lishment of standard criteria to evaluate the appropriate water right grant amount. In addition, the YCDC should build up countermeasures for unregistered utilities and re-applications for abandoned facilities.

- Monitoring Systems

  The YCDC has to assist and strengthen the monitoring activities in consideration of:

  - build up of the systems for obligatory annual reports from each line agency,
  - update of current (annual) water resources utilities,
  - complete management of water resources information systems,
  - promotion of analytical technology for water resources management and
  - build up of adaptable monitoring systems.

2.2 DEVELOPMENT POTENTIAL

The development potential means the sustained yield, groundwater amount of which is possible value of exploitation extending over a long time without any environmental problems influentially. In this regard, development availability can be said equal to the balance of such potential and present extraction. In general, the development potential is considered as smaller value than the groundwater recharge. The value of sustained yield shall be verified by the study and evaluation on the observation results of groundwater level comparing with exploitation amount at those times.

The development potential was studied based on the available existing data obtained from the YCDC. In addition to this, the study on groundwater development potential includes groundwater storage to presume the susceptibility of expected aquifers. This index is referred to the plans for groundwater preservation.

2.2.1 Methodology and Limitation

Groundwater balancing is studied and verified as a unit area of groundwater basin. In addition to this, it is almost none sense to discuss the groundwater balance under the assumed uniform-conditions without any results of surveys, tests, examinations, observations, etc. However, it is significance to create the supporting information on general trends as the situations of groundwater for preparing this comprehensive master plan with showing theoretical process, even dubious assumptions were included.

Regarding the progressive study plans from now on, the conclusive evidences both methodology and assumption values shall be reset up or confirmed to consistent with preservation and exploitation by reviewing of this study including environmental observations in future. To estimate the development potential by Township wise seems to be an unreasonable demand. It is notified that this study was done aggressively for preparation of this master plan, since there might be unknown limitations.

Under the conditions mentioned-above, this study consists of three steps below, and each methodology is described as following.

- Step-I: Estimation of Groundwater Recharge
- Step-II: Assumption of Sustained Yield & Susceptibility
- Step-III: Evaluation of Development Potential

(1) Estimation of Groundwater Recharge

Groundwater recharge was estimated as the sum of: (a) meteorological recharge, (b) artificial recharge and (c) groundwater balance of inflow from and outflow to. Following methodologies are adopted for this study.

- Meteorological Recharge

By definition, groundwater recharge is the inflow flux to a groundwater basin. There are two basic methods to estimate groundwater recharge, one of which is to use a water balance approach and the other one is to use the estimation based on empirical methods. The water balance approach is generally used as in the following equation.

$$P = Et + Sr + Gr + Sm$$

Where: **P**; Precipitation
Et; Evapotranspiration (= Evaporation + Transpiration)
Sr; Surface Run-off
Gr; Groundwater Recharge
Sm; Soil Moisture (ignore)

It is possible to ignore soil moisture in a water balance equation, if the water cycle period is assumed to be one year or longer. Presently, available data are: (a) Township areas, (b) monthly total of precipitation, (c) monthly total of evaporation and (d) land use obtained from Township offices.

For estimation of groundwater recharge, the actual value of evaporation was assumed monthly basis, and the ratios of transpiration and surface run-off were estimated using occupancy rate of land use for ground surface conditions.

- Artificial Recharge

  Artificial recharge factors are composed of: (a) irrigated water in paddy fields and (b) leakage water from water supply pipeline systems owned by the YCDC and the None YCDC.

  Leakage rates of pipeline owned by the YCDC and the none YCDC were estimated based on the study results of field surveys conducted at three model blocks of YCDC pipeline network. Permeability both leakage and irrigation waters was assumed under the ground surface conditions and recharge patterns.

- Groundwater Balance of Inflow-from & Outflow-to

  Using expected hydrogeological boundary as shown in Figure B.4, directions and proportions of groundwater inflow from and outflow to other Townships in the central city area (between Ngamoeyeik Creek and Hlaing River) were assumed based on supposing that groundwater cycle is balanced annually.

  In other Townships, groundwater inflow was not considered because groundwater level is almost same elevation of ground surface. Therefore, groundwater flow seems to be very slow even permeability is high.

(2) Assumption of Sustained Yield & Susceptibility

Generally, permissive limitation of water level lowering is set up at first in terms of environmental problems. Then, the sustained yield is essentially estimated while comparing with water levels and computing results using III-dimensions model flow analysis consists of the finite elements method.

Necessary parameters such as mesh data (at largest every hectare) of: (a) topography, (b) water levels, (c) surface and underground geology, (d) recharge and extraction amount, etc. are not available at present. Therefore, setting up methodologies of mere proportions to estimate the sustained yield and the susceptibility were adopted as follows.

- Sustained Yield

  In this study, permissive rates of recharge as sustained yields were estimated by the proportions to be set up with due consideration of topographical and geological conditions.

- Susceptibility

  The susceptibility is indicated at recharge percentage against storage. To estimate the storage, specific yields (porosity = specific retention + specific yield) were assumed by the geological lithofaces, and aquifer' depth was assumed as the depths of standard tube well designs (referred to Table B.8) by Township wise.

(3) Evaluation of Development Potential

Since present amount of groundwater extraction was totaled with "the YCDC" and "the None YCDC" wells, development availability was estimated as a remaining. In addition to this, information on groundwater quality was also summarized.

- Groundwater Quantity

  Quantity of groundwater potentials was evaluated. Major indexes are groundwater recharge, development potential, present extraction and development availability.

- Groundwater Quality

  Based on available reports, information and field survey conducted by this study, groundwater quality conditions were summarized.

2.2.2 Groundwater Recharge and Storage

The values of groundwater recharge and storage were estimated in accordance with following procedures in detail. Consequently, the city totals of recharge amount and storage volume were estimated at:

Groundwater Recharge	=	353.87	MCM/Y (million cubic meters per year)
Groundwater Storage	=	7,155.41	MCM (million cubic meters)

(1) Meteorological Recharge

Available land use obtained from the Township office is categorized by: (a) residence, (b) government, (c) commercial, (d) industrial, (e) farm and (f) others. These items were exchanged to other items, which are divided by five ground surface conditions relating to transpiration and surface run-off. Adopted proportions between two categories are shown in Table B.20. For this result, ground surface land use plan by Township is shown in Data B.5 (1).

Table B.20 Occupancy Proportion of Ground Surface

Category	Ground Surface				
	Forest	Farm	Built-up	Paddy	Swamp
Residence	-	-	100%	-	-
Government	60%	35%	5%	-	-
Commercial	-	-	100%	-	-
Industrial	-	-	100%	-	-
Farm	-	-	-	90%	10%
Others	-	-	-	100%	

Note: Surface area of Kan Daw Gyi, Inya and Hlawga Lakes are included into "Others".

Precipitation (***P***), evapotranspiration (***Et***) and surface run-off (***Sr***) as unknown factors in water balance equation ($P = Et + Sr + Gr + Sm$) were assumed accordingly to the ground surface category as following. It is noted that soil moisture (***Sm***) is disregarded, because of annual estimation.

- Precipitation (***P***)

  According to the precipitation records at fourteen (14) stations belonging to the Irrigation Department in the Yangon City (referred to Figure B.1), all patterns indicate almost same. Average monthly totals of precipitation at the Kaba-aye Station during the year 1968 to 2000 (33 years) were adopted to all city area. Rainfall amount was, therefore, precipitation multiplied by area (Township).

- Evapotranspiration (***Et***)

  Evapotranspiration is sum up of evaporation and transpiration. Average monthly totals of evaporation at the Kaba-aye Station during the year 1980 to 2000 excluding 1984 (19 years) were adopted to all city area. Transpiration values were estimated by the ratios comparing to evaporation values. Such rates were assumed depending on the type of ground surface. Finally, evapotranspiration values were adjusted to be equal to or less than precipitation values by monthly basis.

- Surface Run-off (***Sr***)

  Precipitation minus evapotranspiration is equal to sum up of surface run-off and groundwater recharge. Surface run-off value was assumed at expected proportions of the balance of precipitation and evapotranspiration depending on the type of ground surface.

Following Table B.21 shows summary of above assumed estimation-rates.

Table B.21 Estimation Rates of Meteorological Cycle

Meteorological Cycle		Ground Surface Land Use				
		Forest	Farm	Built-up	Paddy	Swamp
Rainfall	(1) =	Average Monthly Total of (*P*)				
Evaporation	(2) =	Average Monthly Total of (*Ev*) {on condition that (2) + (3) <=(1)}				
Transpiration	(3) = (2) x	60%	40%	25%	10%	0%
Surface Run-off	(4) = {(1)-(2)-(3)} x	60%	70%	80%	90%	100%
Recharge	(5) =	{(1) - (2) - (3)} x {100% - (4)}				

Note: Evapotranspiration is sum of evaporation and transpiration. (P = Et + Sr + Gr + Sm)

Under such assumed conditions, the values of monthly precipitation, evapotranspiration and surface run-off were estimated by ground surface categories, which is shown in Data B. (2) "Share Rates of Meteorological Cycle by Monthly Basis". Following Table B.22 shows summarized share rates of rainfall/meteorological cycle by ground surface land use.

Table B.22 Share Rates of Meteorological Cycle

Meteorological Items	Ground Surface Land Use				
	Forest	Farm	Built-up	Paddy	Swamp
Evapotranspiration	36.4%	32.4%	29.4%	26.3%	24.3%
Surface Run-off	38.2%	47.3%	56.5%	66.3%	75.7%
Recharge	25.4%	20.3%	14.1%	7.4%	0.0%

Note: Monthly estimation details are shown in Data B.5 (2).

Using annual precipitation, Township areas, ground surface land use plan by Township level (referred to Data B.5 (1)) and share rates of meteorological cycle (referred to Table B.22), meteorological recharge amounts were estimated. Results on meteorological recharges by Township wise are shown in Data B.5 (7) "Study Results on Groundwater Development Potential".

Annual total amount of the meteorological recharge in the city, at 11.9% of precipitation as the city total, was totaled at **201.82 MCM/Y**.

(2) Artificial Recharge

Following are estimation procedures of artificial recharge amounts, factors of which are: (a) irrigation water in paddy fields and (b) leakage water from water supply pipeline systems owned by the YCDC and none YCDC.

➢ Recharge Amount from Irrigation Water

Irrigation water supply for only paddy land was assumed as the form of following.

- Planting Duration, Specified Period and Planting Rate

In the Yangon City, paddy land raises two crops a year, durations of which are four month each from middle June until middle October and from middle December until middle April, respectively. Both numbers of days in planting duration were assumed at 120 days.

During middle June until middle October, paddy lands were naturally irrigated using rainwater. On the other hand, irrigation canals, streams, creeks have been utilized for irrigation water to paddy lands in other period. In this regard, additional recharge was estimated from dry season only with assumed planting rate of mere 20%.

- Estimation of Recharge Amount

Average recharge value from June to August in Data B.5 (2) "Share Rates of Meteorological Cycle by Monthly Basis" was adopted as average recharge from irrigation water. Daily recharge value was estimated at 1.65mm/day (annually 39.7mm/year).

These assumptions are shown in Table B.23 below. Finally, recharge amount from irrigation water was estimates at **9.21 MCM/Y** in the city.

Table B.23 Recharge Conditions of Paddy Land

Cropping Period			Type of Irrigation	Planting Rate	Annual Recharge
from	to	Duration			
middle Jun	middle Oct	120days	Rainwater	100%	-
middle Dec	middle Apr	120days	Canal/Creek	20%	39.7mm

Remarks: Recharge value in rainy season is covered by meteorological cycle.
Average daily recharge value was estimated at 1.65mm/day.

➢ Recharge Amount from Leakage Water

Pipeline leakage was estimated at first, then permeation rate of leakage water was assumed by pipeline situation. Following are detailed procedures.

- Type of Pipelines & Demarcation of Supplied Water

  There are two sectors, which have water supply systems: the YCDC and the None YCDC. The YCDC has two kind of system in terms of water sources. One is surface water fed system with supplemental groundwater, while other one is groundwater fed systems. The None YCDC sector has only one with extraction of groundwater.

- Estimation of Leakage Amount

  Leakage rate against water supply amounts were assumed based on the study results of intake measurement: both surface water and groundwater, leakage survey and pipeline inventory. Table B.24 shows assumptive leakage rates by pipeline system wise. Total amount of leakage in the city was estimated at 206.40MCM/Y, which amounts by Township wise were shown in Data B.5 (3) "Estimation of Leakage Amount using Service Coverage".

Table B.24 Assumptive Rates of Supplied Water

Category		Consumption		No Meter	Leakage
Sector	Source	lpcd	ratio	ratio	ratio
YCDC	SW/GW	200	25%	25%	50%
	GW	180	75%	0%	25%
None YCDC	GW	150	80%	0%	20%

Note: Water demarcations were assumed by the study on "Leakage Reduction Plan".

- Recharge Rate from Pipeline Leakage

  Depending on the leakage levels, recharge conditions are quite variable. Most water is recharged in case of small leakage, while most water is run-off adversely in other case. With due referring the surface run-off rate of 70% in farmland shown in Table B.20, 30% of leakage amount was assumed as recharge rate.

Under the conditions above, recharge amount from leakage water was estimated at **61.92 MCM/Y** in the city.

Artificial recharge amount in the city was estimated at **71.13 MCM/Y**. At Township wise, such detailed amounts are shown in Data B.5 (7) "Study Results on Groundwater

Development Potential".

(3) Groundwater Balance of Inflow-from & Outflow-to

Hydrogeological watershed in the central city was assumed at the geological boundary line between lower Irrawaddy Series and upper Pegu Group as shown in Figure B.4. Based on this map, directions and proportions of groundwater inflow from and outflow to other Townships were estimated under the supposing that groundwater cycle is balanced annually. Such directions and proportions are shown in Data B.4 (4) "Proportions of Inflow From & Outflow To".

According to this groundwater balancing condition, the annual recharge value corresponding to proportion estimated in upstream Townships is supposed to the inflow value for the downstream Townships. Finally, Townships belonging to riverbank discharge groundwater to the sea or the river. At Township wise, such detailed amounts are shown in Data B.5 (7) "Study Results on Groundwater Development Potential".

As a matter of course, when groundwater has been exploited in the upstream area, new proportion of balancing flow will be bone instead of original proportion. In this regard, under ground flow system is not formed to estimate. To evaluate the groundwater potential only at Township level, fixed groundwater flow proportion was aggressively employed for this study.

The groundwater inflow value in 16 Townships was estimated at **80.92 MCM/Y** (about 26% of recharge amounts from rainfall, leakage and paddy land). However, this value is not actual recharge amount to groundwater in the city. This amount is just like a value of internal lending and borrowing in the same wallet. Townships, extensive delta plain is located at the back of which, may have much larger amount of groundwater inflow.

(4) Groundwater Storage

The water existing in the under ground is called as "Subsurface Water". Following Figure B.9 shows the position of groundwater.

<table>
<tr><td rowspan="6">Subsurface Water</td><td colspan="5">Combined Water (Bound Water)</td></tr>
<tr><td rowspan="5">Pore Water</td><td colspan="4">None Hydraulic Cycle (Fossil Water, etc.)</td></tr>
<tr><td rowspan="4">Hydraulic Cycle</td><td colspan="3">Vadose Water (Soil Moisture, Funicular & Capillary)</td></tr>
<tr><td rowspan="3">Saturation Water</td><td colspan="2">Retained Water</td></tr>
<tr><td rowspan="2">Gravitational Water</td><td>Geothermal Vapor</td></tr>
<tr><td>Groundwater</td></tr>
</table>

Figure B.9 Classification of Subsurface Water

Under the groundwater situation in the Yangon City, gravitation water (or specific yield in following Figure B.10) can be evaluated as groundwater storage.

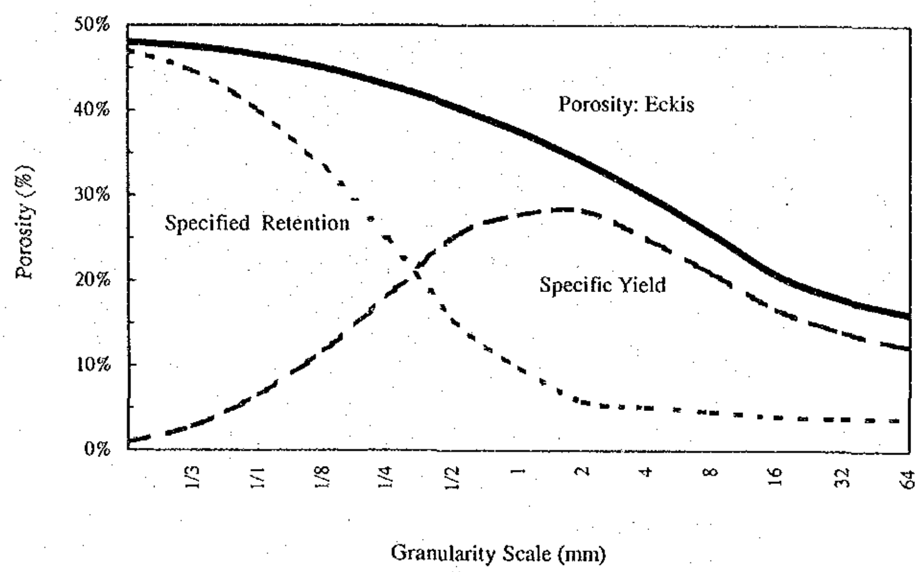


Figure B.10 Soil Porosity

Lithofaces of unconsolidated soil are classified into five (5) groups, such as: silt, sand, gravel, cobble and boulder in fine granularity order. Groups of sand (1/16-2mm) and gravel (2-64mm) are subdivided into five in conformity with the binary scale. Soil granularity of good aquifers is belonging to medium sand to very coarse gravel. Natural soil conditions are not sorted as well, however examinations on soil porosity have been not performed yet. The effective storage rates were roughly estimated by the geological lithofaces as following Table B.25.

