2.3
METEOROLOGY AND HYDROLOGY

2.3 Meteorology and Hydrology

2.3.1 Observation Network on Meteorology and Hydrology

In the Maritza river basin, there are 97 meteorological (37 climatic and 60 precipitation) and 48 hydrometric stations (7 on Maritza mainstream and 41 on tributaries) that are presently operating and are under the control of National Institute of Meteorology and Hydrology (NIMH) of Bulgarian Science Academy. Detailed listings of the meteo-hydrological stations are given in Tables 2.3.1 and 2.3.2. Locations of the stations are shown in Fig. 2.3.1 and 2.3.2. Among the meteorological stations, 14 are automatic and the rest 83 are manual type. Among the hydrometric stations, 1 is telemetric, 15 are automatic and the rest 32 are manual type.

The meteorological stations are well distributed with an average area of 220 km^2 for each station. But the hydrometric stations are sparsely distributed along the Mainstream. There exists only 7 hydrometric stations along the Maritza mainstream, i.e. 1 station for each 44 km. Hydrometric stations along the major tributaries are also very scarce.

2.3.2 Meteorological Characteristics

(1) General Meteorological Condition

Monthly average precipitation, temperature and relative humidity distributions at 7 climatic stations are shown in Fig. 2.3.3. Annual average precipitation varies from 491-652 mm. Monthly maximum and minimum precipitations vary from 56-84 mm (in May) and 26-46 mm (in August) respectively. Monthly maximum and minimum temperatures vary from 19 to 24°C (in July) and –2 to 2°C (in January) respectively. Monthly maximum and minimum relative humidities vary from 75-85% (in December) and 60-70% (in July) respectively.

(2) Selection of Representative Stations

After analyzing the amount of annual precipitations, correlations of annual precipitations and quality of data; 22 representative meteorological stations have selected for detailed analysis on precipitation. Fig. 2.3.4 shows annual precipitations at all the stations including the representative ones.

(3) Basin Mean Precipitation

Thiessen Polygon method has been applied to calculate basin mean precipitation (Fig. 2.3.5). Monthly distribution of basin mean precipitation is shown in Fig. 2.3.6. Annual total basin mean precipitation is calculated to be 597 mm with maximum and minimum monthly precipitations of 70 mm (in May) and 34 mm (in September) respectively. It can be seen that annual precipitation had started decreasing in the mid-1970s and had been continued to decrease until early-1990s with 1992 as the most severe drought year in terms of precipitation. However, in recent years (since around 1993), annual total precipitation has an increasing tendency. Fig. 2.3.6 also indicates that the critical drought months and corresponding precipitations would be:

Period	Critical Drought Month(s)	Basin Mean Precipitation (mm)
1-month	September	34
2-month	September-October	72
3-month	August-September-October	117

(4) Probability Analysis on Minimum Precipitation

Probability analysis applying Gumbel's and Log-Normal Distributions and Thomas (Weibull's) Plotting Position formula which is suitable for drought flow has been carried out for the 22 representative meteorological stations. Probable minimum 4 and 10-year annual basin mean precipitations (using Thiessen Polygon method) are calculated to be 507 and 452 mm respectively.

(5) Outer-basin precipitation

Analysis on 12 nearby meteorological stations lying within other river basins bordering the Maritza river basin (Fig. 2.3.4) shows that, compared to annual precipitation in the Maritza river basin:

- low annual precipitation is observed at stations in the Tundza (Elhovo, Sliven and Kazanlak), Iskar (Murgash Peak, Central Meteorological Station at Sofia and Iskar Reservoir) and Struma (Blagoevgrad) river basins;
- moderate annual precipitation is observed at stations in the Mesta (Bansko and Dospat) and Arda (Raikovo and Kardjali) river basins.

As in the Maritza river basin, very low precipitation was observed in 1992 in the Tundza river basin whereas for other outer basins, very low precipitation was observed mainly in 1993.

(6) Estimation of Potential Evaporations

Monthly potential evaporations for the Maritza mainstream and major tributary basins have been estimated using modified Penman method. It is estimated that annual total potential evaporation varies from 883 mm (at Vacha) to 1,072 mm (at Sazliyka). Monthly maximum and minimum potential evaporations vary from 141-181 mm (in July) and 17-22 mm (in December) respectively.

(7) Relation between Elevation and Meteorological Parameters

There exists good correlation between elevation and meteorological parameters as can be seen from Fig. 2.3.7. However, analysis based on simple linear relations between elevation and meteorological parameters indicates that with a rise in elevation of 100 m, there will be an increase in precipitation of about 21 mm, a drop in temperature of about 0.5°C and a decrease in potential evaporation of about 17 mm.

2.3.3 Hydrological Characteristics

(1) General Hydrological Condition

Analysis on discharge has been carried out at 14 hydrometric stations: 6 on the Maritza mainstream and 8 on major tributaries. Monthly average discharges along with averages of monthly maximum and minimum discharges are shown in Fig. 2.3.8. In general, discharges are high during March to May and are low during July to September. Averages of monthly minimum, average and maximum discharges at Svilengrad station in August (the lowest) are 22, 37 and 86 m^3/s respectively and in March (the highest) are 86, 151 and 367 m^3/s respectively.

Monthly minimum and maximum runoffs at Svilengrad station are 100 (in August) and 405 (in March) million m^3 respectively. Annual total runoff along Maritza mainstream varies from 239 to 3,130 million m^3.

Yearly variation of annual total runoff (Fig. 2.3.9) shows that runoff has considerably been decreased during the last two decades starting from mid-1970s with 1994 as the most critical recent year in terms of runoff. The reason for sharp decrease in runoff can partly be explained by decrease in precipitation during the last two decades, construction of storage facilities during the 1970s and high water uses for different purposes. The figures show no tendency in recovering the runoff.

(2) Specific Discharges and Runoff Rates under Disturbed Condition

Results on specific discharge (Table 2.3.3) and runoff rate (Table 2.3.4) analyses show that both the specific discharge and runoff rate are the lowest at Pazardjik station, possibly due to diversion of discharge through Channel Pashaark. Annual average specific discharge and runoff rate at Svilengrad station are calculated to be 4.66 l/s.km^2 and 0.24 respectively.

Mass curve analysis on runoff rate (Fig. 2.3.10) shows that monthly accumulated runoff rates gradually increase during January to June with maximum in March due to effect of snow melting, after which they remain almost constant

(3) Evaluation of Natural and Disturbed Runoffs and Base Flows

Analysis on natural and disturbed runoffs (Fig. 2.3.11) indicates that for a moderately sized catchment with an area of 3,000 km^2 (about the size of Sazliyka river basin), natural runoff is likely to be about 25% more than disturbed runoff.

An evaluation on base flow for 1995, which represents average year in terms of precipitation, indicates that natural base flow is likely to be about 15% more than disturbed base flow for the entire Maritza river basin.

(4) Relation between Disturbed Annual Runoff Rate and Landuse

Analysis indicates that annual runoff rate for a catchment with forest area of 30% can be as low as 0.23 whereas that for a 100% forest area can be as high as 0.6; which implies that with increase in forest area, annual runoff rate is likely to be increased.

(5) Probability Analysis on Minimum Runoff

By applying Log-Normal Distribution and Thomas Plotting Position formula, probable minimum 4 and 10-year annual runoffs at Svilengrad station are calculated to be about 2,211 and 1699 million m^3 respectively. The results are summarized in Table 2.3.5 and shown in Fig. 2.3.12.

(6) River Bed Morphology

A morphological study on river bed along Maritza mainstream and major tributaries indicates that, in general, degradation / aggradation has been taken place during the two decades of 1970s-1980s. It is found that, degradation has been taken place at Svilengrad on Maritza river, Harmanli on Harmanliyska river, Marko Nikolovo on Chepinska river by about 2, 4 and 0.5 m respectively whereas aggradation has been taken place at Belovo on Maritza river and Bania on Stryama river by about 1.25 and 1.5 m respectively. River bed at Galabovo on Sazliyka is found to be unstable.

TABLE 2.3.1 INVENTORY ON METEOROLOGICAL STATIONS OF NIMH (1/2)

CLIMATIC STATIONS

No.	Region	Code No.	Location	Date of Establishment	Elevation (EL. m)	Geographic Coordinates Latitude	Longitude	Measurement Type
1	Sliven	41030	Sadievo	01-08-1957	136	26°05′	42°32′	M
2		41050	Lyubenova Mahala	24-07-1929	170	25°58′	42°21′	
3	Stara Zagora	42010	Stara Zagora	01-02-1893	200	25°42′	42°22′	
4		42020	Chirpan	01-04-1915	173	25°20′	42°12′	A
5	Haskovo	43010	Haskovo	01-07-1898	194	25°35′	41°57′	
6		43011	Dolno Botevo	15-03-1940	240	25°43′	41°45′	M
7		43020	Svilengrad	21-09-1929	54	26°12′	41°46′	A
8		43030	Harmanli	18-02-1930	78	25°53′	41°56′	
9	Smolyan	45010	Snezhanka Peak	01-03-1969	2,000	24°41′	41°40′	M
10		45030	Chepelare	01-07-1892	1,100	24°42′	41°44′	
11		45060	Hvoina	16-09-1929	707	24°42′	41°52′	
12		45090	Mihalkovo	10-03-1930	525	24°25′	41°50′	
13		45120	Rozhen Peak			24°44′	41°53′	
14		45130	Devin	15-12-1914	710	24°24′	41°45′	
15	Plovdiv	46010	Plovdiv	01-07-1891	160	24°45′	42°09′	A
16		46015	Brestnik	01-03-1958	197	24°44′	42°03′	M
17		46020	Sadovo	01-09-1891	153	24°57′	42°09′	A
18		46030	Assenovgrad	01-09-1934	230	24°52′	42°01′	M
19		46040	Boikovo	23-07-1937	1,108	24°37′	42°00′	
20		46060	Karlovo	01-01-1895	400	24°49′	42°39′	A
21		46070	Hissaria	01-06-1929	278	24°40′	42°30′	M
22		46090	Botev Peak	01-11-1949	2,396	24°50′	42°40′	
23	Pazardjik	47010	Ivailo (Pazardjik)	01-10-1947	214	24°20′	42°13′	A
24		47020	Vetren	01-07-1967	400	24°03′	42°17′	M
25		47030	Yundola	25-02-1929	1,380	23°52′	42°04′	
26		47040	Velingrad	12-05-1929	755	23°58′	42°02′	A
27		47050	Panagyurishte	01-07-1829	565	24°11′	42°30′	
28		47060	Kozarsko	10-05-1934	252	24°25′	42°03′	M
29		47070	Peshtera	01-01-1893	432	24°18′	42°02′	A
30		47081	V. Kolarov Reservoir	01-03-1949	1,535	24°08′	41°49′	
31	Sofia	64101	Ihtiman	04-07-1892	637	23°49′	42°26′	M
32		64115	Georgi Dimitrov / Kostenetz	01-10-1896	837	23°50′	42°15′	
33		64120	Koprivstitza	16-04-1901	945	24°21′	42°38′	
34		64132	Zlatitza	01-01-1943	685	24°09′	42°43′	
35		64215	Mussala Peak	01-12-1932	2,925	23°35′	42°11′	
36		64230	Sitniakovo	01-01-1906	1,741	23°37′	42°14′	
37		64330	Vakarel - Military Station	01-12-1939	851	23°43′	42°33′	

Measurement Type : M => Manual (Non-Recording)
A => Automatic (Recording : Float-Limnigraph)
T => Telemetric

Station Code Number : rrSnn   rr => Region Number; S => Type of Station; nn => Order Number

rr = 29 : Yambol Region
rr = 41 : Sliven Region
rr = 42 : Stara Zagora Region
rr = 43 : Haskovo Region
rr = 45 : Smolyan Region
rr = 46 : Plovdiv Region
rr = 47 : Pazardjik Region
rr = 64 : Sofia Region

S = 0 - 3 : Climatic Station
S = 4 - 7 : Precipitation Station

TABLE 2.3.1 INVENTORY ON METEOROLOGICAL STATIONS OF NIMH (2/2)

PRECIPITATION STATIONS

No.	Region	Code No.	Location	Date of Establishment	Elevation (EL. m)	Geographic Coordinates Latitude	Geographic Coordinates Longitude	Measurement Type
1	Yambol	29520	Skalitza / Kunevo	01-02-1941	160	26°14′	42°18′	
2	Sliven	41480	Polski Gradetz	01-02-1953	165	26°07′	42°11′	
3		41520	Elenovo	25-09-1953	220	26°09′	42°23′	
4		42401	Sarnevo	19-11-1953	128	25°51′	42°22′	
5		42420	Dalboki	01-11-1930	162	25°47′	42°29′	
6	Stara Zagora	42540	Bratia Daskalovi	01-04-1950	235	25°12′	42°20′	
7		42570	Badesthe	11-08-1929	200	25°41′	42°19′	
8		42620	Orizovo	01-01-1930	151	25°10′	42°12′	
9		43401	Merichleri	01-11-1949	150	25°30′	42°08′	
10		43402	Dimitrovgrad	01-09-1947	103	25°35′	42°05′	
11		43410	Mineralni Bani / Brestovo	01-01-1944	390	25°22′	41°56′	
12		43420	Simeonovgrad / Maritza	01-12-1896	108	25°50′	42°02′	
13	Haskovo	43430	Izvorovo	01-08-1929	350	26°09′	41°58′	
14		43460	Oreshetz	01-02-1930	276	25°55′	41°46′	
15		43470	Elena	01-12-1939	210	25°48′	41°50′	
16		43490	Konush	01-12-1941	200	25°31′	41°52′	
17		43520	Tzareva Poliana	18-08-1940	220	25°36′	41°47′	
18		45450	Mugla	01-01-1938	1,360	24°30′	41°33′	
19		45470	Borino	15-04-1954	1,150	24°19′	41°42′	
20		45500	Trigrad	17-01-1951	1,200	24°23′	41°37′	
21	Smolyan	45510	Shiroko Laka	15-05-1952	1,045	24°23′	41°37′	
22		45530	Manastir	01-06-1950	1,450	24°52′	41°43′	
23		45540	Zabardo	16-01-1952	1,140	24°35′	41°48′	
24		45550	Lakki	01-04-1947	1,000	24°51′	43°48′	M
25		45570	Narechenski Bani	23-03-1939	597	24°46′	41°54′	
26		46410	Topolovo	01-01-1905	405	25°00′	41°54′	
27		46420	Briagovo	21-07-1930	235	25°11′	41°59′	
28		46430	Popovitza	01-01-1905	140	25°03′	42°09′	
29		46440	Parvomay	27-05-1929	132	25°14′	42°07′	
30		46460	Bachkovo	01-01-1941	406	24°52′	41°57′	
31		46500	Zdravetz Chalet	01-05-1952	1,165	24°45′	42°00′	
32		46510	Brestovitza	01-06-1960	207	24°36′	42°03′	
33		46540	Krichim	01-12-1938	185	24°28′	42°05′	
34		46550	Proslav	01-01-1948	165	24°41′	42°07′	
35	Plovdiv	46560	Sekirovo	01-11-1940	170	24°56′	42°15′	
36		46580	Chernozem	01-12-1925	229	24°47′	42°24′	
37		46610	Belovitza	01-01-1951	295	24°32′	42°25′	
38			Belovo	01-08-1947	320	24°01′	42°13′	
39		46620	Saedinenie	16-06-1899	200	24°33′	42°16′	
40		46680	Svezhen	01-02-1949	774	25°02′	42°30′	
41		46690	Bania (Plovdivsko)	01-02-1949	295	24°50′	42°33′	
42		46700	Rozovetz	09-01-1915	430	25°07′	42°28′	
43		46750	Rozino	01-01-1905	535	24°33′	42°43′	
44		46760	Klissura	27-07-1928	711	24°27′	42°42′	
45		47401	Pangyurski Koloni	10-08-1930	1,054	24°12′	42°35′	
46		47420	Strelcha	10-01-1905	480	24°19′	42°30′	
47		47440	Poibrene	10-11-1930	420	24°00′	42°30′	A
48		47460	Lessichevo	01-08-1906	228	24°07′	42°21′	
49		47520	Sestrimo	01-01-1941	550	23°55′	42°13′	
50	Pazardjik	47540	Patalenitza	01-08-1929	340	24°12′	42°07′	M
51		47560	Ravnogor	01-07-1940	1,320	24°22′	41°57′	
52		47570	Batak Reservoir	01-07-1892	1,036	24°13′	41°55′	A
53		47660	Chehlovo	01-02-1935	1,450	24°00′	41°48′	
54		47670	Tzvetino	11-01-1952	1,000	23°49′	41°48′	
55		47680	Kurtovo	01-01-1952	1,750	23°48′	42°06′	
56		64501	Topolnitza Reservoir	01-05-1961	420	24°02′	42°25′	
57		64507	Dolna Bania	01-09-1851	637	23°45′	42°18′	M
58	Sofia	64525	Anton	01-07-1949	1,700	24°16′	42°44′	
59		64540	Mirkovo	01-01-1905	673	24°00′	42°42′	
60		64555	Smolsko	01-01-1952	635	23°57′	42°38′	

