2.5 NATURAL CONDITITIONS

Yangon City occupies the southern portion of the country and belongs to Yangon District. The central of City (port area/downtown) is located 34km (21miles) inland from the mouth of Yangon River. The city is physically divided into five blocks by four rivers namely: (a) Pazundaung Creek, (b) Hlaing River, (c) Pan Hlaing River and (d) Thunday Canal. There are eleven (11) bridges in the city, which have traffic connections in northern three blocks. The transportation to other two blocks is either by ferry or boat.

2.5.1 Topography

The relief of the City varies from levelled plains to lowland hills in the central part as shown in Figure 2.4 below.

Area on the center has lowland hills commonly known as the fault ponds with artificial dam namely Kan Daw Gyi Lake, Inya Lake and Hlawga Lake. This long and narrow spur of Pegu Yomas in the central area runs almost N-S direction with an average height of 30m (100ft) and degenerates gradually into levelled plains in eastwards and westwards.

Level plains are extensive and are found mostly in the eastern and western parts as broad level bottoms along the rivers. These levelled lands are formed by delta deposits, areas of which are swampy and are almost occupied by paddy fields with elevation between about 3m (10ft) to 6m (20ft) above sea level.

2.5.2 Geology

An area of Myanmar has dominant features of fold mountains, ranges, cordilleras and longitudinal valleys with N-S direction, most areas of which are mainly attributed to tectonic actions originated from the Himalayas. In this relation, the Yangon City lies in the delta of the Irrawaddy on the bank of Hlaing River.

Based on stratigraphic correlation, the oldest rocks of Oligocene and Miocene epochs are the completely folded and faulted assemblage of marine sedimentary rocks. Overlying unconformably to the basement complex is the Pliocene sequence of sedimentary rocks. The main structures trend more or less N-S direction. In general, the structural trend of the city is attributed to moderate lowland hills. Rock units significant to groundwater storage and permeability are briefly classified in Table 2.4.

The rock units in the city are classified into three main series/groups based on the geologic ages. In geologic age these from older to younger are; (1) the Miocene and Older Systems-Pegu Group, (2) the Pliocene Series-Irrawaddy Series and (3) Pleisto-Holocene System-Quaternary Deposits, respectively mentioned above table by the same order.

The grouping of rock units is related to their potential as groundwater sources. The younger rocks

are essential in groundwater development because of their porosity and permeability relative to the older rocks.

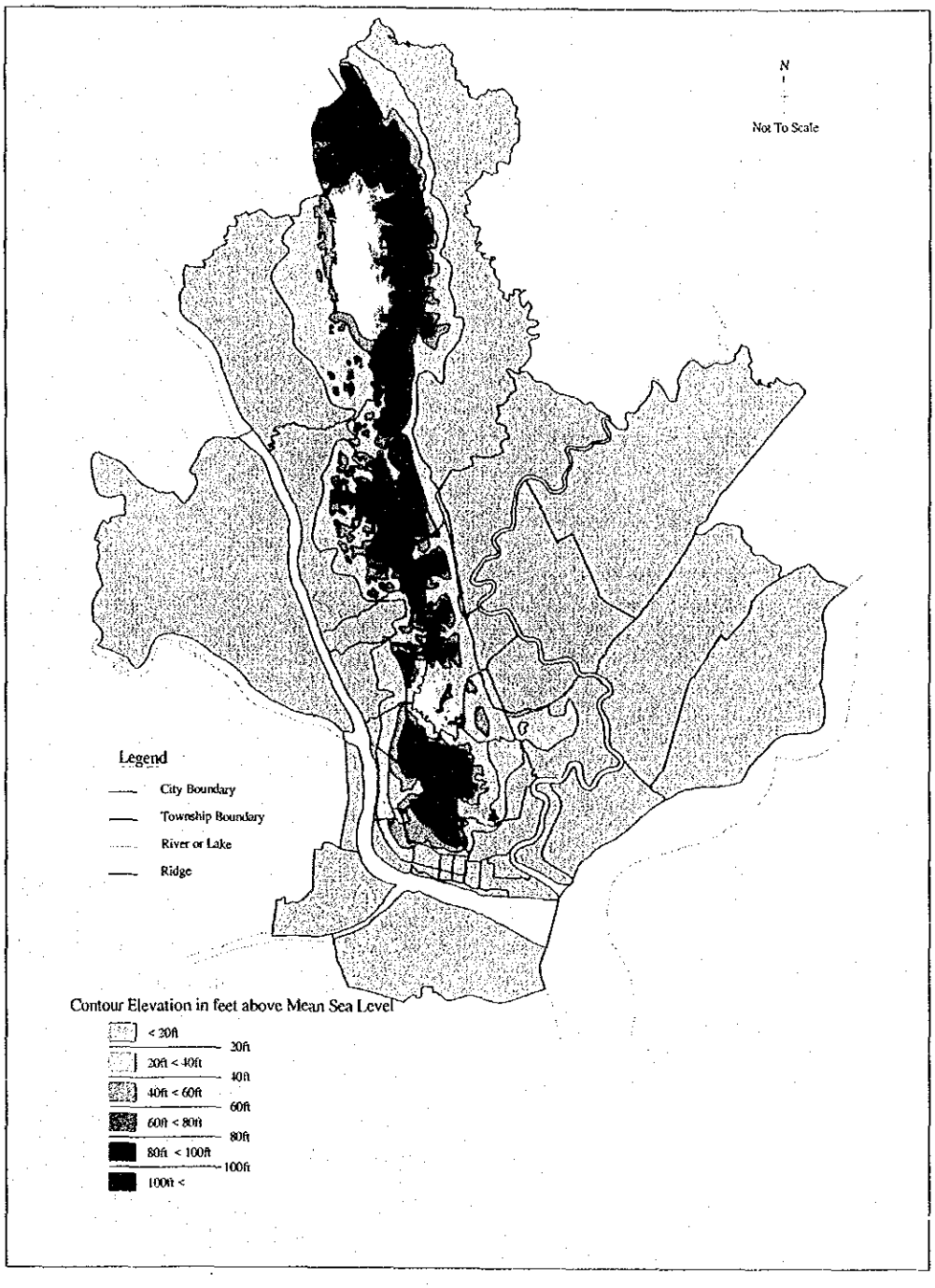


Figure 2.4 Contour Map of Yangon City

Table 2.4 Stratigraphy of Yangon City

Geologic Age			Rock Units and Formation	
Quaternary	Holocene	Q_H	Recent Alluvium	(3) Quaternary Deposits
	Pleistocene	Q_P	Delta Deposits	
			Unconformity	
Tertiary	Pliocene	T_{Pc}	Tanyingon Clay	(2) Irrawaddy Series
		T_{Psa}	Arzanigon Sandstone	
			Unconformity	
	Miocene		Besupet Alternation	(1) Pegu Group
	Oligocene	T_{Osa}	Thadugon Sandstone	
			Hlawga Shale	

Source: Future Prospect of the Underground Water of Yangon, Ministry of Mines, May 1994

The Geological Map of Yangon City is illustrated in Figure 2.5 with same symbols of Table 2.4 above. Its geological and hydrogeological features and in terms of lithologic composition and materials, permeability, groundwater quality, groundwater level, etc. are described below.

(1) Miocene and Older Systems: Pegu Group

Pegu Group occurs at the west side of Hlawga Lake, which is the northern part of the City. The outcrops composed of soft shale with color of brown: Hlawga Shale, hard/compact/massive sandstone with color of greenish-black: Thadugon Sandstones and their alternations: Besupet Alternation. The rocks generally strike NNW-SSE direction and dip of about 40degree towards the east. Total thickness of this group is estimated to be about 1,050m (3,400ft).

Rock units of Miocene and older systems are impermeable, which are classified as aquicludes. The only "Thadugon Sandstones" has a permissive permeability for exploitation, groundwater in which is limited to fractured and weathered zones. The groundwater quality in this aquifer is poor and in most cases not potable owing to higher chloride ion concentration because of marine deposits.

(2) Pliocene Series: Irrawaddy Series

Irrawaddy Series almost cover the central part of the city. They are composed of sands, sandstones, shale and clay with few bands of hard calcareous sandstones and gravels with fragment of rounded shales. In some places the Irrawaddy beds are lateritised to the depth of between 15m (50ft) and 24m (80ft) below ground surface.

Semi-consolidated formation of Pliocene series can be divided into two members. From lower to upper, the sandstone outcrops are found in Arzanigon hill near Shwe Dagon Pagoda: Arzanigon Sandstone, while the clay is found along Thnying-Mingaladon car road: Arzanigon Sandstone. The beds are generally NNW-SSE direction and dips ranges between

10degree to 30degree.

Sedimentary rocks of this series have various ranges of permeability and Arzanigon Sandstone is classified as good aquifer. The average yield is estimated about 55m^3/hr (12,000gph) to 80m^3/hr (18,000gph) with average tube well depth of 50m (160ft). Type of groundwater quality is sodium bicarbonate with calcium and magnesium as second constituents. Where the laterite is rich at expected aquifer, groundwater with high iron ion concentration is observed.

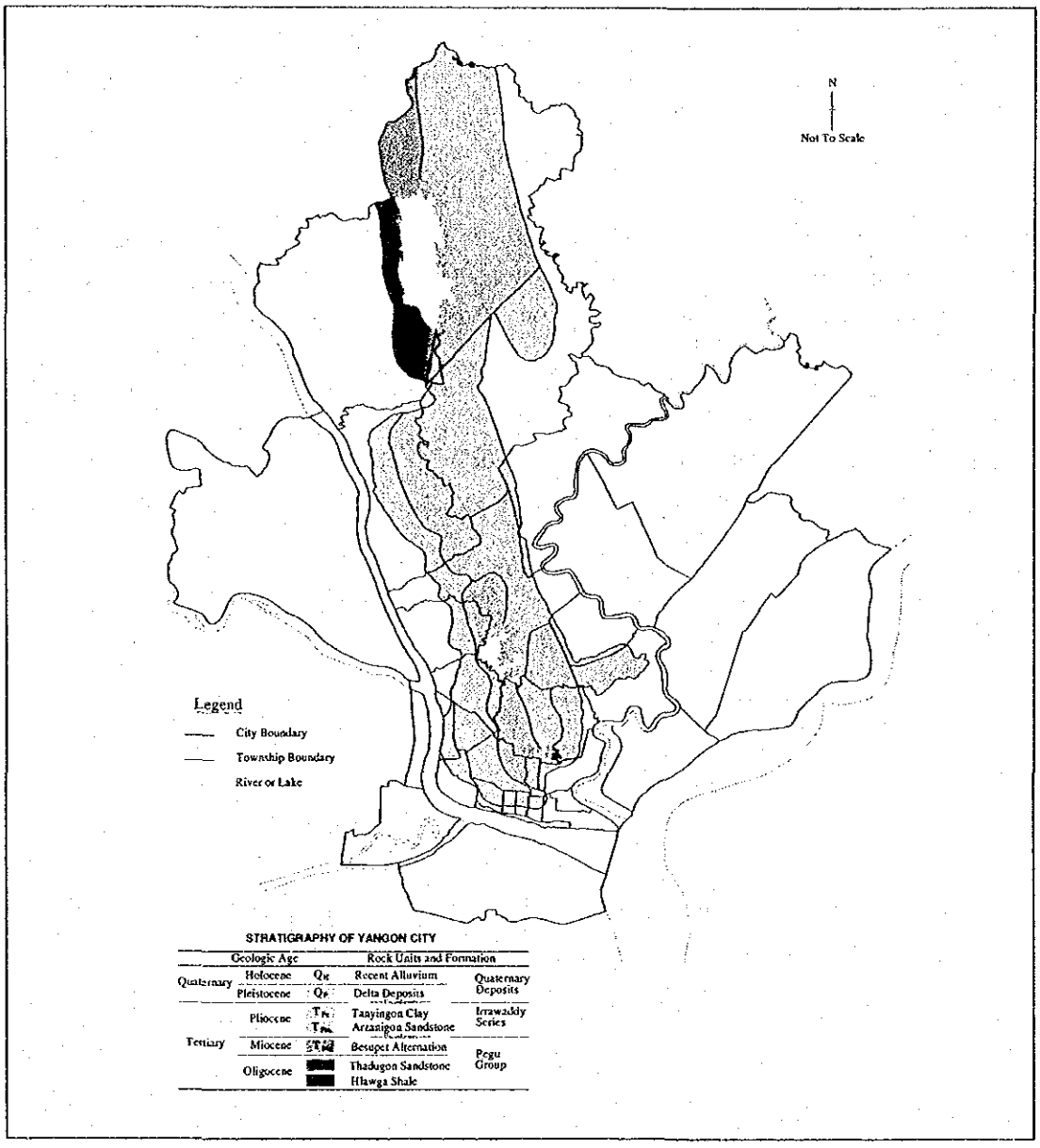


Figure 2.5 Geological Map of Yangon City

(3) Pleisto-Holocene System-Quaternary Deposits

Alluvium consists of lenticular, intertonguing loose coastal and river deposits of boulders, cobblers, pebbles, granules, sands, silt and mud. These are the detrital fragments weathered and eroded from the pre-existing rocks. Quaternary deposits are divided into two portions: Delta Sediments and Recent Alluvium.

Delta sediments consist of sands and gravels, remarkably free from clayey materials and lies upon the eroded surface of Irrawaddy Series. Recent alluvium consists of gravels, clay, silt and laterite. These deposits are widely distributed surrounding the City proper.

Alluvium deposits bear good quality of fresh groundwater excluded in southern Townships. The aquifers are found at the depth of 55m (180ft) with thickness of 18m (60ft). The average yield is about 80m^3/hr (18,000gph).

2.5.3 Meteorology

Yangon City has a type of tropical monsoon climate with three distinct seasons under the coronas classification, such seasons are namely summer, rainy and cool. The summer season covers the period from March till mid-May, the rainy season from mid-May till October and the cool season from October till February.

The meteorological stations in and around the Yangon City are selected as the representative stations considering their location, the period of available data, etc. The daily meteorological data at Kaba Aye (Yangon), Bago and Tharrawaddy are aggregated into monthly data as shown in Table 2.5.

Table 2.5 Meteorological Stations

Station Name	Cord No.	Location		Height (m)
		Latitude	Longitude	
Kaba-aye	48097	16.54	96.10	20
Bago	48093	17.20	96.30	9
Tharrawdy	48088	17.38	95.48	15

Source: Department of Meteorology and Hydrology.

Six parameters have been daily recorded at the meteorological stations, which are: (1) rainfall, (2) maximum and minimum temperatures, (3) humidity at 09:30 and 18:30 in MST, (4) mean wind speed with direction, (5) evaporation and (6) sunshine hour. Table 2.6 shows annual and average monthly meteorological records at selected three stations.

According to statistics of the year 1999 rainfall under the Irrigation Department in Yangon Division, an annual average rainfall totals at 3,024mm (119inches) and was situated from April until October: about 97.5% of annual rainfall, as shown in Figure 2.6 below.

