CHAPTER 5 HYDROLOGY

CHAPTER 5. HYDROLOGY

5.1 TUUL RIVER BASIN

5.1.1 Selenge and Tuul River Basins

Selenge River of which length is measured to be about 2,120km flows the northern part of Mongolia northward to Baikal Lake. Tuul River belongs to Orhon River system which is one of the major tributaries of Selenge River. As shown in Fig. II.5.1, Tuul River flows southward originating Hentii Range which is located in the east edge of Selenge River Basin. The flow changes its direction to west near Nalaih, and runs south of the Ulaanbaatar City area. The river changes its flow direction, and flows into Orhon River near Orhontuul. The total length and the catchment area of Tuul River are measured to be about 819km and 50,400km^2, respectively.

Fig. II.5.2 shows the river profile of Tuul River from the confluence with Orhon River to its most upstream. The river gradient in the upstream reach is as steep as 1/100, and gradually become milder to 1/5,000 near the confluence with Orhon River. Ulaanbaatar City is located in the middle reach of the river, about 650km far from Orhon River. There are tow(2) major tributaries in Tuul River Basin; Haruuh River and Terelj River.

Terelj River which flows into Tuul River east to Terelj town is the largest tributary in Upper Tuul River Basin. It shares 21% of catchment area of Upper Tuul River Basin which is considered to be upstream of the Zaisan Bridge in Ulaanbaatar City.

Tuul River system is located in the high mountain range that reaches the altitude over 2,000m. The vegetation of basin, therefore, varies from place to place depending on its altitude. Foothill zones along the rivers are considered low land which is covered mainly by the shallow root grass suitable for grazing cattle such as sheep, cows, horses and goats. The other higher mountain areas of which altitude is considered to be above the range between 1,400m and 1,800m are covered by forests consisting of a kind of cedar and beech, but such forest area expands only in northern side of the range due to difference of climate.

5.1.2 Upper Tuul River Basin

Upper Tuul River Basin is defined as the drainage area of Tuul River upstream of Tavantolgoi, of which catchment area is measured to be 7,312km^2. As shown in Fig. II.5.3, Upper Tuul River Basin consists of the following four (4) sub-basins.

- Terelj River Basin of which catchment area is measured to be 1,339km^2

- Upper Tuul River Subbasin upstream of the confluence of Terelj River of which catchment area is measured to be 2,740km^2
- Middle Tuul River Subbasin of the reach from Zaisan bridge to the confluence with Terelj River of which catchment area is measured to be 2,221km^2
- Lower Tuul River Subbasin of the reach from Tavantolgoi to Zaisan Bridge of which catchment area is measured to be 1,012km^2

The catchment areas of each subbasin are measured and summarized as shown in Table II.5.1. These subbasins are divided into the following three (3) categories depending on their altitude as shown in Fig. II.5.4.

- Areas of which altitude is less than 1,500m (Mean altitude is assumed to be 1,350m)
- Areas of which altitude is between 1,500m and 2,000m (Mean altitude is assumed to be 1,750m)
- Areas of which altitude is over 2,000m (Mean altitude is assumed to be 2,250m)

The area of each category is then measured subbasin by subbasin, and the average altitude of each subbasin is calculated as presented in Table II.5.2. The calculated average altitude of each subbasin is tabulated below.

Sub-basin	Average Altitude (m)
Upper Tuul River Sub-basin	1,864
Terelj River Basin	1,952
Middle Tuul River Sub-basin	1,689
Lower Tuul River Sub-basin	1,521
Whole Upper Tuul River Basin	1,780

5.2 RAINFALL ANALYSIS

5.2.1 Long Term Trend of Precipitation

Fig. II.5.5 shows the variation of the annual precipitation and surface runoff observed in Ulaanbaatar Station from 1936 to 1993 for precipitation and 1946 to 1993 for surface runoff together with those 5 year moving average values. The annual precipitation varies year by year with a range between 61mm in 1972 and 400mm in 1967. The 5 year average values indicate that the drought occurs with a cycle from 10 to 15 years and it continues for about 10 years once it starts. The surface runoff volume also seems to vary with the similar pattern to precipitation. The trend shown in the figure suggests that the precipitation seems to be decreased these five (5) years since 1988 and this decreasing tendency may continue some years in the future toward drought years of cycle.

5.2.2 Precipitation Pattern in the Basin

Correlation of precipitation is examined among the stations on monthly basis and those regression is worked out applying the precipitation records collected as tabulated below.

Meteorological Stations		Correlation Factor	Regression Equation
Ulaanbaatar	Terelj	0.94	R_{Terelj} = 1.4639 x $R_{Ulaanbaatar}$
Ulaanbaatar	Ih Surguuli	0.96	$R_{Surguuli}$ = 1.0311 x $R_{Ulaanbaatar}$
Ulaanbaatar	Tahilt	0.94	R_{Tahilt} = 1.0417 x $R_{Ulaanbaatar}$

The above correlation is plotted in Fig. II.5.6. Since the calculated correlation factors indicate the values over 0.90, it is considered that the precipitation patterns in Upper Tuul River Basin is almost uniform on monthly basis.

5.2.3 Precipitation and Altitude

As described in the previous section, the precipitation varies place to place depending upon the altitude of such site that the respective meteorological station is located. The mean annual precipitation observed at the stations in and around Upper Tuul River Basin are plotted as shown in Fig. II.5.7, and the following regression is worked out among these precipitation.

[Altitude] = 774.11 x exp(0.0018 x [Precipitation])

Based on the above equation, the annual precipitation of each elevation category that is mentioned in the previous section is calculated as presented below.

Elevation Range	Annual Precipitation (mm)	Referred Elevation (m)
Less than 1,500m	309	1,350
1,500m - 2,000m	453	1,750
More than 2,000m	593	2,250

5.2.4 Annual Precipitation Pattern of Upper Tuul River Basin

The annual precipitation patterns are calculated for each subbasin in Upper Tuul River Basin applying and above estimated elevation wise precipitation and the area distribution in the basin mentioned in Table II.5.2 as summarized below.

(Unit: mm)

Sub-basin	Month												Total
	Jan.	Feb.	Mar.	Apr.	May	[redacted]			Sep.	Oct.	Nov.	Dec.	
Upper Tuul	1.4	3.7	4.6	15.4	23.7	86.5	154.9	121.2	50.8	12.9	8.3	4.5	488.0
Middle Tuul	2.6	3.3	4.3	13.4	25.1	86.3	122.9	104.2	50.1	11.5	6.8	3.6	434.0
Terelj	1.5	3.9	4.9	16.3	25.0	91.1	163.2	127.7	53.5	13.6	8.7	4.7	514.0
Lower Tuul	2.2	2.9	3.7	11.6	21.7	74.6	106.2	90.0	43.3	10.0	5.8	3.1	375.0

The above patterns are presented in Fig. II.5.7.

5.2.5 Probability Analysis

(1) Annual Precipitation

The frequency curve of annual precipitation recorded at Ulaanbaatar Station is drawn as shown in Fig. II.5.8, and the probable values of annual precipitation are worked out for various return periods with the Iwai Method as stated below.

Return Period	Probable Precipitation (mm)	
	Exceeding	Non exceeding
2-year	233.8	233.8
5-year	308.7	177.1
10-year	356.9	153.2
20-year	402.4	135.9
100-year	503.9	108.5
1000-year	648.4	84.3

(2) Precipitation of 1993

As shown in Fig. II.5.8, the precipitation of 1993 measured to be 271.9mm is considered those observed in ordinary years, since its occurrence is calculated to be about 33% and 67% for non exceeding and exceeding conditions, respectively.

5.3 RUNOFF ANALYSIS

5.3.1 Characteristics of Surface Runoff

(1) Seasonal Variation of River Discharge

The daily mean discharges of Terelj and Ulaanbaatar Stations from 1972 to 1991 and the monthly mean discharges of the Ulaanbaatar Station from 1946 to 1971 are collected for the study. The average monthly discharges are calculated based on those data as tabulated below.

Station	Average Monthly Discharge (Unit: m^3/s)												
	Jan.	Feb.	Mar.	Apr.	May	[redacted]			Sep.	Oct.	Nov.	Dec.	Ave.
Terelj	0.01	0.00	0.13	2.28	9.42	15.03	23.38	24.63	16.19	7.36	1.59	0.26	8.36
Ulaanbaatar	0.03	0.03	0.42	6.72	33.32	49.01	85.32	88.02	55.62	17.49	4.41	0.52	28.41

The average annual discharges are calculated to be $8.36m^3/s$ and $28.41m^3/s$ for Terelj and Ulaanbaatar Stations, respectively, and the average specific discharges are calculated to be $6.85l/s/km^2$ for Terelj Station and $4.51l/s/km^2$ for Ulaanbaatar Station. The discharge reaches a peak in July or August, and the most flood discharges are recorded in these tow (2) months. The river flow at Terelj Station is frozen at the end of December or the beginning of January, while that at Ulaanbaatar is frozen in January normally. After winter season the frozen river flow is melted and in March or May the flow starts gradually increasing its discharge toward the rainy season from July to August. Generally in the upstream of Tuul River basin, it is understood that the freezing of river flow starts when the air temperature becomes below zero (0) degree centigrade constantly. Such temperature value that makes water frozen depends on contents of water such as minerals etc. The seasonal variation of discharges in Terelj and Ulaanbaatar Stations are illustrated in Fig. II.5.9.

The maximum and minimum of daily mean discharges are also worked out based on the collected daily mean discharge data as presented below.

Station	Maximum and Minimum Daily Mean Discharge (Unit: m^3/s)											
	Jan.	Feb.	Mar.	Apr.	May	[redacted]			Sep.	Oct.	Nov.	Dec.
Maximum Daily Mean Discharge												
Terelj	0.76	0.09	6.45	37.5	121.0	338.0	190.0	155.0	157.0	21.5	9.64	3.20
Ulaanbaatar	0.76	0.73	15.30	134.0	406.0	618.0	721.0	498.0	565.0	131.0	19.60	35.00
Minimum Daily Mean Discharge												
Terelj	0.00	0.00	0.00	0.00	0.00	0.26	0.42	3.41	2.26	0.76	0.07	0.00
Ulaanbaatar	0.00	0.00	0.00	0.00	1.57	3.19	3.45	6.84	5.20	2.12	0.00	0.00

The recorded maximum daily mean discharges reach 721.0m^3/s and 338.0m^3/s, in Ulaanbaatar and Terelj Stations, respectively, while the minimum discharges during the rainy season reach only 6.84m^3/s and 3.41m^3/s, respectively.

(2) Long Term Runoff Characteristics

Fig. II.5.5 shows the annual runoff volume having been observed at Ulaanbaatar Station since 1946. The average annual volume of runoff is calculated to be 903.1 million m^3, and its 5-year moving average indicates that the runoff volume has changed so far with the fluctuation almost similar to that of the annual rainfall.

It is, however, found that the runoff coefficients varies widely from 0.1 to 0.9 year by year, and especially in 1973, 1974 and 1993 those values are considered high as indicated in Fig. II.5.5. The relationship between accumulated annual precipitation and runoff presented in Fig. II.5.10 also suggests same phenomenon. Fig. II.5.11 presents some examples of annual rainfall patterns observed at Ulaanbaatar Station representing other ordinary years including those of 1973, 1974 and 1993. The rainfall distribution of 1975, 1976, 1978 and 1980 is quite different form that of 1973, 1974 and 1993. In the years when most of the precipitation concentrates to the wet season, runoff coefficients are considered to become high because the soils in the basin is saturated and most of precipitation is considered to be drained as surface runoff directly.

(3) Flow Duration Curve

Fig. II.5.12 shows the flow duration curves worked out based on the collected 20 year daily mean discharges for Terelj and Ulaanbaatar Stations. The daily mean discharge varies from 0m^3/s to 659.00m^3/s in Ulaanbaatar Station and from 0m^3/s to 338.00m^3/s in Terelj

Station. The following table shows the discharges of respective percent of time in both stations which are read in the above table.

(Unit: m^3/s)

Station	Percent of Time								
	10	20	30	40	50	60	70	80	90
Terelj	27.6	19.3	14.3	10.0	8.5	7.0	5.4	3.7	1.8
Ulaanbaatar	90.0	51.0	31.0	21.0	12.3	8.7	6.5	4.2	2.1

5.3.2 High Flow Analysis

Since no record is provided for estimating peak flood discharge, annual maximum of daily mean discharge is worked out for Ulaanbaatar Station from 1972 to 1993 as shown below.

(Unit: m^3/s)

Year	Annual Max.	Year	Annual Max.
1972	108	1983	568
1973	659	1984	345
1974	370	1985	618
1975	406	1986	309
1976	159	1987	227
1977	246	1988	565
1978	218	1989	170
1979	172	1990	475
1980	83.2	1991	406
1981	110	1992	397
1982	327	1993	721

Based on the above values the probable flood discharge is calculated for Ulaanbaatar Station employing Iwai Method, and the calculated flood discharge are converted to those of the proposed dam site taking the proportional amount to the catchment area. Fig. II.5.13 shows the plotted maximum discharges.

Since the actual peak flood is considered larger than the daily mean values, some actual records are collected intermittently for the floods occurred in August 1994 and daily mean values and actual records are plotted as shown in Fig. II.5.14. The maximum difference of the actual discharge from the daily mean is calculated to be about 15%. Therefore, 30% of increase is considered for estimating the peak flood discharge as stated below.

(Unit: m³/sec)

Return Period	Ulaanbaatar Station (6,300 km²) Calculated Value	Ulaanbaatar Station (6,300 km²) Proposed Value*	Proposed Dam Site (6,098 km²)
500-year	1,781	2,315	2,241
200-year	1,474	1,917	1,855
100-year	1,261	1,640	1,587
50-year	1,064	1,383	1,338
40-year	1,003	1,304	1,262
30-year	927	1,205	1,167
25-year	880	1,144	1,108
20-year	824	1,071	1,037
10-year	656	853	826
5-year	499	648	627
4-year	449	584	565
3-year	386	501	485
2-year	295	383	371

Note: *: 30% of the calculated value is added.

5.3.3 Low Flow Analysis

Annual runoff volume is calculated for the period from 1946 to 1993 based on the monthly mean records, and probable drought runoff volume is worked out for Ulaanbaatar Station by Iwai method as plotted in Fig. II.5.15. Applying the average distribution pattern the monthly drought runoff volume is calculated, and these calculated values are converted to the monthly mean discharge. The drought discharge for the proposed dam site is calculated taking the proportional values to the catchment areas. The results of these calculation is summarized below.

Items	Month												Total/ Average
	Jan.	Feb.	Mar.	Apr.	May	[redacted]			Sep.	Oct.	Nov.	Dec.	
1. Station: Ulaanbaatar, 6,300 km²													
1.1 Volume (MCM)													
2-year	0	0	1	15	75	107	192	198	121	39	10	1	759
5-year	0	0	0	8	39	55	99	102	62	20	5	1	464
10-year	0	0	0	3	15	22	39	40	25	8	2	0	358
1.2 Discharge (m³/sec)													
2-year	0.02	0.03	0.35	5.65	28.01	41.19	71.71	73.98	46.75	14.70	3.71	0.44	23.88
5-year	0.01	0.01	0.18	2.90	14.38	21.15	36.82	37.98	24.00	7.55	1.90	0.22	12.26
10-year	0.00	0.01	0.07	1.15	5.71	8.39	14.61	15.07	9.53	3.00	0.76	0.09	4.87
2. Station: Proposed Dam Site, 6,098 km²													
2.1 Volume (million m³)													
2-year	0	0	1	14	73	103	186	192	117	38	9	1	735
5-year	0	0	0	7	37	53	95	98	60	20	5	1	449
10-year	0	0	0	3	15	21	38	39	24	8	2	0	347
2.2 Discharge (m³/sec)													
2-year	0.02	0.02	0.34	5.46	27.11	39.87	69.41	71.61	45.25	14.23	3.59	0.42	23.11
5-year	0.01	0.01	0.18	2.81	13.92	20.47	35.64	36.77	23.23	7.31	1.84	0.22	11.87
10-year	0.00	0.00	0.07	1.11	5.52	8.12	14.14	14.59	9.22	2.90	0.73	0.09	4.71

CHAPTER 6 SURFACE WATER BALANCE IN UPPER TUUL RIVER BASIN

CHAPTER 6. SURFACE WATER BALANCE IN UPPER TUUL RIVER BASIN

6.1 HYDROLOGICAL CYCLE OF UPPER TUUL RIVER BASIN

The circulation of water between the atmosphere and the land is termed the hydrological cycle. As illustrated in Fig. II.6.1, in Upper Tuul River Basin, water enters in the basin by precipitation such as snowfall and rainfall. The snow packed during the winter season from November to February gradually releases moisture to aquifer and streams as it melts especially in the spring season of April and May. Some of water infiltrates and percolates into the bedrock and alluvium, and stored as bank storage. The rest of water flows along the valley as surface runoff, and is gathered forming the flow of Tuul River. The groundwater flows from basement rock through alluvium or directly into streams when the streams are not swollen by snow melt or storm runoff.

The precipitation in the basin reaches to maximum in August, and more than 70% of precipitation occurs in the months from June to August. The maximum surface flow is recorded in this period usually. The surface runoff of this period is considered to be formed by mainly rainfall. Substantial volume of water is transpired and evaporates in the basin.

The surface water is diverted for irrigation in some parts of the basin, but its volume is considered negligibly small comparing with the total volume of precipitation. Ulaanbaatar City takes the municipal water pumping up from the alluvium deposit near the city area.

6.2 ELEMENTS TO BE CONSIDERED IN THE WATER BALANCE STUDY

The hydrological cycle described in the previous section is expressed with the following equation.

$$P = R + E + G + U + ST$$

where; P : Precipitation
R : Surface runoff
E : Evapotranspiration
G : Groundwater runoff
U : Utilized water
ST : Stored water in the Basin

Further, the stored water mentioned above is considered to be accumulated as stated below.

$ST_n = ST_{n-1} + ST$

where; ST_n : Total stored volume accumulated in the basin in nth. year

ST_{n-1} : Total stored volume accumulated in the basin in n-1th. year

ST : Stored water volume in nth. year

All the above elements are considered in the water balance study, and details are explained below.

6.2.1 Precipitation

To generate the series of precipitation for the Upper Tuul River Basin accurately, the following conditions are considered.

- The average precipitation patterns of Terelj Station could be applied for generating those of Upper Tuul River Subbasin and Terelj River Basin.
- The average precipitation patterns of Ulaanbaatar Station could be applied for generating those of Middle Tuul River Subbasin and Lower Tuul River Subbasin.

The annual precipitation of each subbasin in Upper Tuul River Basin is set as discussed in Subsection 5.2. This annual precipitation is compared with those observed in Terelj and Ulaanbaatar Stations, the relationship is worked out as stated below.

Name of Sub-basin	Calculated Annual Precipitation (mm) (A)	Average Annual Precipitation in Terelj or Ulaanbaatar Sta. (mm) (B)	Coefficient (A/B)
Upper Tuul Sub-basin	488.0	396.7 (Terelj)	1.23
Middle Tuul Sub-basin	434.0	242.7 (Ulaanbaatar)	1.79
Terelj River Basin	514.0	396.7 (Terelj)	1.30
Lower Tuul Sub-basin	375.0	242.7 (Ulaanbaatar)	1.55

The precipitation of each sub-basin (P) is generated applying the following equations.

- $P_{Upper\ Tuul} = P_{Terelj} \times 1.23$
- $P_{Middle\ Tuul} = P_{Ulaanbaatar} \times 1.79$
- $P_{Terelj\ River} = P_{Terelj} \times 1.30$
- $P_{Lower\ Tuul} = P_{Ulaanbaatar} \times 1.55$

The precipitation for the overall Upper Tuul River Basin is calculated taking weighted average of the above precipitation considering the catchment areas of each subbasin.

6.2.2 Evapotranspiration

The evapotranspiration is estimated for both Ulaanbaatar and Terelj Stations as described in Subsection 4.3, and the annual values are plotted as shown in Fig. II.5.7 to grasp the relationship with altitude. Same manner as precipitation is employed to calculate the evapotranspiration of each subbasin in Upper Tuul River Basin, and the following results are obtained.

Name of Subbasin	Calculated Annual Evapotranspiration (mm) (A)	Average Annual Evapotranspiration in Terelj or Ulaanbaatar Sta. (mm) (B)	Coefficient (A/B)
Upper Tuul Subbasin	228.0	574.7 (Terelj)	0.40
Middle Tuul Subbasin	415.0	867.4 (Ulaanbaatar)	0.48
Terelj River Basin	134.0	575.7 (Terelj)	0.23
Lower Tuul Subbasin	595.0	867.4 (Ulaanbaatar)	0.69

Note: The following relationship is obtained.

- $P_{Upper\ Tuul} = P_{Terelj} \times 0.40$
- $P_{Middle\ Tuul} = P_{Ulaanbaatar} \times 0.48$
- $P_{Terelj\ River} = P_{Terelj} \times 0.23$
- $P_{Lower\ Tuul} = P_{Ulaanbaatar} \times 0.69$

6.2.3 Surface Runoff

Surface runoff of the basin is considered as the discharge observed at the downstream end of the basin. In Upper Tuul River Basin, the discharge of Ulaanbaatar Station is taken for the study.

6.2.4 Utilized Water

The is no major water utilization found in Upper Tuul River Basin except for the domestic water supply for Ulaanbaatar City area, of which present and future demand is set as listed below.

(ton/day)

Existing and Possible Water Source Sites	Water Demand		Remarks
	Present	Future (2010)	
1. Existing Water Source			
Upper Water Source	25,000	90,000	Upstream of Zaisan Bridge
Central Water Source	100,000	114,300	Upstream of Zaisan Bridge
Industrial Water Source	41,000	41,000	
Meat Complex Water Source	13,000	13,000	
Power Plant Water Source	50,300	83,000	
Sub-total	229,300	341,300	
2. Possible Water Source			
Lower Part of Nalaih	0	40,000	Upstream of Zaisan Bridge
Buheg	0	0	
Lower Part of Power Plant	0	83,000	
Ulaan Hujiriin Bulan	0	0	
Ulahiin Bulan	0	0	
North of Ulaanbaatar City	0	0	
Holiin River	0	0	
Sub-total	0	123,000	
Total	229,300	464,300	

Based on the above demand, the following annual and monthly demands are calculated for the water balance calculation.

(Unit: million m^3)

Items	Upper Tuul River Basin (6,300km²)		River Basin Covering Whole Water Source Area (9,650km²)	
	Present	Future	Present	Future
Annual Demand	46	90	84	170
Monthly Demand	3.8	7.4	6.9	14.0

6.3 SURFACE WATER BALANCE AND AVAILABLE WATER SOURCE IN THE BASIN

Applying the above-explained parameters, the preliminary water balance of Upper Tuul River Basin is worked out both for monthly and annual basis. The results of such balance calculation are discussed below.

6.3.1 Annual Balance

The annual surface water balance of Upper Tuul River Basin is examined applying the annual record from 1946 to 1993 as shown in Table II.6.1 and Fig. II.6.2, and the average values of each parameter are summarized below.

(Unit: million m^3)

Items	Precipitation (1)	Runoff (2)	Evapotranspiration (3)	Present Water Demand (4)	Recoverable Volume (5)	Future Water Demand (6)	Balance (7)
- Balance at Ulaanbaatar Station (C.A. = 6,300km²)	2,836	883	1,726	46	182	44	138
- Specific Value per km²	0.45	0.14	0.27	-	-	-	-
- Balance for all the basin (C.A. = 9,650km²)	4,344	1,352	2,644	84	264	86	178

Note: (5) = (1) - (2) - (3) - (4)
(7) = (5) - (6)

As seen in the above table, in the catchment area upstream of the Zaisan Bridge of which catchment area is measured to be about 6,300km², out of the annual precipitation of 2,836 million m^3, 883 million m^3, 1,726 million m^3 and 46 million m^3 flow out of the basin due to surface runoff, evapotranspiration and domestic water supply, respectively, and 182 million m^3 of water is left for the future increase of water utilization. Since the future incremental utilization is estimated in about 44 million m^3, the rest of water source is expected to be about 138 million m^3.

As for the catchment area covering whole of the expected water source areas, its balance is estimated applying specific values of catchment areas as shown in the above table. About 264 million m^3 of water is expected to be left for the future increase of water utilization, and about 178 million m^3 of water is still available even after deducting 86 million m^3 of the future utilization.

6.3.2 Seasonal Variation of Surface Water Balance

The parameters considered in the water balance study vary year by year depending upon the climate condition, and incoming and outgoing water volumes are not balanced sometimes on annual basis because of the storage effect of the basin. Some of precipitation may be stored in the alluvium in the basin for some years, and contributes to the water balance a few years later.

A water balance calculation is conducted for the basin upstream of Zaisan Bridge (Catchment area: 6,300km^2) from 1986 to 1993 on monthly basis to grasp the seasonal (monthly) variation of water balance in the basin. The results of calculation is presented in Table II.6.2 and Fig. II.6.3, and summarized below.

(Catchment Area: 6,300km^2) (Unit: million m^3)

Items	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Precipitation (1)	11.0	23.7	32.6	85.2	141.1	526.9	926.6	812.7	371.3	79.8	56.5	27.3
Surface Runoff (2)	0.0	0.0	0.1	11.0	112.7	110.6	342.0	344.2	271.1	63.6	14.9	2.0
Evapotranspiration (3)	0.0	5.1	44.4	96.3	239.1	340.7	374.3	316.8	216.7	74.8	17.8	0.0
Domestic Water Supply (4)	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Recoverable Volume (5)	7.2	14.8	-15.7	-25.9	-214.5	71.8	206.5	147.9	-120.3	-62.4	20.0	21.5
Future Water Demand (6)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Balance (7)	3.6	11.2	-19.3	-29.5	-218.1	68.2	202.9	144.3	-123.9	-66.0	16.4	17.9
										Total of Balance:		7.7

Note: (5) = (1) - (2) - (3) - (4)
(7) = (5) - (6)

Deficit occurs in the months from September to October and from March to May. The former is considered to be caused by delayed runoff during the wet season from June to August, and the later by melting of the snow which is packed during the winter season from November to February

Based on the above results, the water balance of the whole basin is worked out including all the expected water source areas, of which catchment area is measured to be 9,650km^2 as summarized below.

(Catchment Area: 9,650km^2) (Unit: million m^3)

Items	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Precipitation (1)	16.8	36.3	49.9	130.5	216.1	807.1	,419.3	,244.9	568.7	122.2	86.5	41.8
Surface Runoff (2)	0.0	0.0	0.2	16.8	172.6	169.4	523.9	527.2	415.3	97.4	22.8	3.1
Evapotranspiration (3)	0.0	7.8	68.0	147.5	366.2	521.9	573.3	485.3	331.9	114.6	27.3	0.0
Domestic Water Supply (4)	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
Recoverable Volume (5)	9.9	21.6	-25.2	-40.7	-329.6	108.9	315.2	225.5	-185.4	-96.7	29.5	31.8
Future Water Demand (6)	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
Balance (7)	2.8	14.5	-32.3	-47.8	-336.7	101.8	308.1	218.4	-192.5	-103.8	22.4	24.7
										Total of Balance:		-20.4

Note: (5) = (1) - (2) - (3) - (4)
(7) = (5) - (6)

As seen in the above table, seasonal variation of the balance is considered similar to that worked out for the basin upstream of Zaisan Bridge. The total of balance for the whole basin, however, indicates negative value (-20.4 million m^3), which suggests that some deficit is caused in the annual water balance. As seen in Fig. II.6.2, this calculation is conducted for the period from 1986 to 1993 which is regarded as the last eight (8) years that is considered a drought period in the long term balance calculation from 1946 to 1993. Therefore, the deficit volume of this eight (8) years is expected to be settled by the surplus storage which has been accumulated in the basin before 1986. Since the long term balance calculation results that 178 million m^3 of the balance is still available in average after deducting the future water demand as mentioned in the foregoing subsection, such deficit that is caused by imbalance in annual water balance calculation is considered to be settled by the storage volume having been accumulated before that drought period.

6.3.3 Buheg Subbasin

Buheg River flowing northwestward to Tuul River is one of the tributaries of Tuul River, and its catchment area is measured to be about 1,621kkm^2. It is considered necessary to examine the water balance of this subbasin in order to confirm the availability of water in the subbasin in addition to the overall balance study. The following table shows the results of calculation.

(Unit: million m^3)

Items	Precipitation (1)	Runoff (2)	Evapo-transpiration (3)	Present Water Demand (4)	Recoverable Volume (5)
- Buheg Sub-basin (C.A. = 1,621km^2)	729.7	227.2	444.1	0.0	58.4

Note: (5) = (1) - (2) - (3) - (4)

As shown in the above table, the volume of 58.4 million m^3/year is expected to be available for the further water resources development in the subbasin.