TABLE 2.3.2 INVENTORY ON HYDROMETRIC STATIONS OF NIMH

No.	Station Code No.		River Name	Location of the Station	Date of Establishment	"0" Gauge Level	JICA Study		NIMH		Measurement Type
	New	Old				(El., m)	Catchment Area of the Station (km2)	Distance from the Mouth / Border (km)	Catchment Area of the Station (km2)	Distance from the Mouth / Border (km)	
1	73370	344a,b	Banska	t. Dimitrovgrad-Durhana	01-12-1953	97.62			326.00	2.45	
2	72270	327a,b	Biala Reka	vil. Kurtovo	11-05-1951	395.33			73.88	13.60	
3	71160	425	Bunovska	vil. Bunovo	17-06-1959	721.36			23.00	17.05	
4	72030	472	Chairdere	vil. Trigrad-Chaira	01-09-1970	1027.87			23.15	10.80	M
5	72040	436a,b	Chairdere	vil. Giovren	10-11-1966	889.87			115.70	2.00	
6	71801	252LK	Channel Pashaark	t. Pazardjik	01-01-1937	201.73			-	-	
7	72450	323	Chepelarska	vil. Narechenski Bani	23-11-1946	607.08		44.50	392.60	49.40	
8	72460	324a,b,v	Chepelarska	vil. Bachkovo	01-08-1949	353.71	839.00	26.50	824.90	30.57	T
9	71390	256a,b,v	Chepinska	Chehliovo	21-05-1950	1456.85		62.00	23.40	70.11	M
10	71400	254	Chepinska	t. Velingrad	01-11-1947	781.11		42.50	431.10	51.00	A
11	71420	249	Chepinska	Marko Nikolovo	07-06-1951	370.53	892.00	14.00	881.00	14.95	
12	72150	266	Cherno Dere	Reservoir "V. Kolarov"	23-08-1949	1530.31			21.29	7.80	M
13	73030	345	Chinardere	vil. Dalbok Izvor	01-12-1953	200.46			48.30	1.20	
14	72170	277a,b,v	Devinska	t. Devin	08-09-1946	708.51			417.30	2.47	A
15	73550	308, 308A,B	Harmanliyska	t. Harmanli	12-05-1932	67.95	983.00	2.50	952.00	3.83	
16	71380	432, 432A	Iadenitza	vil. Goliamo Belovo	11-12-1962	372.05			128.90	2.90	M
17	72230	281a,b,v,g,d	Iugovska	vil. Lakki	08-10-1959	633.84			-	8.56	
18	71550	251a,b	Luda Yana	vil. Sbor	26-10-1941	277.59	593.00	26.20	569.80	25.65	
19	71650	231	Maritza	vil. Raduil	13-09-1946	828.81		286.50	96.68	291.90	A
20	71700	248a,b,v	Maritza	t. Belovo	20-08-1912	316.71	752.00	251.50	741.00	255.60	
21	71800	252	Maritza	t. Pazardjik	18-10-1911	199.58	4,027.00	219.50	4,126.00	222.20	M
22	72700	301a,b	Maritza	t. Plovdiv	01-03-1912	155.08	8,076.00	178.70	7,926.00	189.30	A
23	72850	304	Maritza	t. Parvomay	24-04-1912	116.98	12,918.00	131.50	12,728.00	138.00	M
24	73750	307	Maritza	t. Harmanli	23-07-1912	65.21	19,864.00	51.00	19,693.00	52.25	A
25	73850	309, 309A	Maritza	t. Svilengrad	18-09-1914	46.88	20,860.00	17.50	20,857.00	18.20	
26	71210	431	Mativir	vil. Mirovo	01-11-1962	614.03		16.70	248.50	16.20	M
27	71330	236a,b,v	Ochushnitza	vil. Ochusha	01-11-1950	586.2			57.75	14.60	
28	72420	303a,b,v	Parvenetska	vil. Hrabrino	18-04-1951	287.78			179.10	12.18	A
29	73480	342	Sazliyka	t. Galabovo	27-07-1954	81.85		19.70	3,040.00	19.00	M
30	73400	305a,b	Sazliyka	vil. Rakitnitza	04-11-1925	205.26	353.00	83.50	346.00	108.20	A
31	72100	278a,b,v	Shirokolashka	vil. Shiroka Laka	19-07-1950	1045.76		15.20	63.80	16.92	
32	72120	477	Shirokolashka	t. Devin-Dobrostan	01-11-1974	735.07		1.00	218.00	1.30	M
33	71040	255a,b,A	Sofandere	Tzvetino	20-05-1950	1170.60			73.20	6.25	
34	71340	237	Stara	Georgi Dimitrov	01-11-1947	821.68			47.30	11.70	A
35	72260	337	Stara (Karlovsko)	Hyd. Center Karlovo	01-07-1952	480.14		12.50	51.00	10.60	M
36	71250	336a,b	Strelchanska Luda Yana	t. Strelcha	13-09-1954	481.87		14.50	95.10	17.35	A
37	72500	326a,b	Stryama	t. Klissura	07-07-1952	648.23		93.00	50.50	95.85	
38	72520	325, 325A	Stryama Left & Right	vil. Bania	10-08-1914	268.42	838.00	50.00	832.50	51.50	
39	72060	276a,b	Tenesdere	vil. Mugla	01-06-1950	1330.35			43.40	17.80	
40	72070	438	Tenesdere	vil. Giovren	10-11-1966	869.79			70.34	1.00	M
41	71450	422	Topolnitza	t. Koprivshtitza	19-06-1959	999.79		120.60	57.60	135.00	
42	71470	250a,b,v	Topolnitza	Medet	01-12-1962	577.79	339.00	91.10	339.20	100.60	
43	71480	240a,b,A	Topolnitza	vil. Poibrene	25-08-1912	403.83	918.00	58.60	910.80	67.52	A
44	72020	275a,b	Trigradska	vil. Trigrad	14-06-1950	1171.94			54.28	3.32	M
45	71140	424	Tsarkvishtenska	Zlatitza, sb.Tsarkvishte	16-06-1959	788.79			10.30	9.35	
46	72330	279a,b,v	Vacha	t. Devin-Nastan	07-09-1946	711.27		71.50	416.00	77.65	A
47	72340	421a,b, 422a	Vacha	t. Devin-Zabral	07-09-1946	684.95	668.00	69.00	637.40	74.50	
48	72320	471	Vacha (Buinovska)	Hyd. Center Teshel	01-01-1970	867.83		84.00	146.00	89.50	
I *	71410	257, 257A	Chepinska	vil. Draginovo	01-01-1953	717.64		34.00	756.70	37.35	M
II *	72140	264, 264A	Devinska (Beglishka)	Reservoir "Beglika"	01-12-1942	1494.42			86.60	39.20	
III *	72142	265	Devinska-Tunela	Reservoir "V. Kolarov"	02-02-1952	1525.38			59.05	-	
IV *	72240	343a,b	Iugovska	vil. Iugovo	07-08-1954	487.84			326.60	3.02	A
V *	71130	423a,b	Medetska	Medet	18-06-1959	605.01			31.00	0.66	
VI *	72310	434	Vacha (Buinovska)	Popina Laka	03-11-1966	1074.07		94.7	72.24	99.60	M
VII *	71280	271a,b	Zvezditza	Zvezditza	01-10-1941	1135.65			27.40	6.55	

Measurement Type : M => Manual (Non-Recording : Staff Gauge)
A => Automatic (Recording : Float-Limnigraph)
T => Telemetric

* *Not in operation. Closed in 1996*

Station at Chennel Pashaark (71801) is located on a diversion channel from the Maritza mainstream near Parardjik.

Station at Bania (72520) gives combined discharge of two stations located on the left and right branches of Stryama river upstream of confluence with Biyala river.

JICA Study : remeasured by the JICA Study team by using topographic maps with scales of 1/100,000 and 1/200,000

NIMH : According to National Institute of Meteorology and Hydrology, Bulgarian Science Academy

250a,b,v stand for change in location of the station during different time period.

The last alphabet represent the latest location and the station parameters in NIMH columns are for the latest location

abbreviation : t. => town
vil. => village
sb. => suburb
Hyd. => Hydroelectric

TABLE 2.3.3 SPECIFIC DISCHARGES ALONG MARITZA MAINSTREAM DURING DIFFERENT TIME PERIODS

Station Code No.	Station Name	Catchment Area (km2)	Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Avg. (l/s.km2)
				Specific Discharge (l/s.km2)												
71700	Belovo	752	1946-1995	6.76	7.75	10.99	14.06	23.00	15.91	8.53	5.22	4.73	5.84	7.73	10.08	10.06
			1946-1973	6.94	8.65	13.97	18.67	30.88	21.53	8.75	3.60	4.57	5.53	7.12	11.44	11.82
			1973-1989	7.20	7.90	9.36	11.36	17.92	11.76	9.23	8.00	5.53	7.23	9.21	9.41	9.52
			1989-1995	3.55	3.12	2.94	5.06	6.20	4.22	5.02	3.46	2.89	3.08	5.17	4.94	4.14
71800	Pazardjik	4,027	1946-1995	4.49	5.78	7.90	7.86	7.40	4.94	2.03	1.22	1.76	2.49	3.63	4.48	4.49
			1946-1973	5.44	7.15	10.80	11.02	10.01	6.63	2.29	0.88	1.73	2.42	3.58	4.96	5.56
			1973-1989	3.71	4.97	5.75	6.43	5.76	3.65	1.92	1.94	2.19	3.09	4.04	4.31	3.97
			1989-1995	2.27	2.05	1.98	2.14	1.51	1.19	1.01	0.54	0.76	1.24	2.47	2.71	1.65
72700	Plovdiv	8,076	1946-1995	6.43	7.15	8.90	9.28	8.61	5.73	2.98	2.46	3.29	4.04	5.17	6.21	5.84
			1946-1973	7.43	8.34	11.75	12.50	10.91	7.16	3.10	1.75	3.12	3.93	5.36	7.11	6.86
			1973-1989	5.99	6.75	6.99	7.67	7.13	4.66	3.28	4.05	4.23	4.92	5.45	5.78	5.57
			1989-1995	3.50	2.99	2.62	3.27	3.23	2.34	1.74	1.76	2.25	2.71	3.78	3.85	2.84
72850	Parvomay	12,918	1946-1995	6.79	8.00	9.34	9.80	8.97	6.20	3.19	2.38	3.52	4.19	5.29	6.70	6.18
			1946-1973	8.27	9.75	12.08	12.70	11.13	7.51	3.48	1.71	3.33	4.26	5.68	7.75	7.28
			1973-1989	5.85	7.24	7.88	8.91	7.97	5.43	3.34	3.86	4.55	4.85	5.51	6.19	5.95
			1989-1995	3.32	3.03	3.29	4.06	3.74	2.82	1.77	1.32	1.99	2.54	3.21	3.70	2.90
73750	Harmanli	19,864	1946-1995	5.85	7.36	7.37	7.47	7.01	5.00	2.58	2.02	2.76	3.41	4.06	5.27	5.00
			1946-1973	7.30	9.33	9.43	9.71	8.93	6.30	2.97	1.50	2.62	3.71	4.33	6.17	6.00
			1973-1989	4.98	6.68	7.01	7.07	6.25	4.32	2.67	3.09	3.54	3.70	4.22	4.82	4.85
			1989-1995	3.15	2.64	2.80	3.67	3.32	2.43	1.45	1.08	1.49	2.06	2.83	3.41	2.55
73850	Svilengrad	20,860	1946-1995	5.62	6.66	7.24	6.83	6.33	4.63	2.42	1.79	2.42	3.07	3.82	5.24	4.66
			1946-1973	6.34	7.60	8.94	8.17	7.41	5.33	2.51	1.29	2.15	3.03	4.01	6.17	5.23
			1973-1989	5.36	6.87	7.09	7.01	6.11	4.45	2.74	2.85	3.27	3.50	3.82	4.49	4.78
			1989-1995	3.74	2.96	2.90	4.20	3.75	2.68	1.48	0.94	1.53	2.35	3.09	3.65	2.77

SPECIFIC DISCHARGE CURVE (1946 - 1995)

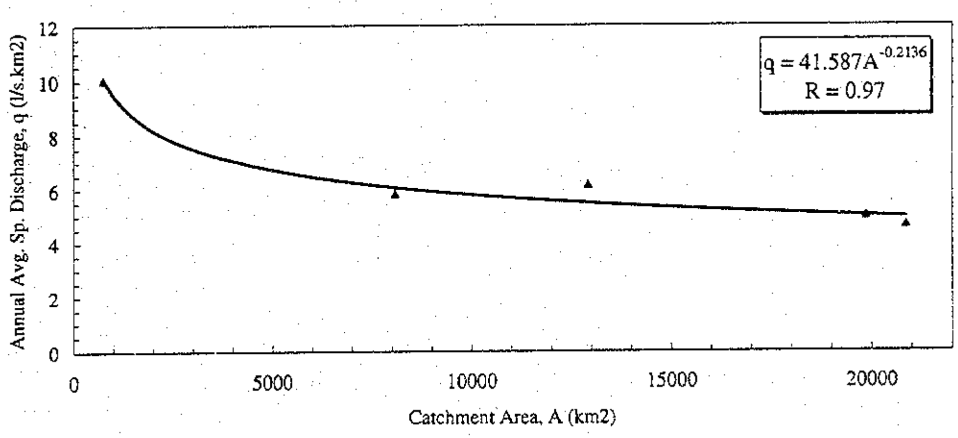


TABLE 2.3.4 DISTURBED RUNOFF RATES ALONG MARITZA MAINSTREAM (1963 - 1995)

MEASURED MEAN RUNOFF (1963-1995)

Station		Catchment Area	Runoff, V_{meas} (million m3)												Annual
Code No.	Name	(km2)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	(million m3)
71700	Belovo	752	13	13	18	24	41	26	16	12	9	12	14	21	219
71800	Pazardjik	4,027	40	52	65	65	66	38	17	15	19	29	36	43	484
72700	Plovdiv	8,076	127	134	152	163	162	97	59	62	74	96	105	122	1,353
72850	Parvomay	12,918	214	241	281	305	289	180	99	95	131	160	176	214	2,384
73750	Harmanli	19,864	289	353	382	367	346	224	124	120	155	194	210	274	3,038
73850	Svilengrad	20,860	312	353	395	365	341	228	128	114	146	191	205	276	3,054

MEAN RUNOFF AS COMPUTED FROM PRECIPITATION (1963-1995)

Station		Catchment Area	Runoff, V_{comp} (million m3)												Annual
Code No.	Name	(km2)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	(million m3)
71700	Belovo	752	32	33	37	41	62	53	44	41	27	31	42	40	483
71800	Pazardjik	4,027	165	154	171	203	319	282	232	199	138	146	201	199	2,408
72700	Plovdiv	8,076	339	310	347	400	613	538	465	378	280	286	400	415	4,770
72850	Parvomay	12,918	544	505	560	651	977	877	766	633	453	468	652	681	7,767
73750	Harmanli	19,864	881	806	886	1,014	1,406	1,292	1,093	928	681	745	1,034	1,084	11,850
73850	Svilengrad	20,860	943	858	944	1,070	1,464	1,346	1,127	957	714	795	1,099	1,159	12,476

DISTURBED RUNOFF RATE (1963-1995)

Station		Catchment Area	Runoff Rate, $C_d = V_{meas} / V_{comp}$												Annual
Code No.	Name	(km2)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average
71700	Belovo	752	0.41	0.41	0.49	0.57	0.66	0.48	0.36	0.28	0.32	0.39	0.35	0.53	0.45
71800	Pazardjik	4,027	0.25	0.33	0.38	0.32	0.21	0.13	0.07	0.07	0.14	0.20	0.18	0.21	0.20
72700	Plovdiv	8,076	0.38	0.43	0.44	0.41	0.26	0.18	0.13	0.16	0.26	0.34	0.26	0.29	0.28
72850	Parvomay	12,918	0.39	0.48	0.50	0.47	0.30	0.21	0.13	0.15	0.29	0.34	0.27	0.31	0.31
73750	Harmanli	19,864	0.33	0.44	0.43	0.36	0.25	0.17	0.11	0.13	0.23	0.26	0.20	0.25	0.26
73850	Svilengrad	20,860	0.33	0.41	0.42	0.34	0.23	0.17	0.11	0.12	0.21	0.24	0.19	0.24	0.24

TABLE 2.3.5 PROBABLE MINIMUM RUNOFFS ALONG MARITZA MAINSTREAM

Station		Non-Exceedence	Return Period	Probable Minimum Runoff (million m3)				
Code No.	Location	Probability (%)	(Years)	1-Month	3-Month	6-Month	9-Month	12-Month
		50	2	4.01	17.85	55.62	105.63	210.64
		75	4	2.61	12.27	38.87	76.04	149.88
		80	5	2.24	10.76	34.30	67.85	133.16
71700	Belovo	90	10	1.65	8.26	26.64	53.82	104.75
		95	20	1.29	6.64	21.62	44.45	85.92
		98	50	0.97	5.19	17.09	35.85	68.75
		99	100	0.80	4.41	14.61	31.06	59.26
		50	2	4.74	26.58	103.38	239.49	481.53
		75	4	2.26	13.39	64.75	165.02	326.68
		80	5	1.70	10.36	54.78	144.85	285.06
71800	Pazardjik	90	10	1.00	6.32	39.29	111.34	216.67
		95	20	0.64	4.21	29.86	89.60	172.76
		98	50	0.39	2.66	21.93	70.18	133.90
		99	100	0.28	1.96	17.85	59.63	112.98
		50	2	33.83	137.10	392.51	766.33	1,355.06
		75	4	21.81	91.16	285.42	581.71	1,016.00
		80	5	18.66	78.94	255.62	529.24	920.22
72700	Plovdiv	90	10	13.67	59.14	204.25	436.05	751.55
		95	20	10.57	46.59	169.71	371.62	635.86
		98	50	7.92	35.62	137.78	310.43	526.84
		99	100	6.53	29.79	119.90	275.35	464.76
		50	2	49.26	226.46	660.70	1,313.57	2,307.74
		75	4	28.73	150.80	473.99	998.11	1,743.63
		80	5	23.62	130.66	422.39	908.42	1,583.68
72850	Parvomay	90	10	16.08	97.99	334.24	749.00	1,300.51
		95	20	11.70	77.27	275.51	638.70	1,105.29
		98	50	8.19	59.14	221.67	533.89	920.46
		99	100	6.45	49.49	191.76	473.77	814.76
		50	2	60.09	277.28	807.96	1,611.76	2,847.63
		75	4	31.22	175.15	582.90	1,224.10	2,133.53
		80	5	24.47	148.68	520.52	1,113.90	1,931.89
73750	Harmanli	90	10	15.30	107.31	413.54	918.11	1,576.95
		95	20	10.38	81.98	342.00	782.68	1,333.62
		98	50	6.71	60.56	276.20	654.03	1,104.42
		99	100	5.01	49.49	239.53	580.25	973.98
		50	2	57.54	263.22	794.00	1,589.61	2,847.23
		75	4	31.23	167.67	579.14	1,235.95	2,211.27
		80	5	24.94	142.80	519.27	1,134.26	2,028.52
73850	Svilengrad	90	10	16.11	103.70	415.81	950.64	1,698.79
		95	20	11.22	79.63	346.12	821.67	1,467.36
		98	50	7.48	59.15	281.57	697.36	1,244.43
		99	100	5.70	48.52	245.38	625.13	1,114.99