Table 2.6 Climate Elements at the Key Stations

Name of Station: Kaba-Aye (Yangon) 1991-2000

Climatic Elements	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average Annual
Rainfall (mm)	4	4	10	28	294	549	574	611	369	197	61	4	2,706
Evaporation (mm)	116	122	163	183	142	75	75	72	81	100	107	111	1,347
Mean Max. Temperature (℃)	33.2	34.7	36.6	37.1	34.3	31.0	30.4	30.0	31.0	32.1	33.1	32.6	33.0
Mean Min. Temperature (℃)	16.6	18.2	21.2	23.9	24.7	23.9	23.5	23.2	23.2	23.2	21.6	18.2	21.8
Mean Temperature (℃)	24.9	26.5	28.9	30.5	29.5	27.4	26.9	26.6	27.1	27.6	27.3	25.4	27.4
Relative Humidity at 09:30 (%)	67	67	70	69	77	87	89	90	87	82	73	69	77
Relative Humidity at 18:30 (%)	56	51	54	59	75	89	89	91	87	81	72	64	72
Sun Shine Hours	9.3	9.4	9.2	9.4	6.2	2.8	2.6	2.3	4.0	6.3	7.9	8.9	6.5
Wind Speed (mph)	2.3	2.4	2.4	2.6	2.7	2.7	2.6	2.3	2.2	2.5	2.6	2.6	2.5
Wind Direction	NE	NE	SW	SW	SW	SW	SW	SW	SW	E	NE	NE	SW

Name of Station: Bago (1991-2000)

Climatic Elements	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average Annual
Rainfall (mm)	2	3	13	33	290	708	739	782	473	197	40	6	3,285
Mean Max. Temperature (℃)	32.0	33.5	35.8	37.1	34.7	30.9	30.4	30.2	31.2	32.4	32.3	31.4	32.7
Mean Min. Temperature (℃)	14.7	16.5	19.8	22.7	23.1	22.3	22.2	22.1	22.1	21.7	19.8	15.8	20.2
Mean Temperature (℃)	23.3	25.0	27.8	29.9	28.9	26.6	26.3	26.1	26.7	27.0	26.0	23.6	26.4
Relative Humidity at 09:30 (%)	77	74	75	72	79	88	90	90	88	83	81	79	81
Relative Humidity at 18:30 (%)	59	54	54	56	72	88	90	90	86	81	73	70	73
Wind Speed (mph)	1.3	1.2	1.2	1.3	1.3	1.1	1.3	1.2	1.1	1.1	1.4	1.5	1.2
Wind Direction	NE	NE	NE	SW	SW	SW	SW	SW	SW	NE	NE	NE	SW

Name of Station: Tharrawaddy (1991-2000)

Climatic Elements	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average Annual
Rainfall (mm)	4	2	3	12	195	477	508	486	284	158	56	6	2,191
Mean Max. Temperature (℃)	32.1	33.5	37.2	39.1	35.9	31.4	30.7	30.6	31.5	32.4	32.3	31.5	33.2
Mean Min. Temperature (℃)	13.8	15.5	18.2	22.6	23.5	23.3	23.0	23.1	23.1	22.6	19.9	16.3	20.4
Mean Temperature (℃)	23.0	24.5	27.7	30.8	29.7	27.4	26.8	26.8	27.3	27.5	26.1	23.9	26.8
Relative Humidity at 09:30 (%)	69	65	67	64	74	86	89	87	86	83	76	72	76
Relative Humidity at 18:30 (%)	58	48	43	47	68	88	88	89	86	82	77	66	70
Wind Speed (mph)	2.4	1.9	2.2	2.5	2.2	2.3	2.2	1.9	1.8	1.5	2.2	3.6	2.2
Wind Direction	N	N	S	S	S	S	S	S	S	S	NE	N	S

Source: Department of Meteorology and Hydrology

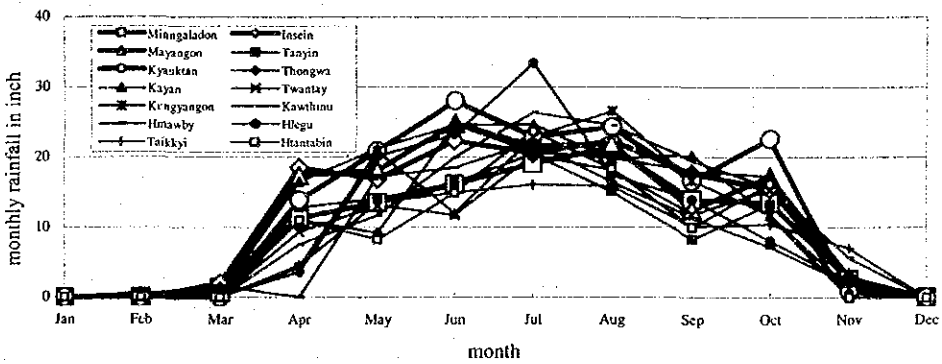


Figure 2.6 Rainfall 1999 in Yangon City

2.5.4 Hydrology

In present and future use of YCDC water supply systems, there are two surface water sources exist. Such water sources are river and reservoir. Following are brief conditions of surface water sources.

(1) Rivers and Hydrological Network

There are three hydrological stations (as of June, 2000) operated by Department of Meteorology and Hydrology in the Hlaing River basin at Kamonseik and Bago River basin at Bago and Zaungtu three of which stations are provided with pile gauge as shown in Fig. 2.6. Bago gauging station excluded from one of the key stations due to the influence of tidal level during the January to mid-May and mid-October to December.

The geographical gradient is a descent from north to south, as a result of which its rivers and creeks have their sources in the Bago Yoma and flow into the sea in the south.

The Hlaing River, also known as Myitmakha River has its source near Paunk Kaung. It flows from north to south approximately parallel to the Ayeyawady River, first joining the Bawle River in Taikkyi township, and then the Kotekowa River in Hmawbi township and finally the Penhlaing River near Hsinmalaik. When it reaches Yangon it continues to flow into the sea as Yangon River.

The total length from its source to its mouth at the confluence of Yangon River is about 330km (205 miles) long. Since it flows directly into the sea there is a tidal flow to a distance of about 80km (50 miles) upstream.

The Bago River has its source near Thikkyi in the Bago Yoma. It flows down the east-facing slope of the Bago Yoma from north to south approximately parallel to the Sittang River. When it reaches Bago it turns to the southwest and flows into the sea as Yangon River.

Total length from its source to its mouth at the confluence of Yangon River is about 260km (162 miles) long. Bago River at Bago gauging station is clearly influenced by tidal level during the period of low flows.

(2) Existing Reservoir

The present surface water sources for supply of water to the Yangon City are consisted of Gyobyu Reservoir, Phugyi Reservoir and Hlawga Reservoir. And Ngamoyeik Resevoir constructed by Irrigation Department, Ministry of Agriculture and Irrigation will be able to supply the water for Yangon City. The characteristics of existing reservoirs for supply of water and the existing, under construction and proposed reservoirs managed by Irrigation Department are summarized in Table 2.7.

Table 2.7 Characteristics of Reservoirs

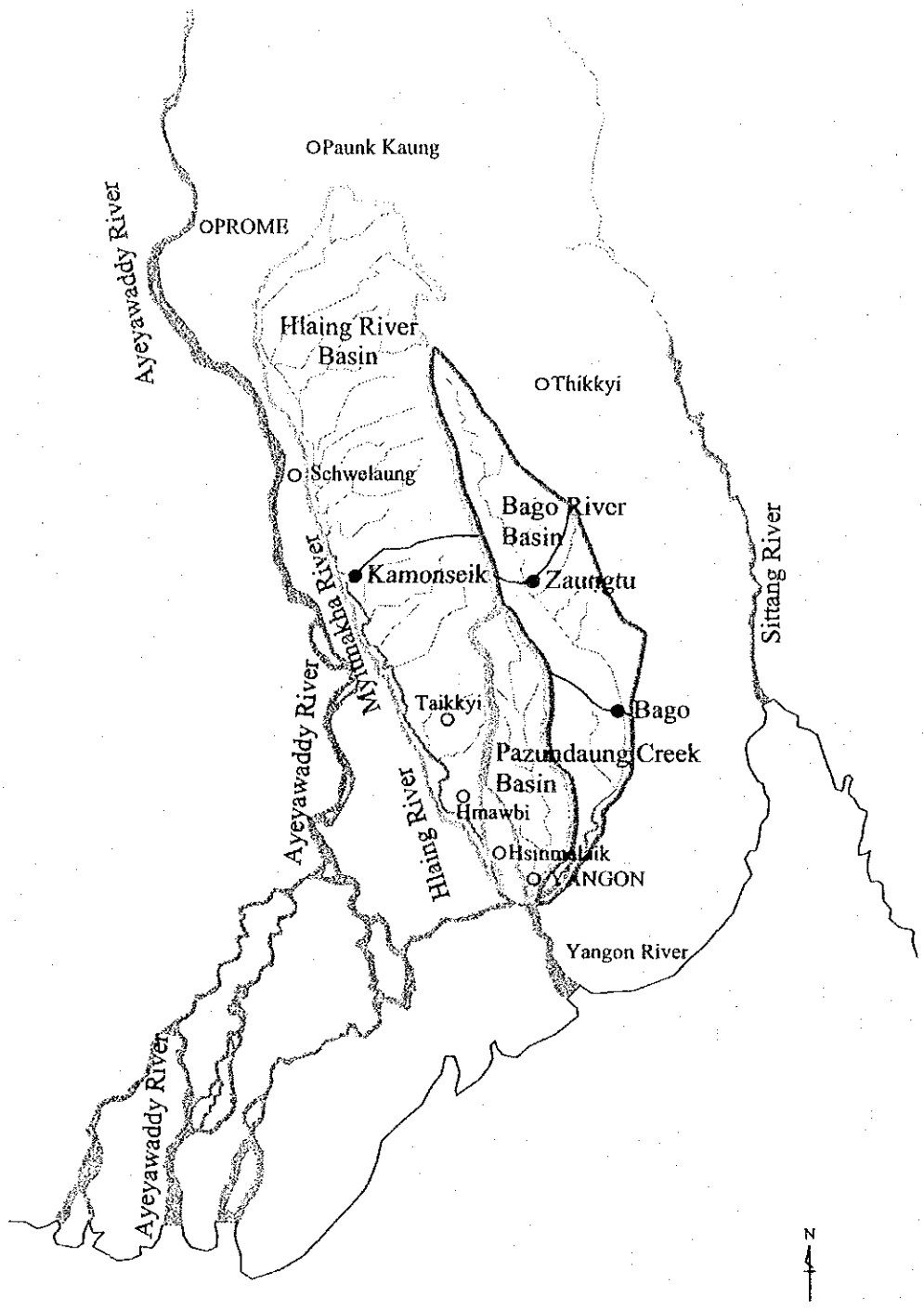
	Name of Reservoir (Present Status)	Catchment Area	Surface Area	Dam Length	Dam Height
		km^2 $mile^2$	km^2 $mile^2$	m ft	m ft
Present	Hlawga	27.2 (10.50)	14.40 (4.40)	2,414 (7,920)	17.9 (62)
Present	Pugyi	70.6 (27.27)	17.61 (6.80)	3,048 (9,999)	15.2 (50)
Present	Gyobyu	32.9 (12.70)	7.25 (2.80)	213 (700)	30.5 (100)
Existing	Ngamoeyeik	414.4 (160)	44.52 (17.19)	4,724 (15,500)	22.9 (75)
Existing	Lagunpyin (under const.)	108.8 (42)	27.11 (6,700)	1,579 (5,180)	18.9 (62)
Existing	Shwepyi	5.18 (2)	1.05 (260)	1,056 (3,464)	10.7 (35)
Existing	Sunpalun	-	0.0405 (10)	109 (357)	11.0 (36)
Existing	Zalathtaw	23.3 (9)	5.58 (1,380)	1,391 (4,565)	15.2 (50)
Existing	Mazin	28.5 (11)	6.17 (1,525)	1,250 (4,100)	18.3 (60)
Existing	Tabuhal	230.5 (89)	31.57 (7,800)	398 (1,305)	29.0 (95)
Existing	Ahlaingni (under const.)	36.8 (14.2)	8.34 (2,060)	1,737 (5,700)	15.8 (52)
Existing	Nagamoeyeik (Proposed)	(-)	(-)	(-)	(-)

2.5.5 Hydrogeology

In the year of 1959, report on "The Geology and Underground Water of Rangoon" was established by the Government of Burma with assistance from Geological Survey of India. Some of such information in the year 1959 was updated by "the Department of Geological Survey and Mineral Exploitation" in early 1990's. There might be different between late 1950's and present in terms of hydrogeologic conditions related to piezometric (contour of static water level) and saline water intrusion.

As shown in Figure 2.4 before, topographic peaks in the central city are ranging north and south through east side of the Hlawga Lake and west sides of the Inya Lake and the Kan Daw Gyi Lake. Trend of groundwater flow is probably toward east and west following to gradient of ground surface.

According to the piezometric map attaching to the report on "Future Prospect of the Underground Water of Yangon", the trend of groundwater flow seems to be eastward at western side of



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG 2.7
	River Basins and Hydrological Networks	

topographic peaks in an area between Kan Daw Gyi Lake and Inya Lake. Because of dipping Irrawaddy Series eastward and unconformity overlaying to Pegu Group (Besupet Alternation), surface geological boundary of lower Irrawaddy Series may be same as watershed boundary of groundwater flow as shown in Figure 2.8.

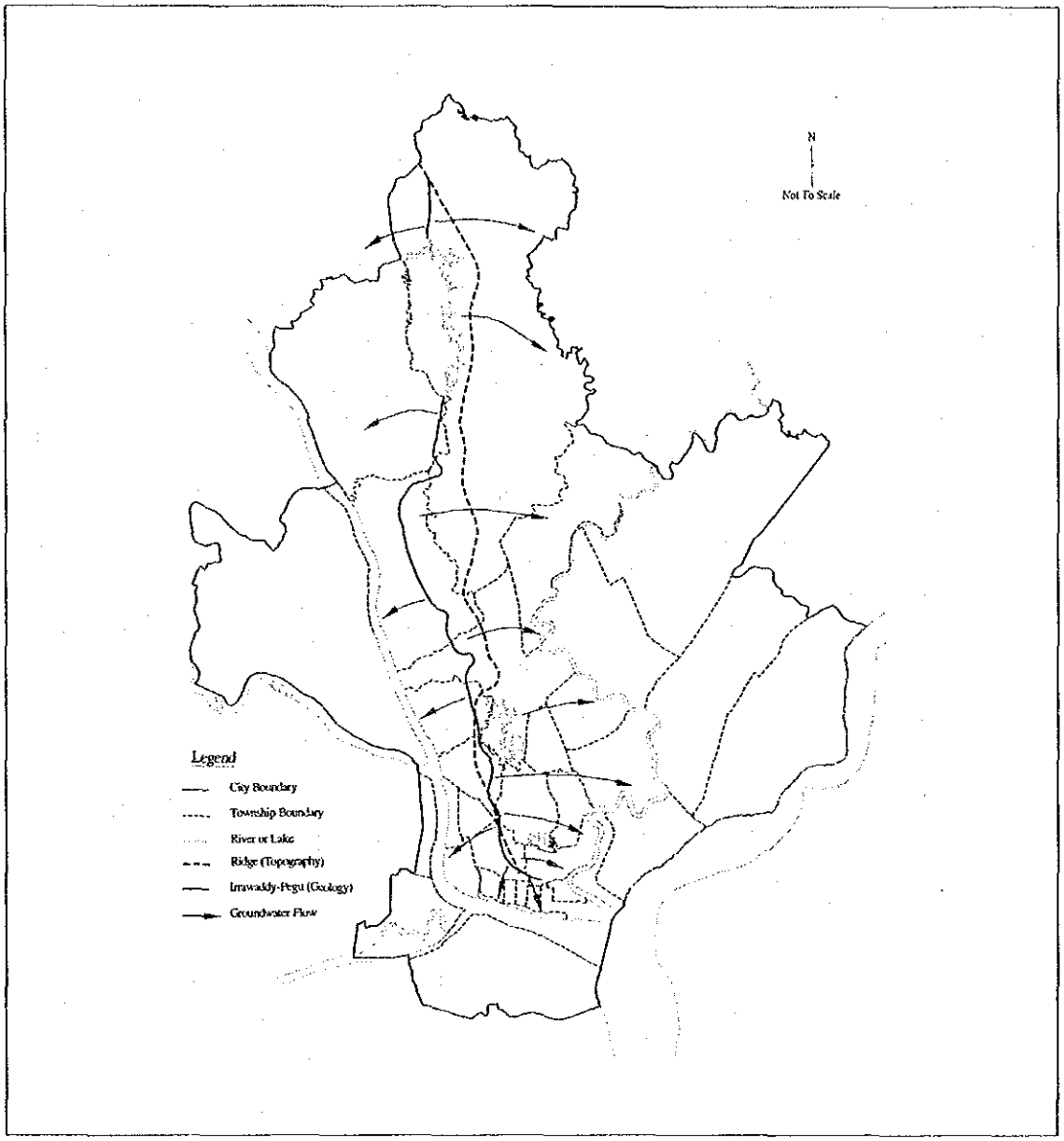


Figure 2.8 Hydrogeological Watershed Boundary

Among the water quality problems of the city, ironic groundwater is serious with a high percentage of affected existing tube wells. The problem is extended to most of the central city. Origin of ironic groundwater was reported because of lateritised members distributing lenticular in Irrawaddy Series. High chloride content in groundwater was also reported in inland and coastal areas, which is believed as the cause of brackish water and/or saline water intrusion.