Table II.2.1 List of Meteo-hydrological Stations in and around Upper Tuul River Basin

(Meteorological Stations)

Location	Year of Establishment	Altitude (m)	Observation Item
1. Ulaanbaatar (Airport)	1936	1,266.5	Temperature, rainfall, humidity, air pressure, wind and sunshine hours
2. Tahilt	1979	1,300.0	Temperature, rainfall, humidity, air pressure, wind and sunshine hours (Evaporation)
3. Terelj	1986	1,540.0	Temperature, rainfall, humidity, air pressure, wind and sunshine hours
4. Ih Surguuli	1982	1,300.0	Temperature, rainfall, humidity, air pressure, wind and sunshine hours
5. Batsumber	1974	1,200.0	Rainfall and temperature
6. Altanbulag	1979	1,210.0	Rainfall and temperature
7. Erdene	1974	1,550.0	Rainfall and temperature
8. Mungunmorit	1974	1,000.0	Rainfall and temperature

(Hydrological Stations)

Location	River	Year of Establishment	Catchment Area (km^2)	Observation Item
1. Bosgin	Tuul River	1985	2,158	Water level
2. Terelj Resort	Terelj River	1969	1,220	Water level and river discharge
3. Ulaanbaatar (Zaisan Br.)	Tuul River	1945	6,300	Water level and river discharge
4. Selbe Resort	Selbe River	1993	34	Water level and river discharge
5. Uliastai Farm	Uliastai River	1989	300	Water level and river discharge
6. Ondershireet	Tuul River	1981	18,427	Water level and river discharge

Table II.3.1 Summary of Rainfall and Discharge Observation Results

(1) Rainfall Observation Results

(Unit: mm)

Items	1993 Sep.	1993 Oct.	1993 Nov.	1993 Dec.	1994 Jan.	1994 Feb.	1994 Mar.	1994 Apr.	1994 May	1994 Jun.	1994 Jul.	1994 Aug.	1994 Sep.	1994 Oct.
Terelj Station*														
Total	0.0	0.0	-	-	-	-	-	-	1.5	82.5	94.0	172.5	87.0	6.0
Max.	0.0	0.0	-	-	-	-	-	-	1.5	15.5	17.5	41.0	22.0	2.5
Min.	0.0	0.0	-	-	-	-	-	-	1.5	0.5	0.5	0.5	1.5	0.5
Selbe Station**														
Total	4.5	0.0	-	-	-	-	-	-	11.5	73.0	77.0	214.0	51.0	2.5
Max.	3.0	0.0	-	-	-	-	-	-	3.5	11.5	12.0	28.5	22.5	2.5
Min.	1.5	0.0	-	-	-	-	-	-	0.5	0.5	0.5	1.0	1.0	2.5
Tahilt Station***														
Total	3.5	0.0	0.0	-	-	-	-	-	2.5	54.0	50.5	153.5	63.5	3.5
Max.	3.0	0.0	0.0	-	-	-	-	-	1.5	11.5	12.0	28.5	16.5	2.5
Min.	0.5	0.0	0.0	-	-	-	-	-	1.0	0.5	0.5	0.5	0.5	1.0

Note: * : Summed amount from Sep. 19 to 30 is taken for that of September 1993.
Summed amount from Oct. 1 to 24 is taken for the month of October 1993.
Summed amount from May 14 to 31 is taken for the month of May 1994.
Summed amount from Oct. 1 to 19 is taken for the month of October 1994.
** : Summed amount from Sep. 19 to 30 is taken for that of September 1993.
Summed amount from Oct. 1 to 26 is taken for the month of October 1993.
Summed amount from May 14 to 31 is taken for the month of May 1994.
Summed amount from Oct. 1 to 14 is taken for the month of October 1994.
*** : Summed amount from Sep. 18 to 30 is taken for that of September 1993.
Summed amount from Nov. 1 to 4 is taken for the month of November 1993.
Summed amount from May 13 to 31 is taken for the month of May 1994.
Summed amount from Sep. 1 to 6 is taken for the month of September 1994.
The observation was not conducted due to cold weather from Oct. 25, 1993 to May 13, 1994 for Terelj Station, from Oct. 27, 1993 to May 13, 1994 for Selbe Station, and from Nov. 5, 1993 to May 12, 1994 for Tahilt Station, respectively.

(2) Discharge Observation Results

(Unit: m^3/s)

Items	1993 Sep.	1993 Oct.	1993 Nov.	1993 Dec.	1994 Jan.	1994 Feb.	1994 Mar.	1994 Apr.	1994 May	1994 Jun.	1994 Jul.	1994 Aug.	1994 Sep.	1994 Oct.
Gachuurt Station (5,397 km2)*														
Mean	79.9	22.3	7.5	0.6	0.3	0.3	0.9	2.9	3.2	21.4	80.8	212.6	179.6	35.7
	14.8	*4.1*	*1.4*	*0.1*	*0.1*	*0.1*	*0.2*	*0.5*	*0.6*	*4.0*	*15.0*	*39.4*	*33.3*	*6.6*
Max.	102.4	47.8	12.7	2.4	0.4	0.3	1.9	3.9	4.6	98.0	137.2	419.0	393.1	59.2
	19.0	*8.9*	*2.4*	*0.4*	*0.1*	*0.1*	*0.3*	*0.7*	*0.9*	*18.2*	*25.4*	*77.6*	*72.8*	*11.0*
Min.	50.6	13.0	1.0	0.4	0.3	0.3	0.3	1.9	2.0	2.0	46.4	76.8	55.6	20.4
	9.4	*2.4*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.4*	*0.4*	*0.4*	*8.6*	*14.2*	*10.3*	*3.8*
Tavantolgoi Station (7,312 km2)**														
Mean	210.5	47.0	18.6	3.7	1.3	2.2	3.4	5.3	9.8	42.0	81.6	410.3	266.6	29.4
	28.8	*6.4*	*2.5*	*0.5*	*0.2*	*0.3*	*0.5*	*0.7*	*1.3*	*5.8*	*11.2*	*56.1*	*36.5*	*4.0*
Max.	390.0	85.0	24.6	12.3	1.7	2.6	4.3	6.3	14.2	172.2	222.0	771.0	407.6	67.6
	53.3	*11.6*	*3.4*	*1.7*	*0.2*	*0.4*	*0.6*	*0.9*	*1.9*	*23.6*	*30.4*	*105.4*	*55.7*	*9.2*
Min.	85.0	25.8	13.8	1.4	0.9	1.7	2.6	4.4	6.3	10.9	25.8	115.0	63.8	17.8
	11.6	*3.5*	*1.9*	*0.2*	*0.1*	*0.2*	*0.4*	*0.6*	*0.9*	*1.5*	*3.5*	*15.7*	*8.7*	*2.4*
Bosgin Station (2,158 km2)***														
Mean	-	8.1	4.9	-	0.0	0.0	0.0	-	17.9	-	-	170.7	119.9	-
	-	*3.8*	*2.3*	-	*0.0*	*0.0*	*0.0*	-	*8.3*	-	-	*79.1*	*55.6*	-
Max.	-	13.6	5.5	-	0.0	0.0	0.0	-	21.8	-	-	290.0	237.4	-
	-	*6.3*	*2.5*	-	*0.0*	*0.0*	*0.0*	-	*10.1*	-	-	*134.4*	*110.0*	-
Min.	-	4.5	4.2	-	0.0	0.0	0.0	-	14.7	-	-	97.4	41.8	-
	-	*2.1*	*1.9*	-	*0.0*	*0.0*	*0.0*	-	*6.8*	-	-	*45.1*	*19.4*	-

Note: The values presented in Italic characters are specific discharges ($l/s/km^2$)
* : Average from Sep. 14 to 30 is taken for that of September 1993.
Average from Sep. 1 to 21 is taken for that of September 1993.
** : Average from Sep. 10 to 30 is taken for that of September 1993.
*** : Average from Nov. 1 to 17 is taken for that of November 1994.

Table II.3.2 Results of Discharge Measurement

Date	Gauge Read (cm)	Flow Velocity (m/s)	Discharge (m^3/s)	Remarks
1. Tavantolgoi Station				
Sep. 13, 1993	279	0.86	111.00	
Sep. 23, 1993	263	-	48.90	
Oct. 20, 1993	234	0.46	19.80	
Dec. 7, 1993	-	0.52	3.50	River was frozen
Jan. 6, 1993	-	0.30	0.89	River was frozen
Mar. 10, 1994	-	0.25	2.93	River was frozen
May 9, 1994	212	0.83	6.85	
Jun. 24, 1994	236	-	44.50	
Jul. 30, 1994	246	1.60	68.30	
Sep. 30, 1994	246	1.23	71.90	
Oct. 31, 1994	215	0.54	23.60	
Nov. 5, 1994	213	0.56	23.00	
2. Gachuurt Station				
Sep. 15, 1993	242	1.24	84.70	
Oct. 20, 1993	-	0.62	15.90	River was frozen
Dec. 7, 1993	-	0.25	0.37	River was frozen
Jan. 6, 1994	-	0.15	0.35	River was frozen
Feb. 28, 1994	-	0.18	0.30	River was frozen
Mar. 10, 1994	-	0.20	0.45	River was frozen
May 9, 1994	194	0.60	9.45	
Jun. 24, 1994	238	1.76	98.60	
Jul. 24, 1994	235	1.82	96.50	
Jul. 30, 1994	255	1.95	138.00	
Sep. 23, 1994	254	1.88	132.00	
Sep. 30, 1994	252	1.83	124.00	
Oct. 18, 1994	203	0.65	21.70	
Nov. 5, 1994	193	0.53	13.50	
3. Bosgin Station				
Sep. 16, 1993	115	-	61.60	
Oct. 8, 1994	85	-	17.10	
Oct. 24, 1994	64	-	11.20	

Table II.4.1 Summary of Climatic Condition of Selected Stations

1. Station: Ulaanbaatar												
Parameter	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Temperature												
Mean	-24.2	-19.6	-9.6	0.6	9.1	14.7	16.7	14.8	7.8	-1.0	-13.4	-21.7
Maximum	-6.5	-1.0	9.7	18.8	28.2	30.5	30.8	29.7	25.1	18.7	5.6	-3.3
Minimum	-37.8	-35.7	-28.1	-17.4	-8.8	-1.5	2.9	0.2	-8.5	-17.9	-29.1	-36.2
Humidity	81	78	67	54	50	59	68	70	68	69	78	83
Precipitation	1.4	1.9	2.4	7.7	14.4	48.8	69.5	57.0	27.6	6.5	3.8	2.1
2. Station: Terelj												
Parameter	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Temperature												
Mean	-24.1	-15.9	-11.8	-1.6	6.5	10.9	13.1	11.4	4.9	-2.8	-14.8	-20.8
Maximum	-6.8	-0.8	7.0	16.2	24.8	27.8	27.8	27.1	21.4	17.4	5.5	0.9
Minimum	-39.2	-37.1	-31.8	-20.9	-10.8	-6.5	-1.9	-0.2	-12.2	-20.0	-32.1	-37.1
Humidity	91	83	81	68	64	71	80	76	79	78	85	91
Precipitation	1.1	2.8	3.9	11.6	17.6	70.8	122.2	106.5	46.3	9.7	6.9	3.2
3. Station: Tahilt												
Parameter	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Temperature												
Mean	-21.5	-17.3	-7.7	0.9	10.0	14.7	17.0	15.1	8.3	0.6	-11.3	-18.7
Maximum	-7.2	-1.5	9.7	19.2	27.9	30.2	30.8	29.2	24.2	19.2	5.6	-4.2
Minimum	-33.4	-30.1	-23.6	-14.4	-6.0	0.8	5.6	3.3	-6.2	-13.9	-24.7	-31.5
Humidity	79	74	63	52	48	57	63	67	63	63	73	79
Precipitation	2.1	2.0	3.7	7.6	12.5	53.3	66.6	81.9	27.5	8.9	4.7	3.0
4. Station: Ih Surguuli												
Parameter	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Temperature												
Mean	-20.9	-17.4	-8.8	0.8	10.1	14.1	16.3	14.7	7.9	0.6	-11.2	-18.3
Maximum	-6.8	-1.3	8.8	18.5	26.2	30.3	30.7	29.0	23.9	19.6	5.7	-3.4
Minimum	-31.9	-29.9	-23.9	-14.8	-5.8	-0.8	3.9	3.1	-5.9	-13.1	-25.2	-31.6
Humidity	79	74	62	52	48	59	67	71	66	65	73	79
Precipitation	1.8	2.1	2.6	8.1	10.3	54.5	79.8	83.9	35.4	10.7	4.4	1.9

Table II.4.2 Mean, Maximum and Minimum Temperature

(Unit: ^{0}C)

Station	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Temperature												
Ulaanbaatar	-24.2	-19.6	-9.6	0.6	9.1	14.7	16.7	14.8	7.8	-1.0	-13.4	-21.7
Terelj	-24.1	-15.9	-11.8	-1.6	6.5	10.9	13.1	11.4	4.9	-2.8	-14.8	-20.8
Surguuli	-20.9	-17.4	-8.8	0.8	10.1	14.1	16.3	14.7	7.9	0.6	-11.2	-18.3
Tahilt	-21.5	-17.3	-7.7	0.9	10.0	14.7	17.0	15.1	8.3	0.6	-11.3	-18.7
Altanbulag	-24.1	-20.3	-8.8	2.0	12.1	17.3	18.8	16.9	9.5	1.3	-11.5	-18.8
Erdene	-19.9	-15.3	-10.9	-0.1	9.5	14.2	16.1	14.5	7.8	-1.3	-8.2	-18.7
Mungunmor	-22.1	-18.4	-11.4	0.9	8.4	14.5	16.8	14.3	8.5	-0.2	-12.8	-20.9
Batsumber	-24.5	-20.8	-9.6	1.0	10.5	15.2	17.7	15.5	9.0	1.7	-11.8	-21.8
Maximum Temperature												
Ulaanbaatar	-6.5	-1.0	9.7	18.8	28.2	30.5	30.8	29.7	25.1	18.7	5.6	-3.3
Terelj	-6.8	-0.8	7.0	16.2	24.8	27.8	27.8	27.1	21.4	17.4	5.5	0.9
Surguuli	-6.8	-1.3	8.8	18.5	26.2	30.3	30.7	29.0	23.9	19.6	5.7	-3.4
Tahilt	-7.2	-1.5	9.7	19.2	27.9	30.2	30.8	29.2	24.2	19.2	5.6	-4.2
Altanbulag	-8.8	-2.7	6.7	19.6	29.2	33.3	32.6	31.7	26.0	19.0	1.8	-3.5
Erdene	-3.4	-1.0	7.3	17.4	26.4	29.0	28.5	26.6	23.0	18.4	5.8	-2.1
Mungunmor	-6.1	-1.6	7.4	17.6	27.9	28.5	31.0	27.0	23.9	19.8	2.8	-6.6
Batsumber	-10.1	-4.7	7.2	18.1	28.4	32.0	31.4	33.5	24.0	17.5	5.4	-6.8
Minimum Temperature												
Ulaanbaatar	-37.8	-35.7	-28.1	-17.4	-8.8	-1.5	2.9	0.2	-8.5	-17.9	-29.1	-36.2
Terelj	-39.2	-37.1	-31.8	-20.9	-10.8	-6.5	-1.9	-0.2	-12.2	-20.0	-32.1	-37.1
Surguuli	-31.9	-29.9	-23.9	-14.8	-5.8	-0.8	3.9	3.1	-5.9	-13.1	-25.2	-31.6
Tahilt	-33.4	-30.1	-23.6	-14.4	-6.0	0.8	5.6	3.3	-6.2	-13.9	-24.7	-31.5
Altanbulag	-39.8	-24.3	-27.6	-17.1	-8.9	-0.7	4.0	2.0	-9.9	-11.8	-27.9	-34.4
Erdene	-34.6	-30.7	-29.3	-17.8	-10.1	-3.0	1.9	-0.7	-8.3	-14.1	-23.3	-30.0
Mungunmor	-35.2	-32.9	-28.6	-18.5	-9.3	-2.1	2.8	0.0	-7.6	-18.6	-27.8	-34.0
Batsumber	-38.8	-36.8	-27.4	-15.5	-4.6	0.3	4.4	0.9	-7.2	-16.9	-27.7	-30.1

Table II.4.3 Evapotranspiration Estimated by Blaney - Criddle Method

1. Station: Ulaanbaatar

Items	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
T (°C)	-24.2	-19.6	-9.6	0.6	9.1	14.7	16.7	14.8	7.8	-1.0	-13.4	-21.7	-
p	0.20	0.23	0.27	0.31	0.34	0.36	0.35	0.32	0.28	0.24	0.21	0.19	-
p(0.46T+8)	-0.6	-0.2	1.0	2.6	4.1	5.3	5.5	4.7	3.2	1.8	0.4	-0.4	-
U24 (m/day)	3.4	3.4	4.0	4.7	5.1	4.6	4.3	4.2	4.1	4.3	3.3	2.9	-
Uday (m/day)	4.5	4.6	5.3	6.3	6.7	6.2	5.7	5.5	5.5	5.8	4.4	3.9	-
f	0.0	0.0	1.0	2.6	4.1	5.3	5.5	4.7	3.2	1.8	0.4	0.0	-
Eto (mm/day)	0.0	0.0	1.0	2.2	5.0	8.2	8.3	7.0	4.5	1.2	0.4	0.0	-
ETo (mm/m)	0.0	0.0	31.0	66.0	155.0	246.0	257.3	217.0	135.0	37.2	12.0	0.0	1,157
Eto(0.75)* (mm/m)	0.0	0.0	23.3	49.5	116.3	184.5	193.0	162.8	101.3	27.9	9.0	0.0	866.6
Evaporation Estimated by Water P. Inst. (mm/m)	-0.8	1.8	21.7	75.5	95.5	86.3	87.5	96.1	89.8	41.2	3.3	0.5	598.4

2. Station: Terelj

Items	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
T (°C)	-24.1	-15.9	-11.8	-1.6	6.5	10.9	13.1	11.4	4.9	-2.8	-14.8	-20.8	-
p	0.20	0.23	0.27	0.31	0.34	0.36	0.35	0.32	0.28	0.24	0.21	0.19	-
p(0.46T+8)	-0.6	0.2	0.7	2.2	3.7	4.7	4.9	4.2	2.9	1.6	0.3	-0.3	-
U24 (m/day)	2.6	2.7	3.3	4.5	4.1	3.6	3.3	3.0	3.4	3.0	2.5	2.4	-
Uday (m/day)	3.4	3.6	4.3	6.0	5.4	4.8	4.3	4.0	4.5	4.0	3.4	3.1	-
f	0.0	0.2	0.7	2.2	3.7	4.7	4.9	4.2	2.9	1.6	0.3	0.0	-
Eto (mm/day)	0.0	0.2	0.7	1.6	4.1	5.3	6.0	5.1	4.0	1.6	0.3	0.0	-
ETo (mm/m)	0.0	5.6	21.7	48.0	127.1	159.0	186.0	158.1	120.0	49.6	9.0	0.0	884
Eto(0.65)** (mm/m)	0.0	3.6	14.1	31.2	82.6	103.4	120.9	102.8	78.0	32.2	5.9	0.0	574.7
Evaporation Estimated by Water P. Inst. (mm/m)	-1.1	1.3	18.0	52.5	59.2	57.6	43.1	45.7	60.2	44.2	2.6	0.3	383.6

Note: * : Considering the deduction of 25% consisting of 15% due to high latitude and 10% due to high altitude

** : Considering the deduction of 35% consisting of 15% due to high latitude and 20% due to high altitude

Equation for Blaney Criddle Method:

$$Eto = c\,[p(0.46T + 8)]$$

where; Eto: Evapotranspiration (mm/day)

T: Mean daily temperature (°C)

p: Mean daily percentage of total annual daytime hours (hr)

c: Adjustment factor

Table II.5.1 Catchment Area of Upper Tuul River Basin

(Unit: km^2)

Sub-basin	Sub-basin Area	Sub-basin Sub-total	Accumulated Catchment Area	Remarks
1. Upper Tuul Sub-basin				
Upper Tuul 1	2,158			Bosgin Br. Gauging Station
Upper Tuul 2	582	2,740	2,740	Confluence with Terelj River
2. Terelj River Basin				
Terelj 1	1,220			Terelj Gauging Station
Terelj 2	119	1,339	4,079	Confluence with Tuul River
3. Middle Tuul Sub-basin				
Middle Tuul 1	2,019			Gachuurt Gauging Station
Middle Tuul 2	202	2,221	6,300	Zaisan Br. Gauging Station
4. Lower Tuul Sub-basin	1,012	1,012	7,312	Tavantolgoi Gauging Station

Table II.5.2 Distribution of Area by Altitude

(Unit: km^2)

Sub-basin	Altitude: Less than 1,500 m	Altitude: From 1,500 m to 2,000 m	Altitude: More than 2,000 m	Total Area	Average Altitude (m)
1. Upper Tuul Sub-basin	-	2,114	626	2,740	1,864
2. Terelj River Basin	-	797	542	1,339	1,952
3. Middle Tuul Sub-basin	405	1,763	53	2,221	1,689
4. Lower Tuul Sub-basin	586	420	6	1,012	1,521
Total	991	5,094	1,227	7,312	1,780

Table II.6.1 Results of Water Balance Calculation

(Unit: million m^3)

Year	Precipitation	Surface Runoff	Evapo-transpiration	Domestic Water	Groundwater Runoff	Stored Volume	Balance
1936							
1937							
1938							
1939	1,810						
1940	3,170						
1941	3,781						
1942	2,160						
1943	2,023						
1944	4,402						
1945	1,578						
1946	2,691	216	1,726	46	143	97	97
1947	2,227	215	1,726	46	187	745	842
1948	2,919	595	1,726	46	200	549	1,391
1949	3,116	473	1,726	46	155	21	1,412
1950	2,420	368	1,726	46	214	993	2,405
1951	3,347	524	1,726	46	158	14	2,419
1952	2,467	744	1,726	46	167	-69	2,350
1953	2,615	598	1,726	46	153	-140	2,210
1954	2,382	542	1,726	46	219	892	3,101
1955	3,424	766	1,726	46	185	164	3,265
1956	2,886	682	1,726	46	139	-426	2,839
1957	2,167	741	1,726	46	189	252	3,091
1958	2,953	959	1,726	46	198	169	3,260
1959	3,097	1,259	1,726	46	193	-211	3,048
1960	3,012	1,100	1,726	46	227	439	3,487
1961	3,537	856	1,726	46	233	772	4,259
1962	3,632	668	1,726	46	172	76	4,335
1963	2,688	597	1,726	46	249	1,276	5,611
1964	3,894	1,156	1,726	46	255	794	6,405
1965	3,977	417	1,726	46	81	-1,005	5,400
1966	1,265	903	1,726	46	220	535	5,935
1967	3,429	1,451	1,726	46	295	1,088	7,023
1968	4,605	763	1,726	46	119	-795	6,227
1969	1,858	1,345	1,726	46	216	39	6,266
1970	3,371	667	1,726	46	170	49	6,316
1971	2,658	1,434	1,726	46	273	780	7,095
1972	4,258	167	1,726	46	45	-1,280	5,816
1973	703	1,906	1,726	46	146	-1,538	4,278
1974	2,287	1,478	1,726	46	140	-1,208	3,070
1975	2,182	1,160	1,726	46	175	-377	2,693
1976	2,729	569	1,726	46	178	255	2,948
1977	2,774	627	1,726	46	112	-758	2,190
1978	1,753	396	1,726	46	145	-47	2,143
1979	2,266	549	1,726	46	153	-91	2,052
1980	2,382	285	1,726	46	136	-66	1,986
1981	2,127	508	1,726	46	106	-734	1,251
1982	1,651	1,064	1,726	46	176	-260	991
1983	2,752	1,080	1,726	46	195	-8	983
1984	3,038	1,075	1,726	46	228	487	1,471
1985	3,562	1,259	1,726	46	217	134	1,605
1986	3,381	843	1,726	46	239	873	2,478
1987	3,727	658	1,726	46	171	66	2,544
1988	2,666	1,487	1,726	46	255	463	3,007
1989	3,977	436	1,726	46	129	-325	2,682
1990	2,011	1,734	1,726	46	220	-295	2,387
1991	3,431	1,527	1,726	46	180	-675	1,712
1992	2,802	1,427	1,726	46	183	-523	1,189
1993	2,859	2,093	1,726	46	183	-1,189	0
Average	2,832	883	1,726	46	182	0	3,116

Table II.6.2 Water Balance Calculation on Monthly Basis

(Unit: million m^3)

Month	Precipi-tation	Surface Runoff	Evapo-transpi-ration	Water Supply	Ground-water Runoff	Stored Water	Balance	Month	Precipi-tation	Surface Runoff	Evapo-transpi-ration	Water Supply	Ground-water Runoff	Stored Water	Balance
Jan-86	14.5	0.0	0.0	3.8	1.2	9.6	1,614.5	Jan-90	5.2	0.0	0.0	3.8	0.4	1.0	2,384.9
Feb-86	15.3	0.0	5.1	3.8	1.2	5.2	1,619.8	Feb-90	35.3	0.0	5.1	3.8	2.9	23.6	2,408.5
Mar-86	71.7	0.0	44.4	3.8	5.8	17.7	1,637.5	Mar-90	29.8	0.0	44.4	3.8	2.4	-20.8	2,387.7
Apr-86	35.2	1.3	96.3	3.8	2.9	-68.9	1,568.5	Apr-90	77.5	5.9	96.3	3.8	6.3	-34.7	2,352.9
May-86	97.6	72.7	239.1	3.8	7.9	-226.0	1,342.5	May-90	52.2	72.8	239.1	3.8	4.3	-267.8	2,085.2
Jun-86	894.3	200.2	340.7	3.8	72.9	276.7	1,619.2	Jun-90	455.5	93.9	340.7	3.8	37.1	-20.0	2,065.1
Jul-86	1,350.1	292.6	374.3	3.8	110.0	569.5	2,188.7	Jul-90	859.1	477.9	374.3	3.8	70.0	-66.8	1,998.3
Aug-86	769.5	128.1	316.8	3.8	62.7	258.2	2,446.9	Aug-90	846.6	602.6	316.8	3.8	69.0	-145.6	1,852.8
Sep-86	185.5	97.7	216.7	3.8	15.1	-147.9	2,299.0	Sep-90	534.3	352.3	216.7	3.8	43.5	-82.0	1,770.7
Oct-86	135.3	32.1	74.8	3.8	11.0	13.6	2,312.6	Oct-90	62.3	93.1	74.8	3.8	5.1	-114.4	1,656.3
Nov-86	49.5	15.0	17.8	3.8	4.0	9.0	2,321.6	Nov-90	98.9	31.9	17.8	3.8	8.1	37.4	1,693.7
Dec-86	55.2	3.9	0.0	3.8	4.5	43.0	2,364.7	Dec-90	75.0	3.9	0.0	3.8	6.1	61.2	1,754.9
Jan-87	20.6	0.0	0.0	3.8	1.7	15.2	2,379.8	Jan-91	9.0	0.0	0.0	3.8	0.7	4.5	1,759.4
Feb-87	13.9	0.0	5.1	3.8	1.1	3.9	2,383.7	Feb-91	27.0	0.0	5.1	3.8	2.2	15.9	1,775.3
Mar-87	62.4	0.0	44.4	3.8	5.1	9.1	2,392.9	Mar-91	28.2	0.3	44.4	3.8	2.3	-22.6	1,752.7
Apr-87	70.9	13.6	96.3	3.8	5.8	-48.5	2,344.4	Apr-91	125.2	6.1	96.3	3.8	10.2	8.9	1,761.7
May-87	127.8	18.3	239.1	3.8	10.4	-143.7	2,200.6	May-91	124.6	307.3	239.1	3.8	10.2	-435.8	1,325.9
Jun-87	329.3	48.6	340.7	3.8	26.8	-90.6	2,110.1	Jun-91	429.2	138.0	340.7	3.8	35.0	-88.2	1,237.7
Jul-87	620.1	101.0	374.3	3.8	50.5	90.6	2,200.7	Jul-91	890.7	472.2	374.3	3.8	72.6	-32.1	1,205.5
Aug-87	946.2	223.2	316.8	3.8	77.1	325.5	2,526.2	Aug-91	429.5	188.4	316.8	3.8	35.0	-114.4	1,091.2
Sep-87	293.3	178.5	216.7	3.8	23.9	-129.6	2,396.5	Sep-91	676.6	318.2	216.7	3.8	55.1	82.7	1,173.9
Oct-87	207.2	64.9	74.8	3.8	16.9	46.9	2,443.5	Oct-91	18.9	82.8	74.8	3.8	1.5	-143.9	1,030.0
Nov-87	68.5	9.1	17.8	3.8	5.6	32.4	2,475.9	Nov-91	32.9	12.7	17.8	3.8	2.7	-4.0	1,026.0
Dec-87	7.0	1.2	0.0	3.8	0.6	1.4	2,477.3	Dec-91	0.4	0.6	0.0	3.8	0.0	-4.0	1,022.0
Jan-88	0.8	0.0	0.0	3.8	0.1	-3.0	2,474.3	Jan-92	10.0	0.0	0.0	3.8	0.8	5.4	1,027.4
Feb-88	50.7	0.0	5.1	3.8	4.1	37.7	2,512.0	Feb-92	2.8	0.0	5.1	3.8	0.2	-6.3	1,021.2
Mar-88	9.8	0.0	44.4	3.8	0.8	-39.2	2,472.8	Mar-92	20.3	0.0	44.4	3.8	1.7	-29.6	991.5
Apr-88	28.1	25.2	96.3	3.8	2.3	-99.4	2,373.4	Apr-92	137.2	4.0	96.3	3.8	11.2	22.0	1,013.6
May-88	395.2	108.0	239.1	3.8	32.2	12.1	2,385.5	May-92	152.2	205.6	239.1	3.8	12.4	-308.7	704.9
Jun-88	845.7	233.0	340.7	3.8	68.9	199.4	2,584.9	Jun-92	361.4	65.4	340.7	3.8	29.4	-77.9	627.0
Jul-88	655.1	246.9	374.3	3.8	53.4	-23.2	2,561.7	Jul-92	1,182.1	157.8	374.3	3.8	96.3	549.9	1,176.9
Aug-88	1,376.5	409.9	316.8	3.8	112.1	533.9	3,095.7	Aug-92	898.5	468.7	316.8	3.8	73.2	36.1	1,213.0
Sep-88	312.1	380.0	216.7	3.8	25.4	-313.8	2,781.9	Sep-92	300.3	442.5	216.7	3.8	24.5	-387.1	825.9
Oct-88	84.7	68.2	74.8	3.8	6.9	-68.9	2,712.9	Oct-92	11.9	61.9	74.8	3.8	1.0	-129.5	696.4
Nov-88	0.8	14.6	17.8	3.8	0.1	-35.4	2,677.6	Nov-92	44.2	18.9	17.8	3.8	3.6	0.2	696.6
Dec-88	9.6	1.7	0.0	3.8	0.8	3.3	2,680.9	Dec-92	12.9	2.7	0.0	3.8	1.1	5.4	702.1
Jan-89	21.8	0.0	0.0	3.8	1.8	16.3	2,697.2	Jan-93	6.0	0.0	0.0	3.8	0.5	1.7	703.8
Feb-89	19.4	0.0	5.1	3.8	1.6	9.0	2,706.2	Feb-93	25.4	0.0	5.1	3.8	2.1	14.5	718.3
Mar-89	21.2	0.0	44.4	3.8	1.7	-28.7	2,677.5	Mar-93	17.7	0.7	44.4	3.8	1.4	-32.7	685.6
Apr-89	173.5	11.2	96.3	3.8	14.1	48.2	2,725.6	Apr-93	33.7	20.8	96.3	3.8	2.7	-89.9	595.7
May-89	134.2	37.1	239.1	3.8	10.9	-156.7	2,568.9	May-93	44.8	79.4	239.1	3.8	3.7	-281.2	314.5
Jun-89	270.7	41.5	340.7	3.8	22.1	-137.3	2,431.6	Jun-93	629.5	64.2	340.7	3.8	51.3	169.6	484.1
Jul-89	487.8	97.5	374.3	3.8	39.7	-27.5	2,404.1	Jul-93	1,368.0	889.7	374.3	3.8	111.5	-11.1	473.0
Aug-89	557.6	136.6	316.8	3.8	45.4	55.1	2,459.2	Aug-93	676.9	596.3	316.8	3.8	55.1	-295.0	177.9
Sep-89	204.3	64.5	216.7	3.8	16.6	-97.3	2,361.9	Sep-93	463.7	335.5	216.7	3.8	37.8	-130.0	47.9
Oct-89	72.2	41.4	74.8	3.8	5.9	-53.6	2,308.4	Oct-93	46.2	64.1	74.8	3.8	3.8	-100.2	-52.4
Nov-89	68.3	5.3	17.8	3.8	5.6	35.9	2,344.3	Nov-93	88.8	11.8	17.8	3.8	7.2	48.2	-4.2
Dec-89	48.5	1.1	0.0	3.8	4.0	39.7	2,383.9	Dec-93	9.5	0.8	0.0	3.8	0.8	4.2	0.0
								Average	257.9	106.0	143.8	3.8	21.0	-16.7	1,754.8

Note: The balance at the end of 1985 is set at 1,605MCM.