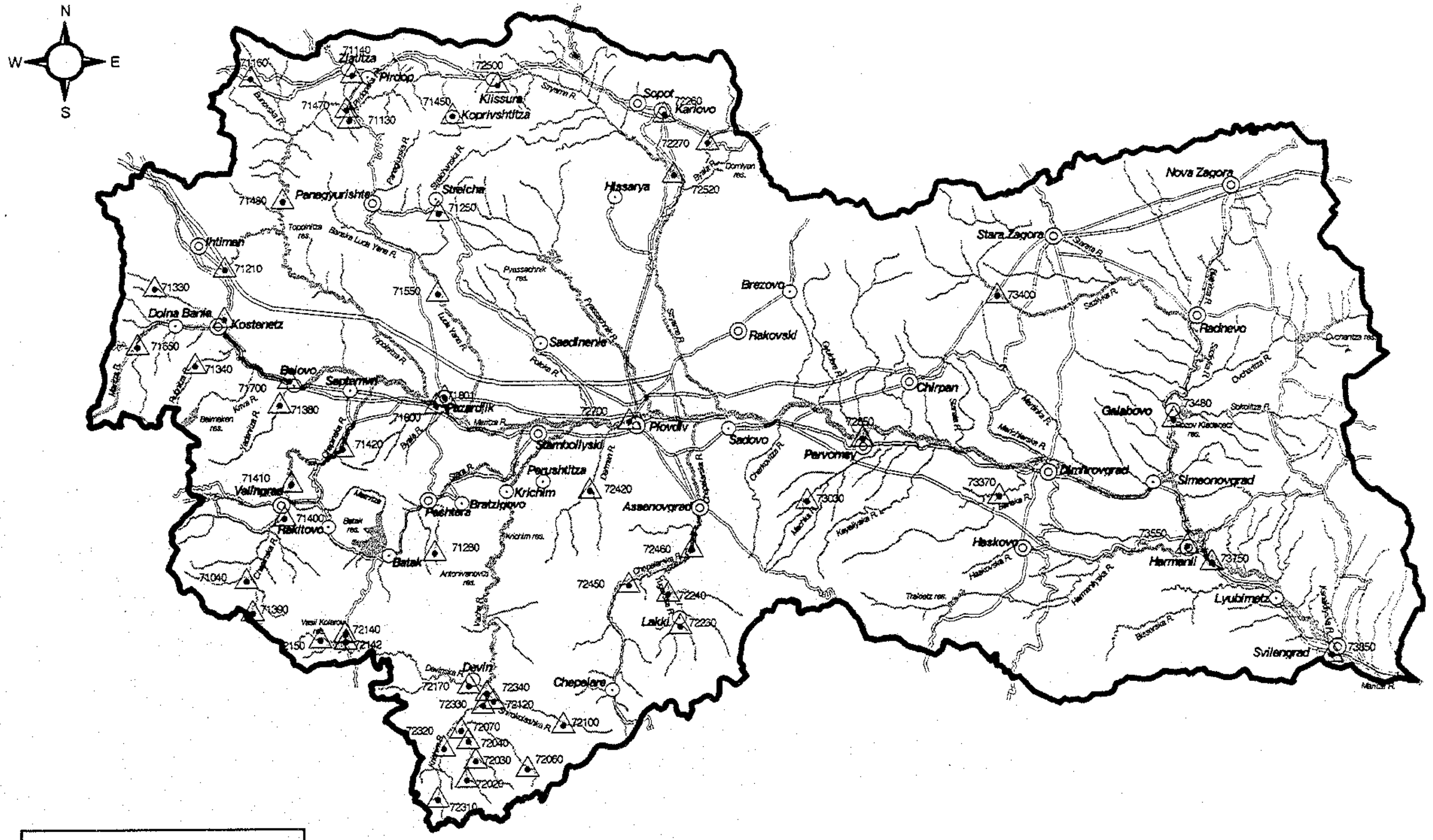
LEGEND

★ Climatic Station
● Precipitation Station

FIG. 2.3.1 OBSERVATION NETWORK FOR METEOROLOGY OF NIMH

SCALE 1:1000000

10 0 10 20 (km)



LEGEND

△ Hydrometric Station
73850 New Code No.

FIG. 2.3.2 OBSERVATION NETWORK FOR HYDROLOGY OF NIMH

SCALE 1:1000000
10 0 10 20 (km)

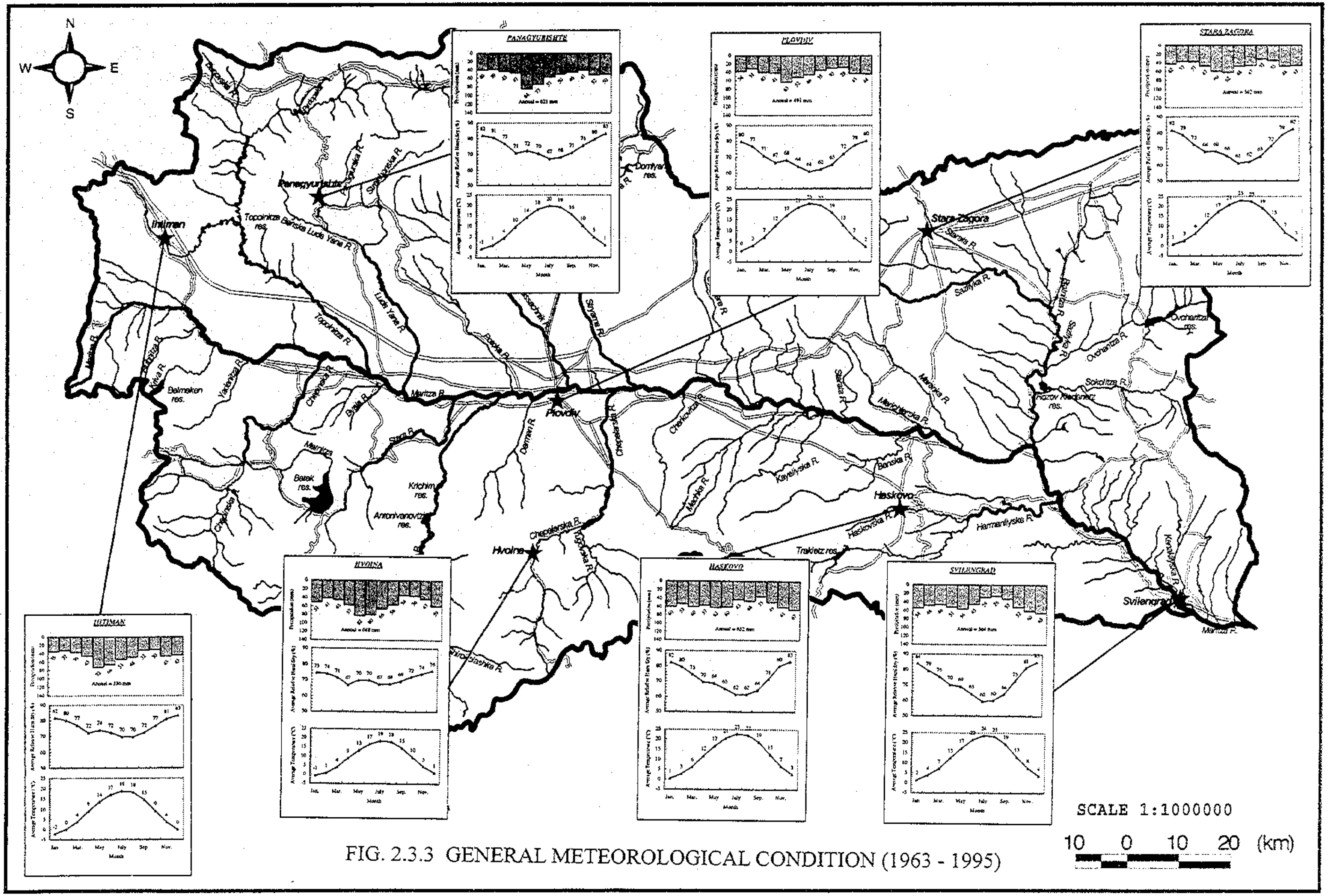
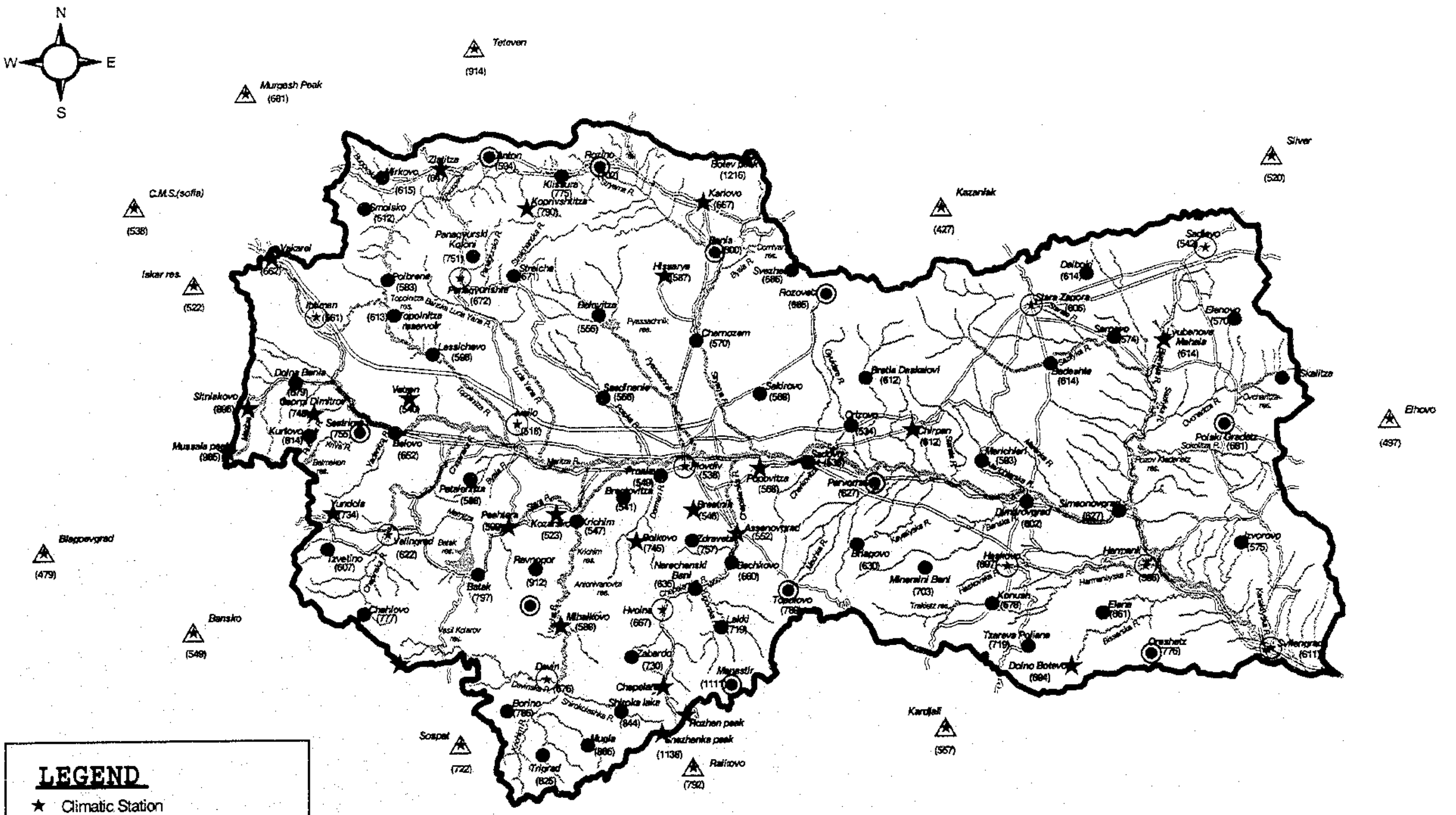


FIG. 2.3.3 GENERAL METEOROLOGICAL CONDITION (1963 - 1995)



LEGEND

- ★ Climatic Station
- ● Precipitation Station
- ⊙ Representative Climatic Station
- ◉ Representative Precipitation Station
- ▲ Outer-Basin Climatic Station
- (1138) Annual Total Precipitation in mm

FIG. 2.3.4 ANNUAL AVERAGE PRECIPITATIONS AT THE METEOROLOGICAL STATION

(For inner-basin stations,data ranges from 1963-1981,
where 1981 is the year up to when NIMH published data is the meteorogical year book
For outer-basin stations,data ranges from 1984-1996,
the data has been newly collected from NIHM)

SCALE 1:1200000

10 0 10 20(km)

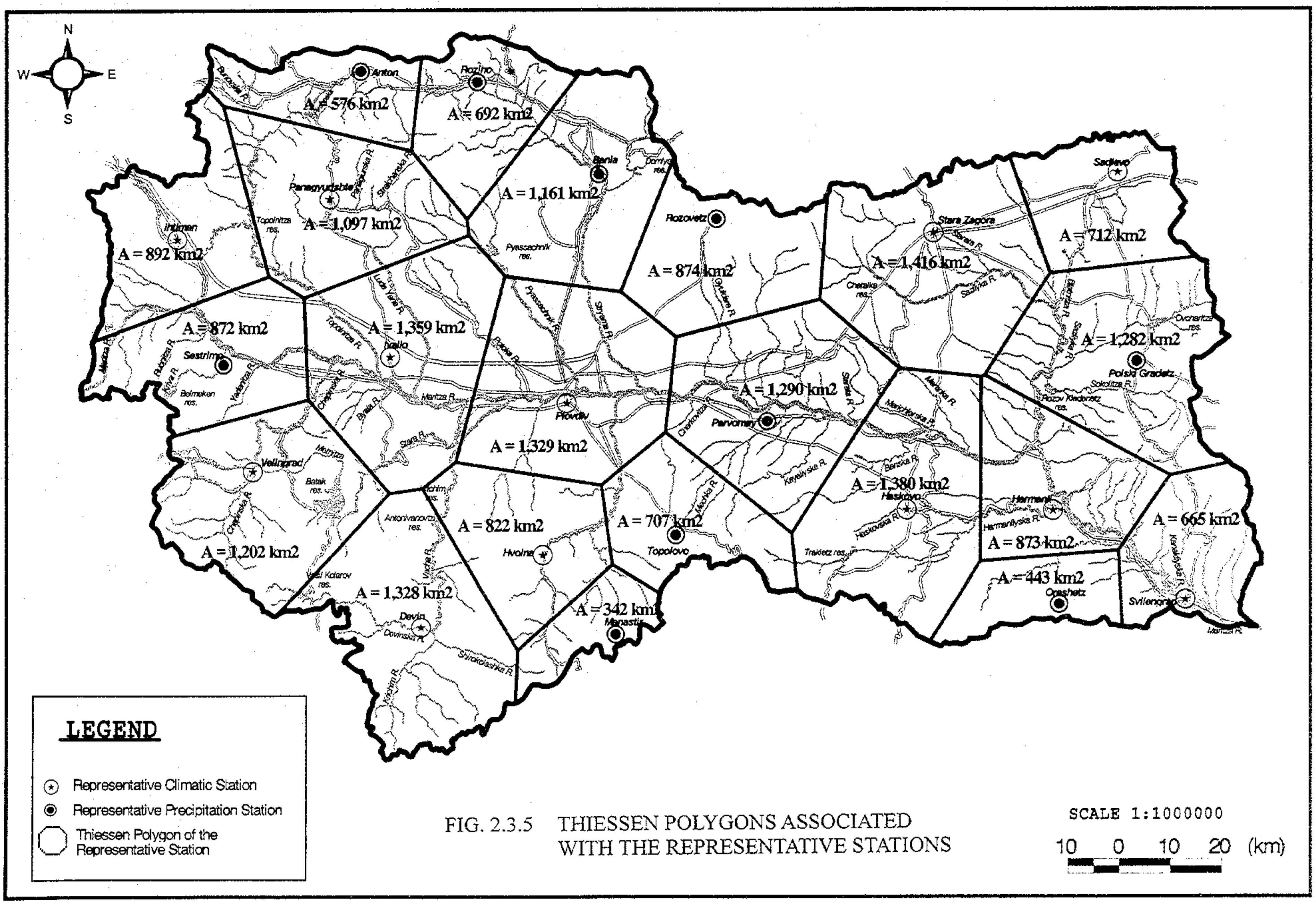
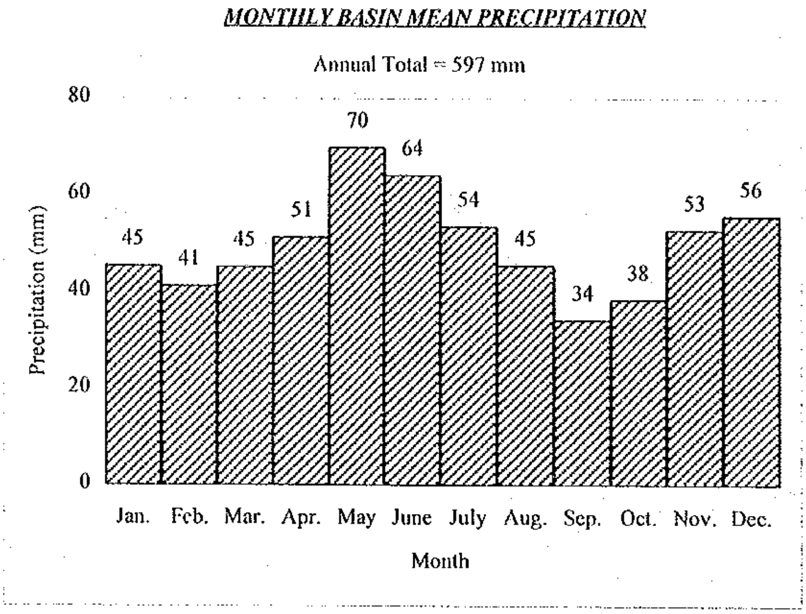
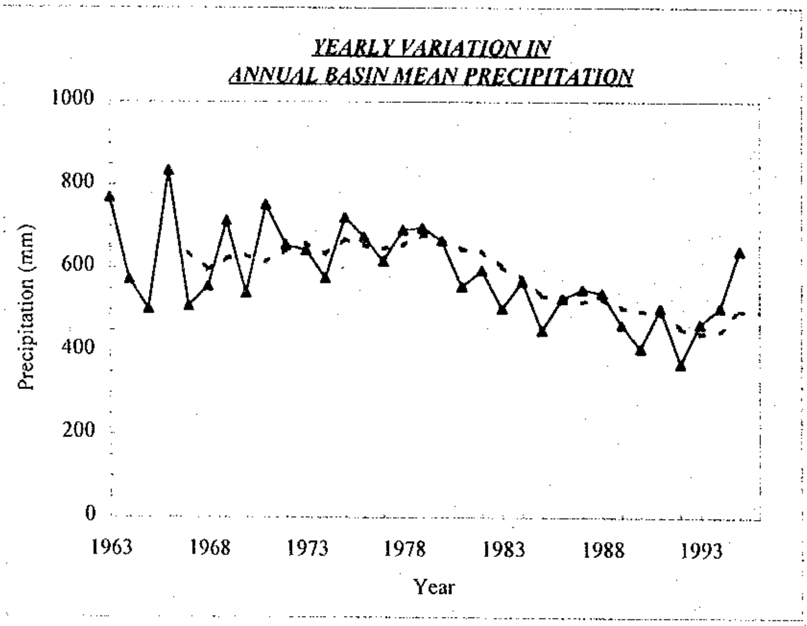


