JAPAN INTERNATIONAL COOPERATION AGENCY

YANGON CITY DEVELOPMENT COMMITTEE

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

FINAL REPORT VOLUME III: APPENDIX

SEPTEMBER 2002

TOKYO ENGINEERING CONSULTANTS CO., LTD.
NJS CONSULTANTS CO., LTD.

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THE STUDY

ON

IMPROVEMENT OF WATER SUPPLY SYSTEM

IN

YANGON CITY

IN THE UNION OF MYANMAR

FINAL REPORT

CONSTITUENT VOLUMES

VOLUME I	SUMMARY REPORT
VOLUME II	MAIN REPORT
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SURFACE WATER SOURCE

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APPENDIX A SURFACE WATER SOURCE

1 PHYSICAL SETTING

Yangon City is located in the delta of the Ayeyawady River and is about 34km (21 miles) away from the sea. The city lies in the area at the confluence of the Yangon River or Haling River, the Pazundaung creek and the Bago River.

Present Yangon originated more than 400 years ago in the form of a small riverside village known as Dagon. The present Central Business District and its street patterns were developed in 1852. Because of two natural barriers, the Hlaing River in the west and Pazundaung Creek in the east, so the city developed northwards in elongated shape.

The southern part of the city, lying between the Yangon River and Bago River, is flat. The land stretching northerly from the western and eastern fringes of this area is also flat, and begins to rise into low hills which form the southern extremity of a narrow range of hills known as the Bago Yomas.

2 METEOROLOGICAL AND HYDROLOGICAL DATA

The meteorological and hydrological data at the existing climate and hydrological observation stations in and around the Yangon City have been accumulated by the Department of Meteorology and Hydrology, Ministry of Transport and other agencies and all the available data at the stations shown in Figure A.1 were collected for the study as follows:

(1) Climatic data

There are 9 observation stations of climatic data in and around the Yangon City, which installed and have been operated by the Department of Meteorology and Hydrology shown in Table A.1.

The key meteorological stations by considering their data availability and their local characteristics were selected as listed in Table A.1 and collected data at all selected stations.

(2) Rainfall

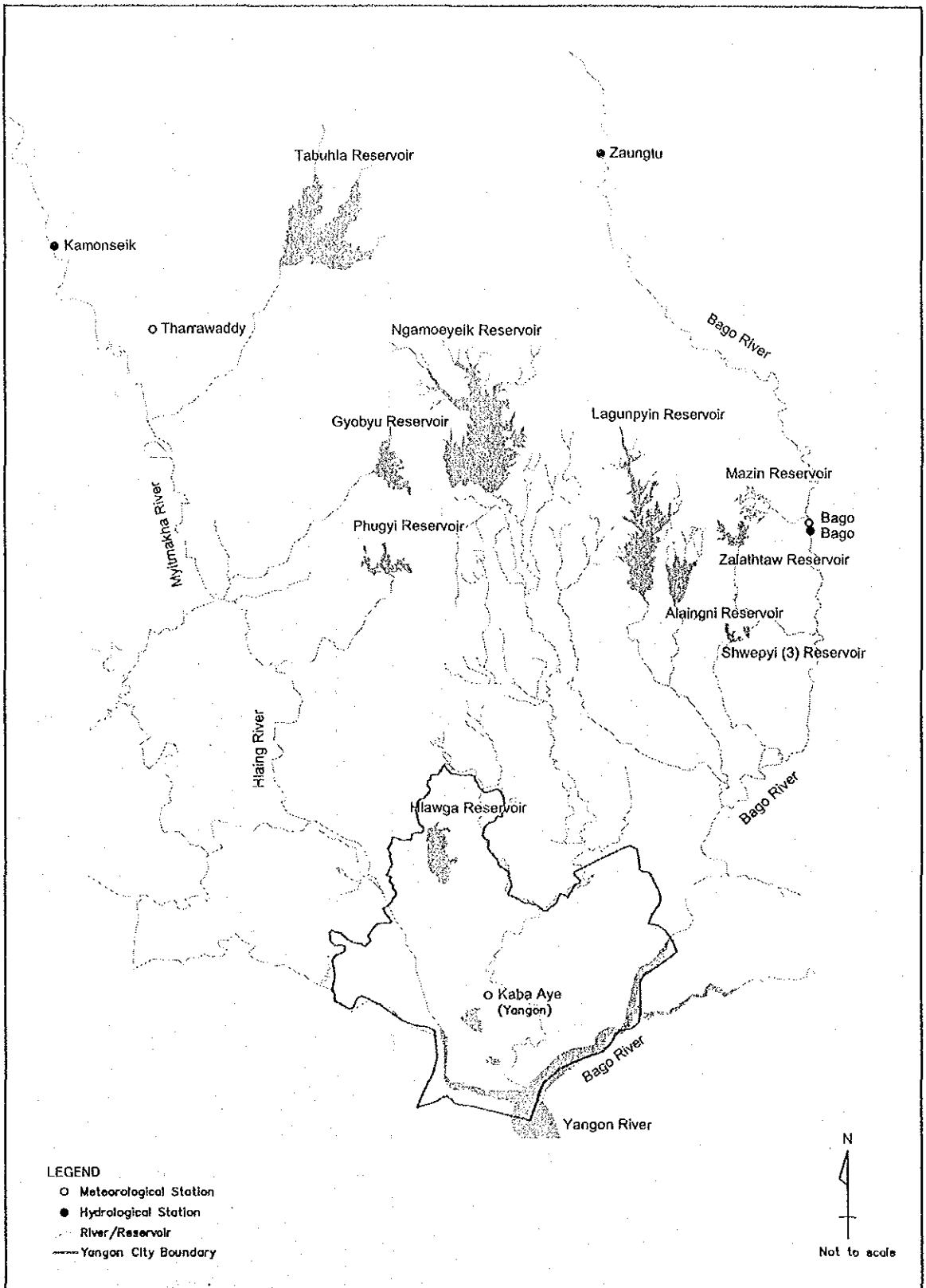
There are only rainfall stations (14 stations) which have been opened in the Yangon Division under the management of Irrigation Department, Ministry of Agriculture and Irrigation. And also rainfall data observed at 3 reservoirs, Gyobyu, Phugyi and Hlawga

Reservoirs for conveying the water supply to Yangon City area and 1 reservoir, Ngamoyeik Reservoir for expecting the water supply to the city area.

(3) Hydrological data

There existing 3 water level and discharge gauging stations which were managed by the Department of Meteorology and Hydrology in the Hlaing and Bago River basins as shown in Fig. A.1 and Table A.2. Of these stations, the Bago station is not observed the records during period, January to May and October to December influenced by taidal level. The discharge record of these stations has been provided by use of water level record and discharge rating table by the Department of Meteorology and Hydrology. These rating tables have been changed several times by use of discharge measurement record taking into account flow condition.

The daily water level record of these reservoirs for water supply to the Yangon City has been observed by YCDC.



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG A.1
	Location of Meteorological and Hydrological Stations	

Table A.1 Inventory of Meteorological Stations

Station	Code	Coordinate			Period of Records						Key Station
	(WMO)	Latitude	Longitude	Height (m)	Temperature	R. Humidity	Rainfall	Sunshine	Evaporation	Wind	Selected
1. Mingaladun	48096	16-54	96-11	28	1965-	1965-	1947-	-	-	1965-	
2. Kaba Aye (Yangon)	48097	16-54	96-10	20	1968-	1968-	1968-	1977-	1975-	1968-	Selected
3. Hmawbi	48092	17-02	95-38	5	1965-	1965-	1965-	-	-	1965-	
4. Khayan	-	16-54	96-34	4	1983-	1983-	1983-	-	-	1983-	
5. Shwekyin	48089	17-55	96-52	12	1964-	1964-	1964-	-	-	1964-	
6. Bago	48093	17-20	96-30	9	1965-	1965-	1965-	-	-	1965-	Selected
7. Zaungru	-	-	-	-	1987-	1987-	1987-	-	-	1987-	
8. Tharrawdy	48088	17-38	95-48	15	1965-	1965-	1965-	-	-	1965-	Selected
9. Gyobinkauk	48083	17-13	95-40	27	1985-	1985-	1985-	-	-	1985-	

Source: Department of Meteorology and Hydrology

Table A.2 Inventory of River Gauging Stations

River /Gauging Station	Code	Location		Catchment Area (km2)	Station Elevation (m)	type of Gauge	Period of Record	Key Station Selected
		Latitude	Longitude					
1. Hlaing (Myitmakha) River								
/Khamonseik	6020	16-31	95-35	-	14.465	Pile Gauge	1987-	Selected
2. Bago River								
/Pegu(Bago)	-	-	-	2,580	-	-	1965-	
/Zaungutu	6220	17-38	96-14	1,927	9.800	Pile Gauge	1987-	Selected

Source: Department of Meteorology and Hydrology

3 CLIMATE AND METEOROLOGY

3.1 GENERAL METEOROLOGICAL CONDITION

Yangon is geographically situated in a region that is influenced directly by the southwest monsoon. In Yangon and vicinity has a semi-tropical monsoon climate with three different seasons each year, the hot season, the rainy season and the cool season. The hot season covers the period from March to April, the rainy season from May to October and the cool season from November till February.

The meteorological stations in and around the Yangon City are selected as the representative stations considering their location, the period of available data, etc. The daily meteorological data at Kaba Aye (Yangon), Bago and Tharrawaddy are aggregated into monthly data as shown in Table A.3 and Figure A.2, A.3. and A.4.

Actural rainfall is recorded each day at 09:30 hours Myanmar Standard Time (MST), throughout country. Temperature and humidity readings are taken at the observatories twice a day at 09:30 hours and 18:30 hours MST.

Table A.3 Climatetic Elements at the Key Stations

Name of Station: Kaba-Aye (Yangon)

Period of Record: 1991-2000

Climatic Elements	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Rainfall (mm)	4	4	10	28	294	549	574	611	369	197	61	4	2706
Evaporation (mm)	116	122	163	183	142	75	75	72	81	100	107	111	1347
Mean Max. Temperature (℃)	33.2	34.7	36.6	37.1	34.3	31.0	30.4	30.0	31.0	32.1	33.1	32.6	33.0
Mean Min. Temperature (℃)	16.6	18.2	21.2	23.9	24.7	23.9	23.5	23.2	23.2	23.2	21.6	18.2	21.8
Mean Temperature (℃)	24.9	26.5	28.9	30.5	29.5	27.4	26.9	26.6	27.1	27.6	27.3	25.4	27.4
Relative Humidity at 09:30 (%)	67	67	70	69	77	87	89	90	87	82	73	69	77
Relative Humidity at 18:30 (%)	56	51	54	59	75	89	89	91	87	81	72	64	72
Sun Shine Hours	9.3	9.4	9.2	9.4	6.2	2.8	2.6	2.3	4.0	6.3	7.9	8.9	6.5
Wind Speed (mph)	2.3	2.4	2.4	2.6	2.7	2.7	2.6	2.3	2.2	2.5	2.6	2.6	2.5
Wind Direction	NE	NE	SW	SW	SW	SW	SW	SW	SW	E	NE	NE	SW

Source: Department of Meteorology and Hydrology

Name of Station: Bago

Period of Record: 1991-2000

Climatic Elements	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Rainfall (mm)	2	3	13	33	290	708	739	782	473	197	40	6	3285
Mean Max. Temperature (℃)	32.0	33.5	35.8	37.1	34.7	30.9	30.4	30.2	31.2	32.4	32.3	31.4	32.7
Mean Min. Temperature (℃)	14.7	16.5	19.8	22.7	23.1	22.3	22.2	22.1	22.1	21.7	19.8	15.8	20.2
Mean Temperature (℃)	23.3	25.0	27.8	29.9	28.9	26.6	26.3	26.1	26.7	27.0	26.0	23.6	26.4
Relative Humidity at 09:30 (%)	77	74	75	72	79	88	90	90	88	83	81	79	81
Relative Humidity at 18:30 (%)	59	54	54	56	72	88	90	90	86	81	73	70	73
Wind Speed (mph)	1.3	1.2	1.2	1.3	1.3	1.1	1.3	1.2	1.1	1.1	1.4	1.5	1.2
Wind Direction	NE	NE	NE	SW	SW	SW	SW	SW	SW	NE	NE	NE	SW