Table B.25 Estimation Rates of Specific Yield

Geological Age		Rock Unit			Specific Yield
System	Series	Lithofaces		Formation	
Quaternary	Holocene	Q_H	Alluvium	Quaternary Deposits	15%
	Pleistocene	Q_P	Delta		10%
Tertiary	Pliocene	T_{Pc}	Clay	Ayeyawaddy Series	0%
		T_{Psa}	Sandstone		8%
	Miocene	T_{Ma}	Alternation	Pegu Group	4%
	Oligocene	T_{Osa}	Sandstone		6%
		T_{Osh}	Shale		0%

Note; Specific yields were assumed by this study.

Based on the Geological Map shown in Figure B.3, geology at Township level was estimated as shown in Data B.5 (5) "Groundwater Storage Rates by Geology".

On the assumption that depth and static water level were adopted from standard tube well design (tube well depth and static water level, referred to Table B.8), apparent porosity was estimated by the geological distribution and specific yield. Apparent porosity is defined as depth of saturated groundwater against aquifer' depth at Township level.

Consequently, groundwater storage was estimated at **7,155.41 MCM.** At Township wise, storage volumes are shown in Data B.5 (7) "Study Results on Groundwater Development Potential". Peculiarity indexes of groundwater storage were estimated by the weighted average using Township areas under such conditions at the city level as shown in Table B.26 below.

Table B.26 Storage Peculiarities at City Level

Occupancy Rate		Aquifer Distribution		Porosity	
Recent Alluvium	Delta Deposits	Depth	SWL	Specific Yield	Apparent Porosity
75%	4%	110.5m	9.3m	11.7%	11.8m

Note; City level is estimated by the weighted average of Township level.

At city level, groundwater recharge and storage were estimated as shown Table B.27 below.

Table B.27 Groundwater Recharge & Storage at City Level

GW Recharge						GW Storage
Natural	Artificial		Actual Recharge	GW Inflow	Total at T/S Level	
Rainfall	Irrigation	Leakage				
201.82	9.21	61.92	272.95	80.92	353.87	7,155.41

Note: Recharge unit is MCM/Y and Storage unit is MCM. GW and T/S mean groundwater and Township.

2.2.3 Groundwater Balance

In this study, permissive rates of recharge as sustained yields were estimated by the proportions to be set up with due consideration of topographical and geological conditions. The susceptibility is indicated as recharge percentage against storage. Following are procedures and estimation results of the sustained yield and the susceptibility.

(1) Sustained Yield

When all recharge value has been developed extending over a long period, groundwater level will be drew indefinitely to the water level of surrounding areas. It means that groundwater level becomes same as sea level finally. Recharge water has been used for the system act of present hydraulic cycle.

On the other hand, groundwater balancing is easily re-formed by the variables of recharge and extraction. It is important that what level is permissive limitation of environmental preservation as the resources for human activities. Therefore, it is notified at the beginning of this article that groundwater management is formed by both environment and exploitation.

Actually, the estimation of sustained yield is studied and confirmed based on the water level observations. Therefore, rates of groundwater recharge were assumed to estimate the sustained yield because of no observation record at present.

It is noted that since geological origins and under ground recharge background are different, two rates were set up for recent alluvium at eastern and western. Following Table B.28 shows assumption values of percentage rates. Proportion of percentages (range: 5% to 75%) at Township level is shown in Data B.5 (7).

Table B.28 Permissive Rates for Sustained Yield

Geological Age		Rock Unit			Permissive Rate	
System	Series	Lithofaces		Formation	West	East
Quaternary	Holocene	Q_H	Alluvium	Quaternary Deposits	75%	35%
	Pleistocene	Q_P	Delta		60%	
Tertiary	Pliocene	T_{Pc}	Clay	Ayeyawaddy Series	5%	
		T_{Psa}	Sandstone		30%	
	Miocene	T_{Ma}	Alternation	Pegu Group	15%	
	Oligocene	T_{Osa}	Sandstone		25%	
		T_{Osh}	Shale		5%	

Note; Permissive rates were assumed by this study.

In the study results of sustained yield, highest percentage of 75% falls on Townships of Dala, Hlaingthaya and Seikkyi Kanaungto and lowest one falls on Yankin Township. At the city level, 39% of recharge value was evaluated as sustained yield.

The sustained yield was estimated at Township level, the city total of which was totaled at **137.90 MCM/Y.** Townships falling on large sustained yield (more than 10MCM/Y) are Dagon Myothit South, Hlaingthaya and North Okkalapa, small one (less than 1.0MCM/Y) is fell on Dawbon, Pazundaung and Yankin.

(2) Susceptibility

Definition of the susceptibility is the index of division recharge value by storage volume. The susceptibility has characteristic trends shown in Table B.29 below.

Table B.29 Characteristic Trends of Susceptibility

Peculiarity	Susceptibility	
	Large %	Small %
Merit	a. Fresh groundwater is recharged (short cycle). b. Water quality is most likely classified into soft water.	a. Water includes minerals being soluble in water. b. Water quality is most likely classified into hard water.
Demerit	a. Water level is easily affected depending on the recharge value.	a. Water level is sustained during dry season.

Note: Those are comparative trend between "Large" and "Small" (no boundary).

Large percentage falls on two Township: Seikan Port (197%) and Tamwe (201%), while small percentage falls on Townships of Yankin (0%), Dagon Myothit Seikkan (1%), Dagon Myothit East, Dagon Myothit North, Dagon Myothit South, Dawbon (2%), Dala, Hlaingthaya, Seikkyi Kanaungto, Shwepyitha and Thaketa (3%), respectively.

However, Yankin was evaluated "no groundwater storage" because of very low permeability. As the city level, the susceptibility was estimated at 5%.

Consequently, sustained yield and susceptibility of groundwater at city level were summarized in Table B.30. At Township wise, storage volumes are shown in Data B.5 (7) "Study Results on Groundwater Development Potential".

Table B.30 City Summary of Sustained Yield & Susceptibility

Description	Sustained Yield	Susceptibility
	Permissive %	Recharge % of Storage
Range of Township Level	5% to 75%	0% to 201%
City Average	39%	5%
Total Amount	137.90 MCM/Y	-

Note; Sustained yield is the product of potential and permissive percentage.
Susceptibility is recharge ratio of storage.

2.2.4 Development Potential

Groundwater development was evaluated in terms of quantity (by technical matter) and quality (by social and economical matter) in this article.

(1) Groundwater Quantity

There are five indexes to express groundwater quantity: (a) recharge, (b) potential, (c) extraction, (d) availability and (e) storage. The unit (MCM/Y or MCM) indexes were divided by respective Township areas to evaluate technically. The indexes and the unit indexes were simply compared, which is shown in Table B.31 by urban (18 Townships) and rural (15 Townships) grouping. At Township level, those indexes are shown in Table B.32.

Table B.31 Comparison of Indexes by Urban & Rural

Category		Area	Recharge	Potential	Extraction	Availability	Storage
Township	Unit	km^2	MCM/Y	MCM/Y	MCM/Y	MCM/Y	MCM
	Urban	65.11	106.09	44.01	13.06	30.95	484.15
	Rural	543.97	247.78	93.89	22.89	71.00	6,671.26
Unit Area	Unit	-	MCM/Y km^2	MCM/Y km^2	MCM/Y km^2	MCM/Y km^2	MCM/km^2
	Urban	-	1.63	0.68	0.20	0.48	7.44
	Rural	-	0.46	0.17	0.04	0.13	12.26

Note; Rural Townships were Dagon Myothit East, Dagon Myothit North, Dagon Myothit Seikkan, Dagon Myothit South, Dala, Hlaing, Hlaingthaya, Insein, Mayangone, Mingalardon, North Okkalapa, Seikkyi Kanaungto, Shwepyitha, Thaketa and Thingangyun.

Table B.32 Indexes of Townships

Township	Recharge MCM/Y km²	Potential MCM/Y km²	Extraction MCM/Y km²	Availability MCM/Y km²	Storage MCM/km²
Ahlone	1.07	0.74	0.86	**-0.12**	8.71
Bahan	0.92	0.16	0.00	0.16	**2.32**
Botataung	1.40	1.04	0.06	0.98	5.46
Dagon	0.86	0.44	0.31	0.13	6.02
Dagon Myothit East	**0.26**	**0.09**	0.01	**0.08**	17.25
Dagon Myothit North	0.38	0.13	0.03	0.10	17.25
Dagon Myothit Seikkan	**0.27**	**0.09**	**0.00**	**0.09**	18.15
Dagon Myothit South	0.37	0.13	**0.25**	**-0.12**	17.70
Dala	0.30	0.22	0.03	0.20	10.05
Dawbon	0.42	0.15	0.05	**0.09**	**19.05**
Hlaing	0.47	0.29	0.18	0.11	7.90
Hlaingthaya	0.30	0.23	0.02	0.21	10.05
Insein	0.43	0.20	0.03	0.16	5.03
Kamayut	0.52	0.30	0.17	0.13	6.94
Kyauktada	3.56	2.40	**1.27**	1.14	5.88
Kyeemyindaing	1.12	0.79	0.23	0.56	9.05
Lanmadaw	2.29	1.46	**1.50**	**-0.04**	5.29
Latha	2.79	1.80	0.06	1.74	5.41
Mayangone	0.75	0.12	0.03	**0.10**	2.82
Mingalardon	0.44	**0.08**	0.00	**0.08**	9.99
Mingalartaungnyunt	3.11	0.95	0.02	0.92	8.16
North Okkalapa	1.42	0.48	0.02	0.46	16.39
Pabedan	3.57	2.49	**1.23**	1.26	6.23
Pazundaung	2.13	0.75	0.13	0.62	6.83
Sanchaung	1.21	0.72	0.53	0.19	6.40
Seikan Port	**10.96**	**8.22**	0.44	7.78	5.55
Seikkyi Kanaungto	**0.25**	0.19	**0.00**	0.19	10.05
Shwepyitha	0.40	0.27	0.05	0.21	11.68
South Okkalapa	1.60	0.54	0.05	0.48	17.88
Tamwe	2.75	0.22	0.00	0.22	**1.37**
Thaketa	0.55	0.19	0.09	0.10	18.83
Thingangyun	1.16	0.30	0.18	0.12	12.71
Yankin	1.33	**0.07**	0.03	**0.03**	**0.00**

Note; Peculiar indexes are typed in boldface. Addition of extraction and availability is not equal to potential value because of round to two decimals.

➢ Urban & Rural Areas

In Table B.31, it can be seen that there is large difference between the indexes of water cycle. The proportions of the sustained yield (divided potential by recharge, referred to Table B.31) are 42% in urban and 37% in rural. The gap of availability is originated from the recharge values. Thereupon, Table B.33 was prepared to compare the breakdown values of recharge below.

Table B.33 Detailed Recharge Values in Urban & Rural

Classification		Rainfall	Paddy	Leakage	Inflow	Total
Urban	T/S Value	24.78	0.49	41.48	39.35	106.09
	Unit Value	**0.38**	0.01	**0.64**	**0.60**	1.63
	Proportion	23%	1%	39%	37%	100%
Rural	T/S Value	177.04	8.72	20.44	41.57	247.78
	Unit Value	**0.33**	0.02	0.04	0.08	0.46
	Proportion	71%	4%	8%	17%	100%
City	City Value	201.82	9.21	61.92	80.92	353.87
	Unit Value	0.33	0.02	0.10	0.13	0.58
	Proportion	58%	3%	17%	22%	100%

Note; Unit of T/S and City values is MCM/Y, Unit value is MCM/Y km^2.

The unit values of rainfall in urban and rural areas are almost same. Significant recharge values of leakage and inflow make such gap. If there is no gap in such values between urban and rural, total recharge values are also most likely same.

This situation means that water level shall be observed carefully in urban area until when the leakage reduction program is promoted and completed by the YCDC. Additionally, water level lowering might be observed in some Townships even now.

➢ Township Wise

The potential or sustained yield is followed the trends of recharge values. The extraction values are reflected present conditions. It is remarkably notified as a kind of worst that the negative groundwater availability in the Townships of Ahlone, Dagon Myothit South and Lanmadaw were estimated because of probable over exploitation.

Consequently, groundwater development in urban/central Townships for the main water supply system is not recommendable plan. New surface water source is rather developed than groundwater for city proper/downtown. On the other hand, groundwater development is recommendable for construction of water supply systems in the right bank of Hlaing River to improve their sanitary environment.

- Irrawaddy Delta Area

Tube well fields for the right bank water supply systems shall be expanded to the outskirts of a city because existence of impertinent groundwater quality for drinking purpose is supposed to be distributed in near populated areas, which is similar to Dala project and Hlaingthaya on-going project.

The groundwater potential was re-evaluated under the local conditions assuming through the field survey and itinerary. However, the proposed projects can be promoted on condition that the safe groundwater quality is confirmed absolutely through the groundwater investigation.

Compositions of re-study on groundwater potential are similar same evaluation items as previous study. Since expected tube well fields are located in the proximity of the city boundary or outskirts of a city, land use and irrigation patterns were newly assumed. Proportion of sustained yield was assumed at same values of previous study result. Probably, present groundwater extraction in such tube well fields is not necessary to consider. Following are study process and results.

<Land Use>

Expected tube well fields are located in the Irrawaddy Delta Plain, which is occupied western side of the city. Land altitudes are less than 3m above mean sea level and such low land was cultivated as flat paddy fields. Precipitation value was estimated as same value of the city. For estimation of meteorological recharge, land use was newly established using aerial photographs as of the year 1970 (probably still same proportion of land use at present). Irrawaddy Delta Plain is a granary region in the Myanmar. Following proportions were assumed as shown in Table B.34.

Table B.34 Expected Land Use in Irrawaddy Delta Plain

Forest	Farm	Built-up	Paddy	Swamp
25%	15%	0%	60%	0%

Note; Proportions were assumed by this study using aerial photographs as of 1970.

<Irrigation Pattern>

Irrigation canals or streams form water supply networks; even those are natural or man-made. Double-cropping pattern could be commonly observed. In this study, proportion rate of paddy field to be irrigated during dry season was assumed at mere 80%.

<Groundwater Inflow>

Background of tube well fields is extensive delta plain formed by the Irrawaddy River originated from east end of the Himalayas in northern part of the Myanmar. This Irrawaddy River and its tributaries cover whole river mouth areas with width of 200km or more. The Yangon city is located in east edge of this delta plain.

Without any survey or reports for this delta plain, it seems to be that much larger groundwater inflow may recharge area where groundwater is extracted. As a hypothesis inflow amount, same value of meteorological recharge amount was assumed as minimum inflow value. In some reports, clayey formations were not distributed in this delta plain. However, only over exploitation is afraid of that land subsidence will be accelerated artificially in the future.

<Recharge & Proportion of Sustained Yield>

Recharge amount in unit area was estimated for the required designing. Permissive rate of recharge as sustained yields was assumed at 75% that is same proportion of previous practices. Table B.35 shows estimation procedure of unit sustained yield.

Table B.35 Estimated Unit Sustained Yield

Meteorological Recharge	Irrigation Recharge	Groundwater Inflow	Total Recharge	Proportion of Sustainability	Sustained Yield
0.37	0.10	0.37	0.84	75%	0.63

Note; Unit is MCM/Y km^2.

<Present Extraction & Availability>

Monitoring information of existing intake facilities is not available at present, but there may be no tube well in this delta plain. Groundwater development availability was, therefore, estimated at **0.63MCM/Y km^2**.

However, following groundwater investigations for the new well fields shall be conducted before proceeding implementation stage.

- Distribution of Expected Good Aquifers

  First step of groundwater survey is to confirm the distributive conditions of available aquifers in the said well fields. For this purpose, electric prospecting is proposed to conduct. Following are tentative technical specifications of this survey by unit area basis.

