Appendix K

Water Balance Study

Appendix K WATER BALANCE STUDY

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Appendix K WATER BALANCE STUDY

K.1 Basin Model

For conducting water balance calculation for the current situation, a basin model was prepared dividing the national land into seven major river basins consisting of 26 sub-basins. The reaches of the major rivers and main tributaries are presented by arcs and river facilities by nodes in the model as origin of the river, conjunction between a major river and a tributary, intakes of municipal, agricultural and industrial water, gauging stations and reservoirs. The above basin model is shown in Figures K.1 to K.8 and summarized below.

Summary of Basin Model

Major Basin	Sub-basin	No. of Node for Municipal and Industrial Water Intake	No. of Node for Agricultural Water Intake	No. of Existing Reservoir
1. Vardar	1) B1-1	2	5	1
	2) B1-2	1	1	0
	3) B1-3	1	2	1
	4) B1-4	3	3	0
	5) B1-5	2	2	0
	Sub-total	9	13	2
2. Treska	6) B2-1	2	1	0
	7) B2-2	0	0	0
	8) B2-3	0	0	1
	Sub-total	2	1	1
3. Pchinja	9) B3-1	2	2	0
	10) B3-2	0	1	0
	11) B-3	1	1	2
	12) B-4	0	0	0
	Sub-total	3	4	2
4. Bregalnica	13) B4-1	3	3	1
	14) B4-2	2	2	2
	15) B4-3	2	1	0
	16) B4-4	1	2	2
	Sub-total	8	8	5
5. Crna	17) B5-1	3	2	1
	18) B5-2	1	1	1
	19) B5-3	0	2	1
	Sub-total	4	5	3
6. Strumica	20) B6-1	1	1	0
	21) B6-2	0	1	1
	22) B6-3	1	2	1
	23) B6-4	0	0	0
	Sub-total	2	4	2
7. Crn Drim	24) B7-1	0	0	0
	25) B7-2	2	4	0
	26) B7-3	2	2	2
	Sub-total	4	6	2
Total		32	41	17

This model was used for a study on water demand and supply balance for target years of 2005, 2015, and 2025 as well as current condition.

K.2 Basic Conditions of the Calculation

The water balance calculation was conducted with the following conditions.

C1: The quantity of demand and supply used in the calculation is not on monthly average basis but on 10-day average one, upon a requirement from the agricultural water process.

C2: Demands of municipal and industrial, and agricultural water are converted to those of 10-day. Demands of municipal and industrial water are further divided into their surface and groundwater components including springs, while that of the agricultural water is only by surface water.

C3: The supply quantity by natural flow, which is classified as surface water for groundwater including springs is also converted to 10-day average one. Natural flow adopted in the calculation is for the period of 36 years from 1961-1996.

C4: The natural flow is derived from the daily flow records at gauging stations. 40 stations have daily flow records for the 36 years. Among them, 12 stations are situated just on the gauging station node in the model. 15 stations are situated upstream of the boundary of sub-basin, and hence their natural flows are adopted after adjusted by ratio of the catchment area of their location and the area of sub-basin. One station is selected, in principle, for each sub-basin except the sub-basin of B4-2, where the natural flows of two stations are combined as the flow for sub-basin.

Gauging Stations Adopted as Water Supply Node

Major Basin	Sub-basin	No. of Node	Name of Gauging Station (No.)		Utilization of Natural Flow	
1. Vardar	1) B1-1	(1) G1-2	Sarakinci	(ST004)	As recorded	(1)
	2) B1-2	(2) G1-6	Skopje	(ST008)	- do -	(2)
	3) B1-3	(3) G1-8	Veles	(ST010)	- do -	(3)
	4) B1-4	(4) G1-9	Demir Kapija	(ST014)	- do -	(4)
	5) B1-5	(5) G1-10	Gevgelija	(ST016)	After adjusted	(1)
2. Treska	6) B2-1	(6) G2-2	Makedonski Brod	(ST023)	As recorded	(5)
	7) B2-2	(7) G2-3	Zdunje	(ST025)	- do -	(6)
	8) B2-3	(8) G2-4	Sveta Bogorodica	(ST026)	After adjusted	(2)
3. Pchinja	9) B3-1	(9) G3-4	Pelince	(ST034)	After adjusted	(3)
	10) B3-2	(10) G3-3	Trnovec	(ST038)	- do -	(4)
	11) B-3	(11) G3-5	Kumanovo	(ST041)	- do -	(5)
	12) B3-4	(12) G3-6	Katlanovska Banja	(ST035)	As recorded	(7)
4. Bregalnica	13) B4-1	(13) G4-3	Ochi Pale	(ST050)	As recorded	(8)
	14) B4-2	(14) G4-4	Laki	(ST055)	After adjusted (right bank)	(6)
		(14) G4-5	Kamenica	(ST054)	After adjusted (left bank)	(7)
	15) B4-3	(15) G4-7	Shtip	(ST052)	As recorded	(9)
	16) B4-4	(16) G4-7	Shtip	(ST052)	After shifted and adjusted to B4-4	(8)
5. Crna	17) B5-1	(17) G5-1	Dolenci	(ST060)	After adjusted	(9)
	18) B5-2	(18) G 5-2	Skocivir	(ST064)	As recorded	(10)
	19) B5-3	(19) G 5-3	Rasimbegov Most	(ST065)	After adjusted	(10)
6. Strumica	20) B6-1	(20) G6-2	Sushevo	(ST103)	As recorded	(11)
	21) B6-2	(21) G6-2	Sushevo	(ST103)	After shifted and adjusted to B6-2	(11)
	22) B6-3	(22) G6-2	Sushevo	(ST103)	- do -	(12)
	23) B6-4	(23) G6-3	Novo Selo	(ST104)	After adjusted	(13)
7. Crn Drim	24) B7-1	(24) G7-1	Boshkov Most	(ST098)	As recorded	(12)
	25) B7-2	(25) G7-2	Lozhani	(ST088)	After adjusted	(14)
	26) B7-3	(26) G7-3	Lozhani	(ST088)	After adjusted	(15)

K.3 Current Water Demand and Supply Circumstance

The current water demand and supply circumstances were taken in the water balance calculation as follows.

(1) Municipal Water Requirement

Water supply by Communal Enterprises (CEs) was derived for each municipality and abstractions were assumed to be applied near the main center in each municipality, namely the principal city. These abstractions were sub-divided into their surface and groundwater components and the surface water component was, therefore, allocated to a municipal water intake node, one for each municipality, located on the nearest main water course adjacent to the principal city.

Groundwater components were excluded from the water balance calculation because they were assumed to be abstracted outside the surface water system. However, a part of the groundwater component was assumed to enter the surface water system at these nodes as return flow.

The surface water demand component included all surface water abstractions by CEs for domestic households, communal and commercial use as well as potable water supplies to industry (supplies for raw industrial process water were separated from municipal water). According to information obtained from selected CEs, the municipal demands vary about 0.7 of the mean annual demand in winter to 1.3 of the mean in summer. Thus the surface water demands were applied across the year as a sinusoidal distribution with a coefficient of variation of 1.3.

(2) Agricultural Water

The agricultural water requirement was allocated to agricultural water intake nodes, amounting to 41 nodes in total in the basin model.

In the water balance calculation in a large area, no return flow from upstream irrigation systems was taken for the downstream systems except the Bregalnica irrigation system (B4-2), where paddy is one of major crops with return rates of 30%.

Considering the current condition of the low irrigation efficiency in the actually irrigated area, namely in the workable part of the irrigation system, that is estimated to be 0.58 composed of the conveyance efficiency of 0.8, the distribution efficiency of 0.9 and the field application efficiency of 0.8 (Ref. Table 37 in FAO Irrigation and Drainage Paper 24 revised 1977 Crop Water Requirements).

As for livestock and fishery waters, the return flow was not considered in the calculation because of its negligible small quantity. Further, the water consumption by the fishery in Macedonia would practically not be needed to be counted because the water taken from a river into a fish pond flows continuously through the pond and flows back to the original river.

(3) Industrial Water

Although data was available for industrial water demands by type of activity from the Statistical Office, there was no national data available giving the geographic distribution of total industrial demand across the country. Resources were therefore made to use sample data from selected industrial information obtained from the industrial water utilization survey carried out from December 1997 to March 1998.

From this sample data it was possible to derive a geographical distribution for industrial demands and hence deduce the industrial water demand for each municipality. This was achieved firstly by amalgamating the sample data from selected industries with that from the water utilization survey and, after eliminating duplicated data, deriving an approximate distribution of industrial demand by type of activity across each municipality.

This distribution was then applied to the data from the Statistical Office. The sample data accounted for about 80% of the total industrial demand on national level and, therefore, the resulting geographic distribution was considered reasonable.

After estimation of the industrial water demands for each municipality, the abstractions were assumed to be applied near the main urban center in each municipality, in the same way as the municipal demands. These industrial abstractions were also sub-divided into their surface and groundwater components, with the surface water component being allocated to the water demand node, located on the nearest main water course adjacent to the principal city.

Groundwater demands were excluded from the water balance as these are assumed to be abstracted outside the surface water system, but included in the calculation of groundwater. A part of the groundwater component was, however, assumed to enter the surface water system at these nodes as return flows together with the surface water return flows.

Industrial water demands were generally constant throughout the year, with the possible exception of certain agricultural processing industries. However, the demands from such seasonal industries were small compared to principal industrial and hence a coefficient of variation of 1.0 has been assumed.

K.4 Results of Balance Calculation for Current Conditions

Water balance calculation for the current situation was conducted with use of current water requirements and river flow data for 36 years from 1961 to 1996 on 10-day basis.

As the results of the calculation, among seven river basins, three basins of the Vardar main stream except the lower reach, Treska and Crn Drim rivers have little water shortage through the 36 years, while the remaining four basins like the Pchinja, Bregalnica, Crna and Strumica rivers and the lower reach of the Vardar river experience the shortage in the dry season.

The high shortage occurrence in each sub-basin obtained through the calculation is represented by the following:

High Shortage Occurrence in Each Sub-basin

River Basin Description	Pchinja (B3-3)	Bregalnica (B4-2)	Crna (B5-3)	Strumica (B6-2)+(B6-3)
1. Main Municipality	Kumanovo	Kochani	Kavadarci	Strumica
2. Seasonal Shortage Period (monthly base)	April - October	April - October	June - October	April - October
3. Shortage Water	Municipal/ Agricultural	Municipal/ Agricultural	Irrigation	Municipal/ Agricultural
1. Shortage of Water (average : 1961-1996 in 10^6m^3/year)	- 89	-239	-112	-76
7. Existing Dam	Glazhnja Lipkovo	Kalimanci Gradche Ratevska	Tikvesh	Turrija Vodocha
8. Net Capacity of Dams (10^6 m^3): Total	24 1.75 25.75	120 2 9 131	360	45 25.1 70.1

The Crna river basin has been supplied from the Tikvesh reservoir in the dry season, while other basins such as the Pchinja, Bregalnica, and Strumica might have water shortage, which was not covered by the existing reservoirs in some years during the 36 years.

In case of Tikvesh area (the Crn river basin B5-3), the shortage amount in the severe drought of 1995 is estimated at around $130x10^6m^3$, which is within the net capacity of the Tikvesh reservoir. Through the information and study results for water-related problem identification, however, the basin was said to have water shortage. It is considered that the reservoir was not filled to the normal water level due to the drought.

In addition to the above, in the basin of Valandovo and Gevgelija (B1-5) on both banks of the most lower reach of the Vardar River, seasonal water shortage is calculated in the months July to September with an average shortage of around $25\ x10^6m^3/3$ months.

K.5 Results of Balance Calculation for Future Conditions

The results are also mostly same as that in the balance calculation for the current conditions; that high shortage was estimated in the river basins of the Pchinija, Bregalnica, Crna and Sutrumica rivers as well as the most lower reach of the Vardar river. The shortage of mostly agricultural water estimated on an average of 36 years against the future demands in 2005, 2015 and 2025 together with that in the current condition is tabulated below (the supply water is a drought which happens every 4 years, or is guaranteed with a duration of 75% in a certain period):

High Water Shortage in Each River Basin

(Unit : $10^6 m^3$/year)

River Basin/Municipality	Current Condition (1996)	2005	2015	2025
1. Vardar River				
B1-5 : Valandovo and Gevgelija	-38.5	-72.6	-70.7	-71.3
2. Pchinja River				
B3-2 : Kriva Palanka	-0.5	-1.5	-126.4	-140.7
B3-3 : Kumanovo	-88.9	-78.1	-72.6	-72.1
3. Bregalnica River				
B4-2 : Kochani, Vinica, etc.	-238.5	-249.1	-249.5	-260.4
4. Crna River				
B5-1 : Prilep	-33.3	-27.3	-26.2	-162.7
B5-3 : Tikvesh	-111.5	-107.4	-102.0	-101.2
5. Strumica River				
B6-2 : Turija	-75.8	-66.5	-62.5	-61.1
B6-3 : Strumica	-42.3	-38.4	-36.0	-35.8

Results of the calculation are compiled in Volume VI-2 Data Book, Appendix P. Figures K.10 to K.25 show 10-day water balance between demand and supply in the sub-basins, which have high water shortage in the current conditions and will have those in the future in 2025.

In the sub-basin of the Pchinja (B3-2), the shortage will be 126.4 x $10^6 m^3$/year, which will be due to increase of irrigation water in the system (22,000 ha) assumed to be developed on Vakuf in 2006 to 2015.

In the sub-basin of the Crna (B5-1), the shortage will be 162.7 x $10^6 m^3$/year, which will be due to increase of irrigation water in the system (27,000 ha) assumed to be developed on Pelagonia in 2016 to 2025.

K.6 Balance Calculation for Groundwater

K.6.1 Water Balance in Current Condition

Groundwater is used as sources of municipal and a part of industrial water supplied by CEs. Referring to answers to the supplemental interview survey for communal enterprises, one municipality (Veles) experiences water shortage throughout a year, and 17 municipalities (Skopje, etc.) have seasonal water shortage, while no water shortage is in 12 municipalities (Kichevo, etc) as tabulated below:

Water Shortage of Municipal and Industrial Water (Current Condition)

No.	Municipality/CEs	(1) Period (month/year)	(2) Municipal Water (10^6m^3)	(3) Industrial Water (10^6m^3)	Remarks
1	Skopje	2	1.6	9.3	
2	Gostivar/Mavrovi Anovi	4	0.3	0.6	
3	Tetovo	8	2.2	3.5	
4	Kichevo	0	0	0	No shortage
5	Makedonski Brod	(1)	0	0	Negligible
6	Kumanovo	4	2.1	2.8	
7	Kratovo	3	0.8	1.5	
8	Kriva Palanka	4	0.3	0.5	
9	Veles	12	2.0	4.5	
10	Sveti Nikole	5	0.5	1.1	
11	Shtip	3	0.2	0.9	
12	Probishtip	3	0.3	0.5	
13	Kochani	+	0	0	No shortage
14	Vinica	4	0.3	0.5	
15	Delchevo	2	0.2	0.2	
16	Berovo	0	0	0	No shortage
17	Demir Hisar	0	0	0	No shortage
18	Krushevo	0	0	0	No shortage
19	Bitola	0	0	0	No shortage
20	Prilep	0	0	0	No shortage
21	Kavadarci	4	0.5	1.0	
22	Negotino/Demir Kapija	6	0.8	1.5	
23	Valandovo	0	0	0	No shortage
24	Gevgelija/Bogdanci/ Star Dojran	5	0.7	1.0	
25	Ohrid	0	0	0	No shortage
26	Struga	3	0.8	1.2	
27	Debar	+	0	0	No shortage
28	Resen	2	0.2	0.3	
29	Radovish	3	0.4	0.7	
30	Strumica	+	0	0	No shortage

(Makedonski Brod has the shortage only one month through the year, of which quantity is negligible small)

K.6.2 Basic Conditions of the Calculation in Future Conditions

Water balance of municipal and a part of industrial water was conducted with the following conditions:

1) Water balance is calculated for 22 municipalities, which are supplied municipal and a part of industrial water from not surface water (reservoir and/or river intake) but groundwater (remaining eight municipalities were excluded in the calculation) exploited up to date.