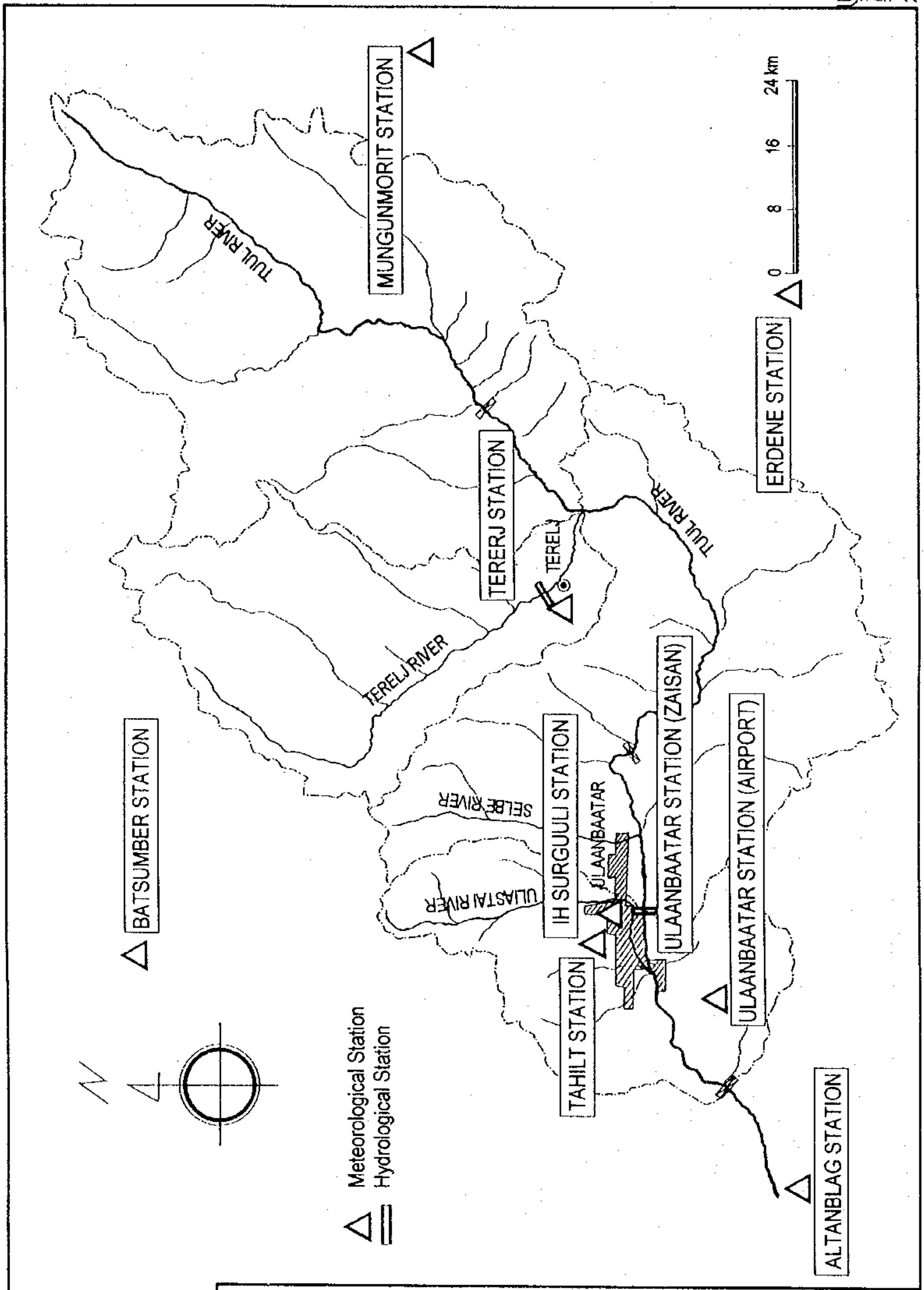

Fig. II.2.1 LOCATION OF METEO-HYDROLOGICAL STATIONS IN AND AROUND UPPER TUUL RIVER BASIN

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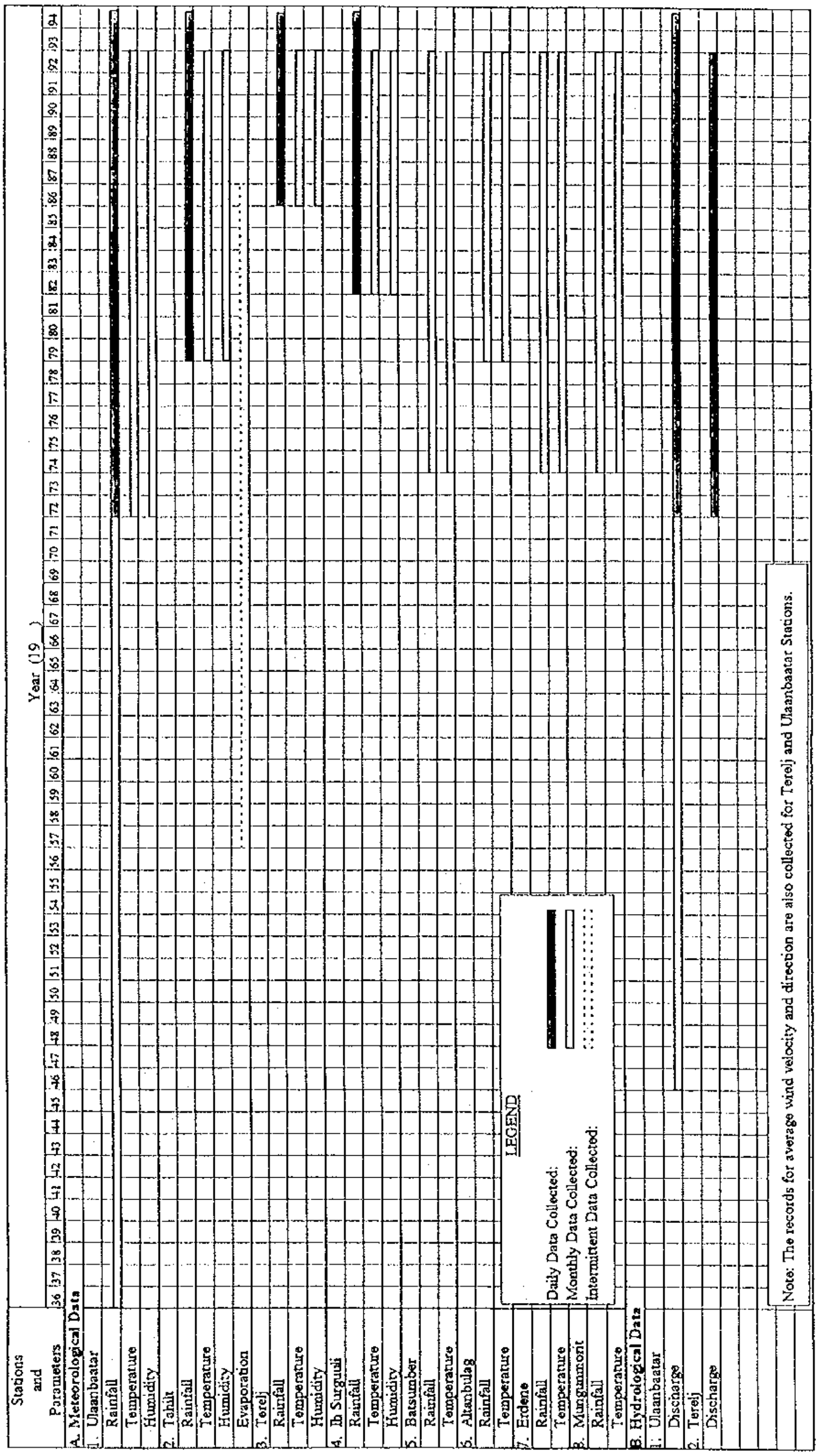

Fig. II.2.2 METEOROLOGICAL AND HYDROLOGICAL DATA COLLECTED

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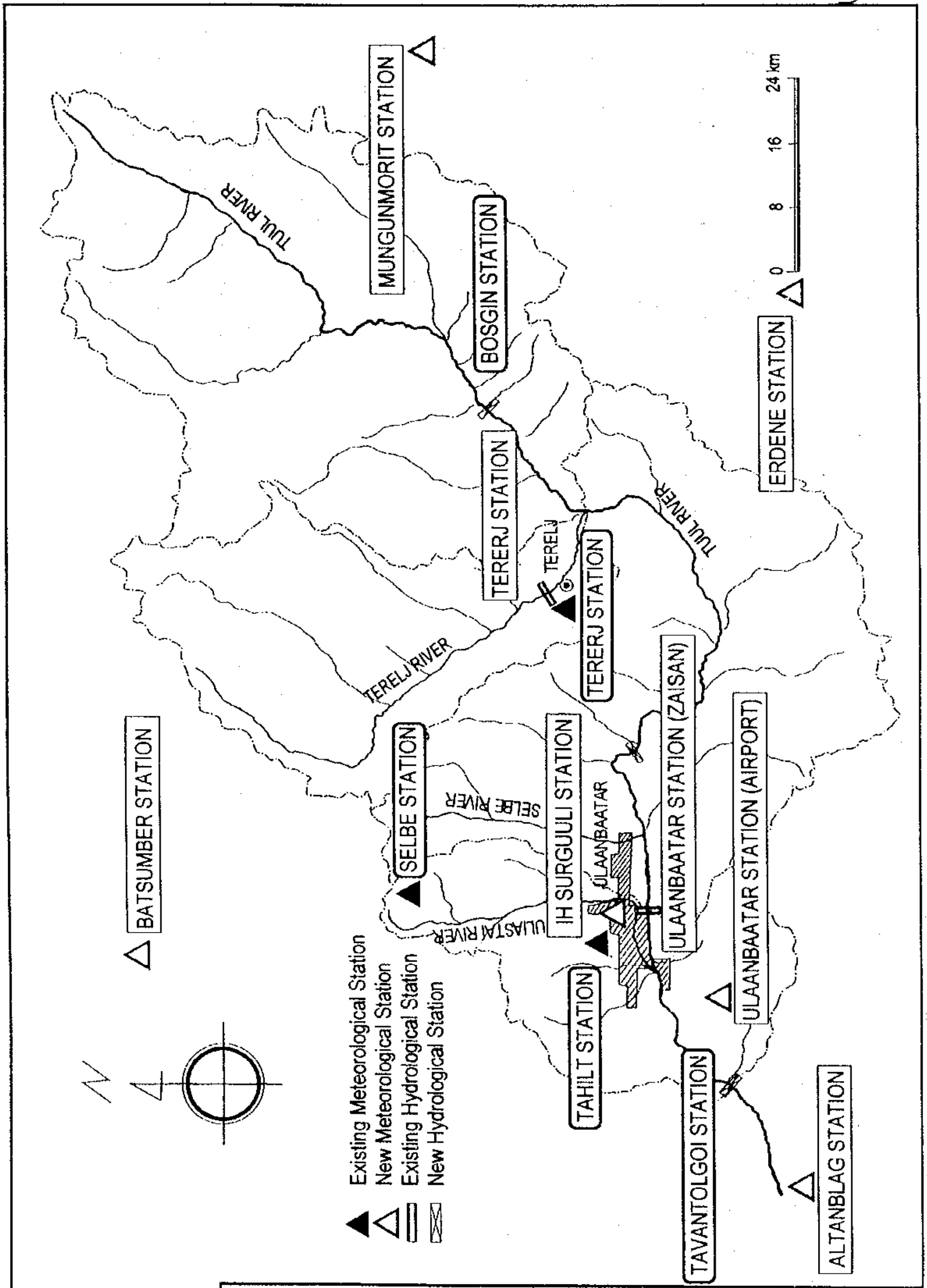

Fig. II.3.1 LOCATION MAP OF NEW METEO-HYDROLOGICAL STATIONS

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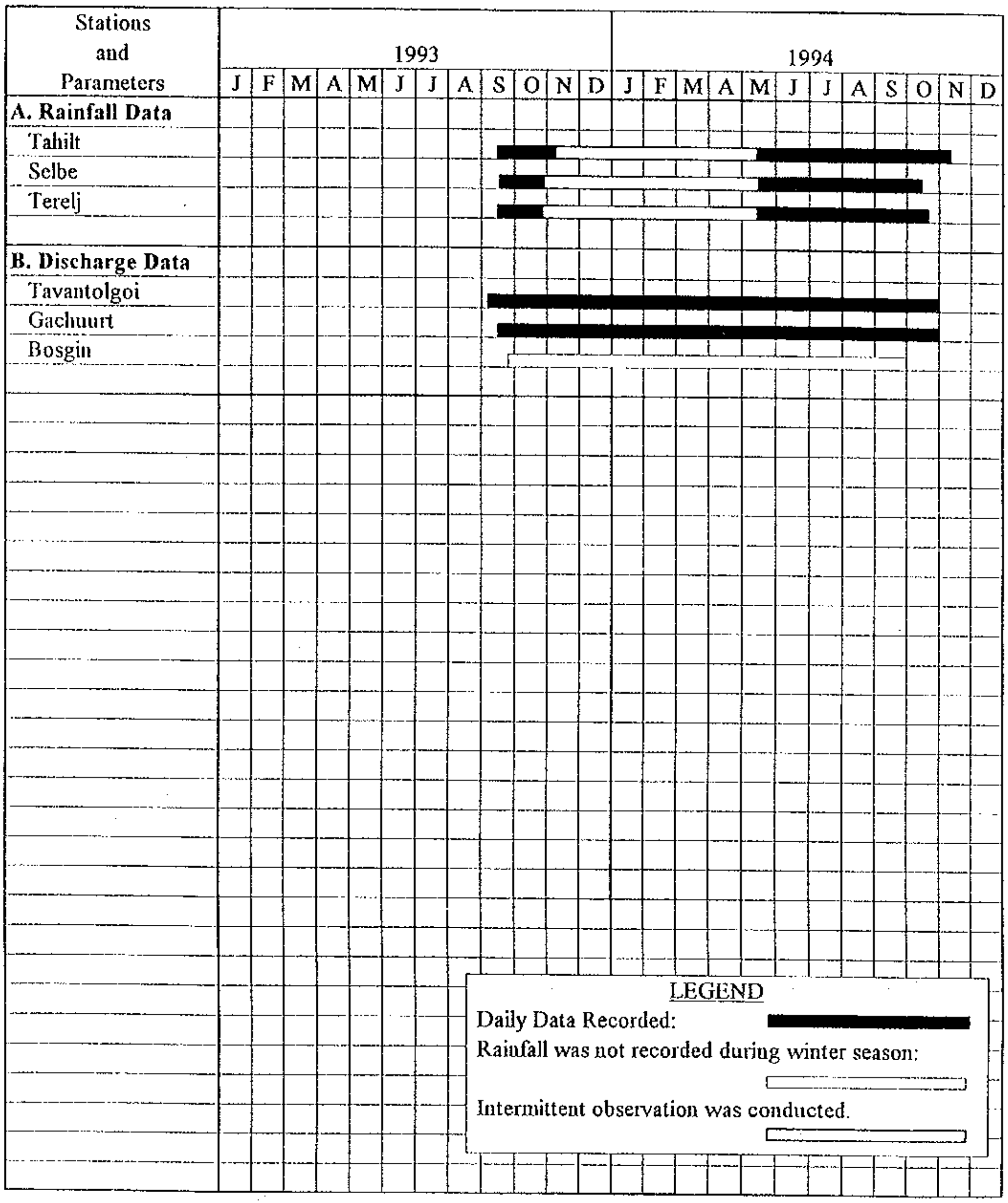

Fig. II.3.2 RAINFALL AND DISCHARGE RECORDED AT NEW STATIONS

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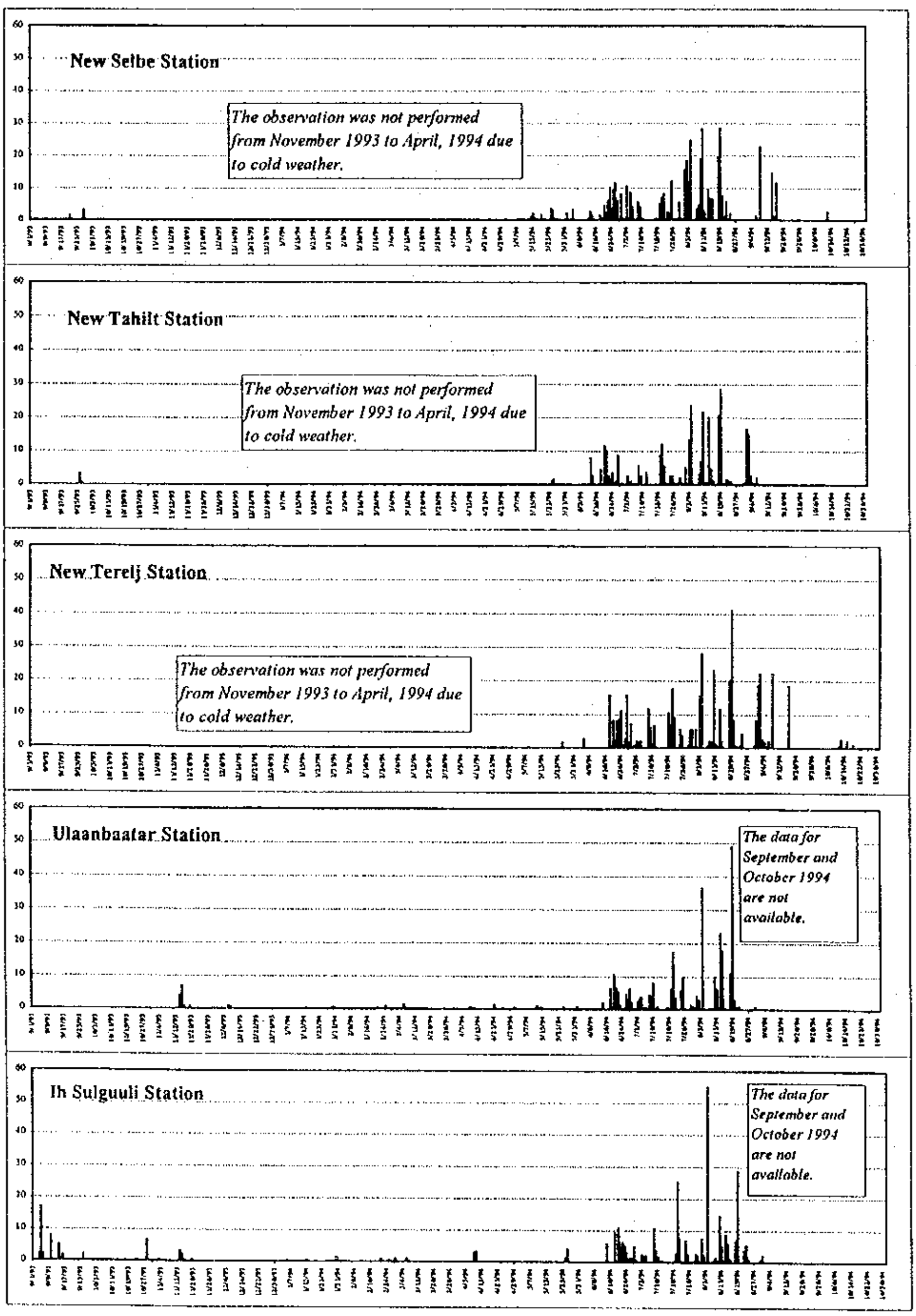

Fig. II.3.3 RECORDED RAINFALL AT NEW STATIONS

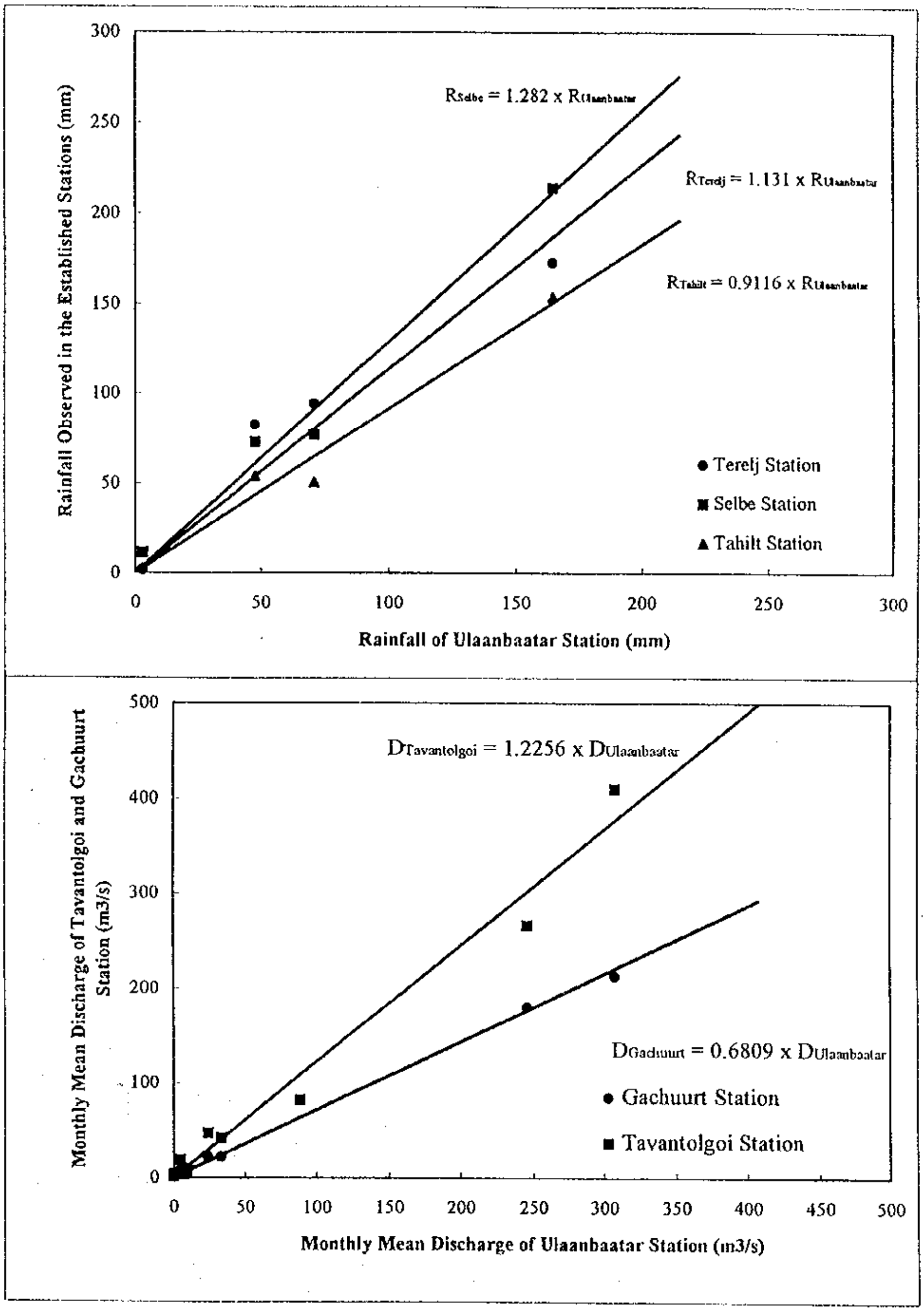

Fig. II.3.4 RELATIONSHIP OF RAINFALL AND DISCHARGE OBSERVED AT NEW AND ULAANBAATAR STATIONS

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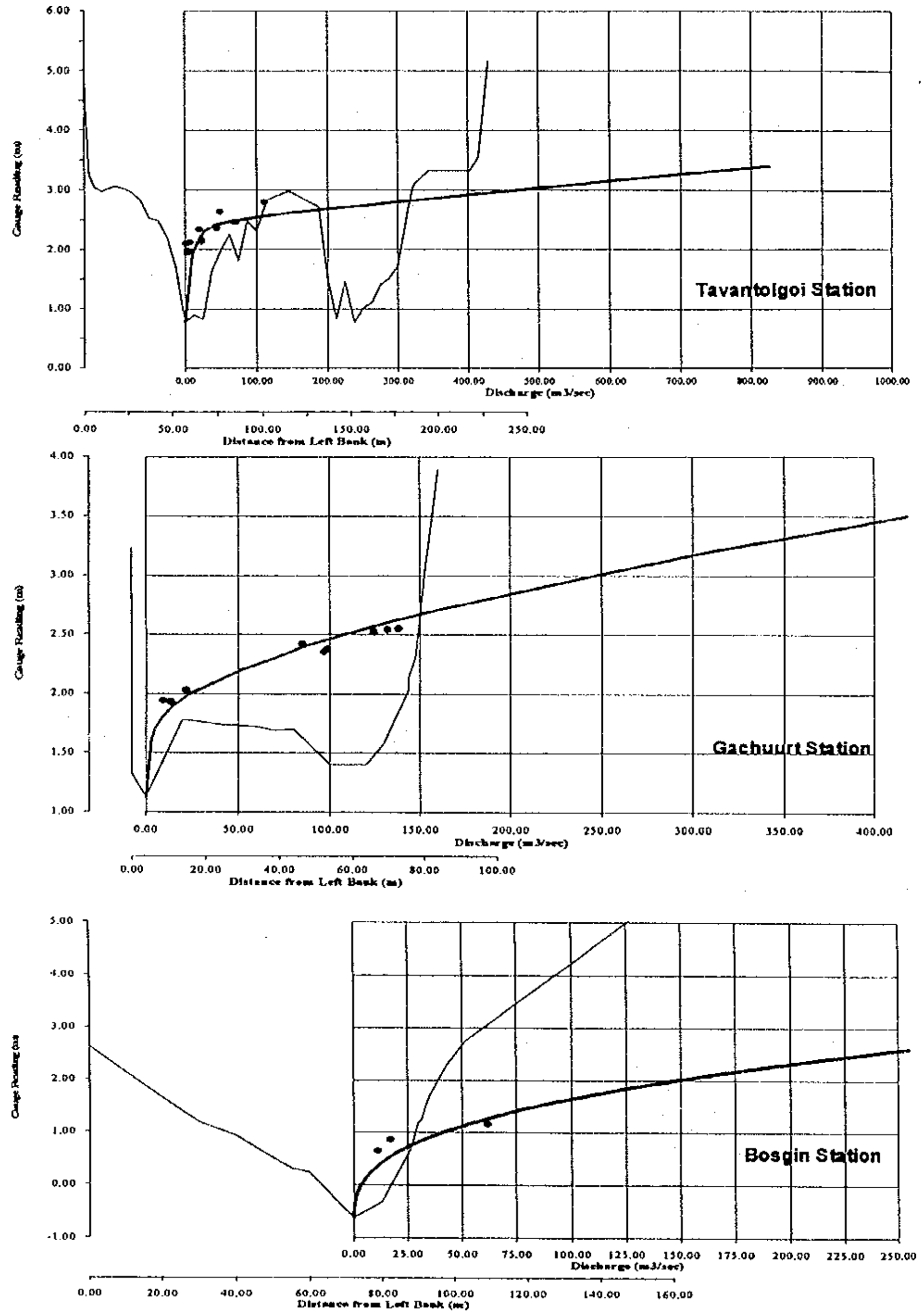

