APPENDIX B

GROUNDWATER MANAGEMENT

APPNDIX B
GROUNDWATER MANAGEMENT

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APPENDIX B GROUNDWATER MANAGEMENT

GENERAL

The study on groundwater management covers the entire city in order to come up with groundwater source potential exploitable as domestic water supply. Emphasis was placed on groundwater availability due to its prevalent use and comparatively conservative development expected through the future in the jurisdiction of the YCDC. It is also advantageous to utilize groundwater for domestic water supply because of better quality and economical use in the development of satellite towns.

Nevertheless, with reference to groundwater development and management, groundwater potential in the city was roughly studied to provide information for the future effective use. However, groundwater balancing was studied with due consideration of conditional assumptions. Additional studies, observations and monitoring shall be, therefore, promoted for reviewing periodically.

1 GROUNDWATER AVAILABILITY

A "Groundwater Availability Map" was prepared, which identifies the areas with available potable groundwater sources. The study has two major components: (1) interpretation of existing geologic and groundwater conditions, and (2) preparation of Groundwater Availability Map to show groundwater potential areas under several categorized zones. Furthermore, standard well specifications by township were also established to reflect in the future development required.

The major data used in the study were obtained from concerned agencies and supplemented by the information gathered through questionnaires from township offices in the field. The field information directly collected by the Study Team was also used to increase the accuracy of the Map. Among the information, the geologic map, the groundwater investigation reports and the well inventory of YCDC are essential for the analysis of groundwater characteristics in terms of quality, quantity and distributions.

The Groundwater Availability Map may be used for city and township levels of master plan and feasibility study at present. However, recommendations on the required investigations were presented for specific areas with scope of survey, as reference for respected townships, to conduct these prior to the detailed design and the construction stage.

Aside from the requirements, updating the map is a requisite to gain more information on prevailing groundwater conditions. An annual review and updating of the database will enable the YCDC and the respective townships to implement water source development on a project site basis.

1.1 NATURAL CONDITIONS AND GEOGRAPHICAL FEATURES

Yangon city, a highly urbanized independent city is the capital of Myanmar as well as the designated economical center. The city occupies the central portion of 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 the rivers namely: (a) Ngamoeyeik 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 only by boat from the Yangon Port.

1.1.1 Meteorology

There are three meteorological stations located in and surroundings of the Yangon City under management of the Ministry of Meteorology, identifications of which are described below Table B.1.

Table B.1 Meteorological Stations

Station Name	Cord No.	Location		Elevation
		Latitude	Longitude	
Kaba-aye	48097	16' 54"	96' 10"	20m
Bago	48093	17' 20"	96' 30"	9m
Tharrawdy	48088	17' 38"	95' 48"	15m

Source: Department of Records, the Ministry of Meteorology, as of June 2001

Of these stations, the Kaba-aye Station is located in the compound at the Ministry of Meteorology, Mayangone Township in the city, while other two stations at out of the city are about 50km of NNE direction and 110km of NW direction away from the city central.
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.

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 B.2 shows average monthly meteorological records at Kaba-aye (Yangon) Station. At these statistical data, averages annual rainfall and evaporation were totaled at 2,706.2 and 1279.9mm/year (106.54 and 50.39inch/year), respectively.

Table B.2 Meteorological Records at Kaba-Aye (Yangon) Station

Parameter	Duration year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Average Monthly Mean/Total											
Rain	mm	4.3	3.9	10.2	28.3	294.4	548.8	574.0	601.7	368.9	197.2	61.2	4.3
68-00	in	0.17	0.15	0.40	1.10	11.60	21.61	22.60	23.69	14.52	7.76	2.41	0.17
Temp.	max	33.2	34.7	36.6	37.1	34.3	31.0	30.4	30.0	31.0	32.1	33.1	32.6
91-00	min	16.6	18.2	21.2	23.9	24.7	23.9	23.5	23.2	23.2	23.2	21.6	18.2
Humid	am	67	67	70	69	77	87	89	90	87	82	73	69
91-00	pm	56	51	54	59	75	89	89	91	87	81	72	64
Wind	V	2.3	2.4	2.4	2.6	2.7	2.7	2.6	2.3	2.2	2.5	2.6	2.6
91-00	D	NW-NE	NW-E	SE-NW	SW-W	E-W	S-SW	S-SW	S-SW	SE-SW	NE-SE	N-E	N-NE
Evap.	mm	115.5	122.1	162.8	183.4	141.8	75.0	75.3	72.2	81.3	100.1	107.1	110.6
81-00	in	4.55	4.81	6.41	7.22	5.58	2.95	2.96	2.84	3.20	3.94	4.22	4.35
Sun.	hr	9.3	9.3	9.2	9.3	6.1	2.7	2.6	2.2	4.0	6.2	7.7	8.9
77-00	%	39%	39%	38%	39%	25%	11%	11%	9%	17%	26%	32%	37%

Remarks: Wind V is velocity in mile per hour and D is direction.
Source: Department of Records, the Ministry of Meteorology, as of June 2001

According to statistics of the year 1999 rainfall at fourteen (14) meteorological stations under management of the Irrigation Department in Yangon Division, an average annual rainfall totals at 3,024mm (119inches) and was situated from April until October: about 97.5% of annual rainfall, as shown in Figure B.1.

In east side of the city, four stations recorded less annual rainfall (average 2,717mm). Average deviation was estimated at negative 0.78. In those stations, rainfall pattern was slightly delayed: 80mm in the month of April against others of 328mm average monthly.

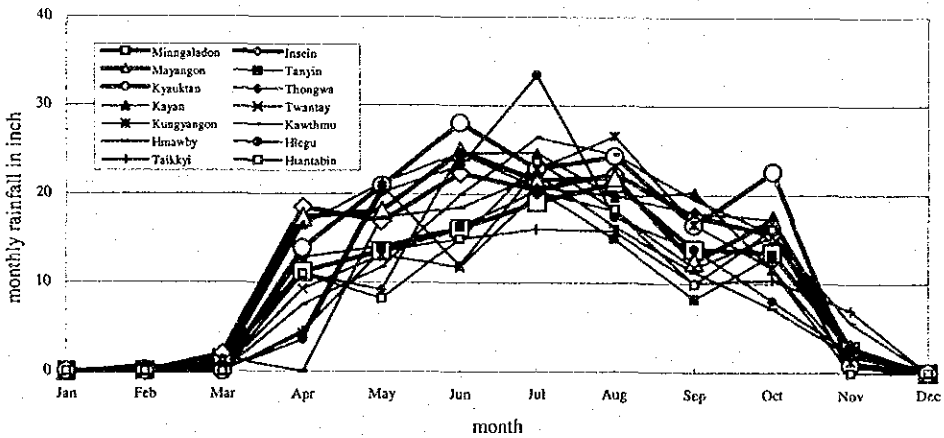


Figure B.1 Rainfall 1999 in Yangon City

1.1.2 Present Land Use and Topography

Remaining forest area constitutes 9.1% of the total land area of the city located mostly in the central and northern lowland hills as presented in Table B.3. Agricultural land occupies 43.8% including areas of farm, paddy, open land and grassland. Primary settlements are concentrated along the port side and the major transport routes.

Table B.3 Present Land Use of Yangon City

Category of Land Use	Area (1km²=247.1acre)		Percentage
	km^2	Acre	
Forest Land	52.22	12,904	9.1%
Farm/Grass/Open Lands	35.48	8,767	5.7%
Built-up (Residential)	257.74	63,688	42.3%
Paddy (Rice Field)	232.05	57,340	38.1%
Swamp (including Fishponds)	29.49	7,287	4.8%
City Total	609.09	150,506	100.0%

Source: Township Offices, as of June 2001

The remaining forest cover must be conserved to primarily serve as watershed. Conversion of the remaining forestland to other uses will restrict its function as a watershed. Correspondingly, a significant increase in forest and agricultural areas will result in a high recharge source of groundwater.

The relief of the city varies from level plains to lowland hills in the central part as shown in Figure B.2.

