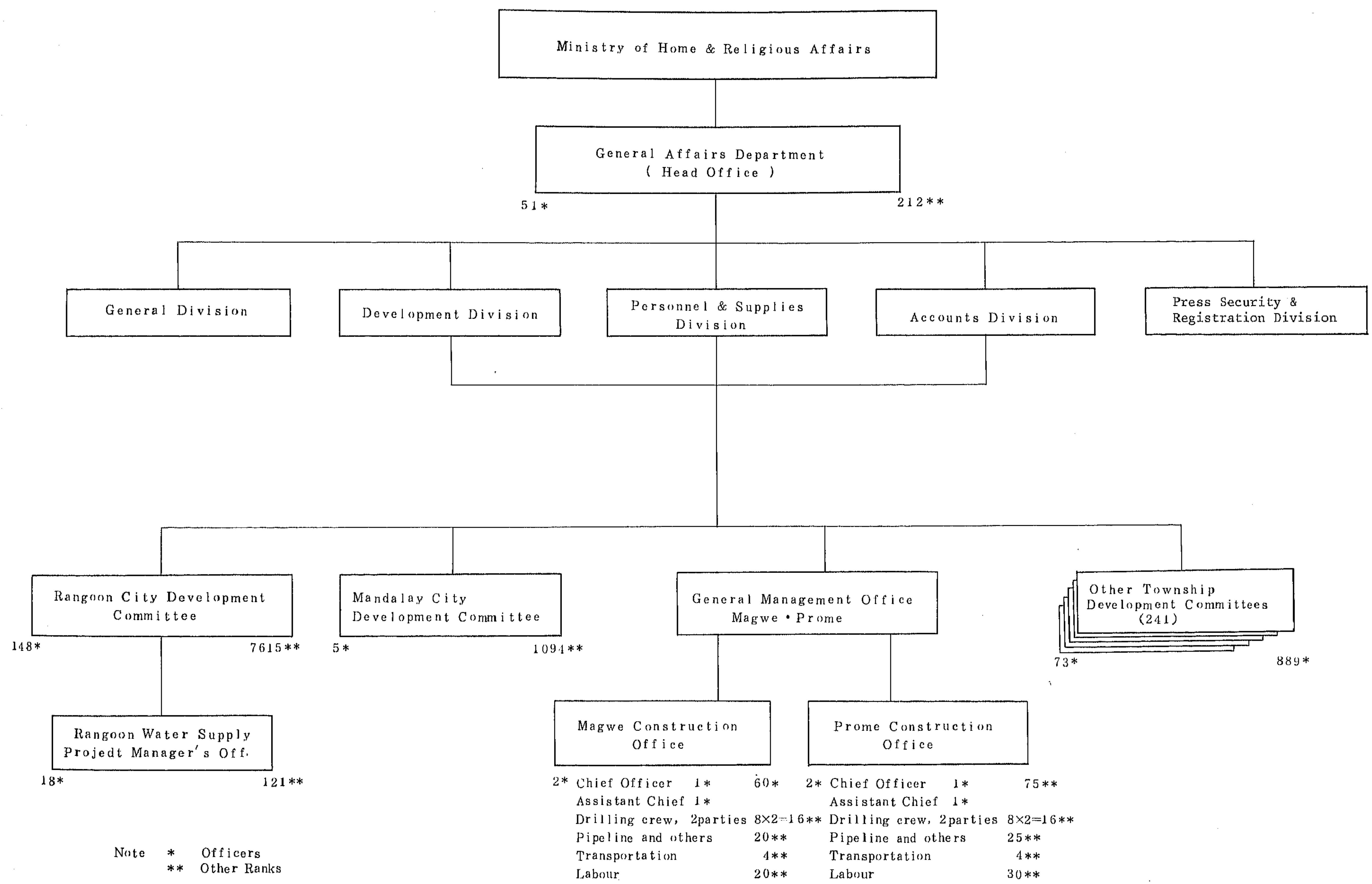
The planned General Management office will conduct construction works for both areas. But it is necessary to station a supervisor, granted with the necessary authority over each area, and ask him to promote development efforts, because Magwe is as much as 150 kilometers away from Prome and their construction situations are expected to differ considerably.