2) Quantities of demand and supply used in the calculation are on a 10-day average ones, to calculate the seasonal condition.

3) Seasonal fluctuation of demand of municipal water ranging from 130% against the annual average in summer to 70% against the annual one in winter.

4) No seasonal fluctuation is considered for demand of industrial water (fluctuation of portable water, which occupies about 30% of the industrial water, is not considered) Seasonal fluctuation of supply water is referred to the fluctuation in the Rashche spring as described in Appendix B of Supporting Report 1.

K.6.3 Results of Balance Calculation for Future Conditions

The results of the calculation for municipal water only is tabulated below, together with that in the current condition:

Results of Water Balance Calculation for Municipal Water

(unit : $10^6 m^3$/year)

No.	Municipality	Current	2005	2015	2025
1.	Skopje	+	+	+	+
2	Gostivar	+	+	+	+
3	Tetovo	-9,1 (Y)	-10.7 (Y)	-13.2 (Y)	-15.6 (Y)
4	Kichevo	+	+	+	+
5	Makedonski Brod	+	+	+	+
6	Kumanovo	(reservoir)	(reservoir)	(reservoir)	(reservoir)
7	Kratovo	(reservoir)	(reservoir)	(reservoir)	(reservoir)
8	Kriva Palanka	-1,3 (Y)	-1.2 (Y)	-1.3 (Y)	-1.3 (Y)
9	Veles	(river)	(river)	(river)	(river)
10	Sveti Nikole	(reservoir)	(reservoir)	(reservoir)	(reservoir)
11	Shtip	-3,5 (Y)	-3.8 (Y)	-4.2 (Y)	-4.6 (Y)
12	Probishtip	-0.6 (Y)	-0.6 (Y)	-0.7 (Y)	-0.8 (Y)
13	Kochani	-0.3 (S)	-0.5 (S)	-0.7 (S)	-1.0 (S)
14	Vinica	(reservoir)	(reservoir)	(reservoir)	(reservoir)
15	Delchevo	-0.2 (S)	-0.3 (S)	-0.6 (Y)	-0.8 (Y)
16	Berovo	(reservoir)	(reservoir)	(reservoir)	(reservoir)
17	Demir Hisar	- 0.2 (S)	- 0.2 (S)	- 0.2 (S)	- 0.2 (S)
18	Krushevo	+	+	+	+
19	Bitola	(reservoir)	(reservoir)	(reservoir)	(reservoir)
20	Prilep	+	+	+	+
21	Kavadarci	- 0.4 (S)	- 0.6 (S)	- 0.8 (S)	-1.1 (S)
22	Negotino	- 1.7 (Y)	- 2.4 (Y)	- 2.6 (Y)	-2.9 (Y)
23	Valandovo	+	- 0.1 (S)	- 0.1 (S)	-0.2 (S)
24	Gevgelija	+	+	+	+
25	Ohrid	+	+	+	+
26	Struga	+	+	+	+
27	Debar	- 0.7 (Y)	- 1.0 (Y)	- 1.3 (Y)	-1.6 (Y)
28	Resen	- 0.2 (S)	- 0.2 (S)	- 0.2 (S)	- 0.3 (S)
29	Radovish	- 1.7 (Y)	- 1.9 (Y)	- 2.2 (Y)	-2.5 (Y)
30	Strumica	(reservoir)	(reservoir)	(reservoir)	(reservoir)

(+ : no water shortage, (Y) : Water shortage through a year, (S) : Seasonal shortage)

Further, combining the municipal water with industrial water, of which resources are from groundwater, the results of the calculation are tabulated below, together with that in the current condition:

Results of Water Balance Calculation for Municipal and Industrial Water

(unit : $10^6 m^3$/year)

No.	Municipality	Current	2005	2015	2025
1.	Skopje	- 0.3 (S)	- 5.6 (S)	- 16.1 (S)	- 43.5 (Y)
2	Gostivar	+	+	+	+
3	Tetovo	-11.6 (Y)	-13.3 (Y)	-15.8 (Y)	-19.2 (Y)
4	Kichevo	+	+	- 0.4 (S)	- 2.5 (Y)
5	Makedonski Brod	+	+	+	+
6	Kumanovo	(reservoir)	(reservoir)	(reservoir)	(reservoir)
7	Kratovo	(reservoir)	(reservoir)	(reservoir)	(reservoir)
8	Kriva Palanka	-1.7 (Y)	-1.6 (Y)	-1.8 (Y)	-1.9 (Y)
9	Veles	(river)	(river)	(river)	(river)
10	Sveti Nikole	(reservoir)	(reservoir)	(reservoir)	(reservoir)
11	Shtip	-7.5 (Y)	-8.8 (Y)	-10.8 (Y)	-14.1 (Y)
12	Probishtip	-1.7 (Y)	-2.0 (Y)	-2.4 (Y)	-3.1 (Y)
13	Kochani	-0.6 (S)	-0.9 (S)	-1.3 (Y)	-1.7 (Y)
14	Vinica	(reservoir)	(reservoir)	(reservoir)	(reservoir)
15	Delchevo	-0.4 (S)	-0.6 (S)	-0.9 (Y)	-1.2 (Y)
16	Berovo	(reservoir)	(reservoir)	(reservoir)	(reservoir)
17	Demir Hisar	- 0.2 (Y)	- 0.3 (Y)	- 0.3 (Y)	- 0.3 (Y)
18	Krushevo	+	+	+	+
19	Bitola	(reservoir)	(reservoir)	(reservoir)	(reservoir)
20	Prilep	+	+	+	+
21	Kavadarci	- 1.1 (Y)	- 1.5 (Y)	- 1.8 (Y)	-2.2 (Y)
22	Negotino	- 2.5 (Y)	- 3.1 (Y)	- 3.4 (Y)	-3.7 (Y)
23	Valandovo	+	- 0.1 (S)	- 0.2 (S)	- 0.3 (S)
24	Gevgelija	+	+	+	+
25	Ohrid	+	+	+	+
26	Struga	+	+	- 0.3 (S)	-0.7 (S)
27	Debar	- 1.0 (Y)	- 1.3 (Y)	- 1.6 (Y)	- 2.0 (Y)
28	Resen	- 0.4 (S)	- 0.5 (Y)	- 0.6 (Y)	- 0.7 (Y)
29	Radovish	- 1.7 (Y)	- 2.1 (Y)	- 2.4 (Y)	-2.7 (Y)
30	Strumica	(reservoir)	(reservoir)	(reservoir)	(reservoir)

(+ : no water shortage, (Y) : Water shortage through a year, (S) : Seasonal shortage)

Water balance in eight municipalities, of which source of water is surface water/reservoir, was reviewed by comparing the demand of municipal water with a net capacity of each reservoir for municipal water use as follows:

Demand of Municipal Water and Reservoir Net Capacity

No.	Municipality	Reservoir	Net Capacity ($10^6 m^3$)	Water Demand ($10^6 m^3$/year) Current(1996)	2025
6.	Kumanovo	Glaznja	24.00*	11.6	14.8
7.	Kratovo	(Zletovia)	1.58	1.0	1.0
9.	Veles	(Lisiche)	23.00	6.3	7.3
11.	Sveti Nikole	Mavrovica	2.52*	2.0	2.1
14.	Vinica	Osojnica	-	1.7	2.2
16.	Berovo	Ratevska	9.00*	1.7	2.0
19.	Bitola	Strezevo	99.50*	10.3	11.6
30.	Strumica	Turija Vodoca	45.00* 25.12*	8.1	10.8

(*: commonly used with irrigation water supply)

Kratovo is supplied from the intake constructed just upstream of the proposed Knezevo damsite/reservoir with a volume of 50 lit/sec (or 1.58 x$10^6$$m^3$/year).

According to the outflow records of the Graznja reservoir, which is the main source of municipal and industrial water for Kumanovo, the periods while sufficient water has been supplied to meet the current water demand (11.6 x 10^6 m^3/year in 1996) were only for 6 years in the last decade (from 1989 to 1998). Out of the period, for 4 years, there have been shortages of municipal and industrial water. Therefore, it can be noted water shortage has been occurred once a two or three years in Kumanovo.

Further, as far as it refers to the above comparison, eight municipalities have no water shortage with an assumption that every reservoir is filled with water before the dry season. It is reported they suffered from seasonal water shortage in the recent drought years like 1993, 1994, etc. It is also reported that water is supplied to Vinica through a Tyrolean intake in the Osojnica River with a supply capacity of 100 lit/sec (or 3.16 x$10^6$$m^3$/year). Vinica has also no water shortage in case of the sufficient water in the river.

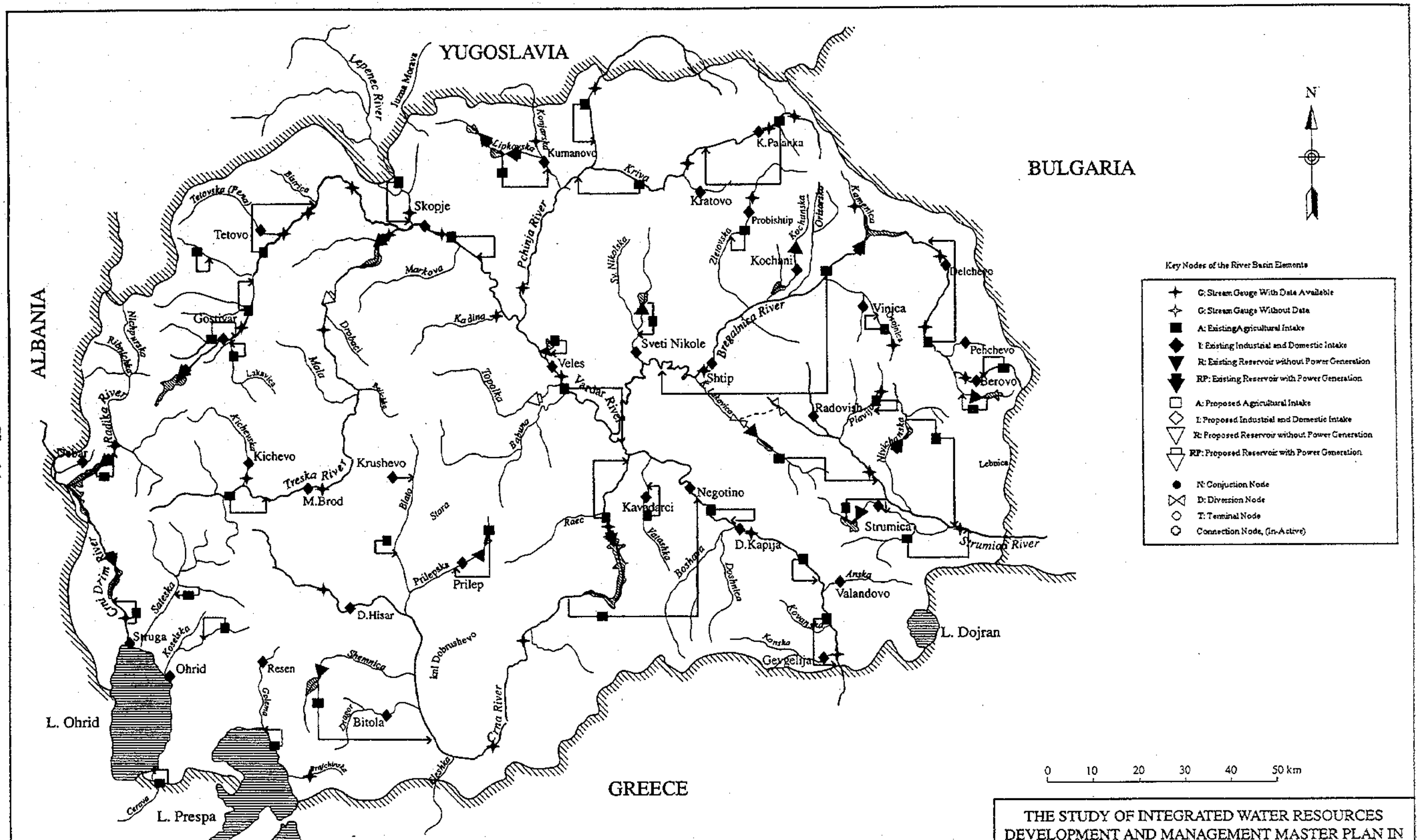
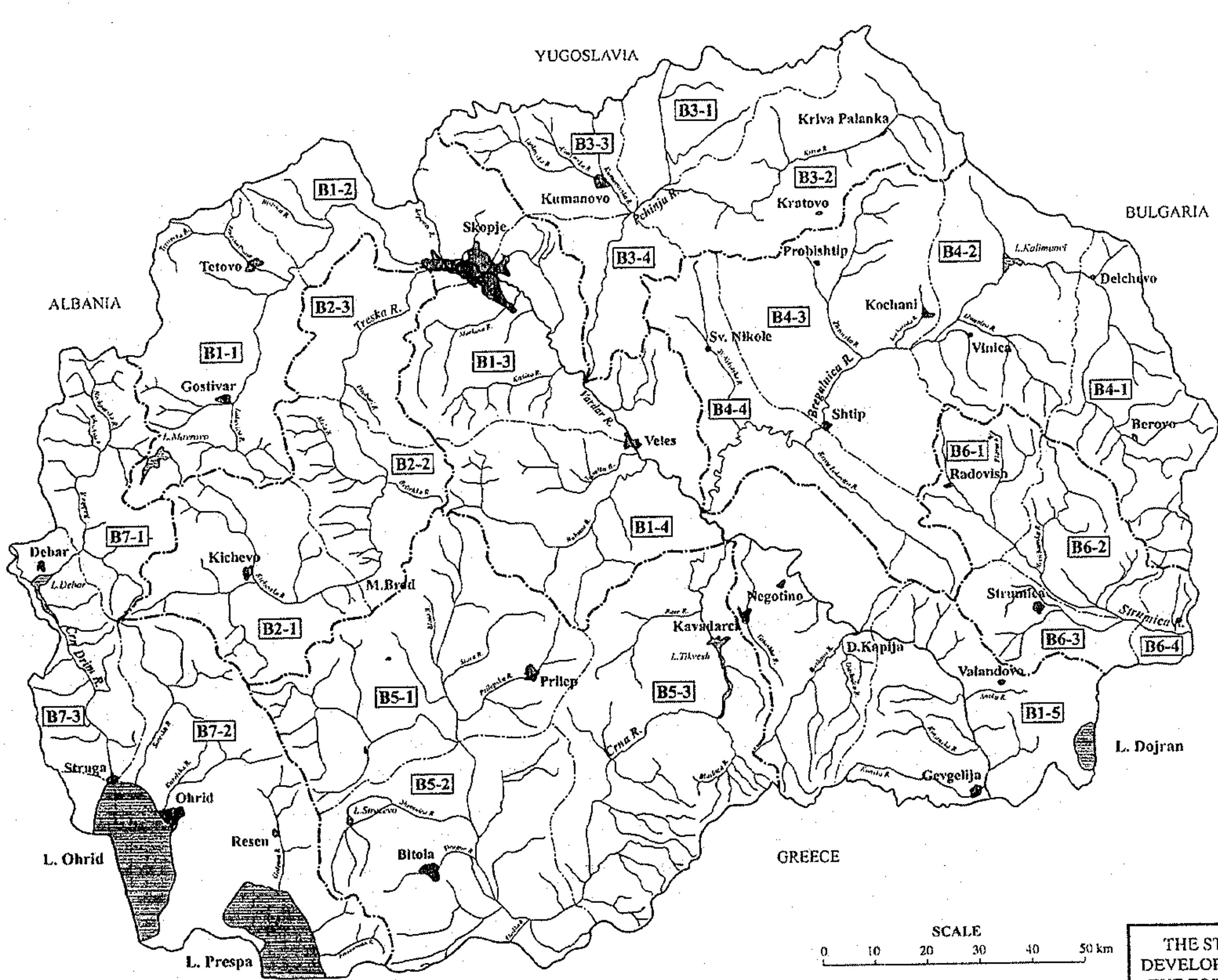