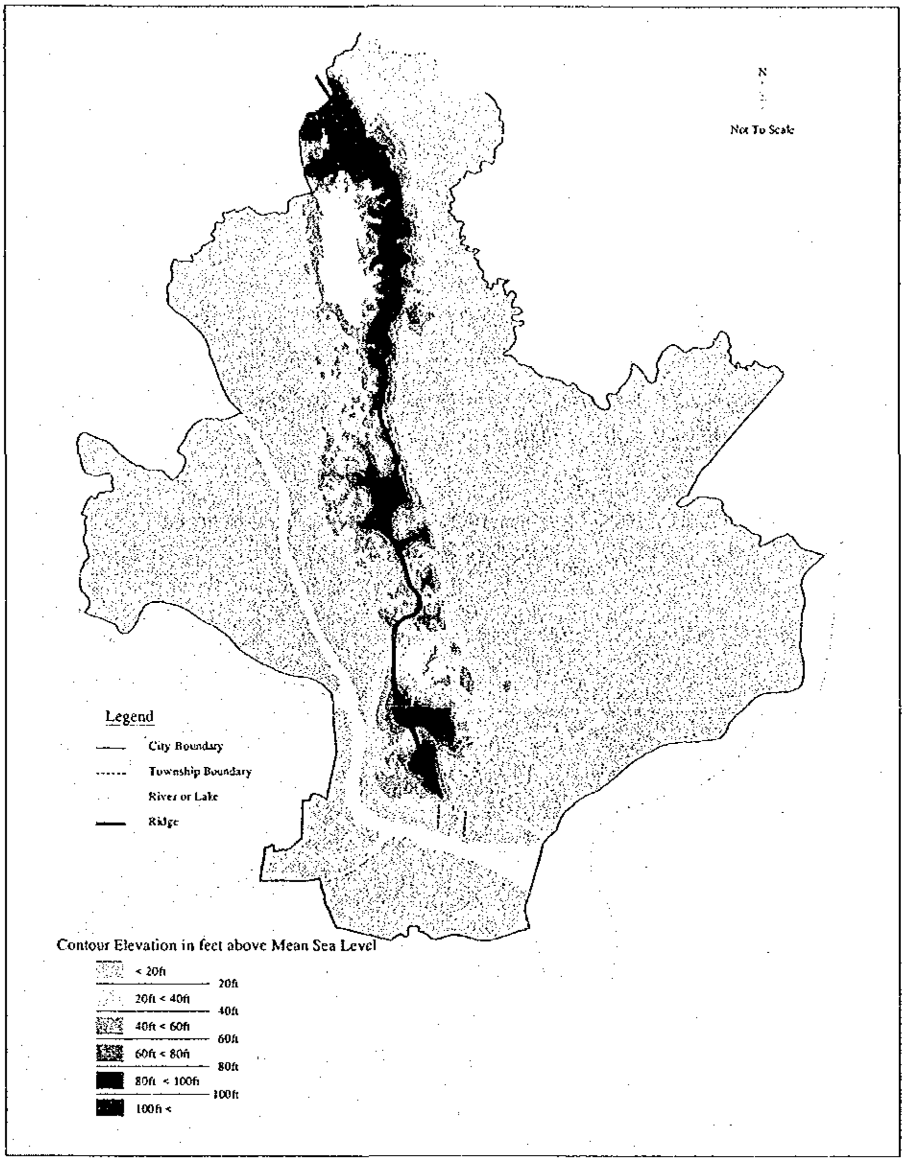


Figure B.2 Elevation Contour Map of Yangon City

Area on the center has lowland hills commonly known as the fault ponds with man-made dams 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 average height of 30m (100ft) and it degenerates gradually into level 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 level 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 mean sea level.

1.1.3 Geology and Hydrogeology

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 un-conformably 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.

For the purpose of preparing the Groundwater Availability Map of the city, only rock units significant to groundwater storage and permeability are briefly classified as shown in Table B.4 below.

Table B.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	T_{Ma}	Besupet Alternation	(1) Pegu Group
	Oligocene	T_{Osa}	Thadugon Sandstone	
		T_{Osh}	Hlawga Shale	

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

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.

The Geological Map of Yangon City is illustrated in Figure B.3 with same symbols of Table B.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 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 about 40degree towards east. Total thickness of this group is estimated about 1,050m (3,400ft).

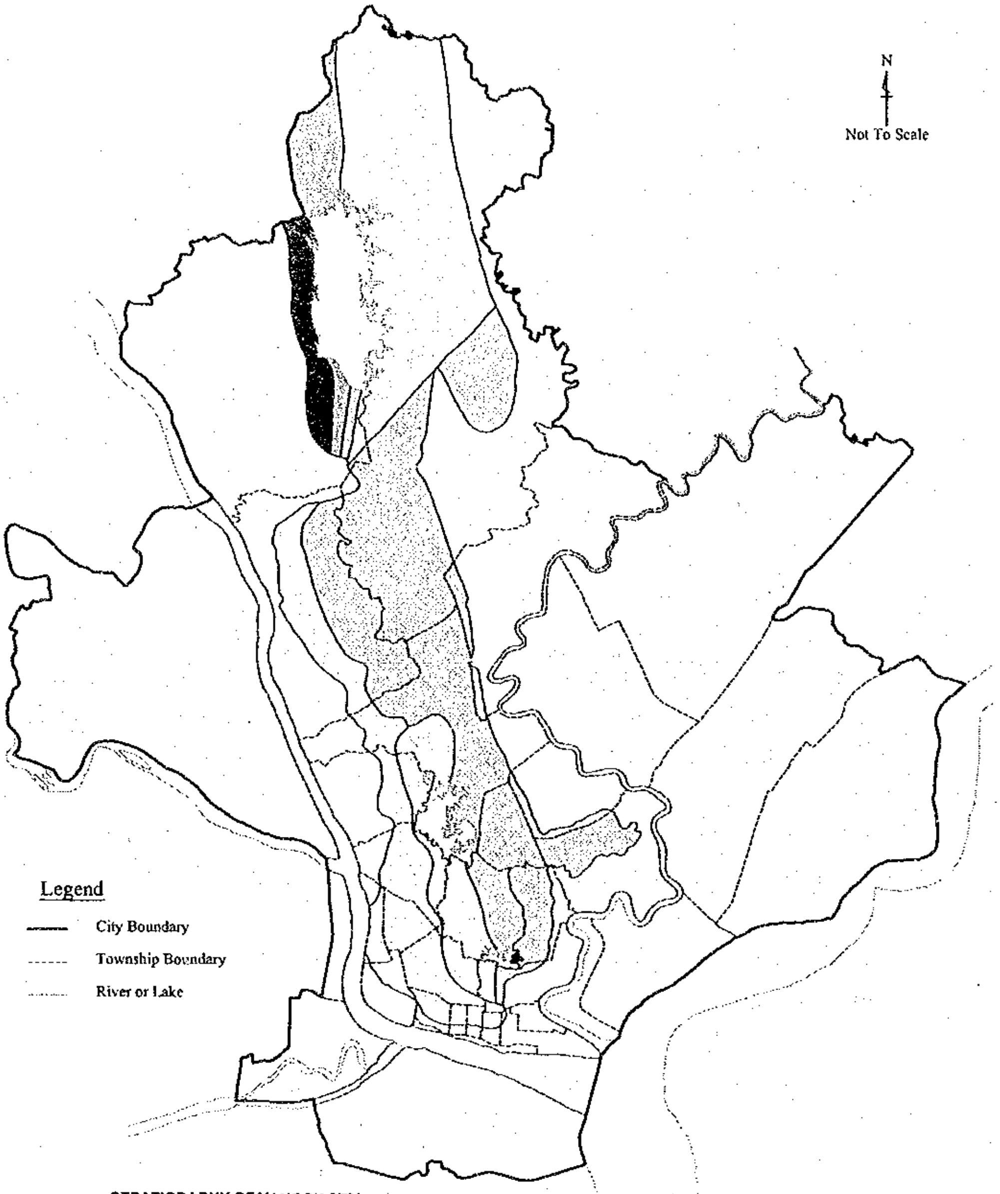
Rock units of Miocene and older systems are impermeable, which are classified as aquicludes. The only "Thadugon Sandstones" has a permissive permeability for exploitation, groundwater in which is limited to fractured and weathered zones. The groundwater quality in this aquifer is poor and in most cases 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 N-S 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.



STRATIGRAPHY OF YANGON CITY

Geologic Age			Rock Units and Formation	
Quaternary	Holocene	Q_H	Recent Alluvium	Quaternary Deposits
	Pleistocene	Q_P	Delta Deposits	
Tertiary	Pliocene	T_{Pc}	Tanyingon Clay	Irrawaddy Series
		T_{Pa}	Arzanigon Sandstone	
	Miocene	T_{Ms}	Besupet Alternation	Pegu Group
	Oligocene	T_{Os}	Thadugon Sandstone	
			Hlawga Shale	

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

FIG B.3

GEOLOGICAL MAP OF YANGON CITY

(3) Pleistocene to 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 are consisting of sands and gravels, remarkable 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 surroundings of 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).

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 B.2 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 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 B.4 below.