Fig. II.3.5 ESTIMATED H-Q RATING CURVES FOR THE NEW STATIONS

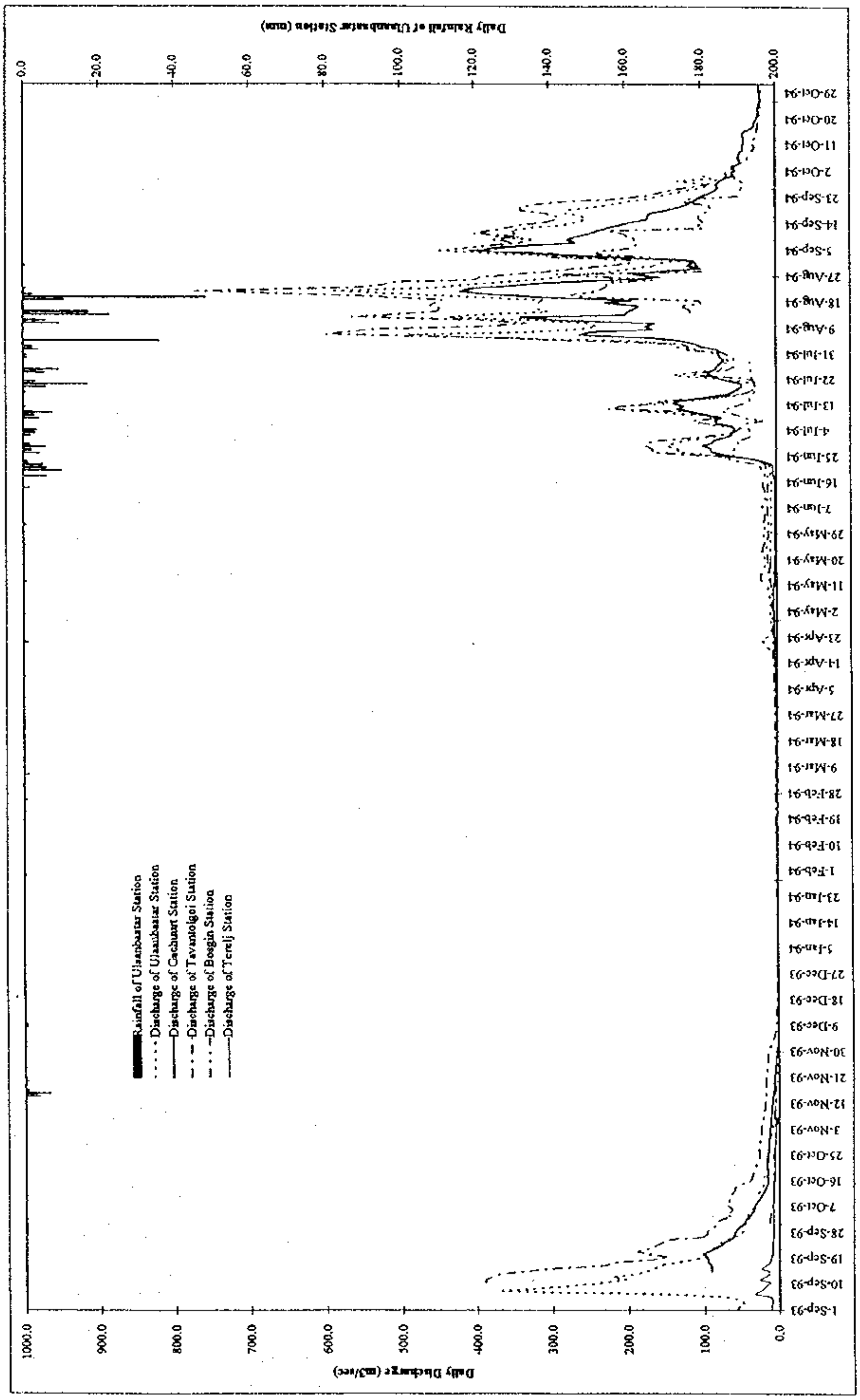

Fig. II.3.6 OBSERVED DISCHARGE AT NEW STATIONS

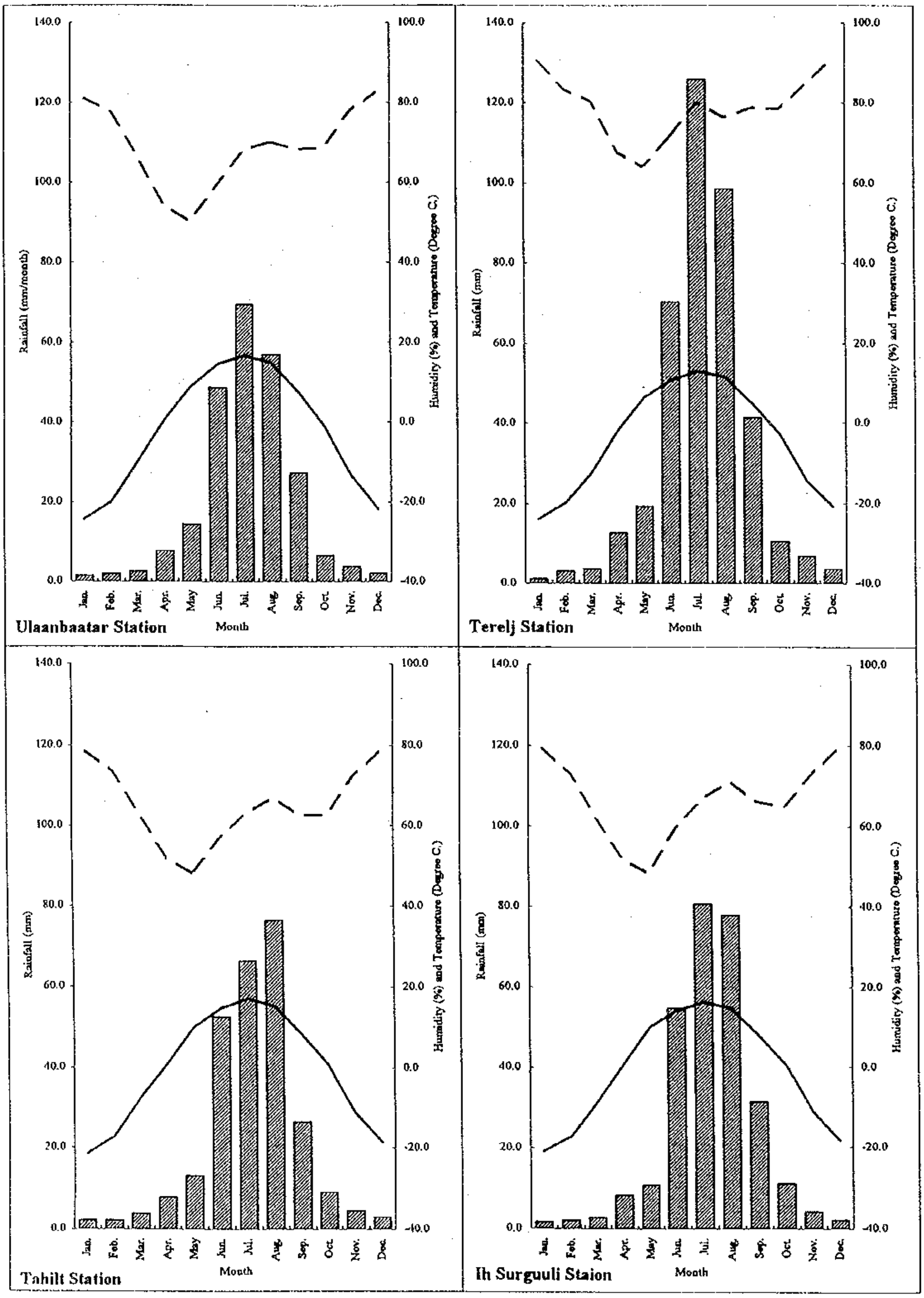

Fig. II.4.1 CLIMATE IN ULAANBAATAR, TAHILT, IH SURGUULI AND TERELJ

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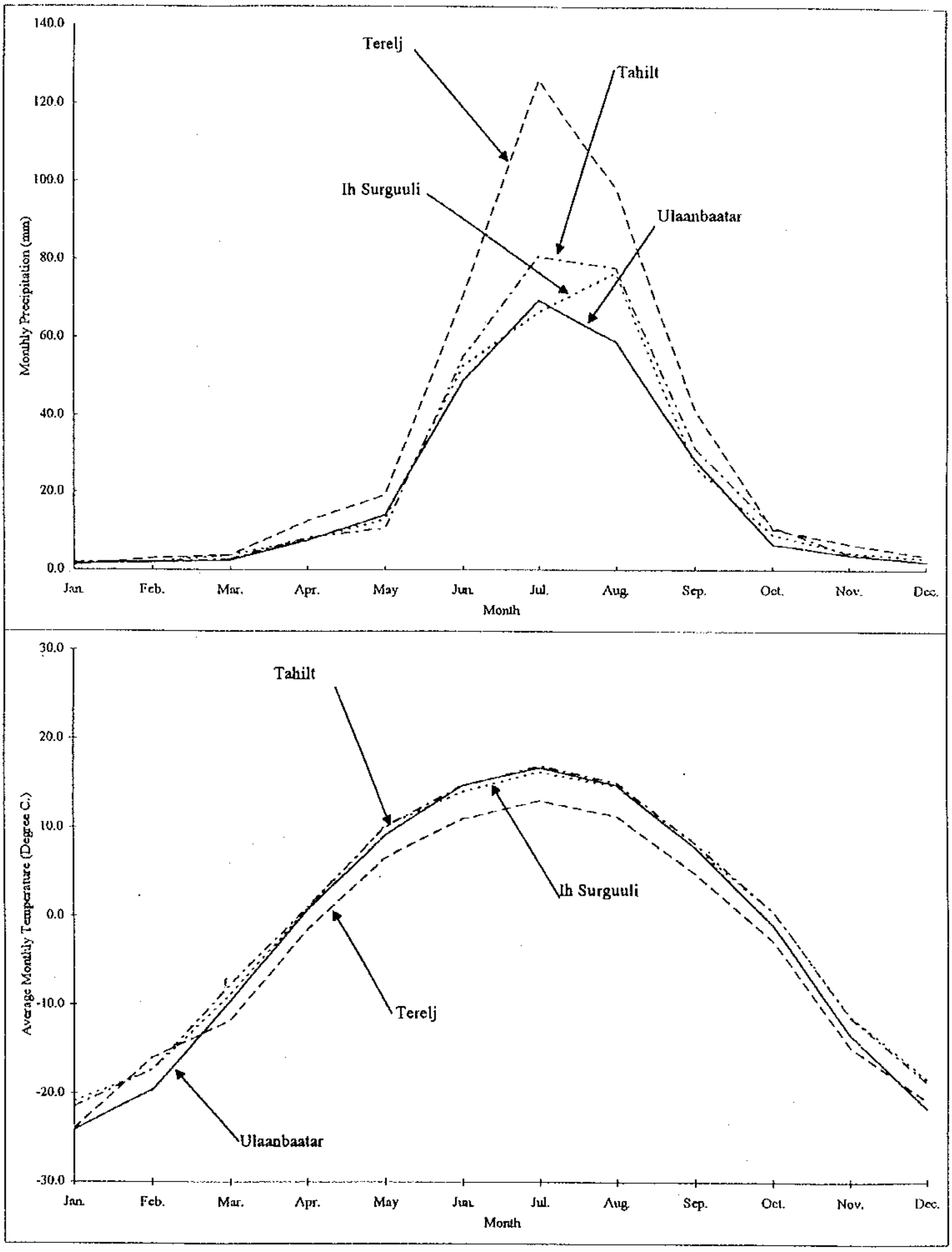

Fig. II.4.2 MONTHLY AVERAGE PRECIPITATION AND TEMPERATURE

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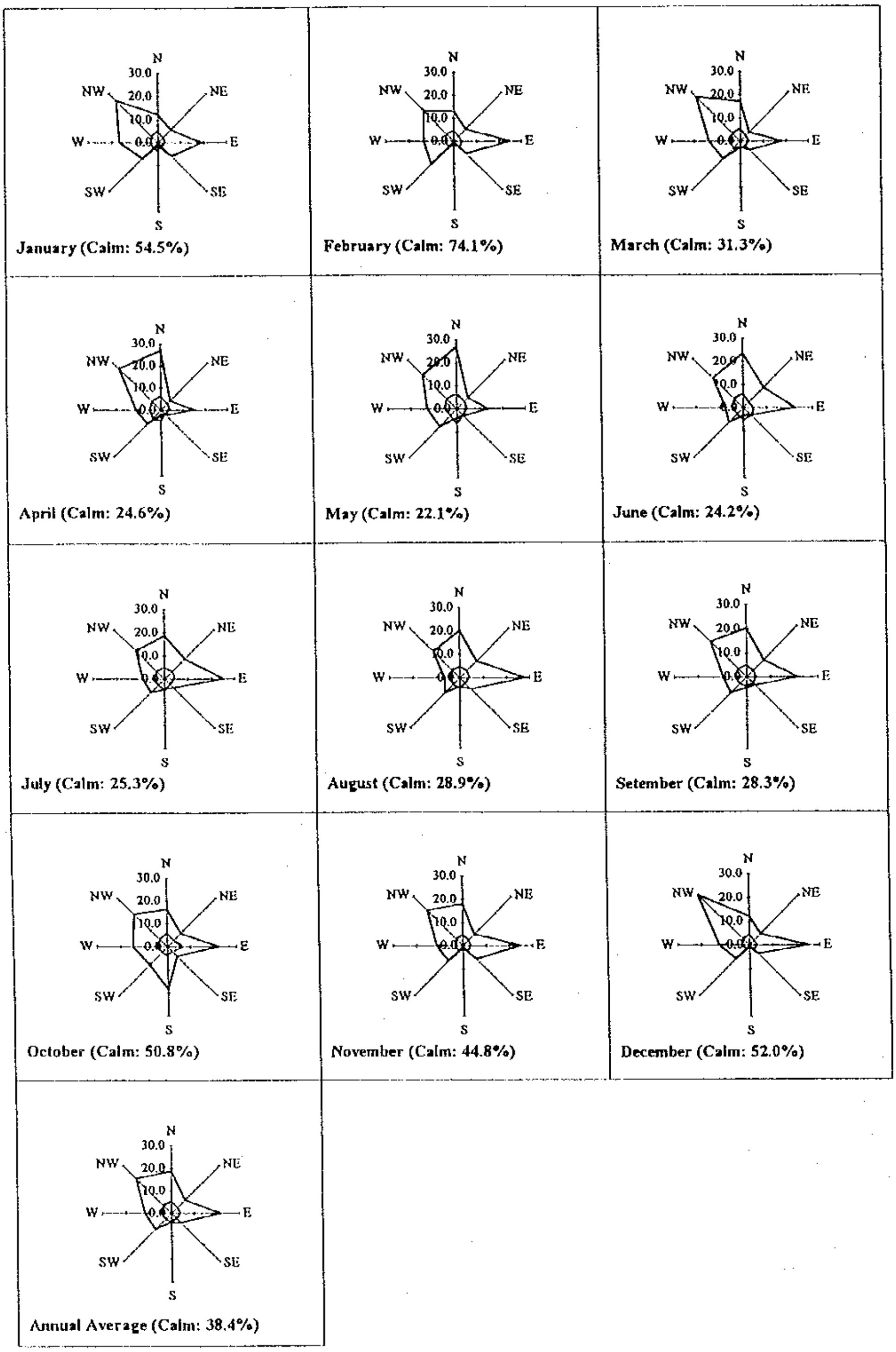