In the present water supply development projects, research through well drillings should be done earlier, so as to locate production wells, and to perform detailed designing for subsequent implementation of construction works. Also necessary is to launch an integrated process of research, designing and construction. Under these circumstances, too, separate supervision of Magwe and Prome is necessary.

The regional supervisor's office to be set up in both Magwe and Prome should be staffed with technical officers and other lower-ranked members who assist the supervisor. (Temporarily named, Magwe Construction Office and Prome Construction Office.)

The technical staff will be composed of engineers from the organizations associated with the General Affairs Department, technical members of regional development committees and others. In the Magwe area, two officers and 60 of other ranks will be recruited. In Prome, on the other hand, two officers and 75 technical staffers of other ranks are to be assigned.

Fig. 5—3—1 Organizational Chart of the General Affairs Department and General Management Office,Magwe• Prome



The construction costs will be financed by the national Myanma Economic Bank, and they will be reimbursed with the revenues from water supply taxes and water supply charges.

5.4 Operation and Maintenance

Under this project, water supply system will be laid on for the entire area of Magwe and Prome, in addition to the existing water systems. Given this factor, it is necessary to operate and maintain the water systems so that the townspeople may be blessed with drinking water, without constant anxiety.

For the operation and maintenance, the following will be developed.

- o Organization
- o Administration
- o Service

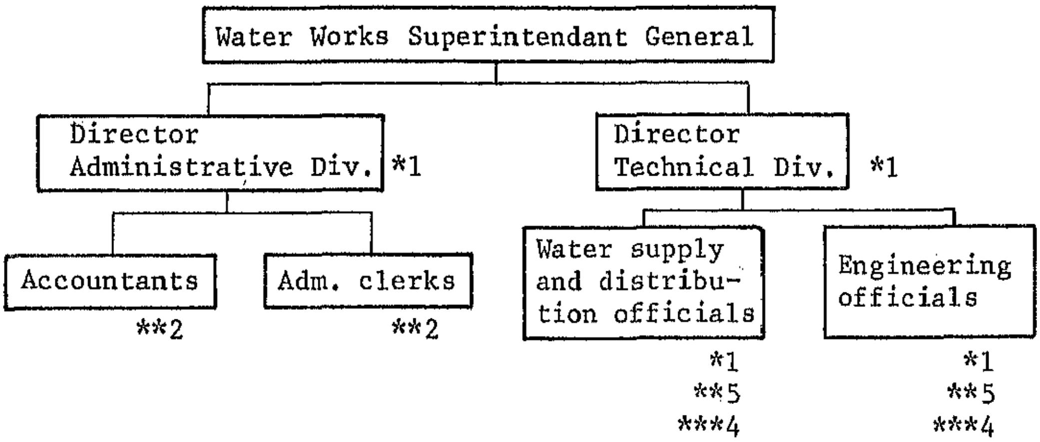
i) Organization

The Township Development Committee (a local autonomous entity) holds itself responsible for the operation and maintenance of the water works. For this project, too, there is a need to carry out operation and maintenance in the following system under the Township Development Committee.

A water works superintendent general will be assigned to take overall charge of the water works.

Under the water works superintendent general, a technical division director will be assigned as the person responsible for the operation and maintenance of technology. Under the director, engineering officials and water supply and distribution officials will be placed. The engineering officials shall take charge of the operation and maintenance of the section from the water source to the storage tanks, whereas the water supply and distribution officials shall be in charge of those

of the main and branch pipes, and the faucets. In the sector of administration, a division director will be assigned. Under the director, administrative clerks and accounts will be placed to deal with administrative matters on the operation and maintenance. The organizational chart of the water service and the assignment of personnel are indicated below.