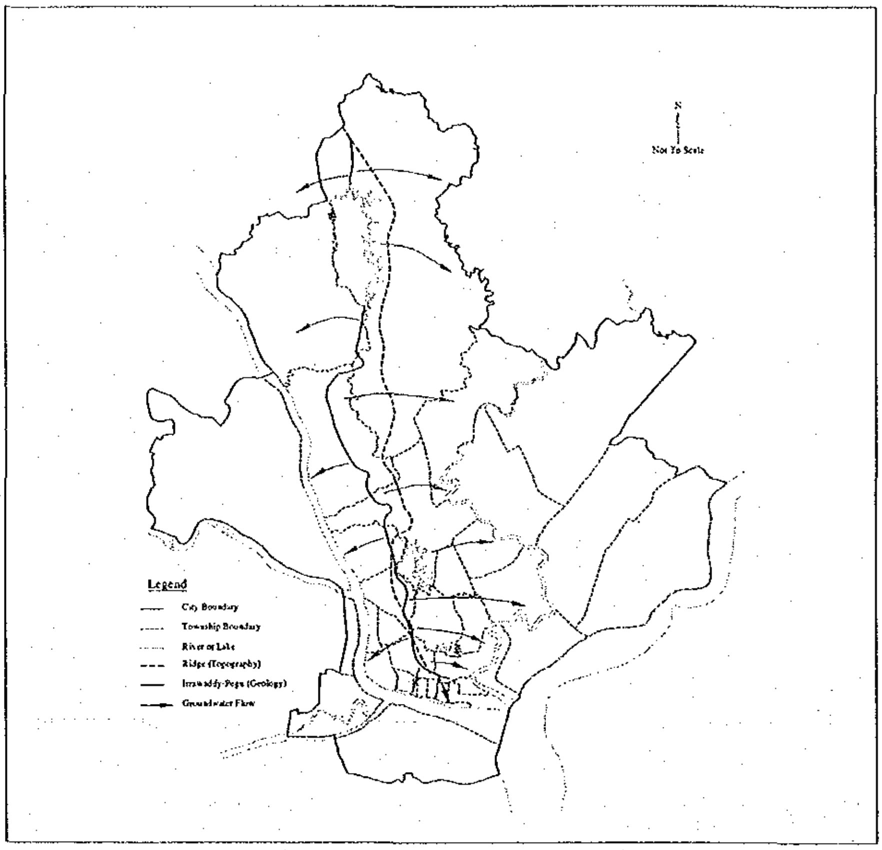


Figure B.4 Hydrogeological Watershed Boundary

Among the water quality problems of the city, high iron concentration groundwater is serious with a high percentage of affected existing tube wells. The problem is extended to most of the central city. Origin of high iron concentration groundwater was reported because of lateritised members distributing lenticular in Irrawaddy Series.

High chloride ion 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. With due consideration of electric conductivity measurement along Yangon River in near city central, most of chloride ion was contaminated by the marine deposits as blackish water.

1.2 GROUNDWATER SOURCES

Based on the study of existing water sources, groundwater is considered as a safe and more economical source for future water supply requirements of the satellite townships.

Dug (open/covered) and tube wells are possible source for domestic water supply. However, their expected aquifers have quite different characteristics especially for safe water quality.

One disadvantage of dug wells is fluctuation of water level during dry season that reduces the discharge rate of the wells. Another disadvantage is the usual high susceptibility of unconfined aquifers to direct infiltration of surface pollutants.

In general, tube wells have better water quality and invariable yields when developed and operated with appropriate technology. This depends if the wells tap to comparatively deeper aquifer. It reduces the hazards of groundwater pollution. In addition, lowering of static groundwater level does not affect the discharge rate. In this regard, tube well facility is adopted for future groundwater sources exploitable in the satellite townships.

1.2.1 Classification of Groundwater Availability

For planning purpose, the city area is divided into the following sub-areas in terms of groundwater availabilities.

(1) Possibility of Economical Tube Well

- Potential Area

  Potential areas could be found in portions underlain by the Pliocene series and recent formations. Most of these areas have several aquifers occurring at various depths. In this area, tube well is applicable for drinking water source because of safe water source, however, dug wells can also be developed.

- Difficult Area

  This area is not suitable for any type of well development. The areas under this category largely consist of rock formations older than Miocene epoch. The groundwater availability in the aforesaid rocks is very risky (low permeability) and water is rarely released in the opened rock fractures.

(2) Yielding of Tube Well

- High Yielding Area

  Wells in this area have larger discharge rate than about 1.0m^3/min. (13,000gph). Yielding rates using submersible pump facility are good for water supply system composed of distribution pipeline network with service level-III*[1)].

- Low Yielding Area

  Most of case, rich clayey formations are distributed in this area. Their expected yielding is smaller than about 0.5m^3/min. (6,500gph). Wells in these areas can be used for only individual water supply facilities with service level-I*[1)] or independent water supply systems with service level-II*[1)].

Notes *1): The services level components of water supply system are defined below and shown in Figure B.5 for this study.

(a) Level-III System

The Level-III system, individual house connection system from the distribution pipeline network, at the township level is usually established and operated by the YCDC and the independent subdivision. Most of water source is surface water. Groundwater is used for supplemental water. Groundwater systems are used in satellite townships.

(b) Level-II System

The Level-II system, communal faucet system using distribution pipeline network, is designed to cater for ward level water supply with a limited service coverage and supply capacity.

(c) Level-I Facility

Level-I facility, point source system is common in rural areas, the majority of which are owned privately. Major facilities are different types of wells equipped with hand-pumps or airlifting-pump with conveyance pipes and one communal faucet.

(d) Individual Facility

Individual facility, in-house water source system is common in rural areas, copious groundwater areas and Level-II/II areas with low supply pressure. The majority of which are owned privately. Major facilities are different types of wells equipped with hand-pumps or electric-pump with conveyance hose and in-house faucet.

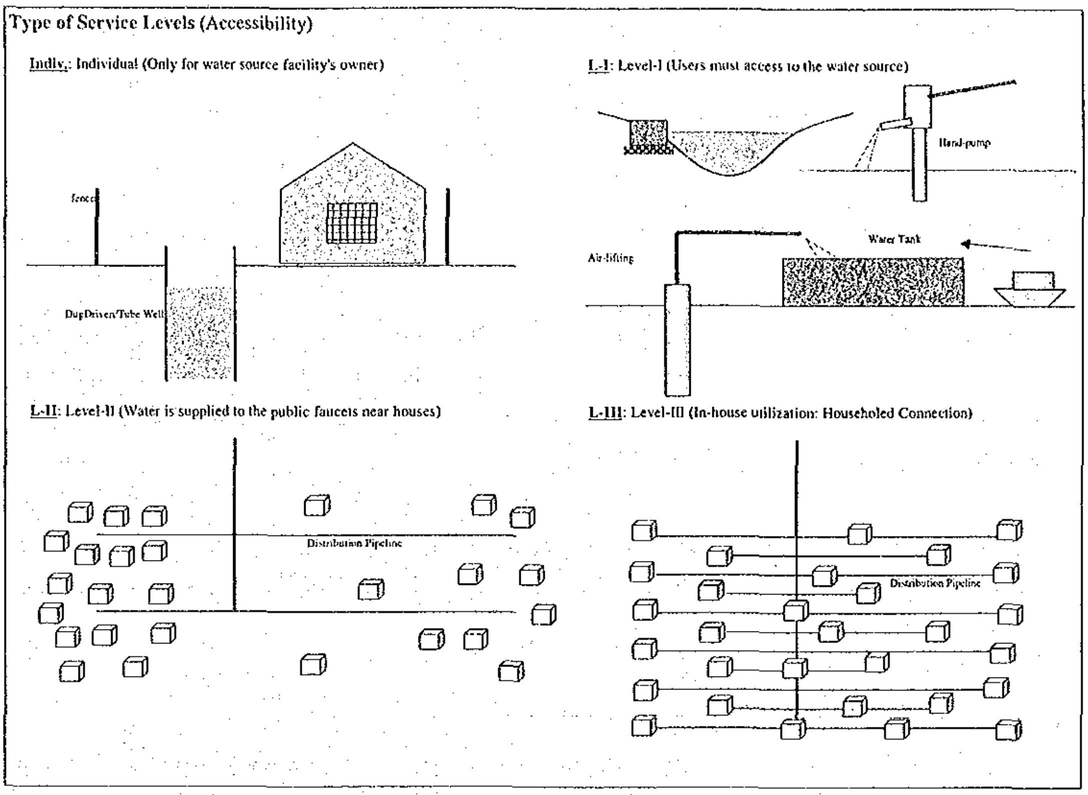


Figure B.5 Definition of Water Supply Service Levels

(3) Expected Water Quality

- High Iron Concentration Groundwater Area

  There is no standard for drinking water quality in Myanmar. According to WHO drinking water quality standard, limitation of iron ion concentration is 0.3mg/L, while permissive limitation of which is 1.0mg/L. In this study, permissive limitation of 1.0mg/L is adopted for evaluation of high iron concentration groundwater.