  Sounding Depth: 100m (Analysis Depth=60m to 70m)
  Measuring Points: Every 500m Intervals (4 points per km^2)
  Output: Cross Section of Apparent Resistivity

- Confirmation Tests in terms of Quality & Quantity

  Conducting of test tube well is only one method to confirm the actual characteristics of groundwater conditions in terms of quality and quantity. Following tube well structures and test contents are requisite to gain the accuracy of future production tube wells to be constructed in the expected fields.

  <Structures of Test Tube Well>
  Bore x Casing x Depth: 450mm x 250A x Tentatively 70m
  Screen Length x Slot: uPVC x 24m x 1.5mm
  Placement: Filtration Gravel and Surface Grouting

  <Test Contents>

  Tests contain the evaluations of aquifer' soil and groundwater characteristics. Necessary test outputs of expected aquifer are: (a) uniformity coefficient and effective grain size, (b) physical logging data, (c) permeability coefficient, transmissivity and storage coefficient, and (d) water quality through the tests below.
  Sieve Analysis: Expected Aquifers
  Physical Logging: Resistivity (long 64"& short 16")
  Step Draw Down Test: 2 hours duration with 8 steps
  Time Draw Down Test: 72 hours with maximum discharge
  Water Quality Examination: Parameters of pH, Cl, EC, Fe, Mn, Na and Ca

(2) *Groundwater Quality*

Based on present information, groundwater quality was evaluated. Groundwater quality problems reported in the city were saline water intrusion, brackish water and high concentration of iron, manganese, calcium and magnesium. Townships falling on those problems are listed in Table B.36 below.

Table B.36 Townships of Quality Problems

Quality		Township	Location
High Chloride	Saline	Ahlone	River side (southwest)
		Botataung	River side (south)
		Dala	Whole area
		Hlaingthaya	River side (east & south)
		Kyauktada	River side (south)
		Kyeemyindaing	Whole area
		Lanmadaw, Latha & Pabedan	River side (south)
		Seikan Port & Seikkyi Kanaungto	Whole area
		Thaketa	River side (southeast)
	Brackish	Dagon	Hill side (northeast)
		Hlaing, Insein & Kamayut	Hill side (east)
		Mayangone	Hill side (central)
		Mingalardon	Hill side (northwest)
		Sanchaung	Hill side (east)
High Minerals	Fe/Mn	Dagon	Whole area
		Hlaing, Insein & Kamayut	Hill side (east)
		Mayangone	Hill side (central)
		Mingalardon	Hill side (northwest)
		Sanchaung	Whole area
		Shwepyitha	Hill side (east)
	Ca/Mg	Insein	Hill side (east)
		Mingalardon	Hill side (central)
		Shwepyitha	Hill side (east)

Source; Report on "Future Prospect of the Underground Water of Yangon", as of 1996

2.3 FUTURE DEVELOPMENT REQUIRED

The YCDC has been developing groundwater being incidental to the population growth, urbanization and versatile human needs with empirical technologies and supplemental studies. At the beginning of the establishment on the YCDC water supply systems, groundwater was developed for a water source with service level-I. Facilities of service level-I were later up graded to level-II or level-III complying with users demands. Water deficit was solved step by step with development of the surface water feeding from reservoirs.

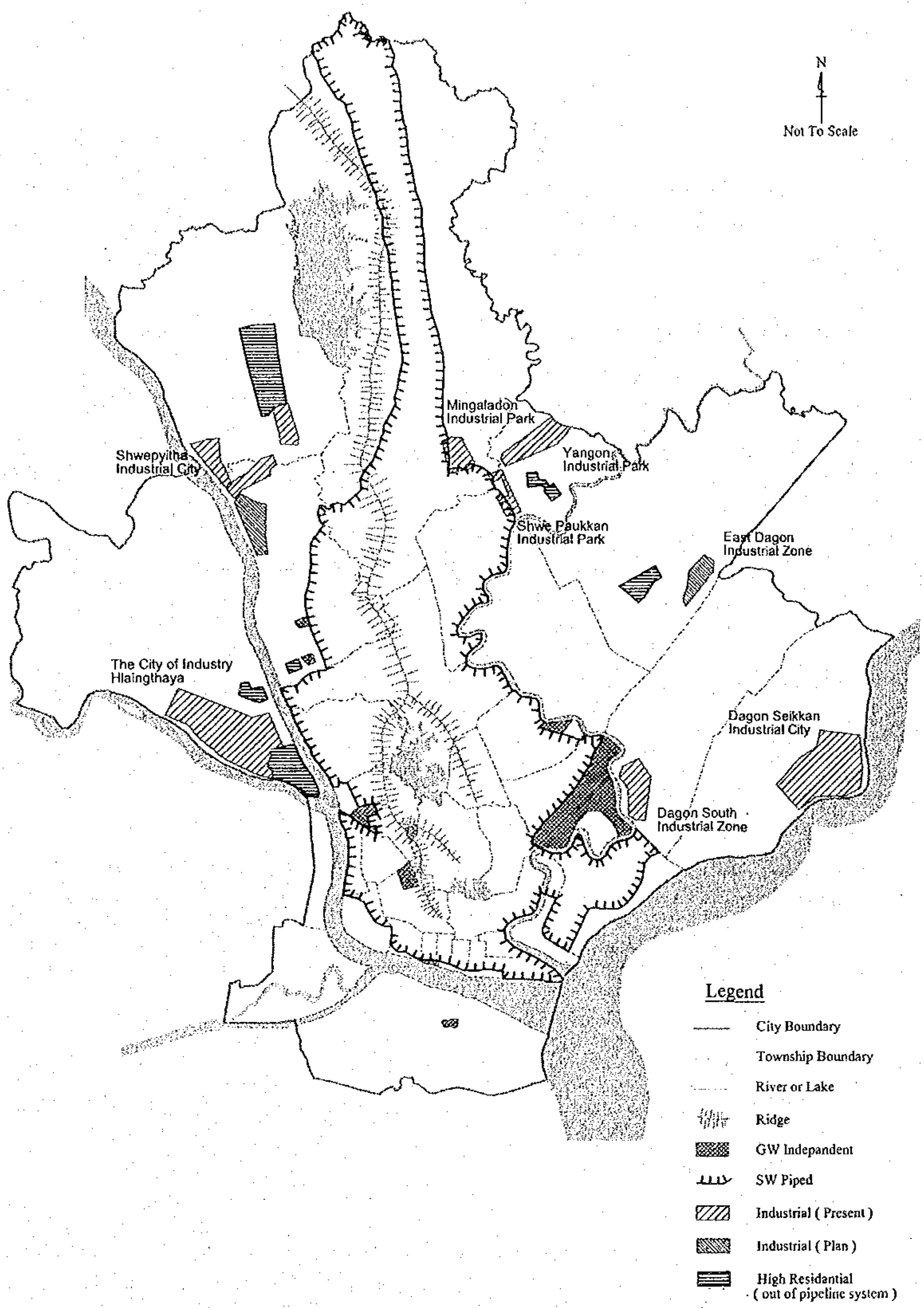
Presently, there are two types of major water supply problems in terms of water quantity and quality, which shall be solved in future as soon as possible. Firstly as a water quantity, the water source shortage in the main system comparing to the demands is occurred with serious magnitudes such as intermittent and low-water-pressure water supply. Secondly as a quality, the citizens have compellingly utilized unsafe water sources (ponds or open dug wells) in right bank of the Hlaing River.

As the basic concept of the final goal for the YCDC water supply systems, safe piped water supply shall cover the entire city with service level of in-house connection. Figure B.11 shows present coverage area of the main water supply system together with high residential and industrial zone (existing and plan) areas where piped water supply services are not available at present. Following service areas will be basically supplied from different water sources to create the priority solution of problems (mentioned above) most economically until the supplies reach the demands.

- Areas in Left Bank of the Hlaing River
  Surface Water feeding from both Ngamoeyeik Reservoir and Hlaing River
- Areas in Right Bank of the Hlaing River
  Groundwater essentially with remaining Surface Water through the City Proper

In this regard, future groundwater development schemes were conceptually assorted following two groups.

- Tube Well Rehabilitation in the Left Bank of the Hlaing River
- New Tube Construction in the Right Bank of the Hlaing River



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

FIG B.11

GROUND WATER DEVELOPMENT SCHEME

2.3.1 Tube Well Rehabilitation

This tube well rehabilitation plan indicates the future guidelines. Operation of existing tube wells shall be modified with due reference to the YCDC' present practices. At first, the independent systems/facilities shall be merged into the main system excluding existing Dala and ongoing Hlaingthaya water supply projects until completion of enough surface water source developments.

The rehabilitation plan was, therefore, divided into two stages. The concepts of the said stages are to increase the production amount of tube wells and to settle the groundwater source in terms of safe, sustain and small cost. Finally, the conversion timing between "increasing" and "settlement" was assumed by Township wise based on the balance of demand and supply using allocated surface water sources, which are the Ngamoeyeik Reservoir and two series of the Hlaing River.

- 1st Stage: Increasing of the Groundwater Production Amount
- 2nd Stage: Settlement of the Tube Well Facilities

(1) 1st Stage: Increasing of the Groundwater Production Amount

Following Table B.37 shows the distribution of two hundred four (204) tube wells in the left bank of Hlaing River.

Table B.37 Ycdc Tube Wells in Left Bank of the Hlaing River

System/Facilities	Tube Well			Production	Operation	Township
	number	S-Pump	Airlift	MCM/Y	hours/day	number
Main System	104	83	21	12.07	7.7	15
Level-II/III Systems	33	24	9	2.17	9.9	7
Level-I Facilities	67	4	63	0.96	3.0	5
Total or Average	204	111	93	15.20	6.3	17

Note; Tube wells for hydrant are not included. "S-Pump" means submersible pump. Production amount was recorded in year 2000. Standby tube wells are not included into operation hours. Township numbers are overlapped; total number is not sum up of system wise.

Concept of this stage is to increase the groundwater production amount with effective investment. It means that tube well facilities shall be improved with avoidance of any expedient exorbitantly.

In this regard, firstly present tube wells were allotted to the regular or abandoned in future use for the realization of groundwater source with "safe", "sustain" and "small cost

- economical". Evaluation items for the settlement of tube wells are existence of problems in terms of water quality as "safe", well structure as "sustain" and yielding as "small cost". Following criteria were assumed for

(a) Water Quality: low Cl ion<200mg/l and low Fe concentration<1.0mg/l
(b) Structure: tube well diameter>100A (4") for pump replacement
(c) Yielding: discharge>300l/min. (annual discharge>0.1MCM/Y)

The parameters of water quality were evaluated by the permissive limitation of WHO drinking water standard. Parameter of electric conductivity (EC) was examined at all tube well sites in September 2001, which is mutually related to the chloride ion concentration. Results of EC examination are shown in Data B.7 (1).

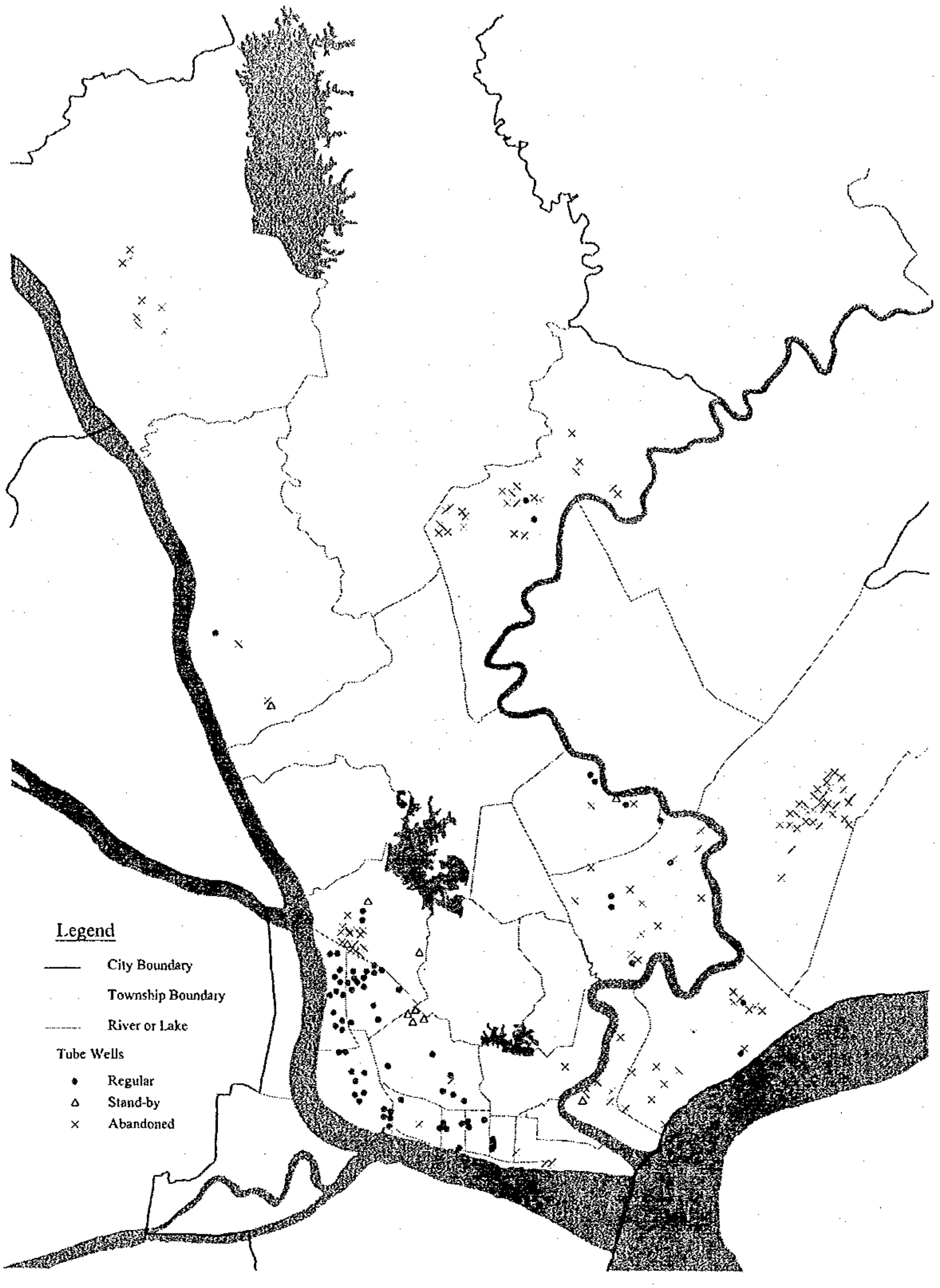
Out of 104 tube wells belonging to the main system, number of regular tube wells was totaled at 75, while the other 29 tube wells were fell on abandoned facilities in future settlement. Consequently, 75 tube wells shall be improved, while remaining 29 tube wells shall be used on condition of present.

Allocation of tube well sites is shown in Figure B.12 and Data B.6 (1). At Township level, tube wells were demarcated into "Regular" and "Abandon" for future use as shown in Table B.38.

Table B.38 Consolidation of Tube Wells for Future Use

	Township	Regular	Abandon
without Problem	Ahlone, Insein, Kamayut, Kyeemyindaing, Latha, Pabedan and Sanchaung (8 Townships)	51	0
with Problems	Botataung, Dagon, Lanmadaw, North Okkalapa, South Okkalapa, Thaketa and Thingangyun (7 Townships)	24	29
	Total of the Main System	75	29

Source; Tube Well Database, as of July 2001
Note; Out of 29 abandoned tube wells in future settlement, 9 wells have water quality problem, 23 wells have small yielding problem and 3 wells have small diameter problem, respectively.



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG B.12
	TUBE WELL LOCATION MAP FOR THE MAIN SYSTEM	

In the year 2000, average daily pump operation in the main system was estimated at only 7.7hrs with annual total production of **12.07MCM/Y** statistically. It means that the duration times of daily high water consumption have restricted to the management of pump operation. Accordingly, longer pump operation makes larger production amount. Daily pump operation time of 16hrs is adaptable condition to fit the YCDC management. Following Table B.39 shows comparison between present and after improvement of objective 75 tube wells.

Table B.39 Comparison of Tube Well Production

Items	Present		After Improvement		Remarks
	Regular	Abandoned	Regular	Abandoned	
Tube Well	75	29	75	29	ditto
(well number)	104		104		
Daily Operation	**7.2**	9.3	**16.0**	9.3	+8.8
(hrs/day)	7.7		14.1		+6.4
Annual Production	**10.25**	1.82	**22.56**	1.82	+12.31
(MCM/Y)	12.07		24.38		

Source; Tube Well Database, as of July 2001

Tube well deterioration shall be considered for future forecasting. According to the YCDC engineers, an average life may be estimated about 20 years. Additionally, when the tube well performance becomes a half of original condition, new tube well will be replaced by new tube well instead of old one. Annual deterioration rate can be estimated by following method.

$$(1-D)^Y = Cf / Co = 0.5$$

Where: **D;** Annual Deterioration Rate (approximately 3.4%)
Y; Duration in Year
Cf; Estimated Well Performance in future
Co; Current Well Performance

In this study, mere 3% of annual reduction was assumed for available production amount. At the year 2020, 54% of present production was assumed as hypothetical well potential on a single well base, because the YCDC has no experience of actual tube well re-development for recovery of the tube well performance.