Figure K.1 Location of Water Balance Element in Each Sub-Basin

THE STUDY OF INTEGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

JAPAN INTERNATIONAL COOPERATION AGENCY



Catchment Area of Sub-basin for Water Balance Study

No.	Name of sub-basin	Code	Catchment area: Macedonia (km²)	Basin out of Macedonia (km²)	Area for trans-basin (km²)	Total (km²)
1	Vardar mainstream	B1-1	1,083.0		+210.5	1,083.0
		B1-2	809.0	690.0		1,499.0
		B1-3	1,326.0			1,326.0
		B1-4	2,333.0			2,333.0
		B1-5	1,262.0			1,262.0
	Subtotal		6,813.0	690.0		7,503.0
2	Treska	B2-1	886.0			886.0
		B2-2	719.0			719.0
		B2-3	463.0			463.0
	Subtotal		2,068.0			2,068.0
3	Pchinja	B3-1	400.1	471.0		871.1
		B3-2	1,003.4			1,003.4
		B3-3	459.8			459.8
		B3-4	509.7			509.7
	Subtotal		2,373.0	471.0		2,844.0
4	Bregalnica	B4-1	845.6			845.6
		B4-2	1,768.4			1,768.4
		B4-3	283.0			283.0
		B4-4	1,410.0		-180.0	1,410.0
	Subtotal		4,307.0			4,307.0
5	Crna	B5-1	1,618.5			1,618.5
		B5-2	1,451.5	905.0		2,356.5
		B5-3	1,915.0			1,915.0
	Subtotal		4,985.0	905.0		5,890.0
6	Strumica	B6-1	520.0		+180.0	520.0
		B6-2	461.0			461.0
		B6-3	350.0			350.0
		B6-4	189.0			189.0
	Subtotal		1,520.0			1,520.0
7	Crn Drim	B7-1	751.0		-210.5	751.0
		B7-2	1,801.0			1,801.0
		B7-3	803.0			803.0
	Subtotal		3,355.0			3,355.0
	Grand total		25,421.0	2,066.0		27,487.0
	Others		292.0			
	Total		25,713.0 (National territory)			

Legend : B1-1, No. of Sub-basin

Figure K.2 Location Map of Basin Division for Water Balance Study

THE STUDY OF INTEGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

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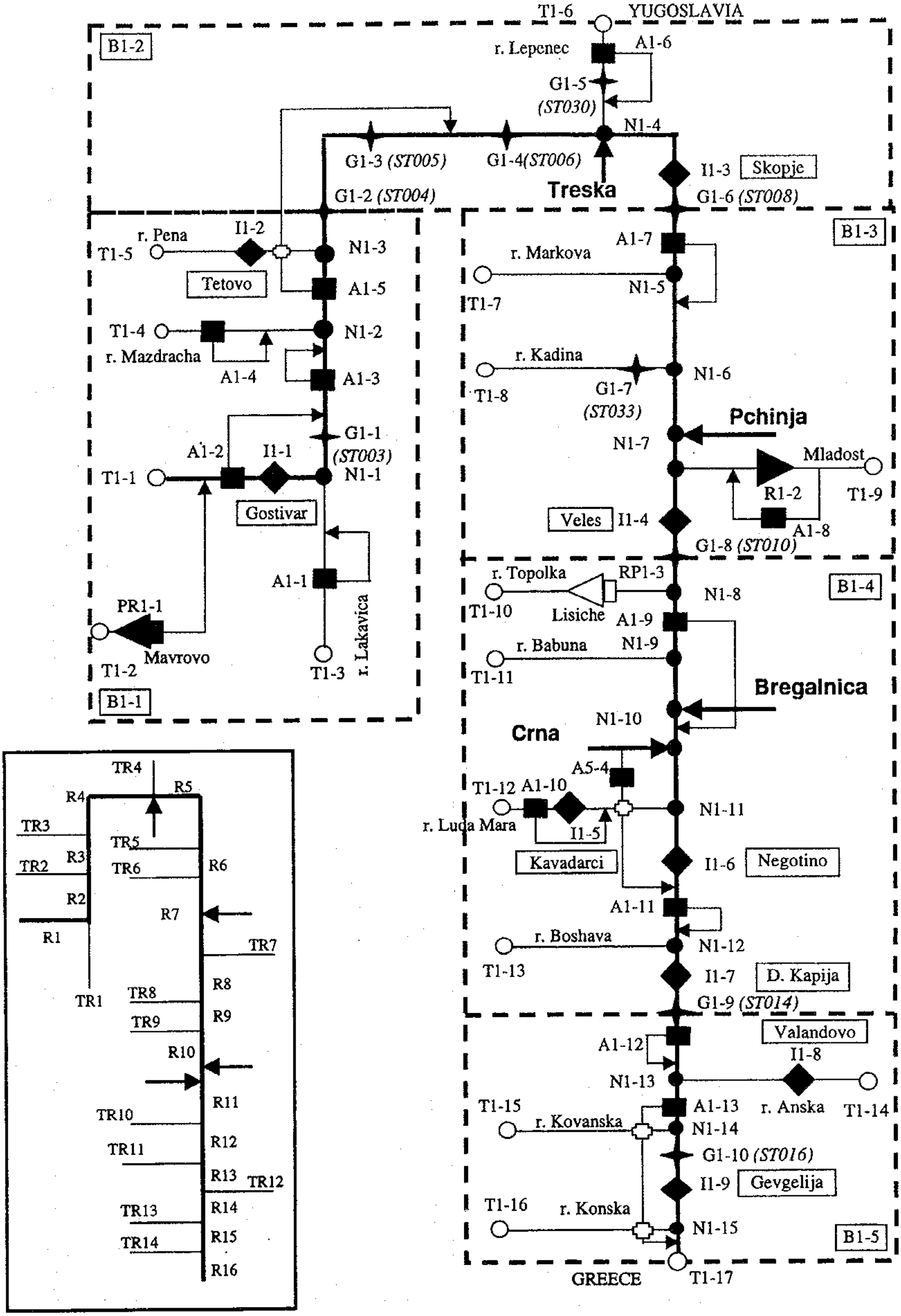


Figure K.3 Basin Model (Vardar River Basin : B-1)

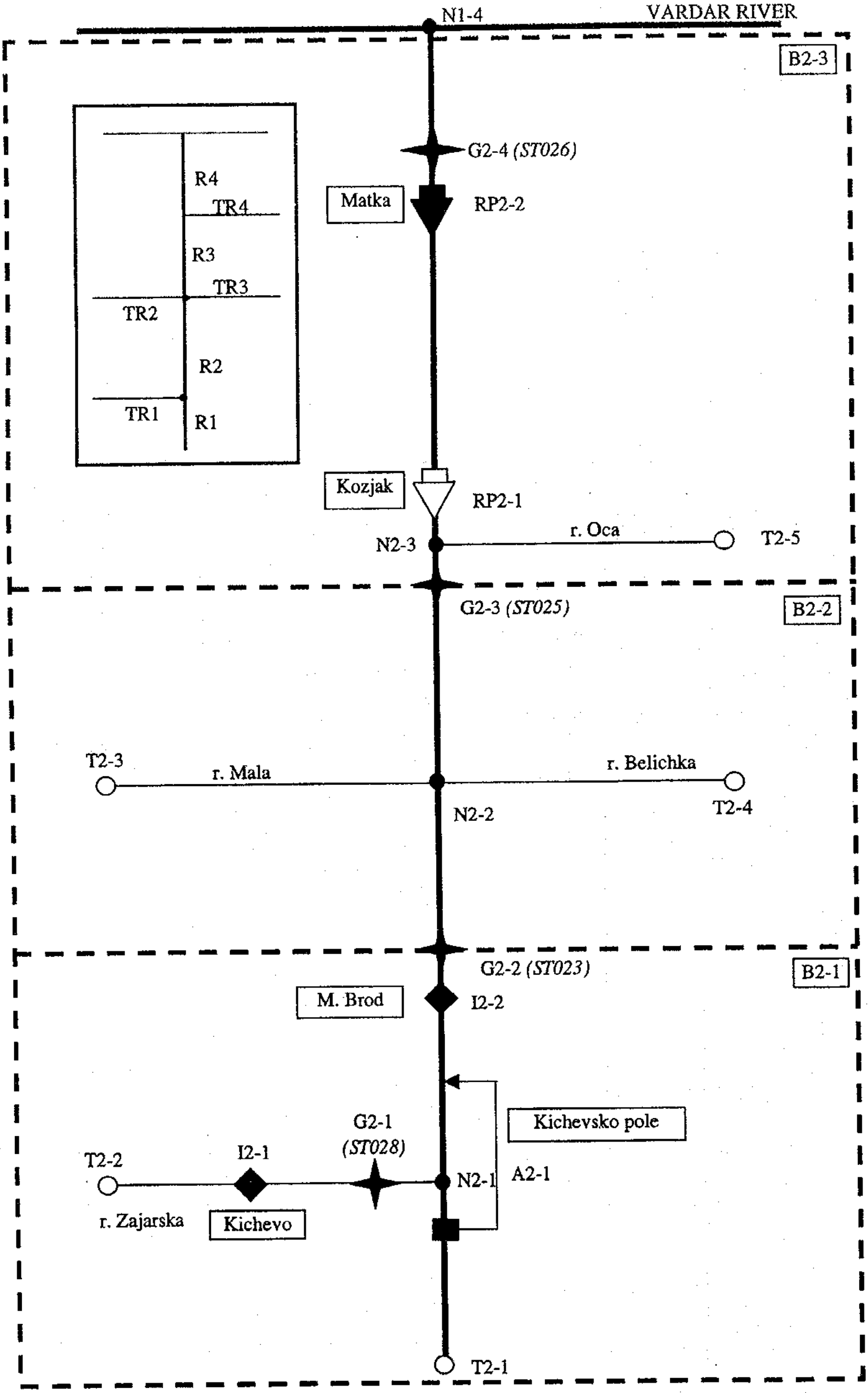
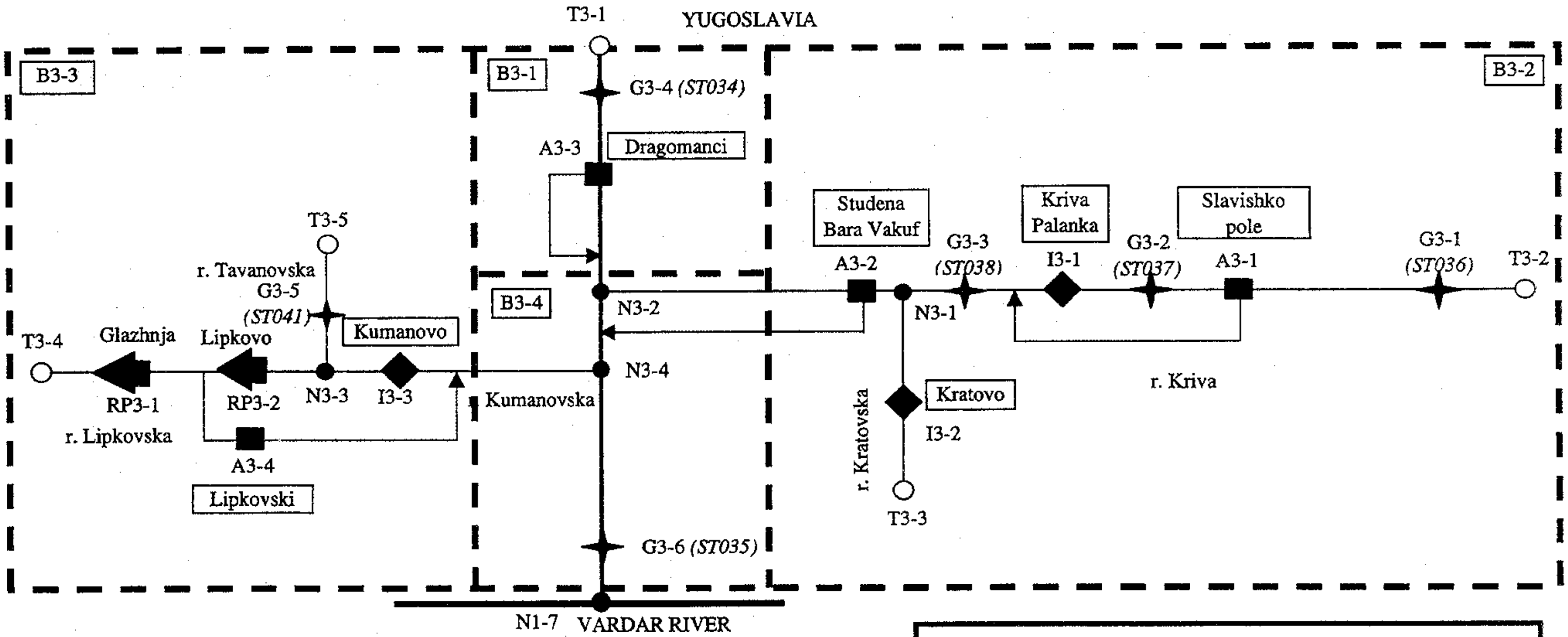


Figure K.4 Basin Model (Treska River Basin : B-2)



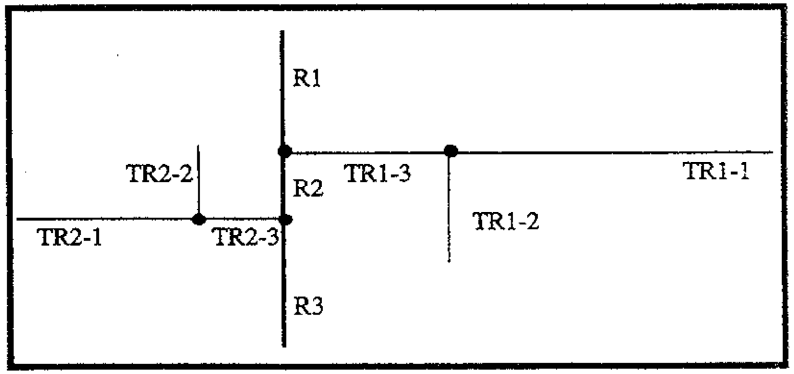
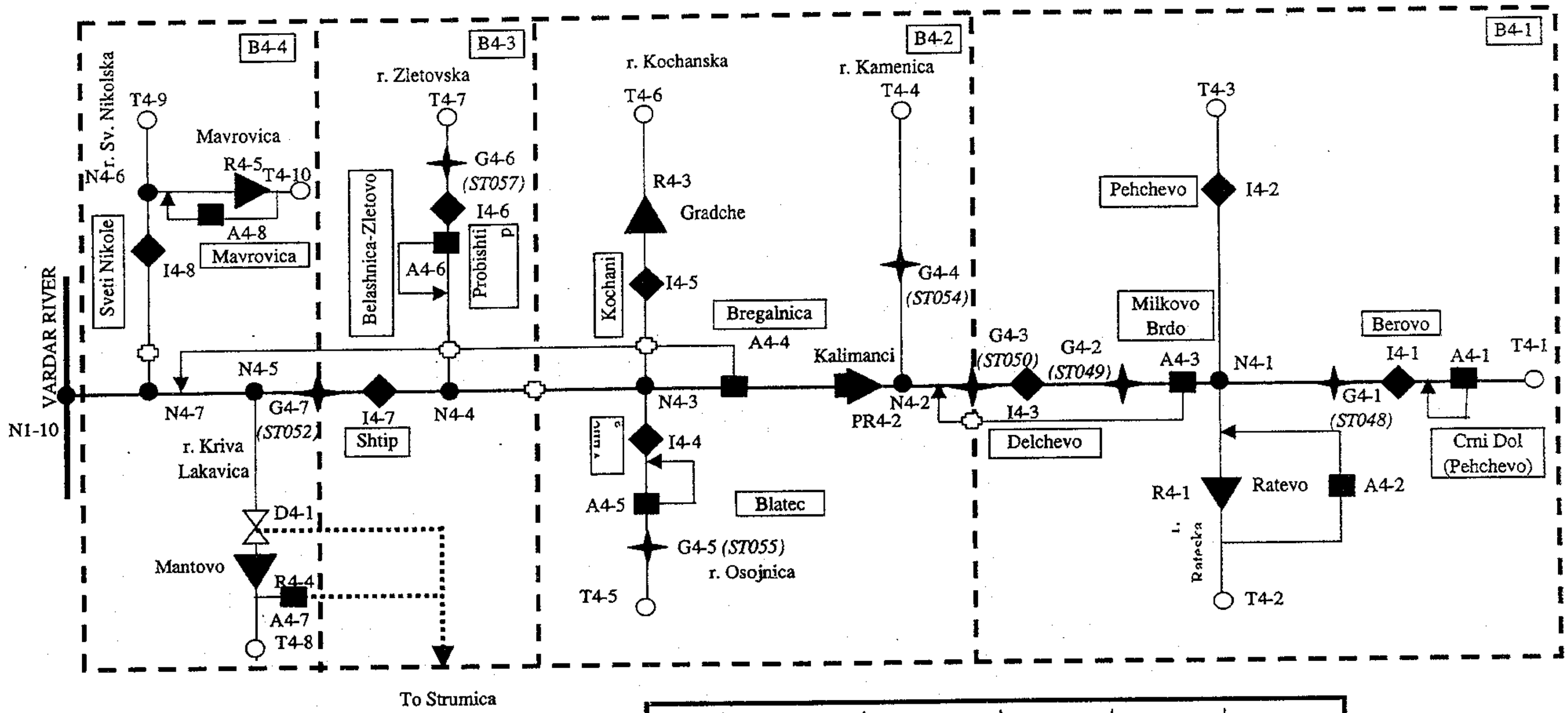