Fig. II.4.3 WIND VELOCITY AND DIRECTION OF ULAANBAATAR STATION

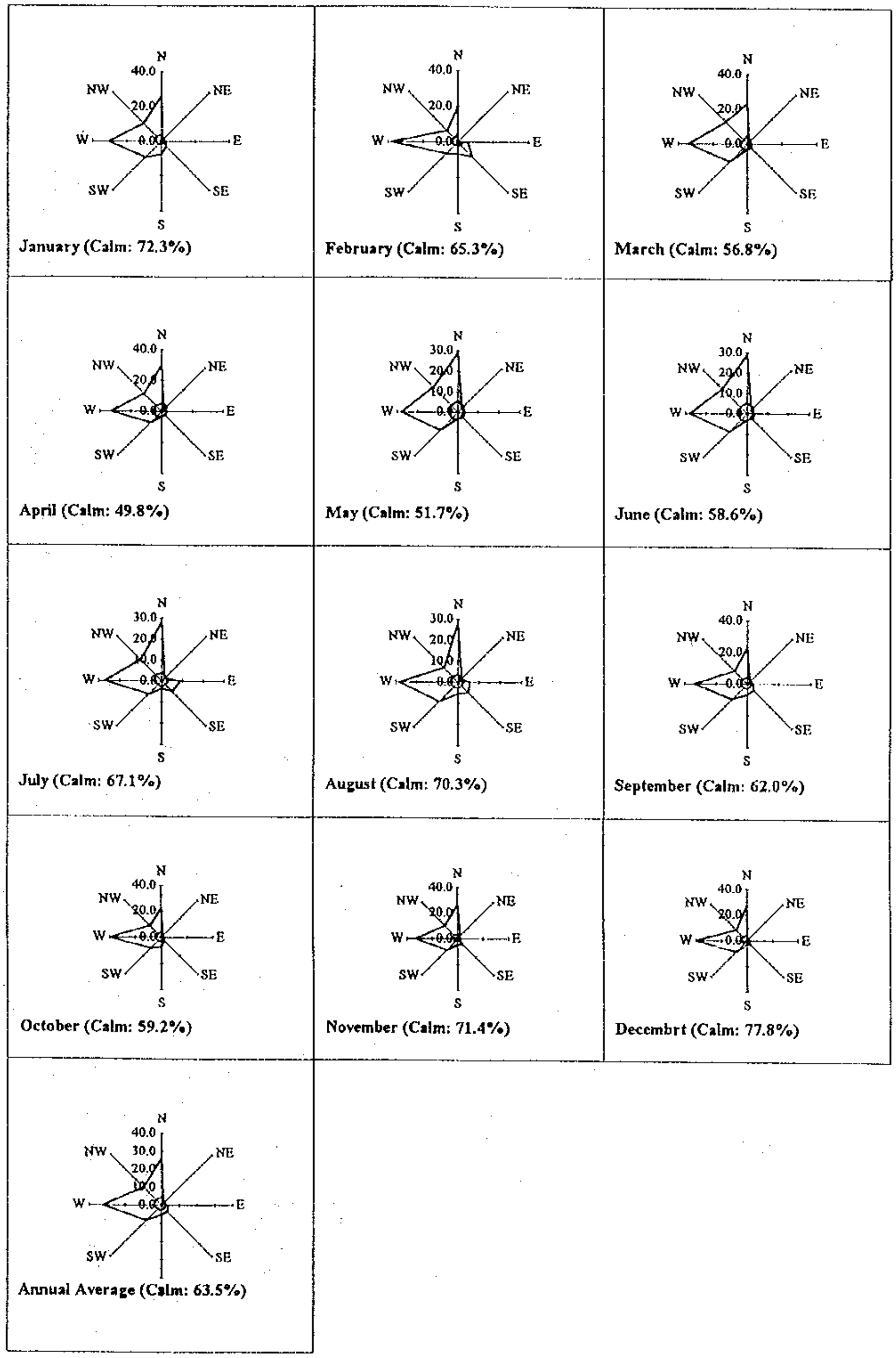

Fig. II.4.4 WIND VELOCITY AND DIRECTION OF TERELJ STATION

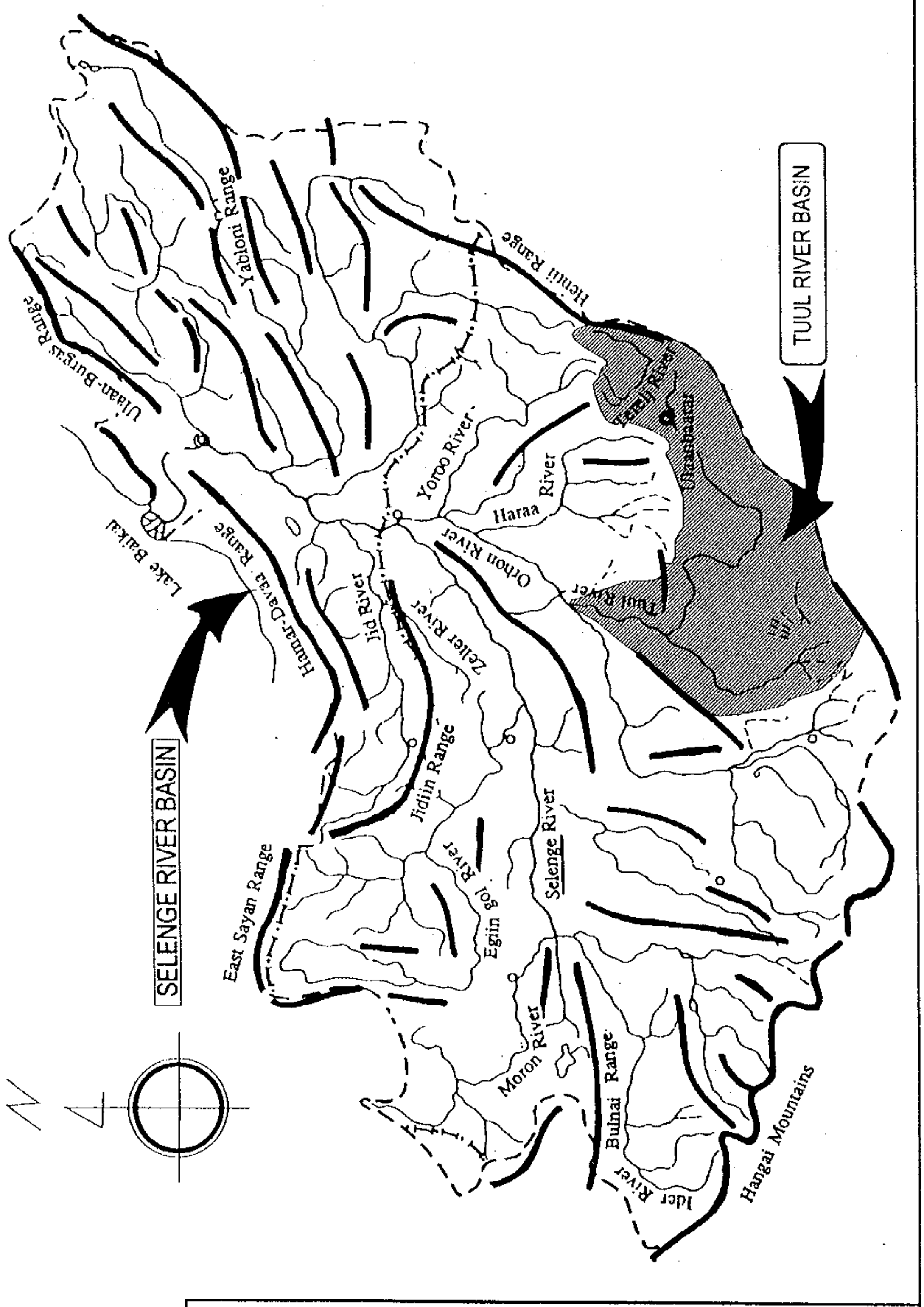

Fig. II.5.1 SELENGE AND TUUL RIVER BASIN

JICA	The Study on Water Supply System in Ulaanbaatar and Surroundings

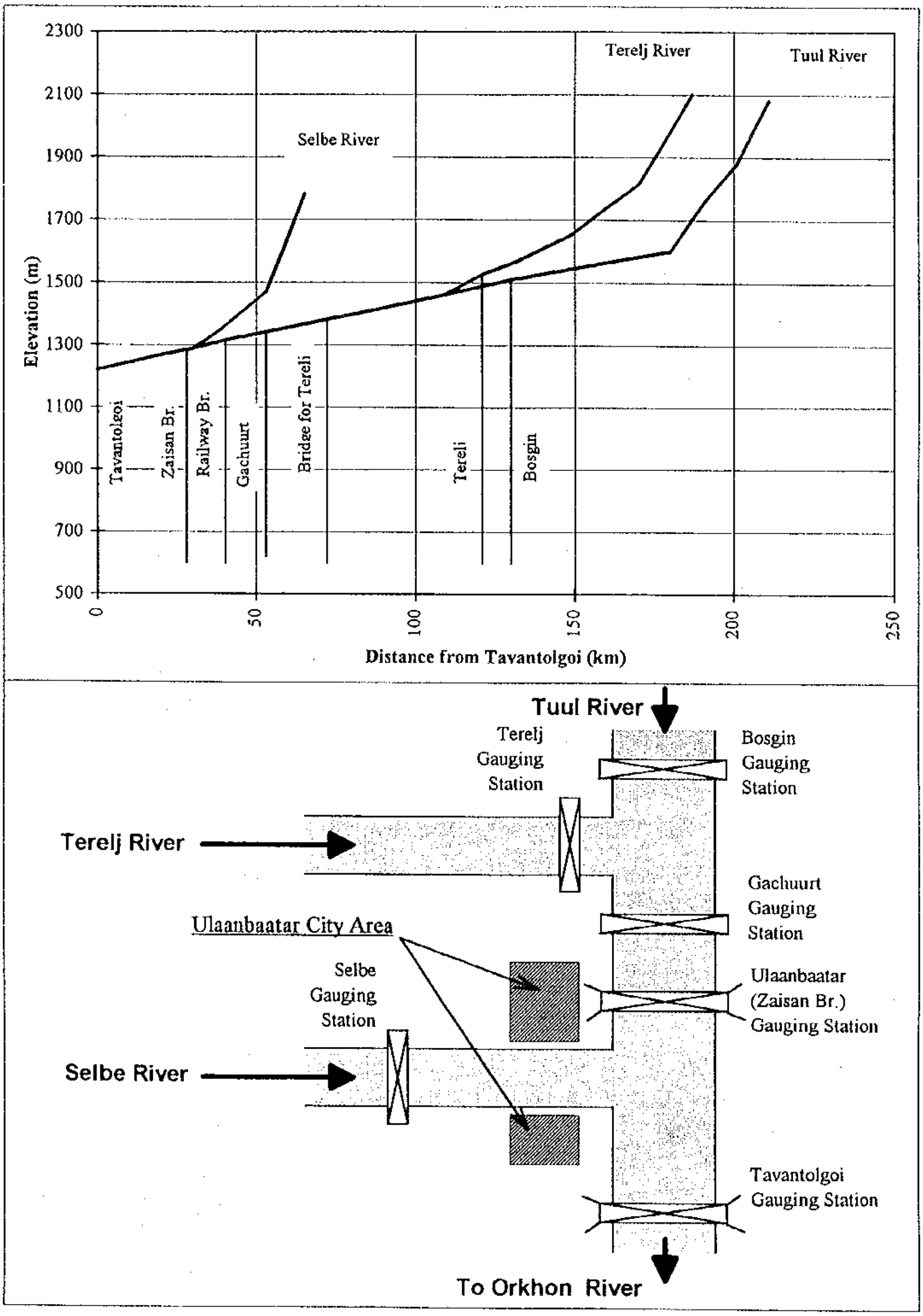

Fig. II.5.2 PROFILE AND SCHEMATIC DIAGRAM OF TUUL RIVER SYSTEM

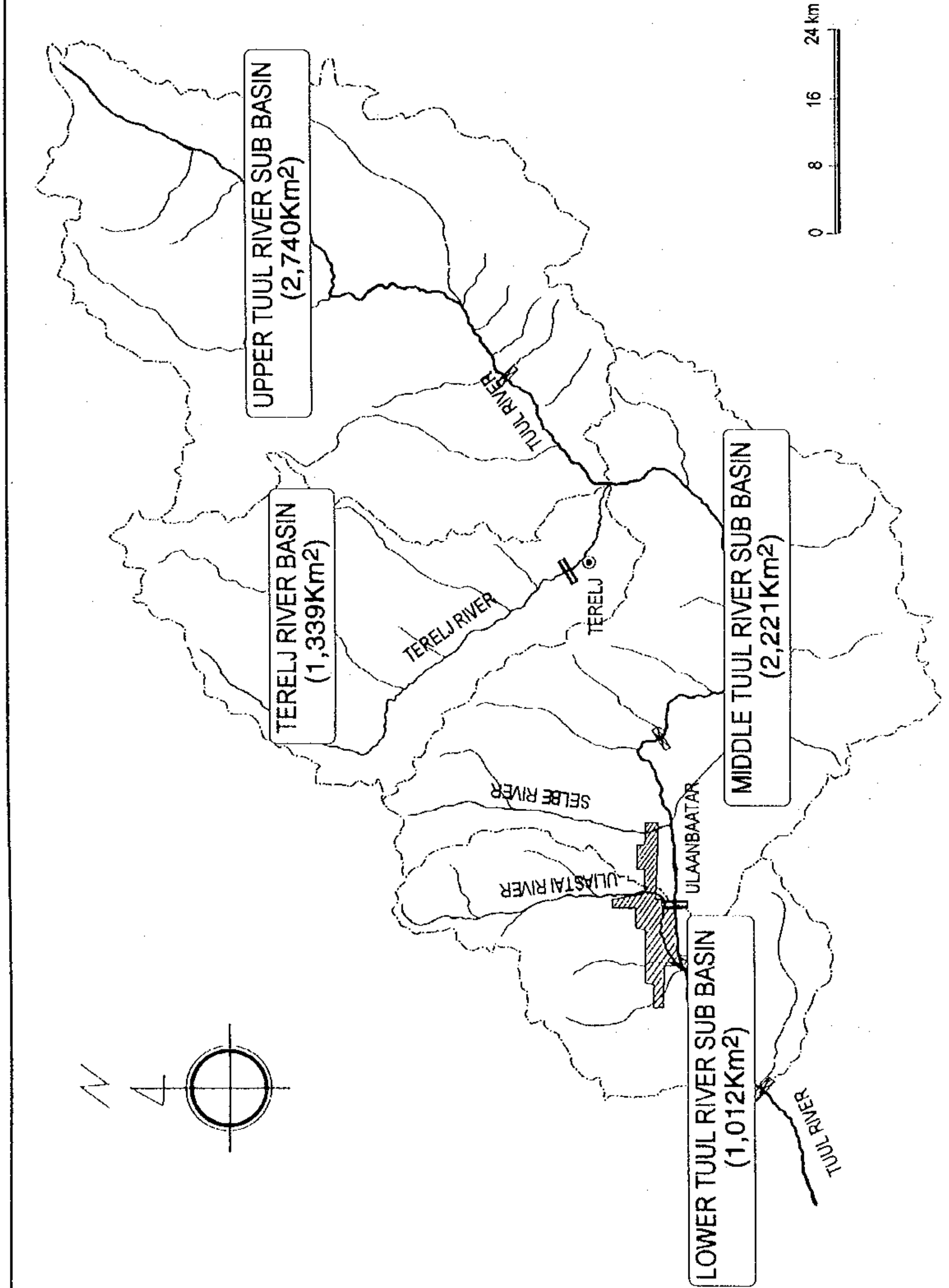

Fig. II.5.3 UPPER TUUL RIVER BASIN

JICA	The Study on Water Supply System in Ulaanbaatar and Surroundings

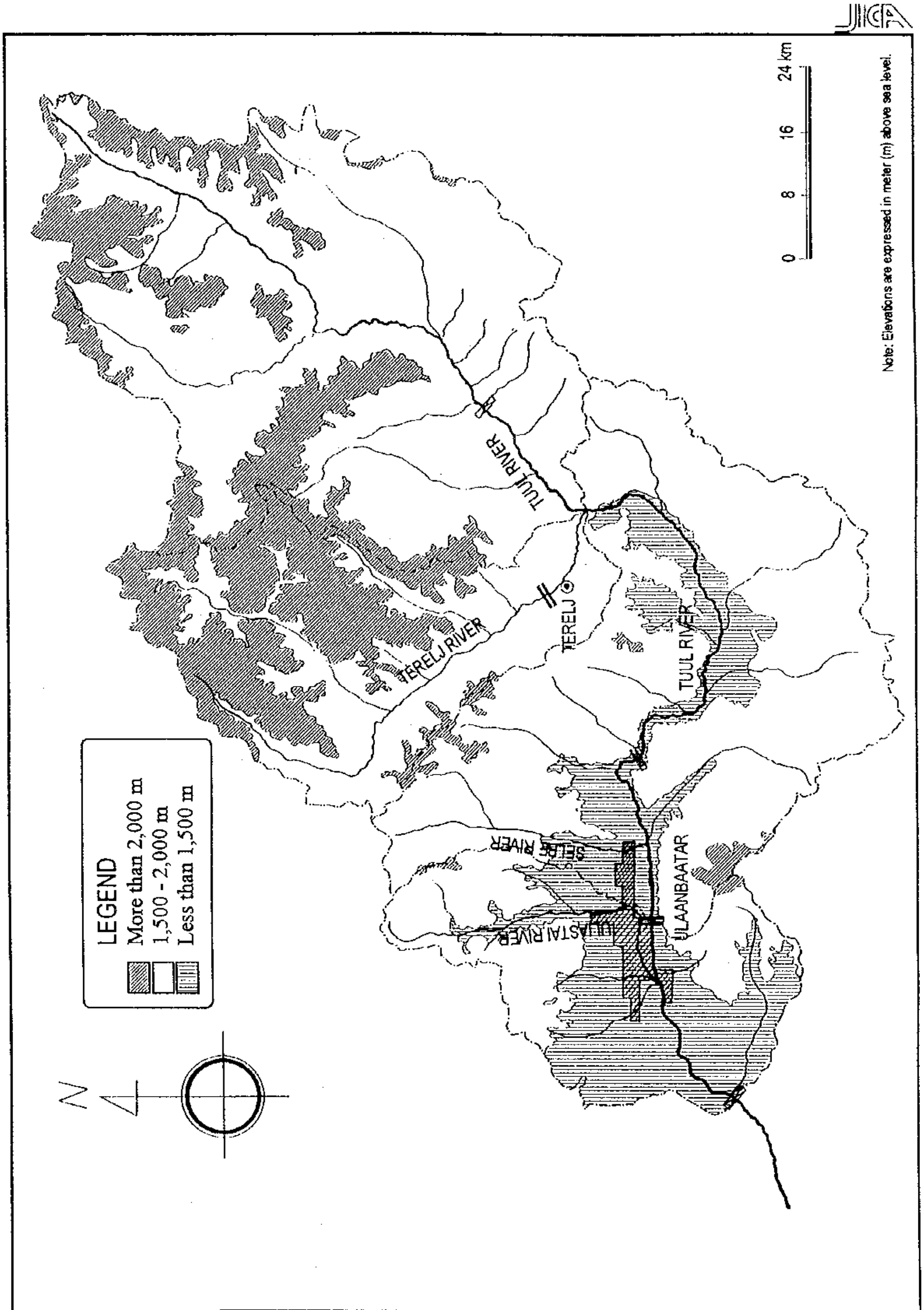

Fig. II.5.4 AREAS BY ELEVATION IN UPPER TUUL RIVER BASIN

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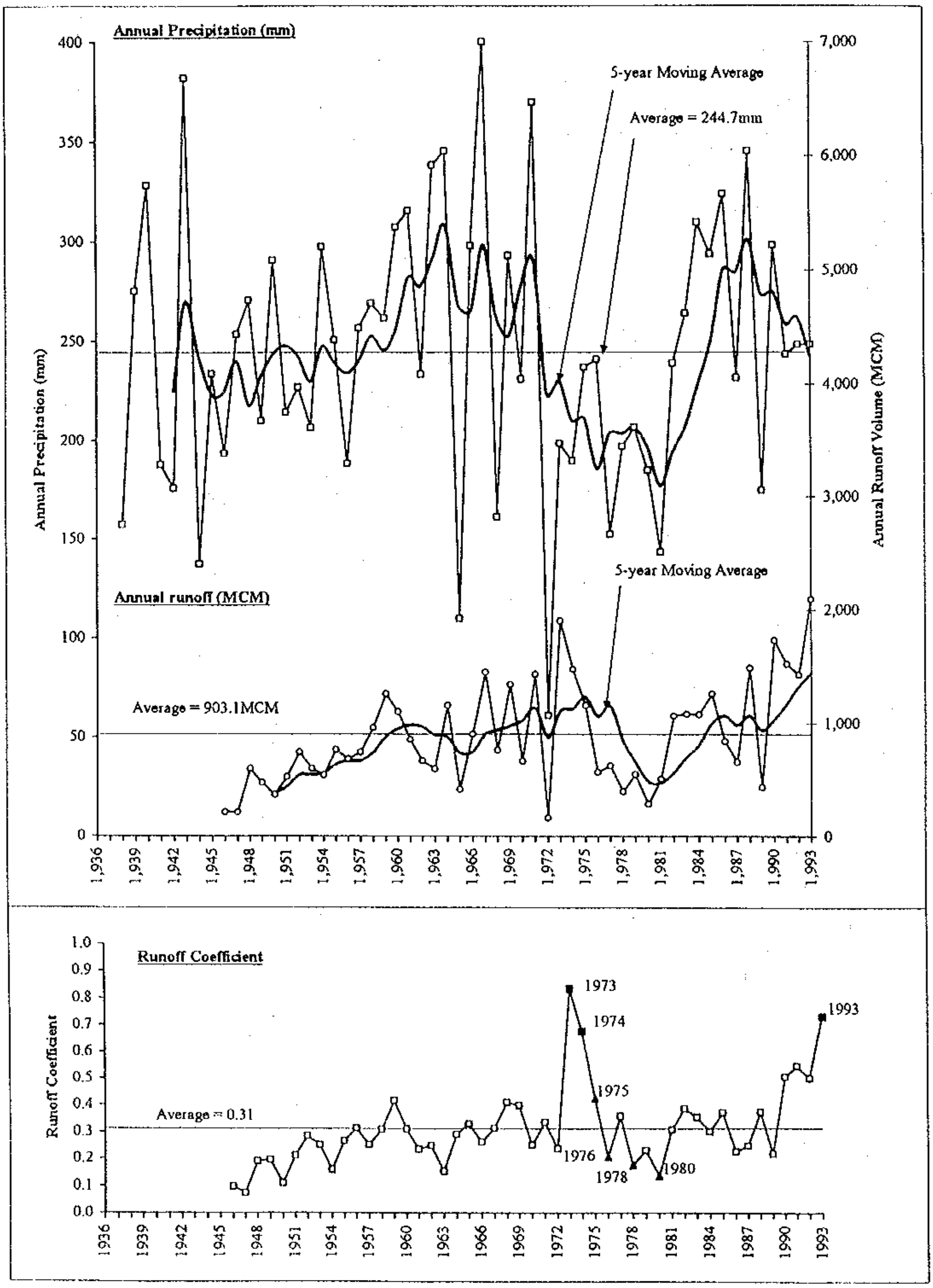

Fig. II.5.5	LONG TERM TREND OF PRECIPPITATION AND SURFACE RUNOFF IN ULAANBAATAR STATION
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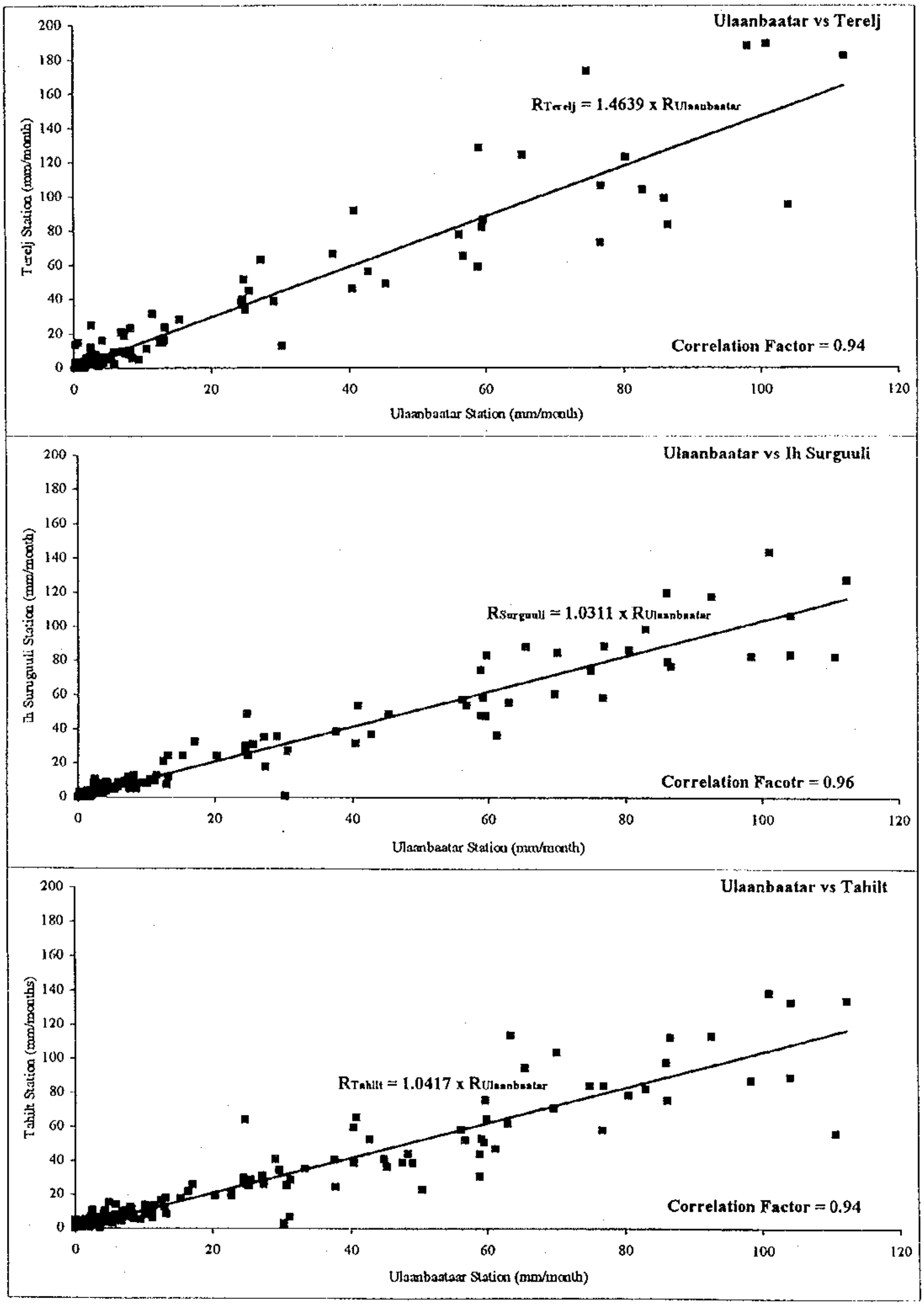

Fig. II.5.6	CORRELATION OF PRECIPPITATION IN UPPER TUUL RIVER BASIN
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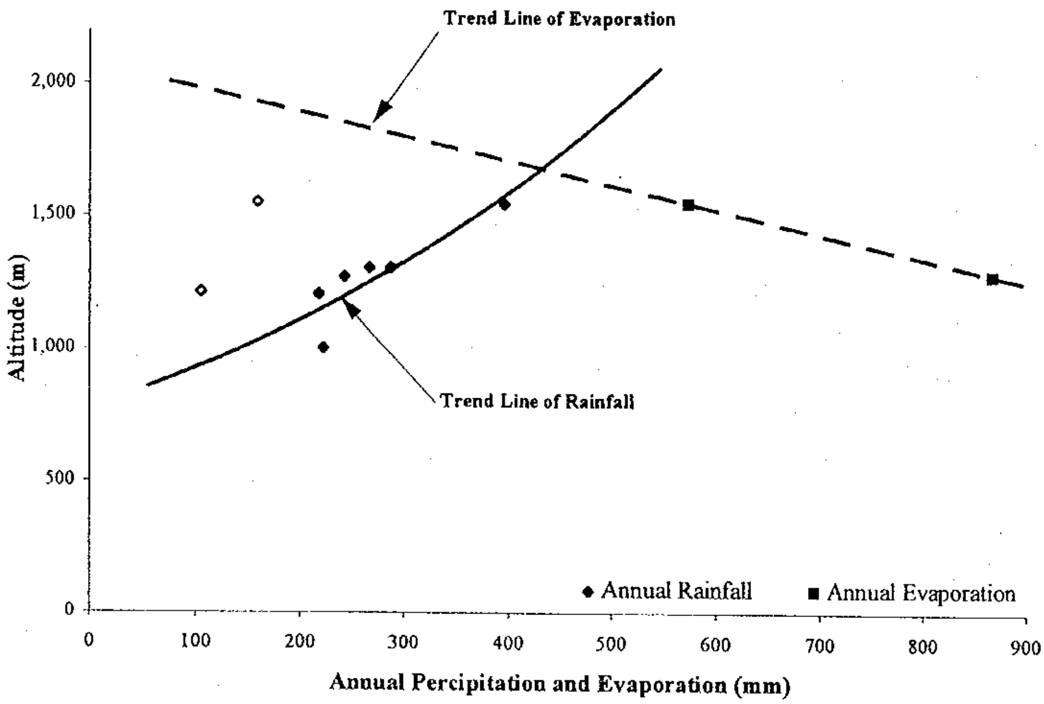
Relationship between Altitude and Precipitation



Annual Precipitation Pattern

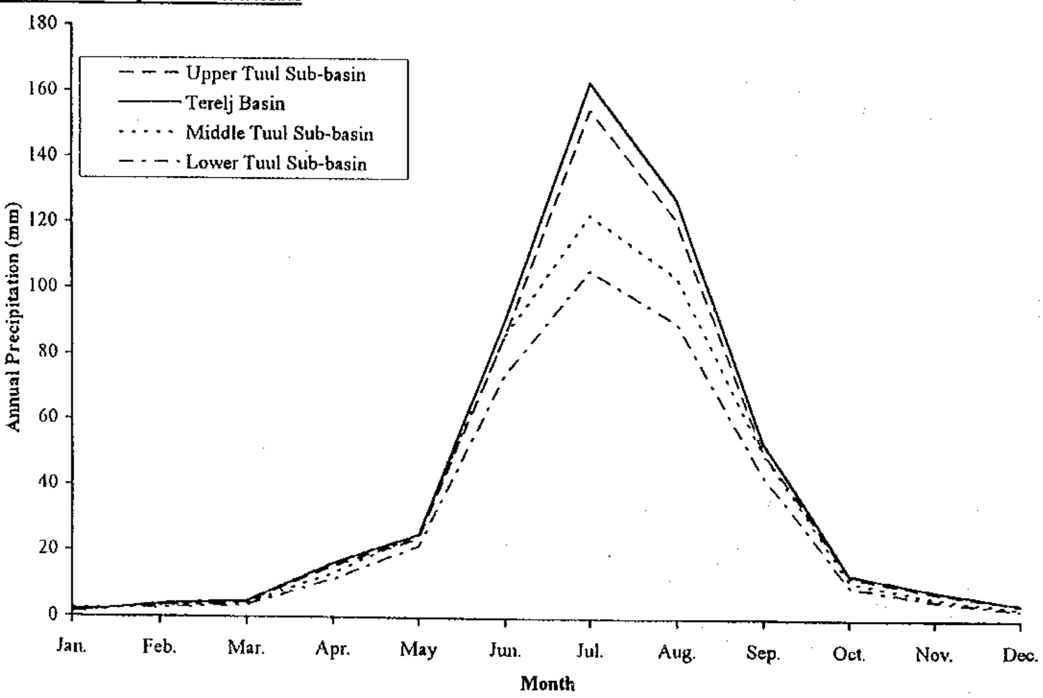


Fig. II.5.7 RELATIONSHIP BETWEEN ALTITUDE AND ANNUAL PRECIPITATION IN UPPER TUUL RIVER BASIN

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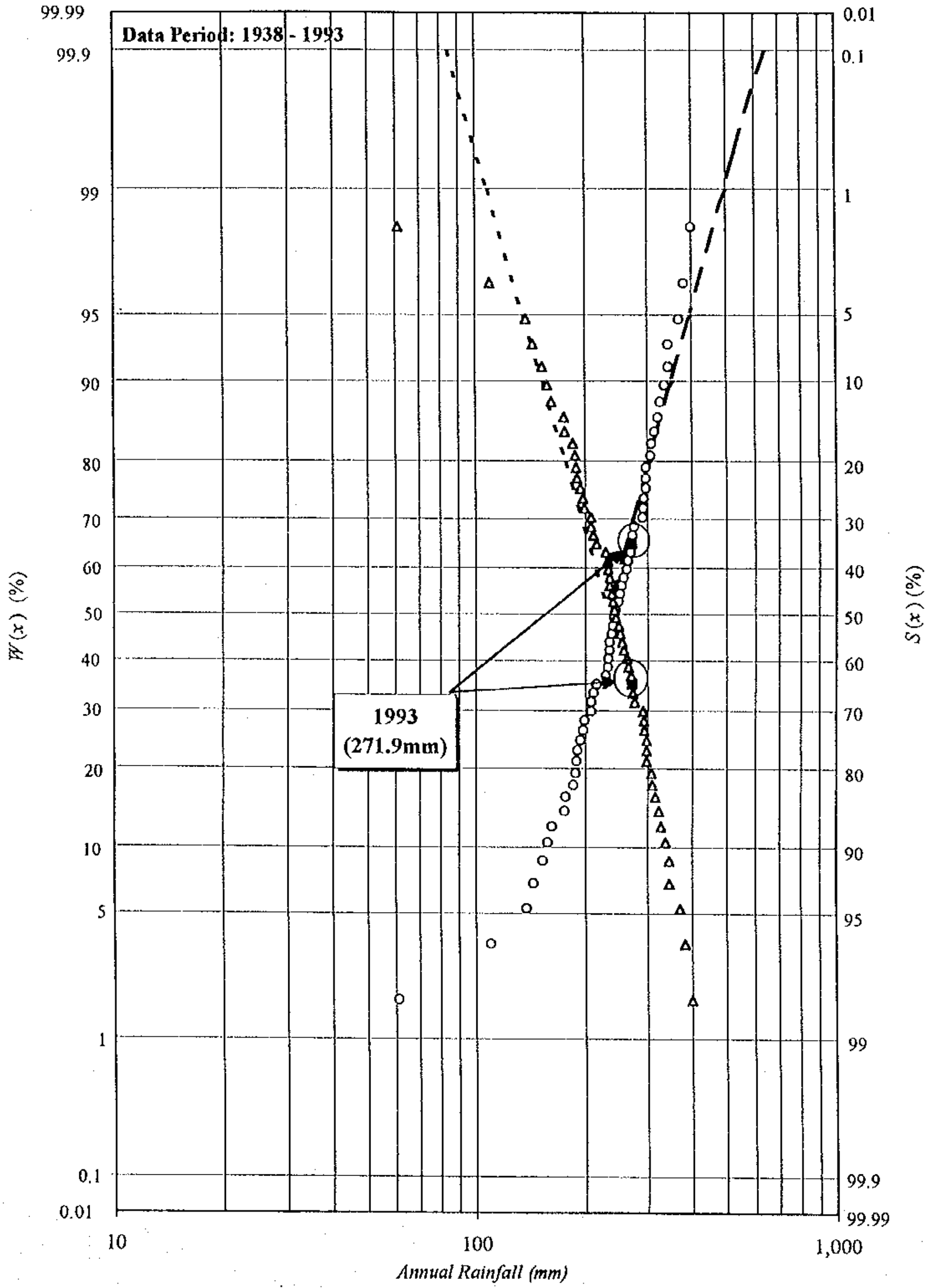
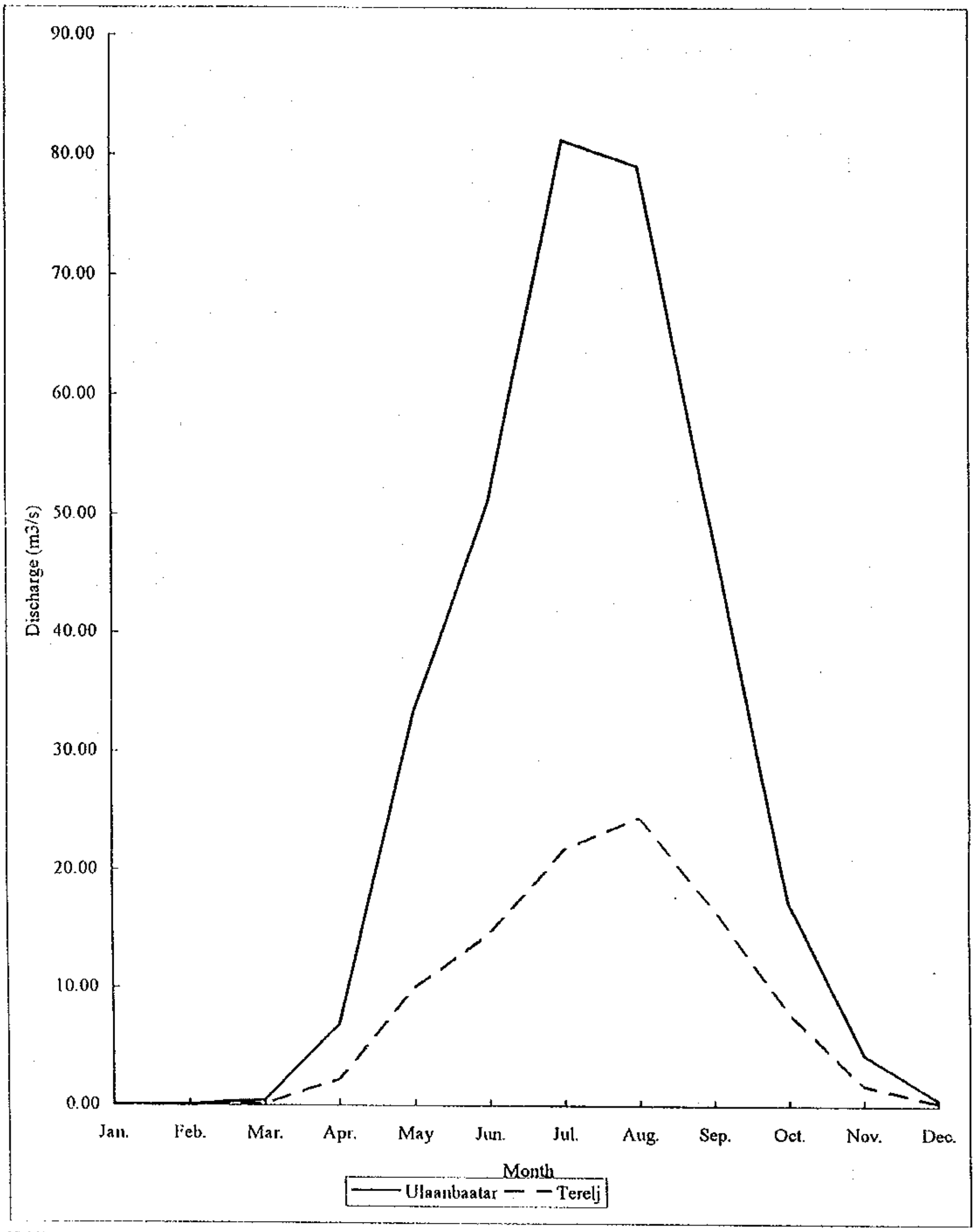


Fig. II.5.8	PROBABLE ANNUAL RAINFALL OF ULAANBAATAR BY IWAI METHOD
JICA	The Study on Water Supply System in Ulaanbaatar and Surroundings



Station	Month												Average
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Ulaanbaatar	0.03	0.03	0.45	6.86	33.41	51.17	81.19	79.04	47.89	17.27	4.39	0.52	26.85
Terelj	0.01	0.00	0.13	2.21	10.06	14.54	21.74	24.48	16.71	7.90	1.73	0.30	8.32

Fig. II.5.9 SEASONAL VARIATION OF DISCHARGE AT ULAANBAATAR AND TRELJ STATIONS

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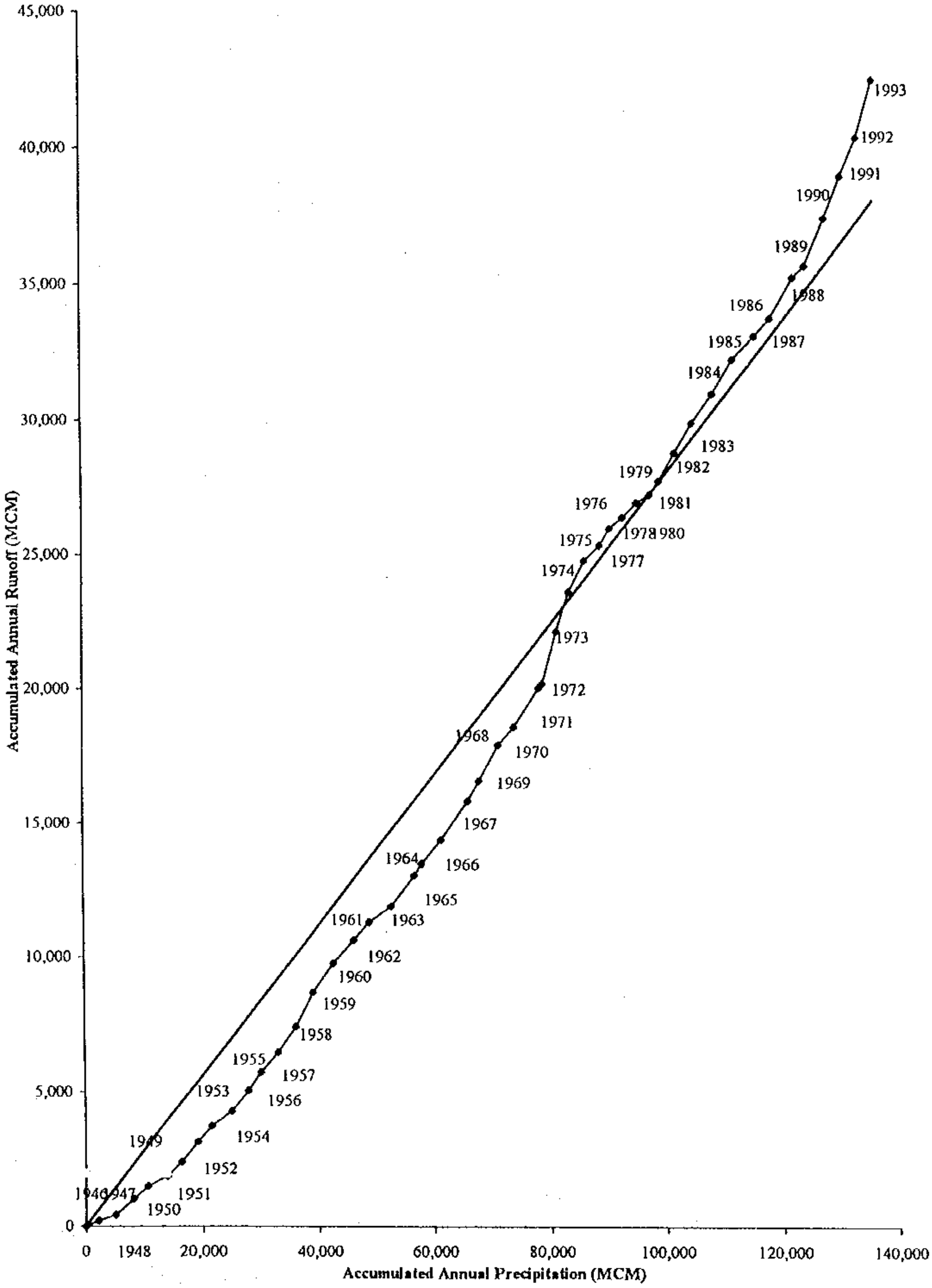