Necessary modification required for future regular tube well is to improve tube wells in terms of water quantity and water quality. Therefore, replacement by adequate pumps for increasing of daily operation hours gradually and protection from surface water contamination are constructive plans. Following are detailed contents for tube well rehabilitation.

➢ Replacement of Pump Equipment

All tube wells should be equipped with appropriate submersible pump. Initial pumping rate of airlifting is much larger than normal well performance; also control of discharge rate is very difficult. Many tube wells product groundwater with existence of sand and/or turbidity because of transient over pumping. There is another disadvantageous to groundwater sampling for examination of some parameters. Compulsive aeration using airlift pump makes changing of water quality, especially iron ion (Fe) and pH value.

To re-evaluate the tube well performance for the replacement of present one by proper submersible pump, pumping test is required to conduct at expected tube wells.

- Manner of Pumping Test (at Regular 75 Tube Wells)

Type of pumping test is step draw down test. Manner of step draw down test is 6 steps and duration time of at least one hour each.

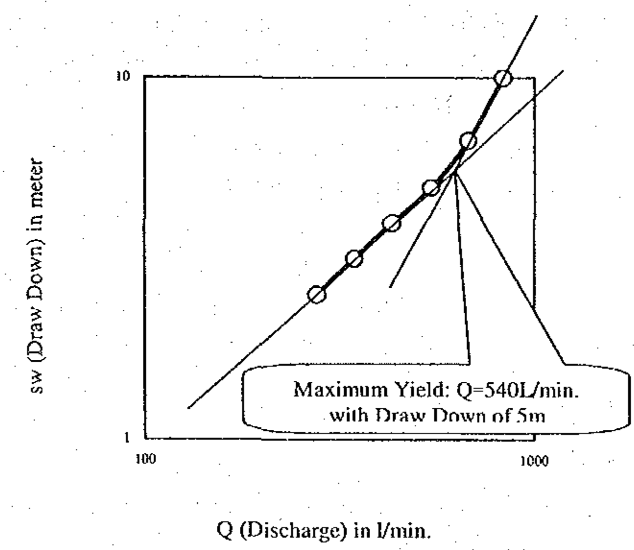


Figure B.13 Typical Q-Sw Test Curve

In simple way, maximum yield of tube well can be assumed by the logarithmic Q-sw test curve. Maximum draw down of 10m is requisite to set up the pumping rate limitation for long life utilization of tube well, because excessive draw down gives conditions of prone to create unnecessary incrustations relating to early deterioration. Typical logarithmic Q-sw test curve is shown in Figure B.13 for explanation of analysis.

➢ Protection of Surface Water Contamination

There are two routes of surface water contamination to the groundwater. Such routes are from: (1) annular space between bore hole and well casing pipes, and (2) well top and inner well casing. Following are realistic countermeasures for water quality improvement.

- Additional Mounting Base

Mounting base made of concrete or clayey soil shall be attached to the tube well casing. For making sure the fruits, surrounding ground of tube well shall be dug as deep as possible and back-filled by concrete or clayey soil up to exceed level of the experienced flood level. In some sites, additional well casing may be required.

- Pump House/Pit and Pump Cover

Tube well point shall be protected by flood and rainwater. Additional pump house or pump pit shall be constructed. Also standard pump cover shall be placed instead of present type.

(2) 2nd Stage: Settlement of the Tube Well Facilities

The gradual consolidation to the main system is a concept for this stage upon confirmation of definite surface water development in terms of quantity. Objective water supply facilities are totaled at 100 tube wells as shown in Table B.37.

For the target of this master plan, the main system shall cover the entire area in the left bank of the Hlaing River. Therefore, supplemental groundwater supply is not effective plans and shall be used for emergency/alternative water source or hydrants.
In this purpose, existing 100 tube wells were classified into standby or abandoned tube wells under the problematic conditions of water quality, yielding and well structures. Selective criteria are same as tube well classification in the current main system. Air-lift pump at standby tube wells shall be replaced by existing submersible pump accordingly. Following are necessary arrangement for this settlement.

➢ Classification of Existing Tube Wells (100 wells)

Out of 100 tube wells, 33 tube wells are fell on Level-II or III, while 67 tube well are fell on Level-I facilities.

There are problems at 24 tube well facilities in the independent water supply systems out of 33; which are water quality problem at 5 tube wells, low yielding at 20 tube wells and small diameter at 2 tube wells including overlapped numbers. On the other hand, there are problematic 66 tube wells in the L-I; bad quality at 44 tube wells, small yielding at 57 tube wells and inadequate structures at 57 tube wells, respectively.

Finally, only 10 tube wells can be utilized for future use as a standby tube well. Data Table B.6 (2) shows detailed classification with judgment of criteria. Following Table B.40 shows the list of standby tube wells.

Table B.40 List of Standby Tube Wells

Identification			Tube Well Structures & Performance		
Township	No.	Service Level	Diameter	Depth	Production
Dagon	No.08	L-II/III	200	30	0.105
	No.09	L-II/III	200	44	0.319
	No.10	L-II/III	200	43	0.399
	No.11	L-II/III	200	39	0.133
Dawbon	No.01	L-I	200	40	0.105
Insein	No.03	L-II/III	200	43	0.105
Kamayut	No.03	L-II/III	250	55	0.172
	No.04	L-II/III	200	43	0.319
	No.06	L-II/III	200	40	0.133
South Okkalapa	No.04	L-II/III	200	55	0.133

Note: Unit diameter is in millimeter, depth is in meter and discharge is in MCM/Y (16hrs/day).

Under above conditions, the conversion timing was assumed based on surface water development. The plans for tube well rehabilitation and surface water development were made as a hypothesis stage. Following Table B.41 shows such planning periods.

Table B.41 Tentative Periods of Proposed Plans

Proposed Plans	Expected Period	Present Status
Tube Well Rehabilitation	2010	Master Plan Level
Ngamoeyeik Reservoir	Before 2005	On-going Project
Hlaing River 1/2 Series	Before 2010	Pre-F/S Level
Hlaing River 2/2 Series	Before 2020	Master Plan Level

Note; Upon completion of Hlaing River 1/2 series, water supply amount reaches demand in 2010.

Each Township falls on the expected conversion timing from rehabilitation stage to settlement stage with due consideration of Township location and present service coverage with growth pattern. Table.B.42 shows conversion periods with their conditions. Accordingly, detailed annual production amounts were estimated as shown in Data B.6 (3) "Forecasting of Tube Well Rehabilitation". Groundwater extraction amount in the left bank of the Hlaing River was totaled at **12.27MCM/Y** in the year 2020.

Table B.42 Conversion from Rehabilitation to Settlement

	Township	Conversion (before year of)	Condition (after implementation of)
11 T/S	Ahlone, Botataung, Dagon, Kyauktada, Kyeemyindaing, Lanmadaw, Latha, Mingalartaungnyunt, Pabedan, Sanchaung and Seikkan Port	2005	Ngamoeyeik Reservoir
4 T/S	Dagon Myothit South, Dawbon, Thaketa and Thingangyun	2010	Hlaing River 1/2 Series
5 T/S	Insein, Kamayut, North Okkalapa, Shwepyitha and South Okkalapa	2020	Hlaing River 2/2 Series

Note; Conversion plans will be implementing step-by-step depending on the progress of water source development.

The YCDC groundwater extraction amount will be decreased and additional water needs from the None YCDC will be covered by the YCDC water supply as a general trends until the year of 2020. Groundwater conditions of sustained yield and availability will be recovered with implementation of above tube well rehabilitation plans. However, groundwater quality and water level shall be observed as an environmental preservation.

2.3.2 New Tube Well Construction (New Satellite Systems)

Areas in right bank of the Hlaing River have been anxious about un-sanitary environment, especially in the complex compounds of Kyeemyindaing. Detached these areas shall be covered by surface water supply system with submerge pipeline crossing to the Hlaing and the Pan Hlaing rivers for economical and simple management. As an intermediation period until completion of sufficient surface water development for the central and eastern parts of the city, groundwater supply systems shall cover the right bank areas initially.

Groundwater development plans by project bases were prepared. The design concepts as a part of master plan include preliminary levels of: (a) design conditions and assumption, (b) design criteria, (c) standard facilities designs and (d) particular requirements to be issued in the detailed design stage. Following subdivisions are design concepts, proposed projects and construction plan.

(1) Design Concepts

Objective development areas cover the right bank of the Hlaing River: Townships of Dala, Hlaingthaya, Kyeemyindaing and Seikkyi Kanaungto. Present Status of these Townships is shown in Table B.43 below.

Table B.43 Present Status of Right Bank Townships

Township	Present Status			
	Population Year 2000	Service Coverage	YCDC Water Supply	Majority Water Sources
Dala	81,317	13%	L-II/III by Groundwater (under operation)	Pond
Hlaingthaya	209,714	0%	L-II/III by Groundwater (on-going)	Dug Well
Kyeemyindaing	30,591	0%	None (the right bank area)	Pond/Boat/Rain
Seikkyi Kanaungto	26,938	0%	None	Pond/Boat

Note: Service coverage includes only piped water supply of the YCDC. Four tube wells were completed to construct in Hlaingthaya.

On the said present status in objective areas, the YCDC supplies the water by boat from Kyeemyindaing in the left bank of the Hlaing River during dry season. During rainy season, most of citizens in these areas fetch water from un-sanitary facilities such as pond, rain collector, shallow driven wells, dug wells, etc.
For preparing of the proposed projects, following common design concepts of sanitary groundwater development facilities were concluded.

- Design Conditions & Assumptions

  <Physical Sources>

  The YCDC employs one crew of the skilled drilling workers at present. The drilling crew has been operating a unit of rotary drilling equipment with manual rotation type. The YCDC has enough spare parts for such equipment.

  <Material Conditions>

  Materials for tube well construction are available at local markets in the city. The well casing pipe made of uPVC (TIS: Thai Industrial Standard) can be procured from manufacturer at Hlaingthaya and the YCDC has been fabricated well screens. Only the submersible pump and its spare parts shall be ordered to France, India or Malaysia.

- Design Criteria

<Water Demands>

Municipal water demands by Township level includes domestic, department, commercial and industrial use were subjected by the water supply planning.

In the right bank of the Hlaing River, one industrial zone exists in southeast portion of Hlaingthaya Township. Almost all factories own tube wells but groundwater quality is not potable and suitable to use. In this plan, such industrial demand was included.

<Tube Well Performance>

Because of saline groundwater quality in the right-bank Townships of the Hlaing River, the YCDC examined groundwater quality in the Irrawaddy Delta, which was within the permissive limitation. Specific capacity in Dala new tube well field has 3.5lpsm, Kyeemyindaing and Seikkyi Kanaungto were estimated at 2.0lpsm and Hlaingthaya in populated area has 1.5lpsm, respectively. Since delta plain has larger specific capacity comparing with older geologic formations, the specific capacity in new well fields was assumed at mere 2.5lpsm with draw down of 10m using previous practices.
It is essentially better choice to control smaller discharge and long-term running with due consideration of groundwater environmental aspect. Operation time was assumed at 16hrs/day and full annual days with allowance time for spare. Consequently, single tube well production rate was estimated at **0.526MCM/Y**.

<Construction Period>

According to the YCDC, following periods for tube well construction were adopted as shown in Table B.44. Such period includes from mobilization until demobilization for single tube well construction works.

Table B.44 Tube Well Construction Period

Performance		Tube Well Structures				Completion Period
Sp.Cap.	Discharge	Borehole	Diameter	Depth	Screen	
lpsm	m³/min.	mm	A	m	m	day
2.0	1.2	400	200	50	24	19
				70		23
2.5	1.5	450	250	50		26
				70		30
3.0	1.8	500	300	50	30	33
				70		38
3.5	2.1			50		33
				70		38

Note: Construction period was estimated by the YCDC.

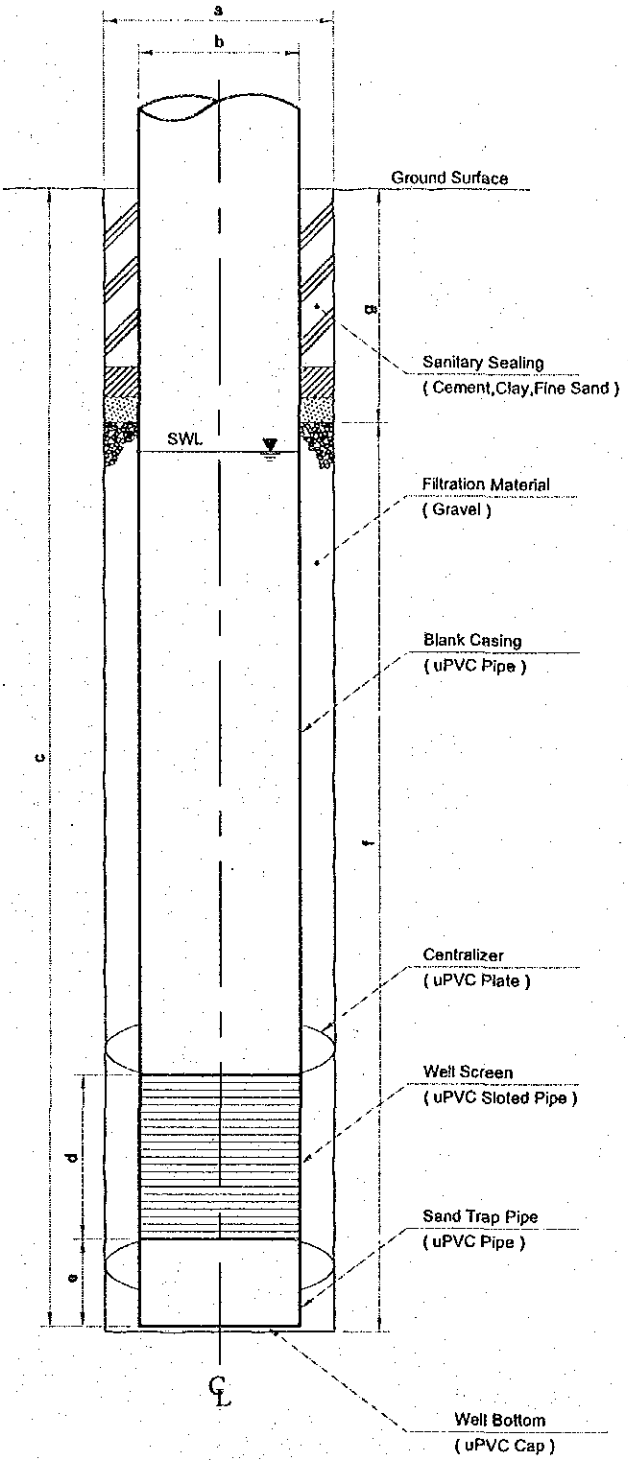
- Standard Design of Tube Well Facility

<Tube Well Structures >

Standard tube well design is depending on the geological background (aquifer depth), tube well performance (diameter and screen length) and ground surface condition (placement program). Figure B.14 shows standard tube well designs and placement program with consideration of sanitary sealing.

<Submersible Pump Installation>

Submersible pump should be selected by the results of pumping test and transmission hydraulic analysis. Related information are: (a) discharge rate, (b) total delivery head, (c) static water level and (d) pumping water level. Figure B.15 shows typical submersible pump installation with plumbing arrangement.