Figure K.5 Basin Model (Pchinja River Basin : B-3)



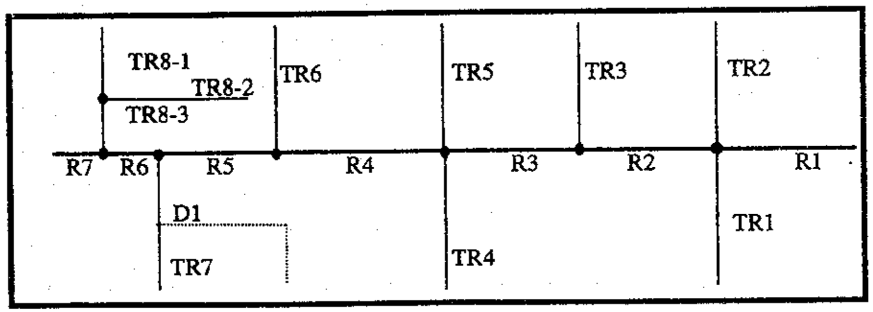


Figure K.6 Basin Model (Bregalnica River Basin : B-4)

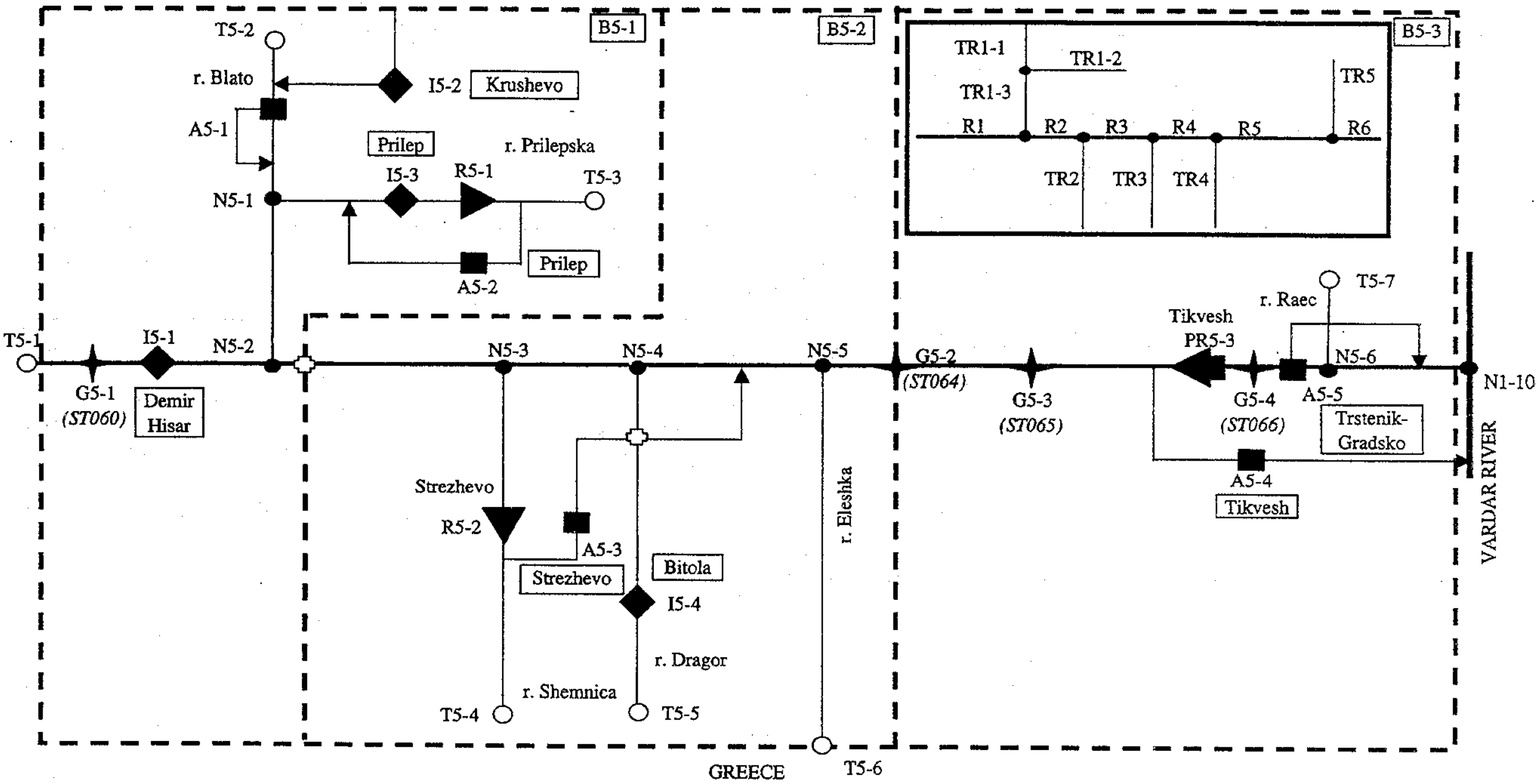
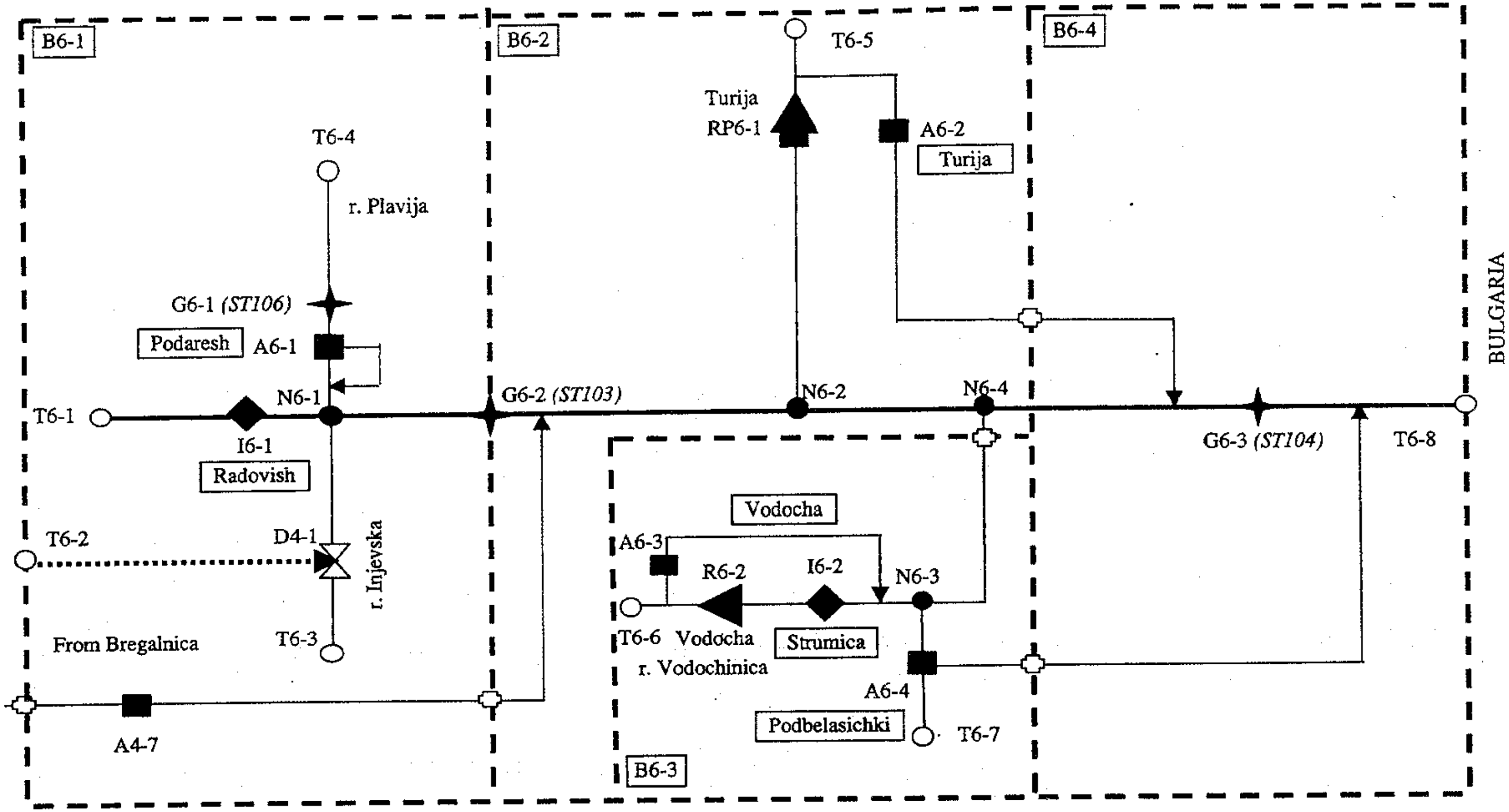


Figure K.7 Basin Model (Crna River Basin : B-5)



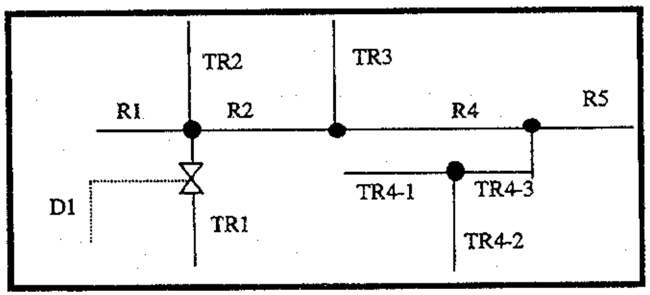


Figure K.8 Basin Model (Strumica River Basin : B-6)

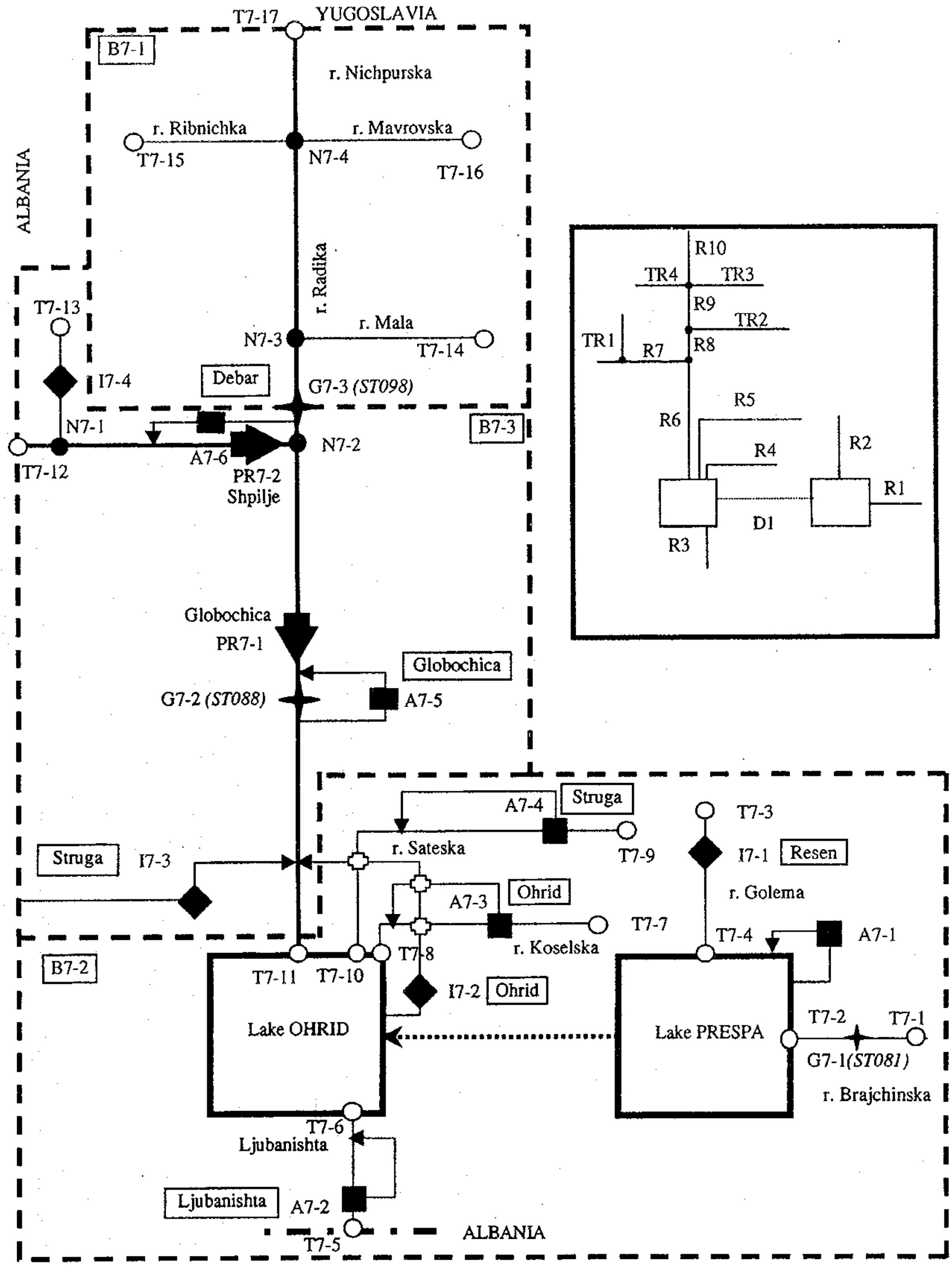


Figure K.9 Basin Model (Crn Drim River Basin : B-7)