Fig. II.5.10	RELATIONSHIP BETWEEN ACCUMULATED ANNUAL PRECIPITATION AND RUNOFF
JICA	The Study on Water Supply System in Ulaanbaatar and Surroundings

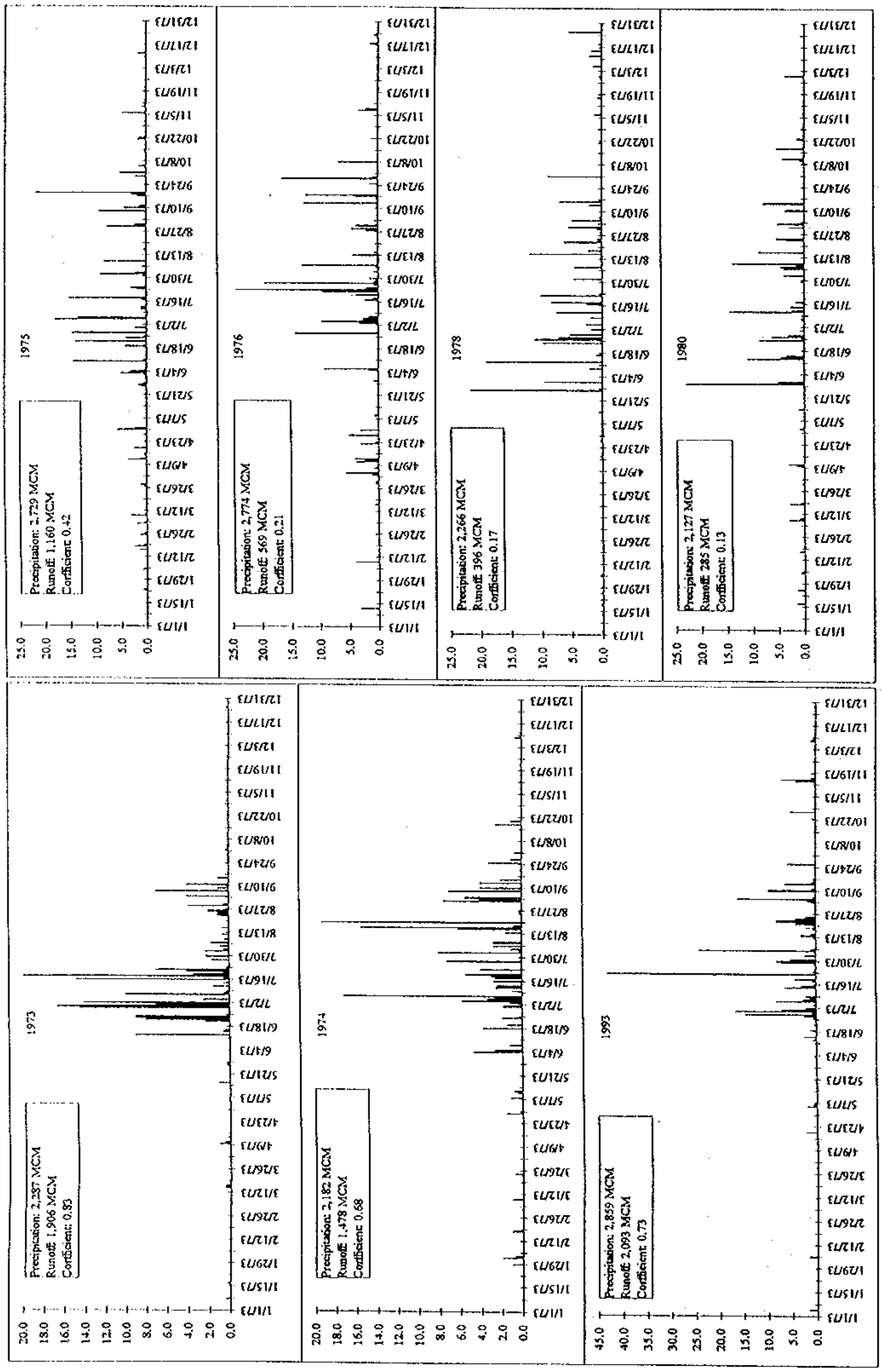


Fig. II.5.11 PRECIPITATION PATTERNS OF ULAANBAATAR STATION IN SOME SELECTED YEARS

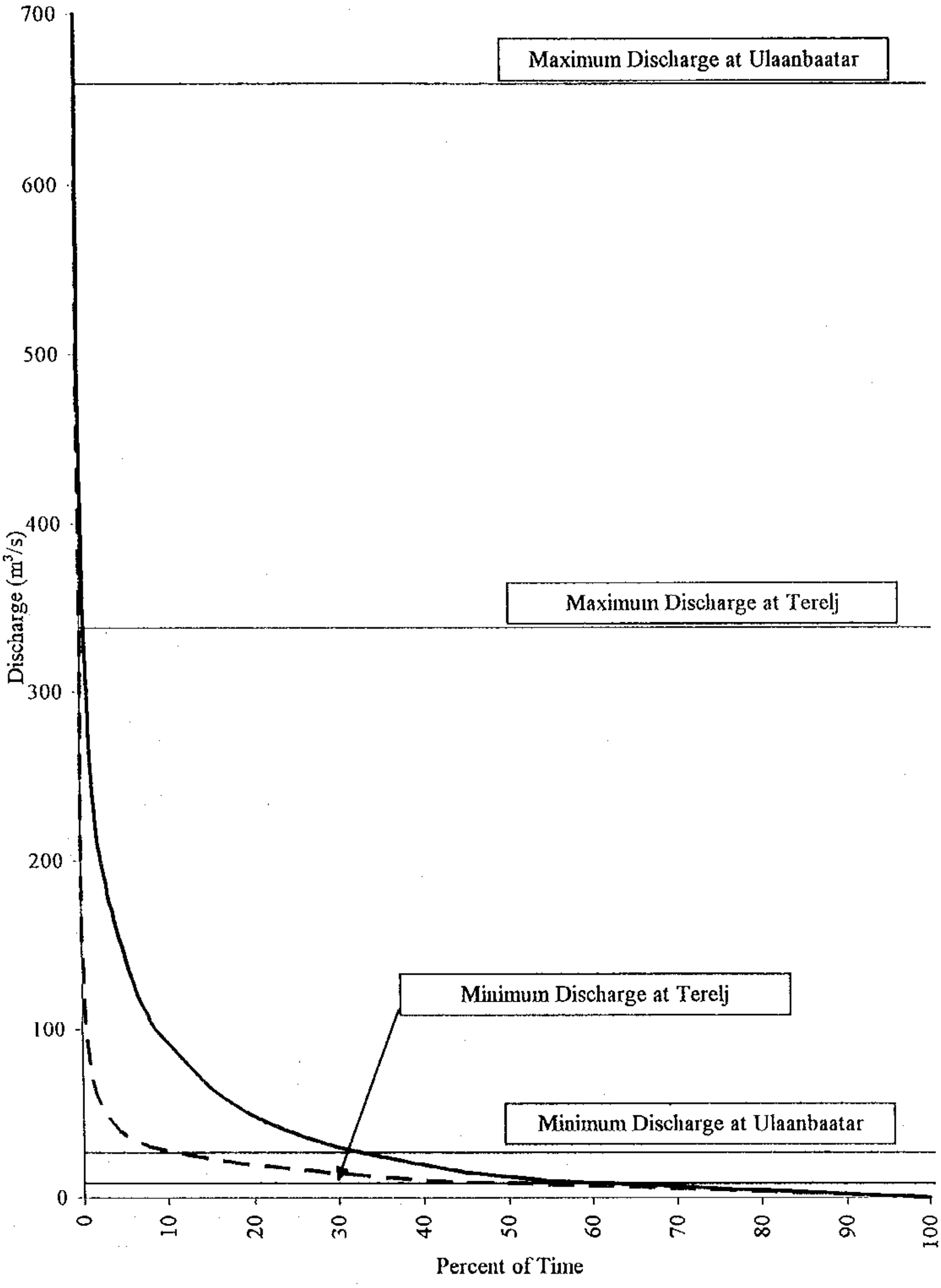
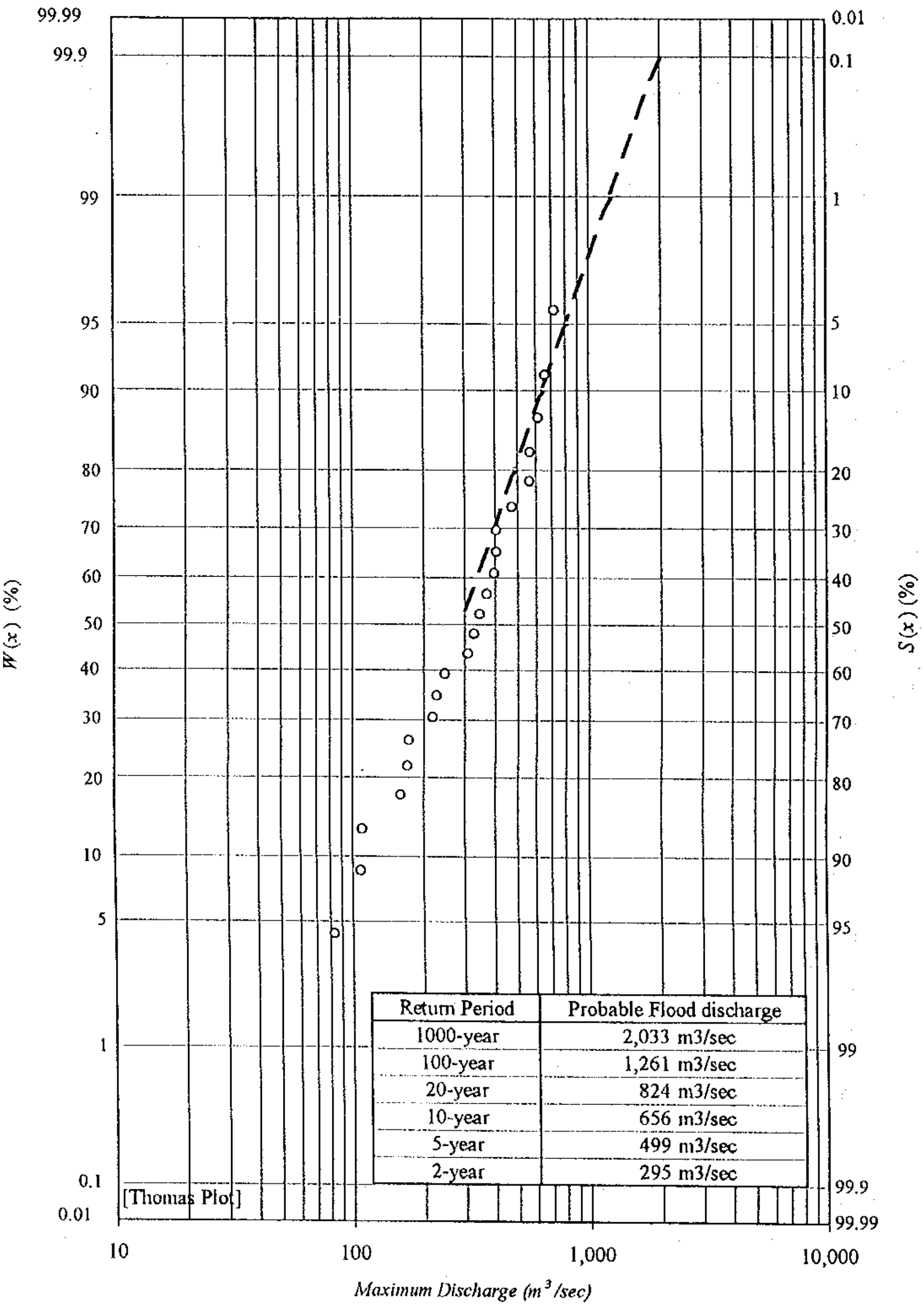


Fig. II.5.12	FLOW-DURATION CURVES FOR TUUL RIVER AT ULAANBAATAR AND TERELJ STATIONS
JICA	The Study on Water Supply System in Ulaanbaatar and Surroundings



Return Period	Probable Flood discharge
1000-year	2,033 m3/sec
100-year	1,261 m3/sec
20-year	824 m3/sec
10-year	656 m3/sec
5-year	499 m3/sec
2-year	295 m3/sec

Fig. II.5.13	PROBABLE MAXIMUM DISCHARGE AT ULAANBAATAR STATION BY IWAI METHOD
JICA	The Study on Water Supply System in Ulaanbaatar and Surroundings

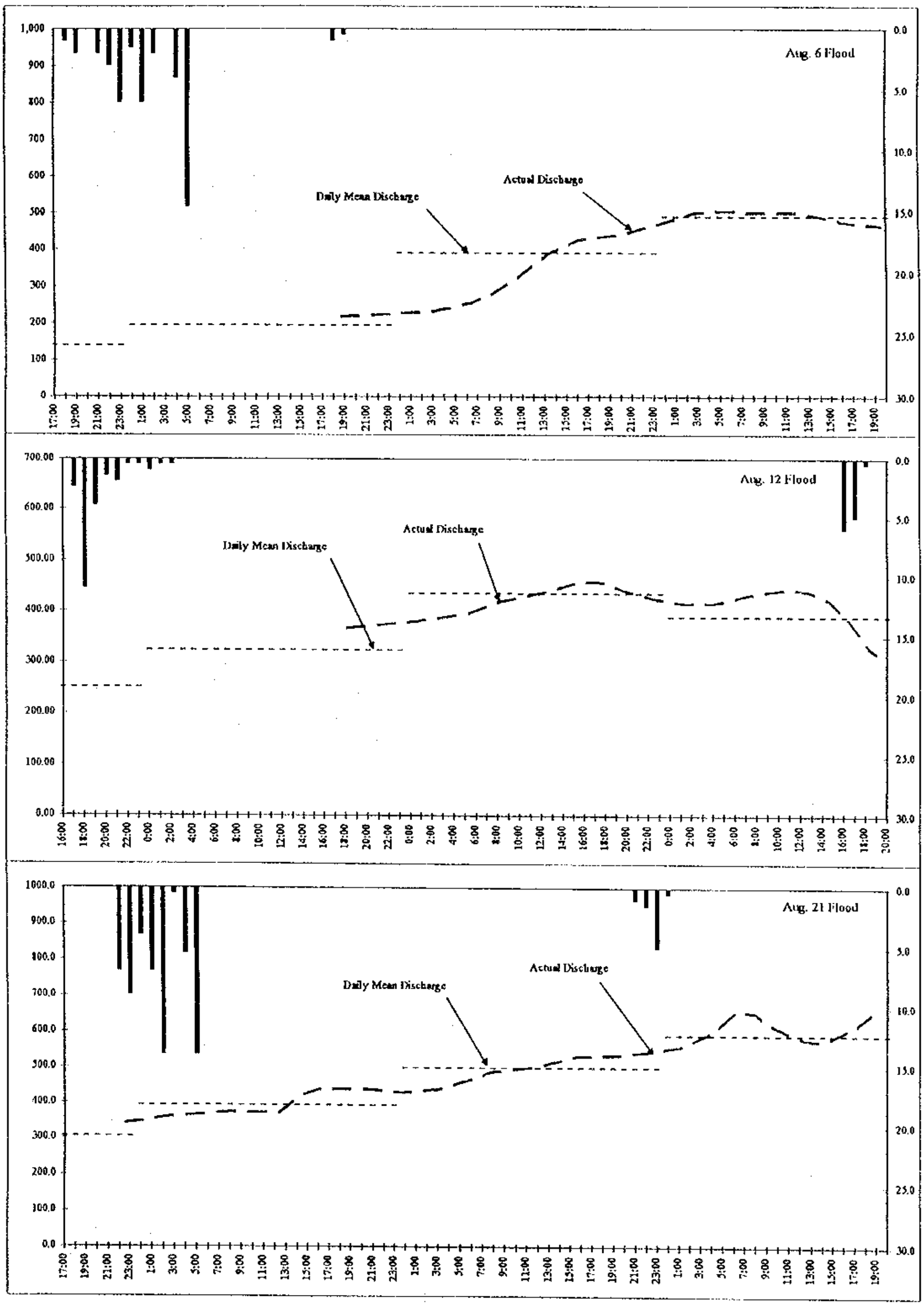
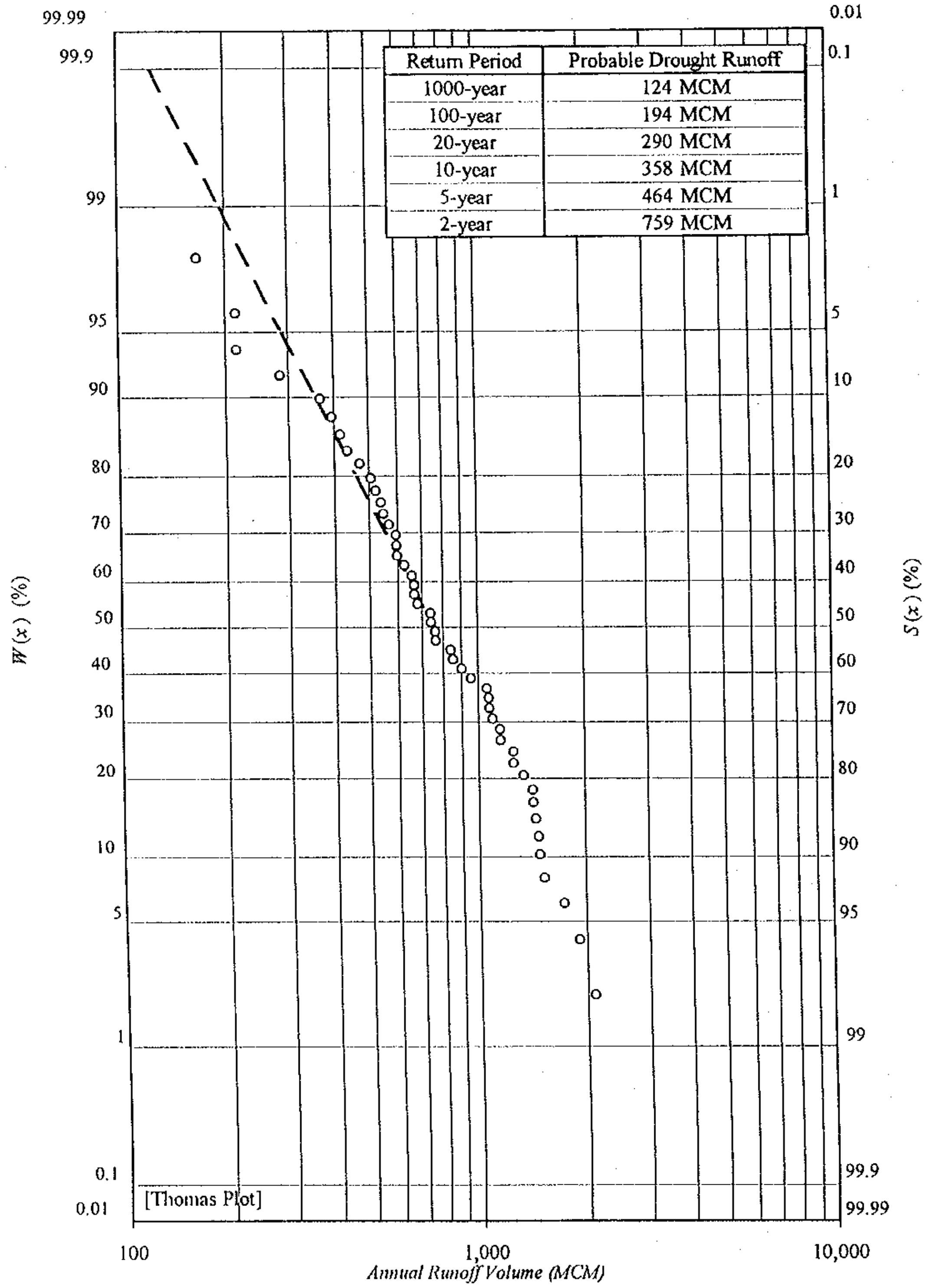


Fig. II.5.14 FLOOD RUNOFF PATTERNS IN AUGUST 1994

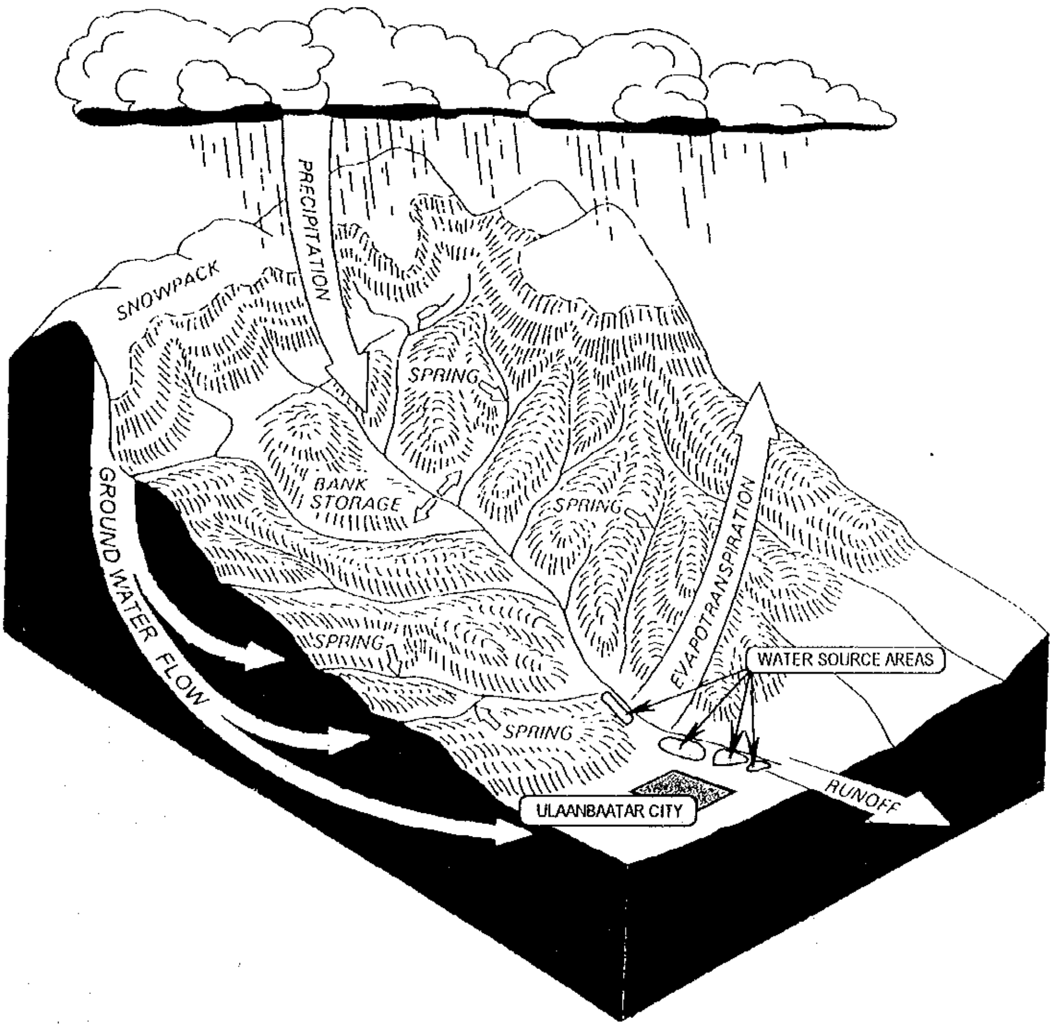
JICA	The Study on Water Supply System in Ulaanbaatar and Surroundings



Return Period	Probable Drought Runoff
1000-year	124 MCM
100-year	194 MCM
20-year	290 MCM
10-year	358 MCM
5-year	464 MCM
2-year	759 MCM

Fig. II.5.15 PROBABLE DROUGHT DISCHARGE AT ULAANBAATAR STATION

JICA | The Study on Water Supply System in Ulaanbaatar and Surroundings



$$P = ET + R + U + ST$$

Where; P: Precipitation
ET: Evapotranspiration
R: Surface Runoff
U: Utilized Water
ST: Stored Water

Fig. II.6.1 HYDROLOGICAL CYCLE OF UPPER TUUL RIVER BASIN

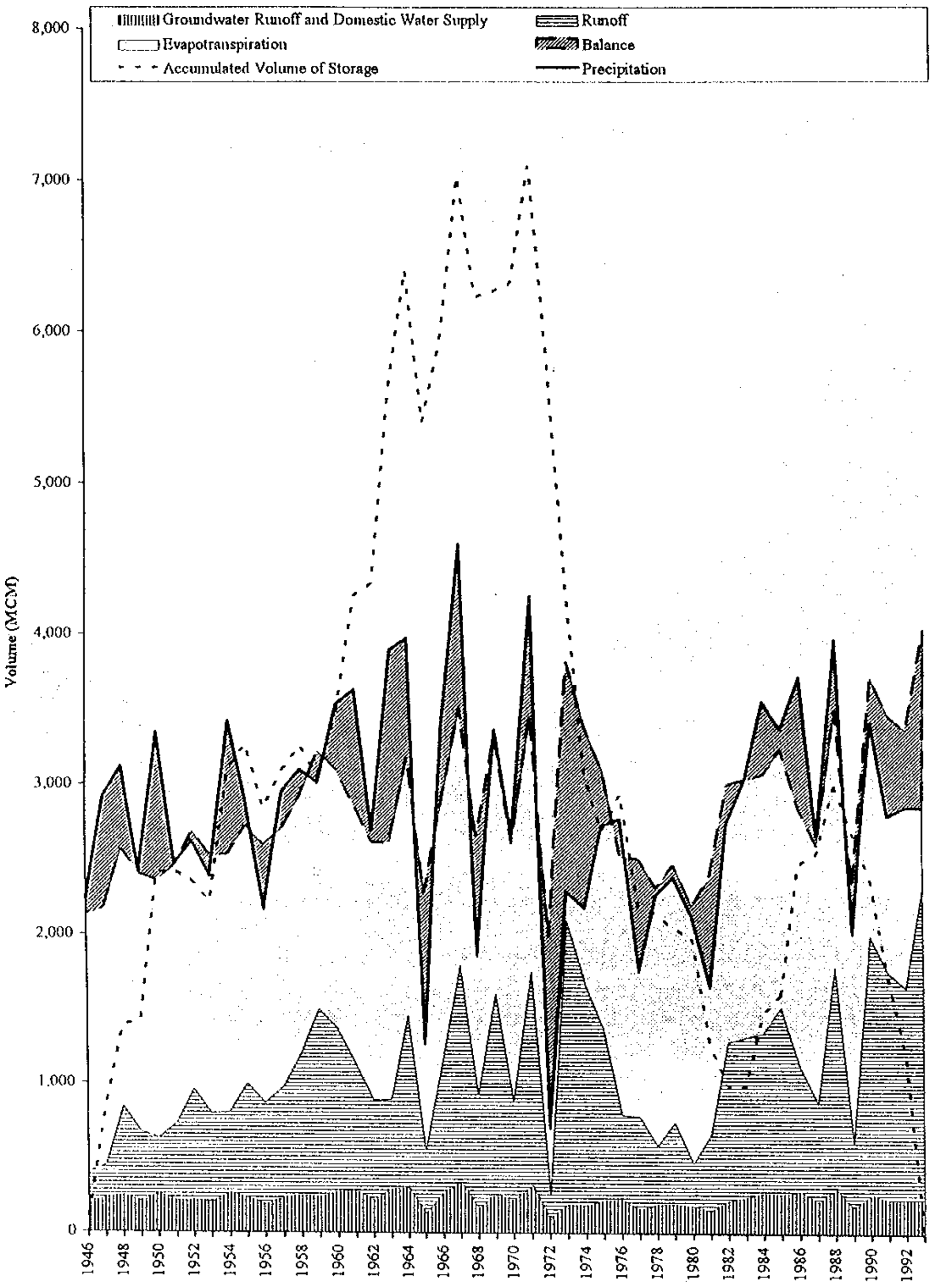


Fig. II.6.2 LONG TERM WATER BALANCE FROM 1946 TO 1993

JICA	The Study on Water Supply System in Ulaanbaatar and Surroundings

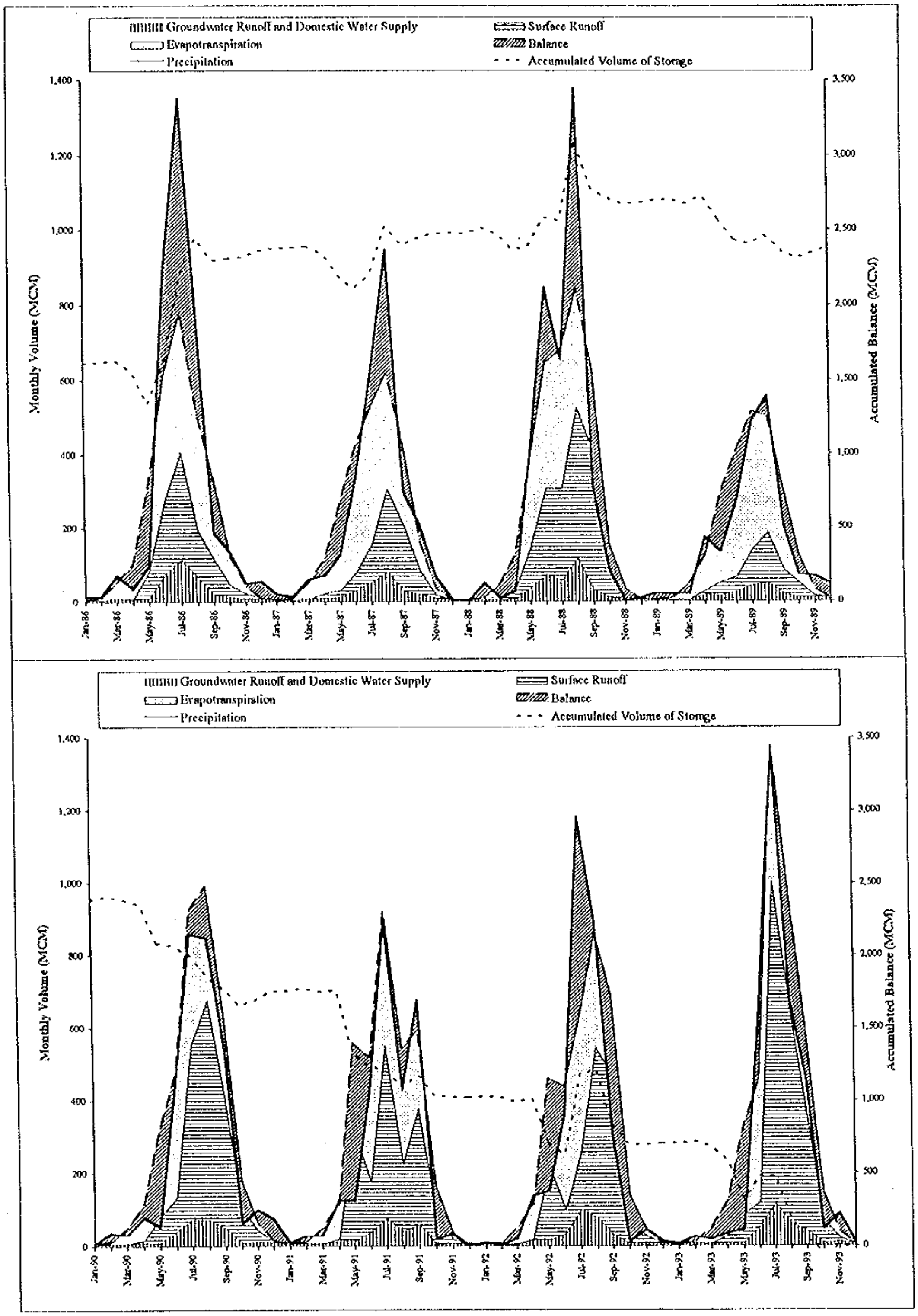


Fig. II.6.3	MONTHLY WATER BALANCE FROM JANUARY 1986 TO DECEMBER 1993
JICA	The Study on Water Supply System in Ulaanbaatar and Surroundings

III WATER SUPPLY SYSTEM

CHAPTER 1 WATER SUPPLY SYSTEM IN ULAANBAATAR CITY

CHAPTER 1. WATER SUPPLY SYSTEM IN ULAANBAATAR CITY

1.1 PRESENT CONDITION OF WATER SUPPLY SYSTEM

1.1.1 Population Served and Service Area

The people of Ulaanbaatar City live either in apartment buildings (9 stories and 4-5 stories in majority) located in the City central area and on low hills, or in Ger dwellings (traditional Ger tents or wooden houses) scattered mainly on northern hills of the City.