Tube Well Section

Demensions of Standard Tube Well Design

Borehole	Tube Well				Placement	
diameter	diameter	depth	screen length	samp length	filter depth	sealing depth
a	b	c	d	e	f	g
350 mm (14")	150 mm (6")	70 m	18 m	at least 6 m	64 m	more than 6 m
		100 m			94 m	
		130 m			124 m	
		160 m			154 m	
400 mm (16")	200 mm (8")	40 m	24 m		34 m	
		50 m			44 m	
		70 m			64 m	
		100 m			94 m	
		130 m			124 m	
450 mm (18")	250 mm (10")	70 m	24 m		64 m	
500 mm (20")	300 mm (12")	70 m	30 m		64 m	

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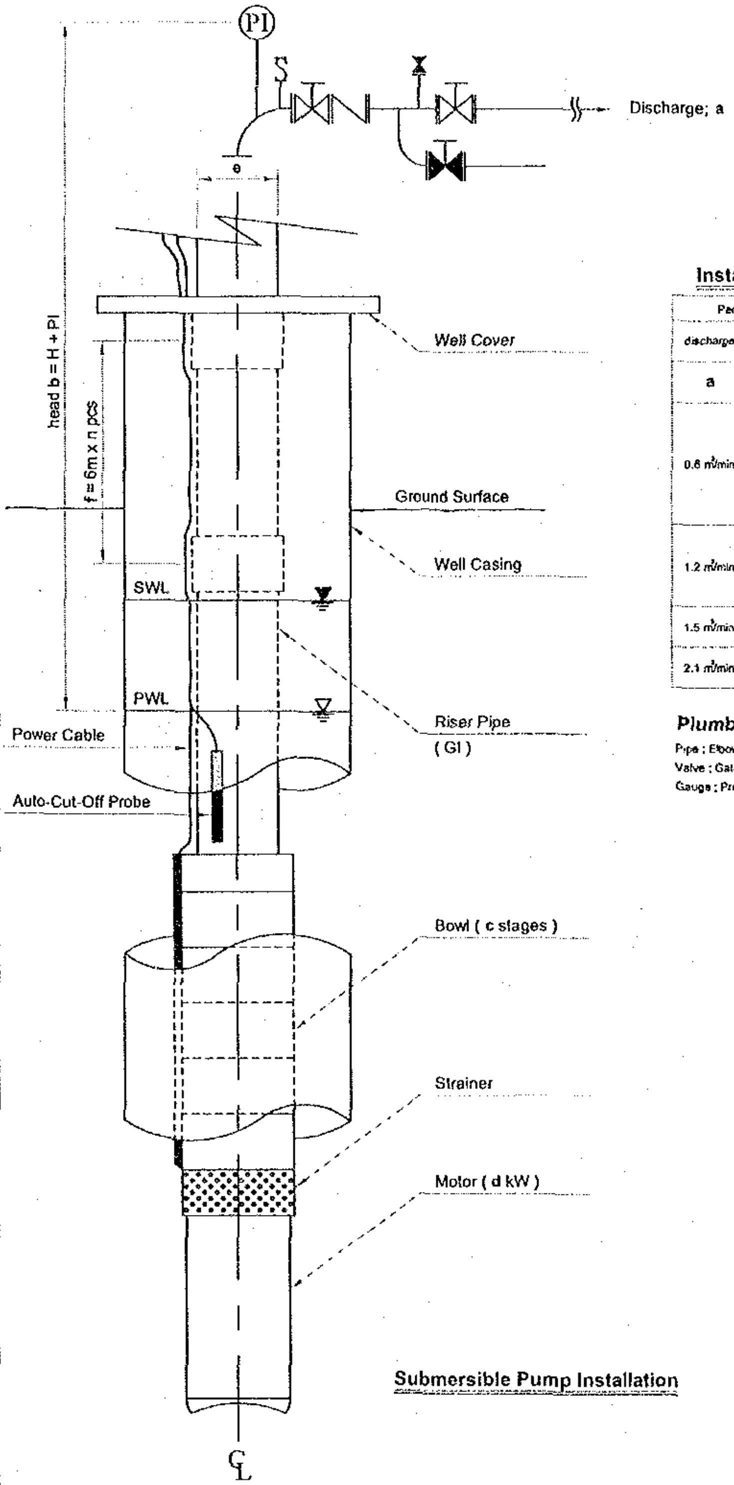
FIG B.13

STANDARD TUBE WELL DESIGN



Submersible Pump Installation

Installation of Standard Submersible Design

Performance		Submersible Pump			Riser Pipe
discharge	*head*	*stage*	*kW*	*delivery*	*length*
a	**b**	**c**	**d**	**e**	**f**
0.6 m³/min	40 m	5 stages	7.5 kW	75 mm	12 m
					18 m
					24 m
1.2 m³/min	40 m	6 stages	11 kW	75 mm	12 m
					18 m
1.5 m³/min	20 m	7 stages	11 kW	75 mm	12 m
2.1 m³/min	20 m	10 stages	15 kW	75 mm	12 m

Plumbing

Pipe ; Elbow, Tee Elbow
Valve ; Gate (3), Check, Cock, Air Release
Gauge ; Pressure Indicator

JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG B.14
	STANDARD SUBMERSIBLE PUMP DESIGN	

- Particular Requirements

<Groundwater Preservation>

In Hlaingthaya on-going water supply project, groundwater quality was examined as potable quality. Since well field is located in the paddy land, groundwater quality should be protected from the fertilizers and/or agricultural chemicals as the preservation activity.

Additionally, observation wells of water level, water quality and land subsidence for monitoring activity should be planned. Details of observation wells are studied in Chapter 3.2.

<Tube Well Arrangement in Irrawaddy Well Field>

Previously, groundwater sustained yield was studied at 0.63MCM/Y km^2, while tube well production was estimated at 0.526MCM/Y, respectively. Therefore, well field for single tube well is estimated at 0.835km^2. Most effective tube well arrangement has a hexagonal hive structure. Hence, distance of each tube well is estimated at 980m.

With due consideration of system operation and maintenance, intake facilities will be grouped by 5 or 6 tube wells with one intake reservoir. Distances of tube wells in same group and other group were considered with economical intake pipeline cost. In this study, tube well distances of 500m in same group and 1,700m for other group were adopted (tube well/0.85km^2).

The arrangement of tube well group is designed as a line square with groundwater flow direction. Since the Irrawaddy River is one of recharge source, flow direction may be most likely NW-SE. The line of tube well group arrangement has general direction of NE-SW.

<Stand-by Tube Well>

Tube well to be used for future maintenance of regular tube wells was also considered as one stand-by tube well for every ten (10) regular tube wells. These tube wells will be used for water level observation well during none operation period.

<Mounting Base and Pump Pit>

Since there are many paddy lands in the objective well fields, flood or swampy conditions shall be considered for protection of surface water contamination with adoption of mounting base and pump pit in the detailed design stage.

(2) Proposed Projects

Three detached blocks in the right bank of the Hlaing River shall be covered by safe groundwater fed systems. For the Townships of Kyeemyindaing and Seikkyi Kanaungto, one water supply system covers both Townships, because of small population and a few construction spaces for the system. Each groundwater development plan was subjected by the scheme below.

(a) Dala: Expansion of Present Groundwater Supply System
(b) Hlaingthaya: Modification of Present On-going Water Supply System
(c) Kyeemyindaing and Seikkyi Kanaungto: New Water Supply System

Under above planning concepts, following groundwater development projects were proposed. Each component has: (a) present conditions, (b) future water demand, (c) required tube well fields and construction numbers, and (d) construction period.

➢ Dala: Expansion of Present Groundwater Supply System

<Present Conditions>

Service coverage was estimated at 13% with Township population of 81,317 (service population: about 10,500capita). Distribution pipeline network covers 6 wards out of 23 wards in the Dala Township. However, many residents have been fetching water from communal faucet through water carriers.

Present tube well field was decided by the trial investigation through the test boring with water sampling and examinations. Finally, tube well field was selected at Yangon Pauk where is 11km distance far from town proper.

Three tube wells with interval spacing of 50m to 70m were constructed in March 2000. Tube well structures are uPVC diameter of 300A and 37m of installation depth. Operation rate was estimated at 2,270m^3/day (average production rate of 0.736MCM/Y) with static water level of about 0.5mbgs. Groundwater quality was examined with high EC values (1,600 micro mho).

<Future Water Demand>

Present service coverage was estimated at 13%. Daily water demands were planned at the year of 2005, 2010, 2015 and 2020. Following Table B.45 shows water demand of Dala.

Table B.45 Water Demand of Dala

Water Demand Unit		Planned Water Demand in Dala			
		2005	2010	2015	2020
Daily	m^3/day	7,841	12,994	19,495	24,515
Annual	MCM/Y	2.862	4.743	7.166	8.948

Source: Water Supply Planning of this study

<Required Tube Well Field & Construction Numbers>

Well depth of 50m with diameter of 250A and well performance of 0.526MCM/Y is proposed design for future expansion. Unit groundwater availability was estimated at 0.63MCM/Y km^2. Table B.46 shows required tube well field and numbers under above conditions.

Table B.46 Required Well Firld & Numbers for Dala

Exploitation Year & Annual Production		Water Demand (MCM/Y)			
		2005	2010	2015	2020
year	MCM/Y	2.862	4.743	7.166	8.948
Present	0.736	0.632	0.543	0.466	0.400
2005	2.230	**2.230**	1.915	1.644	1.412
2010	2.285		**2.285**	1.962	1.685
2015	3.043			**3.043**	2.613
2020	2.838				**2.838**
Well Field	16.4km^2	3.5	3.6	4.8	4.5
Tube Well	**22**	**5**	**5**	**6**	**6**
Standby	**2**	**1**	**1**	**0**	**0**

Note: Deterioration rate was assumed at mere 3% annually.

Upon completion of tube well construction, Figure B.16 shows demand and supply values with full operation of tube well facilities.

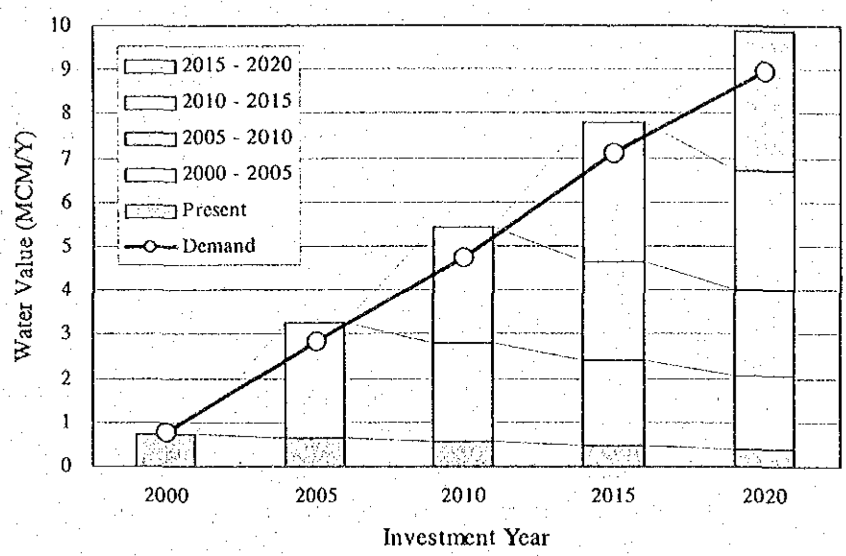


Figure B.16 Demand And Supply Value in Dala

<Construction Period>

The intake pipeline and intake reservoir shall be constructed after confirmation of groundwater quality. For tube well construction of six tube wells in every medium-terms, construction period was estimated at 156 days. Annual working day was assumed at 240days. Therefore, 0.65years per 5-years investment (13%) was requisite to complete groundwater source development for Dala project.

➢ Hlaingthaya: Modification of Present On-going Water Supply System

The water supply plan for Hlaingthaya Township is selected for pre-feasibility study. Therefore, well field with tube well arrangement was studied more deeper than master plan level.

<Present Conditions>

Water supply system in Hlaingthaya is under construction. In June 2001, four tube wells were constructed at well field of Thanbayagone village in Yangon District. For the selection of well field, water quality examinations using several test wells were conducted, but no records available at present.

Tube well field is located at 15km far from town proper. Tube well spacing is estimated at 60m to 100m. Tube well structures are diameter of 250A, depth of 70m with materials of uPVC pipes. Static water level in September 2000 was very shallow about 0.5mbgs.

<Future Water Demand>

Since groundwater shall be utilized as an intermediation source until completion of sufficient surface water supply system, tube wells shall be developed until the year of 2015 according to the Hlaing River development plan. After the year 2015, groundwater source shall be used on condition that of the year 2015.

Daily groundwater demands were planned at the year of 2005, 2010 and 2015. After the year 2015, remaining water demand should be covered by the surface water supply coming from the main system through the Shwepyitha Bridge crossing.

Following Table B.47 shows municipal and industrial water demand of Hlaing-thaya until the year of 2015 and possible groundwater source at the year of 2020.

Table B.47 Water Demand of Hlaingthaya

Study Case & Water Demand Unit			Planned Water Demand in Hlaingthaya			
			2005	2010	2015	2020
Municipal	Daily	m³/day	11,156	43,296	57,469	82,469
Industrial	Daily	m³/day	25,616	32,452	38,566	
Total	Daily	m³/day	34,772	75,748	96,035	82,469
	Annual	MCM/Y	12.692	27.648	35.053	30.101

Source: Water Supply Planning of this study

<Required Tube Well Field & Construction Numbers>

Tube well depth was assumed at 70m with due reference of existing tube wells. Other conditions such as well diameter, single tube well performance, annual deterioration rate and unit groundwater availability are the same design as previous of this section. Table B.48 shows required area for tube well field and construction numbers under above conditions.

Table B.48 Required Well Firld & Numbers for Hlaingthaya

	Exploitation Year & Annual Production		Water Demand (MCM/Y)			
			2005	2010	2015	2020
Municipal & Industrial Water Development	year	MCM/Y	12.692	27.648	35.053	30.101
	Present	0.000	0.000	0.000	0.000	0.000
	2005	12.692	**12.692**	10.899	9.359	8.037
	2010	16.832		**16.832**	14.383	12.351
	2015	11.301			**11.301**	9.713
	2020	0.000				**0.000**
	Well Field	64.5km²	20.1	26.5	17.9	0.0
	Tube Well	**79**	**25** *	**32**	**22**	**0**
	Standby	**10**	**3**	**4**	**3**	**0**

Remarks: Four number of tube wells was reduced from requirement at the year 2005.
Note: Deterioration rate and standby tube well were considered as same bases.

Upon completion of tube well construction for municipal and industrial water supply, Figure B.17 shows demand and supply values with full operation of tube well facilities.

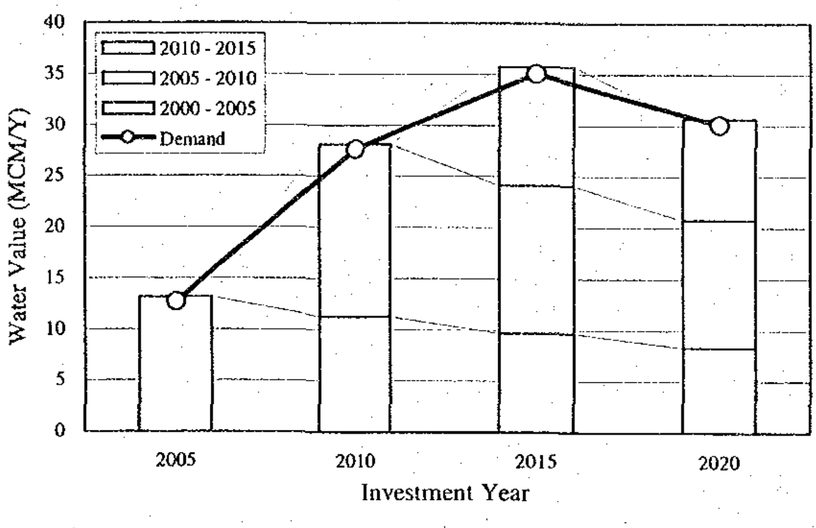
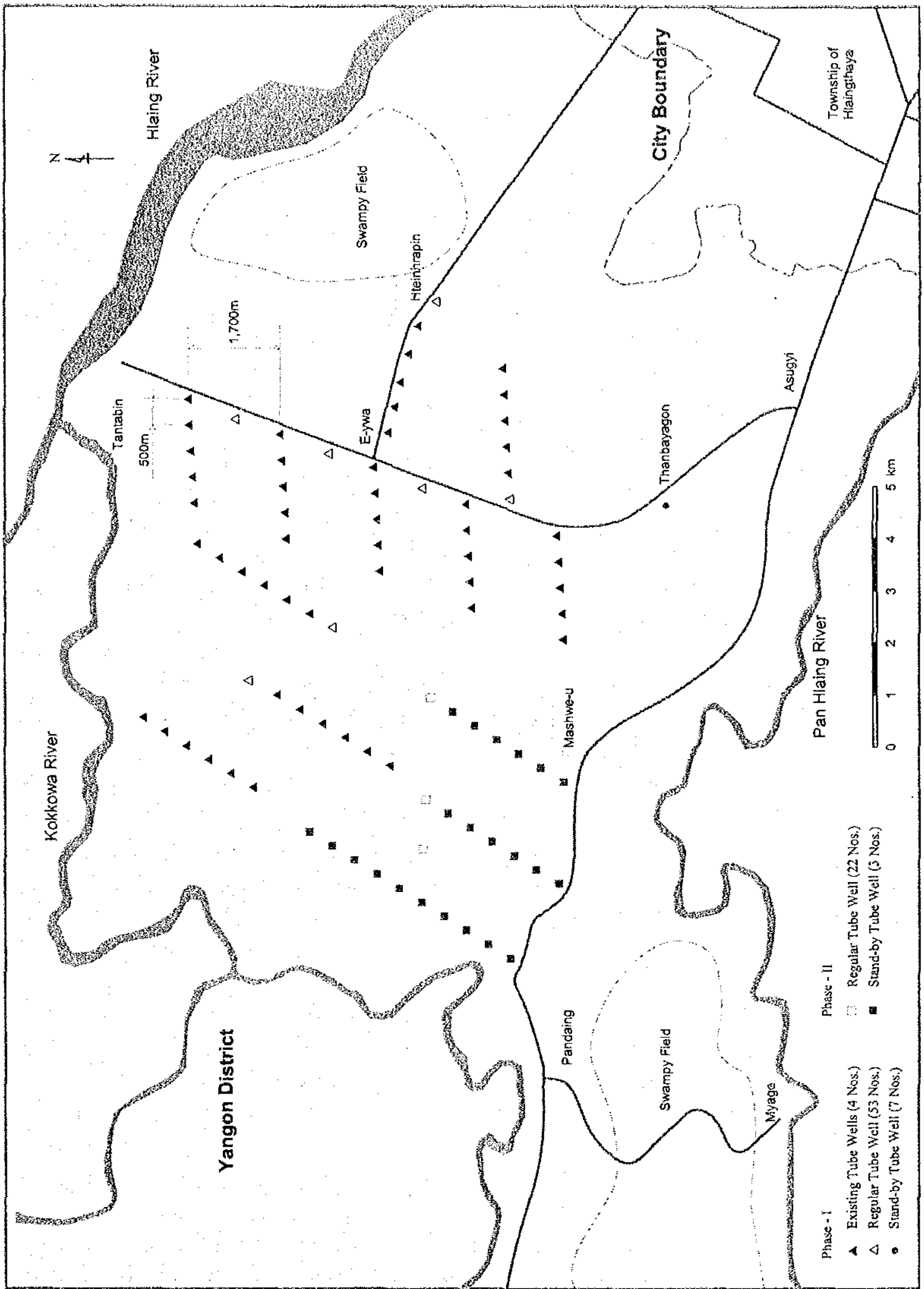


Figure B.17 Demand and Supply Value in Hlaingthaya

Tube well arrangement in the Irrawaddy well field, studied in Chapter 2.2.4 of the design concepts, was designed by field survey on January 2002. Figure B.18 shows location of regular and stand-by tube wells with construction phasing (Phase-I: until the year of 2010 and Phase-II: from the year of 2010 to the year of 2020).