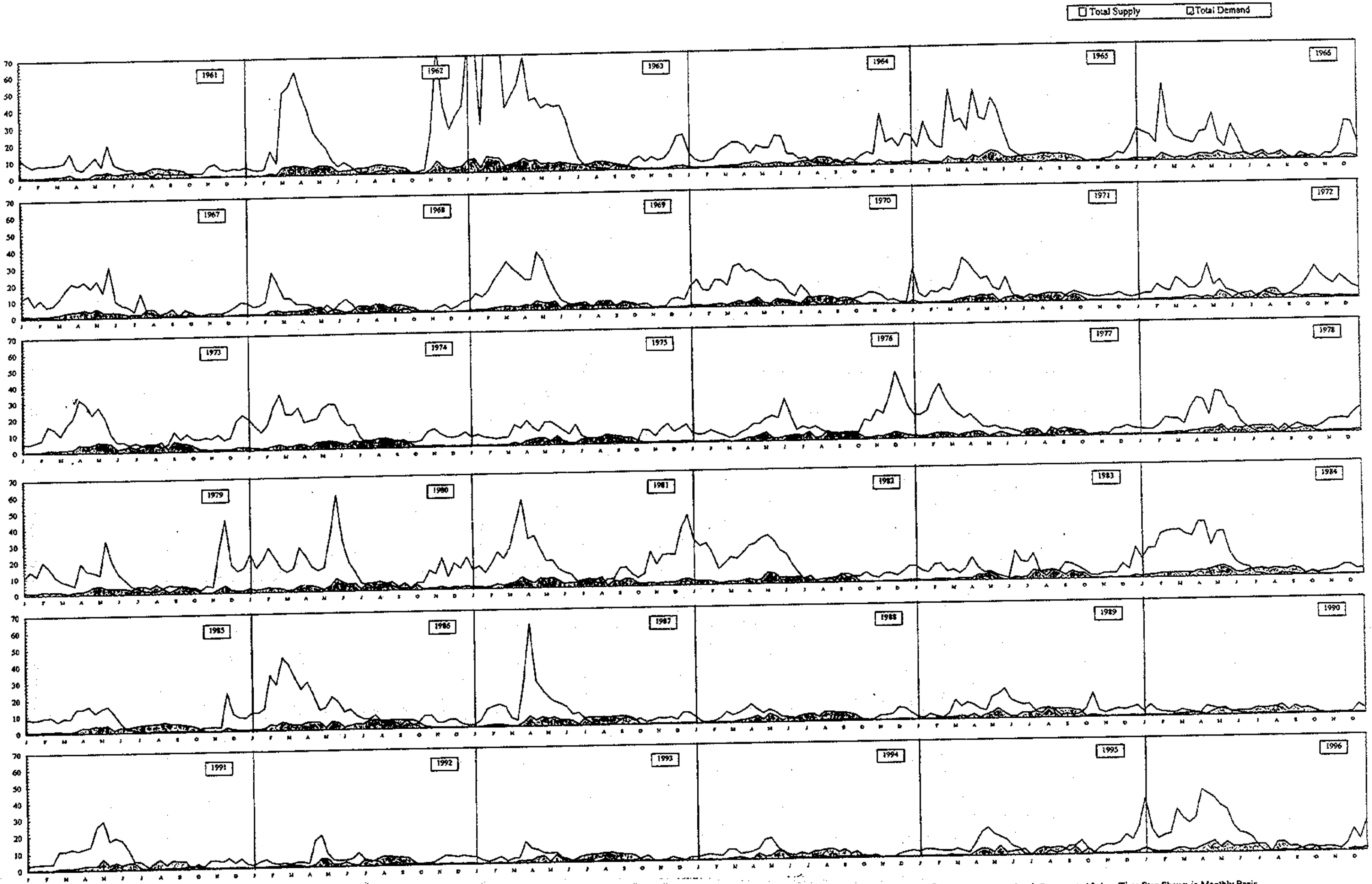


Figure K.10 10-Day Water Balance between Demand and Supply based on Current Condition in 1996 (Vardar River Sub-Basin B1-5)

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

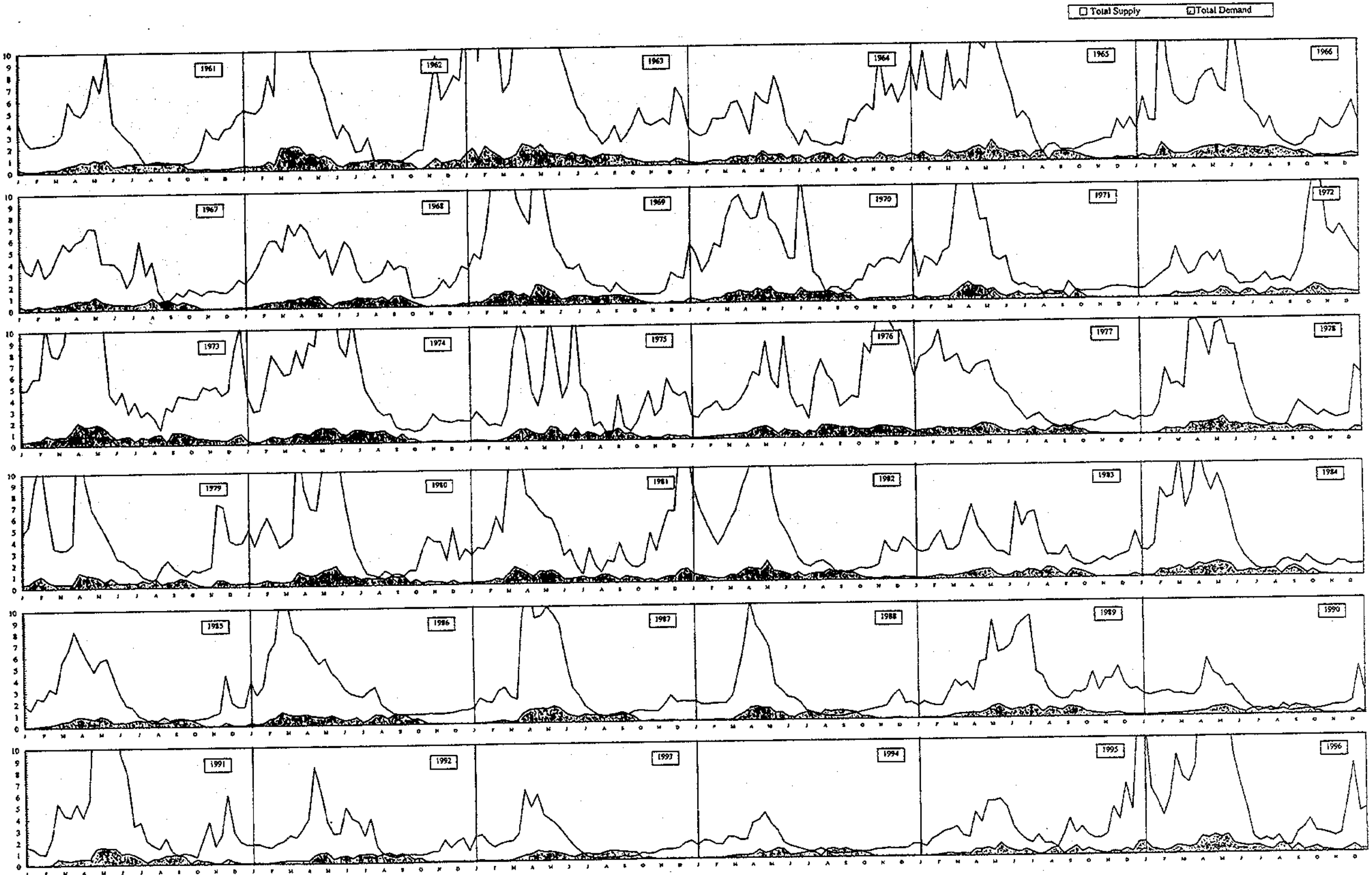


Figure K.11 **10-Day Water Balance between Demand and Supply based on Current Condition in 1996 (Pchinja River Sub-Basin B3-2)**

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

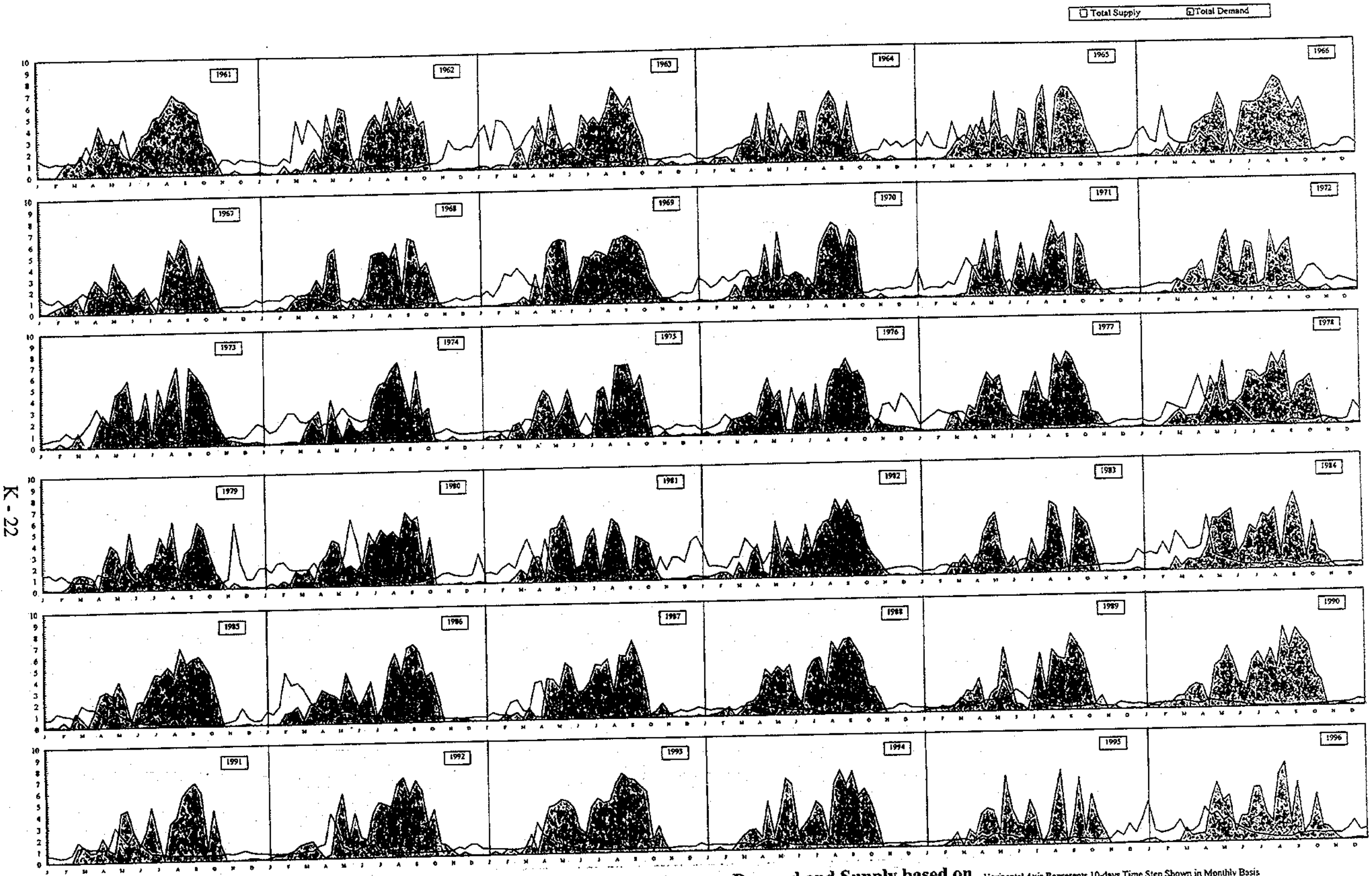


Figure K.12 10-Day Water Balance between Demand and Supply based on Current Condition in 1996 (Pchinja River Sub-Basin B3-3)

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

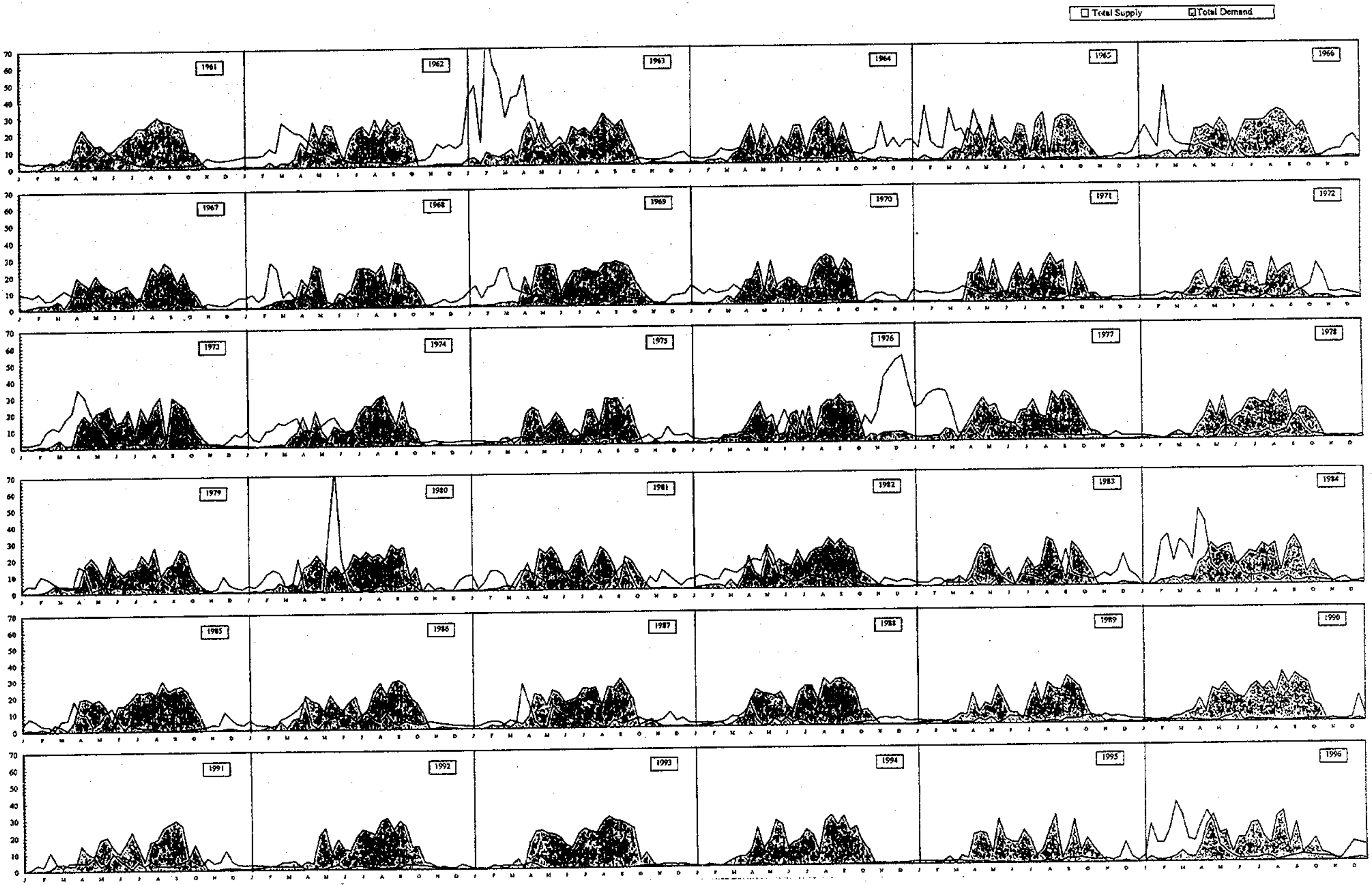


Figure K.13 10-Day Water Balance between Demand and Supply based on Current Condition in 1996 (Bregalnica River Sub-Basin B4-2)