2.6 POPULATION

2.6.1 Past Population Trend (1836 – 1998)

The Study Team collected past population data from various sources, because the data seems to be confidential. The national census was carried out in 1921, 1931, 1953,1973 and 1983. The following Table 2.8 shows the collected Yangon City population data from 1836 to 1998. The data were obtained from three (3) sources ("YANGON THE CITY, 1995", Statistical Abstract 1996, and Manpower & Immigration Department data). 12 data was collected.

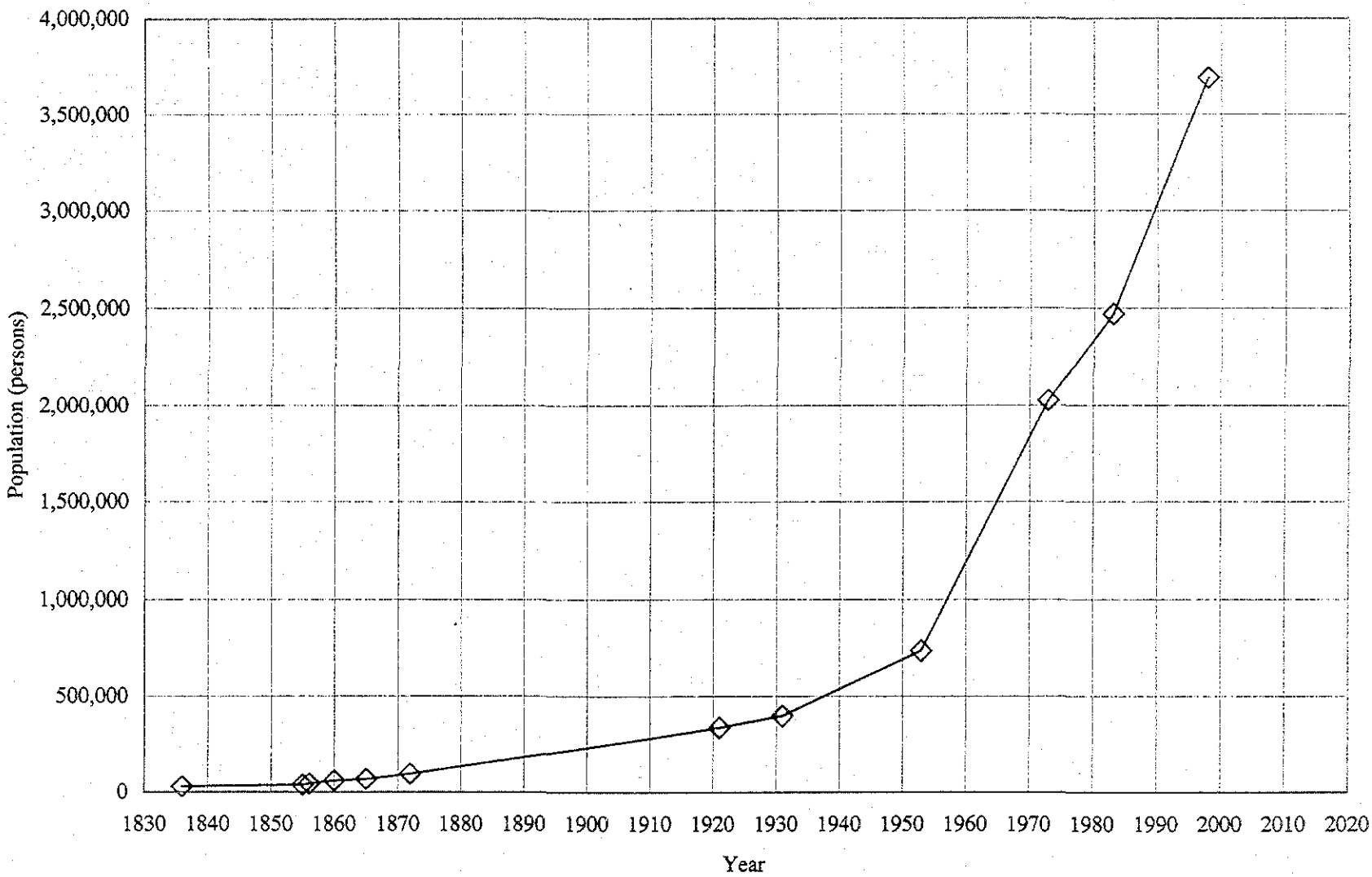
The City population reached about 100,000 in 1872. By 1931, population was more than 400,000 (4 times than that of 1872). In 1800's (1836 – 1872), the growth rate was 3.35 %, in 1900's (1872 – 1973), that was 3.04 %, and recent years (1973-1998), the rate was 2.43 %. The growth rate has been gradually decreasing.

Table 2.8 Past Population and Growth Rate

Year	Population* (Persons)	Annual Growth Rate (%)	
1836	30,000	(1836-1855) 1.26	(1836-1872) 3.35%
1855	38,055	(1855-1856) 20.88	
1856	46,000	(1856-1860) 7.56	
1860	61,570	(1860-1865) 2.56	
1865	69,866	(1865-1872) 4.97	
1872	98,138	(1872-1921) 2.58	(1872-1973) 3.04%
1921	341,962	(1921-1931) 1.59	
1931	400,415	(1931-1953) 2.81	
1953	737,079	(1953-1973) 5.19	
1973	2,027,256	(1973-1983) 2.00	(1973-1998) 2.43%
1983	2,472,176	(1983-1998) 2.71	
1998	3,691,941		

* Source: 1836-1872; YANGON THE GARDEN CITY, 1995
1921-1953; Statistical Abstract, 1996 Central Statistical Organization
1973-1998; ManPower & Immigration Department

Fig. 2.9 shows the graph of the above data, from which we can understand long-term past trends.



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Past Population (1836 - 1998)

FIG 2.9

From Figure 2.9, the following interesting things can be observed, which give some insight for forecasting future population.

- Overall, Yangon City population is growing fast, as an exponential curve in recent years.
- High growth rate has started since 1953.
- 1836 to 1872, growth rate was 3.35 %
- 1872 to 1921, growth rate was down to 2.58 %
- 1921 to 1931, growth rate was down to 1.59 % (the lowest)
- 1931 to 1953, growth rate was up to 2.81 %
- 1953 to 1973, growth rate was up as 5.19 %, the highest growth rate
- 1973 to 1983, growth rate was down to 2.00 %
- 1983 to 1998, growth rate was 2.71 %
- Total population in 1998 is 3.69 million already. In future it seems reasonable to suppose that high growth rate may not continue. Actually, MPID (ManPower & Immigration Department) seems to estimate future population with 2.18 % annual growth rate.
- In the conclusion for the future population, it is still in growth period but not so high growth rate is expected (more than 2.5 %).

2.6.2 Recent Population In Yangon City

Since 1973, 1983, and 1998, data have each township's population, some trend by township is summarized below. Table2.9 and Fig. 2.10 show the population data.

Table 2.9 Population Distribution

No.	Township	Population (persons)		
		1973	1983	1998
1.	Ahlone	46,547	51,849	43,569
2.	Bahan	85,757	102,112	95,114
3.	Botataung	44,057	49,168	52,653
4.	Dagon	35,746	35,541	39,967
5.	Dagon Myothit (East)	-	-	55,192
6.	Dagon Myothit (North)	-	-	101,673
7.	Dagon Myothit (Seikkan)	-	-	18,279
8.	Dagon Myothit (South)	-	-	140,387
9.	Dala	43,503	54,167	77,236
10.	Dawbon	37,439	49,967	79,582
11.	Hlaing	131,587	171,687	167,881
12.	Hlaingthaya	-	-	199,190
13.	Insein	143,625	196,809	240,704
14.	Kamayut	67,309	75,177	82,943
15.	Kyauktada	37,772	37,634	44,076
16.	Kyeemyindaing	64,145	69,866	87,491
17.	Lanmadaw	42,691	41,663	40,597
18.	Latha	31,646	31,061	32,535
19.	Mayangone	108,749	152,616	183,024
20.	Mingalardon	80,867	108,303	170,950

21.	Mingalartaungnyunt	96,287	110,435	109,796
22.	North Okkalapa	155,259	190,905	289,068
23.	Pabedan	40,718	41,913	47,461
24.	Pazundaung	34,763	38,806	38,363
25.	Sanchaung	66,593	68,867	78,788
26.	Seikan	7,732	5,285	1,379
27.	Seikkyi Kanaungto	12,458	15,393	25,586
28.	Shwepyitha	-	-	172,377
29.	South Okkalapa	149,409	183,264	220,214
30.	Tamwe	106,682	119,914	128,455
31.	Thaketa	145,888	193,028	279,799
32.	Thingangyun	141,209	194,100	240,417
33.	Yankin	68,818	82,646	107,195
	TOTAL	2,027,256	2,472,176	3,691,941

Source: ManPower & Immigration Department

The growth rates (1983 to 1998) by each township are different and summarized below.

(1) Population has decreased (3 townships)
Seikan, Ahlone, Lanmadaw

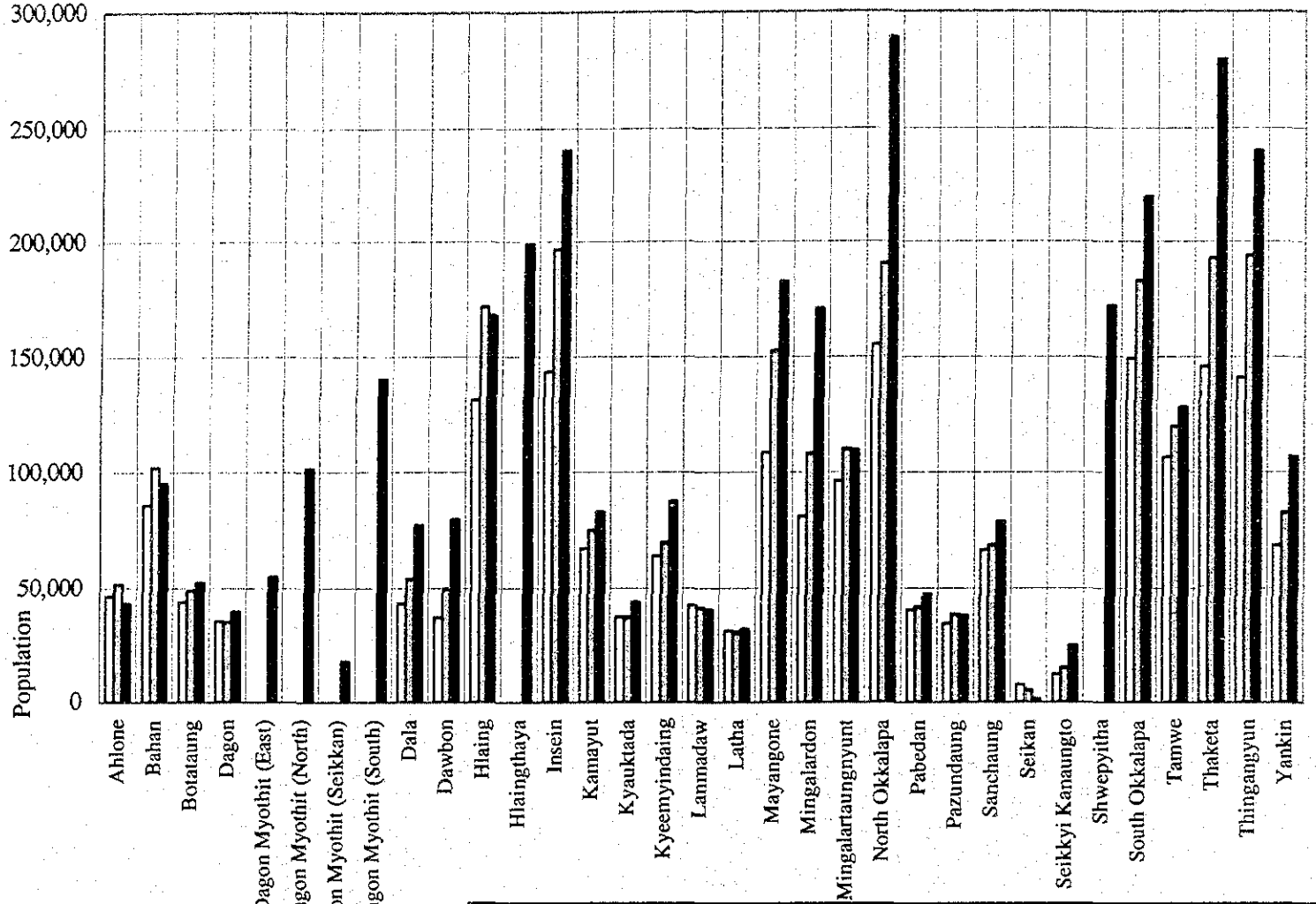
(2) Growth rate is less than 1 % (steady: 12 townships)
Latha, Pazundaung, Bahan, Dagon, Mingalartaungnyunt, Pabedan, Kyauktada, Sanchaung, Botataung, Tamwe, Kamayut, Hlaing

(3) Growth rate is more than 1 % (13 townships 46 %)
The others.

Twenty five (about 88%) townships out of 28 are increased in population and half of the townships has more than 1 % growth rate.

2.6.3 Population Projection

Population was estimated here with the collected data and different estimation methods. The logistic curve can not be applied here, because the population is growing and we can not set the saturated population. Next Table 2.10 shows projection methods.



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Population by Township

FIG 2.10

Table 2.10 Population Projection Method

Method		Data
By Annual Growth Rate	Growth rate :3.02%	1836-1998
	Growth rate :2.43%	1973-1998
	Growth rate :2.18%	1998-2000 (estimated by Man-Power & Immigration Department)
By Linear line	Annual increase :67,750 people	1973- 1998
By Power Curve		1973 – 1998

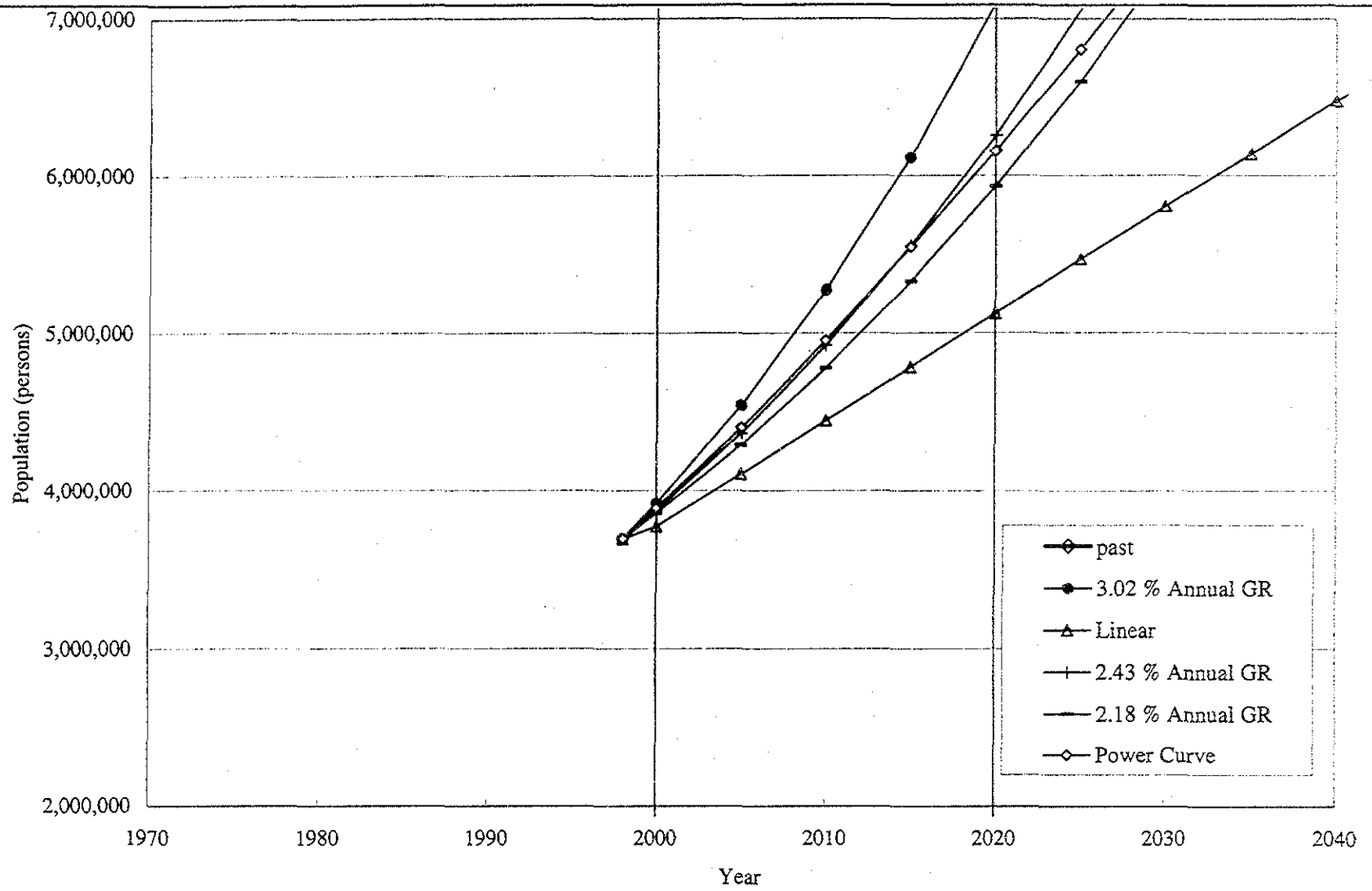
The results are shown in the Table 2.11 and Figure 2.11.