FIG. 2.3.5 THIESSEN POLYGONS ASSOCIATED WITH THE REPRESENTATIVE STATIONS





- - - - - - - - - - - - 5-year moving average trendline

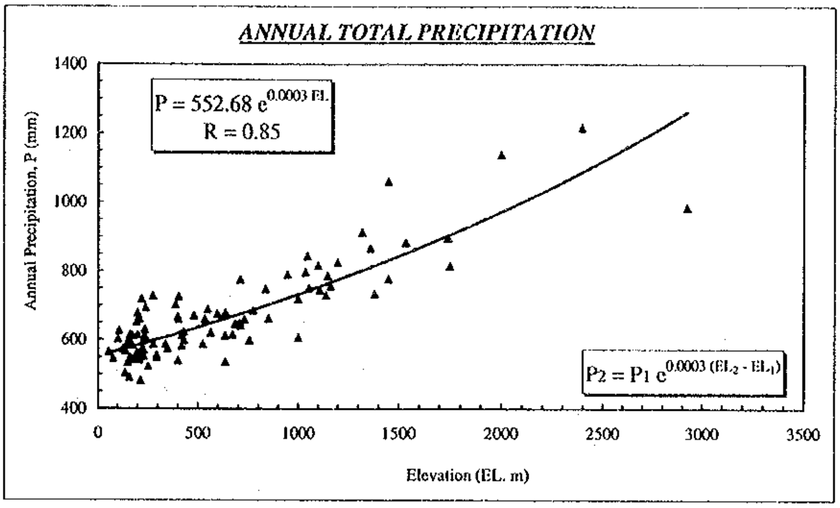
YEARLY VARIATION IN ANNUAL BASIN MEAN PRECIPITATION

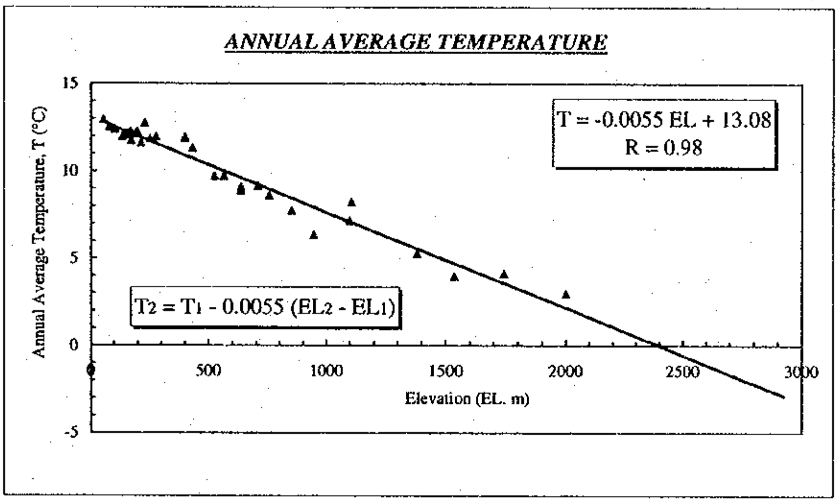
Year	Precipitation (mm)
1963	769
1964	573
1965	502
1966	834
1967	508
1968	557
1969	714
1970	539
1971	752
1972	656
1973	643
1974	575
1975	721
1976	675
1977	617
1978	692
1979	697
1980	666
1981	555
1982	594
1983	502
1984	568
1985	449
1986	527
1987	548
1988	539
1989	464
1990	406
1991	503
1992	369
1993	465
1994	504
1995	642

AVERAGE BASIN MEAN PRECIPITATION FOR DIFFERENT TIME PERIODS

Period	Mean Precipitation (mm)
1963 - 1995	597
1963 - 1973	641
1973 - 1989	590
1989 - 1995	479

FIG. 2.3.6 BASIN MEAN PRECIPITATION (1963 - 1995)





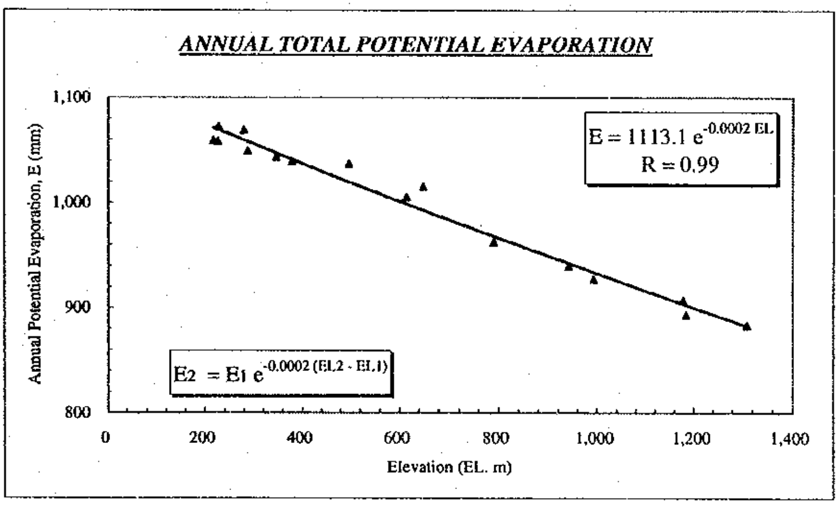


FIG. 2.3.7 ELEVATION-METEOROLOGICAL PARAMETER RELATIONS

(data ranges from 1963-1995 and 1963-1981, depending upon availability)

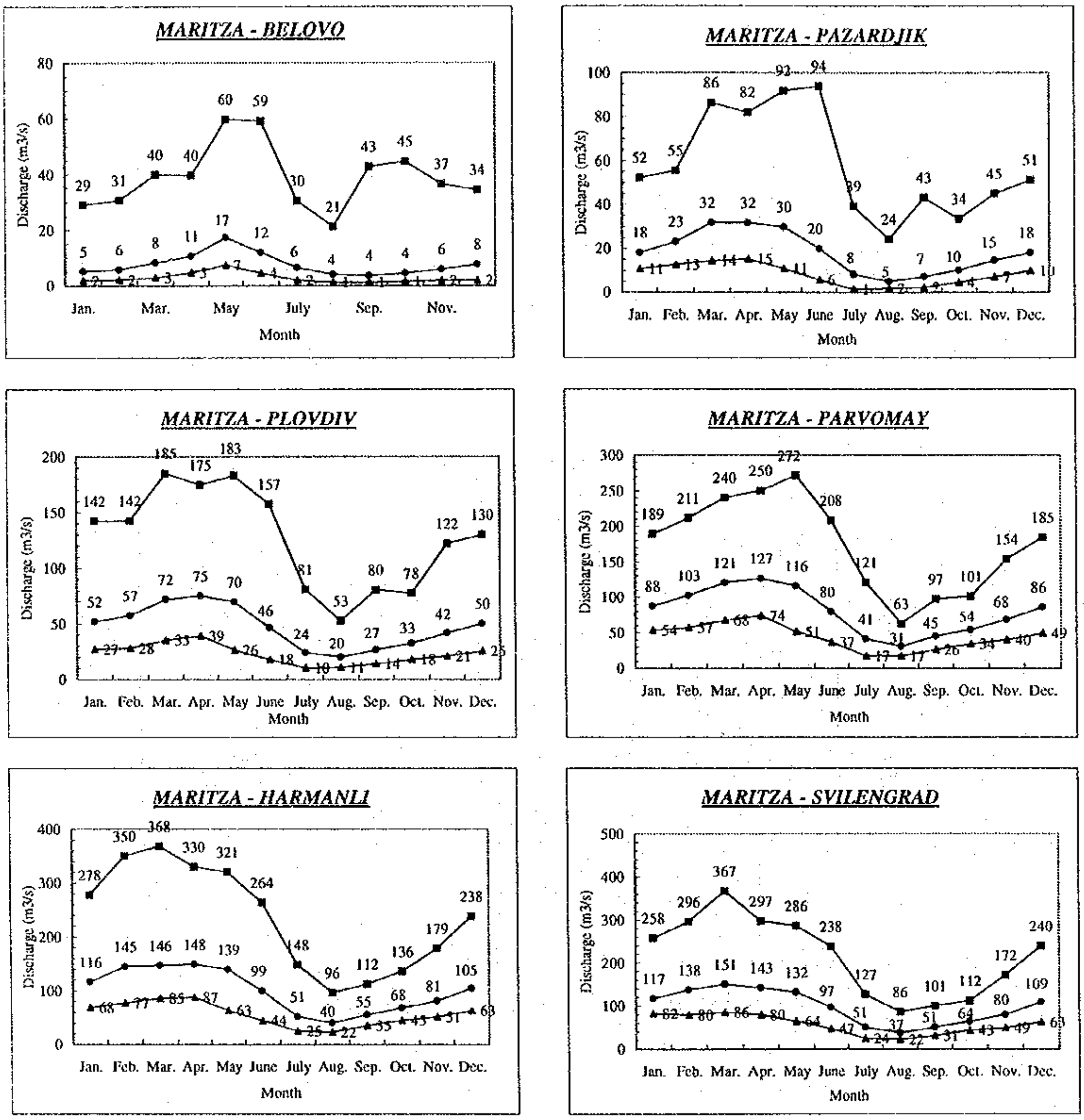


FIG. 2.3.8 MINIMUM, AVERAGE AND MAXIMUM DISCHARGES (1946 - 1995) (1/2)

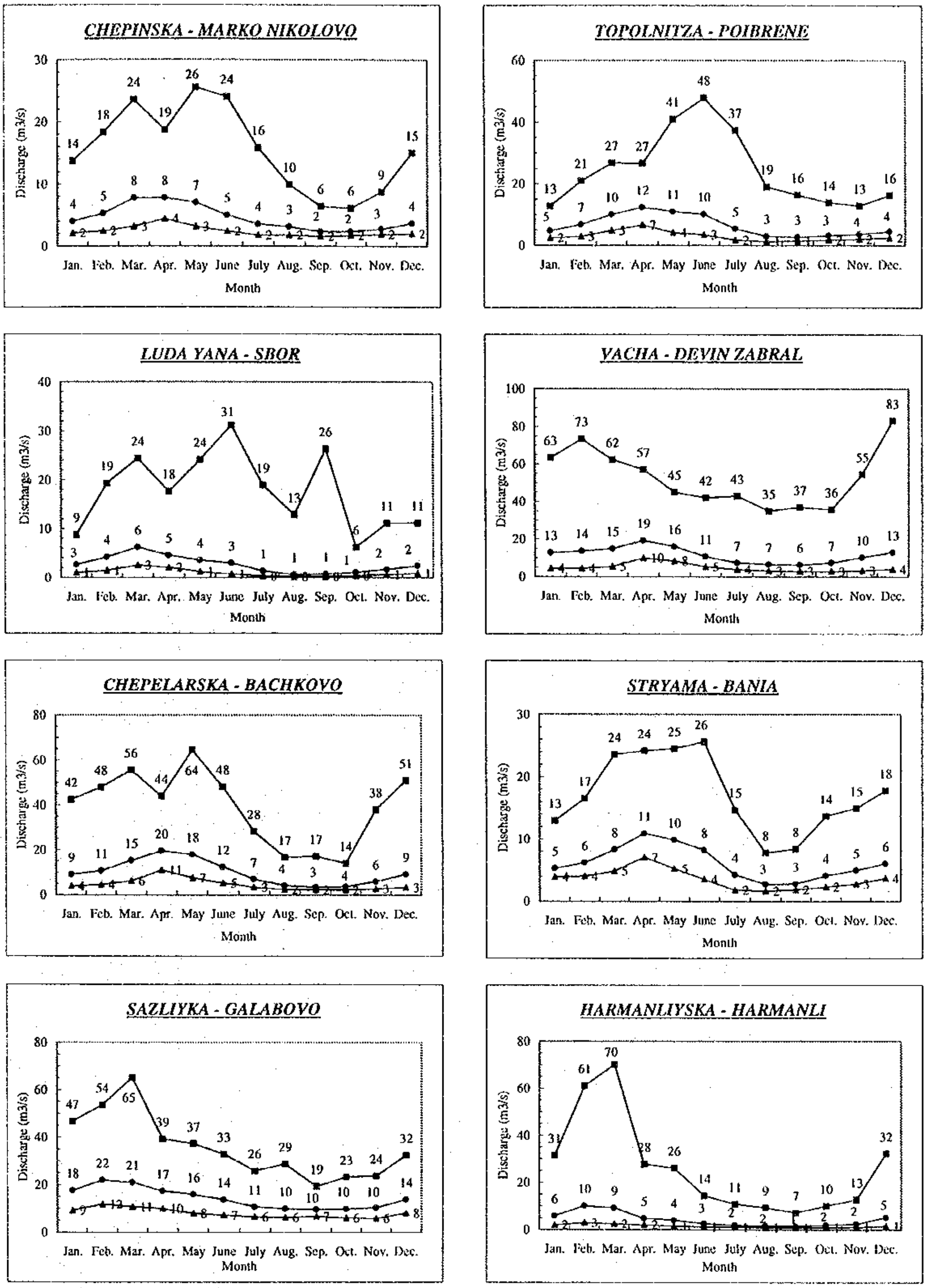
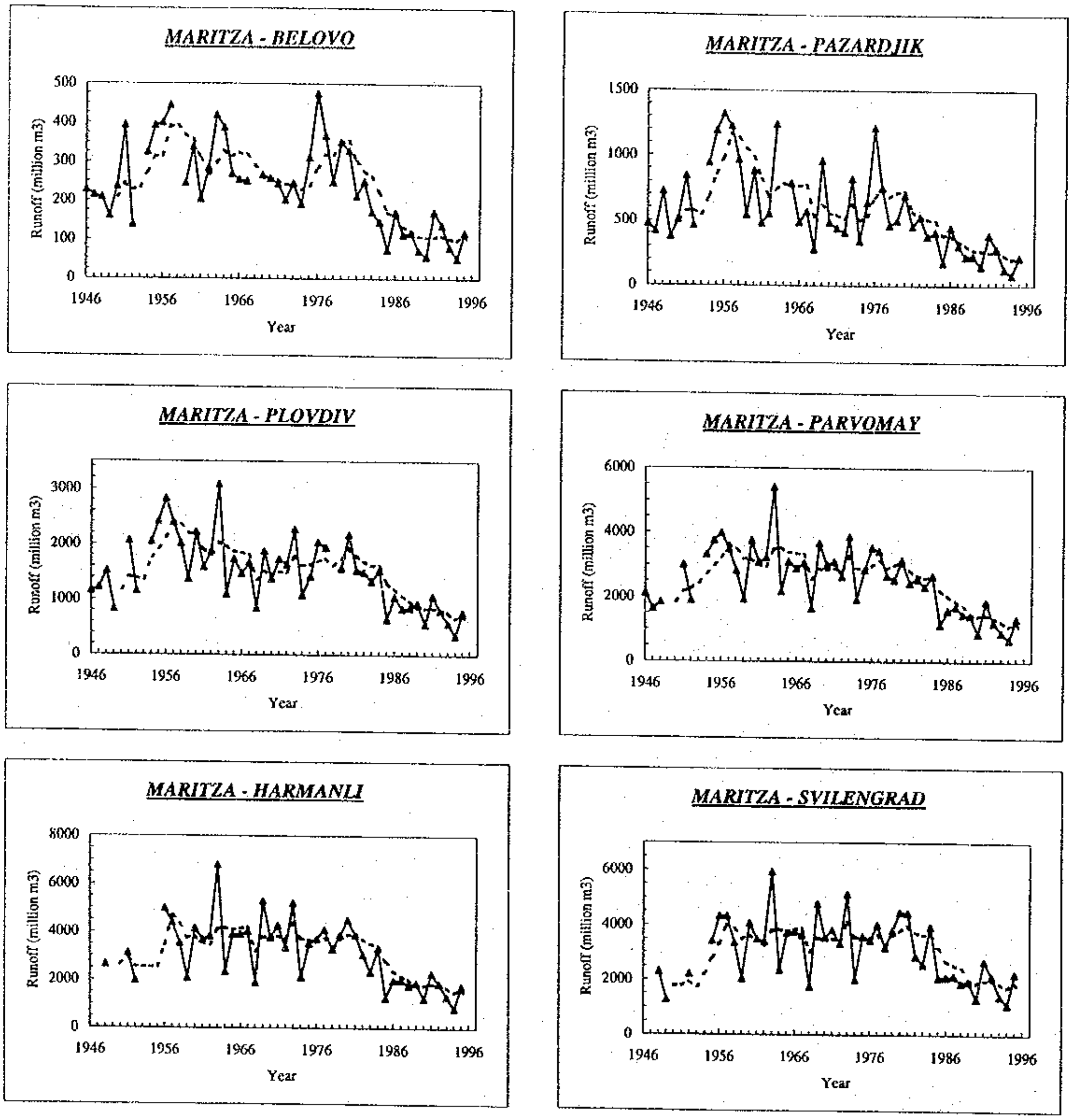
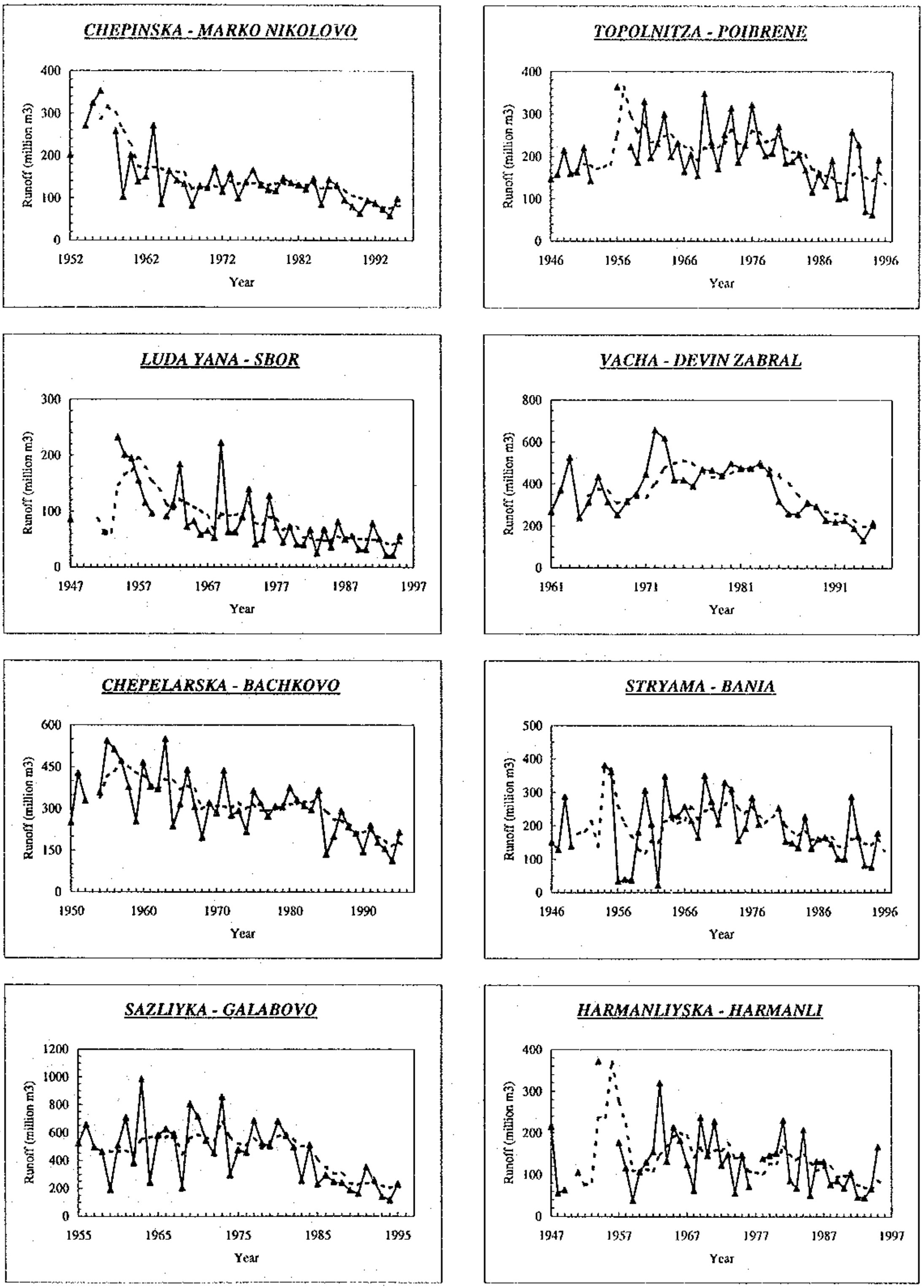