- Saline/Brackish Groundwater Area

  Chloride ion content has also a limitation of 200mg/L in WHO water quality standard. There are two reasons why chloride ion concentration occasionally in the city is higher than 200g/L. One reason is brackish water blockading into the marine deposits in Oligocene to Pliocene epochs. Other one is saline water intrusion including permeation of irrigation water with high chloride ion concentration coming from the river water.

Additionally, contour of static water level is also included into the groundwater availability map. Information of which with depth in meter (feet) below ground surface was obtained from Ministry of Mines, prepared in 1994. Due to lack of records on water levels in the city, area with available contour line is very limited.

1.2.2 Groundwater Availability

The Groundwater Availability Map is presented in Figure B.6. Supplement to this map, the several W-E section maps are also attached in Figures B.7 and B.8. The major databases used in the preparation of the map were obtained from the Department of Geological Survey and Mineral Exploitation, Ministry of Mine.

Technical information on the wells by township is also shown in Chapter 2.1.2 of this Appendix-B. The groundwater development potential areas in the city for the future are summarized below and in Table B.5.

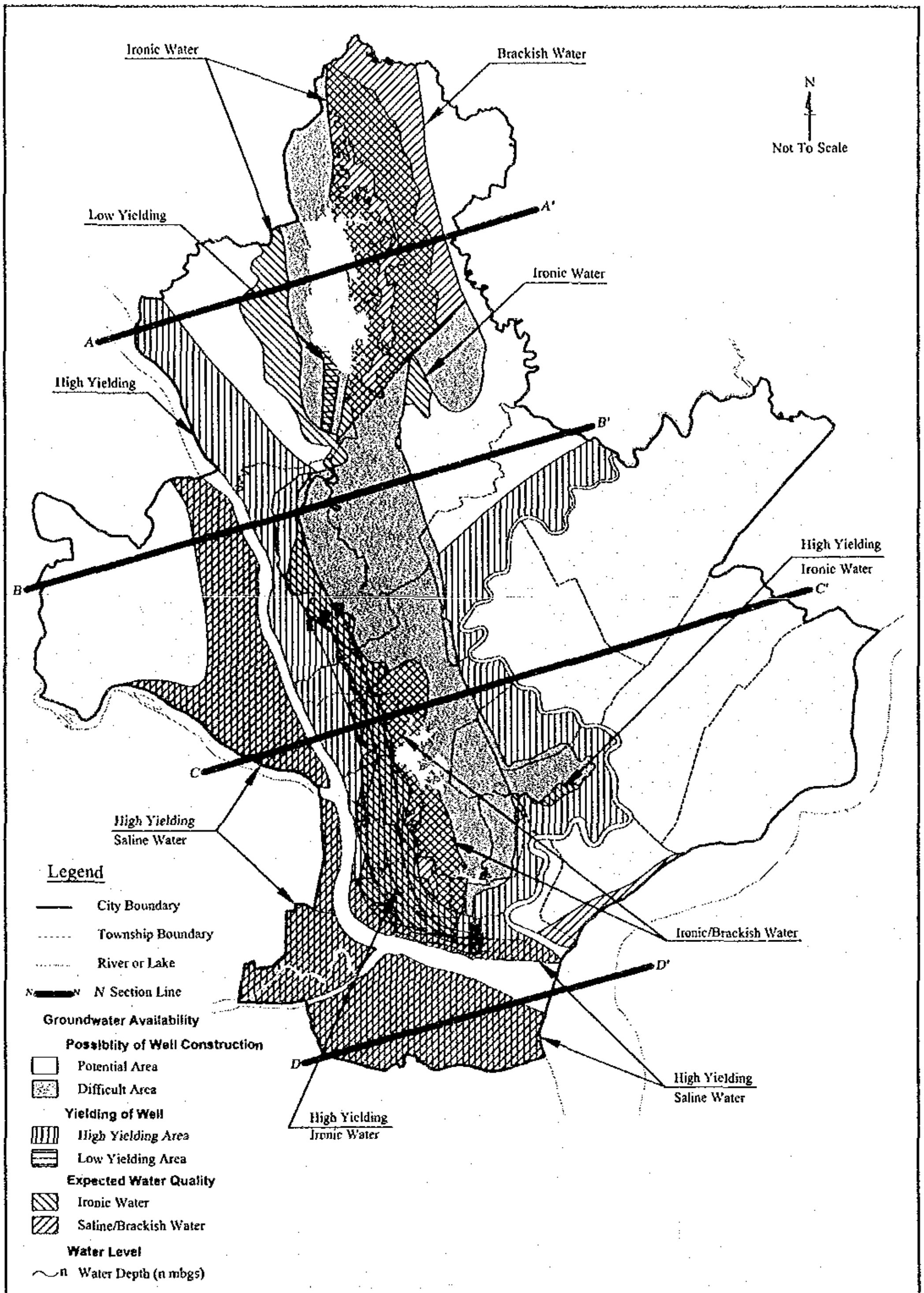
(1) Potential Area

Potential areas cover approximately 82.9% of the city, widely distributed in the city area excluding part of the central lowland hills. There are riverside areas where only unconfined aquifers could be developed due to water quality problem. The depths of unconfined aquifers are assumed ranging from 3.0m to 9.0m.

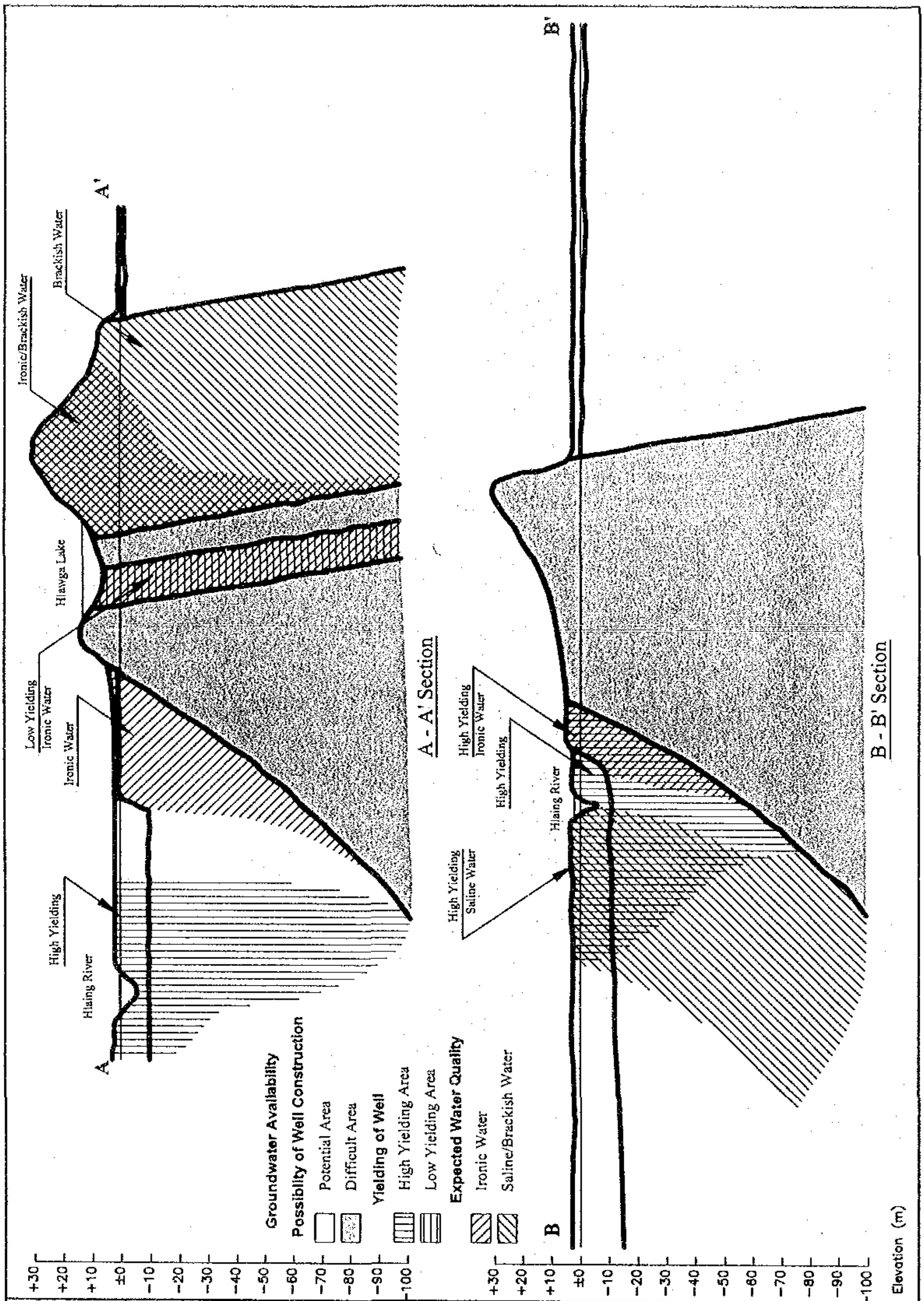
The tube well area is composed of alluvial plain and lowland hills made of sedimentary rocks. The alluvium is composed of recent and delta deposits of clay, silt, sand and gravel, which form a groundwater storage basin for some aquifers. While, the sedimentary formations of Pliocene epoch consist of sandstone and shale in the central part of the city.