Table 2.11 Population Projection

Year	Annual GR (GR:3.02%)	Annual GR (GR:2.43%)	Annual GR (GR:2.18%)	Linear	Power
1836	30,000				
1855	38,055				
1856	46,000				
1860	61,570				
1865	69,866				
1872	98,138				
1921	341,962				
1931	400,415				
1953	737,079				
1973	2,027,256	2,027,256	2,027,256	2,027,256	2,027,256
1983	2,472,176	2,472,176	2,472,176	2,472,176	2,472,176
1998	3,691,941	3,691,941	3,691,941	3,691,941	3,691,941
2000	3,917,950	3,873,312	3,854,459	3,769,296	3,887,045
2005	4,545,369	4,366,683	4,292,746	4,108,047	4,402,558
2010	5,273,263	4,922,899	4,780,870	4,446,799	4,954,885
2015	6,117,722	5,549,964	5,324,498	4,785,551	5,541,135
2020	7,097,412	6,256,902	5,929,942	5,124,302	6,158,975
R^2	0.9938	0.9953	0.9942	0.9784	1.0000

GR=3.02% Y =3,691,941(1 + 0.0302) ^ X (X: Year-1998)
GR=2.43% Y =3,691,941(1 + 0.0243) ^ X (X: Year-1998)
GR=2.18% Y =3,691,941(1 + 0.0218) ^ X (X: Year-1998)
Linear Y =67,750X + (-131,731,336) (X: Year)
Power Y =2,027,256+16,153X ^ (1.440) (X: Year-1973)
R^2 means coefficient of determination.

The highest population at the target year 2020 is 7,097,412 with 3.02 % annual growth rate. This is too high estimation obviously. On the other hand, the lowest estimation is 5,124,302 with linear, this is low and R^2 is low. A 2.43 % GR estimation has little bit high R^2 value compared with the one of GR 2.18% estimation. R^2 for power curve estimation is 1 because it needs 3 data point to estimate, thus this R^2 value is not comparable with other R^2 values. GR 2.43 % estimation and Power curve estimation are almost same, however the characteristic of the power curve (annual growth rate becomes smaller, see Figure 2.11 and Table 2.11). Thus Power curve estimation will be used for forecast.

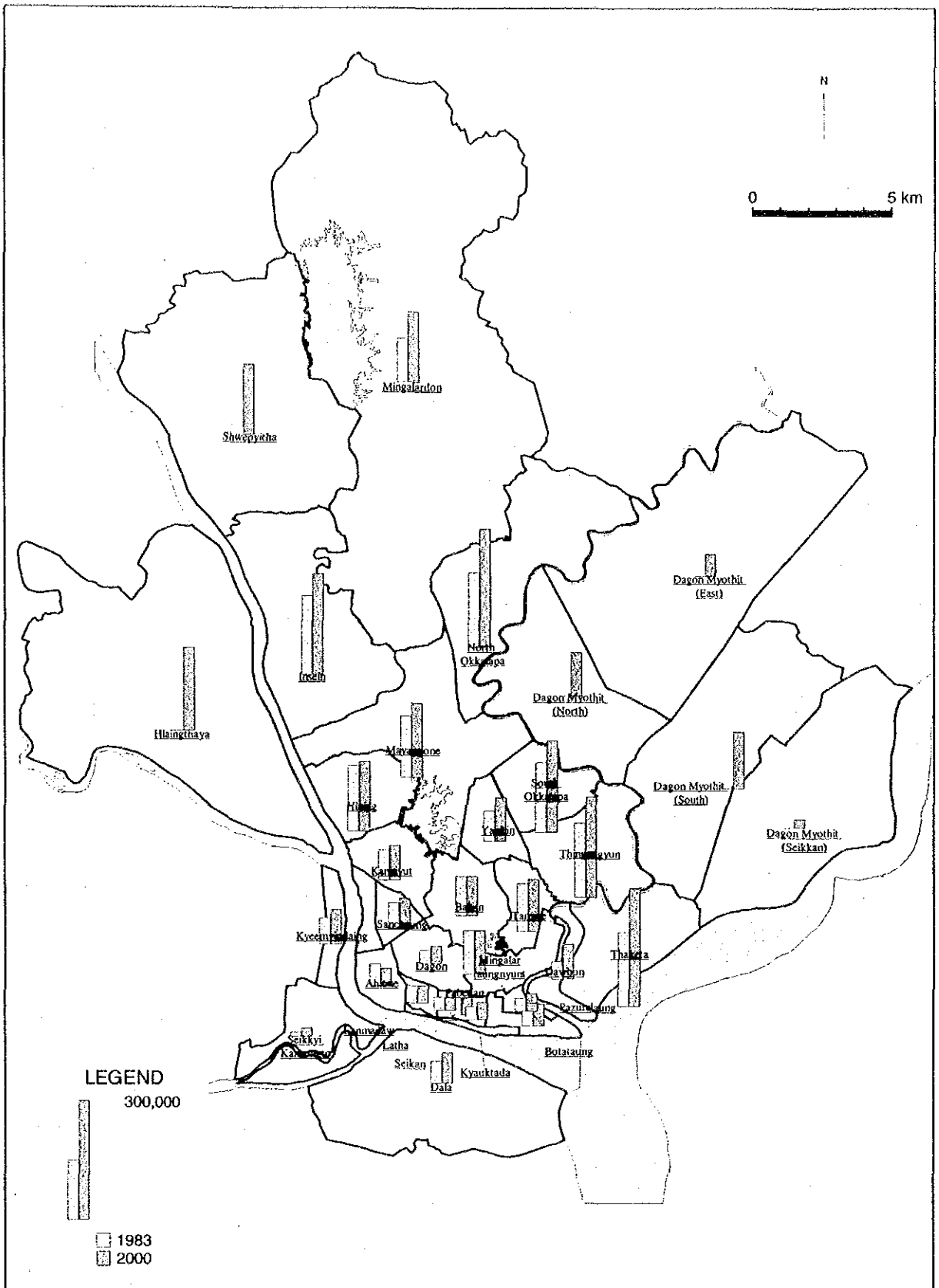


JICA

THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR

Population Estimation

FIG 2.11



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR
1983 and 2000 Population by each Township	FIG 2.12

2.7 LAND USE

Current land use data for the City were hard to obtain. Whenever data was available, their accuracy was another concern. The Study Team employed both review of existing information as well as collecting and checking necessary information provided by YCDC. The aim was to prepare a land use map for the Study Area showing appropriate area under different land use categories.

(1) Current Land Use

Current Land use information was collected from YCDC. The information is input into computer and the results are computerized. The categories are as follows.

1) Residential Area

High, middle, low class residential areas. The commercial area of CBD is included.

2) Government Area

Government office, military area, airport, port, hospital, government factories, parks, government ground are included.

3) Commercial Area

Hotel, market, large commercial areas are included.

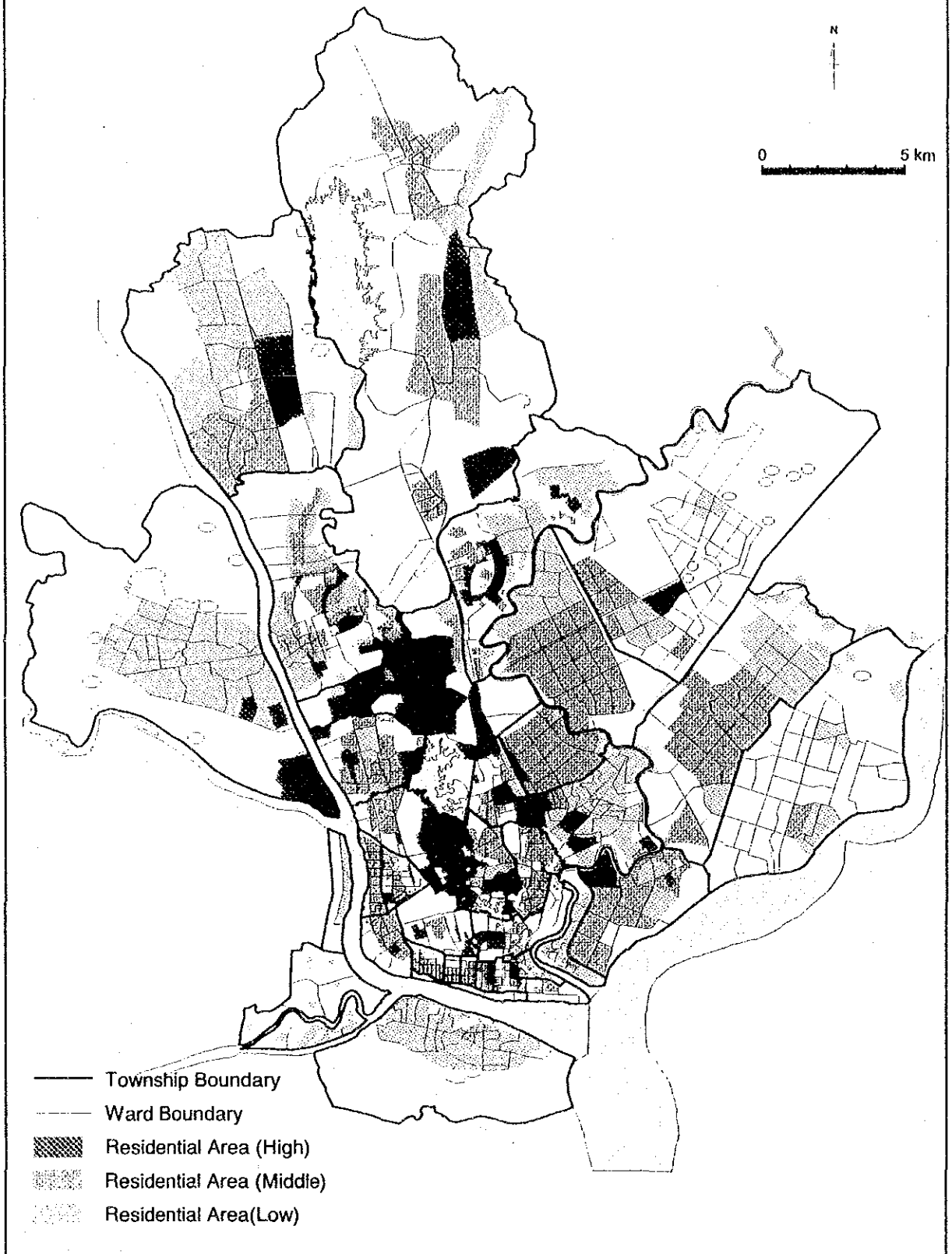
4) Industrial Zone

5) Farm

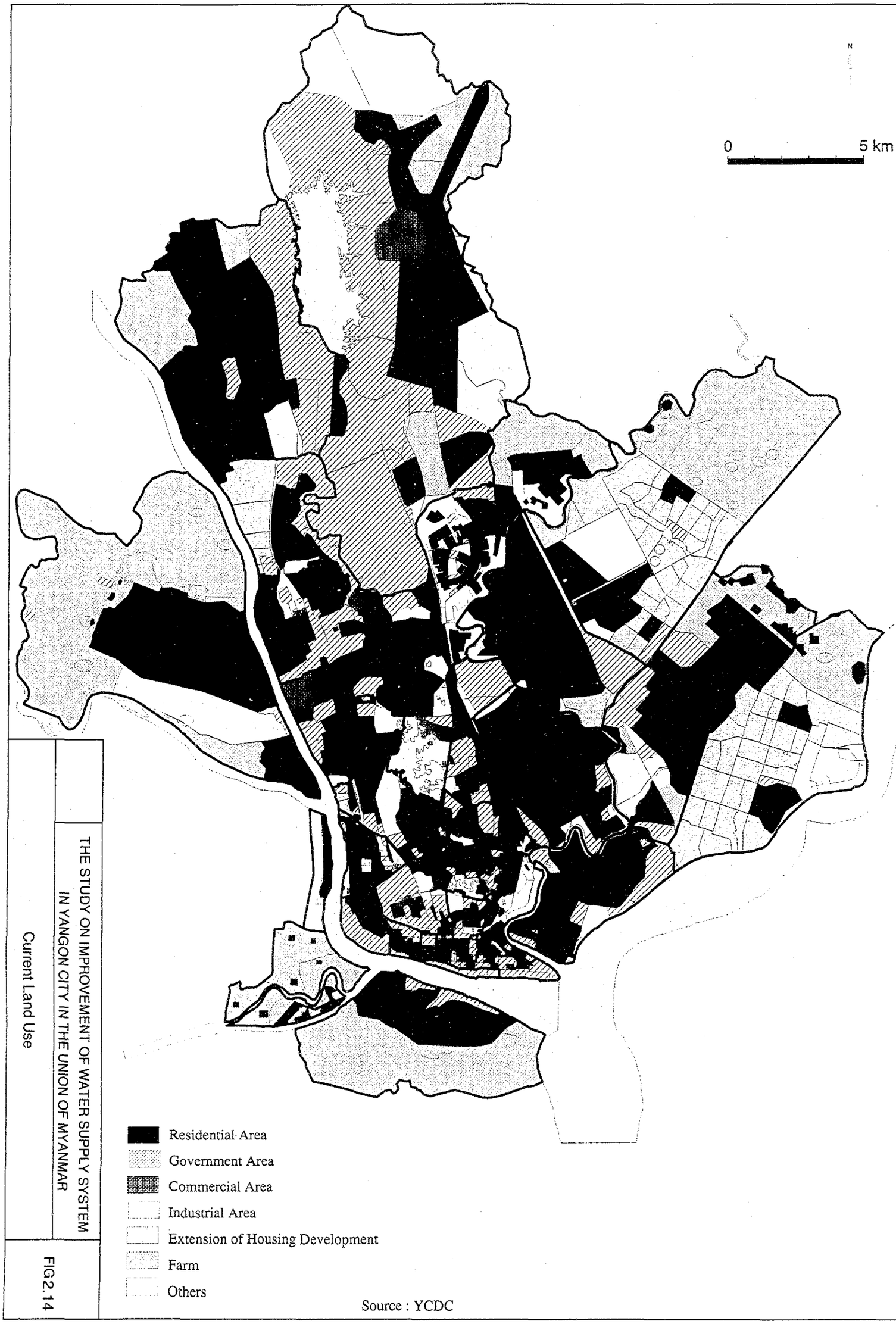
6) Others

Figure 2.13 shows 3 types (high, middle, low class) of residential area..