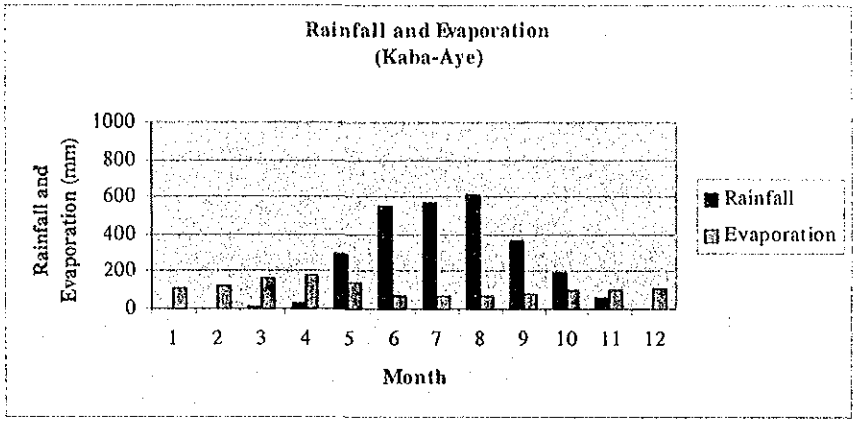
Source: Department of Meteorology and Hydrology

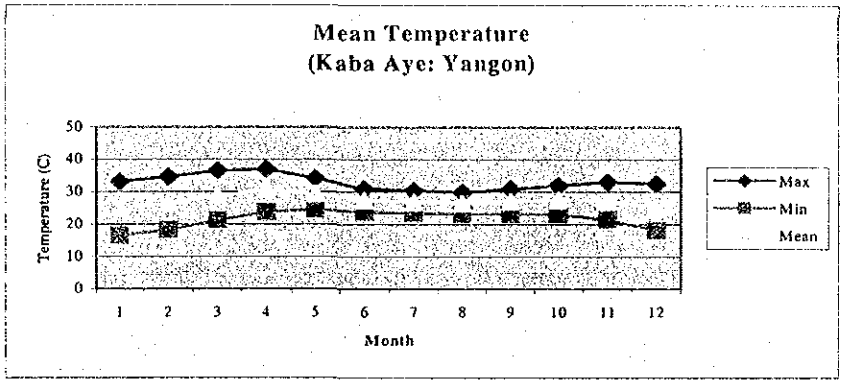
Name of Station: Tharrawaddy

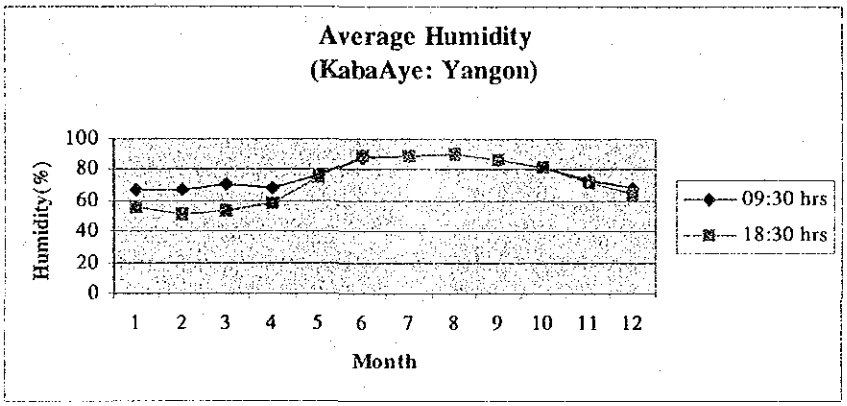
Period of Record: 1991-2000

Climatic Elements	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Rainfall (mm)	4	2	3	12	195	477	508	486	284	158	56	6	2191
Mean Max. Temperature (℃)	32.1	33.5	37.2	39.1	35.9	31.4	30.7	30.6	31.5	32.4	32.3	31.5	33.2
Mean Min. Temperature (℃)	13.8	15.5	18.2	22.6	23.5	23.3	23.0	23.1	23.1	22.6	19.9	16.3	20.4
Mean Temperature (℃)	23.0	24.5	27.7	30.8	29.7	27.4	26.8	26.8	27.3	27.5	26.1	23.9	26.8
Relative Humidity at 09:30 (%)	69	65	67	64	74	86	89	87	86	83	76	72	76
Relative Humidity at 18:30 (%)	58	48	43	47	68	88	88	89	86	82	77	66	70
Wind Speed (mph)	2.4	1.9	2.2	2.5	2.2	2.3	2.2	1.9	1.8	1.5	2.2	3.6	2.2
Wind Direction	N	N	S	S	S	S	S	S	S	S	NE	N	S

Source: Department of Meteorology and Hydrology







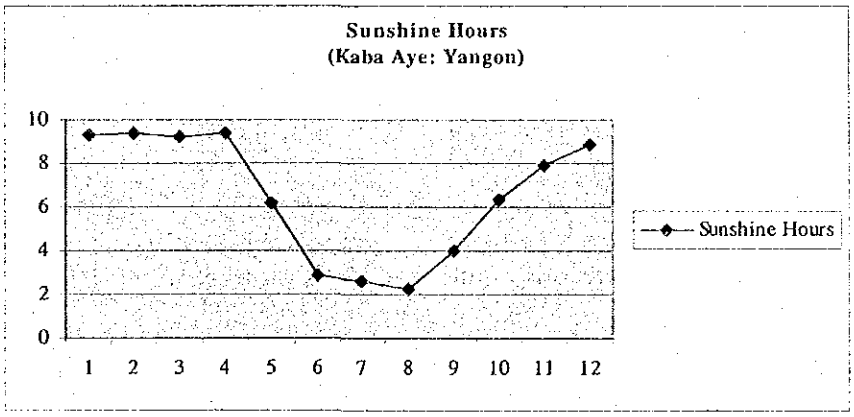
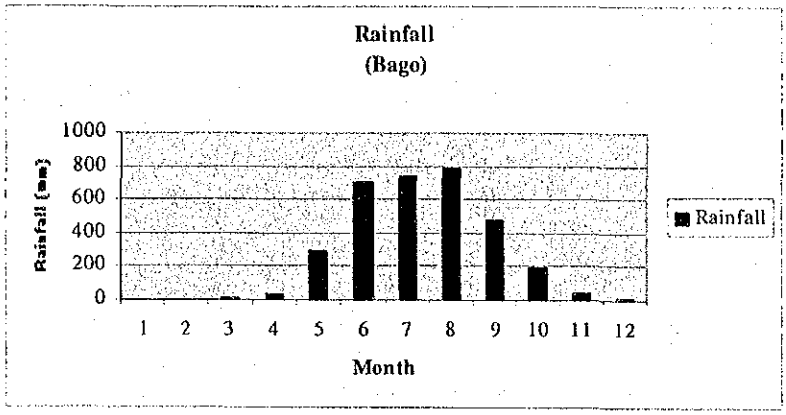
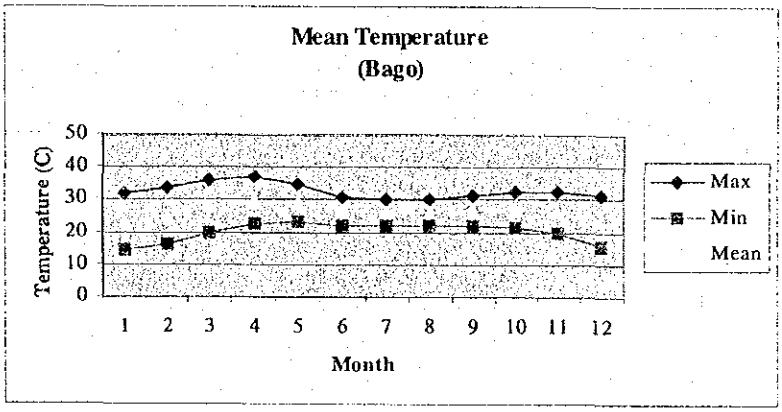


Figure A.2 Monthly Climatetic Elements at Kaba Aye (Yangon)





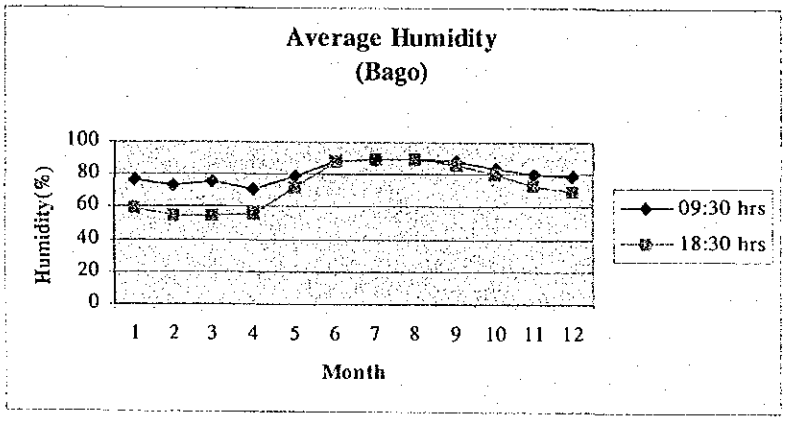
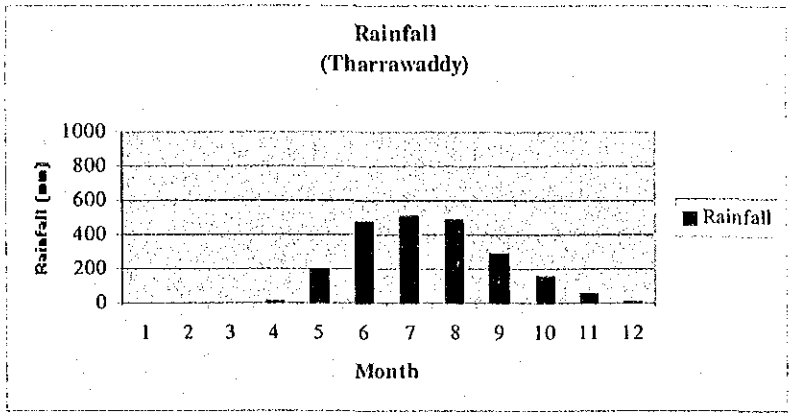
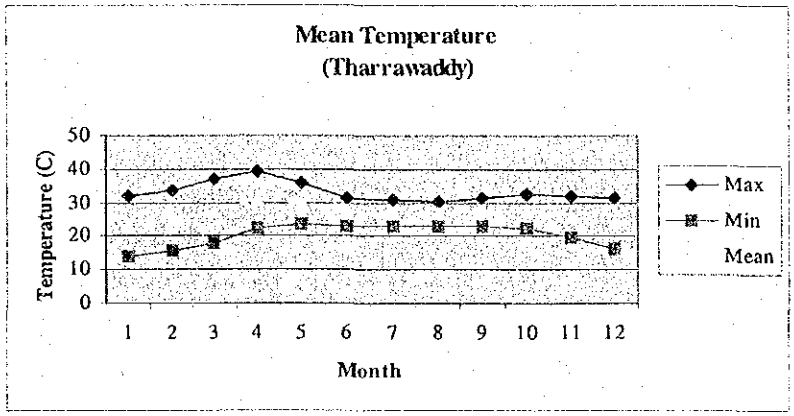


Figure A.3 Monthly Climatetic Elements at Bago





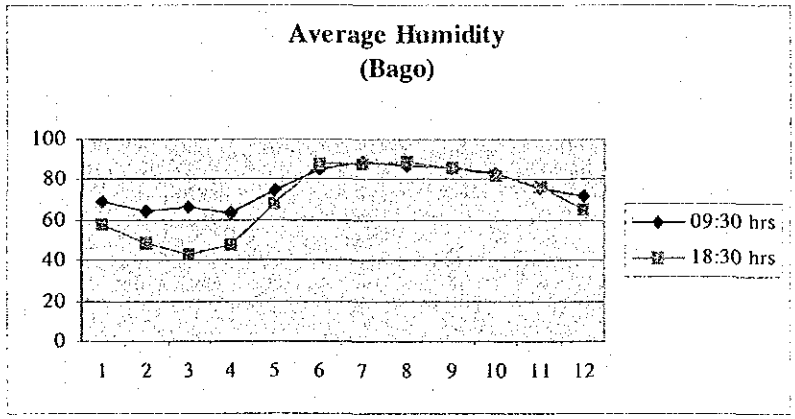


Figure A.4 Monthly Climatetic Elements at Tharrawaddy

3.2 CLIMATE

(1) Temperature

Annual mean temperature has range between 26.4℃ and 27.4℃ in and around the Yangon area. According to collected data, mean maximum temperature 39.1℃ (April) at Tharrawaddy in the north-west area and mean minimum temperature 13.8℃ (January) at Tharrawaddy were recorded respectively during the recent 10 years.