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

FIG B.18

TUBE WELL LOCATION MAP FOR HLAINGTHAYA PROJECT

<Construction Period>

The intake pipeline and intake reservoir shall be constructed after confirmation of groundwater quality, especially parameters of Fe, Mn and Cl.

For municipal and industrial water supply, construction periods of 28, 36 and 25 tube wells in every medium-terms were estimated at the days of 840, 1,080 and 750, respectively. Therefore, the years of 3.5, 4.5 and 3.1 per 5-years investment (70%, 90% and 62%) were requisite to complete groundwater development for Hlaingthaya project.

- Kyeemyindaing and Seikkyi Kanaungto: New Water Supply System

<Present Conditions>

Peoples in the Township of Kyeemyindaing are living along riverside of about 200m width with narrow and muddy walkway. There is no car road. Population density seems to be very high in area where belongs the river coast. Back of populated area is extensive paddy land. Between populated area and paddy land, several dirty ponds are dotted for their domestic water use.

The YCDC supplies the water by boat three or four times in a day with volume of 100m^3 during dry season. Majority of citizen's drinking water sources are un-safe pond in rainy season or un-safe driven wells in dry season.

On the other hand, Seikkyi Kanaungto is much sanitary place. Peoples are living on the sands in the Pan Hlaing River. Residential area is concentrated in the central sands with paved single road (but no car available). There is a boat port in the southeastern end. There were water supply facilities using tube wells. However, such facilities were not used because of un-potable quality.

There are clean ponds in this Township, probably because of the sands. Storage tanks in the compound of Township office exist for boat water supply. Availability of land acquisition is much easier than Kyeemyindaing. Additionally, Dala well field is located at the opposite bank of the Pan Hlaing River.

On these conditions, well field was planned at upstream area (10km from populated area) of the Pan Hlaing River (Seikkyi Kanaungto). However, groundwater quality with parameter of Cl should be examined and confirmed. Therefore, water supply system was planned to operate from the year 2010.

<Future Water Demand>

Since groundwater investigation is necessary to conduct first, daily water demands were planned at the year of 2010, 2015 and 2020. Following Table B.49 shows water demand of Kyeemyindaing and Seikkyi Kanaungto.

Table B.49 Water Demand of Kyeemyindaing & Seikkyi Kanaungto

Water Demand Unit			Planned Water Demand in Kyeemyindaing & Seikkyi Kanaungto		
			2010	2015	2020
Kyeemyindaing	Daily	m^3/day	9,955	14,371	17,293
Seikkyi Kanaungto	Daily	m^3/day	4,494	5,754	6,352
Total	Daily	m^3/day	14,449	20,125	23,645
	Annual	MCM/Y	5.274	7.346	8.630

Source: Water Supply Planning of this study

<Required Tube Well Field & Construction Numbers>

All tube well conditions are the same as Dala project. Table B.50 shows required tube well field and numbers under above conditions.

Table B.50 Required Well Firld & Numbers for Seikkyi Kanaungto

Exploitation Year & Annual Production		Water Demand (MCM/Y)		
		2010	2015	2020
Year	MCM/Y	5.274	7.346	8.630
2010	5.274	**5.274**	4.529	3.889
2015	2.817		**2.817**	2.419
2020	2.332			**2.322**
Well Field	16.1km^2	8.4	4.5	3.7
Tube Well	**21**	**10**	**6**	**5**
Standby	**2**	**1**	**1**	**0**

Note: Deterioration rate was assumed at mere 3% annually. Standby tube well shall be considered one for every 10 tube wells.

Upon completion of tube well construction, Figure B.19 shows demand and supply values with full utilization of tube well facilities.

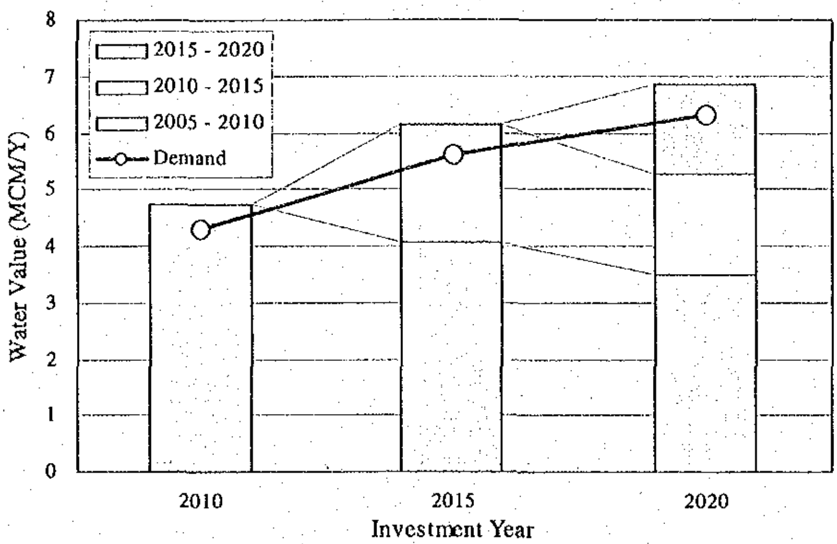


Figure B.19 Demand and Supply Value in Kyeemyindaing & Seikkyi Kanaungto

<Construction Period>

The pipeline of transmission and other facilities shall be constructed after confirmation of groundwater quality at selected land of this plan. For tube well construction of 11, 7 and 5 tube wells in every medium-terms, construction periods were estimated at 286, 182 and 130 days. Therefore, 1.19, 0.76 and 0.54 years per 5-years investment (24%, 15% and 11%) were requisite to complete groundwater source development for Kyeemyindaing and Seikkyi Kanaungto project.

(3) Construction Plan

Finally, prioritization and implementation ability of these proposed projects were evaluated. Following Table B.51 shows the rate of drilling crew operation with number of tube well construction. The total operation rate exceeds 100% during the years of 2005 and 2010. In this situation, advance arrangement of tube well construction is necessary.

Table B.51 Rate of Drilling Crew Operation

Township	Utility	2000-2005	2005-2010	2010-2015	2015-2020
Dala	Municipal	13% 6 wells	13% 6 wells	13% 6 wells	13% 6 wells
Hlaingthaya	Municipal + Industrial	70% 28 wells	90% 36 wells	62% 25 wells	0% 0 well
Kyeemyindaing & Seikkyi Kanaungto	Municipal	0% 0 well	24% 9 wells	15% 5 wells	11% 3 wells
Total	Municipal + Industrial	83% 34 wells	**127%** **51 wells**	90% 38 wells	24% 11 wells

Note: Annual working days were estimated at 240.

In Dala Township, the water supply system exists and is utilized since the year of 2001. Even many people access to this system with lower service level, most of residences can use safe water. For the project in Kyeemyindaing and Seikkyi Kanaungto, groundwater survey was not performed yet. With due consideration of poor access to the well field and difficulty of groundwater quality examination, schedule of design stage for this water supply system can not be fixed.

On the other hand, the Hlaingthaya project is ongoing. Most effective transmission pipeline rout from intake reservoir to service reservoir was different design from present (referred to Figure B.18). Therefore, first implementation priority as Phase-I project hall be given to the Hlaingthaya water supply system.

Table B.52 shows the said allocation result. Another well drilling team is necessary to cope with Hlaingthaya project in 2005 to 2010.

Table B.52 Allocation of Satellite Township Projects

Township	Utility	2000-2005	2005-2010	2010-2015	2015-2020
Dala	Municipal	0% 0 well	0% 0 well	33% 15 wells	39% 18 wells
Hlaingthaya	Municipal + Industrial	0% 0 wells	148% 59 wells	25% 10 wells	23% 0 well
Kyeemyindaing & Seikkyi Kanaungto	Municipal	0% 0 well	0% 0 well	33% 15 wells	13% 6 wells
Total	Municipal + Industrial	0% 0 wells	148% 59 wells	91% 40 wells	49% 21 wells

Note: Annual working days were estimated at 240.

Schedule of groundwater development plans are depending on the progress of surface water development. It is notified that monitoring and review activities are very important to accurate this master plan with accumulation of ceaseless study, observation and examination.

3 GROUNDWATER MANAGEMENT

The groundwater management shall be considered in a broad sense and content extending to both environmental preservation and human needs. Since any human activities in an area with high population density have disturbed environmental equilibrium, it is essentially recognized that how much human beings can permit and survive the aggravate aspects of related environment.

The environmental aspects and human needs as a similar standing act for white papers have not been consolidated for the Yangon City at present. Therefore, only general trends of groundwater management for the starting point can be described in this study. The future needs and action plans for groundwater management were considered and proposed as shown in Table B.53 those are compositions of this section.

Table B.53 Contents of Groundwater Management

Category		Environment	Human Needs
Groundwater Preservation	Monitoring	O	O
	Regulation	O	
Groundwater Observation	Water Quality and Water Level	O	O
	Land Subsidence	O	
Sustainability of Tube Well Facilities	Management		O
	Improvement		O

3.1 GROUNDWATER PRESERVATION

The value of groundwater availability to be extracted artificially is estimated within a value to sustain the groundwater storage. The variate of groundwater storage (delta value related to groundwater level lowering) is standing on the balance of total inflow and outflow.

Under the natural groundwater cycle, outflow value is transformed in alignment with inflow value (greater part from rainfall). However, the value of artificial outflow (groundwater exploitation) does not correspond to the value of natural inflow. Hence the activities for groundwater preservation (i.e. forest conservancy, etc.) in the recharge area must be maintained certainly for the sustainability of groundwater.

Presently, the YCDC roughly knows how much groundwater extracted and how to utilize groundwater by the users in the city through sector monitoring conducted in June 2001. This groundwater study was conducted assumption basis, which were empirical values and statistical information. Therefore, those assumptions cannot be verified and modified at present.

In this regard, any items assuming in this study shall be investigated, observed, researched or measured by taking of statistical monitoring for future review and re-study. Additionally, the system for groundwater permits or rights shall be set up with friendly coordination to line agencies, since the YCDC has responsibility of groundwater management.

3.1.1 Periodical Monitoring and Updating

Many of the water supply systems or facilities constructed earlier in the city have operated in a limited way because of insufficient monitoring and technical support in the post-construction, aside from the problems in promotion of self-reliance and management of the township offices.

This Chapter seeks to recommend a focused, practical and viable approach to strengthen sector and project monitoring. The development of a coordinated monitoring system is one of the key components of an effective management system. Following are proposed monitoring systems, which are related to the sector of water supply and sanitation, and to the projects for new construction, rehabilitation and expansion of water supply systems.

(1) Sector Monitoring

Sector monitoring refers to the overall groundwater situations. One may readily use a demand-supply model for sector monitoring in the city.
Demand would be indicated by such indicators as gaps in coverage and standards for water consumption. Supply would be indicated by the groundwater and surface water resources situation, actual coverage of existing facilities, output volume, types and condition of facilities, by the available funding, and by water associations organized to undertake sector activities.

The monitoring system must support a well-defined and accepted sector development process-model. There are four general aspects of sector monitoring which will be addressed:

➢ Establishing the Database

This involves identifying the types, level, and form of the information to be extracted regarding the performance of the sector's service development, service delivery, and service maintenance systems.

- Data Collection and Transmittal System

  This defines the methods and assigns responsibilities for the recording and relaying of the data from source to the concerned recipients, from raw data to consolidations and reports at the various levels of the hierarchy of sector management.

- Data Analysis

  This prescribes how and by whom the data will be processed, and the purpose of the outputs of the various analysis and reports. The purpose or uses of the data will determine when or how frequently a report will be generated, as well as the parties who should receive the report.

- Response System

  This defines the responsibility, authority and discretion of the recipients of the data flow to take actions, make decisions, alter plans, or take such measures are appropriate given the performances indicated by the data. This system feeds into and is essential to the management and regulatory structures of the sector.

Sector performance deficiencies demand that serious thought be given to innovations to reduce costs in achieving the sector plan. With the monitoring system, the sector should be able to take an objective view of the way to meet current strategies. A sector monitoring system should be flexible to support planning and research studies on such specific policy and operational issues.

In putting together a relevant sector monitoring system, the following should be seriously looked into:

- It should reinforce the linkage between water, sanitation and health. This implies that coverage should be measured for availability of both water and sanitation for a household. Thus, a household can be categorized as having both water and sanitation, water only, sanitation only or none of either. At later stages, health practices can be included in the monitoring.

- It should be reliable and involve the beneficiaries. This mechanism could provide the data quality control, which is missing in existing systems. Distortion of information may occur when implementers are the monitors. The ward will be the basic data capture level.

➢ Monitoring will succeed only with interagency support, particularly in the initial stages. It should be accepted by all sector agencies in the city. A unified set of figures and indicators will greatly help in planning.

➢ It should be practical and implemental. It should start with the current monitoring capacity situation and move up with a clear vision of what the monitoring system should be. This implies phasing/gradual expansion and strengthening of the system/training of staff.

➢ The system should be followed through with effective feedback. It should develop creative ways of providing feedback to the field. The current way in which data is processed, is by consolidation. In the course of consolidation, opportunities for specific feedback useful to project implementers on performance are lost.

It would be useful to have a series of workshops among the different levels of the sector's management structure, to achieve the following:

- Training on project monitoring and data use in the water sector.
- After the database is established, a team will draft the Management Information System (MIS), which will be an input to the next series for workshops.
- Review of MIS draft, revisions, and commitments to test.
- Sharing/reviewing of experiences with MIS draft system. Recommendation on adjustments to MIS for 2nd or next field-testing period. Final recommendations to be incorporated into the Final Draft of MIS system by the MIS Team.
- Review of Final Draft System to be presented by MIS Team of adoption.

Regarding sector development indicators, some important indicators will be more difficult to collect than the others because the sector is not ready to gather them. The YCDC will group indicators into phases based on availability of data with which such information can be collected with improved systems.

A review of the objectives set for the sector almost exclusively shows a focus on coverage. It is important to get sector objectives stated beyond coverage terms in order to encourage use of additional indicators.

Based on past experience, requiring too much information leads to start-up difficulties.

A three-phase build-up meeting sector requirements is outlined in the following sections:

- Phase-I Indicators
  - Access to both adequate water and sanitation
  - Sources of capital development funds
  - Water availability and water quality maps
  - Unit cost (per capita or per facility)
- Phase-II Indicators
  - Household hygiene habits and practices
  - Existence of ward spot maps and facilities ledger cards
  - Existence of O&M arrangements
  - Current costs to households and willingness to pay for improved service
- Phase-III Indicators
  - O&M Costs
  - Financial efficiency and stability indicators
  - Institutional development indicators
  - Low-income groups benefiting from improvements

The YCDC has issued a Resolution in 1993 providing a practical definition of terms for planning and monitoring. The definitions were arrived at after exhaustive discussions and consensus with the implementing agencies.