FIG. 2.3.8 MINIMUM, AVERAGE AND MAXIMUM DISCHARGES (1946 - 1995) (2/2)



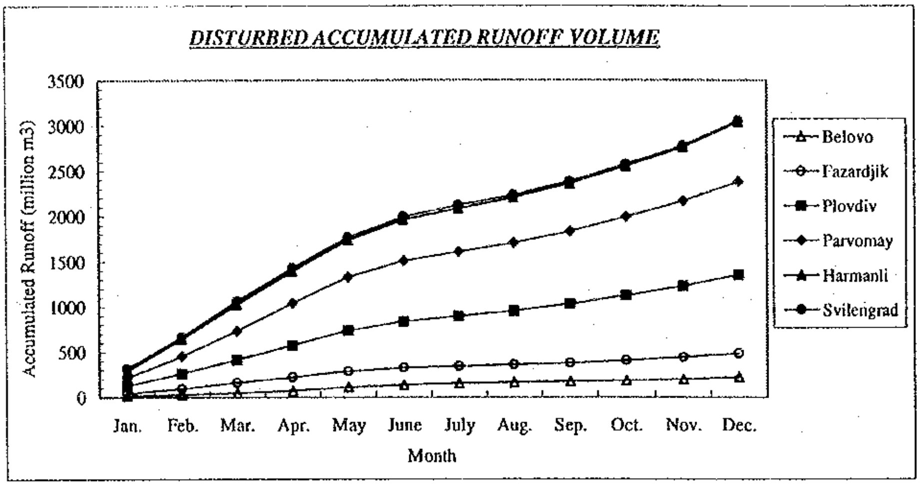
----------------- *5-year moving average trendline*

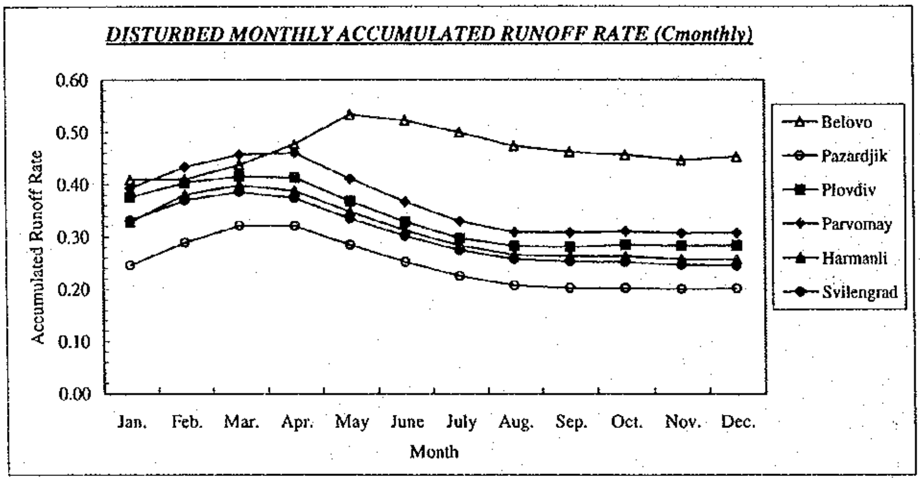
FIG. 2.3.9 YEARLY VARIATION IN ANNUAL RUNOFF (1946 -1995) (1/2)



---------------- *5-year moving average trendline*

FIG. 2.3.9 YEARLY VARIATION IN ANNUAL RUNOFF (1946 -1995) (2/2)





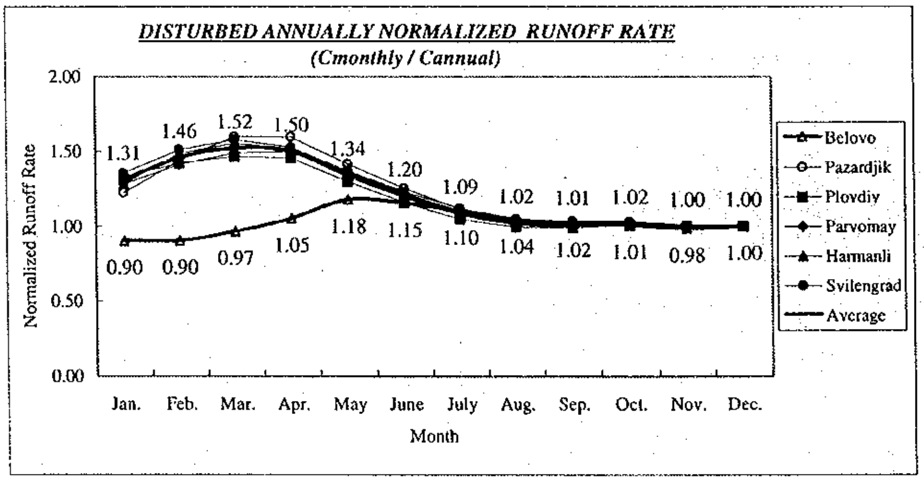
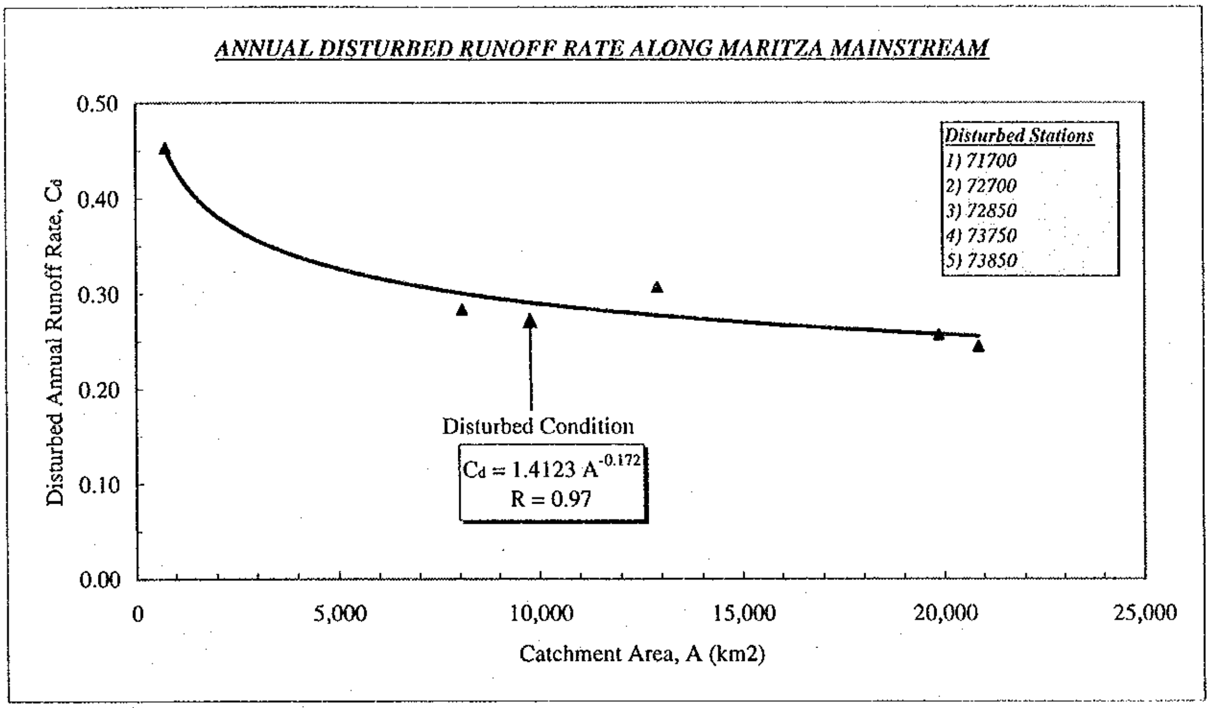
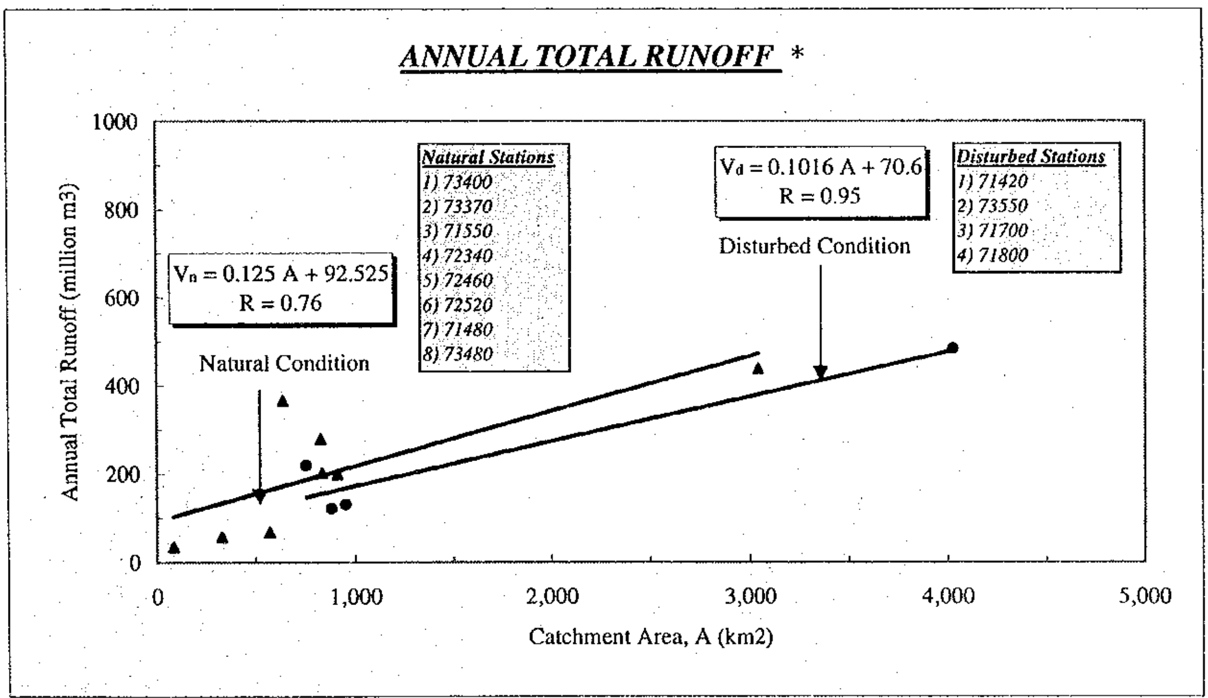


FIG. 2.3.10 MASS CURVES OF DISTURBED RUNOFF RATES (1963 - 1995)





* : *Disturbed hydrometric stations with large catchment sizes have not been included as they provide no clear comparison between natural and disturbed flow.*

FIG. 2.3.11 NATURAL AND DISTURBED ANNUAL RUNOFFS (1963 - 1995)

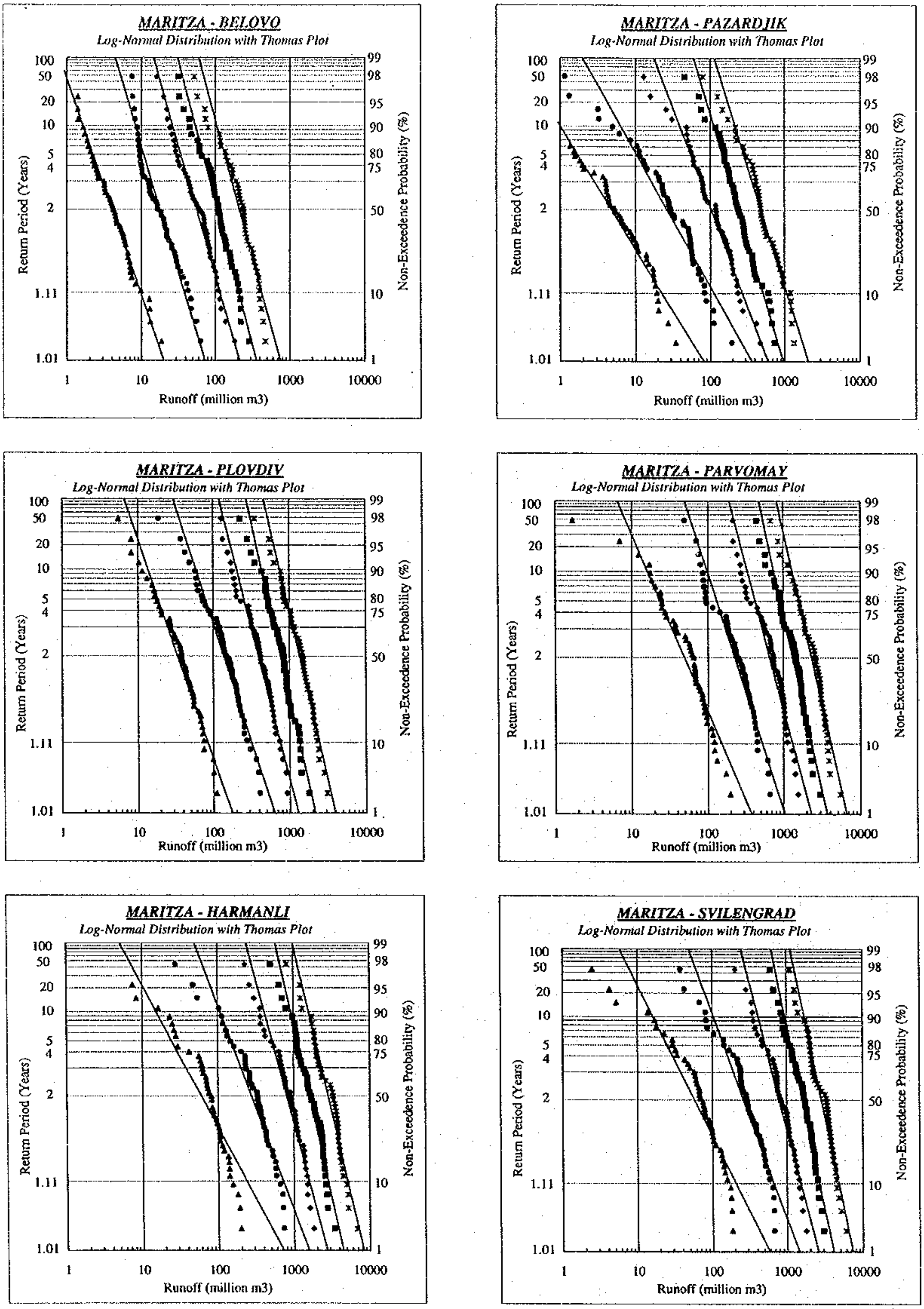


FIG. 2.3.12 PROBABLE MINIMUM 1, 3, 6, 9 AND 12-MONTH RUNOFFS (1946-1995)

2.4
WATER USE AND WATER RESOURCES

2.4 Water Use and Water Resources

Water in the Maritza River Basin is extensively used for irrigation, hydropower, domestic water supply, industry and others. Surface water in the basin is very much disturbed by numerous man-made structures including dams and intakes as well as by inner-basin and inter-basin water transfer facilities and used mainly for irrigation and hydropower. Groundwater is also disturbed by numerous groundwater wells and used mainly for domestic water supply and industry. In relation to water resources in the Maritza River Basin, present condition of water use, water resources potential and water balance were analyzed.