Considering the geological formation, city proper and southwest side of Inya Lake is categorized as a high yielding area for tube well development. While the lowland hills of Oligocene epoch at south side of Hlawga Lake is classified as a low yielding area. In these tube well areas, the depths of existing tube wells are ranging from 26m to 146m. The static water levels are from 0.9mbgs to 30mbgs and yielding from 0.05m^3/min to 1.7m^3/min.

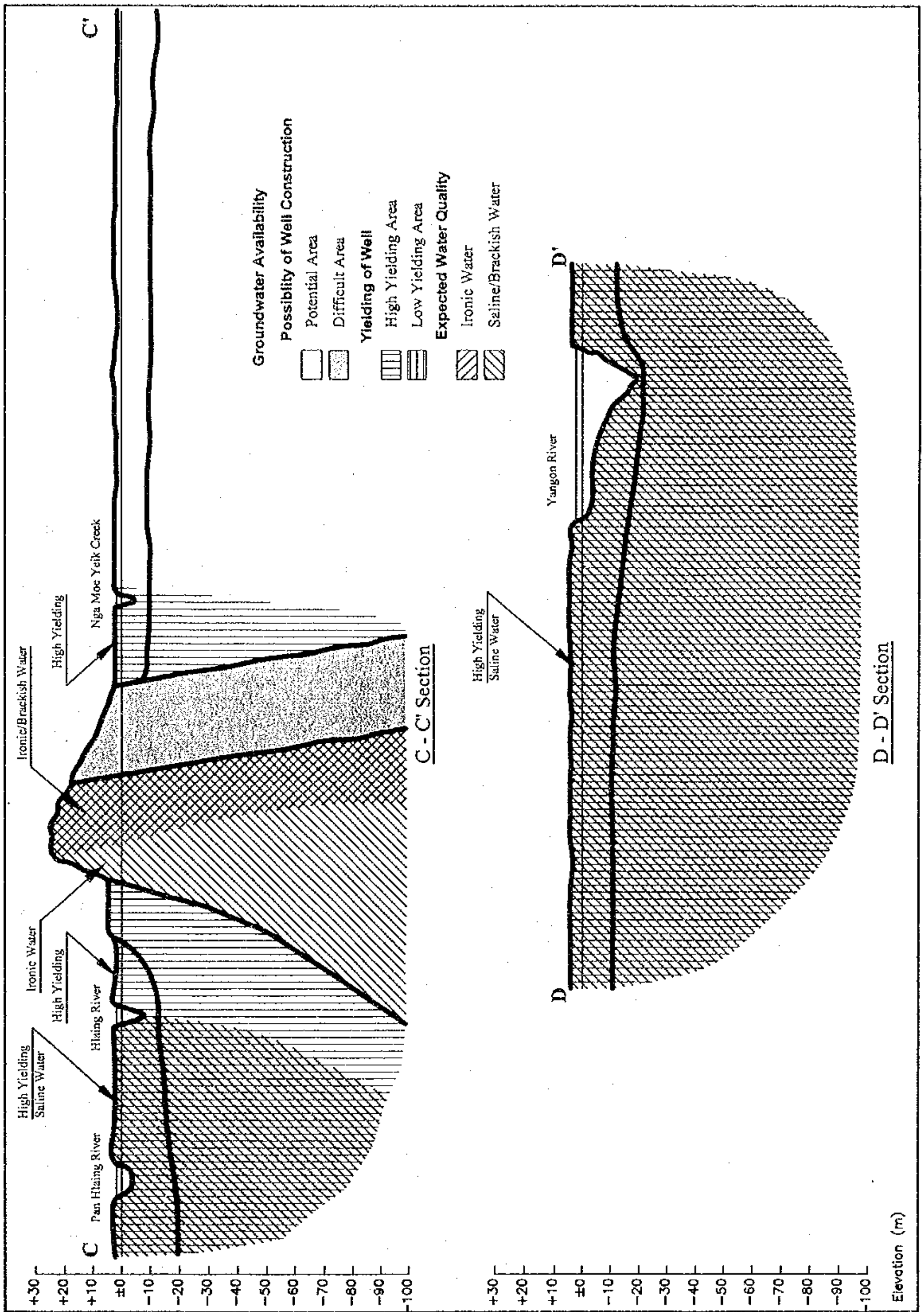
In the northern lowland hills area near Hlawga Lake made of Pliocene series, groundwater development in deeper portion has not yet been performed sufficiently due to none availability of well drilling rig. Deep well development is necessary in this area to secure the safe water source. The average depth of tube wells is assumed at about 150m (500ft) with an average water level of 12mbgs (40ft in depth).



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG B.6
GROUNDWATER AVAILABILITY MAP OF YANGON CITY		



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG B.7
SECTIONAL MAP - 1 OF GROUND WATER AVAILABILITY		



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

FIG B.8

SECTIONAL MAP - 2 OF GROUND WATER AVAILABILITY

Table B.5 Groundwater Development Possibility in the City

Township	Possibility		Water Quality		Yielding	
	Potential	Difficult	Saline	Ironic	High	Low
Ahlone	100%	0%	Bank	Occ	Bank	-
Bahan	60%	40%	-	All	-	West
Botataung	100%	0%	Bank	Occ	Bank	-
Dagon	100%	0%	-	Occ	Plain	Hill
Dagon Myothit East	100%	0%	uk	-	-	-
Dagon Myothit North	100%	0%	uk	-	-	-
Dagon Myothit Seikkan	100%	0%	Bank	-	-	-
Dagon Myothit South	100%	0%	Uk	-	-	-
Dala	100%	0%	All	-	-	-
Dawbon	100%	0%	Bank	-	-	-
Hlaing	100%	0%	-	Occ	Bank	Hill
Hlaingthaya	100%	0%	Bank	-	-	-
Insein	60%	40%	-	Inland	Bank	-
Kamayut	80%	20%	-	Inland	Bank	Hill
Kyauktada	100%	0%	Bank	Inland	All	-
Kyeemyindaing	100%	0%	R-bank	-	All	-
Lanmadaw	100%	0%	Bank	Occ	All	-
Latha	100%	0%	Bank	Occ	All	-
Mayangone	30%	70%	-	Hill	Bank	Hill
Mingalardon	50%	50%	-	Hill	-	Hill
Mingalartaungnyunt	90%	10%	-	Inland	Bank	West
North Okkalapa	95%	5%	-	Occ	Bank	-
Pabedan	100%	0%	Bank	Occ	All	-
Pazundaung	100%	0%	South	Occ	All	-
Sanchaung	100%	0%	-	Occ	All	-
Seikan Port	100%	0%	All	Occ	All	-
Seikkyi Kanaungto	100%	0%	All	-	All	-
Shwepyitha	80%	20%	-	Hill	Bank	Hill
South Okkalapa	90%	10%	-	Occ	Plain	Hill
Tamwe	10%	90%	-	All	East	West
Thaketa	100%	0%	Bank	-	Bank	-
Thingangyun	60%	40%	-	Occ	Bank	Hill
Yankin	0%	100%	-	All	-	-

Remarks: "Bank" means area along the river. "Occ." and "uk" mean "occasionally" and "unknown".

(2) Difficult Area

About 17.1% of the city areas are classified as the difficult area to exploit groundwater, in which the lowland hills areas exist. These are located in the central portions of the city.

The geology is made up of sandstone, shale and their alternations of Oligo-Miocene epochs (Late Tertiary). These rocks and formations are in dense, massive and consolidated conditions, and have impervious characteristics. Groundwater occurs only in fissures or fault fracture zones.

The well design with gravel placement is required for additional well development. Groundwater development for individual or piped water supply in urban satellite townships may require the construction of tube wells with larger casing diameter to ensure larger production rates.

Table B.6 Performance of YCDC Owned Tube Wells

Well		Discharge						Production
Diameter	Number	Range				Average		Ratio
Inch	well	lpm		gph		lpm	Gph	%
2	1	50	50	600	600	50	600	0.0
4	68	90	760	1,200	10,000	210	2,700	5.9
6	21	150	1,140	2,000	15,000	350	4,700	6.8
8	92	115	1,670	1,500	22,000	600	7,900	51.6
10	20	230	1,520	3,000	20,000	820	10,800	15.1
12	15	230	2,270	3,000	30,000	1,260	16,600	20.6

Source: YCDC, as of July 2001

Table B.6 shows the statistical data of YCDC owned tube wells by well diameter size wise. Additionally, minimal well diameter for installation of available submersible pump in the market is 150A presently. For the future development required, well casing diameter of 150A (6B) or larger will be designed with due consideration of submersible pump facility.