Monitoring is best left to parties not directly involved in delivery of the services. The best monitors are the community members themselves since accurate monitoring report is in their best interest. At the data capture level, Township office with midwives and volunteers, is in the best position to take the lead in the ward data gathering.

Computerization of the system can come at later stages. This should be gradually phased in as the sector agencies strengthen their monitoring mode. This will also discourage a ground swell of requests for computer hardware. Computer facilities are available in the city and should be employed for the sector planning. A new sector database program should be designed on that time.

(2) Project Monitoring

Sector monitoring refers to the overall water and sanitation situation in the city, on the other hand, project-monitoring looks at progress of specific activities or projects. Indicators would thus include; disbursements, percent completion, cost over-runs/under-runs, etc. At the city level, project monitoring shall include projects classified under any of the following:

- Foreign, nationally and city-funded projects which are implemented or located in two or several townships in the city or implemented or located in the city;
- Other projects implemented and managed at the city level with funding generated from city sources.

Project Monitoring Committees (PMCs) at the city and township levels are to be tasked with the monitoring of YCDC and local projects funded from national and local government funds, and composed of representatives from different organization levels.

From these representatives, the YCDC selects the chairman and the others as members. The Planning Division (PD) can be delegated to serve as the secretariat and the PMC manages with the assistance of the non-government organizations (NGOs) in the monitoring and validation of project implementation.

The specific roles and responsibilities of the various units in the implementation of the monitoring system are as follows:

- The Project Monitoring Committee (PMC)
  - Provides the list and schedule of all projects to be monitored to the NGOs involved in monitoring;
  - Collects and processes reports of implementers;
  - Pinpoints problems and verifies information to be submitted for analysis and action of the development council;
  - Provides feedback on the remedial actions of the development council and follows-up their implementation;
  - Prepares and disseminates periodic project monitoring report on the status of project implementation; and
  - Elevates to higher-level bodies problems/issues that are not resolved at their level.
- The Secretariat of Project Monitoring Committee (PMC)
  - Prepares the monitoring program to be undertaken by the PMC during any given fiscal year, which will include, among others, the lists of projects and schedule of implementation based on submission of implementing agencies;
  - Provides chief executives with information on the projects to be monitored

by the local PMC's;

- Facilitates inter-agency, inter-governmental and field headquarters coordination whenever necessary.

> The Project Implementers

- Submit periodic reports to the monitoring committee on the status of project implementation base on suggested reporting forms;
- Provide authorized monitors assistance in getting access to more detailed information on project implementation (e.g. detailed work program);
- Submit to next higher level office of line agency reports on status of implementation;
- Implement/institute remedial measures on problems/issues identified as suggested by the development council.

The following is the process model-flow of project monitoring.

- The PMC secretariat provides the NGOs with the monitoring plan, containing information on projects to be implemented at the city level;
- PMC prepares its monitoring program for the calendar year;
- Project implementers undertake projects, prepare and submit status reports on project implementation to the PMC;
- NGOs submit project exception reports to the PMC, with copy furnished the project implementers;
- PMC assesses reports of implementers and NGOs and conducts project visits of projects identified in the monitoring work program;
- PMC processes reports of various implementers and provides the city development council with a consolidated report on status of project implementation in the city;
- PMC evaluates problems, recommends solutions during its regular or special meetings, and refers same to the YCDC for appropriate action;
- YCDC assesses reports and takes proper action (problem solving, referral to appropriate agencies/council);
- Implementers take remedial action on problems/issues encountered in project implementation;
- PMC provides feedback to concerned implementers and other concerned agencies and follow-up implementation of remedial measures; and
- PMC forwards consolidated status report on project implementation in the city to the YCDC.

The PMC determines the schedules for the submission of reports. Reports are submitted to the PMC who will forward the consolidated reports to the YCDC. Submission of the consolidated report from the PMC to the YCDC is usually undertaken on a quarterly basis. The PMC furnishes the City Governor with a copy of the reports for his reference and action.

(3) Evaluation of Plan Implementation and Updating

This Master Plan should be updated at least every five years, most likely at the year from 2005. This will be the responsibility of the PMC in close coordination with the PD. Based on the sector monitoring reports, the PD will review the progress of the sector compared with objectives and the efficiency with which these objectives were achieved. This will be followed by a reformulation of objectives, strategies, new policies and policy revisions and an updated sector investment program.

To initiate the implementation of this sector monitoring system, the Phase-I Indicators shall be used. Formats for the groundwater sources have been drafted for this purpose (see Data B.3). Specifically, the information to be collected are as follows:

- Access to both adequate water and sanitation as a measure of demand:
- Water and sanitation associations organized:
- Capital development costs:
- Sources of capital development funds:
- Water availability and water quality maps: These maps should be continually updated based on field reports on water quality and quantity as they are received from operations reports studies. Areas where, for example, salinity and/or mineral contents are increasing should be indicated. Areas suitable for tube wells and for possible other sources can be indicated (especially for area in the right bank of the Hlaing River).
- At the conclusion of every project, the monitoring specialist prepares a report on actual unit costs incurred. This would include, for example, the cost of drilling for tube wells per meter in depth; the cost of pipeline per linear meter, etc.

For every reporting period, the township sector liaison gathers all the ward level data including those reports of the township health officer (and sanitary inspectors). A township sector report will be thus prepared. Further refinements of this report may be needed in view of future development initiated at the city level.

Based on these reports, the PMC will draft a consolidated report on the performance of the sector during the period including the opportunities and constraints met and a set of recommendations for policy revision. Townships, which have made outstanding progress and associations, which have introduced creative innovations in their operations, would be cited.

Annual reviews shall be organized to analyze not only the attainment on the physical project targets, but also more significantly, whether the vision is being attained. These reviews could also provide the opportunity to sharpen or revise the vision and the mission statement and distill lessons learned from the implementation experiences.

3.1.2 Groundwater Regulation

Basically, the evaluation results of groundwater extraction were considered using a summation of the data and/or information provided from each of the concerned government agencies and/or the field investigation. As mentioned-above, sector monitoring should be conducted at least every five-year intervals. The trends of water rights grants to be provided by the YCDC (the Ministry of Construction would be upper level of the YCDC) will be very helpful to represent the current status of water resources development.

The groundwater and surface water regulation should be established for future environmental preservation. Therefore, the YCDC must know the water source limitation and potential. The system of water rights registration with sectorial groundwater utilization is proposed below with future review.

(1) Initial Grant Amount and Registration Parameters

Water rights or permits should be granted by the YCDC before applicants utilize a water source with their own facilities. The form of water rights is only one information source to cover the state of the water resources in the intermediate period of sector monitoring. Each application parameter should be evaluated in terms of its propriety with the pooled available water sources and their standard criteria, which was subjected by the water source usage, as shown in Table B.54 below.

Table B.54 Typical Standard Criteria for Water Rights Grant

Sub-sector	Typical Standard Criterion for Water Rights Grant
Domestic	Planned population served (capita) and unit water consumption (lpcd)
Commercial	Based on the clearance for processing water permit to be issued by the YCDC with type of business
Industrial	
Recreation	Planned area; golf course, Planned guest numbers; hotel & park

Remarks: There is no other sector in the city, such as irrigation, livestock, fishery and hydropower.

The registration parameters of the water rights, which include location, ownership, permit date, type of source and usage were very helpful to understand the present condition of groundwater usage. Brief summaries are follows.

- Type of Source
  - The types of water source are categorized into surface water and/or groundwater.
  - For surface water, planned location of river/creek/reservoir and structures of intake facilities should be included.
  - For groundwater, there are several types; namely, tube wells, dug and driven wells, infiltration galleries and spring with its intake structures.

- Water Usage
  - All usage for water rights application is put into the eight groups: domestic, commercial, industrial, irrigation, livestock, recreation, fishery and hydropower.
  - Parameters of service level for domestic water supply, business type for commercial and industrial, cropping type and cultivated land area for irrigation, type of animals and its numbers for livestock and fishery, and area of golf course and guest numbers of hotel/park for recreation should also be informed.
  - Approximate peak usage of water in a day, a week, a month, a season or an annual, and extraction discharge will be included.

(2) Monitoring and Re-permits

In the past experiences, it makes most problematic discrepancies that applicants have enrolled the water permits without any water utilization and/or applicants did not inform abandoned utilities. Consequently, water rights have been summed up without any verification. Following are normal procedures after application of water permits.

- Monitoring of Water Utilization and Extraction Amount
  - When the beneficiaries apply their permits of water rights, water intake facilities is not constructed because application should be cleared at planning stage level.
  - Upon completion of water source development by the applicants, structures and dimensions of water intake facilities should be informed within a year after registration. Unless otherwise, water rights will be automatically deleted and the YCDC informs it to the applicants.
  - Based on such information from the applicants, the YCDC should confirm their facilities and production.

- Re-permits of Registered Water Rights
  - To avoid remaining registration of abandoned water intake facilities, the applicants should inform and register their permits every ten years.
  - If there is no re-application, the YCDC should confirm their expanded utilization or abandoned facilities.

3.2 GROUNDWATER OBSERVATION

This study has concluded several problems and issues of groundwater situations in and around the city. Current conditions of groundwater quality are sorted into high Cl and high Fe/Mn. High chloride ion is originated from saline water intrusion and brackish water. High mineral contents in groundwater are considered as a dominant cause of long osculation with rich rocks. Arsenic (As) contamination into the groundwater was reported in rural area of Bangladesh. According to the Japanese NGO in Bagan, there is a possibility of arsenic poisoning in future if the Irrawaddy delta deposits still have rich contents and groundwater from the Irrawaddy delta is developed for a long term.

In the study on groundwater potential, groundwater development availability (balance of potential and extraction) was estimated by township wise. Three townships were evaluated as negative balance even based on the formed assumptions.

There are two schemes on the groundwater development plan. These are tube well rehabilitation for the main system and new tube well construction for satellite systems. In the rehabilitation plan, existing tube wells were classified into regular, stand-by and abandon after development of additional surface water. On the other hand, groundwater investigation should be confirmed in terms of potable groundwater quality and potential for new satellite water supply systems.

On these conditions, the YCDC should monitor following items to be covered expecting areas in terms of groundwater quality/quantity and environmental influence (land subsidence).

3.2.1 Water Quality and Water Level

The purpose of groundwater monitoring is to observe the seasonal variation and annual fluctuation of under ground situations. At present, there are many unknown factors of groundwater conditions. Therefore, the groundwater study results should be verified by actual observation results.

Necessary observation items are groundwater quality and water level. Since the YCDC have many abandoned tube wells in past and future, nominated YCDC tube wells should be modified for observation wells.

(1) Water Quality

Some interrogative matters have to be deeply studied, confirmed and concluded which are gapes between previous reports and present over observations. Accordingly, restricted parameters of EC, Cl, Fe, Mn, Ca and Mg depending on the groundwater characteristics affecting from the influential geological background shall be examined. Basically, parameters of EC and Cl shall be examined for saline and brackish water, while others shall be tested in influential areas of Irrawaddy Series.
In September 2001, the YCDC has conducted EC measurement at YCDC tube wells. Out of 217 tube wells, groundwater samples taking from 167 tube wells were examined on site (referred to Data B.7).

With due consideration of geological background and EC measurement results, twelve observation tube wells were selected for periodical examination. Following Table B.55 shows pointed observation tube wells for water quality with remarkable parameters.

Table B.55 Tube Wells for Water Quality Observation

Township	Tube Well ID & Depth		Remarkable Parameters
Botataung	No. 04	37m	EC & Cl
Seikan Port	No. 01	29m	
Dagon Myothit South	19/04	98m	EC, Fe, Mn & Cl (+As: New Well Field)
Dala	No. 03	37m	
	New Well Field	50m	
Hlaingthaya	09/07	61m	
	New Well Field	70m	
Lanmadaw	No. 04	116m	
Seikkyi Kanaungto	New Well Field	50m	
Thaketa	Tha/16	26m	
Insein	No. 01	64m	EC, pH, Fe & Mn
North Okkalapa	No. 08	125m	

Note: Remarkable parameters were selected by geological background and EC measurement.

Sampling timings are twice annually (April as dry and October as rainy seasons). Water quality parameters of EC and pH are proposed to examine on site and for Fe, Mn, Cl and As are required pre-treatment. It is noted that water samples should be collected using submersible pump with 6 hours or longer operation.

(2) Water Level

Piezometric (groundwater level) contour map was prepared in 1956 and early 1990's. However, since every aquifers have own water levels, contour map for expected aquifer is very difficult to prepare. In the viewpoint of water level fluctuation annually, fixed-point-observation is most realistic method. Additionally, water level is draw down, with being influenced by the surroundings, in an area where groundwater extraction exceeds its potential.

Areas with an apprehensive of water level lowering fall on Townships of Botataung, Dagon Myothit South and Lanmadaw based on the groundwater balancing study. Also large groundwater developments were required for satellite township supply in well fields at Dala and Hlaingthaya, locations of which are proximity of city boundary. Finally, above six Townships were nominated for sites of water level observation wells.

Water levels should be sounded monthly with altitudes at measuring point and atmospheric air pressure on each measurement time. Better locations for water level observation is located inland area. If possible, distance from existing tube well will be longer than 500m to avoid well interference. Table B.56 shown pointed observation tube wells for water level.

Table B.56 Tube Wells for Water Level Observation

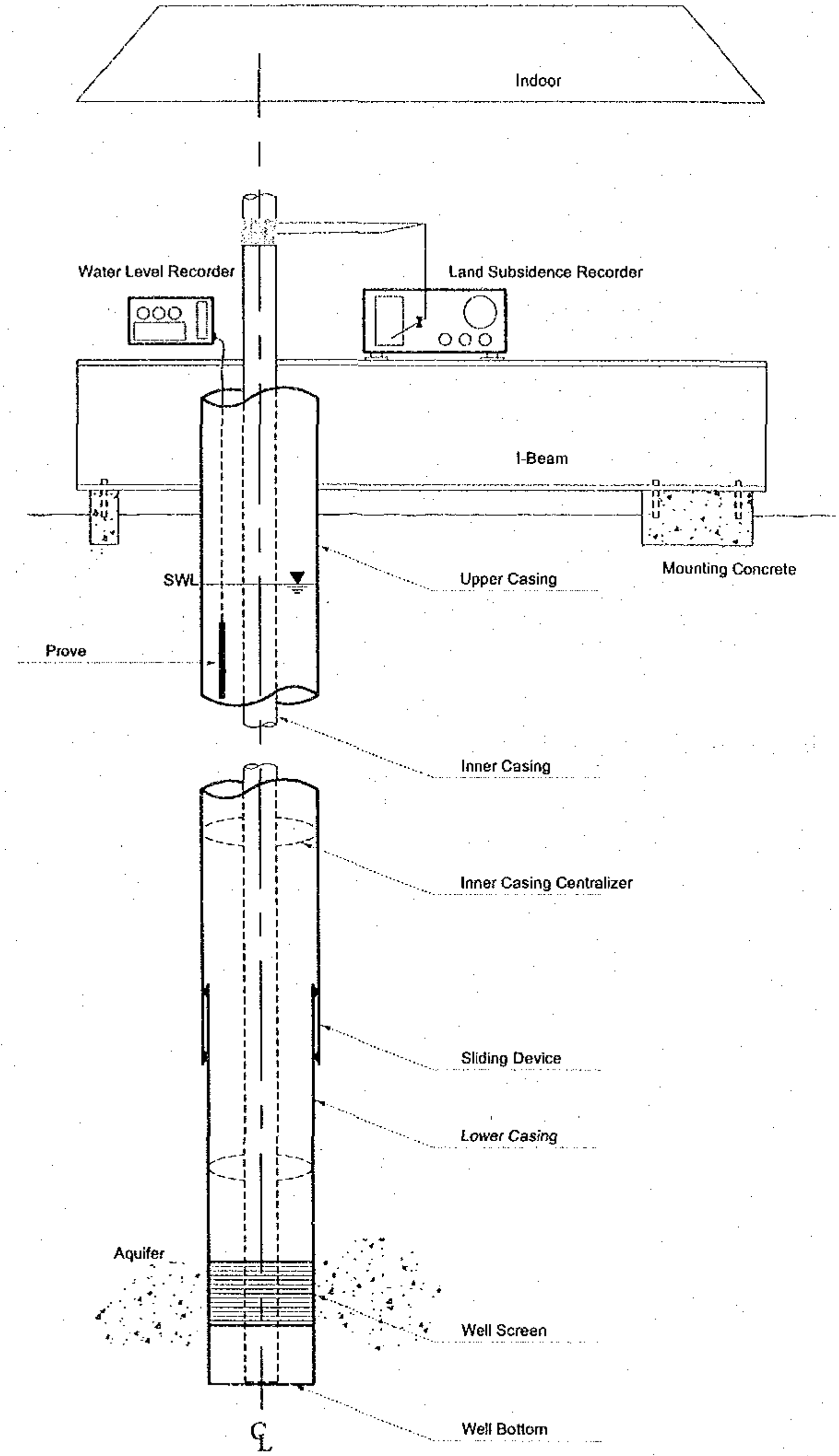
Township	Tube Well ID & Depth		Status
Botataung	No. 04	37m	Existing Tube Wells
Dagon Myothit South	19/04	98m	
Lanmadaw	No. 01	40m	
Dala	New	50m	Selected from Stand-by Tube Well
Hlaingthaya		70m	

Note: Two tube wells for water level observation should be constructed as stand-by tube wells.