(2) Evaporation

The observation of evaporation pan data is observed by Department of Meteorology and Hydrology at Kaba Aye station (Yangon). Annual mean evaporation is 1347.2mm at Kaba Aye with 50 % of annual rainfall.

Evaporation pan·data after converted by using a pan coefficient (0.6-0.8) is useful for estimating the value for lakes or reservoirs.

(3) Relative Humidity

Annual mean relative humidity in Yangon area is ranging between 76 and 81 %. The relative humidity during May to December shows almost similar pattern of fluctuation.

(4) Sunshine Hours

According to the collected data, annual mean sunshine hours have about 6.5 hours/day at Kaba Aye station. Sunshine hours at Kaba Aye station during the rainy season are shorter than the other seasons showing different pattern of fluctuation.

(5) Wind Speed and Direction

The mean monthly wind speed is stable at range between 2.2 and 2.7 mph at Kaba Aye and at range between 1.1 and 1.5 mph at Bago throughout the year. The wind condition in Yangon area depends on the influence of the southwest monsoon.

3.3 RAINFALL

Stations have measured the rainfall data in and around the Yangon City with different organizations and different observation periods. Figure A.5 shows the monthly rainfall observed at 3 reservoirs, Gyobyu, Phugyi and Hlawga Reservoirs for the water supply to Yangon City area and 1 reservoir, Ngamoyeik Reservoir for the water supply to the city area and Irrigation. Actual rainfall is recorded each day at 09:30 hours Myanmar Standard Time, throughout the country.

(1) Seasonal Fluctuation of Rainfall

Seasonal variation of monthly totals is similar in different parts of the Yangon area as shown in Figure A.2, Figure A3 and Figure A4. As mentioned seasonal fluctuation of rainfall, most rainfall of about 96% to97% of annual rainfall is brought by the rainy season from May to October with the highest amount of rainfall in July or August as summarized in Table A.4.

Table A.4 Seasonal Fluctuation of Rainfall (mm)

Station Name	Annual Rainfall	Seasonal Rainfall (during May to Oct.)	Percent of Seasonal Rainfall	Period
Kaba Aye (Yangon)	2706	2594	95.9	1968-00
Bago	3285	3188	97.1	1965-00
Tharrawaddy	2191	2108	96.2	1965-00
Gyubyu Reservoir	2304	2234	97.0	1990-00
Phugyi Reservoir	2571	2458	95.6	1983-00
Hlawga Reservoir	2102	2024	96.3	1990-00
Ngamoyeik Reservoir	2695	2619	97.2	1998-00

(2) Annual Rainfall Distribution

Using the recorded annual mean rainfall data, the following rain characteristics in Yangon area can be observed;

a) Bago at the eastern side of the Yangon area has the highest annual rainfall volume.
b) Tharrawaddy at the northwestern side of the Yangon area has the lowest annual rainfall.
c) Kaba Aye (Yangon) at Central area has second highest annual rainfall volume.

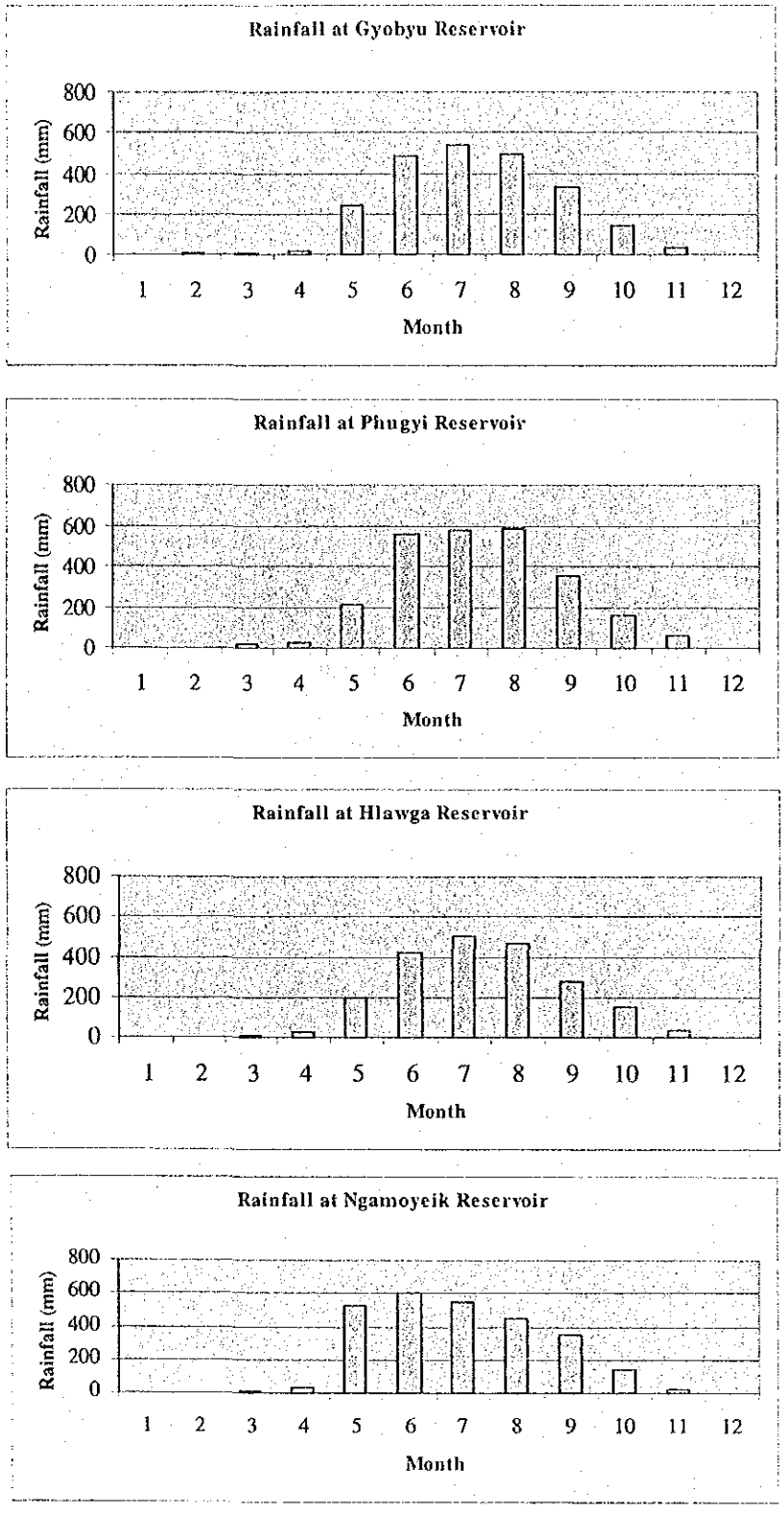


Figure A.5 Monthly Rainfall at Each Reservoir

(3) Long Term Fluctuation of Annual Rainfall

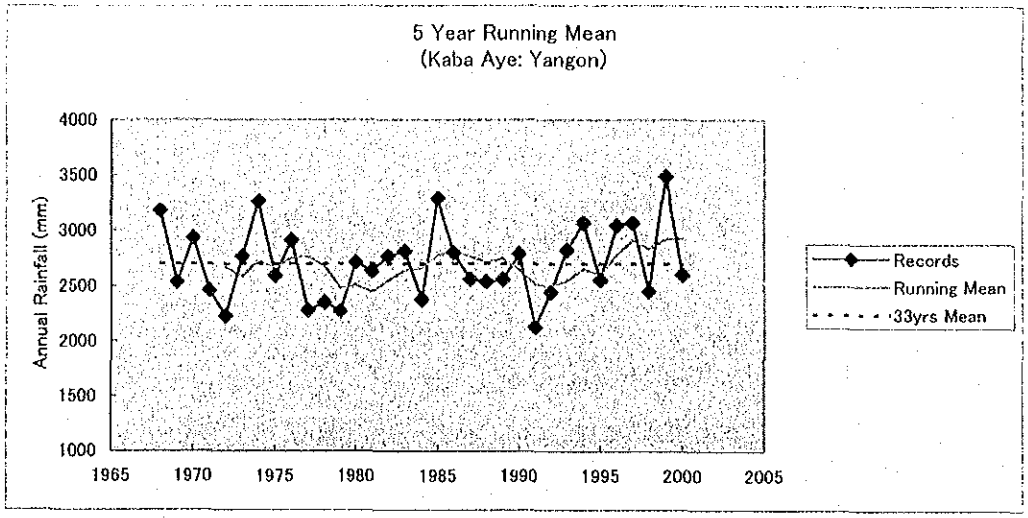
Figure A.6 shows the long term fluctuation of annual rainfall by using 5 year running mean at Kaba Aye, Tharrawaddy and Phugyi Reservoir where rainfall is observed for a long period. As seeing the Figure A.6, the characteristics of long term fluctuation of annual rainfall by running mean are summarized as follows;

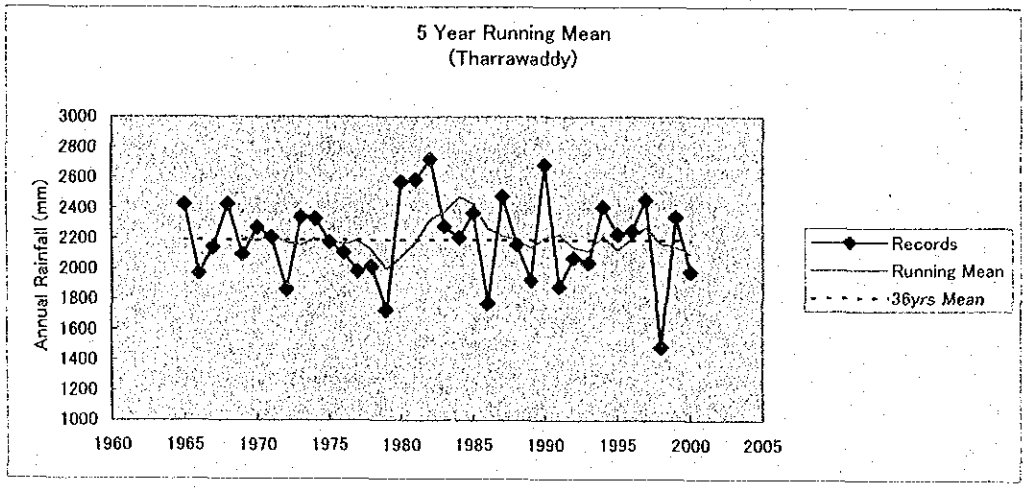
- Three stations do not show similar pattern of fluctuation
- Although the cycle of wet and droughty periods is not clear, there are clear periods of wet and drought.
- It is indicated that the cycle of wet years occur during the recent 5 years in the Yangon City area.
- It is shown that the trend of droughty years occur in the recent years at Tharrawaddy and Phugyi Reservoir in the north and northwest of Yangon area.

Table A.5 shows the distinguishable period of wet and drought years to estimate the long term fluctuation of annual rainfall. According to Table A.5, it is found that the rainfall fluctuation cycles repeat the range from 5 to 7 years in Yangon area, and the severe drought year is identified at 1998 in and around the sources of water supply for the Yangon City area.