By these analyses, it was found that the water use in the basin is conducted in inefficient way due to lack of management of water use from river basin point of view. Furthermore, surface water is used excessively and groundwater is used almost with sustainable level.

As the water resources in the Maritza River Basin is limited and it is one of the key factor for sustainable development in the basin, it would recommendable to conduct management of water resources including water use and water resources potential from river basin point of view.

2.4.1 Water Use Systems

Irrigation systems, hydropower systems, domestic water supply systems, industries are the major users of water in the Maritza River Basin. Other users are animal breeding and fish breeding.

(1) Irrigation Systems

There are wide irrigation areas in the Maritza River Basin owned by Irrigation Systems Ltd. and private cooperatives (refer to Fig. 2.4.1). As the private cooperatives are being formulated after collapsing of former state cooperatives due to on-going agrarian reform, their real situation is still not clear. There are 16 state irrigation systems with estimated total area of 255,900 ha in the Maritza River Basin. 6 branch offices of the Irrigation Systems Ltd. composed of Pazardjik, Plovdiv, Stara Zagora, Haskovo and others manage the state irrigation systems.

Command area and actual irrigated area with crops in 1996 for the state irrigation systems are shown in Table 2.4.1. Actual utilization rate of state irrigation systems in the present is estimated to be only 16.4 % and that of the cooperative irrigation systems is said to be probably smaller than this percentage.

Major water resource of the irrigation systems is surface water supplied from major irrigation reservoirs of Topolnitza, Pyassachnik and Trakietz Reservoirs, about 680 numbers of medium and small size reservoirs/ponds, river intake weirs and major hydropower/multipurpose reservoirs of Belmeken, Batak and Krichim Reservoirs in the Basin. Main water sources of Stara Zagora IS and Nova Zagora IS are the transferred water from Koprinka and Jrevchevo Reservoirs in the Tundza River Basin (refer to Table 2.4.2).

(2) Hydropower Systems

Electric power generation composed of thermal power, hydropower and nuclear power generation is conducted by the Nasionalna Electricheska Kompania AD (NEK). Dams and Cascades Enterprise, which is a subordinated agency of NEK, controls hydropower/multipurpose reservoirs and relating hydraulic facilities.

There are three major hydropower systems in the Maritza River Basin: Belmeken-Sestrimo-Chaira, Batak Cascade and Dospat-Vacha Cascade Schemes (refer to Fig.2.4.1). Thermal power systems in the basin are the Maritza East I,II,III and Maritza III. Among the total power generation of Bulgaria (42003 GWh in 1996), Maritza River Basin produced 14155 GWh (34 %), which is composed of thermal power generation (12783

GWh) and hydropower generation (1372 GWh).

The major water sources of the hydropower systems are the hydropower/multipurpose reservoirs such as Belmeken, Batak, Antonivanovtzi and Krichim. Inter-basin water transfer has been conducted from Struma and Mesta River Basins to Maritza River Basin. On the other hand, water has been sent to Iskar River Basin from the Belmeken Scheme to supplement domestic water for Sofia City.

(3) Domestic and Industrial Water Supply

There are 7 water supply and sewerage companies (VIKs) of the MoRDPW and 5 VIKs of the municipalities in the Maritza River Basin. They are Sofia, Plovdiv, Pazardjik, Smolian, Peshtera, Batak, Velingrad, Haskovo, Stara Zagora and Sliven VIKs. Almost all the population in the Maritza River Basin is served by public water supply. Sewerage treatment is also conducted by VIKs. About 95 (%) of domestic water comes from groundwater and about 5 (%) of it comes from surface water.

There are about 530 industries in the Maritza River Basin composed of food processing (24 % of number), machinery (20 % of number), chemical (8 % of number), pulp and paper (2 % of number) and others. About half of the industries have their own water source of groundwater and about half of them use municipal water supply, so industries depend mainly on groundwater. Some industries such as Agrobiohim in Stara Zagora receive surface water from irrigation systems.

(4) Others Water Use

Animal breeding:

Based on NIS's data, there are about 156000 cattle, 660000 sheep, 422000 pigs and 2763000 fowls in the Maritza River Basin in 1994. Among them breeding farms have about 36000 (23 %) cattle, 46000 (7 %) sheep, 286000 (68 %) pigs and 442000 (16 %)

fowls and rests of them are bred by private farmers.

Fish breeding:

Fish breeding is conducted by using ponds and reservoirs in the Maritza River Basin. Along the main stream of the Maritza River, there are fish breeding ponds and they depend on surface water supplied through irrigation canals.

(5) Environmental Discussion about Hydraulic Facilities

Hydraulic structures such as dams and intake weirs are used for irrigation, hydropower and others. A recommendation for post-evaluation of environmental impacts for some of the existing hydraulic structures is described below to achieve sustainable water use considering balance with environment.

Dams:

Outflow from outlet of some of the dams to the downstream river reach is very small (Belmeken, Batak Pyassachnik and Trakietz Dams), although the total outflow is not so small.

Irrigation intakes:

In relation to irrigation systems, there are 22 intakes in the basin composed of 4 major gated weirs, 1 river closing overflow dike, 3 temporary river closing dikes and others. Water is very much taken from these intakes and closing dikes, so that very small quantity of water flows in the downstream reaches between spring and autumn.

Hydropower intakes:

In relation to the Belmeken-Sestrimo-Chaira and Batak Hydropower Systems, there are complicated water collecting systems composed of intakes and feeder canals to collect water from Maritza River Basin as well as from neighboring river basins of Struma and Mesta.

JICA Study Team conducted site investigation for one of the major water collecting systems of the Belmeken Scheme called Granchar Feeder Canal in the Rila National Park. The feeder canal is composed of conduit and tunnel with intakes at the galley streams. The intakes stop stream flow and take almost all the water to the feeder canal. According to MoEW, almost all the water is taken to the feeder canal and there is no water in the downstream galley especially between spring and beginning of autumn.

Necessity for post-evaluation of environmental impacts:

Considering the above situation of the existing hydraulic structures, it is highly recommendable to assess the environmental impacts by these existing facilities to achieve future sustainable water use by the irrigation and hydropower systems considering balance with environment.

2.4.2 Water Demand

(1) Irrigation

Irrigation water demand in the Maritza River Basin was estimated for Year 1994 (4-year drought) and Year 1995 (recent average hydrological year) based on FAO's method. Water is used for irrigation during April to September. Annual water demand by the state irrigation systems in the basin becomes about 260 (mil. m^3) in 1995 and 295 (mil. m^3) in 1994 (refer to Table 2.4.3).

On the contrary, actual supplied water to the state irrigation systems during 1992 to 1996 was almost 7 to 10 times larger than the estimated demand. Therefore, irrigation water supply has been conducted with almost same level before 1989, when the irrigation systems were fully utilized.

(2) Hydropower

In relation to the major three hydropower systems of Belmeken-Sestrimo-Chaira, Batak and Dospst-Vacha Schemes, there are 13 hydropower stations.

Total water used by the hydropower systems was 737 (mil. m^3) in 1995 and 550 (mil. m^3) in 1994.

(3) Domestic and Industrial Water Supply and Others

Annual domestic water demand in the Maritza River Basin was estimated to be 153 (mil. m^3). On the other hand, actual supplied water was 199 (mil. m^3) including loss.

Annual industrial water demand in the Maritza River Basin was 310 (mil. m^3). 20 biggest industries use about 90 (%) of industrial water. Among the 20 industries, 6 food processing factories, 3 machinery factories, 2 chemical factories and 3 pulp and paper factories are included.

As the other water demand, annual water demand of animal breeding was about 24.8 (mil. m^3) in 1994.

(4) Total Water Demand

Following table shows summary of estimated annual water demand as well as actual supplied water in the Maritza River Basin in Year 1995 and Year 1994 (see Table 2.4.4 as well).

Estimated Present Water Demand and Actual Supplied Water Volume

Item	Water demand		Actual supplied water	
	Year 1994 (mil. m^3)	Year 1995 (mil. m^3)	Year 1994 (mil. m^3)	Year 1995 (mil. m^3)
1. Total water volume				
1) Gross volume	1391	1536	2505	3819
2) Net volume	841	800	2376	3082
2. Surface water volume				
1) Gross volume	929	1073	1998	3312
2) Net volume	378	337	1869	2576
3. Groundwater volume				
1) Gross volume	463	463	506	506
2) Net volume	463	463	506	506

Notes: 1) Gross volume includes water for hydropower.

2) Net volume does not include water for hydropower.

It is clear that the actual supplied net water volume in Year 1994 and Year 1995 were much bigger than the real water demand. Therefore, water use is necessary to be conducted in more efficient way. Composition of the surface water and groundwater in Year 1994 and Year 1995 for the net water demand is estimated to be 42 – 45 % and 58 – 55 % respectively. That of actual water supply was estimated to be 84 – 79 % and 16 – 21 % respectively.

2.4.3 Water Resources Potential

(1) Surface Water Resources

Natural potential of surface water resources was estimated for Year 1995 and Year 1994. The estimation was based on the basin mean monthly rainfall and runoff rate in the basin. Fig. 2.4.2 shows estimated natural potential of surface water in Year 1994 and Year 1995.

Fig. 2.4.3 shows estimated disturbed potential of surface water in Year 1994 and Year 1995 considering outflow from major reservoirs into river basins as well as the comparison with the natural potential. Also the disturbed potential includes inter-basin water transfer. Amount of the inflow volume to the Maritza River Basin by inter-basin water transfer between Year 1987 and Year 1996 is 234 mil.m^3 (Year 1994) to 433 mil. m^3 (Year 1996) including 250 mil. m^3 (Year 1995). Outflow volume to Iskar River Basin from Belmeken Scheme (from Grancha Canal in Mesta River Basin) between Year 1987 and Year 1996 is min. 44 mil. m^3 (Year 1990) to max. 111 mil. m^3 (Year 1991) including 64 mil. m^3 (Year 1994) and 106 mil. m^3 (Year 1995). Following table shows estimated water resources potential at the most downstream point of the Maritza River (at Svilengrad: Jct.1) in Year 1994 and Year 1995.

Water Resources Potential at Jct.1 (at Svilengrad)

Water resources potential	Year 1994 (mil. m^3/year)	Year 1995 (mil. m^3/year)
Natural surface water potential	3536	4294
Disturbed surface water potential	3584	4411

Disturbed potential of surface water resources are almost same amount as the natural potential in terms of annual amount as well as seasonal amount except Jct. 6. Therefore reservoir operation as well as inter-basin water transfer would necessary to be revised to attain more effective utilization considering balance with environment.

(2) Total Potential of Water Resources

Total potential of water resources composed of surface water and groundwater was estimated for Year 1994 and Year 1995 at junction points in the Maritza River Basin as shown in the following table. In terms of groundwater, recharge potential to the groundwater was estimated from precipitation.

Water Resources Potential at Jct.1 (at Svilengrad)

Water resources potential	Year 1994 (mil. m^3/year)	Year 1995 (mil. m^3/year)
Natural surface water potential	3536	4294
Groundwater recharge potential	1298	1692
Total potential	4834	5986

Among the total potential, natural potential of surface water of Year 1994 and Year 1995 was estimated to be 33 (%) and 31 (%) respectively and groundwater recharge potential was estimated to be 12 (%).

2.4.4 Water Balance

(1) Surface Water Balance

Fig. 2.4.4 shows actual water balance of surface water in Year 1995 and Year 1994 at junction points in the Maritza River Basin, which are based on the estimated disturbed potential and observed discharge volume. Present actual utilization rate of surface water is 49 (%) at Junction 1 to 75 (%) at Junction 6 in Year 1995 (average year) and 69 (%) at Junction 1 to 85 (%) at Junction 6 in Year 1994 (4-year drought). These utilization rates are very high, so the surface water is too much used actually.

If water is utilized efficiently, water utilization rate becomes less than 10 (%) to 11 (%) and it will create large possibility for another utilization for human activity as well as for enhancement of natural environment (refer to Fig. 2.4.5).

(2) Total Water Balance

Utilization rates of water at Jct.1 are shown in the following table.

Water Utilization Rates at Jct.1 (at Svilengrad)

Water resources potential	Year 1994 (%)	Year 1995 (%)
Natural surface water potential	53	60
Groundwater recharge potential	39	30
Total potential	49	51

Notes: 1) Net water demand is applied for above calculation.

Total water resources in the Maritza River basin is too much utilized especially for surface water. As the groundwater level is almost stable with dropping water level in limited places, groundwater utilization can be said almost in sustainable level in the present. Therefore, management of surface water as well as groundwater is very important for sustainable development in the basin.

TABLE 2.4.1 AREA AND PATTERN OF CROPS OF IRRIGATION SYSTEMS

1 Estimated Crop Areas by Irrigation Systems in 1996

Irrigation System	Command area (ha)	Actual irrigated area (ha)	Percent of irrigation (%)	Maize (ha)	Tobacco (ha)	Sugar beet (ha)	Lucerne (ha)	Vegetable (ha)	Fruit trees (ha)	Rice (ha)	Other (ha)
1) Pazardjik Irrigation Branch	**49421**	**5013**	**10.1**	**1675**	**582**	**0**	**30**	**371**	**620**	**711**	**1024**
Karabunar IS	9578	972	10.1	318	111	0	6	70	118	155	194
Varvara IS	7033	713	10.1	234	81	0	4	52	86	114	143
Aleko Pazardjik IS	27410	2780	10.1	910	316	0	16	202	337	443	556
Peshtera IS	3145	319	10.1	124	43	0	2	28	46	0	76
Velingrad IS	2255	229	10.1	89	31	0	2	20	33	0	54
2) Plovdiv Irrigation Branch	**130168**	**20147**	**15.5**	**5891**	**1622**	**20**	**342**	**2039**	**1148**	**2353**	**6732**
Topolnitza IS	63413	9815	15.5	2606	718	9	151	902	508	1942	2978
Stryama Chirpan IS	13408	2075	15.5	551	152	2	32	191	107	411	630
Domlyan IS	8805	1363	15.5	451	124	2	26	156	88	0	516
Karlovo IS	2817	436	15.5	144	40	0	8	50	28	0	165
Krichim Cheshnigirovo IS	30986	4796	15.5	1588	437	5	92	550	309	0	1814
Small ISs of Parvomay, Assenovgrad ISs	10739	1662	15.5	550	152	2	32	190	107	0	629
3) Stara Zagora Irrigation Branch	**36572**	**7820**	**21.4**	**3560**	**582**	**120**	**502**	**323**	**686**	**165**	**1882**
Stara Zagora IS	32198	6885	21.4	3125	511	105	441	284	602	165	1652
Small ISs in Sazliyka Basin	4374	935	21.4	435	71	15	61	39	84	0	230
4) Sliven Irrigation Branch	**12863**	**2750**	**21.4**	**1279**	**209**	**43**	**180**	**116**	**246**	**0**	**676**
Nova Zagora IS	12863	2750	21.4	1279	209	43	180	116	246	0	676
5) Haskovo Irrigation Branch	**26877**	**6253**	**23.3**	**2285**	**1235**	**0**	**90**	**1207**	**25**	**0**	**1411**
Trakietz IS	21383	4975	23.3	1818	983	0	72	960	20	0	1123
Biser IS	5494	1278	23.3	467	252	0	18	247	5	0	288
Whole Systems	**255900**	**41983**	**16.4**	**14690**	**4230**	**183**	**1144**	**4056**	**2725**	**3229**	**11725**

Note:

1) Irrigation System (IS), Irrigation Branch (IB)

2) (Utilized area of IS)=(Command area of IS) x (Percentage of irrigation of IB)

3) Crop areas of IS with rice cultivation:
(Rice area of IS)=(Rice area of IB) x (Max. area of IS)/((Max. area of IB)-(Area of IS without rice))
(Area of other crops)=((Total crop area) - (Rice area)) x (crop percentage without rice)

4) Crop areas of IS without rice cultivation:
(Area of other crops)=(Total crop area) x (crop percentage without rice)

5) Crop areas of Topolnitza IS is estimated based on the crop pattern of Plovdiv IB.

6) Crop areas of Aleko Pazardjik IS is estimated based on the crop pattern of Pazardjik IB.