3.2.2 Land Subsidence

Land subsidence was not reported and not observed yet. Typical structures of observation well to measure land subsidence with water level in expected aquifer is shown in Figure B.20.

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. Additionally, groundwater extraction amount will be reduced by the settlement of existing tube wells when surface water development is completed.



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG B.20
	TYPICAL OBSERVATION WELL OF LAND SUBSIDENCE	

In this regard, delta plain is one of possible area of land subsidence when large amount of groundwater is developed. Since three projects of satellite township water supply were required for future implementation, target areas for the observation well of land subsidence were selected at Townships of Dala and Hlaingthaya.

Groundwater development potential was assumed at 0.526MCM/Ykm^2 by the balancing study with formed conditions of well fields. Since land subsidence will be occurred extending to the great-sphere, location and number of observation well should be decided with due consideration of future expansion plan for the well fields.

For future evaluation of actual groundwater potential, observation well should be set forth in every 4km to 5km intervals. On the assumption as present conditions, number of observation well was planned one for development value of every 10MCM/Y (19km^2 or 4.4km interval). Table B.57 shows proposed well sites for land subsidence observation.

Table B.57 Proposed Sites of Land Subsidence Observation

Township	Proposed Site	Well Structures with Proposed Well Number
Dala	New Well Fields	100A x 150A x 50m x 1well
Hlaingthaya		100A x 150A x 70m x 3wells

Note: Observation well numbers were assumed by one well per every development value of 10MCM/Y.

3.3 SUSTAINABILITY OF TUBE WELL FACILITIES

The YCDC has to manage the tube well facilities precisely. Facility identifications in the city have been changing every moment by moment, which are tube well number (addition/abandonment), performance (deteriorated/rehabilitated), pumping rate, water quality, etc. These factors are subject to restrictions of natural and/or man-made conditions.

For the proper management of tube well facilities by the YCDC, facility records from nativity to vanish should be booked from now on. Following are proposed recording items and systems with methodologies of evaluation. Additionally, possible action plan for water quality improvement of existing tube wells was suggested on conditions of current situation.

3.3.1 Management of Tube Well Facilities

Construction records are very important to review and evaluate tube well performance. Geological background and groundwater conditions should be recorded using items of concrete measure as shown in Table B.58. For future reviewing, completion records should be formatted and detailed records should be attached to site book. Completion records were temporally formatted for the reference materials as shown in Figure B.21.

Table B.58 Typical Items for Completion Records

	Category	Contents
Comparison	Geological Column	Lithofaces & Drillers Log
	Geophysical Log	Resistivity & Spontaneous Potential
	Drilling Log	Penetration Log
	Well Structures	Borehole, Placement & Well Strings
Construction	Equipment	Rig, Mud Pump, Logging Device, Development Device & Pumping Device
	Schedule	Mobilization, Drilling (Pilot & Reaming), Logging, Casing Installation with Placement, Well Development, Pumping Test, Water Sampling & Demobilization
Test	Pumping Test	Step Draw Down with Sand Contents, Time Draw Down with Interference Value & Recovery
	Water Quality	EC, pH, Fe, Mn, Cl, As, etc.

Note: Completion records should be gathered every tube wells.

Functions of water well structures are; (1) to separate groundwater from soil at expected underground depth and (2) to retain the housing space for installation of pumping equipment below groundwater level. Well casing and well screen with gravel (filtration materials) have to be designed correctly to perform above functioning.

Well performance under operation period will be affected by groundwater balancing (water level lowering), increasing of well loss (deterioration), sand pumping (screen damaged), none availability of pump installation (casing collapse), etc. Among these aspects, most serious problem may be deterioration on a single well base. The reasons of this phenomenon are divided into physical and chemical factors.

Physical deterioration means clogging the filtration materials by fine particles coming from soil. This is why filtration system with grain size and thickness was not designed precisely against soil grain size at expected aquifer and pumping rate (inflow velocity). Well screen does not have any functioning for separating groundwater from soil. It is only for stabilization of filtration materials. Groundwater to be pumped up rather has a few sands (but not exceed 50mg/l) than no sand contents during operation because of better clogging level to the porous spaces.

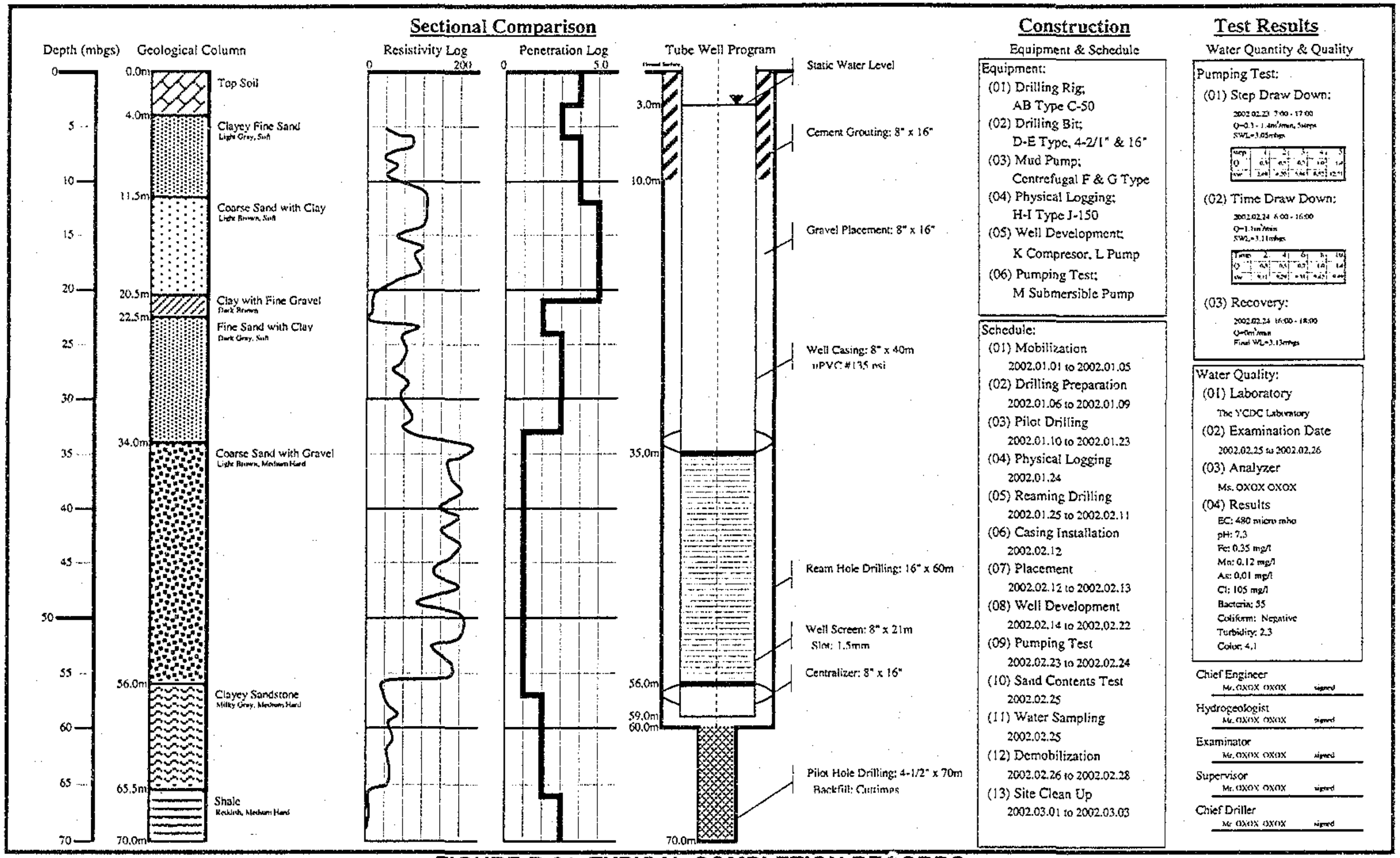


FIGURE B.21 TYPICAL COMPLETION RECORDS

Chemical deterioration means clogging the opening portions of well screen by incrustations producing from groundwater chemical contents. Any minerals could be solved in water if time span is not considered. Hence, groundwater contains various minerals depending on the oscu-lation time, rock type and rich level. These mineral contents are precipitated by several fac-tors.

Majority of these factors in case of water well is to fluctuate the water head during pump opera-tion. Especially in the vicinity of screen portion, water head is increased in conformity to the accelerated motion and is decreased suddenly when water passes the screen slot openings.

In the YCDC tube wells, high Ca/Fe/Mn concentrations were examined previously. Formation of calcium carbonate precipitate from calcium bicarbonate and in cases of Iron and Manganese incrustation are the classic example:

<Calcium>

$Ca(HCO_3)_2$ + delta P = $CaCO_3$ (precipitated) + CO_2 (dioxide) + H_2O

<Iron>

$Fe(HCO_3)_2$ + delta P = $Fe(OH)_2$ (agglomerated) + $2CO_2$ (dioxide)

$4Fe(OH)_2 + 2H_2O + O_2$ = $4Fe(OH)_3$ (precipitated)

<Manganese>

$2Mn(HCO_3)_2 + 2H_2O + O_2$ = $2Mn(OH)_4$ (precipitated) + $4CO_2$ (dioxide)

Consequently, it is better to operate pump equipment continuously as long as possible and smaller draw down for the long well-life. The steady operation makes also sustained per-formances in terms of quality and quantity of groundwater. So far, pump operation was man-aged by discharge rate previously. Probably, draw down of water level in the well becomes larger, which makes a vicious circle to increase physical and chemical deterioration.

It is important to set up the criteria for the timings of well rehabilitation or abandonment. Generally, when the deterioration rate (specific capacity: Q/sw) became the value about 80% or 70% of initial performance, the tube well rehabilitation should be considered to make plan, while well performance has reached 50% or less, the tube well may be abandoned and be newly re-constructed.

Rehabilitation methods will be decided depending on the reason of deterioration, which is physical, chemical or both of them. For physical deterioration, intermittent over pumping with airlifting (or say well surging) and jetting to the screen portions are proposed to remove clogging fine particles from filtration materials.

On the other hand for chemical deterioration, the injection/mixing of hexa-phosphoric acid, hydrochloric acid, sulfamic acid (aminosulfonic, amidosulfonic and amidosuluric) or hydroxyacetic acid with mechanical treatment will be selected. Finally, well dredging is required to confirm the depth of tube well bottom.

Operation and maintenance records were very helpful to judge the timing of well rehabilitation or abandonment for the YCDC' action plans. Periodical measurements of pump discharge, water level sounding (SWL/PWL) and simple water quality examination, therefore, should be conducted by the Township offices. An annual report should be prepared and submitted to the YCDC headquarter for booking and evaluation. Following Table B.59 shows items to be required for operation and maintenance records.

Table B.59 Recording Items for Operation & Maintenance

Items to be Measured		Measuring Conditions & Periods	
Pumping Discharge	Q; m^3/min.	After 16hrs Operation	Monthly Records
Water Level	SWL; mbgs	Before Daily Operation	
	PWL; mbgs	After 16hrs Operation	
Water Quality	EC; micro mho	After 16hrs Operation by On-site Examination	Quarterly Records
	pH; none unit		

Note: Well interference should be considered.

3.3.2 Improvement of Groundwater Quality

Groundwater characteristics will be examined by periodical water sampling at regular tube wells with parameters of EC and pH, and at pointed tube well with parameters of EC, pH, Fe, Mn, Cl and As by the YCDC. Therefore, parameters of water quality examination relating to biological human health were described in this section.

Outbreaks of water born disease may cause by contaminated or poorly treated groundwater tending to occur mainly during the period of rainy season. In the past, the purity and sanitary quality of groundwater was assumed, and even when groundwater sources were used for drinking water supplies, little or no treatment was thought to be required. But in the recent years, it has become obvious that groundwater may not always be safe to drink without adequate treatment.

All water that seeps into the ground is contaminated to some degree even before entering the subsurface environment. Rainwater picks up carbon dioxide, minerals, bacteria and inorganic contaminants, such as oxides of sulfur and nitrogen, from the atmosphere and soil. Once in the ground, any water percolating through landfill sites picks up bacteria, viruses and toxic substances. In addition, water seeping through soils near certain industrial plants can become heavily contaminated with industrial solvents or chemical residues related to particular manufacturing or processing activities.

With due consideration of above general conditions in the city, several protection methods were required in order to the stages of well utilization. These were sorted into four stages: (1) selection of well site, (2) selection of aquifer portion: proper well design, (3) sanitary sealing by placement materials and (4) periodical disinfection. Following are these instructions for existing and future construction tube wells.

(1) Selection of Well Site

Minimum distances from a well to possible sources of pollution should be great enough to provide reasonable assurance that subsurface flow or seepage of contaminated water will not reach the well. The following minimum distances are typical of good practices. A well should be at least:

- Buried Sewer (septic tanks): 20m
- Cesspools (leaching pits): 25m
- Manure Storage (agricultural chemicals): 30m
- Spray Materials (fertilizers): 50m

The distances listed above are minimal, and larger separations between wells and potential contaminating sources are strongly recommended whenever possible. The recommended distances do not apply when highly mobile contaminants such as volatile organic chemicals are present or when the terrain consists of coarse gravel, limestone, or disintegrated rock near the ground surface. Some Contaminants can travel great distances in these rock types of formations with little chance of natural purification by the filtration system.

(2) Selection of Aquifer Portion

Construction of a well should be planned and carried out to utilize fully every natural sanitary protection afforded by the geologic and groundwater conditions. Similarly, the well must be designed so that both natural and man-made contamination can be avoided. In selecting the proper well design and construction method, the following principles should be followed:

- The well materials that are to be a part of the permanent well should be durable.
- The well should be designed so that no unsealed opening will be left around the well that could conduct surface water, contaminated groundwater, or low quality groundwater vertically to the intake portion of the well.
- The well should be designed so that formations that are or may be contaminated or formations that have undesirable physical or chemical characteristics are sealed off.

Adequate depth of well casing is an important factor in sanitary protection. It provides vertical protection that augments the horizontal distance between a intake portion and possible contaminant sources with aquicludes. Therefore, confined aquifers are better choice for sanitary well design in many cases.

(3) Sanitary Sealing by Placement Materials

Sealing around part or all of the casing strings is an important factor in assuring that the well will remain free from contamination caused by surface or sub-surface sources. All high-capacity municipal and industrial wells are grouted. Grouting procedures vary depending on the well drilling and screen installation method.
On the current conditions of the YCDC tube wells, new tube wells to be constructed for satellite townships should be designed with proper placement program (sanitary sealing). On the other hand for the existing tube wells in the central city, additional mounting base and pump house to be protection to the surface contaminants should be promoted for future improvement.

(4) Periodical Disinfection

Most of the cases, problems were interruption and inadequate disinfections. This section shows correct procedures of chlorination to the tube wells. Use of a chlorine solution is the simplest and most effective way to disinfect or sterilize wells. Chlorine is a powerful oxidizing disinfectant that kills bacteria on contact. The effectiveness of the chlorine procedures will depend on:

- chlorine concentration,
- free-chlorine residuals,
- pH value of the water,
- retention time, and
- turbidity.

The chlorine concentration must be high enough so that a free-chlorine residual remains several hours after treatment. High pH waters require higher chlorine dosage than that of low-pH waters to obtain the same level of disinfection. Enough retention time must be allowed until the chlorine can kill the bacteria. High turbidity tends to reduce the effectiveness of the chlorine treatment, but this condition is generally not a problem with groundwater.

Solution strengths of 50 to 200mg/l chlorine are used commonly for sterilizing well. Duration of contact with the chlorine solution is another important factor in effective disinfection. After being agitated in the well, the chemical should be left for at least four hours and preferably longer to assure complete disinfection. Periodical disinfection should be planned at least annually.

The effectiveness of sanitary protection should be checked after completing the work by testing water samples for the presence of coliform bacteria. The well must be pumped and piping system flushed out thoroughly to remove all traces of chlorine before collecting water samples for testing. Samples should be collected in containers supplied by the laboratory and in accordance with laboratory instructions.

Although rarely performed for domestic wells unless contamination is suspended, chemical analysis can be done to assure that the water does not have concentrations of any toxic substances. This analysis will indicate whether the water must be treated before use. Even though the water may seems to be potable because no pathogenic organisms are present, other highly dangerous substances may be in the water.