Table A.5 Long Term Fluctuation of Annual Rainfall (mm)

Station Name	Annual Mean Rainfall	Annual Min. Rainfall	Year Estimated Lower Annual Rainfall	Period
Kaba Aye (Yangon)	2706	2127(1991)	1971, 1972, 1977, 1978, 1979, 1984, 1991, 1992, 1998	1968-00
Bago	3285	2274(1998)	1977, 1979, 1983, 1986, 1987, 1989, 1991, 1998	1965-00
Tharrawaddy	2191	1481(1998)	1966, 1972, 1977, 1979, 1986, 1989, 1991, 1998	1965-00
Gyubyu Reservoir	2304	1634(1998)	1991, 1998	1990-00
Phugyi Reservoir	2571	1670(1998)	1983, 1984, 1987, 1989, 1998	1983-00
Hlawga Reservoir	2102	1660(1991)	1991, 1995, 1998, 2000	1990-00
Ngamoyeik Reservoir	2695	2380(1998)	1998, 2000	1998-00





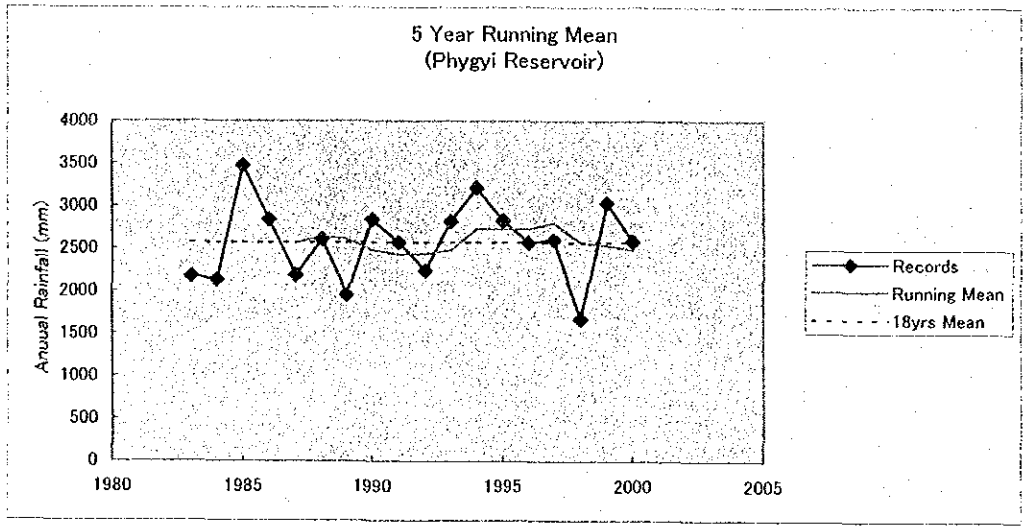


Figure A.6 5 Year Running Mean Rainfall

(4) Probability of Non-exceedance by Annual Rainfall

Probability by annual rainfall have been studied using the annual rainfall from January to December and the hydrological annual rainfall from May to April by the data at Kaba Aye, Bago, Tharrawaddy and Phugyi Reservoir where the long term observation records are available. The probable annual rainfall at these stations were estimated by means of the Gumbel's Minimum Values method using the aforesaid annual rainfall series as shown in Table A.6. Probable 1/10 drought year (once in ten years) is close to the year of 1998 at Phugyi Reservoir.

Table A.6 Probability of Non-exceedance by Annual Rainfall (mm)

(Calendar Year: January to December)

Station/ Retrun Period	2 yrs	5 yrs	10 yrs	20 yrs	30 yrs	50 yrs	80 yrs	100 yrs	No. of Records
Kaba Aye	2680.7	2413.8	2296.5	2214.5	2177.5	2139.7	2111.8	2100.4	33
Bago	3284.9	2922.3	2740.0	2598.7	2529.8	2454.5	2394.8	2369.3	36
Tharrawaddy	2206.1	1963.4	1829.9	1719.1	1662.1	1597.1	1543.0	1519.2	36
Phugyi Reservoir	2578.2	2188.3	1987.6	1829.2	1750.9	1664.3	1594.8	1564.9	18

Note: Estimated by Gumbel Method (Minimum Values)

(Hydrological Year: May to April)

Station/ Retrun Period	2 yrs	5 yrs	10 yrs	20 yrs	30 yrs	50 yrs	80 yrs	100 yrs	No. of Records
Kaba Aye	2712.3	2441.3	2303.9	2196.8	2144.2	2086.6	2040.7	2021.0	32
Bago	3269.9	2944.9	2798.3	2693.8	2646.0	2596.5	2559.4	2544.2	35
Tharrawaddy	2212.2	1975.1	1844.8	1736.8	1681.2	1617.8	1565.2	1541.9	35
Phugyi Reservoir	2558.8	2209.1	2043.3	1920.5	1862.6	1801.2	1753.9	1734.1	17

Note: Estimated by Gumbel Method (Minimum Values)

4 HYDROLOGY OF SURFACE WATER

4.1 RIVERS AND HYDROLOGICAL NETWORK

There are 3 hydrological stations (as of June, 2000) operated by Department of Meteorology and Hydrology in the Hlaing River basin at Kamonseik and Bago River basin at Bago and Zaungutu of which 3 stations are provided with pile gauge as shown in Figure A.7. Bago gauging station excluded from one of the key stations due to the influence of tidal level during the January to mid-May and mid-October to December.

The basins of Hlaing River and Bago River are divided into three major portions, i.e., the Bago Yoma area, the alluvial plain and the hilly zone extending between the above-mentioned two. The geographical gradient is a descent from north to south, as a result of which its rivers and creeks have their sources in the Bago Yoma and flow into the sea in the south.

There are 3 formations geologically in the River basins, such as Quaternary formations, Irrawaddy formations and Baguian series formations. The area along river course is underlain by sandstone and shale of the Miocene to Oligocene series. Sandstone of Pliocene series known as the Irrawaddy series overlies the above-mentioned bed rock. The Quaternary formations lie on the Irrawaddy series.

Sandstone and shale of the Bafuian series are the major component of the hilly land and extending between the Bago Yoma area and the alluvial plain. The Irrawaddy series is characterized by the presence of sandstone containing quartz pebble and iron oxide and clay inclusions, and forms the joint portion of the hilly zone and the alluvial plain. The vast alluvial plain is overlain by the Quaternary formations. In addition, the formations are also observed in chaung and terrace deposits.

(1) Hlaing River

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

At Schwelaung village, Hlaing River meets with Thenet River, a branch of Ayeyarwaddy (Irrawaddy) River . The inflow of water from the Ayeyarwaddy River into Hlaing River

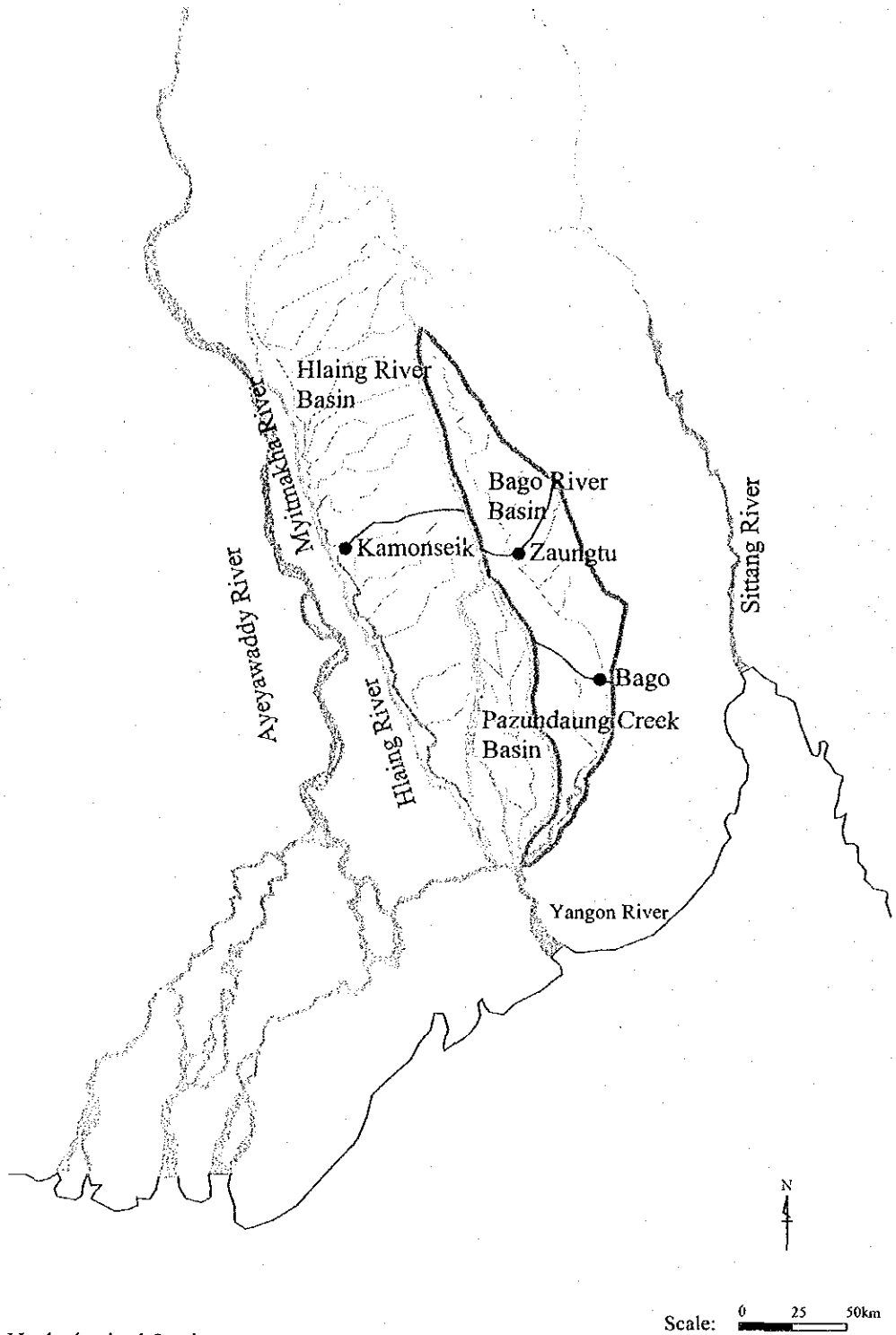
through Thenet River during high water period in rainy season.

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

(2) Bago River

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

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



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG A.7
	River Basins and Hydrological Networks	

4.2 EXISTING RESERVOIRS

The present surface water sources for supply of water to the Yangon City are consisted of Gyobyu Reservoir, Phugyi Reservoir and Hlawga Reservoir. And Ngamoyeik Reservoir constructed by Irrigation Department, Ministry of Agriculture and Irrigation will be able to supply the water for Yangon City.

The characteristics of existing reservoirs for supply of water and the existing, under construction and proposed reservoirs managed by Irrigation Department are summarized in Table A.7 and Table A.8.

(1) Gyobyu Reservoir

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

(2) Phugyi Reservoir

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

(3) Hlawga Reservoir

Hlawga Reservoir is situated at about 27 km (17 miles) north of Yangon. It has a dependable yield of 75,100 m3/day (16.5 mgd) and was completed in 1906. The water from Hlawga is pumped through a 1,050 mm dia cast iron pipeline to Yegu, when it is pumped to the city's distribution system.

(4) Ngamoyeik Reservoir

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

Table A.7 Characteristics of Existing Reservoirs for Water Supply

Name of Reservoir	Unit	Hlawga (Existing)	Pugyi (Existing)	Gyobyu (Existing)	Ngamoeyeik (Existing)
Catchment Area	km2 (sq. miles)	27.2 (10.50)	70.6 (27.27)	32.9 (12.70)	414.4 (160)
Water Surface Area	km2 (sq. miles) (acre)	11.40 (4.40)	17.61 (6.80)	7.25 (2.80)	44.52 (17.19) (11,000)
Effective Capacity	MCM (m. g.) (acre-tf)	48.2 (10,600)	86.4 (19,000)	38.2 (8,400)	207.2 (45,538) (168,000)
Total Capacity	MCM (m. g.) (acre-ft)	54.6 (12,000)	104.6 (23,000)	75.5 (16,600)	222.0 (48,791) (180,000)
Length of Dam	m (ft)	2,414 (7,920)	3,048 (9,999)	213 (700)	4,724 (15,500)
High Water Level (Flooding)	m (ft)	18.9 (62)	35.1 (115)	65.5 (215)	32.6 (107)
Full Water Level (Normal)	m (ft)	18.9 (62)	35.1 (115)	65.5 (215)	32.6 (107)
Low Water Level	m (ft)	14.3 (47)	27.4 (90)	42.1 (138)	24.7 (81)
Top of Spillway	m (ft)	18.9 (62)	35.1 (115)	65.5 (215)	32.6 (107)
Width of Spillway	m (ft)	36.6 (120)	91.4 (300)	65.5 (215)	45.7 (150)
Sluce Gate	nos	3	3	3	3
Daily Water Supply	m3 m3/s (m. g.)	75,100 0.87 (16.5)	245,700 2.84 (54)	93,300 1.08 (20.5)	409,500 4.74 (90)
Irrigable Area	ha (acre)	-	-	-	23,868 (58,976)

Source:

(1) Hlaing River Water Supply Project, Final Feasibility Study Report, March 1992, Beture Setame – YCDC
(2) Yangon City's Water Supply System, Water Supply & Sanitation Department, YCDC, May 2001
(3) Location Map of Existing, Under-construction and Proposed Reservoirs in and around Yangon Area
(4) Preparatory Study Report for the Study on Improvement of Water Supply System in Yangon City in the Union of Myanmar, JICA, November 2000

Table A.8 Characteristics of Existing and Proposed Reservoirs for Irrigation

Name of Reservoir	Unit	Lagunpyin (Existing)	Shwepyi (3) (Existing)	Sunpalun (Existing)	Zalathtaw (Existing)	Mazin (Existing)	Tabuhal (Existing)	Ahlaingni (Under construction)	Nagamoeyeik (2) (Proposed)
Cacthment Area	km2 (sq. miles)	108.8 (42)	5.18 (2)	-	23.3 (9)	28.5 (11)	230.5 (89)	36.8 (14.2)	(-)
Surface Area	km2 (acre)	27.11 (6,700)	1.05 (260)	0.0405 (10)	5.58 (1,380)	6.17 (1,525)	31.57 (7,800)	8.34 (2,060)	(-)
Effective Capacity	MCM (acre-ft)	177.1 (143,550)	4.51 (3,660)	-	21.09 (17,100)	32.44 (26,300)	210.4 (170,550)	45.91 (37,220)	(-)
Total Capacity	MCM (acre-ft)	183.5 (148,800)	4.56 (3,700)	0.654 (530)	22.20 (18,000)	35.52 (28,800)	240.4 (194,900)	48.11 (39,000)	(-)
Length of Dam	m (ft)	1,579 (5,180)	1,056 (3,464)	109 (357)	1,391 (4,565)	1,250 (4,100)	398 (1,305)	1,737 (5,700)	(-)
High Water Level (Flooding)	m (ft)	26.14 (85.763)	22.29 (73.14)	-	34.81 (114.19)	26.94 (88.376)	60.53 (198.6)	26.14 (85.763)	(-)
Full Water Level (Normal)	m (ft)	24.99 (82)	21.34 (70)	-	33.53 (110)	25.91 (85)	59.44 (195)	24.99 (82)	(-)
Low Water Level	m (ft)	14.02 (46)	15.24 (50)	-	25.51 (83.7)	17.68 (58)	47.24 (155)	15.24 (50)	(-)
Top of Spillway	m (ft)	24.99 (82)	21.34 (70)	-	33.53 (110)	25.91 (85)	59.44 (195)	24.99 (82)	(-)
Width of Spillway	m (ft)	15.24 (50)	7.62 (25)	3.05 (10)	6.10 (20)	10.97 (36)	60.96 (200)	15.24 (50)	(-)
Sluce Gate	nos	2 (4' x 6')	1/3' (dia)	-	1	1(4' x 6')	3 (4' x 6')	1 (4' x 6')	(-)
Daily Water Supply	m3 m3/s (m. g.)	-	-	-	-	-	-	-	-
Irrigable Area	ha (acre)	8,903 (22,000)	506 (1,250)	-	809 (2,000)	263 (650)	21,044 (52,000)	8,903 (22,000)	(-)

4.3 CHARACTERISTICS OF RESERVOIR WATER LEVEL

(1) Annual Water Level Fluctuation

Using the last 6 years period (1995-2000), daily water level patterns at each reservoir are shown in Figure A.8 and A.9.

Based on Figure A.8 and A.9, the characteristics of actual reservoir operation at each station are summarized as follows;

- It is not useful to operate the effective storage capacity from full water level to low water level at Gyobyu, Phugyi and Hlawga reservoir for water supply use only to Yangon City. But because of small-scale catchment area, it will be not able to restore to the full water level at once a year during the rainy season.
- Hlawga reservoir does not reach the full water level at once a year.
- Ngamoyeik reservoir reaches the low water level on May 1997, though it is not supply the water to Yangon City yet.

(2) Long Term Water Level Fluctuation

According to Figure A.8 and A.9, it is found that the actual daily water level of reservoir occur the same fluctuation cycles, but especially the different fluctuation pattern is clearly occurred during the rainy season on 1998.

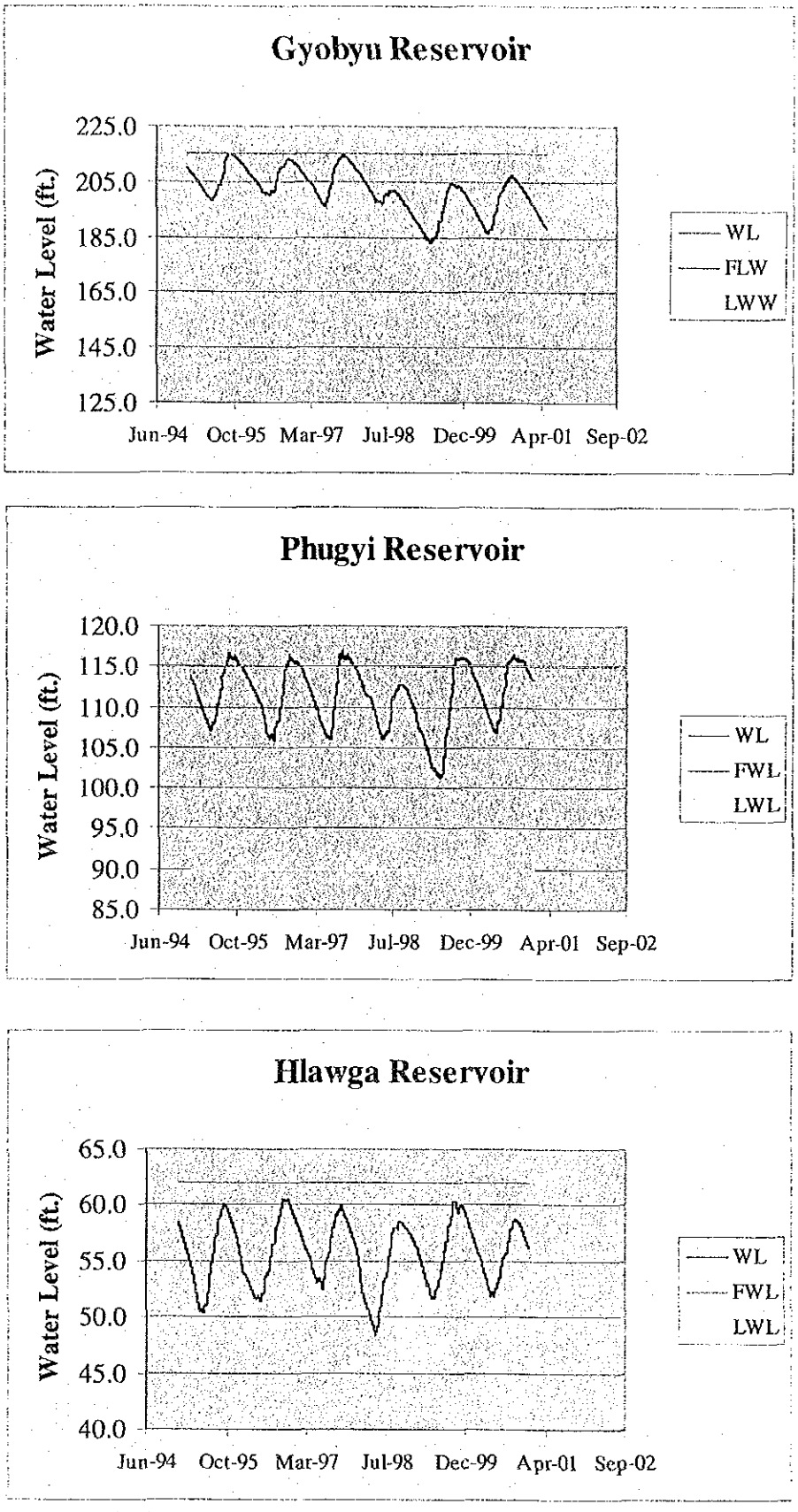


Figure A.8 Daily Water Level of Each Reservoir (1)

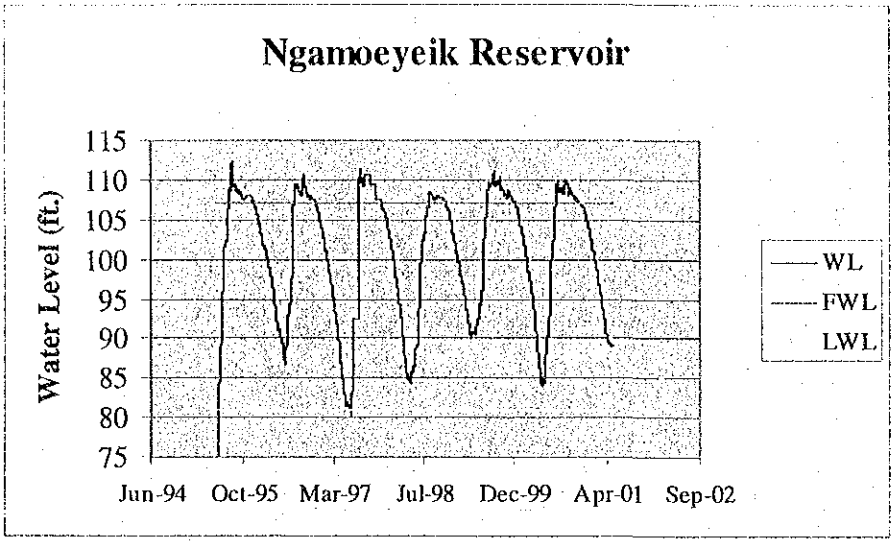


Figure A.9 Daily Water Level of Each Reservoir (2)

4.4 CHARACTERISTICS OF RIVER FLOW

(1) River Flow Regime

The flow regime shows the annual condition using the daily discharge at each hydrological station and shall be indicated by the daily discharge and number of exceeded days. The annual flow regime of each selected stations shows as follows;

- High discharge (95^{th} daily discharge from the greatest)
- Normal Discharge (185^{th} daily discharge from the greatest)
- Low Discharge (275^{th} daily discharge from the greatest)
- Drought Discharge (355^{th} daily discharge from the greatest)

The flow regime is commonly used to find the fluctuation in the daily discharge, and utilized for determining the potential surface water characteristics in Japan.

The flow regime computed by station was adapted for 14 years period (1987-2000), and mean value of the 95^{th}, 185^{th}, 275^{th} and 355^{th} daily discharge for the last 14 years period were calculated. The results of mean flow regime for the last 14 years period are summarized in Table A.9, and Figure A.10 shows flow regime curves at the select hydrological stations.

As seeing in Table A.9 and Figure A.10, the coefficient of river regime extremely differs by rivers. Although the low flow by Hlaing River at Khamonseik and Bago River flow at Zaungtu are not steady and their coefficients of river regime are so large. Especially, it is found that the flow regime by Bago river at Zaungtu has not a sustainable quantity of base flow.