Figure 2.14 shows current land use (Government, Commercial, Industrial, Farm, and Residential areas).



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG 2.13
	High, Middle, Low Residential Areas	



Source : YCDC

THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR

Current Land Use

FIG 2.14

With regard to the residential areas, the following issues are to be noted.

Townships which Residential Area is more than 1000 ha (Large residential area Township)
Dagon Myothit (North) (1,830ha Middle & Low),
Dagon Myothit (South) (4,764ha Middle & Low),
Hlaingthaya (1,798ha Low),
Mayangone (1,255ha High),
Mingalardon (2,162ha High, Middle, Low),
Shwepyitha (2,208ha Middle, Low)

Township Residential Area(Total) / Township total area is greater than 60%
Bahan (76%), Dagon Myothit (North) (70%), Dagon Myothit (South) (60%),
Dawbon (68%), Kyauktada (60%), Lanmadaw (61%), Pabedan (69%),
Pazundaung (74%), South Okkalapa (92%), Tamwe (69%), Thingangyun (74%)

Township with High Residential area (Township Residential Area(High) >= 500ha)
Mayangone (1,090ha)
((Township Residential Area(High) / Township total area) >= 40%)
Bahan (52%), Mayangone (43%)

Township with Middle Residential Area (Township Residential Area(Medium) >= 500ha)
Dagon Myothit (North) (1,314ha), Dagon Myothit (South) (2,717ha), Insein (632ha), Mingalardon (1,320ha), Shwepyitha (621ha), South Okkalapa (651ha), Thaketa (552ha)
((Township Residential Area(Medium) / Township total area) >= 40%)
Ahlone (44%), Dagon Myothit (North) (50%), Kyauktada (60%), Lanmadaw (61%), Latha (46%), Pabedan (69%), South Okkalapa (85%), Tamwe (60%), Thaketa (42%)

Township with Low Residential Area (Township Residential Area(Low) >= 500ha)
Dagon Myothit (East) (516ha), Dagon Myothit (North) (516ha), Dagon Myothit (Seikkan) (713ha), Dagon Myothit (South) (2,047ha), Dala (672ha), Hlaingthaya (1,715ha), Mingalardon (514ha), Shwepyitha (1,326ha), Thingangyun (647ha)
((Township Residential Area(Low) / Township total area) >= 40%)
Dawbon (64%), Thingangyun (56%)

(2) Industrial Zone

There are 7 main industrial zones in the City, which were developed by the DHSHD (Department of Human Settlement and Housing Development, Ministry of Construction). In addition two new industrial zones are planned. The following Table 2.12 shows summary of the industrial zones and Figure 2.15 shows its locations.

Table 2.12 Summary of the Industrial Zones

Name	Area	No. of Plot			Start Year	No. of Workers
	ha	Total(a)	Operating(b)	% (b/a)		
Shwepyitha	254	584	101	17.3	1992	14432
Hlaingtharyar	580	1048	271	25.9	1995	36543
Dagon South	157	2019	737	36.5	1992	11822
Dagon Seikkan	334	432	22	5.1	1996	3606
Mingaladon	90	39	2	5.1	1995	-n.a
Shwe Paukkan	31	348	70	20.1	1998	4205
Yangon	202	194	0	0.0	2000	
Sub Total	1648	4664	1203			70608
PLANNED						
East-Dagon	200	143				
Shwepitha 4	161	398				

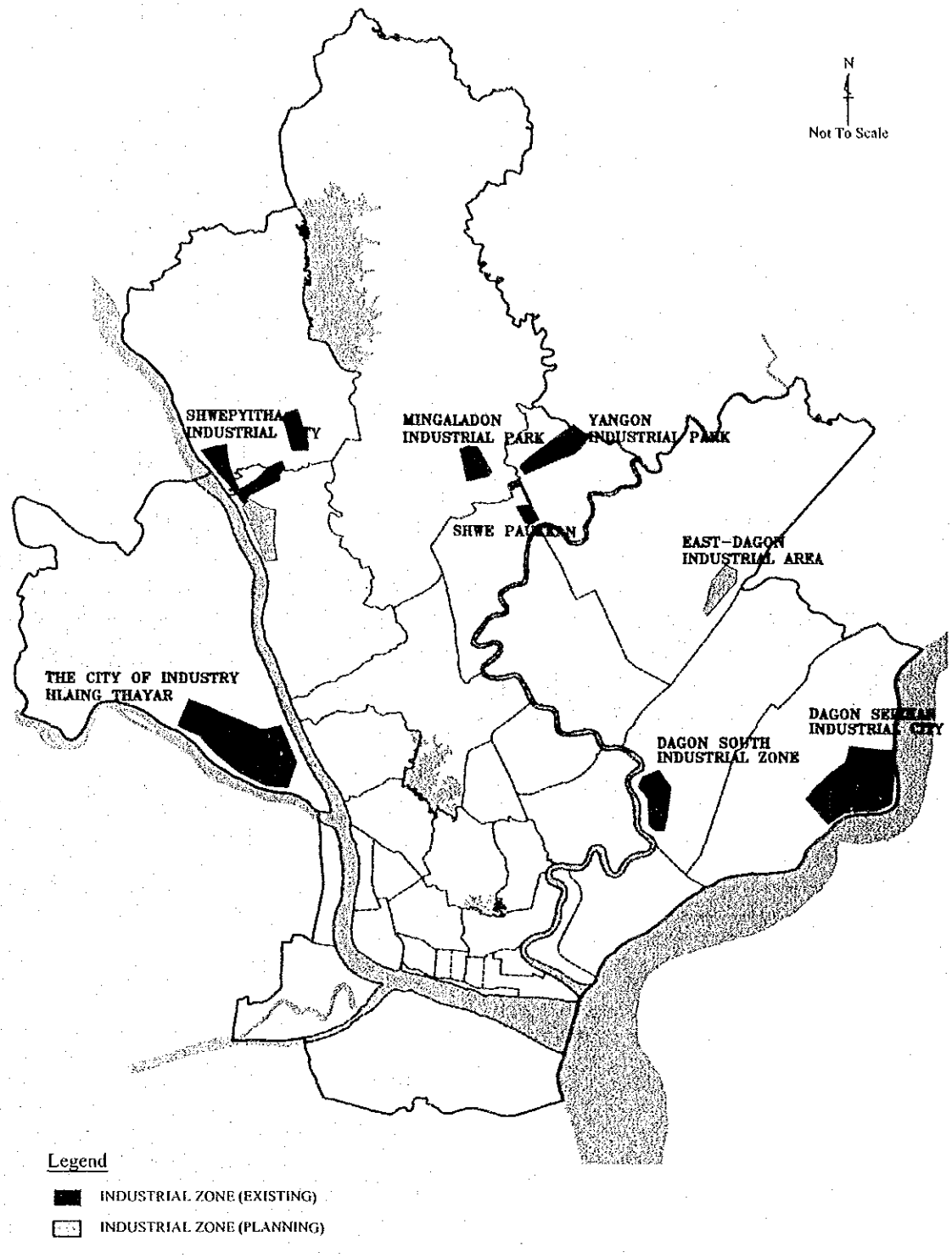
Source: DHSHD(Department of Human Settlement and Housing Development)

As can be seen in the above Table, Industrial zone development started in 1992 and is still developing (build up rate is not so high, 18% on average). However about 1203 companies are operating in total. Most of industrial zones exist in the satellite towns. Actually, DHSHD has the responsibilities of establishing new satellite towns incorporating planned industrial zones, to promote the national economy through industrial sector and to create job opportunities in the new area.

Type of factory is mainly light industries such as Garment, Food, Plastic, Wood, Food, Steel/Metal, Plastic, Paper, Grinding, Brewery, Machinery parts.

Currently, each industrial zone has their own water sources (tube wells) and no YCDC water is supplied to most of industrial zones. In our demand forecast, we will estimate industrial zones' water consumption using the consumer survey results and estimated build up rate.

Two (2) new industrial zones are planned to start 2003 for East-Dagon and 2004 for Shwepitha 4.



SOURCE: DATA FROM URPD, D.H.S.H.D, MINISTRY OF CONSTRUCTION

JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG 2.15
	Industrial Zone (Existing and Planned)	

2.8 STATUS OF WATER SUPPLY

The area has a population of 3.88 million and 540,378 households (in the year of 2000). In addition, many social and economic amenities such as markets, restaurants and hotels, shops, schools and other educational institutions, government ministries, religious establishments, hospitals and a large number of industries in several industrial zones are also present in the City. There are several industrial zones characterising large and small industries within the Yangon City Development Committee (YCDC) area. Water is needed by all these players both as a basic commodity in itself as well as an important raw material in the production process.

The aim of this section is to provide a description of status of water supply for the current City population. This is discussed under several headings starting from water sources, status of water supply and the institutions and organizations involved. It is noted that YCDC is sole agency to provide water within YCDC area.

2.8.1 Water Sources

The three main sources of water utilized to a varying degree are surface, groundwater and rain water. The main surface water source in the study area comes from three reservoirs namely, Gyobyu, Pugyi and Hlawga. The groundwater comes both from shallow and deep underground aquifers. It is used either individually or supplemented to piped-water supply system. The water sources and the methods of supply available to the population in the study area are summarized in the following Figure 2.16. Present status of reservoirs managed by YCDC are presented in Chapter 3.

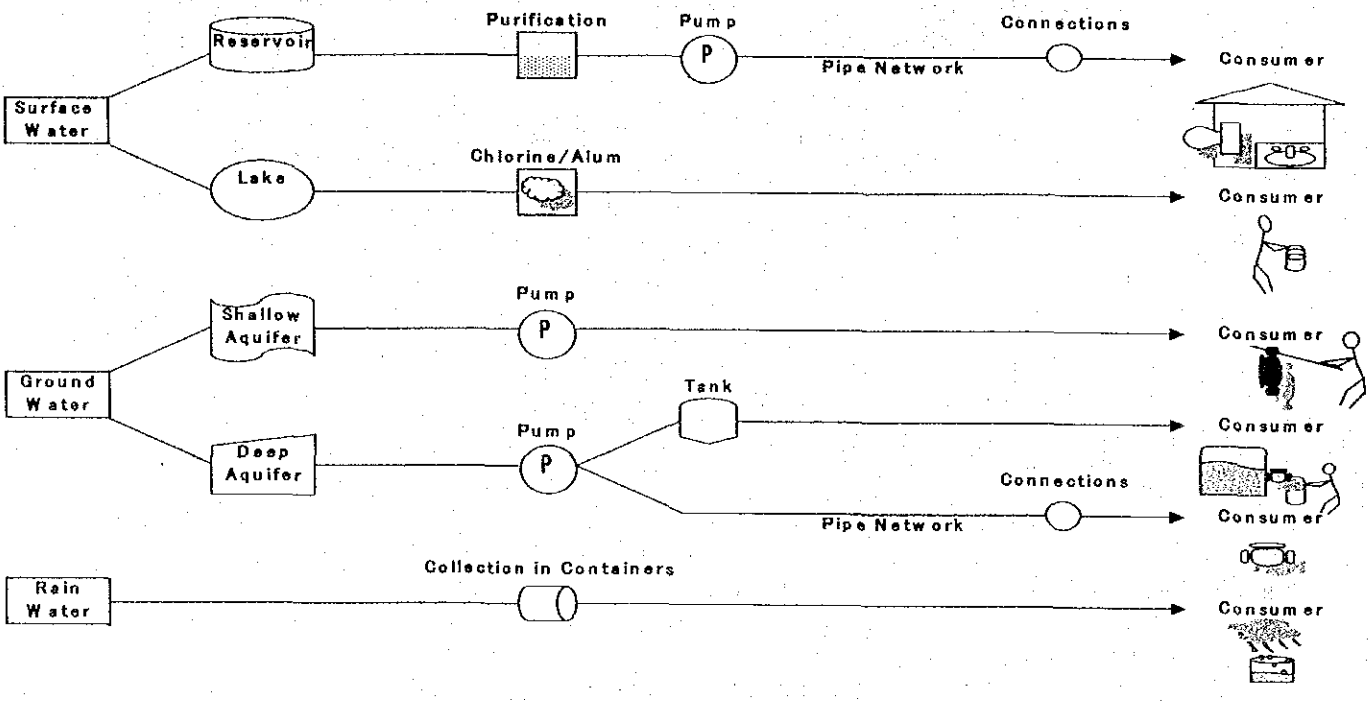


Figure 2.16 Water Sources and Service Status in Yangon City

(1) Surface Water Ponds

A unique characteristic of the study area is the presence of several lakes and ponds scattered over the landscape. Two of these lakes namely, Kandawgyi and Inya were the only source for City water until the construction of Hlawga Reservoir (1904). Since then many lakes particularly those in the central area of the City have subsequently been used mainly for recreation and aesthetic purposes. However, people in 12 townships within the study area draw their domestic water from several lakes and ponds. A discussion on this issue is found in Chapter 3.

(2) Undergroundwater

The two types of undergroundwater utilized in the study area come from shallow aquifers and deep aquifers. .

(3) Rain Water

Rain water is the main source of water for utilized by almost all people in Seikky Kanantungy township during the rainy season. Being an area across the river and without any reliable drinking water source, rain water is the only source of potable water for the people. However, any systematic method of collecting it nor the use of improved techniques that have proven to be more efficient in other Asian countries is yet to be introduced to the Study Area.

2.8.2 Water Supply Institutions and Organizations

This section outlines the main institutions and organizations involved in water supply including a brief description of the nature of institutions themselves, their main water supply role and the coverage of activities within the study area.

Historically, the Yangon City Development Committee (YCDC) and its predecessors had been entrusted with the responsibility for water supply for the City. By Notification No. 6/99, the YCDC has empowered the management and distribution of water for people living in the City of Yangon. Hence, YCDC is the only institution which has an overall responsibility for water supply within the study area.

However, because of the complex nature of the StudyArea itself including its expansion into several new areas around the former City frontier, and various other constraints, a host of other institutions and organizations has evolved out and are actively involved in the supply of water to the City dweller and for other activities. This includes a large number of private entrepreneurs who have developed and managed their own supply systems to suit their domestic as well as industry water demands. The above suggests that no single institution has been able to meet the demand for water within the study area at present.

(1) Mix of Institutions

Although YCDC has the legal authority to supply water to the City, the present level of supply by this institution is hardly adequate for the entire population. It was noted that several large water

users have problems in meeting their demands even within the CBD area. As a result of YCDC supply limitations, a host of other institutions and organizations have evolved out to supply water as well as to provide many services needed to provide water supply.

The institutions responsible for water supply and the provision of other related services within the study area can be grouped under five types as listed below:

1) Government Ministries including the Yangon City Development Committee
2) Private Entrepreneurs and Organizations
3) Other State Institutions
4) Community Based Organizations
5) Non Governmental Organizations

Many of the above institutions are directly involved in the supply of water while a few implement activities which strength water supply capacity of institutions. The first group of institutions are direct water supply institutions while others are assisting institutions of water supply.

Tables 2.13 to 2.15 summarize the main activities of institutions and organizations involved in water supply within the study area.