* (Officers)
** (Other Ranks)
*** Labour

Remarks: The chairman of the Township Development Comittee serves as the water works superintendent general some cases.

ii) Administration

Administration will be divided into technical and clerical sectors. This is not the place for an elucidation on the clerical sector.

In the technical sector operation and maintenance will be conducted on the following under a technical administrator.

a) Water Source and Incidental Facilities

This is not the place to dwell on the person responsible for operation and maintenance of the water sources, as a description is given in the guideline attached to the report.

b) Filtration Plants and Water Tanks

The filtration plants and water tanks must always be in the best condition. The facilities must be inspected at least once a year and, if necessary, repaired.

c) Water Distribution Facilities

The Section between the Storage Reservoir and faucets. The distribution pipe will go through the filled up area, so that there is a need to prevent leakage and inflow of foul water through damage to the distribution pipe. It is also necessary to detect leaks and to repair the damaged parts as early as possible.

iii) Service

The water facilities are designed to offer public service to community residents. Particularly, in this project, where emphasis is put on urban drinking water, it is necessary to make constant efforts for their operation and maintenance so that water supply may not be disrupted even temporarily.

iv) Operation and maintenance cost

In principle, the operation and maintenance cost will be provided by the Township Development Committee through the revenues from water supply tax and charges. For this purpose, it

is necessary to calculate operation and maintenance cost and other expenditures, with which to determine a water supply charging sysem, covering water supply tax and charges.

The following is the approximate annual operation and maintenance cost for each well and for all wells in Magwe and Prome. (as of August 1981, 1 Kyat ≒ 30 yen)

Magwe

a)	Energy cost	:	15kW × 18 hrs. × 365 days × 0.25 Kyats/kW = 24,637.5 Kyats/year
	Operating and security	:	4,320.0 Kyats
	Total operation cost	:	28,957.5 Kyats/well/year
b)	Maintenance cost		
	Maintenance	:	3,000 Kyats
	Electrical component	:	1,000 Kyats
	Total maintenance cost	:	4,000 kyats/well/year
c)	Overall cost	:	32,937.5 Kyats/well/year
d)	Magwe 17 wells cost	:	≑ 560,000 Kyats/year

Prome

a)	Energy Cost		
	Operating and security	:	30kW × 18 hrs. × 365 days × 0.25 Kyats/kW = 49,275 Kyats/year
	Total operation cost	:	4,320 Kyats
b)	Maintenance cost	:	53,595.0 Kyats/well/year
	Maintenance	:	3,000.0 Kyats
	Electrical component	:	1,500.0 Kyats
	Total maintenance cost	:	4,500.0 Kyats/well/year

c) Overall cost : 58,095 Kyats/well/year

d) Prome 15 wells cost : 872,000 Kyats/year

The annual cost for operation and maintaining wells is 560,000 Kyats/year in Magwe and 872,000 Kyats/year in Prome.

Also, as to the maintenance cost for water-supply systems, the annual personnel costs are almost the same in both areas, excepting that for superintendent general and number of the Administrative Division (as of August 1981).

Type of job	No. of staffers	Annual personnel cost	Total cost (Kyats)
Sub Assistant Engineer	1	6,300	6,300
Junior Engineer	2	5,040	10,080
Engineer Grade (1)	2	3,600	7,200
" (2)	4	3,360	13,440
" (3)	4	2,520	10,080
Labour	8	2,160	17,280
Total	21		≒ 65,000 Kyats

Besides the personnel cost for staffmembers, expenses for materials, non-durable goods and office equipment altogether, are taken as the total annual expenditures, 80,000 Kyats. In Magwe, overall rough estimate for the total annual expenditures of operation and maintenance costs is 640,000 Kyats per year, and in Prome 952,000 Kyats per year respectively.