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

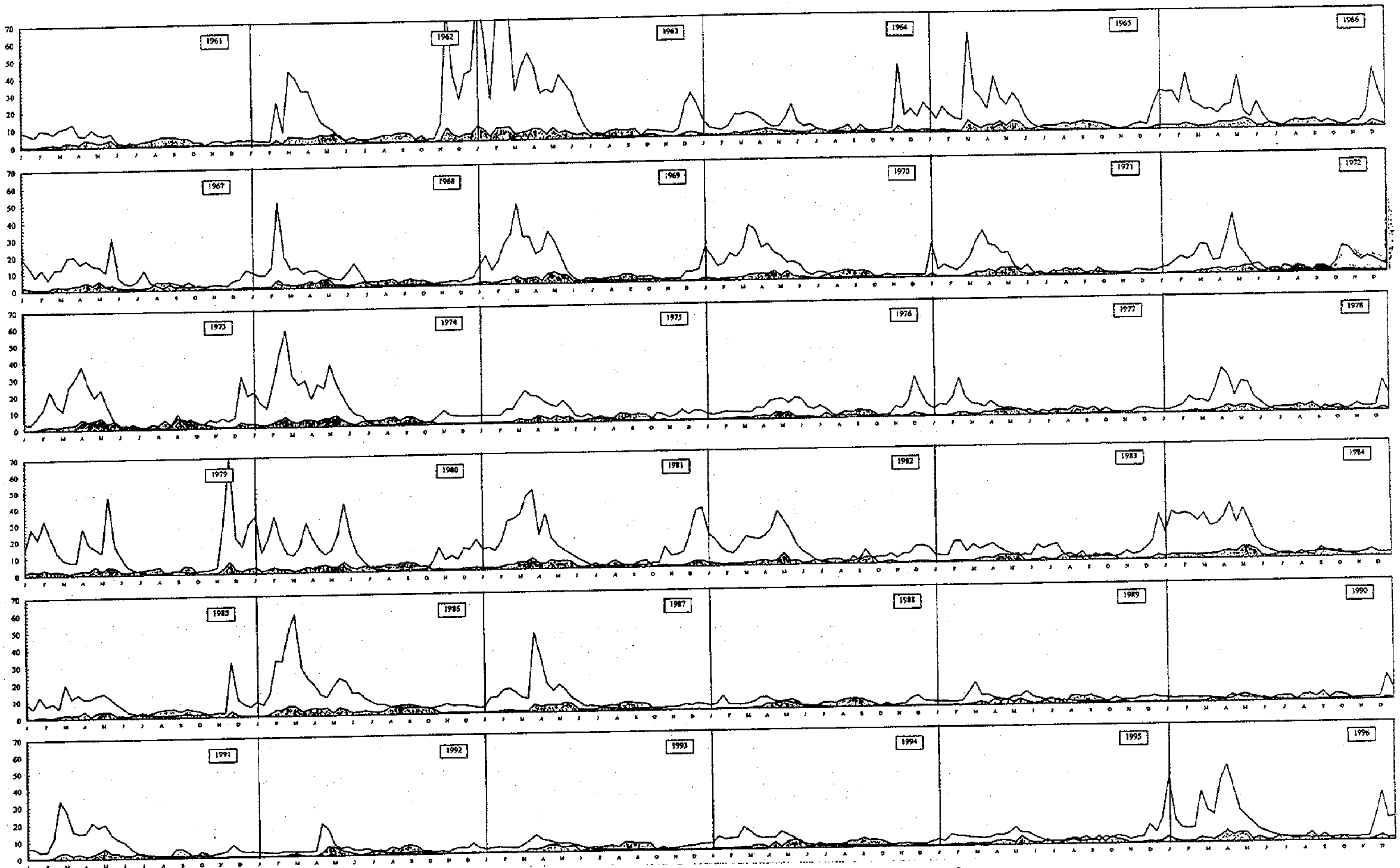


Figure K.14 **10-Day Water Balance between Demand and Supply based on Current Condition in 1996 (Crna River Sub-Basin B5-1)**

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m³/sec/10days)

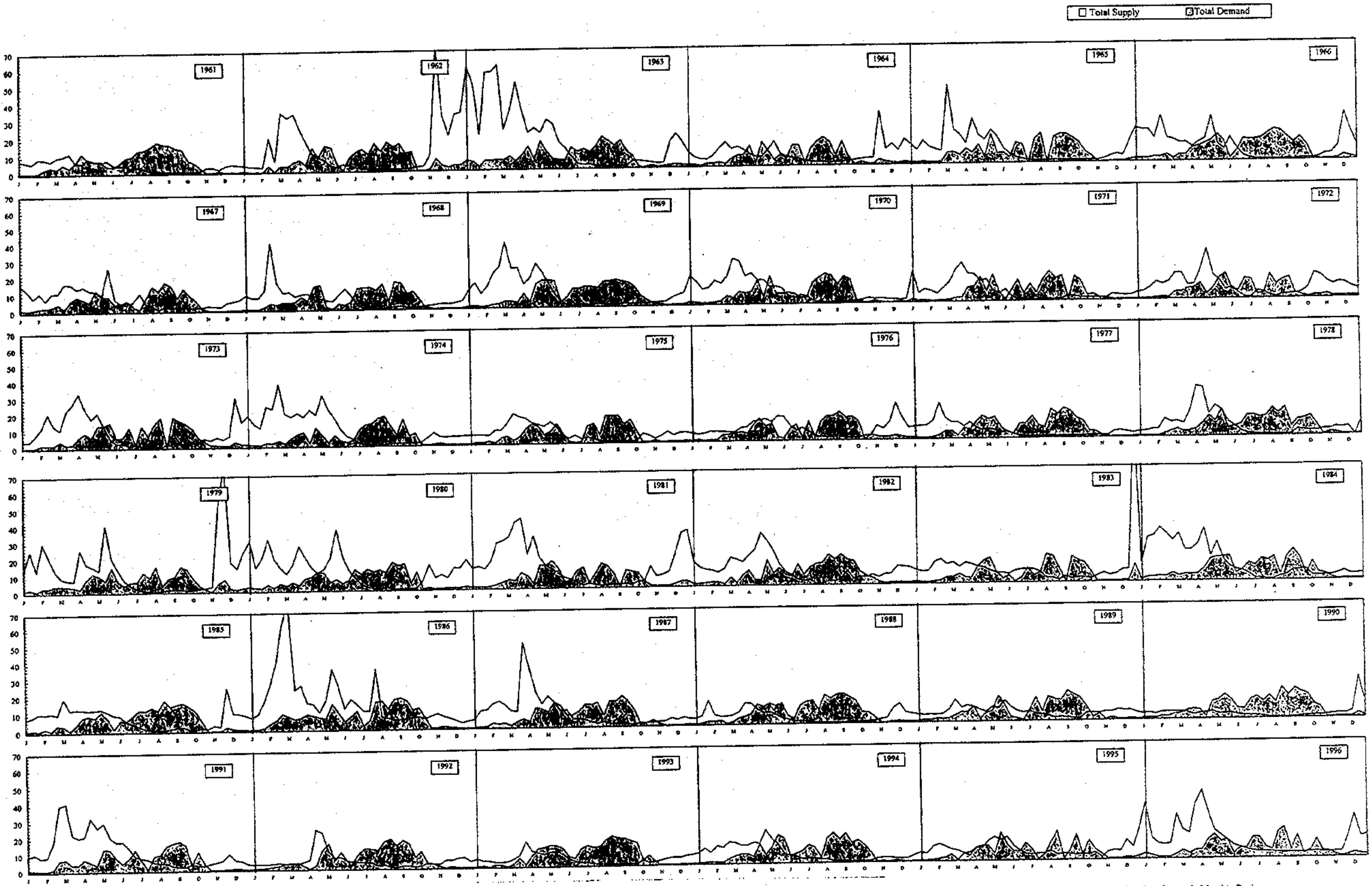


Figure K.15 **10-Day Water Balance between Demand and Supply based on Current Condition in 1996 (Crna River Sub-Basin B5-3)**

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

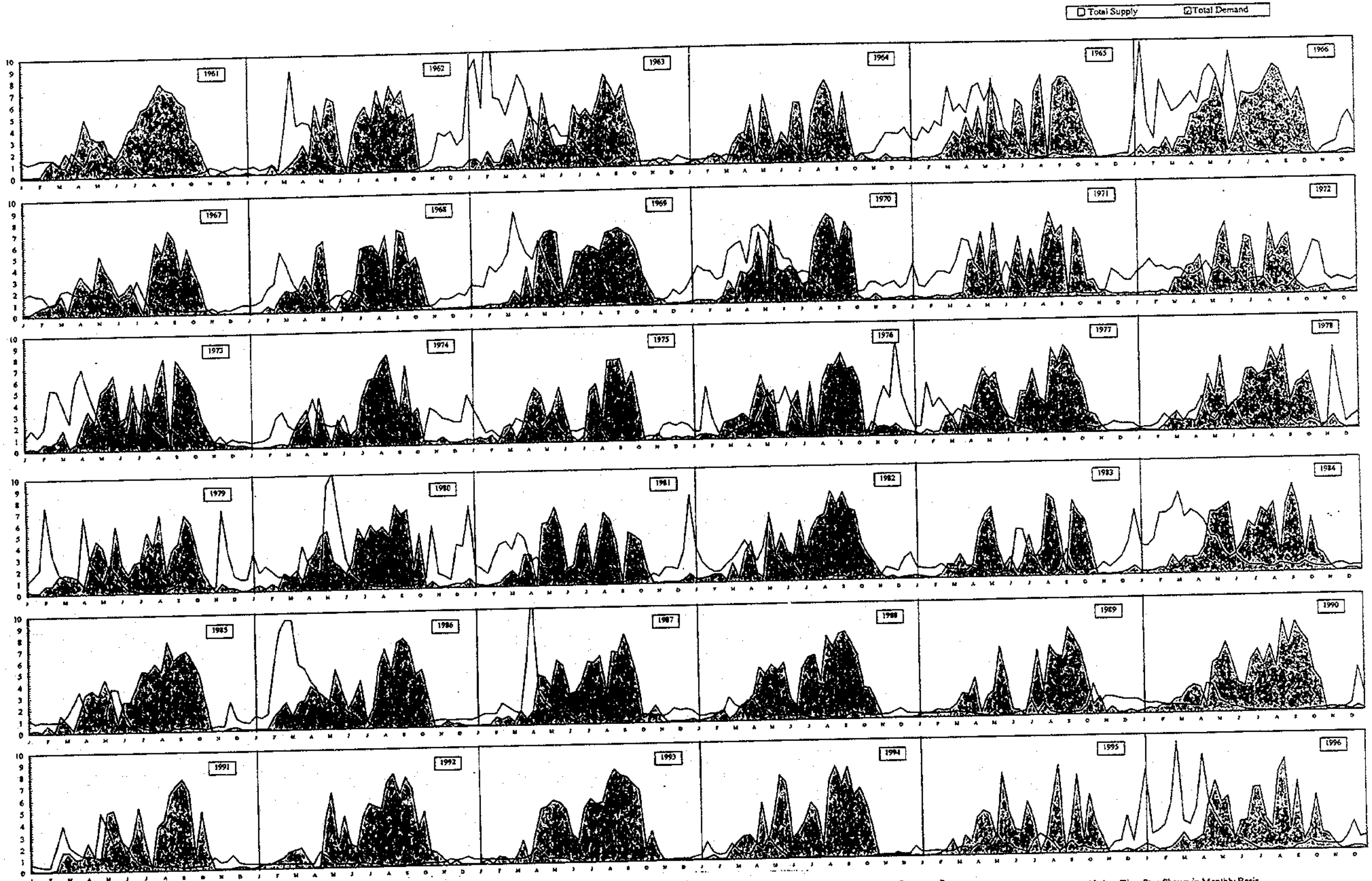


Figure K.16 10-Day Water Balance between Demand and Supply based on Current Condition in 1996 (Strumica River Sub-Basin B6-2)

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

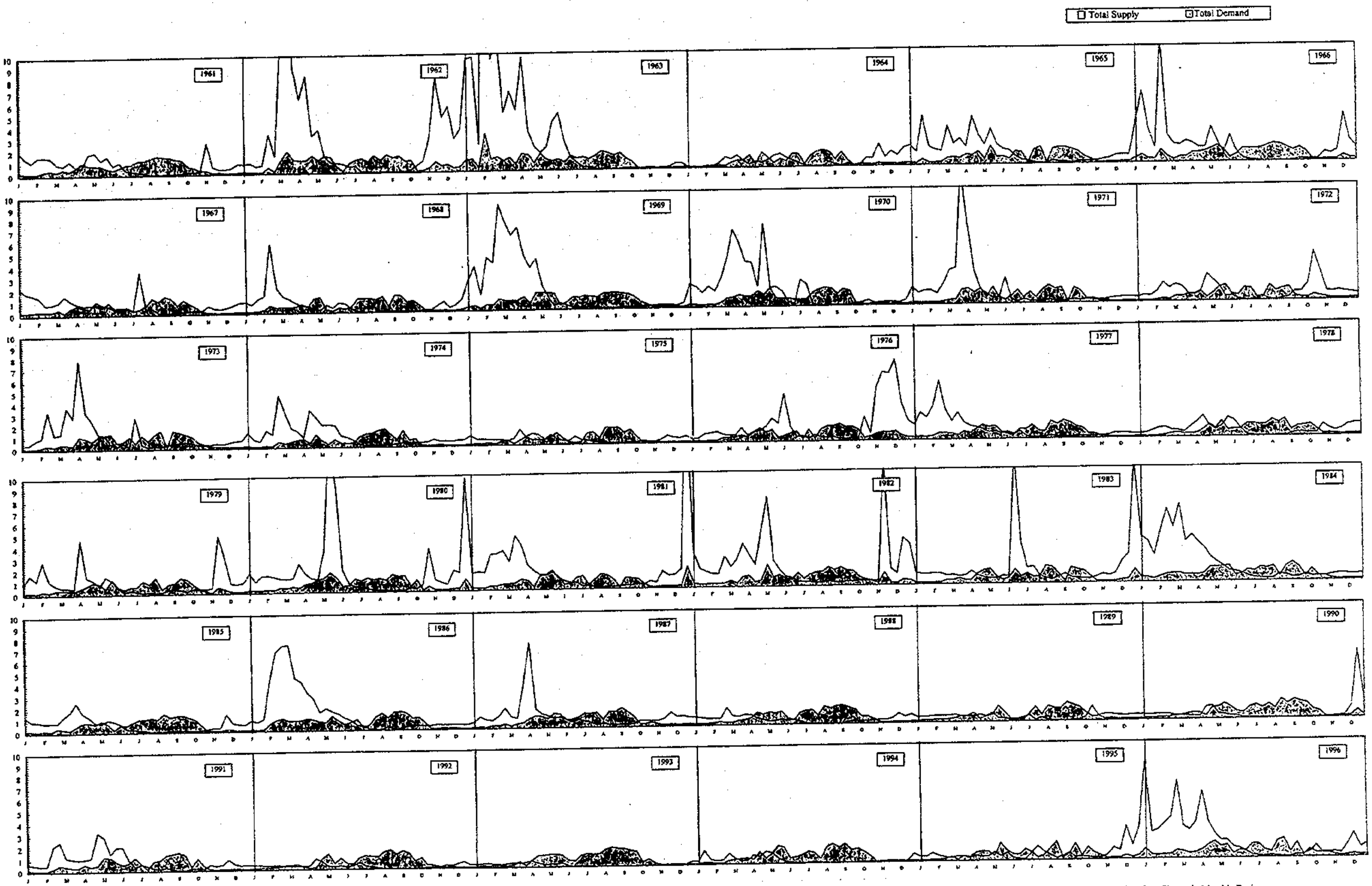


Figure K.17 **10-Day Water Balance between Demand and Supply based on Current Condition in 1996 (Strumica River Sub-Basin B6-3)**