Table 2.13 Government Ministries involved in Water Supply within the Study Area

Institutions & Organizations	Water-related Activities	Coverage	Operational Area
Yangon City Development Committee	Planning, construction, O&M and management of reservoirs, ponds, lakes, tubewells, pipe networks, tanks, pumping stations and other facilities, related machinery and buildings. Actual supply of water for City dweller and industries	20% to 100% customers in townships where YCDC water supply exists	28 townships. See Table 3.1 for a list.
Ministry of Home Affairs	General Administration Department is responsible for the administration of Peace & Development Councils (PDCs). PDCs have the responsibility for coordination of all development and social sector activities in townships including water supply.	Information not available	Not available
Ministry of Co-operatives (Co-perative Department)	Co-operative societies undertake planning, drilling tubewells, install and manage water supply systems, provide water to society members, and overall management of their water facilities	29 co-operative societies operate 33 tubewells and distribute water to customers	12 townships. See Appendix Table K-6
Ministry of Agriculture & Irrigation (Water Resources Utilization Department)	Drilling tubewells at the request of YCDC, other ministries and organizations	Not operational in study area	Not operational
Ministry of Construction (Dept of Human settlement & Housing Development)	Issue licence for drilling tubewells, own and operate18 tubewells, provide water to housing estates	Provide water to 20 housing estates and manage their water facilities	14 townships
Ministry of Hotels & Tourisms	Overall planning and coordination relating to hotel water supply; provide assistance and advice in providing water to hotels; coordinate with Ministry of Health for water quality monitoring	Each main hotel has a minimum of one tubewell	Throughout study area. Details not available
Ministry of Health	Monitoring water quality in private and industry tubewells; issue certificate of fitness in respect of new tubewells. Own tubewells to provide water to institutions under the Ministry.	*All private and industry tubewells at the time* of construction. Subsequent quality monitoring is done in industry wells on an annual basis.	Data not available
Ministry of Industry I	Overall planning and coordination of water supply for heavy industries	Information not available	Not available
Ministry of Industry II	Overall planning and coordination of water supply for small and cottage industries	Information not available	Not availanble
Ministry of Livestock Feed Stuff and Fishery	Operation and maintenance of tubewells owned by the ministry to provide water to livestock farms under the ministry, fisheries ponds, laboratories, and offices of the ministry.	All farms, laboratories and offices except for offices in Mingalardon and Insein townships are supplied with own tubewells. Details are not available.	Isein;Mingalardon;Thaketa;Dagon East; Dagon North

Table 2.14 Private Sector establishments involved in Water Supply within the Study Area

Type of Organization	Water-related Activity	Coverage	Operational Area
Individuals	Digging and construction of tubewells and open wells; operate and manage wells to supply water; bear the cost of construction and operational cost; sharing and selling water	Majority of private tubewells are serviced by themselves	Throughout
Entrepreneurs	Digging and construction of deep tubewells; installation of water supply network for domestic and industry use; sharing and selling water; management of private distribution networks; drilling, construction, operate and maintain tubewells; install, operate and manage private water supply systems for individual / groups of houses and industries; water selling to public and restaurants	Provide water needs of over 60% of customers in different townships; provide 90% of the plumbing service in the study area	Throughout
Private organizations	Digging deep tubewells and install mechanisms to obtain water for industries and hotels; manufacture and/or import materials needed for the water service organizations including YCDC; stock and sell materials to the public and organizations	Total needs by the industry	Whole area

Table 2.15 Water Supply Activities of other Organizations in the Study Area

Type of Organization	Water-related Activity	Coverage	Operational Area
Township Peace and Development Council (Other)	Coordinate all development and social service activities including water supply in townships/wards; resolve conflicts relating to water supply/demand; provide leadership in and organize cleaning of drinking water lakes and adding alum to lakes; distribute water delivered by YCDC to customers in designated townships	Coordination of activities with YCDC in 28 townships; lake cleaning work in 7 townships; distribute water in Seikky Kanantungy township	All townships
Ward Peace and Development Council (CBO)	Coordination of development and social sector activities at the ward level; collect data on water sector activities including the numbers of wells and other water services.	Low profile on water supply activities	Throughout
Union Solidarity and Development Organizations (USDA)	The responsibility of this organization is to facilitate grassroots development including water-related activities; provide logistic and organizational support to other organizations; provide information on broken pipes and leaks to supply staff; improve public awareness on water use	Though activities are insignificant scale at present cover the entire study area	The whole area
MSF – Holland (NGO)	Water sector service provision including improvement of hand pumps, sanitary education and water supply work	About 15 wards and 10 villages	Hlainghtayar township

In spite of varied attempts made by the Study Team to contact the government institutions listed in the Table 2.13 to 2.15, it was possible to meet and discuss sector activities only with three government institutions (ie. Ministry of Co-operatives, Department of Human Settlement and Housing Development, and Ministry of Livestock Feed Stuff and Fishery) in addition to YCDC. Therefore, the proceeding discussion on the activities and history of water supply institutions is limited only to three of government institutions in addition to YCDC. They are:

- Ministry of Construction
- Ministry of Co-operatives
- Ministry of Livestock Breeding and Fishery

It should be emphasised that a detailed review of all government institutions involved in City water supply is mandatory before making a comprehensive plan for water supply improvement in the study area.

(2) Yangon City Development Committee and its History of Development

YCDC is the only institution which has the responsibility for providing water to the citizens and carrying out all related services within the Study Area. The present organization has evolved over the developments that had taken place during the past 125 years.

A brief history of the development of YCDC is presented below.

The first commissioner of Yangon was appointed in 1850s who was also the town Magistrate. The main responsibility of the commissioner was to clear the mess created by years of neglect of the social and basic living facilities including water supply within the City. As the country was opened for trade and many foreigners were already involved in trade, the population began to increase. These developments made the need for a comprehensive plan to develop the City. Obviously it was not possible for one person to handle all the development and operational matters. Accordingly, the Governor appointed the first Municipal Committee (MC) comprising of 32 members in 1874. Together with this appointment, the first Municipal Act No.7 was promulgated to formalize administration of the City.

The Municipal Act was subsequently found to be inadequate to manage the development affairs underlying the City. On the recommendation of the MC, a comprehensive act was formulated and submitted for the approval of the Governor. The new Municipal Act of 1922 changed the name of the MC to Yangon Municipal Corporation (YMC) comprising not more than 40 members. The expansion of the City began in 1940s which necessitated the formation of the Rangoon Development Trust. Accordingly, the YMC was named as Rangoon Municipal Corporation (RMC).

With the outburst of the World War II, much damage was done to the City and the British government was evacuated to India in 1942. The rehabilitation of the chaotic state of the City called for the reorganization of the RMC. This resulted in the formation of Yangon Municipal Committee (YMC) for the second time. An interim MC was formed after the dissolution of the ad-

ministration in 1945. The Chairman of the MC was made the Municipal Commissioner. By Independence, the City of Yangon had deteriorated. On the one hand, the destruction of the City created by the World War II had still to be cleared. The influx of people from rural areas into the capital made housing and living in the City much to be desired. The MC could not do much to clear the mess.

With the caretaker government assuming State power in 1958, a municipal commissioner was appointed and cleaning up operations began. Because of the City population had grown, the expansion of the limits by incorporating new townships started. Given the dimension of the task of City administration, the YMC was given an autonomous body in 1964. The government notification No.270 created the Yangon City Municipal Committee (YCMC) with 59 members. The change in State power in 1974 resulted in creation of the Rangoon City Development Committee (RCDC) which was institutionalized in 1978.

The RCDC was replaced by Yangon City Development Committee (YCDC) in 1984. The next major development in YCDC was its elevation to Ministerial rank in 1990. The YCDC was made an independent body in 1990.

The present structure of YCDC consists of an executive committee with 7 members (Figure 2.17). The institution has 20 departments, 4 district executive offices and 33 township offices.

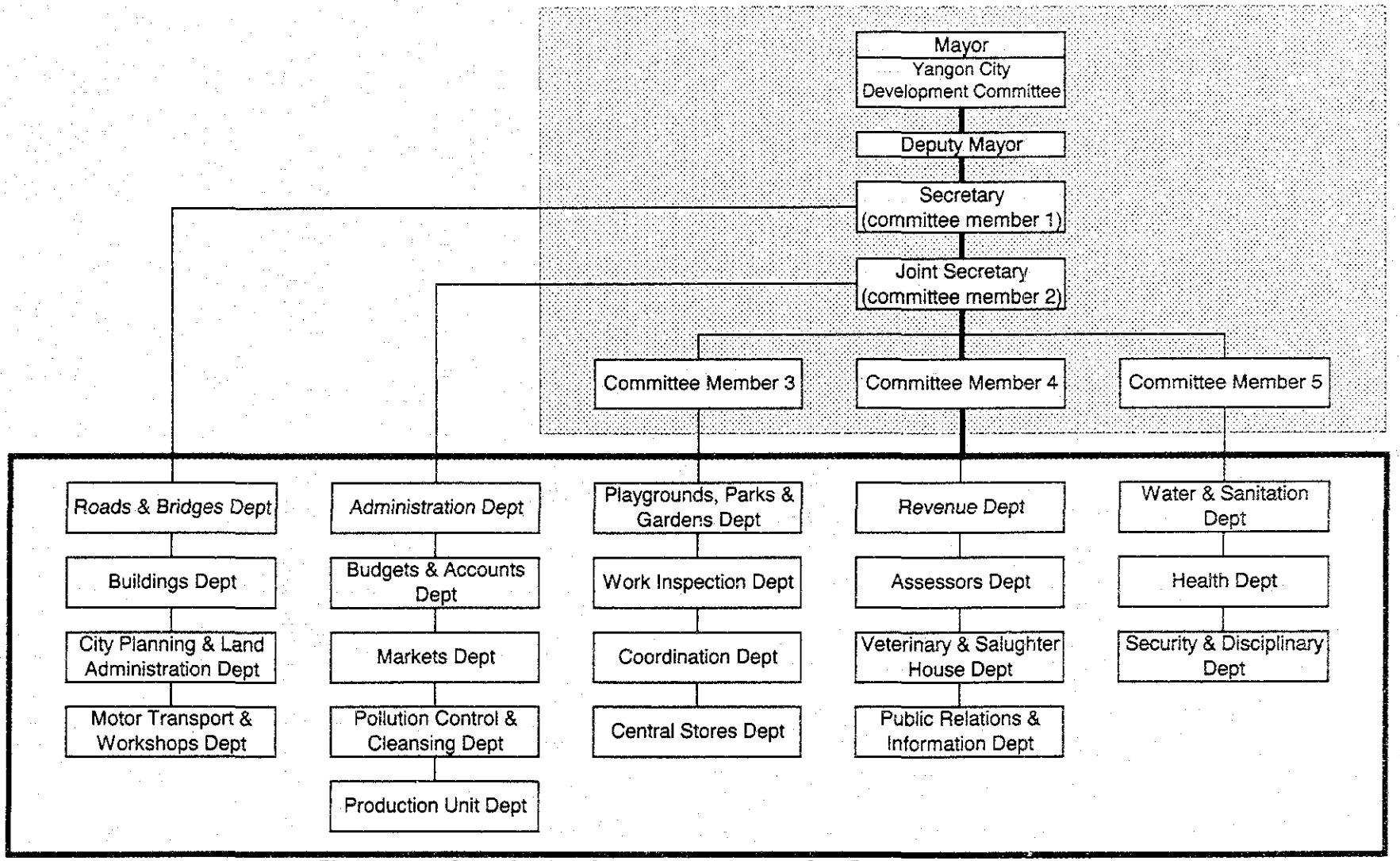


Figure 2.17 Organization Structure of Yangon City Development Committee

Source: YCDC

Note) The shaded area composed of YCDC executive committee.
Direct flow of command is shown in bold lines where coordination line of command is shown in continuous line.

(3) Ministry of Construction

The main role of this ministry is planning and coordination of all construction work within the City. The other responsibilities include City planning including planning and construction of townships, provide approval for the construction of private tubewells after inspecting water quality, coordinate with the Ministry of Health in the monitoring of quality of water in tubewells operated by hotels, industry, and operation and management of tubewells supplying water to institutes under the Ministry. Its water quality monitoring programme for private tubewells is both irregular and inadequate as water quality is checked once only at the time of construction. Further checks are done only on an ad-hoc basis.

(4) Ministry of Co-operatives

Several co-operative societies are involved in the provision of water supply to their members. These co-operative societies are organized under the co-operative department of the Ministry. The total membership of co-operative societies undertaking water supply work for their members is 30 in the study area. The population benefitted by their activity is about 19,900.

The co-operatives are selling water to their members at cents 25-30 per 50-galons.

List of co-operatives providing water to their members is given in Appendix Table K-6.

(5) Private Sector

Private sector involved in Yangon City water supply consists of individuals who plan and manage their own water supply systems, entrepreneurs who provide other water-related services to individuals and companies, and private organizations providing a large number of services for the water sector. The private sector consisting of complex and varied individuals and organizations are responsible for the supply of water to City dwellers and a large number of industries. Table 2.14 indicates the scale of water supply activity of private sector.

(6) Entrepreneurs

In addition, private individuals are active in several water supply-related trades in the city area. They dig and construct wells, fix water supply network for individual as well as several houses, repair water facilities, and offer plumbing service for individuals and organizations. These services are prevalent throughout the Study Area.

Furthermore, private water vendors were reported to be supplying this indispensable commodity to individual houses and shops in 7 townships. The private water vendors are of several types namely, collecting and carrying water in a saddle, barrel-mounted bullock carts and push carts, and water bowsar. The latter category was reported in water supply to large restaurants, hotels and some industries.

(7) Private Organizations

Private organizations undertake activities similar to private entrepreneurs. The main difference being the scale of operations which is larger in the case of organizations. There are several well

drilling companies, plumbing companies and organizations which manufacture and/or import spare parts, accessories and chemicals needed by the water sector of Yangon.

CHAPTER 3

CURRENT WATER SUPPLY SYSTEM

CHAPTER 3 CURRENT WATER SUPPLY SYSTEM

The Yangon City Development Committee (YCDC)'s overall responsibility in the City water supply is stated as follows:

> **"The Committee shall manage and perform to distribute adequate water of suitable quality for people living in the City frontier"**
> (YCDC Notification No.6/99, 17th December 1999)

> **"Where YCDC has given public notice that sufficient water is available from its water works for furnishing a reasonable supply of water for domestic purposes, it shall forthwith take measures to ensure the supply of such water"**
> (The Rangoon Municipal Manual, 1922, Section 114)

According to above, YCDC is committed to supply water to the City in sufficient quantity. The Committee attempts to achieve this task through a host of activities such as raw water production, water purification, storage, pumping, transmission, distribution to consumers, and the implementation of regulations. All water supply and related tasks are the functions of YCDC's Water Supply and Sanitation (WSS) department. This department is responsible for planning and implementation of all activities related to water supply and sanitation within the study area.

The aim of this chapter is to provide an in depth analysis including the past and current performance of the status of water service managed by YCDC (WSS), the organizational structure of the department and the institutional arrangements to deliver a range of services. The history of water supply system in the City is provided as a backdrop to this chapter.

3.1 HISTORY OF WATER SUPPLY SYSTEM

Yangon Water Supply system has a long history of more than 150 years. The supply system was instigated in 1842 with 30 open wells, during the reign of King Thar Yar Wadi. The supply area was about 0.04 mile^2 (2.5 furlong^2)
In **1879**, while King Thibaw was ruling Upper Myanmar, water supply was introduced using water pumps, by joining of 250 mm (10") Cast Iron (CI) pipe from Kandawgyi Lake (constructed same year). Potable and drinking water was distributed to Botataung and Pazaundaung wards. There was a population of about 35,000 at that time.

In **1884**, Inya Lake water after renovation was fed to Kandawgyi Lake by 750 mm (30") pipes and distributed to City wards between Morton St. and Theinbyu St. by 675 mm (27") Pipe.

In the year **1894**, Shwedagon Service Reservoir was constructed with 4540 m^3 (one million gallons) capacity. The water derived from Kandawgyi lake via Hpo Sein P/S (Pumping Station) with

675 mm (27") pipe to the Shwedagon pagoda reservoir. The water was fed to west downtown area (between Lanthin and Theinbyu Roads) with 675 mm (27") pipe.

In **1898**, with the aim of sufficient water for use by 650,000 Yangon residents, at the rate of 25 gallons per capita per day, Hlawga Lake was started to be built and completed in **1904** (During the period 1921 to 1924, Hlawga Lake was extended to the Northern side). Since that time, no more water was taken from Kandawgyi and Inya Lakes.
Hlawga water was supplied to Yangon wards by cast-iron pipes through the Hpo Sein Street Water P/S (Pumping Station) with 1050 mm (42") pipe.

In **1906**, construction of Yegu Pumping Station was completed, from which, using 3 steam engine pumps, water was pumped in 42" up to Shwedagone pagoda reservoir to distribute to the whole of Yangon. Since that year (1906), the working of Hpo Sein Street-Tamwe pump station has ceased.