2 Estimated Percentage Crop Areas by Irrigation Systems in 1996

(Unit: %)

Irrigation System	Maize	Tobacco	Suger beet	Lucerne	Vegetable	Fruit trees	Rice	Other	Total
1) Pazardjik Irrigation Branch	**33**	**12**	**0**	**1**	**7**	**12**	**14**	**20**	**100**
Karabunar IS	33	11	0	1	7	12	16	20	100
Varvara IS	33	11	0	1	7	12	16	20	100
Aleko Pazardjik IS	33	11	0	1	7	12	16	20	100
Peshtera IS	39	14	0	1	9	14	0	24	100
Velingrad IS	39	14	0	1	9	14	0	24	100
2) Plovdiv Irrigation Branch	**29**	**8**	**0**	**2**	**10**	**6**	**12**	**33**	**100**
Topolnitza IS	27	7	0	2	9	5	20	30	100
Stryama Chirpan IS	27	7	0	2	9	5	20	30	100
Domlyan IS	33	9	0	2	11	6	0	38	100
Karlovo IS	33	9	0	2	11	6	0	38	100
Krichim Cheshnigirovo IS	33	9	0	2	11	6	0	38	100
Small ISs of Parvomay, Assenovgrad ISs	33	9	0	2	11	6	0	38	100
3) Stara Zagora Irrigation Branch	**46**	**7**	**2**	**6**	**4**	**9**	**2**	**24**	**100**
Stara Zagora IS	45	7	2	6	4	9	2	24	100
Small ISs in Sazliyka Basin	47	8	2	7	4	9	0	25	100
4) Sliven Irrigation Branch	**47**	**8**	**2**	**7**	**4**	**9**	**0**	**25**	**100**
Nova Zagora IS	47	8	2	7	4	9	0	25	100
5) Haskovo Irrigation Branch	**37**	**20**	**0**	**1**	**19**	**0**	**0**	**23**	**100**
Trakietz IS	37	20	0	1	19	0	0	23	100
Biser IS	37	20	0	1	19	0	0	23	100
Whole Systems	**35**	**10**	**0**	**3**	**10**	**6**	**8**	**28**	**100**

TABLE 2.4.2 MAJOR RESERVOIRS IN THE STUDY AREA WITH RELATING RESERVOIRS

Reservoir	River	Purpose	Reservoir Volume (mil. m3)	Dam Height (m)
Topolnitza	Topolitza River	Irrigation、hydropower	141.35	78.0
Trakietz	Harmanliyska River	Irrigation	114.00	44.0
Pyassachnik	Pyassachnik River	Irrigation	211.40	42.0
Ovcharitza	Ovcharitza River	Cooling water of thermal P.P	45.80	22.0
Belmeken	Kriva River	Hydropower, irrigation, water supply	144.04	98.0
Batak	Matnitza River (Chepinska R. Basin)	Hydropower, irrigation	310.30	35.0
Antonivanovtzi	Vacha River	Hydropower, irrigation	226.10	144.0
Krichim	Vacha River	Hydropower	20.30	104.5
Relating reservoir (other basin)				
Koprinka	Tundza River	Irrigation, water supply	142.20	44.0
Jrebchevo	Tundza River	Irrigation, water supply	400.00	53.0
Dospat Reservoir	Nestos River (Mesta R. Basin)	Hydropower, irrigation, water supply	446.38	60.5
Vasil Kolarov Reservoir	Upstream of Vacha River Basin	Hydropower	62.11	46.5
Shiroka Poliana Reservoir	Left tributary of Nestos River (Mesta R. Basin)	Hydropower	24.00	16.0
Beli Iskar Reservoir	Iskar River Basin	Water supply	400.00	53.0

Data source: Irrigation Systems Ltd.

TABLE 2.4.3 ESTIMATED MONTHLY WATER DEMAND OF STATE IRRIGATION SYSTEMS

1 Year 1994

	Month Irrigation System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Actual supplied irrigation water					Before 1989
															1992	1993	1994	1995	1996	by EWI
1	**Pazardjik Irrigation Branch**	0	0	0	103	6528	12389	18085	17877	7333	0	0	0	62316	702839	394844	392678		386016	372585
	Karabunar IS	0	0	0	12	794	1571	2187	2253	741	0	0	0	7557						33910
	Varvara IS	0	0	0	8	568	1158	1564	1675	490	0	0	0	5462						38310
	Aleko Pazardjik IS (70 %)	0	0	0	47	1922	3602	5499	5153	2117	0	0	0	18342						153636
	Topolnitza IS (30 %)	0	0	0	25	3157	5723	8264	8023	3428	0	0	0	28619						128661
	Peshtera IS (80 %)	0	0	0	6	55	197	373	490	318	0	0	0	1439						9408
	Velingrad IS	0	0	0	3	33	138	200	283	240	0	0	0	897						8660
2	**Plovdiv Irrigation Branch**	0	0	0	260	11331	23016	36550	42256	23010	0	0	0	136423	2690148	1484000	916617		1184249	
	Topolnitza IS (70 %)	0	0	0	59	7365	13353	19282	18720	7998	0	0	0	66777						300209
	Aleko Pazardjik IS (30 %)	0	0	0	20	824	1544	2357	2208	907	0	0	0	7861						65844
	Peshtera IS (20 %)	0	0	0	2	14	49	93	122	80	0	0	0	360						2352
	Stryama Chirpan IS	0	0	0	74	2181	3736	5604	5543	2396	0	0	0	19535						
	Domlyan IS	0	0	0	0	152	609	1259	2523	1960	0	0	0	6503						
	Karlovo IS	0	0	0	0	44	306	373	863	637	0	0	0	2223						
	Krichim Cheshnigirovo IS	0	0	0	54	552	2603	5737	8872	6726	0	0	0	24545						110390
	Small ISs of Parvomay, Assenovgrad ISs	0	0	0	50	199	815	1846	3404	2306	0	0	0	8620						
3	**Stara Zagora Irrigation Branch with Nova Zagora IS**	0	0	0	61	2083	7932	13646	24413	16006	0	0	0	64141	253725	173897	192062		492002	
	Stara Zagora	0	0	0	48	1601	6077	9591	16294	10451	0	0	0	44062						
	Nova Zagora	0	0	0	0	359	1475	2855	6044	4120	0	0	0	14852						
	Small ISs in Sazliyka Basin	0	0	0	13	123	381	1201	2074	1435	0	0	0	5227						
4	**Haskovo Irrigation Branch**	0	0	0	3	614	3111	8802	12308	7178	0	0	0	32017	194701	46536	34260		61990	
	Trakietz	0	0	0	3	479	2301	7113	9756	5728	0	0	0	25380						
	Biser	0	0	0	0	136	811	1689	2552	1450	0	0	0	6637						
	Whole System	0	0	0	428	20556	46448	77084	96853	53528	0	0	0	294898	3841413	2099277	1535617		2124257	

2 Year 1995

	Month Irrigation System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Actual supplied irrigation water					Before 1989
															1992	1993	1994	1995	1996	by EWI
1	**Pazardjik Irrigation Branch**	0	0	0	357	6329	10575	15954	15340	6482	703	0	0	55740	702839	394844	392678		386016	372585
	Karabunar IS	0	0	0	56	735	1277	1909	1864	771	75	0	0	6688						33910
	Varvara IS	0	0	0	40	532	1048	1381	1369	569	55	0	0	4993						38310
	Aleko Pazardjik IS (70 %)	0	0	0	138	1847	3192	4717	4470	1812	162	0	0	16338						153636
	Topolnitza IS (30 %)	0	0	0	91	3142	4816	7515	6948	2869	365	0	0	25745						128661
	Peshtera IS (80 %)	0	0	0	21	47	153	276	404	276	25	0	0	1201						9408
	Velingrad IS	0	0	0	11	25	89	156	285	186	22	0	0	774						8660
2	**Plovdiv Irrigation Branch**	0	0	0	623	11331	18494	32806	36310	19170	2430	0	0	121164	2690148	1484000	916617		1184249	
	Topolnitza IS (70 %)	0	0	0	213	7331	11236	17534	16212	6695	851	0	0	60072						300209
	Aleko Pazardjik IS (30 %)	0	0	0	59	792	1368	2022	1916	777	70	0	0	7002						65844
	Peshtera IS (20 %)	0	0	0	5	12	38	69	101	69	6	0	0	300						2352
	Stryama Chirpan IS	0	0	0	54	2173	3089	5300	5015	2007	262	0	0	17899						
	Domlyan IS	0	0	0	43	127	155	1241	2093	1641	218	0	0	5518						
	Karlovo IS	0	0	0	19	45	43	387	578	518	70	0	0	1660						
	Krichim Cheshnigirovo IS	0	0	0	173	607	1817	4728	7626	5434	699	0	0	21084						110390
	Small ISs of Parvomay, Assenovgrad ISs	0	0	0	56	245	749	1526	2770	2029	253	0	0	7628						
3	**Stara Zagora Irrigation Branch with Nova Zagora IS**	0	0	0	457	2027	6593	13521	20932	9790	1017	0	0	54337	253725	173897	192062		492002	
	Stara Zagora	0	0	0	304	1601	4365	8880	14224	6335	667	0	0	36375						
	Nova Zagora	0	0	0	130	302	1584	3525	5075	2499	266	0	0	13381						
	Small ISs in Sazliyka Basin	0	0	0	23	124	644	1116	1633	956	84	0	0	4581						
4	**Haskovo Irrigation Branch**	0	0	0	6	580	4940	8656	9561	4872	501	0	0	29116	194701	46536	34260		61990	
	Trakietz	0	0	0	6	451	4007	6823	7427	3799	405	0	0	22917						
	Biser	0	0	0	0	129	934	1833	2134	1073	96	0	0	6199						
	Whole System	0	0	0	1442	20268	40602	70937	82143	40314	4651	0	0	260357	3841413	2099277	1535617		2124257	

Note:
1) Monthly and annual irrigation water demand were estimated by JICA Study based on actual cropping pattern and FAO's standard for irrigation water requirement.
2) Actual irrigation water of the Irrigation Branch was based on the data of the Irrigation Systems Ltd.
3) Estimated irrigation demand includes 50 % water loss.
4) Estimated past irrigation demand before 1989 was from the study results of "Bulgaria Hydropower Study" by Electrowatt Engineering Services Ltd. with Energoproekt, 1994.

TABLE 2.4.4 WATER DEMAND AND SUPPLY FROM SURFACE WATER AND GROUNDWATER

1 Water Demand in Year 1995 (average year)

(Unit: 1000 m3/Year)

No.	Water Demand	Estimated Demand			Esimated Supplied Amount		
		Surface water	Groundwater	Total	Surface water	Groundwater	Total
1	Irrigation water demand (IR)	312,428		312,428	2,549,108		2,549,108
1)	State irrigation	260,357		260,357	2,124,257		2,124,257
2)	Cooperative irrigation	52,071		52,071	424,851		424,851
2	Hydropower	0		0	0		0
1)	Demand (HD)	736,706		736,706	736,706		736,706
2)	Outflow	-736,706		-736,706	-736,706		-736,706
3	Domestic water supply (DW)	7,632	145,004	152,636	9,928	188,638	198,566
4	Industrial water supply (IW)	15,481	294,135	309,616	15,481	294,135	309,616
5	Animal breeding (AW)	1,242	23,607	24,849	1,242	23,607	24,849
	Gross Demand (GD)	1,073,489	462,746	1,536,235	3,312,466	506,380	3,818,846
	Percentage	69.9%	30.1%	100%	86.7%	13.3%	100%
	Net Demand (ND)	336,783	462,746	799,529	2,575,760	506,380	3,082,140
	Percentage	42.1%	57.9%	100%	83.6%	16.4%	100%

2 Water Demand in 1994 (4-year drought)

(Unit: 1000 m3/Year)

No.	Water Demand	Estimated Demand			Esimated Supplied Amount		
		Surface water	Groundwater	Total	Surface water	Groundwater	Total
1	Irrigation water demand	353,877		353,877	1,842,740		1,842,740
1)	State irrigation	294,898		294,898	1,535,617		1,535,617
2)	Cooperative irrigation	58,980		58,980	307,123		307,123
2	Hydropower	0		0	0		0
1)	Demand	550,496		550,496	128,993		128,993
2)	Outflow	-550,496		-550,496	-128,993		-128,993
2	Domestic water supply	7,632	145,004	152,636	9,928	188,638	198,566
3	Industrial water supply	15,481	294,135	309,616	15,481	294,135	309,616
4	Animal breeding	1,242	23,607	24,849	1,242	23,607	24,849
	Gross Demand (GD)	928,728	462,746	1,391,474	1,998,385	506,380	2,504,765
	Percentage	66.7%	33.3%	100%	79.8%	20.2%	100%
	Net Demand (ND)	378,232	462,746	840,978	1,869,392	506,380	2,375,772
	Percentage	45.0%	55.0%	100%	78.7%	21.3%	100%

Note: Proportions of surface water and groundwater were set as follows;

State irrigation:	Almost all water (about 100 %) supplied by surface water Supplied water in 1996 was used for the supplied water amount in 1995.
Cooperative irrigation:	- ditto - Demand and supplied amount was supposed to be 20 (%) of those of state irrigation systems
Domestic water supply:	5 (%) from surface water and 95 (%) from groundwater
Industrial water supply:	5 (%) from surface water and 95 (%) from groundwater
Animal breeding:	5 (%) from surface water and 95 (%) from groundwater

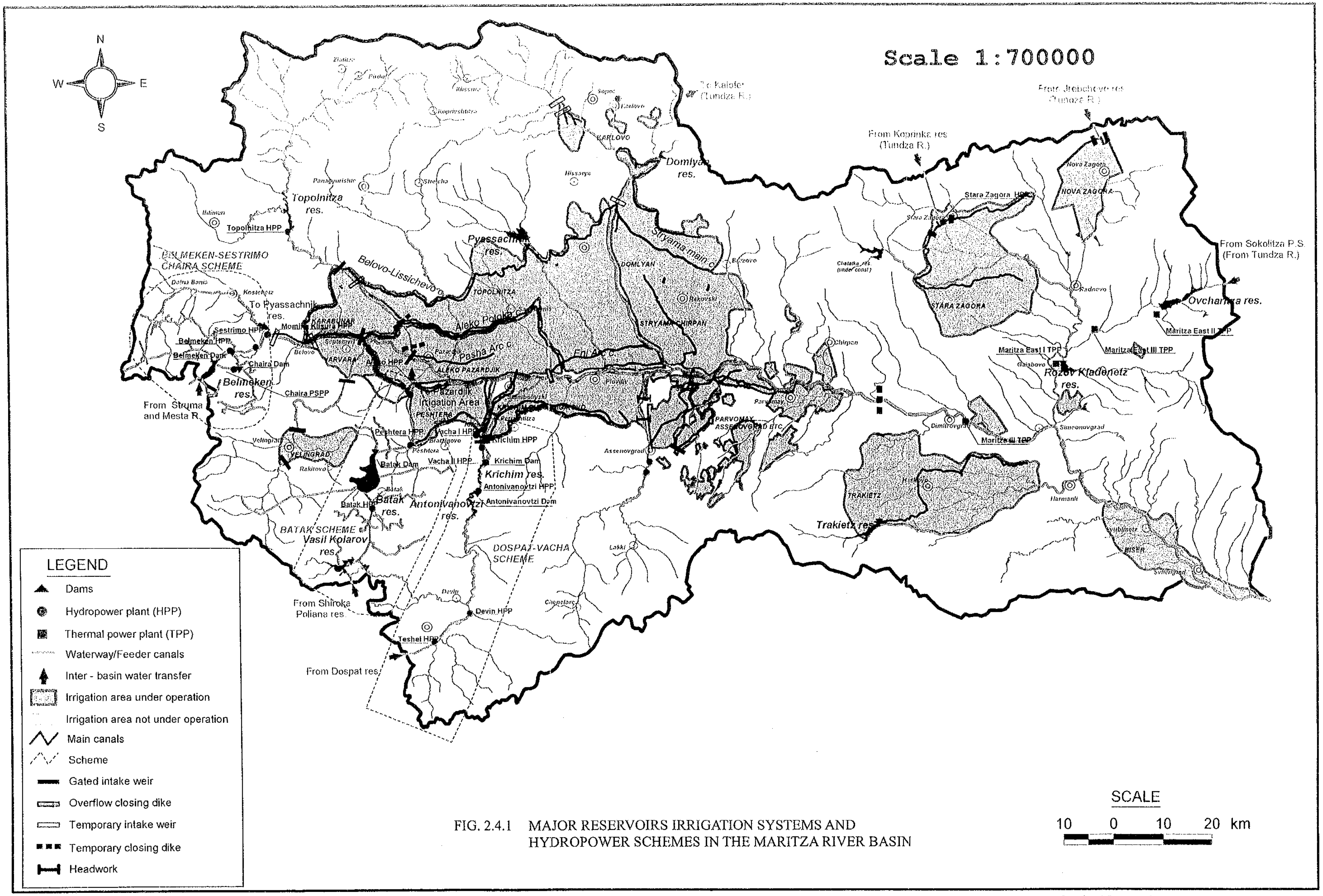
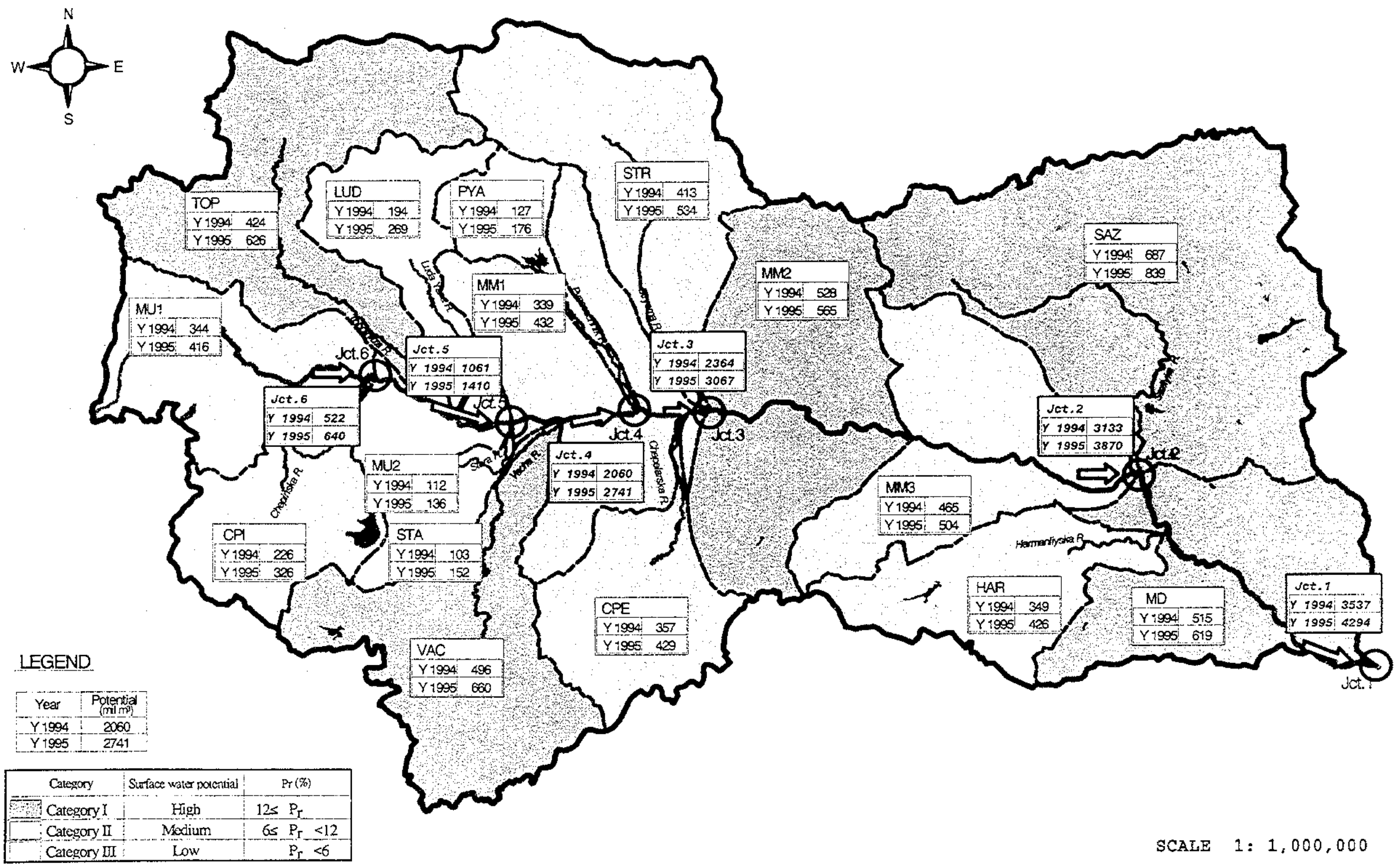
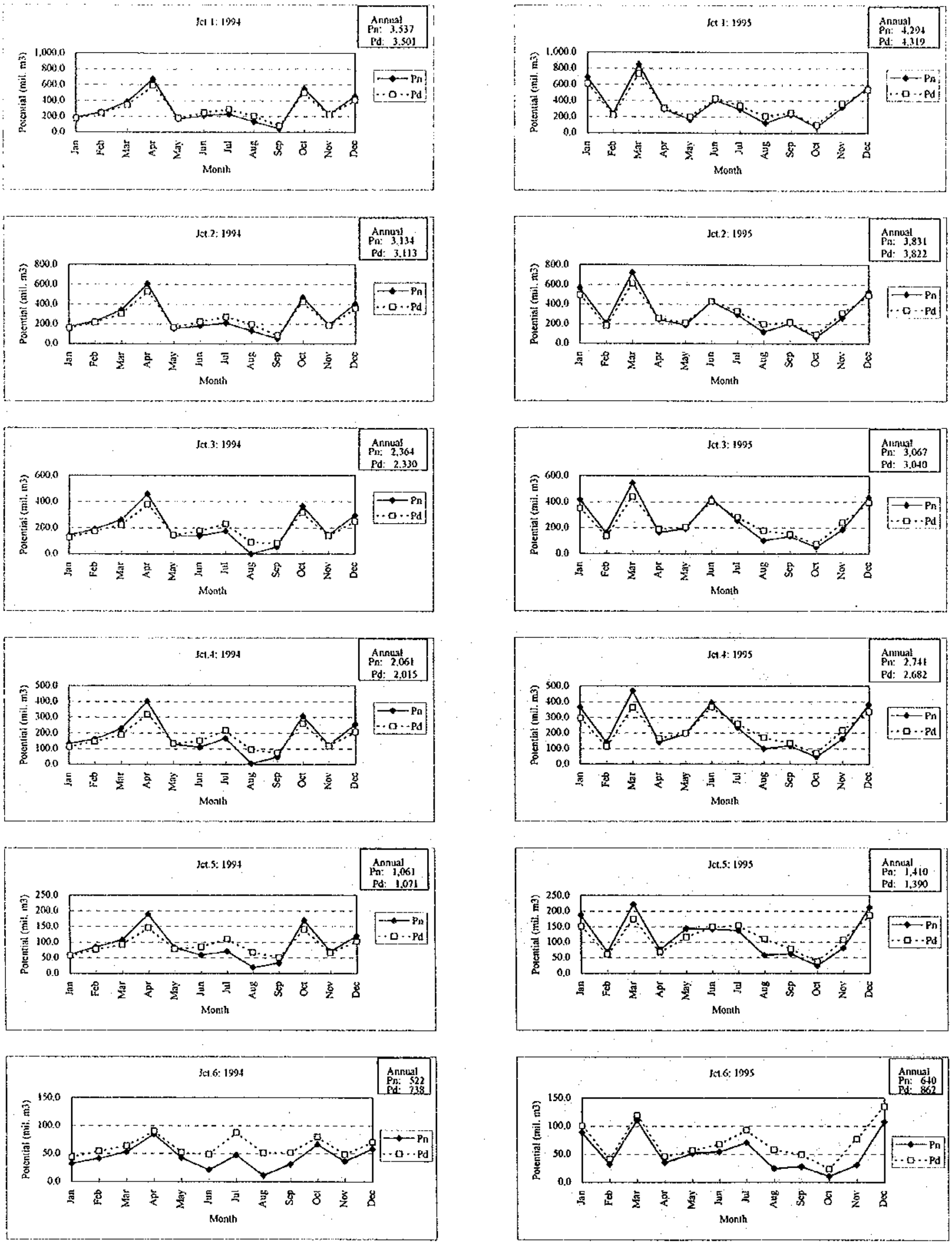