In these cases, short spacing intervals between the adjacent wells often cause the well interference due to the large lowering of pumping water level when the adjacent wells are operated simultaneously in a longer period. As the remedy of the problem pump operation with excess electric consumption and deterioration of deep well life may be obliged.

Thus, appropriate spacing interval and number of wells to be constructed per km^2 (100ha) shall be considered. Following presents reference information on spacing arrangements for planned wells by the single tube well basis. The formula used to determine proper well spacing is the Jacob modified equation.

- Specific Capacity

  According to the existing tube well source information, specific capacity was considered with ranges from 0.5lpsm (120gph-ft) to 4.0lpsm (965gph-ft). To simplify the calculation, an average value in each range is adopted in the calculation of interference radius.

- Expected Permissive Drawdown

  Spacing allocation for tube wells was examined considering assumed drawdown of 1cm (approximately 1/2inches) at the interference radius for a pumping duration of 16hours.

- Pumping Rate

  The pumping rate was estimated by assuming a drawdown of 10m (33ft) with the average value of specific capacity and pump operation of 16hours/day.

Table B.7 presents the estimated spacing requirements and number of wells to be constructed within a well field of one km^2. The spacing interval between adjacent wells to avoid well interference is planned to be more than twice the distances of the calculated interference radius.

Table B.7 Spacing Arrangements for Planned Tube Wells

Range of Specific Capacity	Estimated Pumping Rate		Estimated Interference Radius		Estimated Number of Wells per	
lpsm	m^3/16hrs	gph	m	ft	km^2	ha
0.5 - 1.0	450	6,200	60	195	80	0.80
1.0 - 2.0	850	11,700	75	245	51	0.51
2.0 - 3.0	1,450	19,950	90	295	36	0.36
3.0 - 4.0	2,000	27,500	100	330	29	0.29
4.0 <	>2,300	>31,600	>105	>345	<26	<0.26

Note: The formula used to determine proper well spacing is the Jacob modified equation.

Most of the tube well facilities, newly constructed, had been designed with well materials made of uPVC (un-plasticize polyvinyl chloride). Previous tube wells made of galvanized iron, mild steel or low carbon steel in the area where groundwater with acidic pH is observed, well casing pipes and/or screens were corroded. About 65% of tube wells made of corrosive materials in the city will be abandoned due to corrosion.

1.2.3 Standard Well Specifications

For the preparation of the long/medium-term development plan in terms of groundwater source development, standard tube well specifications on the single well basis by township were prepared. The parameters, such as: proportion of well depth and diameter, static water level and specific capacity are shown in Table B.8.

These were established using the well information obtained from YCDC and Townships Offices (detailed databases are included in Chapter 2.1.2 of this Appendix-B), and the hydrogeological assessment presented in Chapters 1.1.3 and 1.2.2 of this Appendix-B.

Groundwater source availability is reflected in Table B.8 that was assumed based on groundwater source study considering the limited information on geology, topography, water sources inventory, etc. The groundwater source availability indicates the general profile of the different types of groundwater source available in the townships. Hence, the descriptions have no projected meaning on future development values.

Dug wells are currently used in some townships. The township areas are categorized into tube well areas considering the on-going practices. The proportions (%) by tube well and difficult areas are determined with reference to groundwater development potential in the Groundwater Availability Map. For townships without any well data, the well parameters are estimated using the data of adjoining townships, provided they have similar hydrogeologic features.

Table B.8 Standard Tube Well Specifications by Township

Township	Proportion	Well Structures			Performance	
		Dia.	Dep.-s	Dep.-d	SWL	Sp.Cap.
	%	A	m	m	mbgs	lpsm
		B	ft	ft	ft-bgs	gph-ft
Ahlone	100	200	45	60	3.0	2.0
		8	150	200	10	480
Bahan	60	150	45	60	12.0	0.5
		6	150	200	40	120
Botataung	100	200	-	30	3.0	2.0
		8	-	100	10	480
Dagon	100	200	45	60	6.0	1.5
		8	150	200	20	360
Dagon Myothit East	100	150	90	120	15.0	1.0
		6	300	400	50	240
Dagon Myothit North	100	150	90	120	15.0	1.0
		6	300	400	50	240
Dagon Myothit Seikkan	100	150	90	120	9.0	1.0
		6	300	400	30	240
Dagon Myothit South	100	150	90	120	12.0	1.0
		6	300	400	40	240
Dala (out of city)	100	300	45	60	3.0	3.5
		12	150	200	10	845
Dawbon	100	150	90	120	3.0	1.0
		6	300	400	10	240
Hlaing	100	200	45	60	6.0	2.0
		8	150	200	20	480
Hlaingthaya	100	200	45	60	3.0	1.5
		8	150	200	10	360
Insein	60	200	45	60	9.0	2.0
		8	150	200	30	480

Remarks: "Dep-s" & "Dep-d" mean that minimum and maximum depth of proposed tube wells.
"SWL" means Static Water Level, "Sp.Cap." is Specific Capacity of proposed tube wells.
"mbgs" & "lpsm" mean "meter below ground surface" and "litter per second meter".

Table B.8 Standard Well Specifications by Township: cont'ed

Township	Proportion	Well Structures			Performance	
		Dia.	Dep.-s	Dep.-d	SWL	Sp.Cap.
	%	A	m	m	mbgs	lpsm
		B	ft	ft	ft-bgs	gph-ft
Kamayut	80	200	45	60	6.0	2.0
		8	150	200	20	480
Kyauktada	100	200	30	45	3.0	2.0
		8	100	150	10	480
Kyeemyindaing	100	200	45	60	3.0	2.0
		8	150	200	10	480
Lanmadaw	100	200	30	45	3.0	2.0
		8	100	150	10	480
Latha	100	200	30	45	3.0	2.0
		8	100	150	10	480
Mayangone	30	200	45	60	4.5	2.0
		8	150	200	15	480
Mingalardon	50	150	120	150	12.0	1.0
		6	400	500	40	240
Mingalartaungnyunt	90	200	45	60	6.0	2.0
		8	150	200	20	480
North Okkalapa	95	150	90	120	15.0	1.0
		6	300	400	50	240
Pabedan	100	200	30	45	3.0	2.0
		8	100	150	10	480
Pazundaung	100	200	30	45	4.5	2.0
		8	100	150	15	480
Sanchaung	100	200	45	60	6.0	2.0
		8	150	200	20	480
Seikan Port	100	200	-	30	3.0	2.0
		8		100	10	480
Seikkyi Kanaungto (out of city)	100	250	45	60	3.0	2.5
		10	150	200	10	605
Shwepyitha	80	200	60	90	12.0	1.5
		8	200	300	40	360
South Okkalapa	90	200	90	120	4.5	1.5
		8	300	400	15	360

Remarks: "Dep-s" & "Dep-d" mean that minimum and maximum depth of proposed tube wells.
"SWL" means Static Water Level, "Sp.Cap." is Specific Capacity of proposed tube wells.
"mbgs" & "lpsm" mean "meter below ground surface" and "litter per second meter".

Table B.8 Standard Well Specifications by Township: cont'ed

Township	Proportion	Well Structures			Performance	
		Dia.	Dep.-s	Dep.-d	SWL	Sp.Cap.
	%	A	m	m	mbgs	lpsm
		B	ft	ft	ft-bgs	gph-ft
Tamwe	10	150	60	90	9.0	0.5
		6	200	300	30	120
Thaketa	100	200	90	120	4.5	2.0
		8	300	400	15	480
Thingangyun	60	200	90	120	9.0	2.0
		8	300	400	30	480
Yankin	0	-	-	-	-	-
		-	-	-	-	-

Remarks: "Dep-s" & "Dep-d" mean that minimum and maximum depth of proposed tube wells.
"SWL" means Static Water Level, "Sp.Cap." is Specific Capacity of proposed tube wells.
"mbgs" & "lpsm" mean "meter below ground surface" and "litter per second meter".

For the furtherance in collecting accurate information to design the concrete specifications of the planned wells, the following recommendations are made. Prior to the feasibility study or detailed design stages, additional detailed groundwater investigations entailing the construction of test wells shall be conducted.

Majority of problems on the groundwater investigation are lacking of geological survey in the satellite townships and periodical groundwater quality examination in downtown townships along the Hlaing River. The townships falling on these investigation areas are shown in Table B.9 with their requirements.

At the candidate site for new satellite townships, electrical prospecting is firstly required. Test wells based on the results of prospecting shall include the examinations of sieve analysis, geo-physical logging, pumping test and water quality analysis. To design of screens proportions at test well, single aquifer shall be selected to evaluate their hydrogeological performance in the expected well fields.