Population in the city was 569,405 in the year 1994; and is almost evenly distributed among the apartment buildings and Ger Area.

(1) Population Served

Population in the Ulaanbaatar City was done in cooperation with the Town Planning Department in detail. Ulaanbaatar City was divided into 12 districts until the end of 1994, among which six (6) districts (No.1-No.6) were located in the central area of the city and the other six (6) districts (No.7-No12) were in the suburbs area of the city.

The six (6) districts (No.1-No.6) were further divided into subdistricts. Present population of each subdistrict was divided into two (2) categories, that was, those in the area covered by the central water supply system of USAG (Water Facilities Exploitation Department, Ulaanbaatar City) and these in the area not covered by the central system. Residents in the area not covered by the central system use private wells or water supply system of one's own.

Moreover, in each category, the population number was divided into Apartment residents and Ger dwellers. Detailed survey results are shown in Appendix III.1.1. The results of this survey showed 569,405. For our calculation of the present water balance, the latter has been utilized.

The summary of the population served and not served by the central water supply system is shown in following table.

(Unit : Person)

Served Area			Covered by central water supply system of USAG		Not covered by central water supply system of USAG		Total
	No	Districts	Apartments	Ger	Apartments	Ger	
Central area of the city	1	Han-Uul	19,429	29,631	2,341	0	51,401
	2	Bayanzurh	50,529	39,863	1,891	0	92,283
	3	Suhbaatar	45,397	23,987	0	0	69,384
	4	Chingeltei	28,282	55,539	0	0	83,821
	5	Bayangol	90,737	16,741	0	0	107,478
	6	Songinohairhan	56,235	50,304	0	0	106,539
		Sub-total	290,609	216,065	4,232	0	510,906
the Suburbs area of the city	7	Baganuur	0	0	13,007	3,268	16,275
	8	Bagahangai	0	0	3,422	2,282	5,704
	9	Nalaikh	0	0	5,890	17,514	23,404
	10	Gachuurt	0	0	0	3,450	3,450
	11	Jargalant	0	0	720	5,697	6,417
	12	Tuul	0	0	548	2,701	3,249
		Sub-total	0	0	23,587	34,912	58,499
Total			290,609	216,065	27,819	34,912	569,405
			51%	38%	5%	6%	
			506,674	(89%)	63	(11%)	

(Note) Population number of Districts No.1- 6 : as of October, 1994
Population number of Districts No.7-12 : as of December,1993
Source: Town Planning Department

(2) Service Area

USAG's service area is divided into districts and subdistricts and apartment area and Ger area, excluding the six (6) districts (No.7-No.12), as shown in Fig. III.1.1.

1.1.2 Present Water Supply System

(1) Outline of the System

The system which is operated and managed by a public water supply organization (USAG) extracts raw groundwater and supplies to consumers, after chlorinating in principle.

The water is supplied through pressured pipelines to apartment buildings with individual house connections and by way of water tank lorries to Ger Area people at water vending centers (kiosk).

The apartment buildings are supplied with both cold and hot water throughout the year through the community heating centers (CTP; 51 CTP existing in the city as of 1994), where a part of cold water derived from distribution pipelines is heated. Therefore, the apartment buildings receive two types of water, namely cold (ordinary) and hot, through dual service pipes. A supply ratio of cold water to hot water is estimated to be about 63%:37% in quantity. The USAG is responsible for supplying water up to the entrance of the CTP; and tertiary distribution pipelines thereafter and service pipes/faucets/taps are the responsibility of the community companies which maintain CTP. The CTP distributes both cold and hot water by their own booster pumps, which are installed in CTP buildings after receiving cold water from USAG.

At present CTP is located at 51 places in the central area as of 1994. The list of CTP is shown below.

CTP Number in Ulaanbaatar City

Section No	1991	1992	1993	1994
1	6	6	6	6
2	3	3	3	3
3	3	3	5	5
4	6	8	8	8
5	4	4	4	4
6	2	2	2	2
7	0	0	0	0
10	2	2	2	2
11	2	2	2	2
12	4	4	4	4
13	2	2	2	3
14	0	0	1	1
15	8	8	8	8
16	2	2	2	2
21	0	0	0	1
Total	44	46	49	51

Data Source : Town Planning Department, Ulaanbaatar Municipality in 1994

Water meters have neither been installed in individual houses nor in apartment buildings. All the CTP were once equipped with water meters at the time of their commissioning. However, at present, all of them are out of service due to the mechanical failures.

In Ger Areas, there are about 280 kiosks for vending the drinking water to the dwellers. The USAG maintains water service stations (7 stations in the city) and water tank lorries (equipped with about 5 m^3 water tank). The Department obtains water from pressured distribution pipelines and transports it to the above-mentioned kiosks.

CTP as well as the water service stations obtain water from distribution pipelines (sometimes through supply reservoirs located on the northern hills in the city) into which groundwater is pumped by distribution pumping stations located in the precincts of water sources.

In water sources located along Tuul River, groundwater is collected by tube wells and is pumped by submersible pumps to storage reservoirs, located in the premises of distribution pumping stations. Chlorination is in principle done in the storage reservoirs, before distributing to consumers.

A schematic flow chart of the public water supply system for Ulaanbaatar City is shown in Fig.III.1.2.

(2) Present Water Balance

The water balance of the present water supply system is shown in the following table, was calculated from actual water usage records which described below tables..

Present Water Balance

No	Item	Capacity (Average) (M3/day)	(%)	Remarks (Basis)
1	Actual Supply Capacity (Q)	165,304	100.0	Refer to Table III.1.3
2	Breakdown of Supply Capacity			
-1	Apartment dwellers (q1)	122,056	73.8	Refer to Table III.1.1 & Table III.1.4 q1=290,609 persons * @420 Liter/Person/day
-2	Ger People (q2)	1,600	1.0	Refer to Table III.1.1 & Table III.1.5 q2=216,065 persons * @ 7.4 Liter/Person/day
-3	Industrial factories (q3)	11,452	6.9	Refer to Table III.1.6
-4	Other Consumers (q4)*-1	8,100	4.9	Refer to Table III.1.7
-5	Loss (q5)*-2	22,096	13.4	q5 = Q - [(q1)+(q2)+(q3)+(q4)]

Note: *-1: Recorded by Water Meters
*-2: including the supply water to un-recorded consumers

Actual supply capacity for the last one (1) year from the existing water sources are following table. Total average of supply capacity for the past one (1) year was 165,304m^3/day.

Actual Supply Capacity for the last one (1) Year

[Unit : m3/day]

Year	Month	Existing Water Sources: Central	Industrial	Meat	Upper	Total
1993	10	70,455	43,200	15,120	24,000	152,775
	11	69,891	43,200	15,120	24,000	152,211
	12	78,052	43,200	12,000	24,000	157,252
1994	1	79,373	43,200	12,000	24,000	158,573
	2	94,286	43,200	12,000	24,000	173,486
	3	96,000	43,200	15,120	24,000	178,320
	4	96,000	43,200	12,000	23,933	175,133
	5	90,000	42,648	12,000	23,742	168,390
	6	91,600	43,200	12,000	26,000	172,800
	7	96,731	30,240	12,000	24,000	162,971
	8	95,143	30,240	12,000	24,000	161,383
	9	92,327	39,840	14,184	24,000	170,351
	Average	**87,488**	**40,714**	**12,962**	**24,140**	**165,304**
Remarks	Design Capacity	**97,000**	**43,000**	**15,000**	**72,000**	**227,000**

Data Source : It was calculated due to the operation records of distribution pumps of water source respectively it has recorded by USAG.

The water consumption survey of apartment dwellers was conducted by the Ministry of Communities in 1988 and was also conducted by JICA Study Team in 1994. The results are shown below.

Water Consumption of Apartment Dwellers

	Investigators: The Ministry of Communities (in 1988)	JICA Study Team (in 1994)
Unit Water Consumption	421 l/p/day	419.7 l/p/day

The detailed survey results of both investigations are described in Appendix III.1.3 and III.1.4 respectively. As the results of above both survey, the existing unit water consumption is 420 l/p/.

As the results of water consumption survey in the Area, the existing unit water consumption is 7.4 ℓ/p/ at present as shown below. The more detailed results of survey are refer to Appendix III.1.5.

Water Consumption of Dwellers

No	Surveyed Methods	Per Capita (Liter/Person/day)
1	Pre-Paid Ticket	6.2 *-1
2	Transportation by Tank Lorries	6.1 *-2
3	Interview to Area People	7.4
	Conclusion	7.4

Note
(*-1) : 1349 m3/day x 1000 / 216,065 = 6.2 l/p/day
(*-2) : 1313 m3/day x 1000 / 216,065 = 6.1 l/p/day

Water supply capacity recorded to industrial factories from USAG for the last one (1) year was carefully surveyed by USAG. The results are shown below

Water Consumption of Industrial Facilities

[Unit : m^3/Month]

Month / Year		Water Consumption
January	1994	402,658
February	1994	374,470
March	1994	344,399
April	1994	351,527
May	1994	350,734
Jun	1994	359,510
July	1994	312,466
August	1994	268,590
September	1994	362,042
Average (m3/Month)		347,377
Average (m3/Day)		11,452

Note: 1. Data Source : from USAG (Nov 1994)

Water Consumption of Other Consumers

[Unit : m^3/Month]

Month / Year		Water Consumption
January	1994	266,859
February	1994	245,273
March	1994	245,593
April	1994	262,138
May	1994	260,111
Jun	1994	255,154
July	1994	217,445
August	1994	202,359
September	1994	256,369
Average (m3/Month)		2,211,300
Average (m3/Day)		8,100

Note: 1. Data Source : from USAG (Nov 1994)

According to the USAG, water usage by other consumers amounts to 23,618m^3/day for the last one (1) year (Average), among which the measured value is 8,100m^3/day and the other 15,518m^3/day is a contract value with consumers.

Other consumers consist of schools, hospitals, hotels, shops, offices, sports halls and others. Contract value not measured is included in "Loss" in our calculation of the present water balance.

(3) Water Source

The water source for Ulaanbaatar City depends solely on groundwater. It is utilized the waters from Tuul River flowing south of the city. The water sources belonging to the Department are located at four (4) places along the river. The groundwater is extracted through tube wells which are equipped with submersible pumps. The water sources are outlined in the following table.

Table Water Sources of Ulaanbaatar City

No.	Name of Water Source	Years of Development	Number of Existing Well	Depth of Well in Average	Capacity of Pump in Average
1)	Central Water Source	1950s-	70Nos.	30m	53m^3/hour
	Remarks: - Oldest water source (developed in 1950s) in Ulaanbaatar City. - Present main water source for domestic use water for the city. - Groundwater is excessively taken. - Facilities such as tube wells, intake pumps, electric facilities, distribution pumps have been deteriorated, and heavy damages on the facilities happen very frequently.				
2)	Industrial Water Source	1960s-	16Nos.	33m	130m^3/hour
	Remarks: - Main water source to industrial factories. - Facilities deteriorated.				
3)	Meat Complex Water Source	1960s-	8Nos.	31m	119m^3/hour
	Remarks: - Main water source to meat processing factories. - Water quality is questionable for drinking purpose. - Facilities deteriorated.				
4)	Upper Water Source	1990	39Nos.	32m	127m^3/hour
	Remarks: - Located about 40km upstream of the city, along Tuul River. - Newest water source for the city. (Commissioned in 1991) - Considered supplemental water source to Central Water Source. - Presently water intake is comparatively conserved, as if it were extra water source. - High power cost is necessary to transmit groundwater to the city.				
Total/Average			133Nos.	32m	87m^{3}hour

Schematic layouts of water source facilities are illustrated in Fig. III.1.3 to III.1.6.

(4) Intake Facilities

Intake facilities consist of intake wells, intake pumps and collection pipelines.

Groundwater is collected by intake wells (Depth: 21-53m, Casing diameter: 200-400mm), and is pumped by submersible pumps (Capacity: 25-200m3/hour, Head: 60-150m, Power: 11-55kw) to storage reservoirs through collection pipelines (Steel pipe; Diameter: 100-700mm). These facilities are described below.

1) Intake Wells

Intake wells had been constructed in four water sources along Tuul River and count 133 Nos. as of October 1993. First in 1957, Central Water Source (70 wells presently) was developed under the aid of former Soviet Union; since then, Meat Complex Water Source (8 wells presently) was developed in 1962, and Industrial Water Source in 1963. The groundwater taken from the riverbed is suitable both in quantity and quality; the public water supply system operated by USAG fully depends on the groundwater.

Recently, in the year 1990, order to supplement the above water sources, Upper Water Source consisting of 39 wells was developed.

The wells in Central Water Source have comparatively shallow depth of 29.6m in average. The average ground level is +1,286.2m above the sea level. The height difference between the highest well and the lowest is about 30m. Average static water level of the wells is 2.47m below the ground level; and corresponds to the water level of Tuul River. Borehole diameter of the well is 400-600mm in general; and casing steel pipe diameter is 300-400mm. Screens made of steel pipe, have 15.9m length in average and openings of 10-20mm in diameter and 700-1,000 numbers per meter length.

The wells in Meat Complex Water Source have 31.3m depth in average. The average ground level is +1,269.1m and difference of the ground levels is about 3.0m. Average static water level is 2.36m below the ground level; considered to be infiltrated water from the river. Borehole is 350-600mm in diameter and casing pipe is 200-400mm in diameter. Average screen length is 17.6m.

An average depth of wells in Industrial Water Source is 32.8m and average ground level is +1,272.9m and difference of the ground levels is about 10m. Average static water level is 2.40m and this is considered infiltrated water from the river as well as the above water sources. Borehole is 500-600mm in diameter and casing pipe diameter is 400mm in general. Average screen length is 20.0m .

The wells constructed in Upper Water Source have 31.7m depth in average. The average ground level is +1,423.7m above sea level. These wells are located at the highest places among the four (4) existing water sources. Difference of the ground levels is 42.0m. Static water level is 1.9m below the ground level, similar to Tuul River water level. Borehole is 530-630mm and casing diameter is 325mm. Screens have 14.7m length in average and openings are 10-20mm in diameter and 860-980 in number per meter length. This water source was developed very recently and data for the intake well construction has been well maintained.

During the survey period, September-November 1993, actual conditions of the wells were surveyed. All the wells together with intake pumps were installed in brick-made and single / double locked pump houses; and they were well protected. As a result, 102 wells in total were surveyed, except some of the Upper Water Source wells which were not accessible because they were surrounded by river streams.

Technical data of the intake wells of all the water sources is given in Appendix III.1.6.

2) Intake Pumps

The groundwater collected by intake tube wells is lifted to collection pipelines by intake pumps installed in the pump houses which are made out of brick with 50cm wall thickness.

As accessories for the intake pump, an air-release valve and a pressure gauge are installed on the delivery pipe; and a non-return valve, a water meter and a manual stop valve are on the delivery pipeline. These accessories have been installed as a rule in all pump houses with certain design criteria. Although they might have worked at the time of their commissioning, most of them are not functioning properly at present. Except in Upper Water Source, all the pressure gauges and the water meters had already been damaged and are out of service. Accordingly, actual pressure and water flow-rate can not be measured, and also pumps are being operated with proper engineering support.

The two (2) type of the pumps used are submersible pumps and vertical turbine pumps driven by electric motors. At the time of development of Central Water Source, the type of the pump used was the vertical turbine pump only; and after their deterioration, they had been replaced with submersible pumps. Presently all of the intake pumps in Central Water Source had been replaced with submersible pumps. The vertical turbine pumps are still used in Meat Complex Water Source (1 unit) and Industrial Water Source (5 units). At present, such kind of pumps are not manufactured because of large size and low efficiency, and their spare parts are no longer available. Therefore, these pumps could become out of service at any time in the near future.

Also in the case of the submersible pumps, except the pumps in Upper Water Source, almost all of the pumps have been once damaged and repaired since their installation. Most of the damaged parts were electric motors which could be repaired as far as spare parts were available. However, when the spare parts were not available, they were taken from old pumps, as well as in the case of the vertical turbine pumps.

The USAG keeps a workshop for pump repair work and a warehouse for spare parts; however, no new spare parts are available and damaged pump parts are piled in the yard. All the existing pumps were made in the former Soviet Union, and procurement of the spare parts is currently very difficult, after the collapse of the former Soviet Union. Thus, working condition of the intake pumps has deteriorated, progressively.

Lists of the existing intake pumps are given in Appendix III.1.7 and drawings of typical pump house including pipe arrangement is shown in Appendix III.1.8.

3) Electric Facilities

The electric power required for operation of intake facilities is supplied by the public power plants. Electric cables (3 phases) and electric poles (reinforced concrete made: underground and 2m above ground; wooden made: upper part) have been constructed exclusively for the intake facilities. The power (6000 volts / 50Hz / 3 phases) coming into the substations is to be transformed 380 volts to operate intake pumps. The power is then distributed to a transformer panel, control panel, remote operation panel and room heater in each intake pump house.

Electric facilities in Central Water Source were installed in 1961-1984. Therefore, most of the facilities were deteriorated and some of them have already been replaced; although no serious trouble has been observed for pump operation. However, control equipment and remote operation system had been damaged and they are now completely out of service. Also in Meat Complex Water Source and Industrial Water Source, present conditions of electric facilities are almost similar to those of Central Water Source.

Upper Water Source was developed in 1990, and facilities are generally new and have no remarkable technical problems. However, the remote operation system has been damaged, and operation and maintenance for the intake pumps has faced much difficulty, because intake wells existing beyond the river have to cross over, and have difficult access.

4) Collection Pipelines

The groundwater taken from water sources is transmitted to storage reservoirs located in the premises of distribution pumping stations by way of raw water collection pipelines which are summarized in the following table.

Their diameters range from 150-700mm, and their distance totals 97,340m as of October 1993. The pipe material is steel for all the diameters and the type of the joint is welding.

The pipelines have been laid underground with earth covering depth of 2.5-3.0m in general. These pipelines were constructed at the time of water source development.

Presently the collection pipelines are considered to have no serious technical problems in general.

List of Raw Water Collection Pipelines (As of October 1993)

Pipe Diameter	Pipe Material	Total Length	Year of Construction
700mm	Steel	20,813m	1972, 1983, 1990
600mm	"	10,271m	1958-1984
500mm	"	8,600m	1966-1972
400mm	"	23,873m	1966-1972
300mm	"	13,970m	1959-1980
250mm	"	5,392m	1959-1968
200mm	"	11,430m	1959-1972
150mm	"	2,946m	1980
100mm	"	45m	1980
Total Length		97,340m	

(5) Distribution Facilities

Distribution facilities consist of storage reservoirs and distribution pumps. Groundwater taken from tube wells and intake pumps is transmitted and collectively stored in storage reservoirs in water source fields; then distributed to consumers by distribution pumps, after chlorination. Each water source has its own storage reservoirs and distribution pumps.

1) Storage Reservoir

Groundwater is collected and stored in storage reservoirs located adjacent to the distribution pump house in the premises of a distribution pumping station in the water source field.

Reservoirs, made out of reinforced concrete, are constructed at the ground level and are covered with earth (about 1.0 meter on the roof slab). Their shapes are either rectangular or circle, and the water depth is 4.80m as a rule.

Chlorine gas injection is done for the reservoir water after to be diluted it by pure water, with a dosage rate of 0.8 - 1.2 mg/l, in principle for the purpose of disinfection. Chlorination equipment is installed in the pumping stations of Central, Industrial and Meat Complex Water Sources.

Storage reservoirs in the distribution pumping stations are outlined in the following table.

Presently, the storage reservoirs have no serious technical problems in general.

List of Storage Reservoirs

Name/Location of Reservoir	1) Upper Water Source Reservoir	2) Central Water Source Reservoir	3) Industrial Water Source Reservoir	4) Meat Complex Source Reservoir
Capacity	1,000m^3 x 2Nos. = 2,000m^3	6,000m^3 x 1 3,000m^3 x 1 500m^3 x 2 Total= 10,000m^3	2,000m^3 x 2Nos. = 4,000m^3	2,000m^3 x 2Nos. = 4,000m^3
Dimensions (Size)	14m x 15m x 4.8m x 2Nos.	36m x 36m x 4.8m x 1No. 25m (Dia) x 4.8m x 1No. 10.5m (Dia) x 4.8m x 2Nos.	18m x 24m x 4.8m x 2Nos.	18m x 24m x 4.8m x 2Nos.
Year of Construction	1991	1972 1959 (10.5m Dia. x 2)	1963	1966
Water Level above Sea Level	HWL = +1,430.0m LWL = +1,425.2m	HWL = +1,299.95m LWL = +1,295.15m	HWL = +1,283.8m LWL = +1,279.0m	HWL = +1,271.88m LWL = +1,267.08m
From Where Water Coming	From 39 wells in Upper Water Source	From 70 wells in Central Water Source	From 16 wells in Industrial Water Source	From 8 wells in Meat Complex Water Source
To Where Water Going	To communities	To communities and Tasgan Reservoir	To industrial factories and communities	To meat factories and communities, and to North-West Reservoir in 1994

Total Capacity of Storage Reservoir = 2,000 + 10,000 + 4,000 + 4,000
= 20,000m^3

2) Distribution Pumps

Distribution pumps supply chlorinated groundwater from the storage reservoirs to consumers through distribution pipelines and CTP. Some water is supplied directly by these pumps, and the other through supply reservoirs located on the northern hills of the city.

There are five (5) distribution pumping stations. Four (4) water sources have their own distribution pumping stations. In addition, there is a boosting pumping station in Tasgan.

Lists of these pumps are given in Table III.1.1 to III.1.5, and layout of the pumping stations is shown in Appendix III.1.9. Present status of the pumps (As of October 1993) are summarized below.

No.	Distribution Pumping Station	Numbers	Number of Pump Units to be Replaced due to Heavy Damage
1)	Central Pumping Station (Old)	4 units	4 units
2)	" " (New)	3 "	1 units
3)	Tasgan Pumping Station	4 "	1 units
4)	Industrial Pumping Station	4 "	2 units
5)	Meat Complex Pumping Station	4 "	-
6)	Upper Source Pumping Station	6 "	2 units
	Total	25 units	10 units

In general, distribution pumps and their accessories have deteriorated and been heavily damaged, and more than one-third units of the existing pumps are required to be replaced with new pumps urgently.

(6) Service Facilities

The service facilities consist of supply reservoirs, distribution pipelines and some service facilities for Ger Area.

1) Supply Reservoirs

There are four (4) supply reservoirs located on the northern hills in the city and one (1) reservoir located at east side of Ulaanbaatar City.

The supply reservoirs, as well as the storage reservoirs, made out of reinforced concrete, are constructed at the ground level and covered with earth (about 1.0m on the roof slab). Their shapes are rectangular and water depth is 4.80m as a rule.

Water from distribution pumps flows into distribution pipelines and first goes to CTP in principle; and when water is in excess of CTP's demand, the excessive water flows into supply reservoirs for storage. Particularly water is stored during night time.

A list of the supply reservoirs is shown in the following table. At present North East Reservoir is not being used as it is no more required. And Zavsariin Reservoir of Upper Water Source is left in between, and the North-West Reservoir is under construction as of November 1993. Presently, two (2) reservoirs, the Tasgan Reservoir and the 3/4 district Reservoir are working.

Presently, the supply reservoirs except the Zavsariin Reservoir have no serious technical problems in general, and no problem was found in the storage reservoirs. The Zavsariin Reservoirs are located on the hill of east of Ulaanbaatar City. The construction works for Zavsariin Reservoir started in the end of nineteen eighties together with the Distribution Pipeline. And the concrete basins and pipeline from the distribution main to the basins were constructed. However, the construction works stopped due to the lack of the budget in 1990, before installation of the equipment required for the operation such as water level meter, telecommunication system, etc. Therefore the Zavsariin Reservoir is out of use at present.

If the necessary equipment is installed, the Zavsariin Reservoir can be operated and the water supply capacity from the Upper Water Source will be increased.

List of Supply Reservoirs

	1)	2)	3)	4)	5)
Name/Location of Reservoir	North-East Reservoir	Tasgan Reservoir	3/4 Districts Reservoir	North-West Reservoir	Zavsariin Reservoir
Capacity	6,000m^3 x 2Nos. = 12,000m^3	6,000m^3 x 3Nos. = 18,000m^3	3,000m^3 x 2Nos. = 6,000m^3	3,000m^3 x 2nos. = 6,000m^3	3,000m^3 x 2Nos. = 6,000m^3
Dimensions (Size)	36m x 36m x 4.8m x 2Nos.	36m x 36m x 4.8m x 3Nos.	24m x 27m x 4.8m x 2Nos.	24m x 27m x 4.8m x 2Nos.	24 x 27m x 4.8m x 2Nos.
Year of Construction	1985	1972-2 Nos. 1986-1 No.		Under Construction	Level off construction
Water Level above Sea Level	HWL = +1,386.86m LWL = +1,382.06m	HWL = +1,334.8m LWL = +1,330.0m	HWL = +1,374.8m LWL = +1,370.0m	HWL = +1,346.8m LWL = +1,342.0m	HWL = + 1,429.8m LWL = + 1,425.0m
From Where Water Coming	To be from Upper Source Distribution Pumps	From Central Source Distribution Pumps	From Tasgan Reservoir Distribution Pumps	To be from Meat Complex Source Distribution Pumps	From Central Source Distribution Pumps
To Where Water Going	To communities by gravity	To communities by gravity, and to 3/4 Districts Reservoir by pumps	To communities by gravity	To be to communities by gravity	To communities by gravity
Remarks	Not being used because of no need currently			To be completed in 1994	Not Completed

Total Capacity of Supply Reservoir = 12,000 + 18,000 + 6,000 + 6,000
(Except the Zavsariin Reservoir) = 42,000m^3

2) Distribution Pipelines

Distribution pipelines constructed in Ulaanbaatar City are summarized below. Their diameters range from 100-800mm, and their distance totals 200,340m as of October 1993. For the pipe diameter 400mm and greater steel (SP; L = 133,310 m 57%) has been used and Cast Iron material is used for pipe diameter 700mm or lesser (CIP; L = 87,030m, 43%).

The pipelines are laid underground with earth covering depth of 2.0 to 3.0m in general. The pipelines networks had been designed to keep water pressure of 26m on main corners of the streets in the city.

These pipelines had been constructed along with the development of the city and water sources. Some of them might have already superannuated, causing leakage problems, although visual leakage on the ground surface from the pipelines is not so remarkable. Accordingly, it is recommended that old pipelines be carefully surveyed for the purpose of the leakage detection for repair/replacement of the pipelines. This work would take longer period, and should be solved by daily routine work of the USAG.