FIG. 2.4.1 MAJOR RESERVOIRS IRRIGATION SYSTEMS AND HYDROPOWER SCHEMES IN THE MARITZA RIVER BASIN



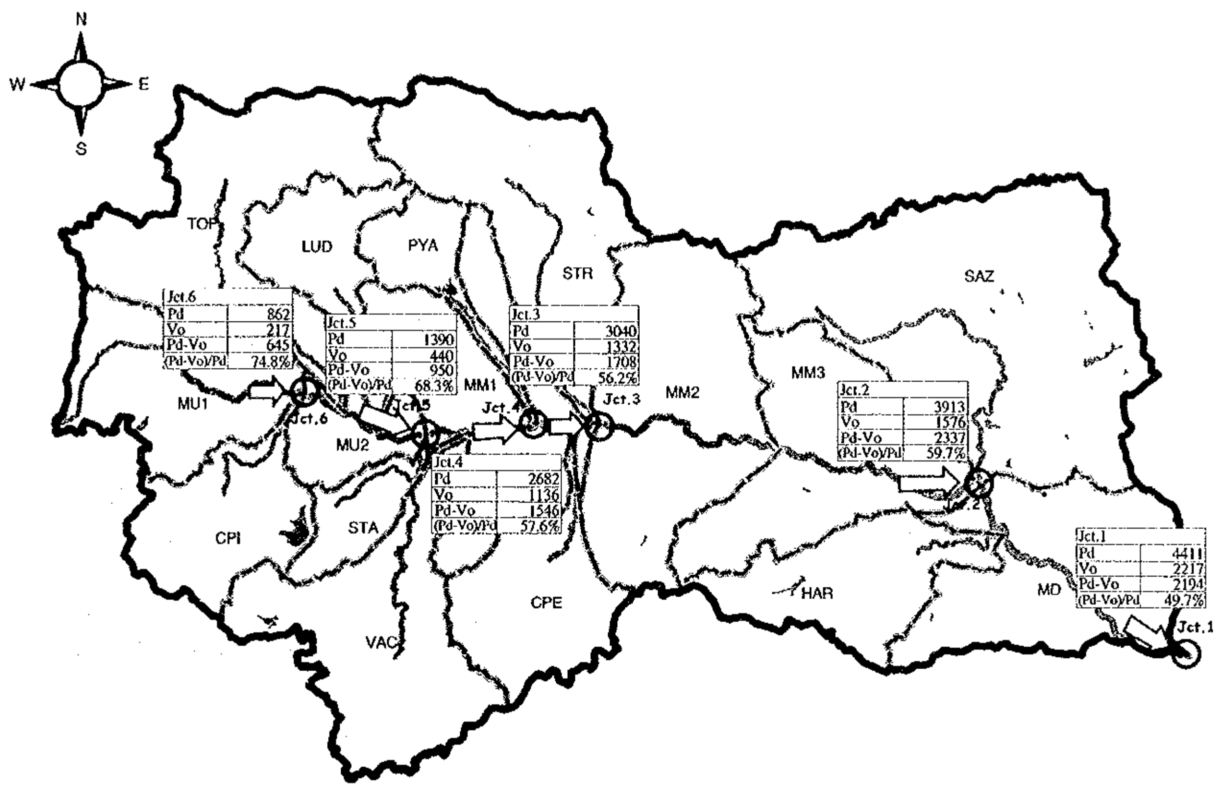
Note : Pr : (Natural surface water potential of each basin) /(Natural surface water potential at Jct.1)

FIG. 2.4.2 NATURAL SURFACE WATER POTENTIAL IN 1994 AND 1995

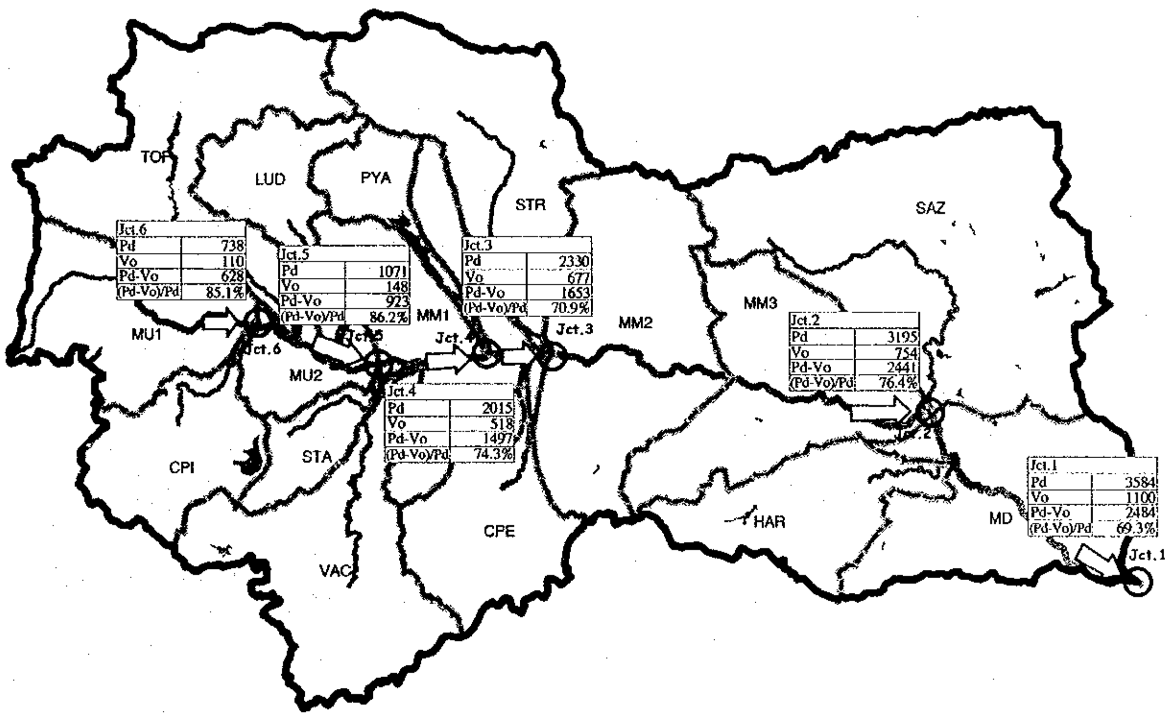


Pn : Natural runoff potential Pd : Runoff potential with major dams

FIG. 2.4.3 COMPARISON OF MONTHLY NATURAL RUNOFF POTENTIAL WITH DISTURBED POTENTIAL WITH MAJOR DAMS IN 1994 AND 1995



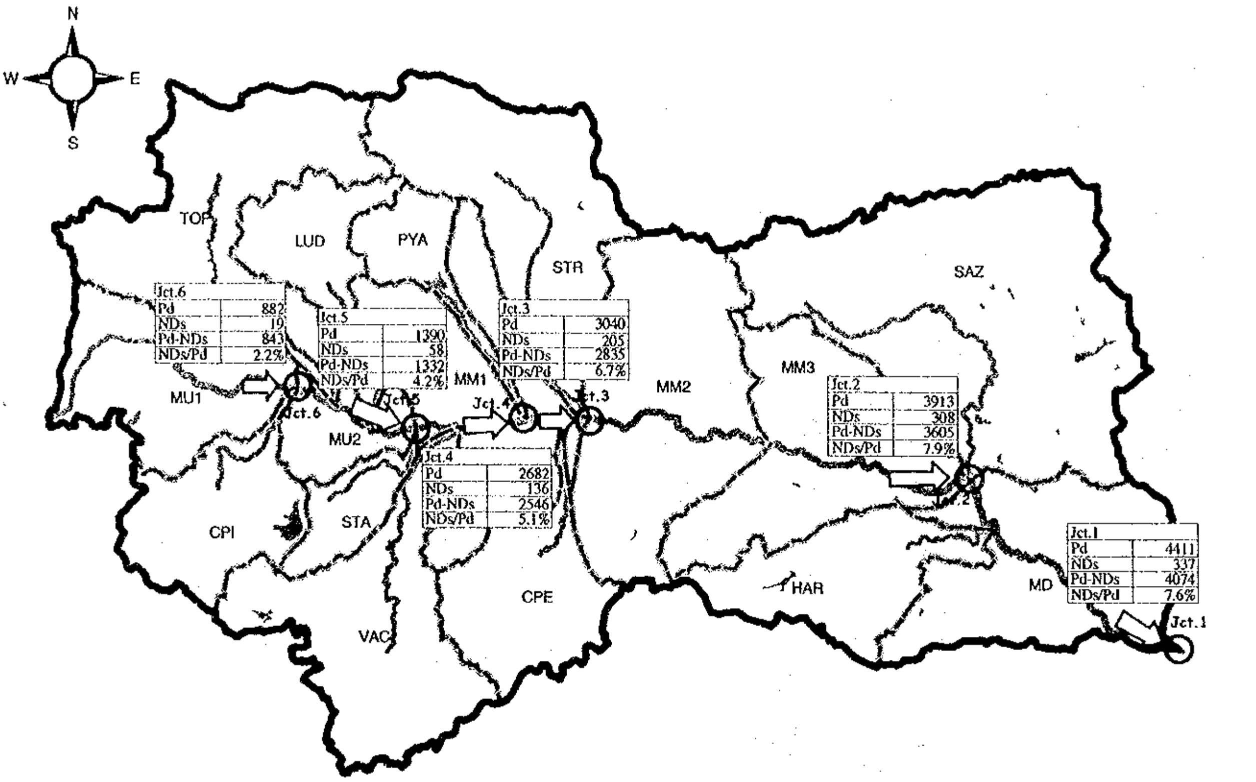
ANNUAL BALANCE IN 1995 (AVERAGE YEAR)



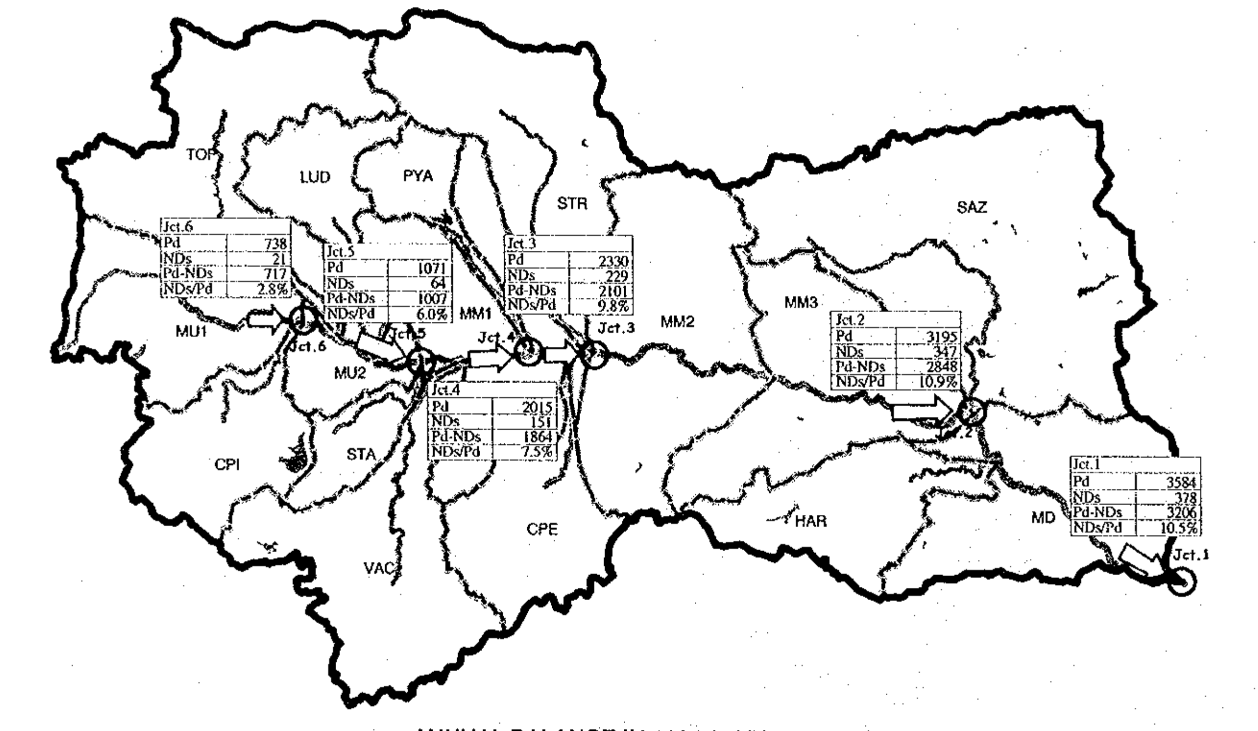
ANNUAL BALANCE IN 1994 (4-YEAR DROUGHT)

Pd : Surface water potential with major dams (mil.m^3/year)
Vo : Observed discharge volume (mil.m^3/year)
Pd-Vo/Pd : utilization rate of surface water (%)

FIG.2.4.4 PRESENT SURFACE WATER BALANCE BASED ON THE OBSERVED DISCHARGE



ANNUAL BALANCE IN 1995 (AVERAGE YEAR)



ANNUAL BALANCE IN 1994 (4-YEAR DROUGHT)

Pd : Surface water potential with major dams (mil.m³/year)
NDs : Net water demand cmposed of irrigation ,domestic WS,industrial WS and animal breeding (mil.m³/year)
NDs/Pd : water utilization rate (%)

FIG.2.4.5 POSSIBLE SURFACE WATER BALANCE IN THE PRESENT BASED ON THE ESTIMATED WATER DEMAND