In **1925**, at Kokhine 90,900 m3 (20 million gallon) water reservoir was constructed, from which connection was made to Shwedagon pagoda reservoir and water was supplied to Eastern and Western parts of Yangon, in addition to the then existing water supply.

In **1927**, another pump station was constructed at Sangyi-wa at Hlawga Lake, from which up to 15 million gallons of water per day was supplied.

During the period **1928-37**, to increase the water supply for Yangon, many exploration and research projects were done for the establishment of Gyobyu water reservoir.

In **1940**, "Gyobyu" reservoir located about 45 miles to the northern part of Yangon was fitted with a 1400 mm (56") steel pipeline as a connection to Kokhine water reservoir through Yegu P/S (Pumping Station).

By **1958**, it has been estimated that about 755,000 people of Yangon were using the water from Hlawga and Gyobyu reservoirs at the rate of 34 million gallons per day including the water from boreholes.

In **1964**, the long-used steam driven pumps were replaced with electric powered 7 pumps with the capacity of 40 million gallons of water per day, and up to 3 to 4 million gallons per day, from the tube wells of Kyimyindine .

In **1973**, Phugi water supply project was started. On 11th May **1987**, Gyobyu (56") main pipe line was cross-connected to Phugi line. On 9th February **1989**, as in the original design, Phugi water has began to flow into Hlawga reservoir with 1500 mm (60") pipe.

In **1990**, Seven (7) new pumps were installed at Yegu P/S in place of the former unit used since 1964.

In April **1992**, Phugi project (laying 1650 mm (66') pipeline from Hlawga to Yegu P/S) was fully accomplished and drinkable and potable water has been distributed to Yangon city of the rate of 385900 m3/day (85 million gallons per day).

Out of the public services rendered by YCDC for the people within the City limits, accessible and potable water supply is the main essential item: The present is as shown below.

Water Resource per Day Water Distribution (in million gallons)

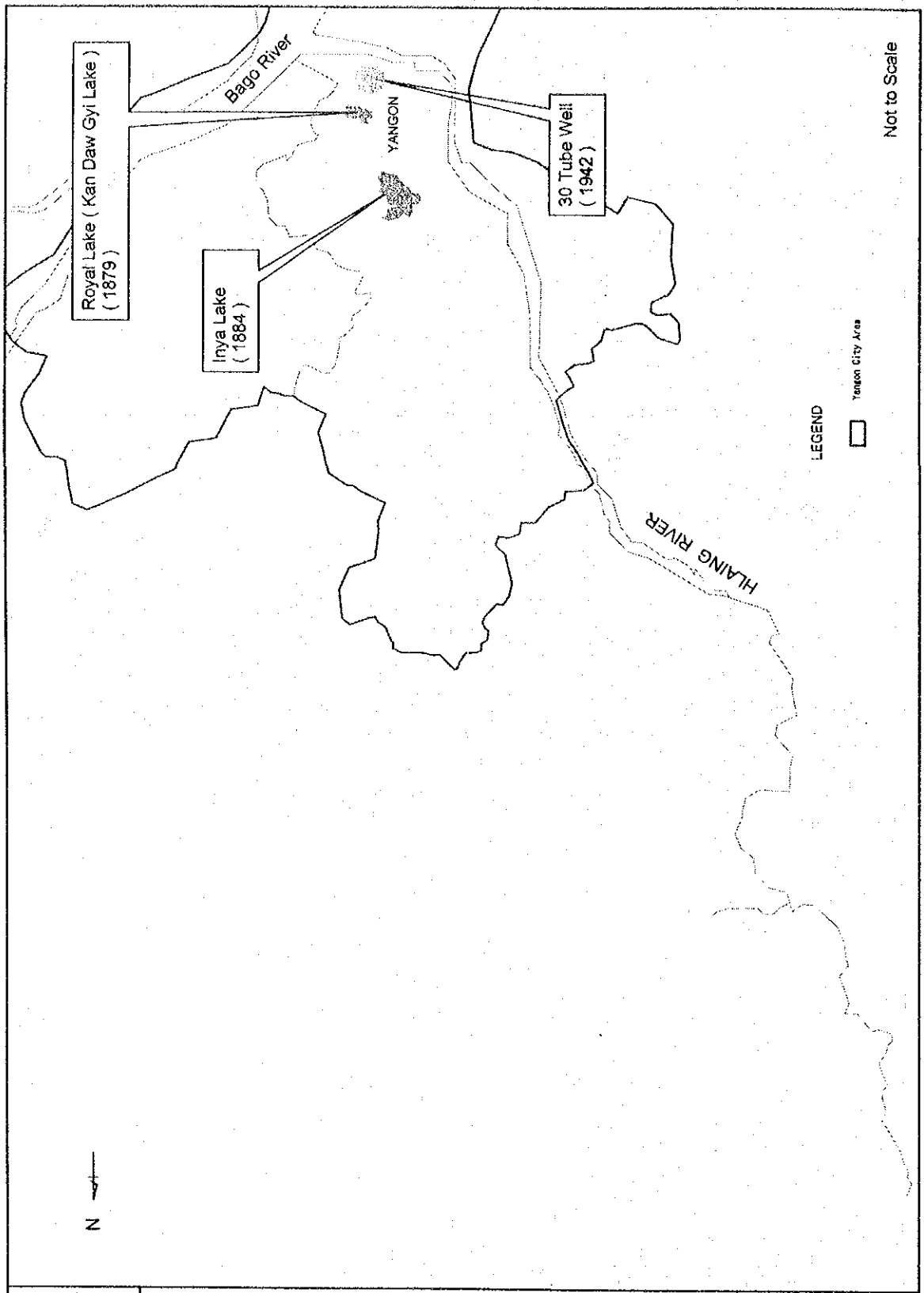
(a)	Gyobyu Reservoir	30 million gallons
(b)	Hlawga Reservoir	45 million gallons
(c)	Phugi Reservoir	(up to Hlawga lake only)
(d)	YCDC owned tube wells	10 million gallons
	TOTAL	85 million gallons

The history from 1984 to 1992 confirm the following things,

(1) No capital investment since 1992.
(2) Current production rate could be 385,900 m3/day (85 million gallons per day).
(3) The main pipeline downstream of the Yegu P/S have no improvement since 1925.

Beside the above history, Central Service Reservoir was also completed in 1965 but due to the heavy leakage from side walls, it has not been operated since then.

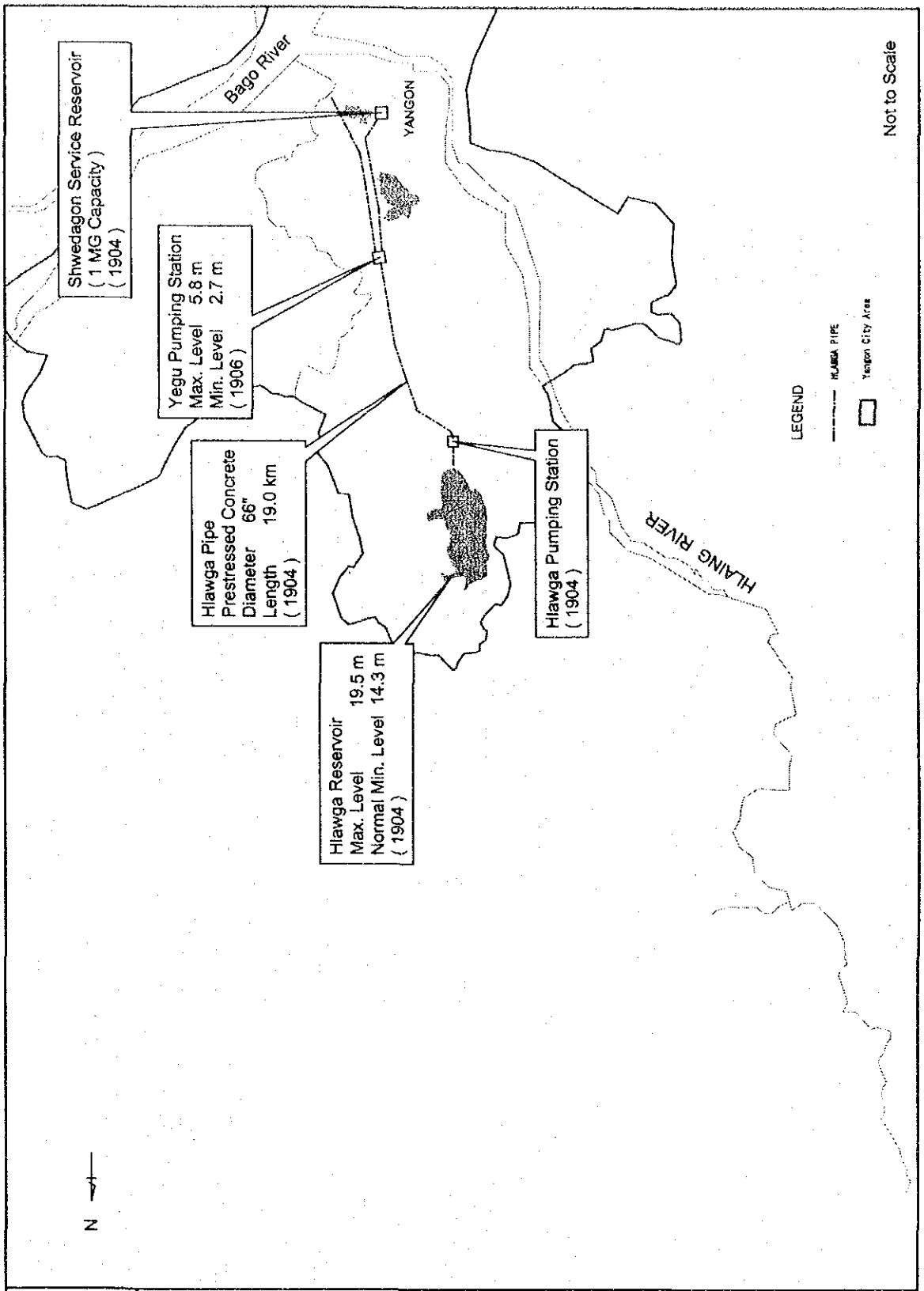
Figures 3.1 to 3.5 show the history of water system development in Yangon City



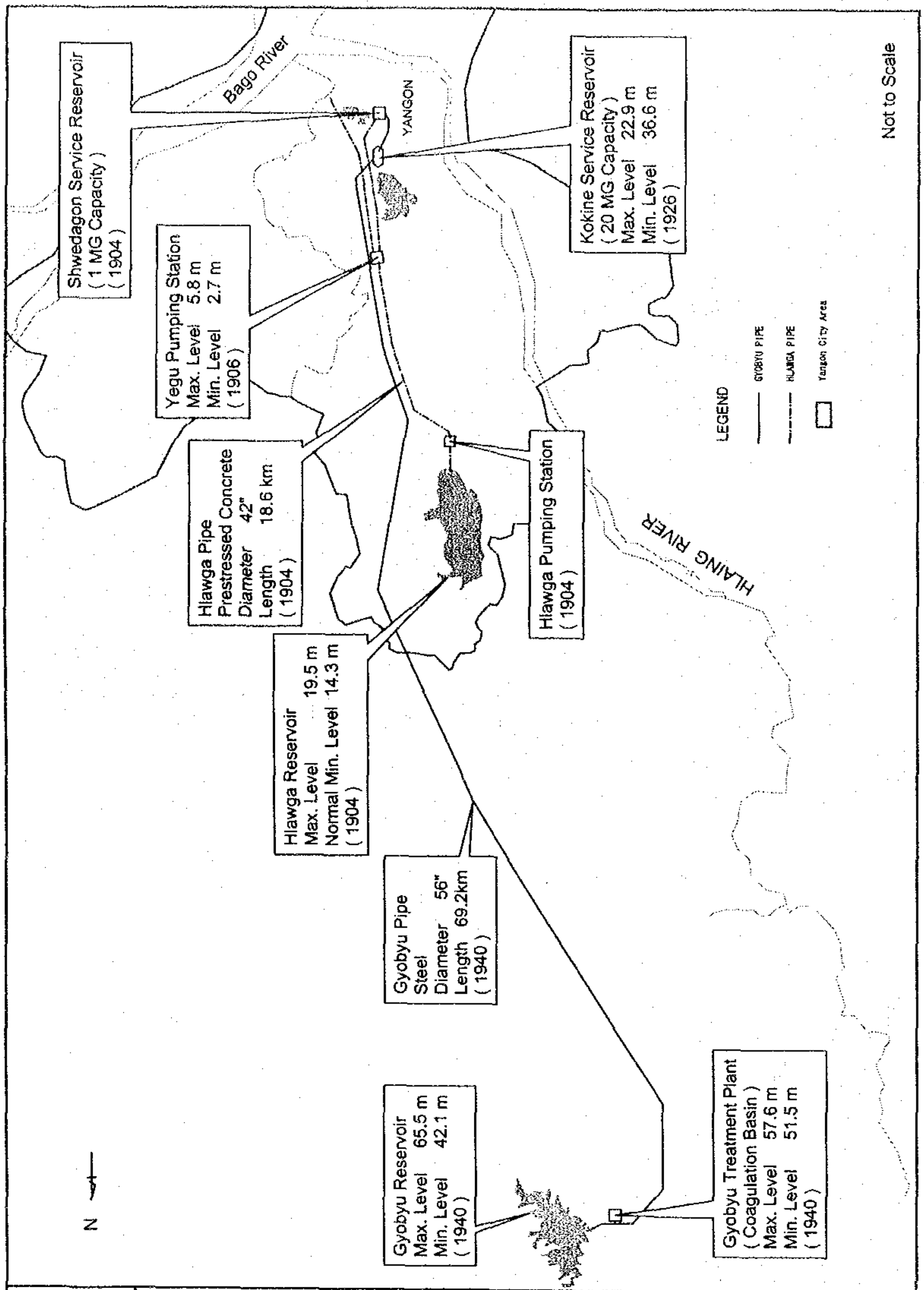
THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR