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

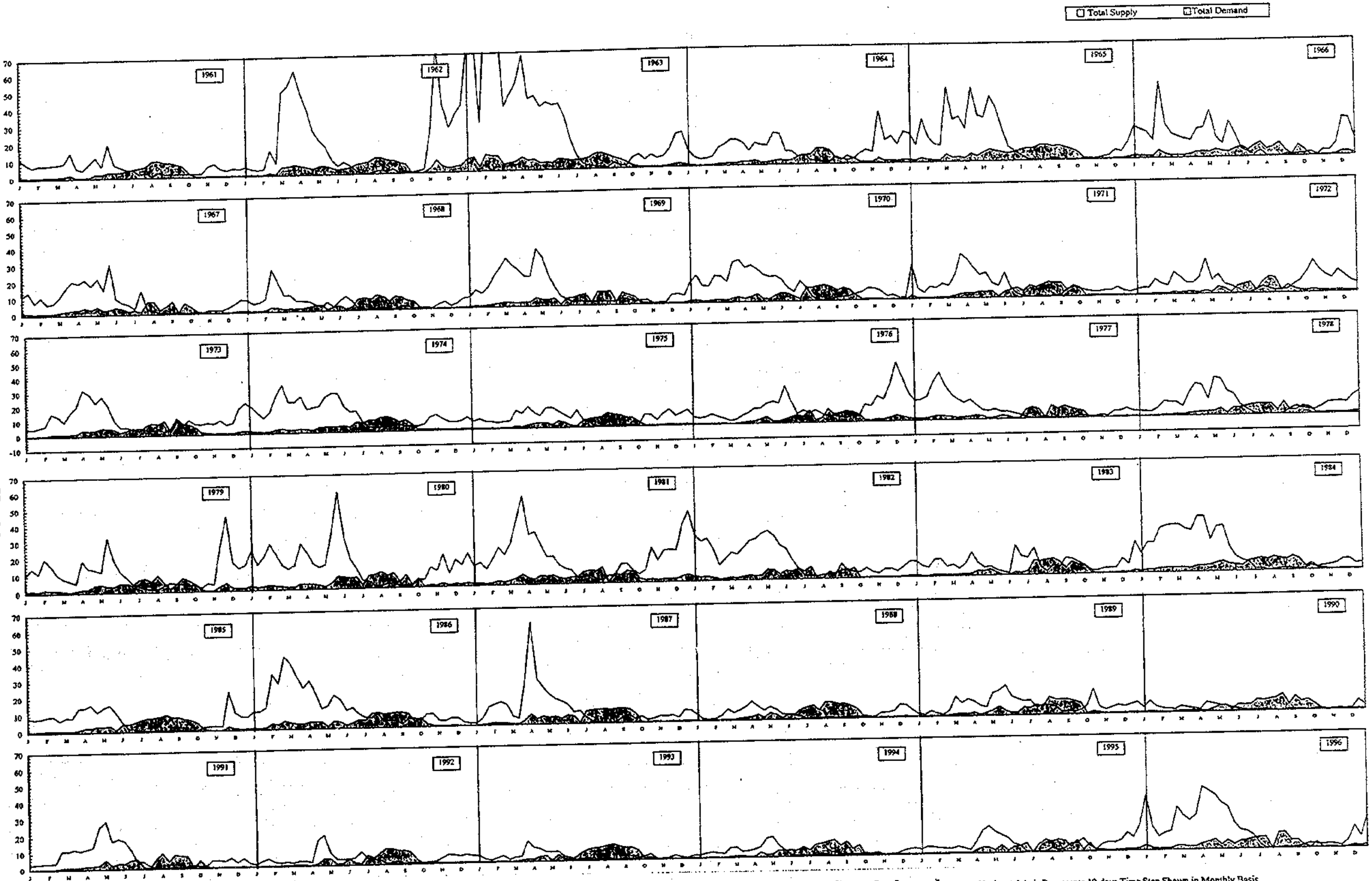


Figure K.18 **10-Day Water Balance between Demand and Supply based on Future Condition in 2025 (Vardar River Sub-Basin B1-5)**

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

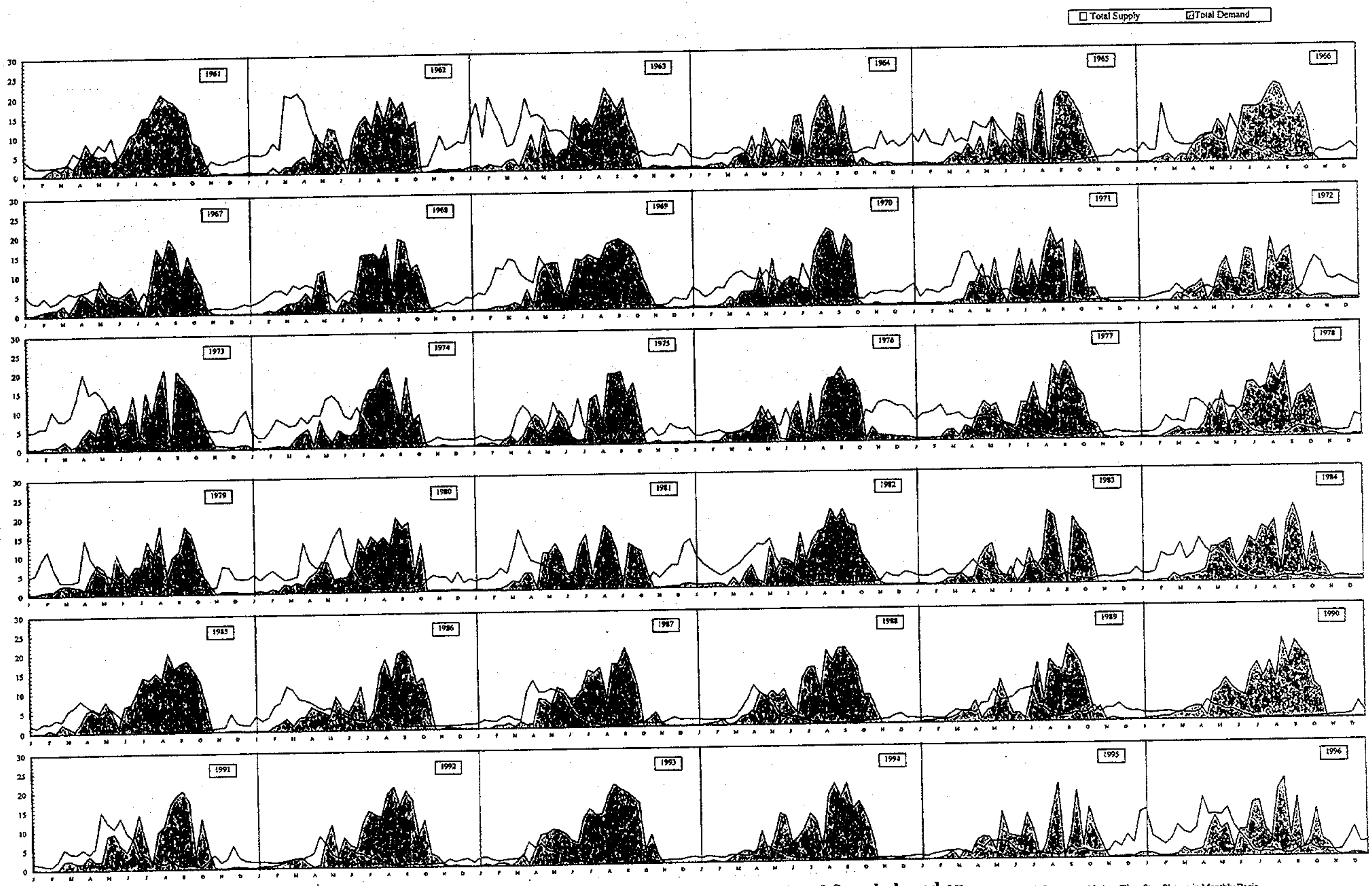


Figure K.19 **10-Day Water Balance between Demand and Supply based on Future Condition in 2025 (Pchinja River Sub-Basin B3-2)**

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

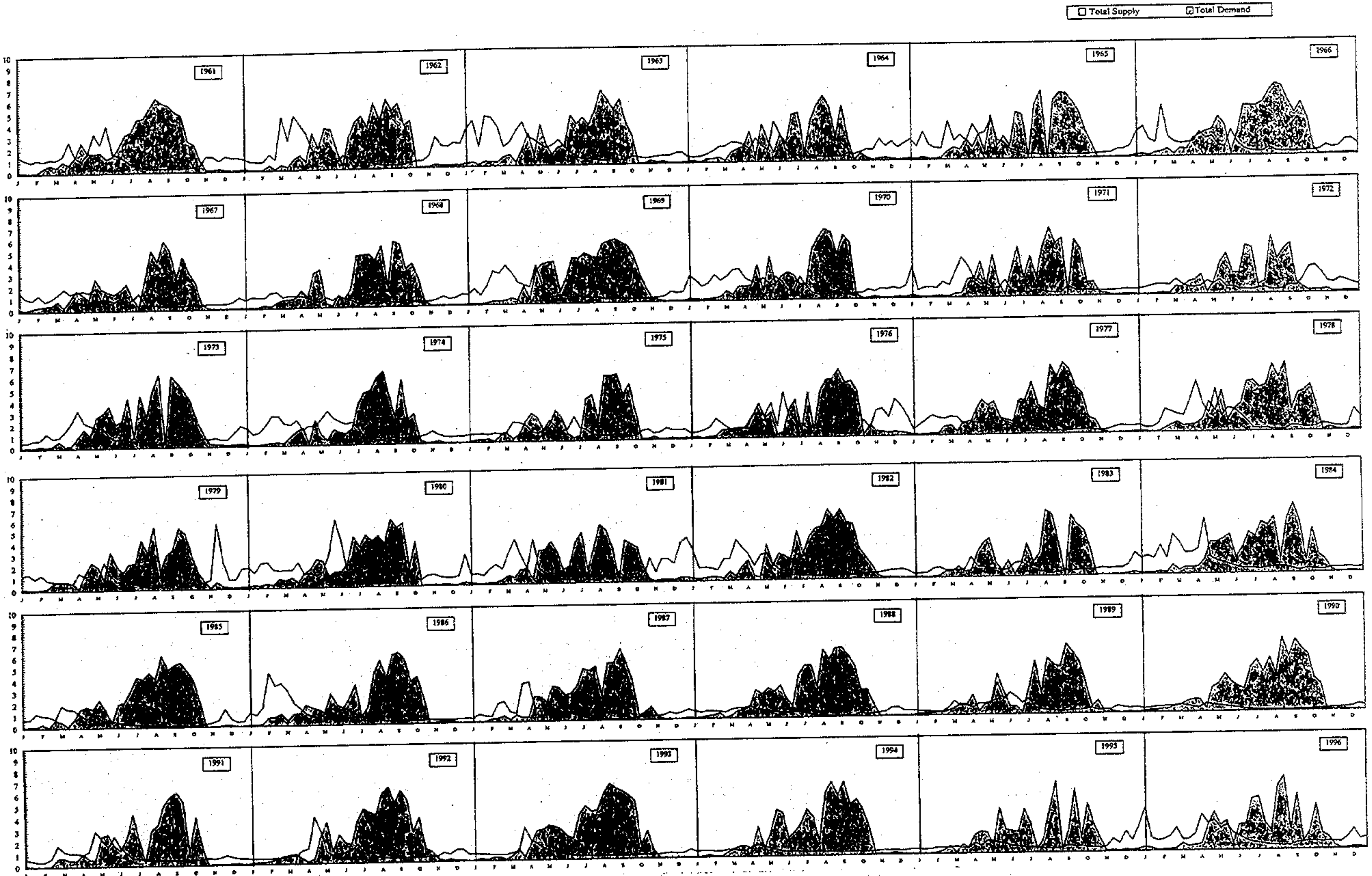


Figure K.20 **10-Day Water Balance between Demand and Supply based on Future Condition in 2025 (Pchinja River Sub-Basin B3-3)**

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

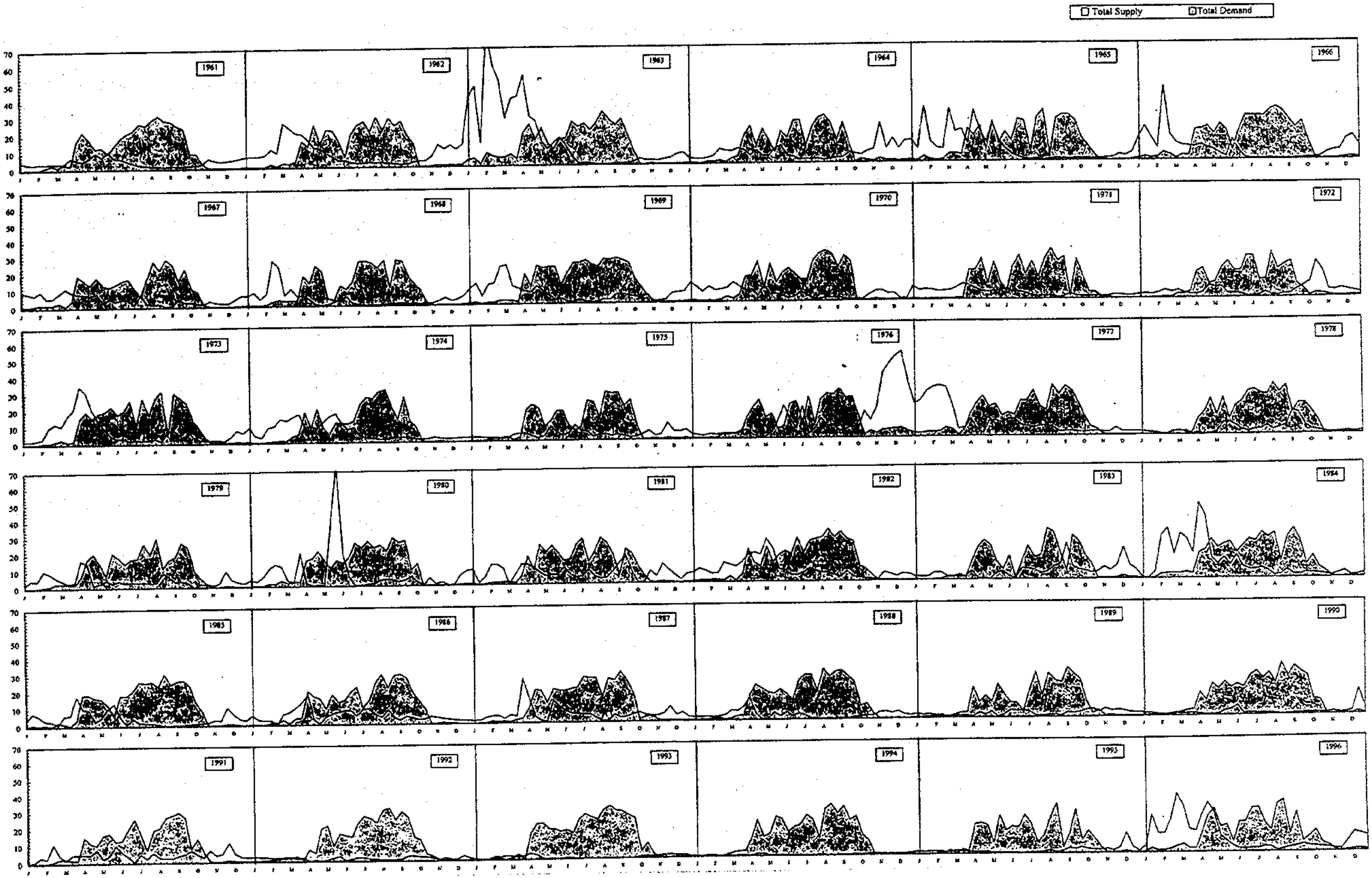


Figure K.21 10-Day Water Balance between Demand and Supply based on Future Condition in 2025 (Bregalnica River Sub-Basin B4-2)