Table A.9 Flow Regime
(mean values for the last 14 years period (1987-2000))

River: Hlaing (Myitmakha) River

Station: Khamonseik

Year	Daily Discharge (m3/s)							
	Max.	95th day	185th day	275th day	355th day	Min.	Mean	Coefficient of River Regime
1987	2577	1366	24	11	8	8	612	322.1
1988	-	-	-	-	-	-	-	-
1989	2260	1177	33	20	17	17	520	132.9
1990	2570	1460	46	15	11	10	687	257.0
1991	2652	1238	51	16	13	13	656	204.0
1992	1680	869	22	17	14	13	426	129.2
1993	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	-	-
1995	2390	1452	228	5	3	3	703	796.7
1996	2330	1290	172	22	9	9	602	258.9
1997	2752	1214	22	11	9	8	609	344.0
1998	2133	932	57	36	20	11	574	193.9
1999	2026	1161	356	34	27	27	656	75.0
2000	1842	1332	77	28	23	21	573	87.7
Mean	2292	1226	99	20	14	13	602	176.3

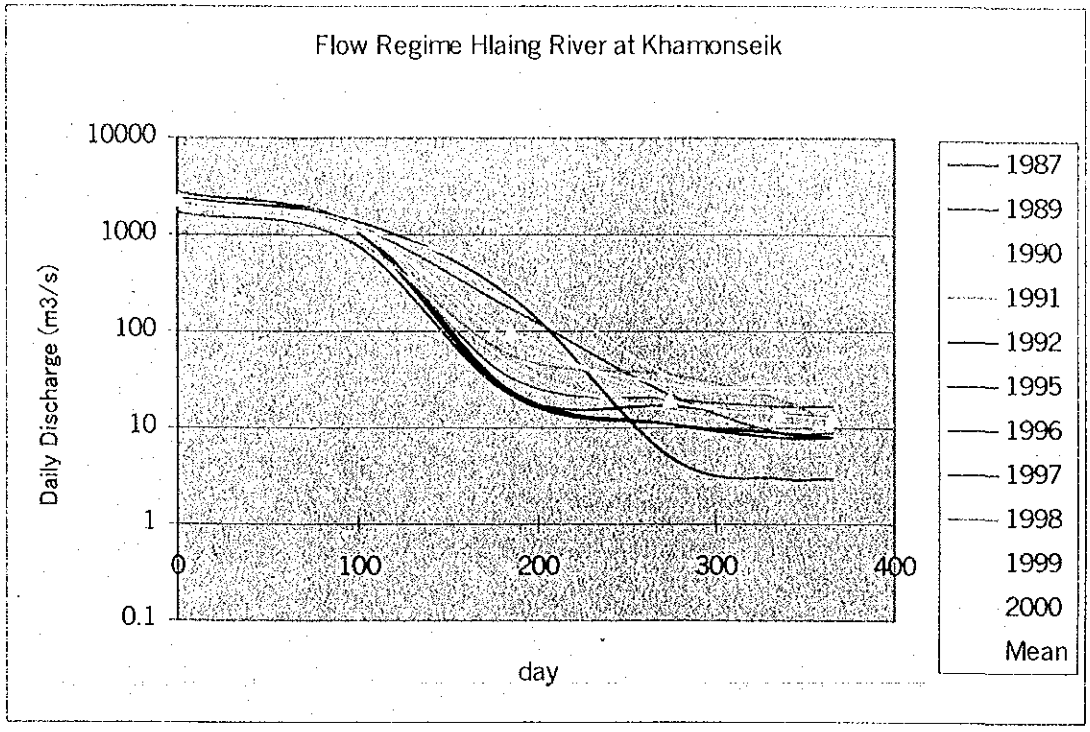
Note: Coefficient of River Regime = Max. Discharge / Min. Discharge

River: Bago River

Station: Zaungtu

Year	Daily Discharge (m3/s)							
	Max.	95th day	185th day	275th day	355th day	Min.	Mean	Coefficient of River Regime
1997	741	89	11	1	1	1	72	741.0
1988	538	59	14	1	1	1	56	538.0
1989	623	80	23	5	1	1	64	623.0
1990	1108	183	6	1	1	1	122	1108.0
1991	708	49	2	1	1	1	59	708.0
1992	1069	66	7	1	1	0	67	-
1993	752	44	1	0	0	0	54	-
1994	1237	64	3	1	0	0	71	-
1995	790	31	3	0	0	0	60	-
1996	933	65	6	1	0	0	64	-
1997	1034	74	2	1	1	1	73	1034.0
1998	510	75	31	1	0	0	63	-
1999	722	133	15	1	0	0	82	-
2000	951	141	69	22	1	1	103	951.0
Mean	837	82	14	3	1	1	72	837.0

Note: Coefficient of River Regime = Max. Discharge / Min. Discharge



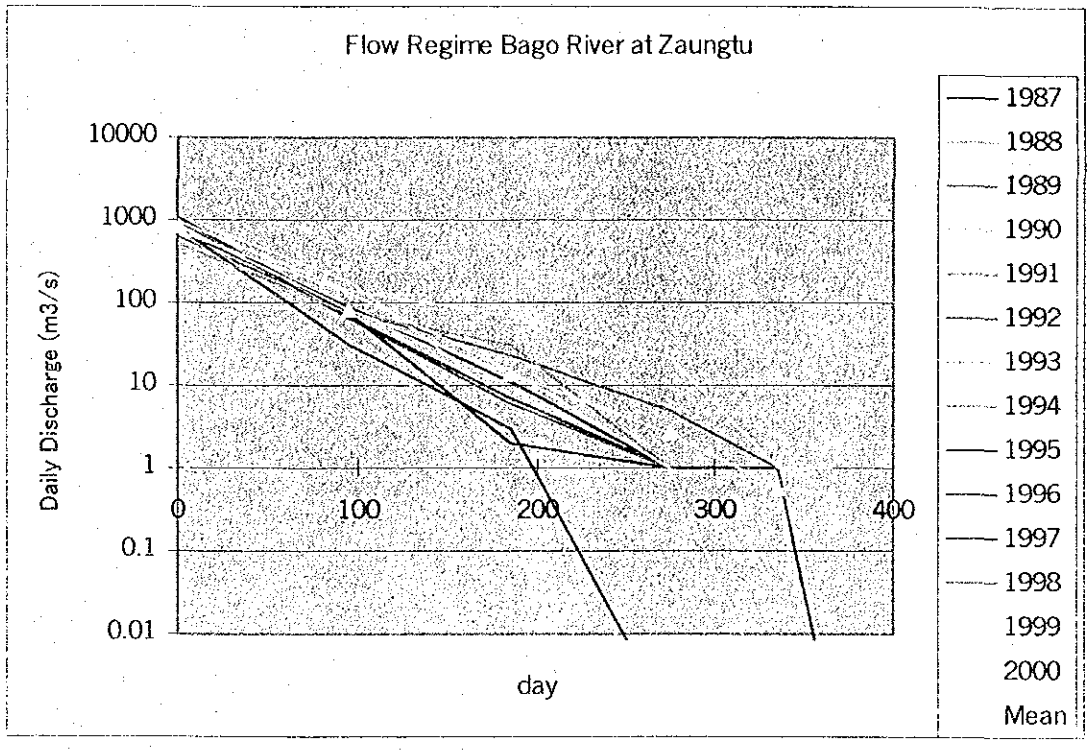


Figure A.10 Flow Regime
(mean values for the last 14 years period (1987-2000))

(2) Seasonal Discharge Fluctuation

Using the last 14 years period (1987-2000), average monthly flow patterns at Khamonseik station (Hlaing River) and Zaungtu station (Bago River) are given as Table A.10 and Figure A.11, and maximum and minimum daily discharge of each month at their stations are shown in Table A.11 and Table A.12.

Based on Table A.10 and Figure A.11, the characteristics of monthly discharge at each station are summarized as follows;

- The fluctuation of runoff peak exists only once a year on August at each station
- The monthly discharge shows on the decrease from December to May at Khamonseik and from December to April at Zaungtu.
- The monthly fluctuation pattern is clearly occurred from June to November at Khamonseik and from May to November at Zaungtu.

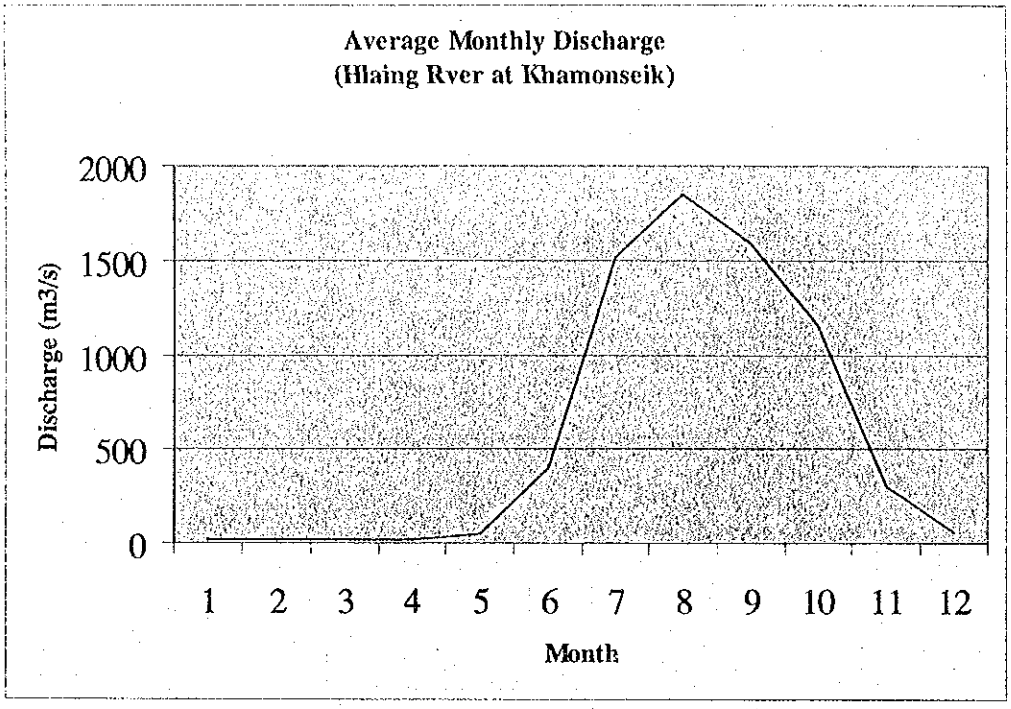
Table A.10 Monthly Flow Pattern (Mean Discharge)

Hlaing River at Khamonseik (Unit: m3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987	13	11	10	9	12	374	1177	2071	2039	1460	88	24	7287
1988	16	15	-	44	-	448	1156	1661	1930	871	305	87	-
1989	28	21	20	18	18	144	1022	1722	1174	1413	569	32	6183
1990	22	15	12	11	59	777	2155	2148	1420	1405	118	24	8166
1991	19	16	15	13	68	348	1738	2323	1419	1314	495	34	7801
1992	23	20	18	19	17	32	1195	1461	887	1016	365	14	5068
1993	13	11	13	16	17	451	1625	1902	2211	-	-	-	-
1994	-	-	-	-	5	260	1245	1352	1228	641	49	9	-
1995	7	5	4	3	126	552	2129	1978	1534	1538	330	151	8358
1996	37	13	13	34	130	239	1608	2059	1656	1027	313	50	7179
1997	11	10	9	10	16	238	1599	2109	1470	1650	83	22	7228
1998	36	34	39	24	69	520	1584	1837	1789	630	240	38	6842
1999	35	33	29	28	65	602	1409	1796	1806	1014	834	186	7837
2000	39	29	26	23	61	664	1588	1499	1610	1073	184	48	6844
Average	23	18	17	19	51	404	1516	1851	1584	1158	306	55	7003

Bago River at Zaungtu (Unit: m3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1987	2	1	1	3	3	90	253	213	193	54	47	3	863
1988	1	1	1	2	6	96	173	179	61	82	53	15	670
1989	12	17	23	1	19	82	144	247	157	56	6	2	766
1990	1	1	1	1	110	275	352	361	263	75	13	3	1456
1991	1	1	1	1	1	42	213	306	78	34	14	3	695
1992	1	1	1	2	8	37	174	283	203	78	11	2	800
1993	1	0	0	0	3	109	96	257	160	14	2	1	644
1994	1	1	3	1	14	168	287	208	116	16	0	32	846
1995	0	0	0	0	16	128	229	146	182	7	11	2	721
1996	1	3	1	1	12	93	209	214	160	50	12	2	759
1997	1	1	1	1	4	106	219	327	157	46	4	2	868
1998	1	1	1	0	9	63	180	166	144	109	44	30	747
1999	7	1	1	1	40	112	162	324	236	84	10	1	979
2000	1	2	11	28	37	134	233	157	323	139	91	75	1231
Average	2	2	3	3	20	110	209	242	174	60	23	12	860