Tube wells may be utilized initially in the satellite townships and supplementary when large demands required to be covered by the surface water development. Since the right bank areas of the Hlaing River had apprehension of un-sanitary water supply conditions, prioritized groundwater investigation required shall be conducted to improve.

Table B.9 Detailed Groundwater Investigation Required

Township	Area	Specifications
Dagon Myothit East, North, Seikkan and South	New Satellite Townships Development Areas	Electric Prospecting: 200m in depth x 30points Test Wells: 150A x 120m x 3wells
Dala, Hlaingthaya, Kyeemyindaing (Right Bank of Hlaing) and Seikkyi Kanaungto		Electric Prospecting: 150m in depth x 10points Water Quality Examination: pH, EC & Fe, Mn
Mingalardon		Test Well: 150A x 150m x 1well
Shwepyitha		Test Well: 200A x 90m x 1well
Botataung to Kyeemyindaing	Downtown (Left Bank of Hlaing)	Water Quality Examination: pH, EC & Fe
22 Townships where existing Tube Wells present in	Existing Tube Wells	Pumping Test: Step Drawdown Test

Remarks: Township and Area at above-mentioned are not pinpointed in detail at present.

Tube wells connecting to present pipelines as supplemental water source are operated to supply groundwater into the distribution pipeline networks without any periodical water quality examination. Especially in the city proper, there is a possibility to occur the saline water intrusion in right bank area of Hlaing River and high iron concentration/brackish groundwater problems are observed in hilly area.

High iron and manganese concentration was examined at new tube wells in the Township of Hlaingthaya. Well field is located about 20km far from central lowland hill where is believed as formation of iron/manganese origin.

Also groundwater characteristics have range variations depending on the recharging condition in up stream area. Therefore, the minimal parameters of pH, EC (electric conductivity) and Fe shall be examined twice annually (dry and rainy seasons) using available tube wells.

Addition to these investigations, fresh groundwater survey in southern inland area of the city shall be conducted to establish water supply systems for the townships of Seikkyi Kanaungto and right bank of Kyeemyindaing.

2 GROUNDWATER DVELOPMENT

Groundwater development is composed of following three (3) studies relating to groundwater management in terms of sustained yield and development facilities.

(1) Present Conditions of Groundwater Production

Groundwater production was roughly estimated as annual extraction groundwater amount in the year of 2000. Ownerships of groundwater extraction facilities were divided into two categories such as the YCDC and the None YCDC. Production amount in the year of 2000 was estimated using database obtained from YCDC and monitoring results of groundwater extraction facilities owned by the None YCDC.

(2) Development Potential as a Balance of Sustained Yield and Production

Development potential was presumed with due considerations of practical trials and assumptions. It is a part of groundwater management as an environmental side. In this study, development potentials by township were aggressively estimated. Consequently, three (3) Townships were nominated, in where there might be high possibility of groundwater imbalance (lowering of groundwater table) out of 33 Townships.

(3) Future Development Required

For preparation of master plan, groundwater exploitation units were preliminary designed. Depending on the water demands, groundwater will be extracted using such facilities within a permissive limitation of groundwater availability. It is a part of groundwater management as a human utility side. Requirements consisting of tube wells connected to pipeline networks were included.

2.1 PRESENT CONDITIONS

This study was carried out based on the available existing data, records, information, etc., regarding groundwater utilization provided by the YCDC. There are several categories of groundwater extraction in terms of ownership, utilization and facility type. Groundwater extraction facilities were classified into YCDC and None YCDC by ownership. Sector monitoring was conducted by the YCDC through the township offices to take statistics of none YCDC wells. Such statistics are one of study's bases.

2.1.1 Form of Groundwater Development

The present forms of groundwater development by Township wise were put in orders of: (1) ownership and utilities, and (2) type of wells with service level as following.

(1) Ownership & Utilities

Municipal water is divided into the categories of domestic, industrial, commercial and recreation waters. Such waters are supplied by the systems/facilities with operation bodies of public (YCDC) and privately. The allotment of ownership and utility is shown in Table B.10 below.

Table B.10 Allotment of Municipal Water

Utility	None Public (None YCDC)		Public
	Government	Private	
Domestic	Domestic		YCDC
Industrial	Industrial		
Commercial	Commercial		
Recreation			

(2) Type of Wells with Service Level

The facilities for groundwater utilization are classified into spring and well. The wells are vertical wells and horizontal infiltration gallery. Wells have various types depending on production needs, utilization, hydrogeological characteristics, construction ability, etc. The principal wells are tube and dug wells in the city.

There are four levels of water supply service by the accessibility as mentioned in Chapter 1.2.1 Classification of Groundwater Availability. Following Table B.11 shows well type and service level by ownership.

Table B.11 Well Type & Service Level by Ownership

Type of Well	YCDC	None YCDC		
		Domestic	Industrial	Commercial
Tube	L-I/II/III	L-III	L-III	L-III
Dug	-	L-I/Individual	-	-

Usually, the unit of cubic meter per day (m^3/day) is used for measuring groundwater production, availability and inflow, etc. and liter per second meter (lpsm) is used for measuring specific capacity of well. 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 as a common understanding with other tasks.

2.1.2 Groundwater Production

Amounts of groundwater productions were estimated by the YCDC and the None YCDC sectors in accordance with the forms of groundwater development. The YCDC tube wells have daily operation records and that was used for the annual estimation. For the none YCDC tube/dug wells, there was statistical information in the housing department. However, such data did not cover the entire facilities and without any up dating until now.

In this regard, information of privately owned well facilities were collected through the sector monitoring that was first experience for the YCDC. Even such sector monitoring was not enough for the estimation of groundwater development in the city, the trend and/or proportion of groundwater extraction from privately owned well facilities could be observed.

(1) YCDC Groundwater Production

Presently, the YCDC owns 217 tube wells located in 22 Townships as of July 2001. Several tube wells are under construction or were completed, which are waiting for civil works to connect the pumps and pipelines.

According to the database prepared by the YCDC (referred to Data B.2 YCDC Owned Tube Well Inventory as of July 2001), tube well identifications and records are indicated. Following Table B.12 shows categorized such recording parameters.

For evaluation of the YCDC water supply systems/facilities, annual production amounts of groundwater extraction from the YCDC tube wells were estimated in accordance with parameters of system, service level and Township. Meaning of annual duration was set up from January until December.

Table B.12 Tube Well Parameters of YCDC Database

Category & Parameter		Description		
		Valid No.	Range	Remarks
Location	Township Ward Street Numbering	217 wells	-	22 Townships
Structures	Diameter	217 wells	50-300A	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. 744m³/day
	Pump	100 wells 117 wells	50-250A 100-300A	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	200A	3 Townships
Operation	Monthly Q Jan/98-Dec/00	199 wells	2,128-620,529 m³/month	3 wells: Hydrant 2 wells: Stand-by 13 wells: No Records

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

Following Table B.13 shows annual production amounts in years of 1998, 1999 and 2000. Amount in year 2000 was adopted as a present production.

Table B.13 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 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 B.14 below.

Table B.14 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) None YCDC Groundwater Production

At the beginning of study, the YCDC Township offices possess private well inventory as of the year 1996, called "None YCDC" wells in accordance with forms of groundwater development. Such well inventory, without any up dating until now, was estimated using water rights registration obtained from the Department of Housing, Ministry of Construction.

In this regard, sector monitoring (referred to Data B.3 Monitoring Form of None YCDC owned Well) related to groundwater usage had been conducted by the YCDC during June and July 2001. Following Table B.15 shows parameters of sectorial well information.

Table B.15 Sectorial Well Information Parameters

Sector	Parameters
Common	Ownership, Type of Well/Pump, Number of Well, O/M Body, Completion Year, Utility, Daily Operation and Monthly Discharge
Domestic	Water Quality Problems, Operational Condition in Dry Season and Number of Served Household
Industrial	Type of Factory and Water Recycle Use
Commercial	Type of Business
Irrigation	Type of Crop, Area of Farm/Fishpond and Duration of GW Usage

Administrative information was collected by the YCDC. However, engineering and technical data were so lacking (referred to Data B.4 None YCDC Owned Well Inventory as of July 2001). As the results of monitoring, there are 69,172 wells in 30 Townships. Table B.16 shows well numbers by sector and ownership.

Table B.16 Summary of None YCDC Well Numbers

Sector	Ownership		
	Private	Government	Total
Domestic	68,507	316	68,823
Industrial	330	16	346
Commercial	3	0	3

Note: Commercial includes commercial, institutional and recreation.

Majority of wells are classified into the domestic use (68,823 wells: 99.5%). For estimation of annual groundwater production amount, following assumptions were adopted in each sector.