FIG 3.1

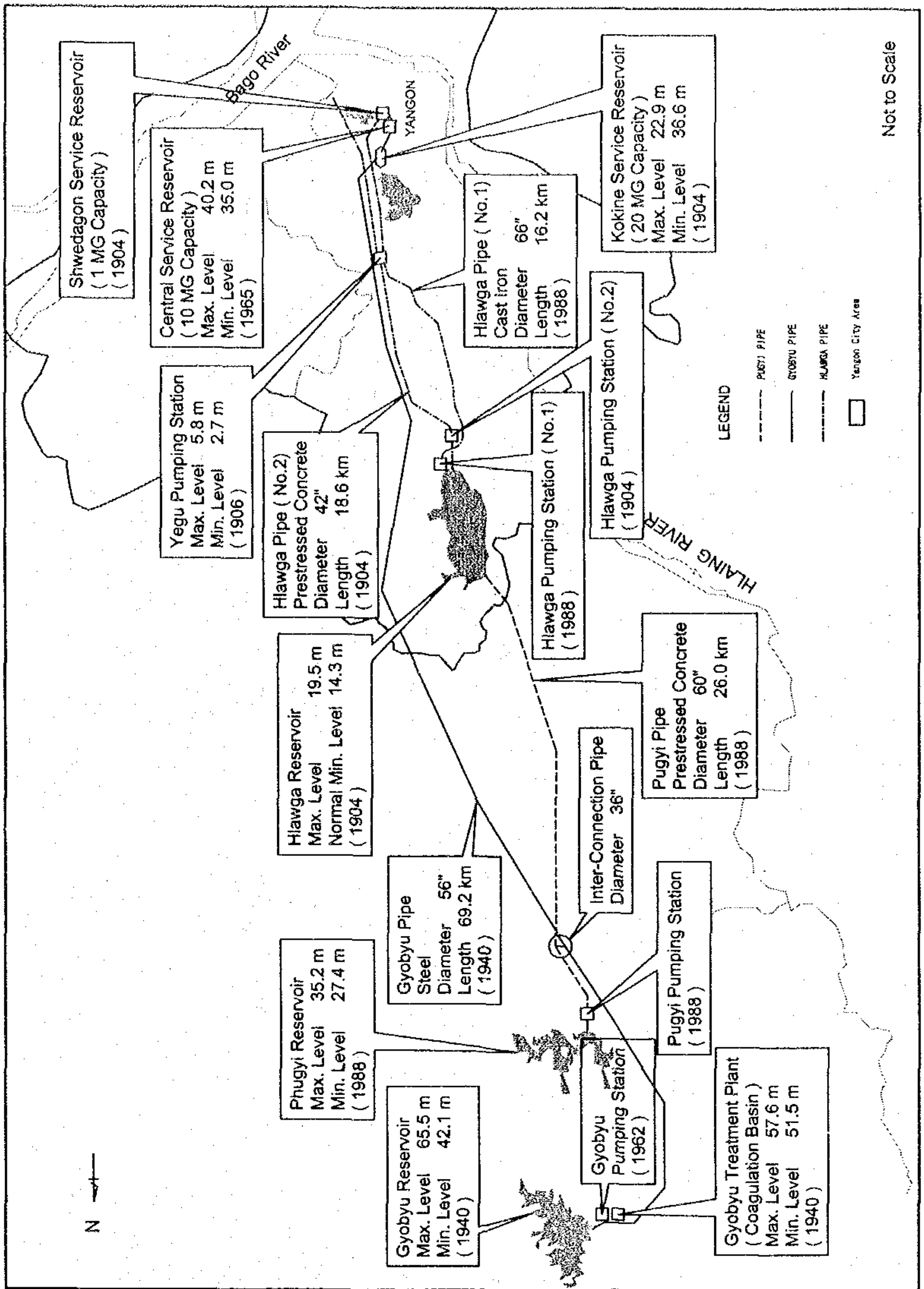
Water Supply System in 1884



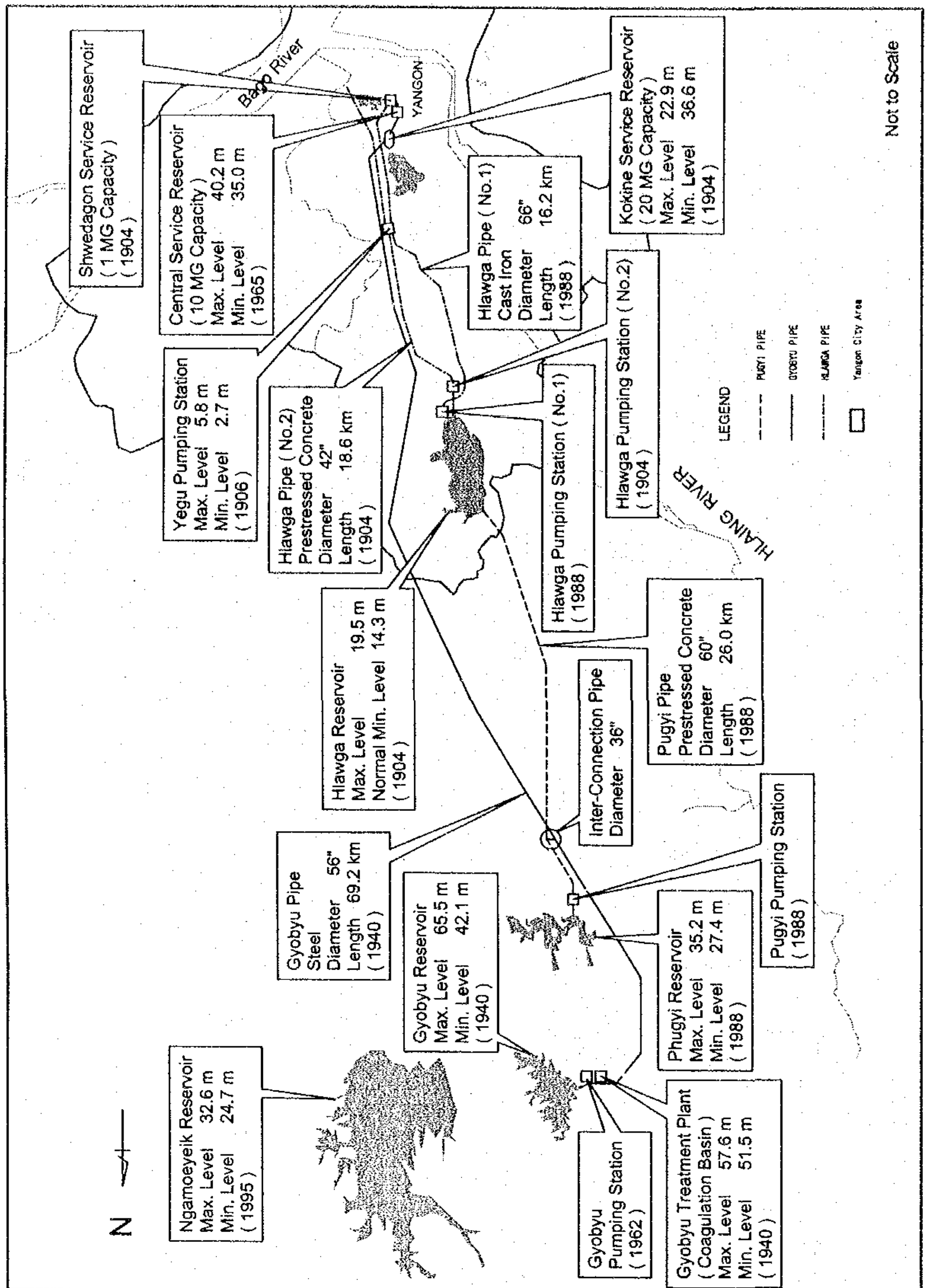
JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR
Water Supply System in 1906	FIG 3.2



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG 3.3
	Water Supply System in 1940	



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG 3.4
	Water Supply System in 1988	



THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR

FIG 3.5

Present Water supply System

3.2 WATER SOURCES

The production rate of the existing water sources is estimated as 439,440 m3/day (96.7 mgd) as of 2000 and come from both surface water and groundwater.

Surface water (Reservoirs)	: 395,550 m3/day (87.0 mgd)
Groundwater	: 43,890 m3/day (9.7 mgd)
Total	: 439,440 m3/day (96.7 mgd)

3.2.1 Surface Water

A total amount of 395,550 m3/day (87.0 mgd) of surface (reservoir) water is developed from three reservoirs as follows. The location of each reservoir is referred to "Location of Major Reservoir and Water Supply Facilities," the top figure of this report.

(1) Gyobyu Reservoir

Gyobyu has dependable yield of 93,300 m3/day (20.5 mgd) and was completed in 1940. It is located at about 64km (40 miles) north of Yangon. Water is carried through 1,400 mm diameter steel pipe to Yegu pumping station by gravity. When the level in the reservoir falls closer to the treatment plant or when the flow is not adequate to meet the demand, 3 low lift pumps are available for raising the amount of flow.

(2) Phugyi Reservoir

Phugyi Reservoir was completed in 1992 and has a dependable yield of 245,700 m3/day (54mgd) of water, however current production rate is 227,250 m3/day (50 mgd). Water is transmitted from Phugyi by pumping through a 1,500 mm dia presented concrete pipeline to Hlawga Reservoir.

(3) Hlawga Reservoir

Hlawga Reservoir is situated at about 27 km (17 miles) north of Yangon. It has a dependable yield of 75,000 m3/day (16.5 mgd) and was completed in 1906. The water from Hlawga is pumped through a 1,050 mm dia cast iron pipeline to Yegu, when it is pumped to the city's distribution system.

(4) Ngamoyeik Reservoir (reservoir exists but water is not utilized yet)

Ngamoyeik dam was constructed in 1995 by the Irrigation Department, Ministry of Agriculture and Irrigation in the upper reach of the Pazundaung Creek at the confluence of the Ngamoyeik Creek and the Mahoe Creek about 48km (30 miles) north of Yangon. The reservoir is planed to be operated by Irrigation Department for multipurpose, providing Irrigation water for about 70,000 acres, Flood control for the lower, Tidal reaches of the Creek, and will be able to supply the water up to 409,500 m3/d (90 mgd) of water for Yangon City.

3.2.2 Groundwater

Groundwater extraction facilities in the city were divided into two categories; YCDC tube wells

and None YCDC dug/tube wells. Annual groundwater production managed by the YCDC was roughly estimated for the year of 2000 using database obtained from the YCDC.

Usually, the unit of cubic meter per day (m^3/day) is used for measuring groundwater production, availability, inflow, etc. and liter per second meter (lpsm) is for indexes of well performance. The unit of million cubic meters per year (MCM/Y) was used for the annual groundwater development amount in consideration of groundwater's seasonal variations and varying rainfall patterns.

(1) Groundwater Production

The YCDC has 217 tube wells located in 22 Townships as of July 2001 with three levels of water supply service. Table 3.1 shows categorized such database parameters.

Table 3.1 Tube Well Parameters of YCDC Database

Category & Parameter		Description		
		Valid No.	Range	Remarks
Location	Township	217 wells	-	22 Townships
	Ward			
	Street			
	Numbering			
Structures	Diameter	217 wells	50-300mm	22 Townships
	Depth	217 wells	24-146m	
	Year Completed	45 wells	1965-2001	5 Townships
Performance	Water Quality	16 wells	pH, Fe, Cl	10 Townships
	Discharge	217 wells	50-2,270lpm	Av. 744m^3/day
	Pump	100 wells 117 wells	50-250mm 100-300mm	Air-lifting Submersible
Utility	Level-I	74 wells	74 facilities	6 Townships
	Level-II GW	5 wells	2 systems	2 Townships
	Level-III GW	31 wells	16 systems	6 Townships
	Level-III SW/GW	104 wells	1 system	15 Townships
	Hydrant	3 wells	200mm	3 Townships
Operation	Monthly Q Jan/98-Dec/00	199 wells	2,128-620,529 m^3/month	3 wells: Hydrant 2 wells: Standby 13 wells: No Records

Remarks; GW=Groundwater, SW=Surface Water, Q=Discharge
Sources; YCDC Township Office, as of July 2001

Annual production amounts of groundwater extraction were estimated in accordance with parameters of system, service level and Township. Meaning of annual duration was set up from January until December. Following Table 3.2 shows annual production amounts in years of 1998, 1999 and 2000.

Table 3.2 Annual Production of YCDC Tube Wells

Identifications				Annual Production Amount (MCM/Y)		
System/Service		Township	Well No.	1998	1999	2000
SW Fed System Combined with GW	Majority of L-III including L-II	Ahlone	10	12.22	13.23	12.07
		Botataung	2			
		Dagon	7			
		Insein	1			
		Kamayut	2			
		Kyauktada	4			
		Kyeemyindaing	12			
		Lanmadaw	6			
		Latha	4			
		North Okkalapa	6			
		Pabedan	3			
		Sanchaung	16			
		South Okkalapa	6			
		Thaketa	17			
		Thingangyun	8			
		Sub-total	104	12.22	13.23	12.07
GW Fed Systems or Facilities (independent from SW Fed System)		Dala	3	0.00	0.00	0.74
		Insein	1	0.04	0.04	0.04
			2	0.08	0.08	0.08
		Kamayut	7	0.29	0.31	0.30
			1	Records are not available at present.		
			1	0.12	0.11	0.10
			1	0.16	0.18	0.15
			2	Records are not available at present.		
			3	Records are not available at present.		
			2	Records are not available at present.		
		Mingalartaungnyunt	1	0.12	0.12	0.12
		South Okkalapa	1	0.03	0.03	0.03
		Thingangyun	2	0.03	0.06	0.08
			2	0.12	0.12	0.12
			1	0.04	0.04	0.04
			1	0.02	0.01	0.01
		Sub-total	31	1.05	1.10	1.81
	L-II	Dagon	4	0.60	0.60	0.60
		Seikan Port	1	0.50	0.50	0.50
		Sub-total	5	1.09	1.09	1.10
	L-I	Dagon Myothit South	32	0.35	0.34	0.34
		Dawbon	7	0.17	0.17	0.17
		Hlaingthaya	7	0.08	0.08	0.08
		North Okkalapa	18	0.34	0.33	0.33
		Shwepyitha	8	0.09	0.09	0.09
		Thingangyun	2	0.02	0.02	0.02
		Sub-total	74	1.06	1.04	1.04
	Hydrant	Botataung	1	0.00	0.00	0.00
		Mingalartaungnyunt	1	0.00	0.00	0.00
		Sanchaung	1	0.00	0.00	0.00
		Sub-total	3	0.00	0.00	0.00
City Total			217	15.42	16.47	16.02

Source; YCDC Township Offices, as of July 2001

In terms of daily pump operation hours, remarkable disparity could be observed between different service levels. Because of existence of elevated service reservoirs and needs of water supply amount, daily operations have been controlled flexibly. Statistical daily operation hours are shown in Table 3.3 below.

Table 3.3 Tube Well Operation by Service Level

Category			Pump Operation (hrs/day)			
Service Level	System	Well	1998	1999	2000	Average
L-III SW/GW	1	104	7.6	8.1	7.7	7.8
L-III GW	16	31	4.3	4.4	5.1	4.6
L-II GW	2	5	12.0	12.0	12.0	12.0
L-I GW	74	74	3.2	3.1	3.1	3.1
Hydrant	3	3	0.0	0.0	0.0	0.0

Source; YCDC Township Offices, as of July 2001

(2) Service Reservoirs for Tube Wells

There are 21 service reservoirs existing in the main system at present. Table 3.4 shows the identifications of such service reservoirs for consideration of the future diversion below.

Table 3.4 Existing Service Reservoirs in Main System

Type of Service reservoir			Volume (m^3)				Townships
Identification		No.	Mini.	Ave.	Max.	Total	
Elevated	Gravity	5	14.5	64.2	227.1	320.9	Botataung, Insein Sanchaung, South Okkalapa & Thaketa
Ground	Pump	11	14.5	134.0	454.6	1,473.8	Kyeemyindaing, North Okkalapa, South Okkalapa & Thaketa
	Gravity	5	14.5	28.4	45.5	141.9	North/South Okkalapa & Thaketa
Total		21	3.6	92.2	454.6	1,936.6	7 Townships

Source; Township Office, the YCDC, as of September 2001

(3) Present Problems of Groundwater

The physical problems associated with groundwater were described. Groundwater problems are formed in terms of quality and quantity. Qualitative and quantitative problems shall be improved from a standpoint of safe and enough water supplies.

1) Qualitative Problems

In the Yangon City, several water quality problems are reported and confirmed, which are saline water intrusion, brackish water and high iron/manganese concentration, etc. In particular, four Townships (Hlaingthaya, Kyeemyindaing, Seikkyi Kanaungto and Dala)

located at right riverbank of the Hlaing River are fall on serious water quality problems, because availability of economical water source is only groundwater at present.

<Saline Water Intrusion & Brackish Water>
Saline water intrusion was reported along the both banks of Hlaing River near the Yangon Port. The main reason for this phenomenon stems from an insufficient and/or declining groundwater recharge rate, geological conditions, and the difference of density between saline and fresh water coming from both sides (sea and inland). This problem usually has been induced by the over exploitation of groundwater.

Brackish groundwater, in most cases not potable owing to higher chloride ion concentration because of marine deposits, is pumped in areas where "Thadugon Sandstones" of Pegu Group is distributed in the northern city.

<High Fe & Mn Concentration>
In the central city area, groundwater with high iron and manganese concentration has been developed for a long time. Locations of such tube wells are concentrated in areas where Irrawaddy Series formations almost cover the central part of the city are distributed. Groundwater characteristics are sodium bicarbonate with calcium and magnesium as second constituents.

<Sanitary Seal and Well Cover>
Well is not merely structure for groundwater extraction, but also contamination rout from surface to under ground immediately without any enough filtration system. Recently, surface portion of well annular space between well casing and borehole has been grouted by the cement milk or sand cement. Additional mounting base around tube wells with older ages and smaller diameter shall be constructed instead of surface sanitary sealing.

Worse rout is tube well its self. Most of tube wells do not have well cover. Since well fields are located in lowland areas, some fields of tube well sites are swampy during rainy season.

2) Quantitative Problem
Airlifting is effective method for well development. Most likely sand contents exceeding permissive limitation (50mg/l) could be observed at tube wells with compulsive initial extraction using air compressor as shown in Table 3.5.