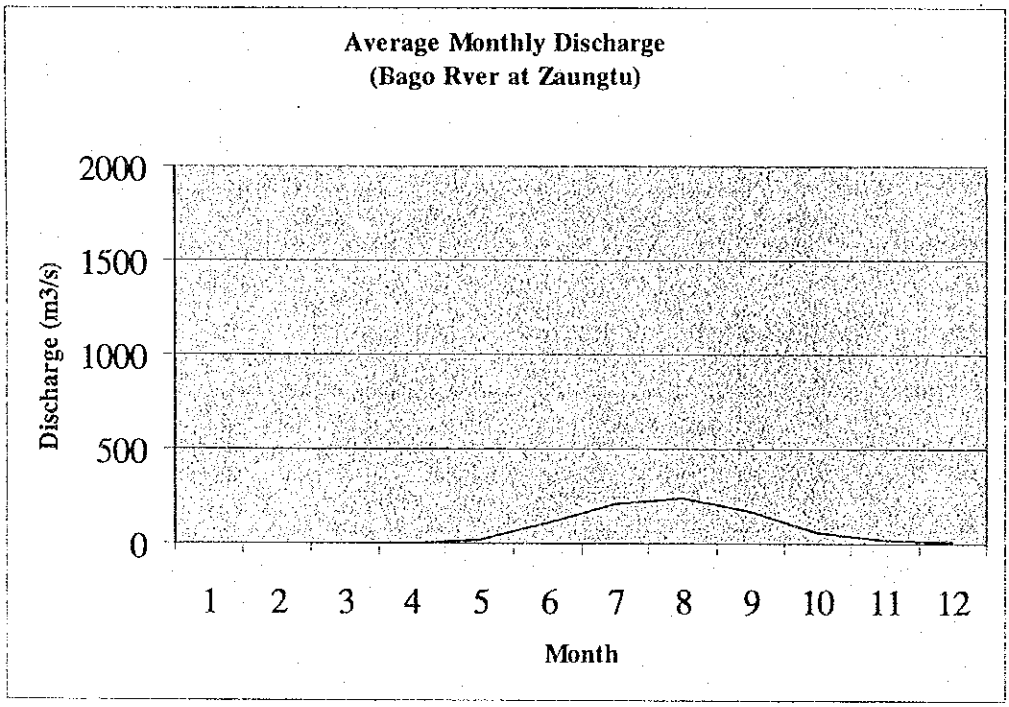


Figure A.11 Mean Monthly Flow Pattern

Table A.11 Monthly Flow Pattern (Max. and Min. Daily Discharge) (1)

Hlaing River at Khamonseik (Unit: m3/s)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	Max.	15	12	10	10	19	849	1507	2577	2429	2275	136	39	2577
	Min.	12	10	10	8	8	20	560	1481	1890	206	39	18	8
1988	Max.	18	16	-	47	-	693	1636	2000	2124	1203	923	140	-
	Min.	15	14	-	41	-	234	757	1305	1262	645	55	38	-
1989	Max.	35	24	21	19	22	515	1398	2260	1512	1927	1923	36	2260
	Min.	24	19	19	17	17	17	431	1017	955	1177	37	25	17
1990	Max.	25	18	13	11	305	1478	2272	2570	1757	1955	291	32	2570
	Min.	18	13	12	10	10	159	1626	1655	1122	311	33	20	10
1991	Max.	20	17	15	14	275	1050	2652	2631	2196	1558	1005	57	2652
	Min.	17	16	14	13	13	15	1082	2043	1137	1169	65	26	13
1992	Max.	25	21	19	41	36	139	1629	1680	1125	1668	1518	16	1680
	Min.	21	19	17	16	15	16	180	1139	790	590	17	13	13
1993	Max.	13	12	14	17	24	1041	2007	2320	2358	-	-	-	-
	Min.	12	11	11	14	15	27	1049	1650	1747	-	-	-	-
1994	Max.	-	-	-	-	8	916	1833	1564	1641	1014	182	11	-
	Min.	-	-	-	-	5	5	987	1131	1019	205	11	8	-
1995	Max.	8	5	5	4	574	1380	2390	2385	2124	2208	453	290	2390
	Min.	6	5	4	3	4	155	1435	1532	1082	530	209	65	3
1996	Max.	62	20	28	63	348	504	2277	2330	1927	1887	481	154	2330
	Min.	21	10	9	13	12	74	594	1858	1374	316	161	14	9
1997	Max.	14	11	10	13	32	653	2537	2472	2032	2752	283	22	2752
	Min.	11	10	9	8	8	9	675	1915	1059	328	22	21	8
1998	Max.	37	35	54	37	177	935	1946	1946	2133	958	841	40	2133
	Min.	35	34	32	11	38	187	1031	1733	986	415	40	37	11
1999	Max.	37	34	32	29	123	948	1731	1986	2026	1481	1102	435	2026
	Min.	34	32	28	27	28	147	1005	1609	1496	799	456	52	27
2000	Max.	45	33	27	24	385	1338	1806	1675	1833	1842	423	68	1842
	Min.	34	27	24	22	21	137	1255	1323	1469	442	71	39	21
Period	Max.	62	35	54	63	574	1478	2652	2631	2429	2752	1923	435	2752
	Min.	6	5	4	3	4	5	180	1017	790	205	11	8	3

Table A.12 Monthly Flow Pattern (Max. and Min. Daily Discharge) (2)

Bago River at Zaungtu (Unit: m3/s)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	Max.	5	2	1	56	13	362	622	741	554	242	216	5	741
	Min.	1	1	1	1	1	10	68	39	58	18	11	2	1
1988	Max.	2	1	1	18	41	381	538	535	266	507	490	17	538
	Min.	1	1	1	1	1	27	27	47	16	14	5	13	1
1989	Max.	13	26	24	1	79	264	580	623	605	188	16	4	623
	Min.	12	11	22	1	1	12	22	92	45	15	3	2	1
1990	Max.	1	2	1	1	544	970	765	1108	678	274	106	3	1108
	Min.	1	1	1	1	1	26	95	104	12	1	3	2	1
1991	Max.	2	1	1	1	3	119	708	652	278	143	177	24	708
	Min.	1	1	1	1	1	1	22	74	20	6	2	1	1
1992	Max.	2	2	1	13	51	173	495	1069	523	414	25	4	1069
	Min.	1	1	1	0	1	2	37	54	42	9	5	1	0
1993	Max.	1	1	0	0	42	624	334	648	752	140	14	1	752
	Min.	1	0	0	0	0	4	28	25	13	1	1	1	0
1994	Max.	1	1	63	1	61	987	1237	513	480	305	1	34	1237
	Min.	1	0	0	1	1	7	51	21	9	1	0	32	0
1995	Max.	0	0	0	0	174	385	684	593	790	32	108	4	790
	Min.	0	0	0	0	0	2	3	7	4	3	3	1	0
1996	Max.	1	19	1	15	78	462	933	623	890	259	47	17	933
	Min.	1	1	1	0	1	2	18	44	27	7	3	1	0
1997	Max.	1	1	1	1	33	586	869	1034	559	162	17	2	1034
	Min.	1	1	1	1	1	2	66	69	14	11	2	1	1
1998	Max.	1	1	1	1	54	214	510	371	434	419	117	44	510
	Min.	1	1	1	0	0	20	52	43	39	32	28	23	0
1999	Max.	21	1	1	3	382	305	299	722	317	145	57	1	722
	Min.	1	1	0	0	2	35	38	129	141	31	1	1	0
2000	Max.	1	4	43	41	56	258	527	287	951	289	107	113	951
	Min.	1	1	2	16	20	44	124	106	149	96	69	50	1
Period	Max.	21	26	63	56	544	987	1237	1108	951	507	490	113	1237
	Min.	0	0	0	0	0	1	3	7	4	1	0	1	0

(3) Long Term Discharge Fluctuation

Table A.13 shows the distinguishable period of wet and drought years to estimate the long term fluctuation of annual discharge. According to Table A.13, it is found that the river discharge fluctuation cycles repeat about 10 year at Khamonseik and the range from 2 to 3 years at Zaungtu.

Table A.13 Long Term Fluctuation of Annual Discharge (m3/s)

Station Name	Annual Mean Discharge	Annual Min. Discharge	Year Estimated Lower Annual Discharge	Period
Khamonseik (Hlaing River)	7003	5068(1992)	1989, 2000	1987-00
Zaungtu (Bago River)	860	670(1988)	1988, 1991, 1993, 1995, 1998	1987-00

5 SURFACE WATER RESOURCE

5.1 GENERAL

Study on surface water resources in and around the Yangon City area for formulating a future water supply plan to the Yangon City up to the Year 2010. The contents of the study are composed as follows;

(1) to review and estimate the present water resources for water supply by relevant reservoirs,
(2) in case of estimating the reservoir water source, especially, to consider the surplus water from spillway in the rainy season,
(3) to review the previous studies relevant to the water source in the Hlaing River basin, and
(4) to estimate the available water resources on the river direct intake type.

The present surface water sources for supply of water to the Yangon City are consisted of Gyobyu Reservoir, Phugyi Reservoir and Hlawga Lake Reservoir operated by YCDC, and Ngamoyeik Reservoir constructed by Irrigation Department. Furthermore, there are 8 reservoirs for irrigation purpose only of existing, under construction and stage of planning level managed by Irrigation Department around the Yangon City area.

In order to review and estimate the available water source of relevant reservoirs, the study is conducted at 5 reservoirs of Gyobyu Reservoir, Phugyi Reservoir, Hlawga Lake Reservoir Nagamoyeik Reservoir and Lagunbyin Reservoir because of considering the location, storage capacity and purposes of reservoir.

In addition, for the possible surface water source around the Yangon area, there are 2 river basins of Hlaing River and Bago River for water supply to Yangon City.

5.2 RESERVOIR WATER BALANCE STUDY

The water balance study is simulated the available water source for reservoirs on the basis of monthly runoff at each reservoir. According to accuracy and availability of observed data, simulation period adapted for the last 6 years (May 1995-Dec. 2000) because of covering the severe drought year of 1998 evaluated to correspond to that with a return period of 10 years.

(1) Simulation Premises

1) Runoff

Since there are no runoff data at the existing reservoirs for water supply to Yangon City, runoff is applied based on monthly runoff at Tabuhla Reservoir and Ngamoyeik Reservoir estimated by the actual daily operation analysis. Runoff has been derived from daily operation study considering actual daily outlet flow from reservoir by Irrigation Department at Tabuhla Reservoir and Ngamoyeik Reservoir, respectively. Monthly basis runoff for about 6 years from May 1995 to 2000 at Tabuhla Reservoir and June 1995 to 2000 at Nagamoyeik Reservoir are applied to the simulation.

In this estimation, the monthly runoff at the Key Stations, Tabuhla Reservoir and Ngamoyeik Reservoir are converted into those at the each reservoir by using annual rainfall and catchment area of the Key Stations and other reservoirs as follows;

$$Q_{site} = Q_{key} * (R_{site}/R_{key}) * (A_{site}/A_{key})$$

where,

Q_{site}, R_{site}, A_{site}: Monthly runoff, annual rainfall and catchment area at the project site, respectively.

Q_{key}, R_{key}, A_{key}: Monthly runoff, annual rainfall and catchment area at the Key station, respectively

Catchment area and Annual rainfall of the Key stations and project sites are shown in Table A.14. Because there are no rainfall records at Lagunbyin Reservoir completed in the beginning of rainy season of 2001, annual rainfall at Lagunbyin Reservoir is applied to be similar rainfall at Ngamoyeik Reservoir in this simulation.

Table A.14 Catchment Area and Hydrological Yearly Rainfall at each site

Key Station		Project Site		Hydrological Yearly Rainfall (mm)					
Name	Catchment Area (miles)	Name	Catchment Area (miles)	1995-96	1996-97	1997-98	1998-99	1999-00	2000
Tabuhla Reservoir	86.0	Tabuhla Reservoir	86.0	2155	2366	2114	1826	2801	2028
		Gyobyu Reservoir	12.7	2657	2204	2298	1736	2354	2228
		Phugyi Reservoir	27.27	2893	2498	2601	2020	2728	2549
		Hlawga Lake Reservoir	10.5	1789	2088	2082	1972	2231	1905
Ngamoyeik Reservoir	160.0	Ngamoyeik Reservoir	160.0	1966	2473	2596	1843	3027	2362
		Lagunbyin Reservoir	42.0	-	-	-	-	-	-

Note: Hydrological Year --- from May to April

" – " --- Not Available

2) Lake Evaporation Loss

Lake evaporation has been estimated at 80 percent of pan evaporation at Kaba Aye (Yangon) Meteorological Station in the water balance study due to the technical information of Irrigation Department.

3) Seepage loss

Seepage loss is composed of losses from reservoir bed and through dam body. This study, however, does not count such seepage loss in the study due to the technical information of Irrigation Department.

4) Area and Capacity Curves

Area and Capacity table and curves for reservoirs are prepared by YCDC and Irrigation Department.

5) Initial Storage Capacity

Simulation of water balance has been conducted from May and/or July 1995 to Dec 2000. Minimum storage capacity in the end of dry season from 1995 to 2000 is considered to be initial storage capacity in May and/or July 1995 as shown in Table A.15. Initial storage capacity is applied the average ratio of initial storage capacity on total storage capacity regarding Gyobyu, Phugyi and Hlawga Lake Reservoir.