List of Distribution Pipelines (As of October 1993)

Pipe Diameter	Pipe Material	Total Length	Year of Construction
800mm	Steel	18,846m	1985-1990
	Cast iron	-	
700mm	Steel	29,103m	1972, 1983, 1990
	Cast iron	1,200m	
600mm	Steel	23,381m	1958-1984
	Cast iron	4,480m	
500mm	Steel	21,780m	1966-1972
	Cast iron	1,430m	
400mm	Steel	20,200m	1966-1972
	Cast iron	7,650m	
300mm	Steel	-	
	Cast iron	21,340m	1959-1980
250mm	Steel	-	
	Cast iron	29,600m	1959-1968
200mm	Steel	-	
	Cast iron	5,510m	1959-1972
150mm	Steel	-	
	Cast iron	14,140m	1959
100mm	Steel	-	
	Cast iron	1,680m	1959
Sub Total	Steel	113,310m	
	Cast iron	87,030m	
Total Length		200,340m	

3) Service Facilities for Ger Area

To Ger Areas where nearly half of Ulaanbaatar population live, USAG supplies water for their domestic use not through pipelines, but by transporting water through tank lorries.

The tank lorries take water from the water service stations (7 stations in the city) located on the distribution mains, and transport it to kiosks (280 kiosks in the city) scattered in Ger Areas, where people buy drinking water with their own containers.

The USAG maintains the following facilities for water supply to Ger Areas.

(i) Water service stations : 7 buildings
(ii) Water vending centers (kiosk) : 280 buildings
(iii) Tank lorries : 55 Nos.

Among the above, most serious issue is the shortage of tank lorries.

Most of them are quite old and deteriorated and supplement of the tank lorries is required. The result of the study on the supplement is shown in 1.1.4, (5)-5) of this chapter.

(7) Technical Problems in the Existing Water Supply Facilities

The followings are major technical issues related to the existing water supply facilities, found during the course of this study. Among them, countermeasure work for items 1) - 6) is proposed to be implemented by the emergency rehabilitation program.

On the other hand, countermeasure for items 7) - 12) is recommended to be executed by the daily routine work of the USAG, based on their own long term schedule.

Problems to be Taken up by the Emergency Rehabilitation Program

1) Damage or deterioration of the existing intake pumps.
2) Breakage (out of service) of the existing remote operation system for intake pumps.
3) Damage of the existing distribution pumps.
4) Shortage in number of tank lorries.
5) Deterioration of the existing intake tube wells.
6) Lack/damage of water flow-rate measuring devices at CTP

Problems to be Solved by the USAG in the Long Term Plan

7) Lack/damage of water flow-rate measuring devices at household.
8) Damage of water faucets (water taps) of consumers.
9) Wastage of water by domestic consumers.
10) Deterioration of distribution pipelines.
11) Excessive energy consumption (high electric power cost) to supply water by pumps, throughout the supply system.
12) Lack of emergency power supply facilities, such as generators.

1.1.3 Organization and Management

(1) Short History of Organization

Municipal water supply system in Ulaanbaatar began with ten (10) wells, having the capacity of 4,500m^3/day, which were constructed inside the present Central Water Source area, by the former Soviet Union's assistance , in 1955.

An organization for municipal water supply under the administration of Municipality was established in 1959.

Sewerage system for town area under the control of the same organization was constructed in 1963.

From since 1959 to 1972 the organization belonged to the Municipality.

In 1972, a new Ministry under the Government of Mongolia was established, combining the communal services, as the Ministry of Communal Services.

And the organization belonged to the Ministry of Communal Services from 1972 until 1990, when the major change occurred.

In 1990, the organization started as USAG under the administration of Municipality.

(2) Organization and Management of USAG

1) USAG is one of the Departments under the administration of the Municipality. However, it is an independent enterprise economically. As for financial condition of USAG, refer to 1.1.5 in this chapter.

2) USAG covers the water supply facilities up to Community Heating Centers (CTP), including the water sources, pumping stations, reservoirs, piping in the centralized system, and sewerage (piping and sewage treatment plant) in the Municipality.

3) Planning and budgeting, operation and maintenance of the above facilities are the main tasks of USAG.

4) The number of employees of USAG is 1,185 at present including the chairman as shown in Fig. III.1.7.

5) Detailed organization of USAG is shown in Fig. III.1.8.

1.1.4 Operation and Maintenance

(1) Purpose of Operation and Maintenance (hereinafter called O&M)

1) Operation

The purpose of operation of water supply facilities shall be to operate the facilities properly as planned at the designing stage so that the water can be supplied safely and steadily to the consumers.

Therefore an operation manual for daily use and education of the operators are considered to be indispensable.

On the other hand, it would be important to operate the facilities economically depending on the circumstances; for instance, to change the numbers of operating pumps in accordance with the supply capacity of water.

2) Maintenance

Maintenance of the water supply facilities should be conducted periodically so as to keep the facilities safely as long as possible. At the same time, daily inspection of the facilities is required.

A maintenance manual and education of the employee are also necessary.

Competitiveness of the enterprises, not only water supply enterprise but also other production companies, depends on the capability of the maintenance.

Preparation of spare parts and scheduling of the replacement of the equipment will also be required in due course of the maintenance.

(2) Facilities requiring O&M

Following facilities required O&M.

(a) Intake Facilities of four(4) Water Source;
Upper Source, Central, Industrial, Meat Complex

(b) Distribution Pumping Stations of four(4) Water Source and one(1) Reservoir
Upper Source, Central, Industrial, Meat Complex and Tasgan

(c) Storage and Supply Reservoirs

(d) Transmission and Distribution Pipeline

(e) Service Facilities for Ger Area

(f) Workshop of USAG

[Special Remarks]

1) Drinking Water for apartments in central area of the city is supplied from the centralized piping system of USAG.
However, at the entrance of all apartments, there exist "Community Heating Centers" called CTP without exceptions to make a hot water.
At CTP, water from distribution pipeline of USAG is divided into two(2) lines, cold water and hot water line, before entering to each apartment.
Hot water is made by heat exchanger using the hot water from Power Stations. Both cold water and hot water are boosted by pumps inside CTP. Refer to Fig. III.1.9.

2) CTP is belonging to the Central Heating Company and O&M of CTP is conducted by the company.

(3) Organization

At present, the employees in charge of O&M for Water Supply Facilities of USAG are as follows.

*	Engineer	:	10 persons
*	Supply Stations (Intake Water Well , Pumping Stations and Reservoirs)		
	Laboratory	:	5 persons
	Upper Source	:	57 persons [12 Hr/Day * 2 Shift/Day *4 Group]
	Central Source	:	87 persons [12 Hr/Day * 2 Shift/Day *4 Group]
	Industrial Source	:	73 persons [12 Hr/Day * 2 Shift/Day *4 Group]
	Meat Complex Source	:	33 persons [12 Hr/Day * 2 Shift/Day *4 Group]
*	Pipeline	:	41 persons
*	Construction Machine	:	40 persons

* Materials Supply Group : 28 persons
* Water Transportation Center : 500 persons

(4) Present Situation of Existing Water Supply Facilities (As of May, 1994)

1) Intake Facilities

(i) Present Situation of Existing Facilities

i) Intake Wells and Intake Pumps

At present, the situation of intake wells and these pumps is summarized below .

Present Situation of Intake Wells and Pumps

Numbers	Water Source				Total
	Upper	Central	Industrial	Meat Complex	
Nos of Existing Intake Wells	39	70	16	8	133
Nos of Workable Intake Wells	39	62	9	3	113
Nos of Workable Intake Pumps	34	49	8	3	94

ii) Valves and Pipes in the Pump House

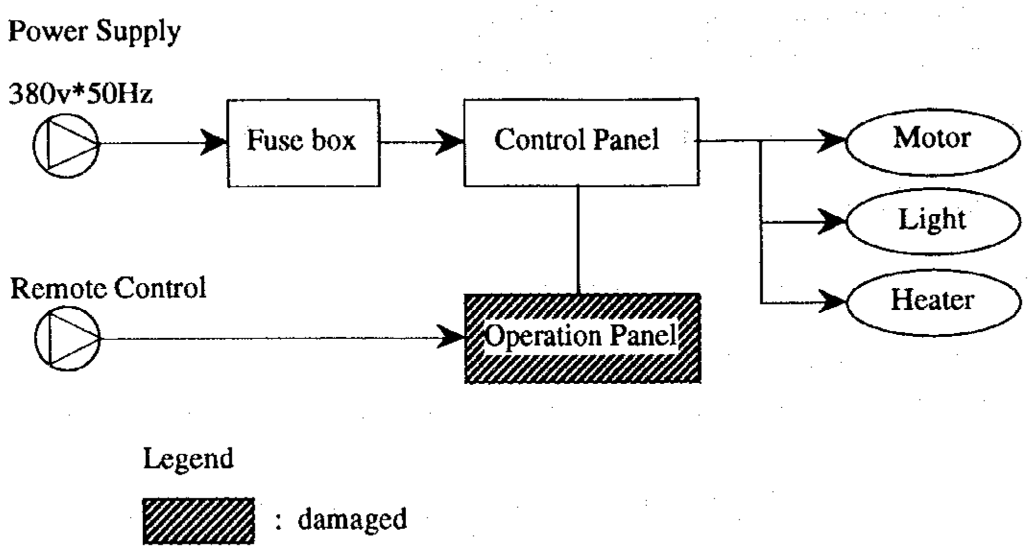
Almost all of them are not damaged. However, a few valves are damaged due to a freezing. And all valves are hand-operated type.

iii) Instrumentation Equipment

The instrumentation equipment such as flow meter, pressure gage, level gage and so on are not installed or have been already broken.

iv) Power Supply Equipment

Basically, power supply equipment is not damaged except the remote control system. However, control panels and other electrical equipment has deteriorated and look unsafe. The diagram of power supply system is shown below.



[The Power Supply Diagram for Intake Wells]

v) Freezing Countermeasure for the Intake Houses

Inside the intake houses, an electric heater is installed as a freezing countermeasure. And intake houses are installed as semi-subterranean type. However, a few heater system has damaged.

vi) Freezing Countermeasure for Non-Operation Wells

A freezing countermeasure for non-operation (not working) wells is taken by the back flow water from the collection pipeline.

(ii) O&M

i) Operation Method

Operation of a intake well pump is conducted by a manual operation at a control panel on machine site. An automatic system is not adopted at present.

ii) Remote Control System

The remote control system had been utilized from Dec. 1990 to Feb. 1992. However, this system cannot be utilized at present except some cables. The reason is lacking of some parts of control panel inside.

iii) Countermeasure for Power Failure

The countermeasure for power failure such as generator and two (2) lines power supply system is not provided. However, there has not been a large trouble for consumers in the past.

iv) Operation Management.

An operation management of the intake facilities is conducted by pumping station of each districts. However, the keys of intake houses are kept by adjacent resident. A lot of them live in Ger houses.

2) Distribution Pumping Stations

(i) Present Situation of Existing Facilities

i) Distribution Pumps

At present, the situation of these pumps is shown in the following table.

Present Situation of Distribution Pumps

Numbers	Pumping Station					Total
	Upper	Central	Industrial	Meat Complex	Tasgan	
Workable	2	3	2	4	2	13
Damaged	2	2	0	0	1	5
Under Repair	2	2	2	0	1	7
TOTAL	6	7	4	4	4	25

The main reasons of pump troubles are as follows.

Major breakdown problems are related to bearings and motors.

The parts required to be replaced can not be procured in this country.

ii) Valves and Pipes in the Pumping Stations

Some numbers of the delivery motor-drive valves of pumps has already broken. However, they can use as manual valves at present. The present situation of motor-drive valves is shown in the following table.

Present Situation of Motor Drive Valves

Numbers	Pumping Station					Total
	Upper	Central	Industrial	Meat Complex	Tasgan	
Workable	14	0	0	0	3	17
Damaged	0	6	0	0	1	7
Under Repair	0	0	0	0	0	0
TOTAL	14	6	0	0	4	24

iii) Chlorinators

The chlorine for sterilization is injected into the reservoirs at Central, Industrial and Meat Complex Water Source except the Upper Water Source. The chlorine is made by chlorine gas which was diluted by pure water. The chlorine dosage is 0.8 to 1.2 mg/ℓ in accordance with the results of measuring the residual chlorine of the end of distribution pipe in principle. An actual chlorine consumption in year 1992 and 1993 are approximately 4,000 kg/Month, it is shown in Table III.1.19'.

iv) Electrical Equipment

The electrical equipment of incoming panels, control panels, operation panels and so on are wholly old and look unsafe. However, the fundamental function is working.

v) Instrumentation Equipment

The instrumentation of flow meter, pressure gage. level gage and so on are not installed or have already broken except the orifice plate for water flow measurement. Orifice plates are installed at the following stations.

Upper Pumping Station	:	two(2) Main Discharge Pipeline
Central Pumping Station	:	Discharge side of No1 to No4 Pump
Industrial Pumping Station	:	Discharge side of No1 to No4 Pump
Meat Complex Pumping Station	:	Discharge side of No1 to No3 Pump

vi) Freezing Countermeasure for the Pumping Stations

Inside the pumping stations, an electric heater is installed as a freezing countermeasure. And pumping houses are installed as semi-subterranean type.

(ii) O&M

i) Operation Method

An operation method of a main pump is a manual operation of control panels or operating panels. An automatic system is not provided.

ii) Control Method of the Water Supply Quantity

The control of the water supply quantity from each pumping station respectively is decided by USAG's engineers in accordance with water level of Tasgan Reservoir and water pressure value of main distribution pipeline. And numbers of pumps to be operated at the pumping stations are set up.

iii) Countermeasure for Power Failure

The countermeasure for power failure such as generator, two (2) lines power supply system and so on is not provided. However, there is not so much trouble at present.

iv) Operation Management.

An operation management of the pumping stations is managed by Supply Stations Group of USAG.

3) Storage and Supply Reservoirs

(i) Present Situation of Existing Facilities

Regarding reservoirs, including Tasgan Reservoir, there has not been a trouble yet.

Among four(4) supply reservoirs, North West Reservoir, is under construction and is scheduled to be completed in 1994. But it will be delayed. And North East Reservoir is not used at present because it is not necessary for consumers.

(ii) O&M

An operation management of the reservoirs is managed by Supply Stations Group of USAG.

4) Transmission and Distribution Pipeline

(i) Present Situation of Existing Facilities

Although some leakages in the existing pipeline occurred inside the Ulaanbaatar City, they have not caused fundamental problems. Because USAG could repair them easily by welding, because materials of most of the pipeline are steel.

The materials and installation year of existing pipeline are shown in Table III.1.16.

(ii) O&M

O&M of existing pipeline are managed by Pipeline Sector of USAG.

5) Service Facilities for Ger Area

(i) Present Situation of Existing Facilities

i) Outline of Works

The water transportation facilities are managed by water transportation group of USAG. And, where pipeline system does not exist, they supply the potable water to Ger Area and so on by tank lorries. These facilities are as follows.

* Water Transportation Center
* Tank Lorries (55 Nos)
* Water Service Stations (7 Nos)
* Water Vending Center (280 Nos)

ii) Employee

Total number of employee in this sector are about 500 parsons including administrators, tank lorry drivers ,water service stations and water vending centers staffs.

iii) Tank Lorries (made in Russia)

Present situation of Tank Lorries (as of May, 1994) is as follows.

Total number	:	55 Nos
Workable Number	:	33 Nos

* 22 Nos have already been damaged.

Service Distance		
Actual (on Nov, 1993)	:	120 ~ 180 km/day/car.
Water Tank Volume	:	5 ~ 8 m^3 (almost 5 m^3)
Water Tank Structure	:	Double Casing of Aluminum and Mild Steel
Times of Delivery	:	Minimum 155 Times/day
(on January, 1993)		Maximum 366 Times/day
		Average 262 Times/day

The times of delivery of tank lorries are described in Table (2) of Appendix III.1.5 "Working record of tank lorries to Ger Area".

iv) Land Space of Water Transportation Center

A center has enough parking space and sufficient workshops for repairing of tank lorries. Administration building is sufficient also.

(ii) O&M

i) Water Service System by Tank Lorries

The tank lorries supply the potable water to about 280 Water Vending Center in the Ger Area, after filling water into the tank at 7 Water Service Station.

Road condition in the service areas is bad enough to cause damages to tank lorries.

ii) Troubles in repairing the Tank Lorries

Repairing of tank lorries has faced problems due to lacking of spare parts, especially spare tire and battery.

iii) Numbers of Tank Lorries Required

The results of interview to chief of Water Transportation Center of USAG is as follows.

In order to cover a present service area, the following tank lorries are is necessary in minimum.

Winter Season	:	35 ~ 40 Nos
Summer Season	:	40 ~ 45 Nos

Some people in the Ulaanbaatar City move to Ger Houses as their second house during summer season. This is the reason why the numbers in Summer season are more than in Winter season.

6) Work Shop of USAG

(i) Present Situation of Existing Facilities

i) Location of Workshop

A workshop is adjacent to USAG office.

ii) Machine Handcraft

A small-scale repair (manufacture of small diameter shaft ,cutting, surface processing) can be conducted in this machine handcraft chamber.

The handcraft machine are lathes, ball board, cutter and so on.

iii) Equipment of Shop Test

The equipment for shop test, for intake pumps and other pumps repaired, are installed.

iv) Electrical Equipment

A workshop does not have a function to repair an electrical equipment. It has to be sent to a contractor if necessary.

(ii) O&M

i) Employee of Workshop

Eight(8) machine tool workers and about forty(40) electric workers are belonging to this shop.

7) Community Heating Centers (CTP). [Out of Scope of USAG Works]

(i) Present Situation of Existing Facilities.

i) Outline of Works

CTP has water supply facility that supplies hot and cold water to consumers of apartments and another buildings. As mentioned above, O&M are managed by Central Heating Company.

ii) Water Supply System of CTP

The typical water supply system of CTP is shown in Fig. III.1.9.

iii) Tariff Collection

Each CTP collects the Water Tariff from the dwellers of the apartment buildings belonging to the CTP and USAG receives the Water Tariff from each CTP.

iv) Instrumentation Equipment

The instrumentation such as flow meter, pressure gage and so on are not provided or already broken if any.

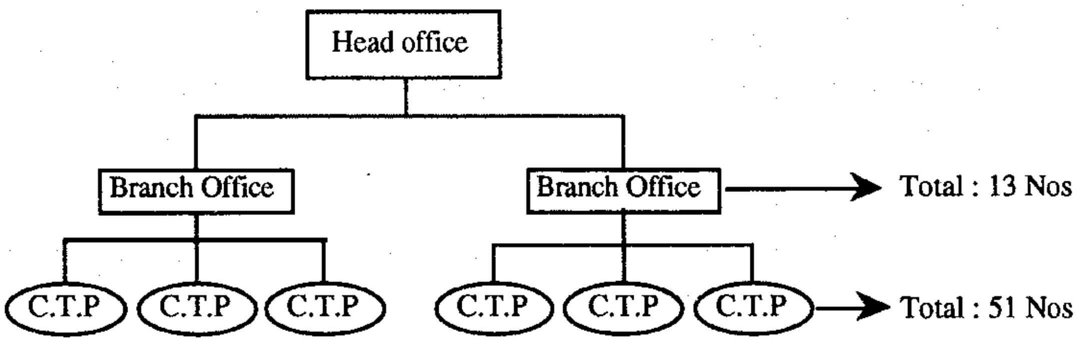
v) Freezing Countermeasure

The facilities of CTP are equipped wholly inside a building.

(ii) O&M

i) Organization

An organization of CTP is shown below.



[Organization of CTP]

ii) Outline of Works

The scope of works are management, operation and maintenance of facilities of CTP and water supply facilities inside apartment.

iii) Operation Method

An operation method of booster pumps is a manual operation at a control panel. An automatic system is not provided.

iv) Countermeasure for Power Failure

The countermeasure for power failure such as generator or two(2) lines power supply system is not provided. However, there has not been a large trouble for consumers in the past.

v) Number of Workers

Number of workers per for each CTP is as follows.

Shift Worker (3 persons) : Working Time 24 Hours/Day * 1 Shift /Day

vi) Scope of Works of Shift Workers.

The scope of works of shift workers are operation and maintenance of water supply facilities in the CTP and water taps in the apartments.

8) Water Supply Facilities in the Apartments

(i) Present Situation.

i) Water Taps

Interview survey was conducted by the Study Team to examine the leakage conditions of taps inside apartments in Phase 1 (1993). Refer to Appendix III.1.10.

Continuously the actual leakage water capacity from the taps is investigated as being consistence of the water usage and leakage survey in Phase 2, 1994. Details results of them are shown in Table 3 on Appendix III.1.4.

The results of above surveys, shows that about 14 - 66 % of taps have leakage problems. Present condition of water taps in the buildings is summarized below.

Present Situation of Water Taps

	Survey Period						
	Phase 1 (1993)				Phase 2 (1994)		
District					Han-Uul	Sukhbaatar	Chingeltei
Building Age	Semi-Old	Semi-Old	Old	Old	21 Years-Old	35 Years-Old	35 Years-Old
Building No.	No.3	No.30	No.13		No.37	No.28	No.6
Number of Home Surveyed	12	9	12	7	28	35	15
Number of Existing Water Taps	36	36	70	25	84	105	45
Number of Leakage of Taps	12	6	46	16	12	30	13
Percentage of Leakage taps	33.3%	16.7%	65.7%	64.0%	14.2%	28.6%	28.9%

ii) Roughly Usage Ratio of Hot and Cold Water

The results of "Survey for Water Usage and Leakage in the Apartment Buildings" also indicate the usage ratio of hot and cold water as follows. Refer to Appendix III.1.4.

Cold Water : 63.3 %

Hot Water : 36.7 % (Temperature is about 70 °C)

(5) Survey Results

Regarding O&M of Water Supply Facilities, survey results (consideration / recommendation) are as follows.

1) Intake Facilities

(i) Replacement of the Intake Pumps

To maintain water supply quantity to Ulaanbaatar City, the heavily damaged and the broken pumps should be replaced. Details are shown in "Emergency Rehabilitation Program" in Appendix of the Main Report.

(ii) Electrical Equipment

The fundamental function is not damaged. However, panels of intake facilities are old and unsafe except those in the Upper Water Source. Therefore the electrical panels for replaced pumps shall also be replaced.

(iii) Remote Control System

Adoption of remote control system for the intake facilities from the distribution pumping station will bring the great merits as shown below.

* Water quantity required can be controlled easily and quickly.
* Working frequency to use of each equipment can be controlled and can be uniform.
* O&M management can be easy, since an operation condition of the facilities can be supervised at the pumping station.
* Economical operation can be conducted by controlling the numbers of operating pumps.

The remote control system should include at least the following items.

* Operation of intake pumps.
* Operation of a motor drive valve installed on the delivery side of intake pump.
* Indication of operating and damaged intake pumps and motor drive valves.

(iv) Preparation of Spare Parts

The major spare parts of machine, electricity and instrumentation should be prepared.

2) Distribution Pumping Stations

(i) Replacement of the Distribution Pumps

To maintain water supply quantity to Ulaanbaatar City, older and damaged pumps should be replaced. Details are shown in "Emergency Rehabilitation Program" in Appendix of the Main Report.

(ii) Electrical Equipment

Though the fundamental function is not damaged, the electrical equipment such as incoming panels, control panels, operation panels and so on are totally old and look unsafe. Therefore the electrical panels for replacement pumps shall also be replaced

(iii) Instrumentation Equipment.

A measuring device of flow rate and pressure of distribution pipeline should be installed.

(iv) Emergency Power Supply Facilities

At present, no countermeasure for power failure is installed. Power failure will cause the suspension of water supply. However, the existing water supply system in Ulaanbaatar City has reservoirs and a long distance of distribution pipeline connected to four(4) water sources.

Therefore a short time power failure will not cause the immediate suspension of water supply. The study for the countermeasures for emergency will be required.

(v) Preparation of Spare Parts

The major spare parts of machine, electricity and instrumentation should be prepared. Especially the bearings of pump and motor is one of the most important spare parts.

3) Storage and Supply Reservoirs

(i) Almost all reservoirs are not equipped with an accurate water level gauge. For protection of intake and distribution pumps, and for the proper operation of these pumps, water level gauge for reservoirs should be provided.

(ii) The operation of the North West Reservoir which is under construction, and the North East Reservoir is not being used at present,.

4) Collection and Distribution Pipeline

The length of collection and distribution pipeline are about 100 km and 200 km respectively. And materials of pipes are made of steel and cast iron. As mentioned above, the oldest pipe was installed in the year 1958. Therefore, the old existing pipeline must be replaced sequentially in near future. However, reconstruction works will possible only if USAG get the materials.

Regarding the replacement of existing pipeline, USAG has no schedule at present.

5) Service Facilities for Ger Area

(i) Supplement of the Tank Lorries

For continuous water supply service to Ger Area, seven (7) supplementary tank lorries are required as soon as possible. The basis of the numbers are shown below.

i) A relation between necessary number of tank lorries (N) and working time per day of tank lorry (C : hours/day).

Average working time per one work cycle of tank lorry (t) was measured as follows during the field survey by the study team.

$t = t1 + t2 + t3 = 20 + 30 + 20 = 70$ min./cycle

t1 (minutes) : Filling water into Tank Lorry at Service Station (20)

t2 (minutes) : Transportation (30)

t3 (minutes) : Supply water from Tank Lorry at Vending Center (20)

On the other hand , a relation between "N" and "C" is as shown below.

$N = (t \times T) / C \times 60$

[where]

C	: Working hour (8 hours)
T (times/day)	: Daily delivery times of Tank Lorries T = Q / V = 270 times/day
Q (m^3/day)	: Daily water supply quantities [Q = 1350 m^3/day]
V (m^3/Tank)	: Water tank volume of a Tank Lorry [V = 5 m^3/Tank]

Therefore,
$N = (70 \times 270) / 8 \times 60 = 40$

Seven (7) supplementary tank lorries are required.

ii) On the other hand, the relation between "N" and daily service distance per one (1) lorry (K : km/day/lorry) is as follows.

$N = L/k$

[where]

L (km/day) : Total service distance for lorries per day

At present, 33 numbers of lorries are working and the average service distance per one (1) lorry is 150 [(120+180)/2]km/day/lorry.

Therefore, L = 33 x 150 = 4,950 km/day.
N = 4,950 / k
Here, in case N = 40
K = 124km/day/lorry

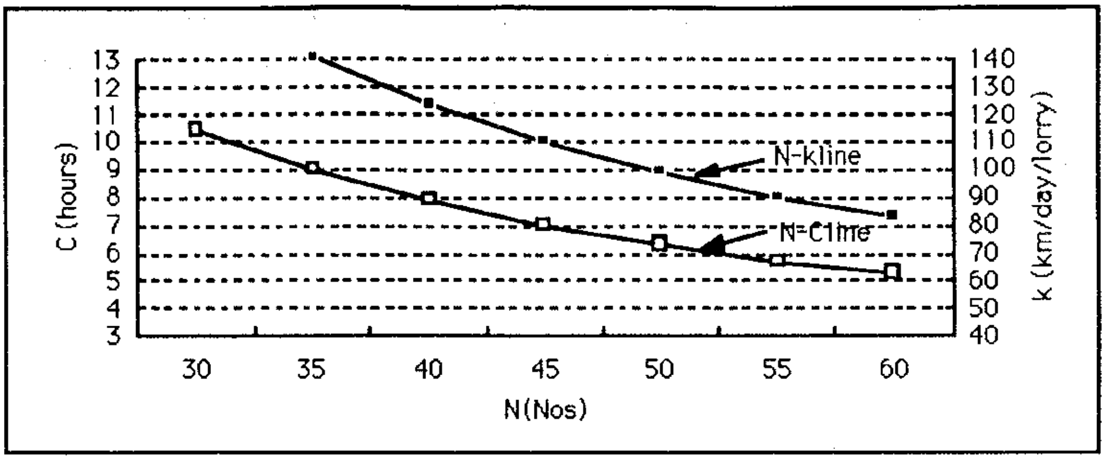
Considering average actual service distance per lorry is 150km, this distance (124km) will be appropriate [Refer to 1.1.4 (4) -5)].

The relations between "N" and "C", and between "N" and "K" are shown below.

6) Others

(i) O&M Manual and Training of Employee

O&M manual for mechanical and electrical equipment should be prepared. Training of employee for O&M will also be required.



[Necessary Number of Tank Lorries]

(ii) Maintenance of the Tank Lorries

Although the workshop for tank lorries is already installed, maintenance of them is now facing difficulties due to the unavailability of spare parts.

(iii) Important parts of the Tank Lorries

Important spare parts for tank lorries are tires and batteries, which are difficult to obtain in this country. Bad road condition increases the necessity of tires.

6) Community Heating Centers (CTP)

(i) Operation and Maintenance of the Facilities

O&M inside the CTP seem to be not so difficult, because the equipment are only pumps, piping and heat exchangers. However, appropriate maintenance inside the apartment buildings requires more man powers for improving the water leakage from the taps. One shift system for workers should be improved.

(ii) Emergency Power Supply System

Emergency countermeasure for power failure inside the CTP is not provided yet. It should be considered in future.

(iii) Measurement of Water Supply Quantity from USAG

Almost all flow meters installed at the boundary between CTP and USAG are already broken. They should be installed if the water tariff would be paid according to the actual flow rate.

7) Water Supply Facilities in the Apartment

At present, consumers pay the water tariff based on the constant calculation basis (8 Tg/m^3 * 150 ℓ/person/day) which has no relation with the actual consumption.

In future, a tariff system based on the actual consumption should be adopted, which will cause the decrease of leakage of taps and consequently lead to the water save consciousness of the consumers and finally decrease the water sources required.

1.2 WATER USAGE OUTSIDE THE MUNICIPAL WATER SUPPLY SYSTEM

1.2.1 Industrial Water System

(1) In the Ulaanbaatar City, around 100 factories exist at present. Most big scale industries are concentrated in South-West and West parts of the city.

(2) USAG supply the water (average 18,000m^3/day) to the industrial facilities (79-82 factories) mainly for drinking purpose.

(3) Regarding the industrial water, some industries like Power Plants have their own wells and water recalculation facilities such as cooling towers.

(4) Some of the waste water from industries are treated to some extent before flowing into the Sewerage System of USAG.