- Domestic Use

There are two types of well: dug well (68,736 wells) and tube well (87 wells). Unit annual production amounts by well types were estimated below with due consideration of present situations. Consequently, annual production amount for domestic is totaled at **10.96 MCM/Y.**

Dug Well; **$153.3\ m^3/year$** = (50% x 1 + 50% x 3) x 7 x 30/1000 x 365

- Rates of service L-I and L-II are shared 50% each.
- Served household numbers of L-I and L-II are assumed at 1 and 3 (household capita is 7).
- Water consumption per capita is set up at 30Lpcd with 365 working days.

Tube Well; **$4,841.1\ m^3/year$** = (30 x 7 x 60/1000 x 365)/95%

- Service level is L-III.
- Served household numbers of L-III is assumed at 30 (household capita is 7).
- Water consumption is set up at 60Lpcd with 365 working days.
- Pipeline leakage is assumed at mere 5%.

- Industrial Use

There is only one type of well: tube well (346 wells). Types of factory were divided into 5 for estimation of production amount in order of high water consumption. Unit annual production amounts were estimated below using water consumptions to be assumed by factory types. Consequently, annual production amount for industrial is totaled at **8.89 MCM/Y**.

Type A; **$80,000\ m^3/year$** = (300 x 240)/90% 0 well
- Mining and Refinery
- Water consumption is set up at $300m^3/day$
- 5 day/week and 20 days of national/new year holiday (240 days)
- Leakage is set up at mere 10%

Type B; **$26,087\ m^3/year$** = (300 x 240)/92% 331 well
- Chemical, Food Processing and Marine Related (Export Oriented)
- Water consumption is set up at $100m^3/day$
- Leakage is set up at mere 8%

Type C; **$19,143\ m^3/year$** = (75 x 240)/94% 10 well
- Light to Heavy Industry and Manufacturing
- Water consumption is set up at $75m^3/day$
- Leakage is set up at mere 6%

Type D; **$12,500\ m^3/year$** = (50 x 240)/96% 5 well
- High Technology, Precision Assembly and Electronics
- Water consumption is set up at $50m^3/day$
- Leakage is set up at mere 4%

Type E; **$4,898\ m^3/year$** = (20 x 240)/98% 0 well
- Automobile (Part Supply), Garments (Textile) and Furniture
- Water consumption is set up at $20m^3/day$
- Leakage is set up at mere 2%

- Commercial Use

There is only one type of well: tube well (3 wells). Types of business were divided into 3 for estimation of production amount in order of high water consumption. Unit annual production amounts were estimated below using water consumptions to be assumed by business types. Consequently, annual production amount for commercial is totaled at **0.08 MCM/Y**.

Recreation; **$74,490\ m^3/year$** = (200 x 240)/98% 1 well
- Water Consumption is assumed at 200 m^3/day. Room number may be 100 with employee of 400 persons. Per capita con-

sumption is assumed at 400Lpcd.
- Days of whole year working are adopted.
- Leakage is set up at mere 2%.

Commercial; **5,000 m^3/year** = (20 x 240)/96% 2 wells
- Water Consumption is assumed at 20 m^3/day. Forty employees consume 500Lpcd each is adopted.
- Weekly five days and 20 days of national/new year holiday (240 days) are adopted.
- Leakage is set up at mere 4%

Institutional; **10,212 m^3/year** = (40 x 240)/94% 0 well
- Water Consumption is assumed at 40 m^3/day. Two hundred capita is adopted with 200Lpcd consumption.
- Annual 240 working days is adopted.
- Leakage is set up at mere 6%

Assumptions above-mentioned are summarizes in Table B.17 below.

Table B.17 Summary of Assumptions for None YCDC

Identification		Working Day	Usage Ratio	Water Consumption			Leakage	Annual Q (MCM/Y)
Utilization	Type			HH	Capita	lpcd		
Domestic	Dug	365	50%	3	7	40	0%	153
			50%	1				
	Tube		100%	30		60	5%	4,841
Industrial	Type A	240	100%		300m^3/day		10%	80,000
	Type B				100m^3/day		8%	26,087
	Type C				75m^3/day		6%	19,149
	Type D				50m^3/day		4%	12,500
	Type E				20m^3/day		2%	4,898
Commercial	Recreation	365	100%		200m^3/day		2%	74,490
	Commercial	240	100%		20m^3/day		4%	5,000
	Institutional		100%		40m^3/day		6%	10,212

Remarks; Type of industrial factories were categorized 5 groups shown in Data B.3 (1).

Consequently, annual groundwater production amount from wells owned by "None YCDC" was estimated at **19.93 MCM/Y** as shown in Table B.18.

Table B.18 Annual Production of None YCDC Wells

Sector	Well Number	Production Amount (MCM/Y)
Domestic	68,823	10.96
Industrial	346	8.89
Commercial	3	0.08
Total	**69,172**	**19.93**

Source; Sector Monitoring conducted July 2001

2.1.3 Present Problems

The problems associated with groundwater are sorted into physical and administrative problems. Since the problems outlined below were reported, the YCDC as a core promotion body with co-ordination from concerned agencies should follow up and promote preservation program in near future.

(1) Physical Problems

Groundwater problems are formed in terms of quality and quantity, and environment. Prioritized countermeasures shall be given to environment from a viewpoint of groundwater preservation, while quality and quantity shall be improved from a stand-point of safe and enough water supplies.

- Natural and/or Artificial Environment Problem

  Land subsidence on a so-serious scale has not been reported. The main reason of land subsidence originates in the drainage of groundwater from clayey sediments. Artificial subsidence means that groundwater has been extracted compulsory by artificial structures such as wells and other apparatuses.

  Areas where large groundwater amount has been extracted in the central city are located on consolidated sediments and/or on thin unconsolidated sediments. However, the YCDC and concerned agencies were not dealing with recognition of groundwater environmental problems caused by groundwater over exploitation.

- Natural Qualitative Problem

  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.

In August 2001, river waters at Yangon Port were taken on times of low and high tides, and were examined with parameter of low chloride ion (less than 10mg/l). On the other hand, groundwater extracting from tube wells for Dala Township water supply indicated high electric conductivity (more than 1,000 micro-mho) in the same duration of river water samplings, even well field of which is located at about 11km far away from the Hlaing River.

Presently, specified reasons and their trends of high chloride ion concentration are not yet confirmed especially in Townships at the right bank of the Hlaing River.

<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.

From new tube wells located at western side of Hlaingthaya Township, groundwater with high iron and manganese concentration (both parameters more than 1.0mg/l) was examined by the YCDC. Material of tube wells casing and screen pipes are made of uPVC. Probably iron and manganese were corroded from lateritic formations and were permeated to such area.

- Artificial Qualitative Problem

Groundwater has been utilized for human life because of better quality and its sustainability. Majority of pollutants and contamination process in the city are described below.

<Groundwater Pollution>

All city areas have the possibility of being polluted by human activities. The areas susceptible to or vulnerable to groundwater contamination should be necessarily described, identified and delineated by the promotion of monitoring activities on groundwater pollution. In consideration of the Yangon City' situation, the major pollutants might be sewage and factory wastes (agricultural chemicals and fertilizers are not confirmed) in down town and industrial zones.

<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.

- Artificial 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 (referred to Table B.19).

Table B.19 Number of Tube Well Pump by Service Level

Category		Tube Well Numbers		
Service Level	System No.	Submersible	Air-lifting	Total
L-III SW/GW	1	83	**21**	104
L-III GW	16	22	**9**	31
L-II GW	2	5	**0**	5
L-I GW	74	4	**70**	74
Hydrant	3	3	**0**	3
YCDC Total		117	**100**	217

Source; YCDC Township Offices, as of July 2001

According to previous tube wells designed by the YCDC, total length of well screen is 6m or 12m in any case of casing diameter. Gravel placement to annular space at screen portion means that well structure is filtration separator of solid and fluid (in this case soil and water). Therefore, filtration velocity (3cm/sec or less) has to be confirmed for final well design with due consideration of filtration thickness and grain size of filtration materials.

(2) Administrative Problems

Now the YCDC is the responsible agency for water resources management. For more effective and realistic water management, the YCDC should coordinate with line agencies to a greater extent. The most important matter is the interrelationship or communication between the relevant government agencies. The following are necessary action matters for the YCDC to undertake.

➢ General

Early government level decision on a scheme for water resources management should be followed by the YCDC, and then this promotion should be implemented using more effective coordinated organization and communication systems between the line agencies built up by the YCDC.

➢ Pre-exploitation of Water Resources

The YCDC should research and act regarding the approach stage for water resource development such as planning, study, assistance and suggestions to each line agency regarding progressive development planning.

➢ Water Rights Registration

The YCDC should improve or add the items of application forms for the estab-