Table A.15 Initial Storage Capacity at Each Site

Reservoir	Initial Capacity (acre-ft) applied for study by Irrigation Department	Water Level (ft) of the end of April, 1995	Min. Water Level (ft) and (Date) in last 6 years	Initial Storage Capacity (acre-ft)
Gyobyu	-	200' 7"	183' 2" (May 04, 1999)	24560 (184')
Phugyi	-	107' 4.25"	101' 4" (May 24, 1999)	39803 (102')
Hlawga Lake	-	51' 5.5"	48' 4.25" (May 19, 1998)	14400 (49')
Ngamoyeik	30199	72' 10" (Jun. 10, 1995)	80' 4" (Jun. 19, 1997)	30199 (87')
Lagunbyin	-	-	-	62500* (67')

Note: * 42% of total capacity (average ratio at Gyobyu, Phugyi and Hlawga Lake Reservoir)

6) Water Demand

For water supply to Yangon City the following monthly fluctuation of water demand is applied in water balance simulation as follows;

Table A.16 Monthly Fluctuation of Water Demand for Water Supply

No. of Case	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Average
Case-0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Case-1	1.2	1.2	1.2	1.2	1.2	1.2	0.8	0.8	0.8	0.8	0.8	0.8	1.0
Case-2	1.0	1.0	1.0	1.2	1.2	1.2	1.0	1.0	1.0	0.8	0.8	0.8	1.0
Case-3	1.0	1.0	1.0	1.2	1.2	1.2	1.2	1.0	0.8	0.8	0.8	0.8	1.0
Case-4	1.0	1.0	1.2	1.2	1.2	1.2	1.2	0.8	0.8	0.8	0.8	0.8	1.0
Case-5	1.0	1.0	1.0	1.3	1.3	1.3	0.9	0.9	0.9	0.8	0.8	0.8	1.0

Note: Case-5 for Phugyi Reservoir

For Irrigation water the following monthly of water demand for Ngamoyeik Reservoir and Lagunbyin Reservoir are applied in water balance simulation. The irrigation

demand has been carried out the analysis of actual daily reservoir operation by Irrigation Department from 1995 to 2000.

The irrigation demand for Lagunbyin Reservoir is presented by Irrigation Department as shown in Table A.17.

Table A.17 Irrigation Demand for Lagunbyin Reservoir

For 10000 acres

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Expected Irrigation Demand (acre-ft)	12350	17333	14975	13283	5350	-	-	-	-	-	-	-	63291

Source: Irrigation Department

Unit: acre-feet

For 22000 acres

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Expected Irrigation Demand (acre-ft)	27170	38133	32945	29223	11770	-	-	-	-	-	-	-	139241

Source: Irrigation Department

Unit: acre-feet

In order to release the supply of water (409500 m3/d (90 mgd)) to the Yangon City, the release plan of water supply for irrigation and urban purpose may have been proposed by Irrigation Department as shown in Figure A.12. In this simulation, the study is carried out to consider the aforesaid release plan for Ngamoyeik Reservoir and Lagunbyin Reservoir.

7) Safe Water Utilization Ratio

Safe water utilization ratio is to be designed to allow water shortage to occur in once 10 years for water supply to Yangon City.

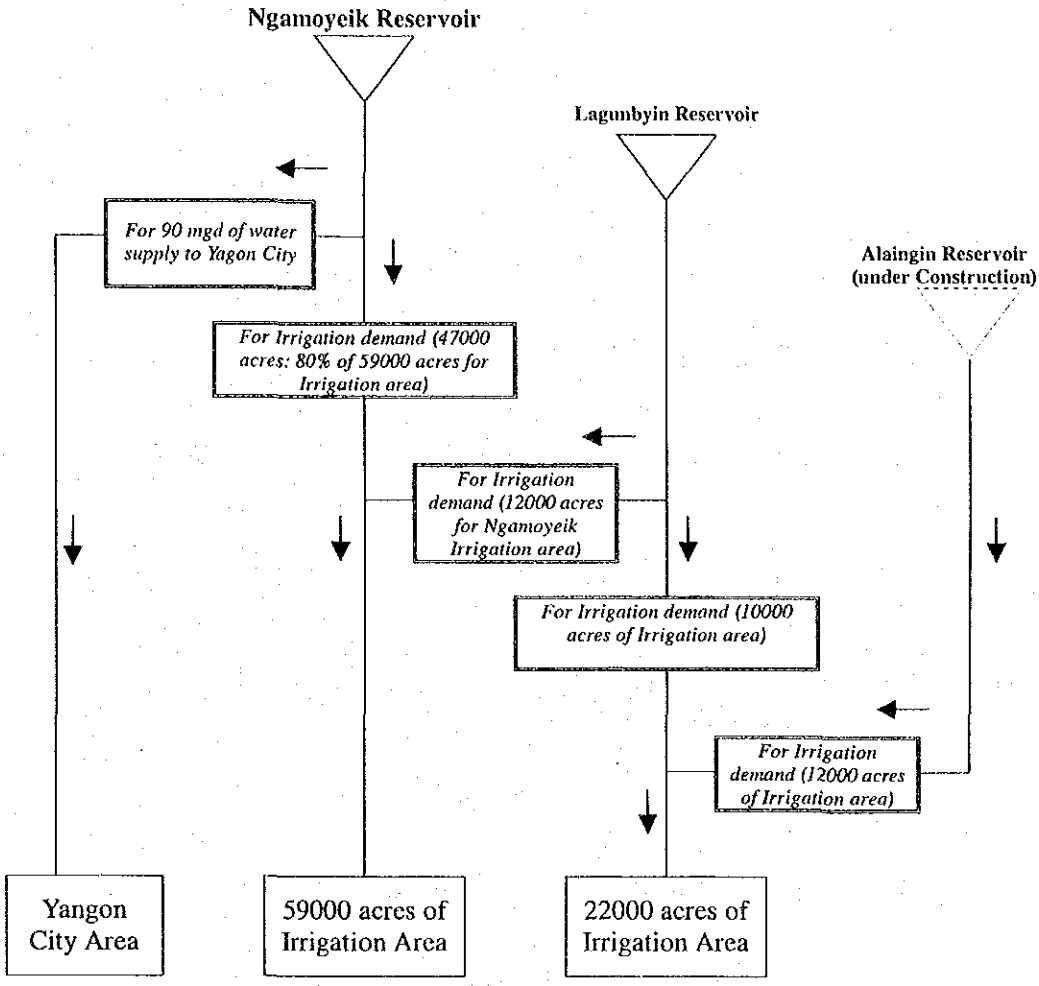


Figure A.12 General System Diagram Proposed by Irrigation Department

(2) Results of Water Balance Study

The results of above analysis for the water balance study are summarized in Table A.18. As seeing in Table A.18, available surface water for Yangon City is confirmed that the existing reservoirs could be developed as future water sources from 894075 m3/d (196.5 mgd) in Maximum to 869050 m3/d (191.0 mdg) in minimum.

Table A.18 Results of Reservoir Water Balance Study

Reservoir	Low Water Level (ft)	Water Demand m3 (MGD)	Calculated Lowest Water Level (ft)					
			Case-0	Case-1	Case-2	Case-3	Case-4	Case-5
Gyobyu	138.0	93275 (20.5)	187.87	191.27	189.54	189.60	190.18	-
		118300 (26.0)	173.35	178.02	175.96	176.03	176.76	-
Phugyi	90.0	245700 (54.0)	90.32	93.98	92.30	92.36	92.92	93.12
Hlawga Lake	47.0	75075 (16.5)	50.77	50.62	50.81	50.82	50.83	-
Ngamoyeik	81.0	409500 (90.0)	80.59	84.39	83.07	83.72	84.48	-
Lagunbyin	46.0	45500 (10.0)	46.33	47.75	47.22	47.26	47.55	-

Note: No. of Case

(reference to Table A.16 Monthly Fluctuation of Water Demand for Water Supply)

5.3 SURFACE WATER AVAILABILITY FOR RIVER DIRECT INTAKE

In Hlaing River basin there is a hydrological station at Khamonseik operated by Department of Meteorology and Hydrology. Although there are 2 hydrological station in Bago River basin at Bago and Zaungtu, Bago station has been excluded from one of the key stations because of the influence of tidal level during the January to mid-May and mid-October to December. Therefore, there are no observed records during the aforesaid period of each year at Bago station.

(1) Previous Study in Hlaing River Basin

There are 2 reports on the river flow measurement records for Hlaing River as follows;

- "Feasibility Report on Hlaing River Water Resource for Supply of Water to the City of Rangoon, March 1988), YCDC"
- "Hydrometric Survey of Hlaing River for Yangon City Water Supply, June 1992, Department of Meteorology and Hydrology" for "Final Feasibility Study Report on Hliang River Water Supply Project, March 1993"

According to the "1988 Report" flow discharge had been observed 105.4 m3/s (2000 MGD) at Zigon village (before it meets the Bawle River), and 63.2 m3/s (1200 MGD) at Gwedanshe (after it meets the Bawle River) in February 1988, respectively.

And according to the "1992 Report", the survey team of Department of Meteorology and Hydrology had carried out the hydrometric works of Hlaing River at Gwedanshe and Kyweku sites in April to May, 1992. The results of flow measurements are summarized as follows;

- The minimum rate of flow during the low tide period is estimated to be about 7.5 m3/s on 26th, April.
- The minimum mean rate of flow during the low tide period is about 63 m3/s on 27th, April.

As the results of above study, the flow discharge in Hlaing River are estimated as follows,

- In case of "1988 Report", since the observation were performed in February the flow rate was comparatively low and the rate of flow in rainy season is much higher than that in February. Therefore Hlaing River water source can adequately supply the amount of water that is required forYangon.
- In case of "1993 Report", the conclusion of hydrological Department stated that 2.64 m3/s (50 MGD) could be safely extracted from Hlaing River and the minimum discharge has been estimated at 7.5 m3/s.

However, as seeing in Table A.9, Table A.10 and Table A.11, the flow discharge of above study are evaluated to correspond to the high amount year of discharge during the dry season. Since the results of above study were consisted of including the amount of discharge influenced by tidal level effects, the results of flow measurements are evaluated the excessive amount discharge during the period of low flows.

Considering the above-mentioned and the physical condition of river basins, it should be necessary to design the weir for river direct intake plan to maintain the intake water level and the intake discharge in design drought year.

(2) Available Surface Water Source for River Direct Intake

Based on the results of river flow regime (refer to Table A.9), low flow discharge are

estimated at the prospective sites as shown in Table A.19.

As seeing in Table A.19, available river flow discharge in design drought year is estimated approximately from 4.3 m3/s in occurrence of failure of 1 time for 11 years to 11.4 m3/s in occurrence of failure of 2 times for 11 years at Gwedanshe in Hlaing River. Because its base flow is very poor in Bago River basin, river flow discharge is estimated approximately 1.3 m3/s in occurrence of failure of 7 times of 14 years at Bago Gauging Station.

Table A.19 Estimated Low Flow Discharge at the Prospective Sites

River	Site	C.A. (km2)	Low Discharge (275th daily discharge)			Drought Discharge (355th daily discharge)			Annual Min. Discharge		
			Mean	2/N	1/N	Mean	2/N	1/N	Mean	2/N	1/N
Hlaing	Khamonseik Gauging Stn.	5840	20	11	5	14	8	3	13	8	3
	Kungyangon	7960	27.3	15.0	6.82	19.1	10.9	4.09	17.7	10.9	4.09
	Gwedanshe	8290	28.4	15.6	7.10	19.9	11.4	4.26	18.5	11.4	4.26
	35km Point	8810	30.2	16.6	7.54	21.1	12.1	4.53	19.6	12.1	4.53
	25km Point	8990	30.8	16.9	7.70	21.6	12.3	4.62	20.0	12.3	4.62
Bago	Zaungtu Gauging Stn.	1927	3	0	0	1	0	0	1	0	0
	Bago Gauging Stn.	2580	4.02	-	-	1.34	-	-	1.34	-	-
	35km Point	2970	4.62	-	-	1.54	-	-	1.54	-	-
	30km Point	3220	5.01	-	-	1.67	-	-	1.67	-	-

Note:
C.A.: Catchment Area estimated by using map of 1:2,000,000 scale
N: No. of Records
1/N: Case of the occurrence of failure of 1 times for 11 years in Hlaing River, and case of the occurrence of failure of 1 times for 14 years in Bago River
2/N: Case of the occurrence of failure of 2 times for 11 years in Hlaing River, and case of the occurrence of failure 2 times for 14 years in Bago River