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

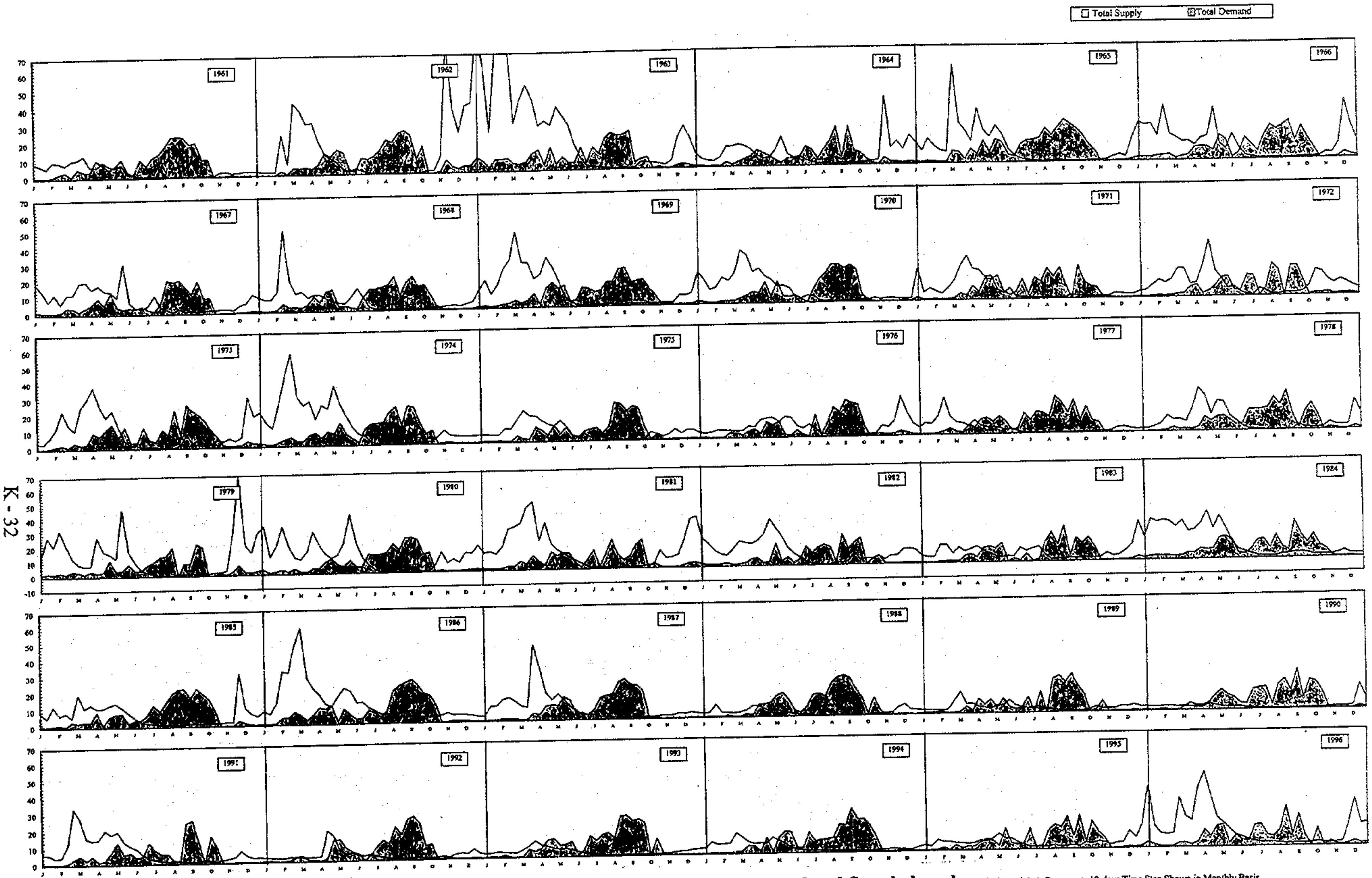


Figure K.22 **10-Day Water Balance between Demand and Supply based on Future Condition in 2025 (Crna River Sub-Basin B5-1)**

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

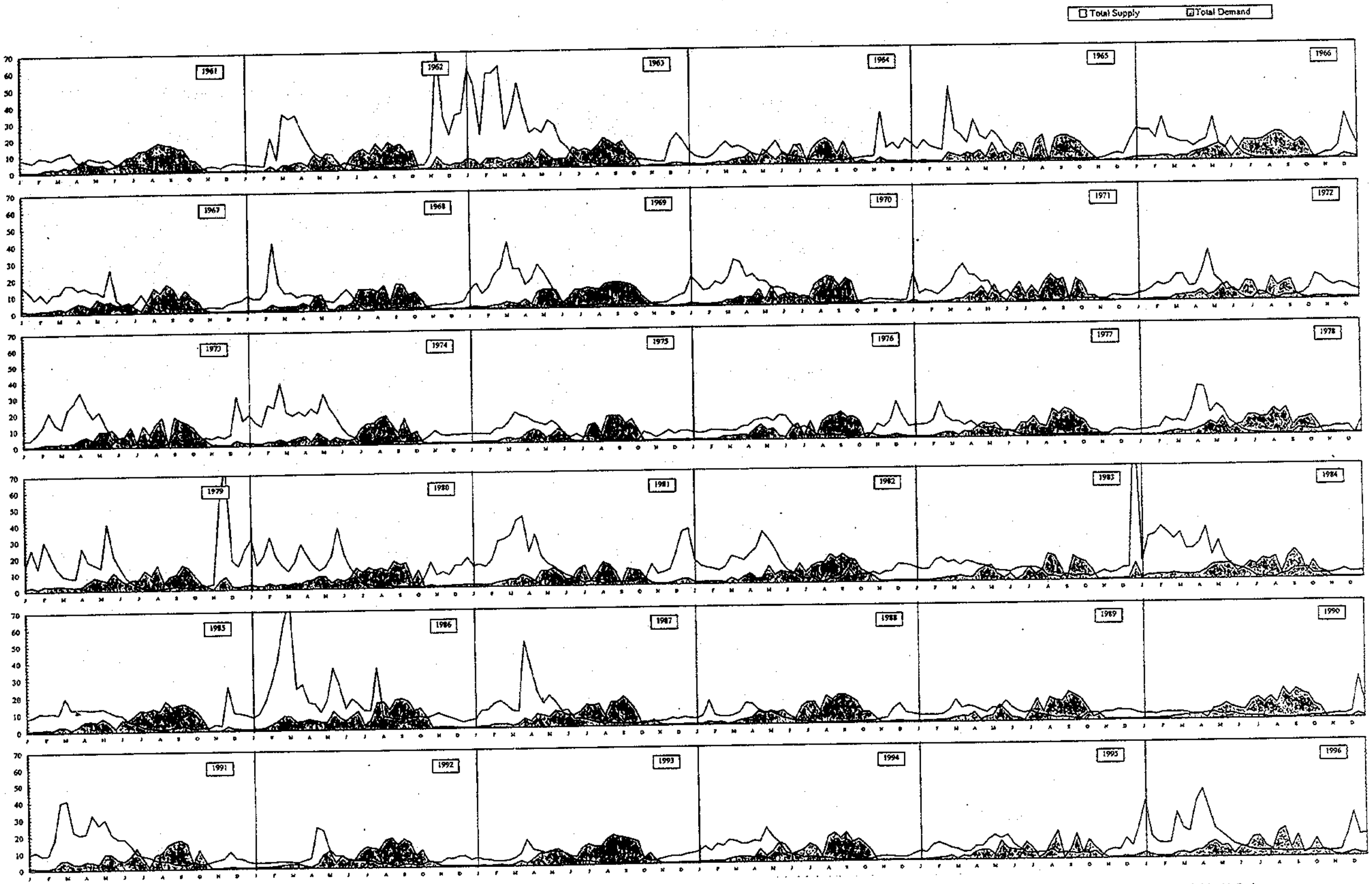


Figure K.23 10-Day Water Balance between Demand and Supply based on Future Condition in 2025 (Crna River Sub-Basin B5-3)

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

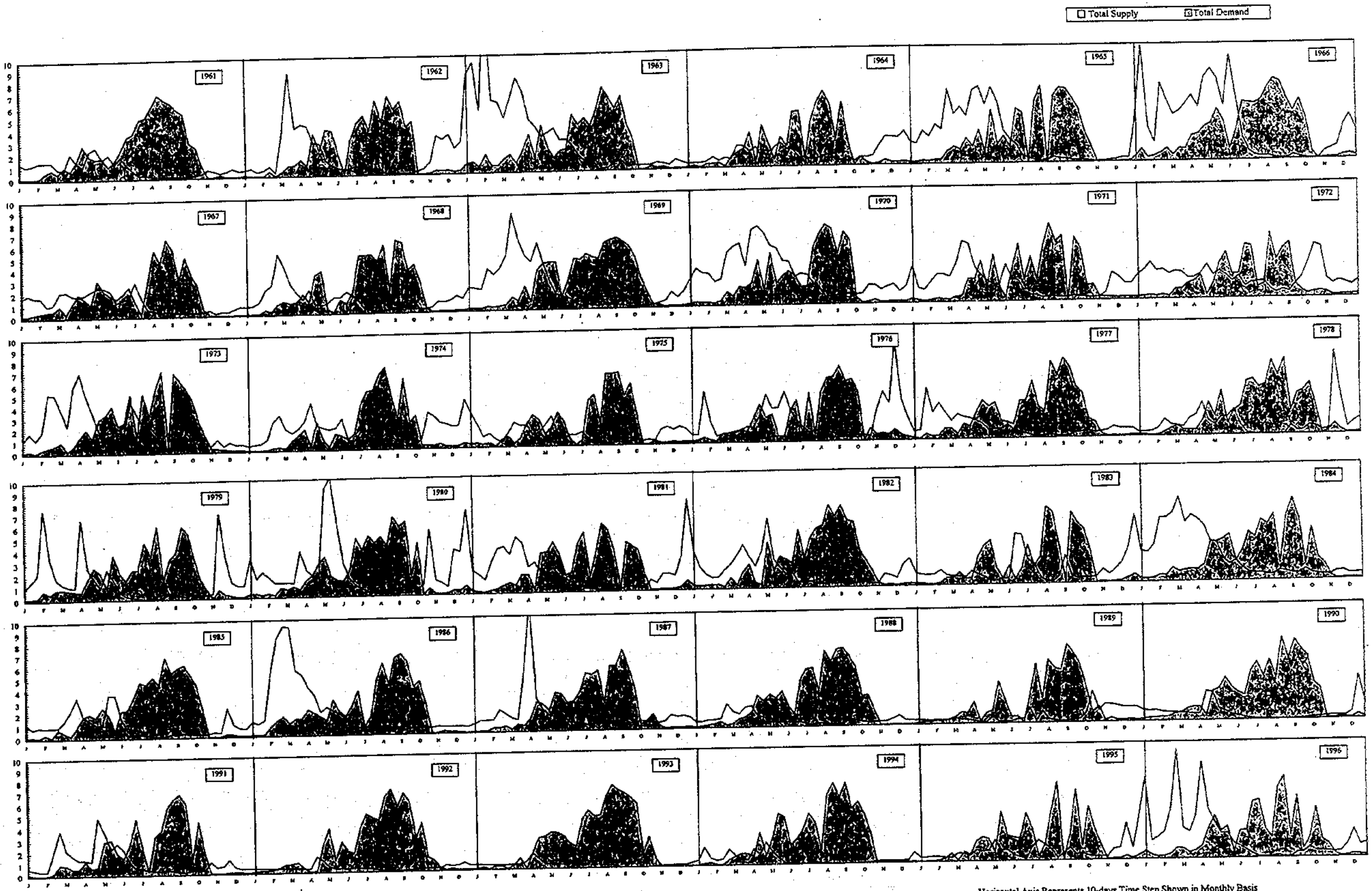


Figure K.24 **10-Day Water Balance between Demand and Supply based on Future Condition in 2025 (Strumica River Sub-Basin B6-2)**

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

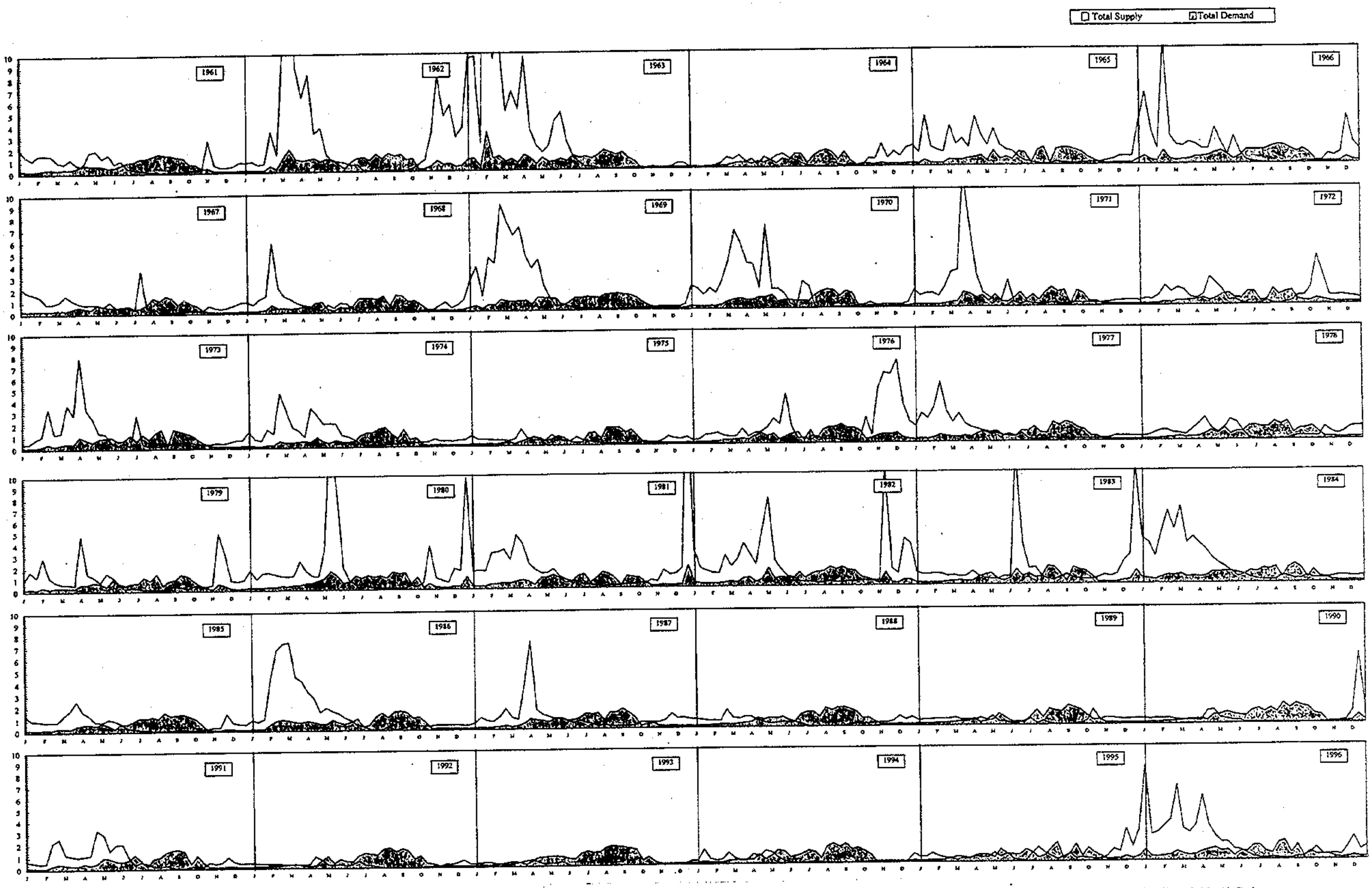


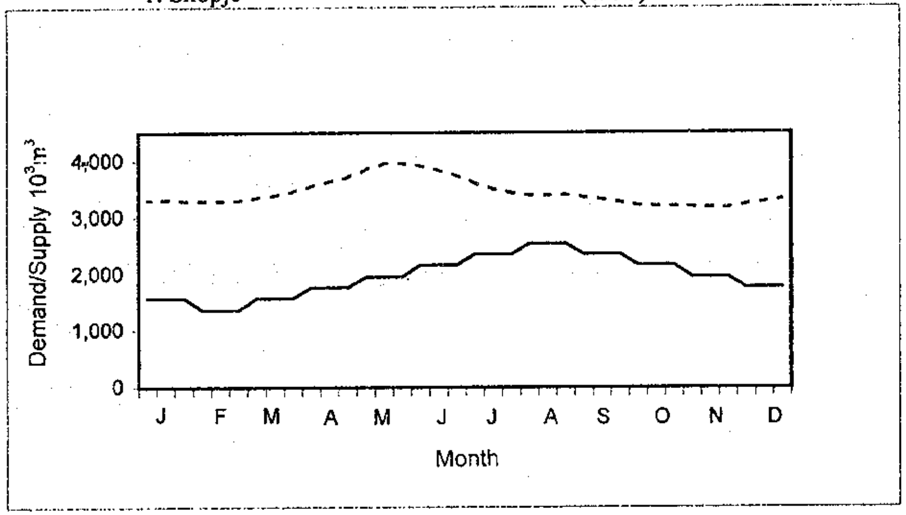
Figure K.25 **10-Day Water Balance between Demand and Supply based on Future Condition in 2025 (Strumica River Sub-Basin B6-3)**

Horizontal Axis Represents 10-days Time Step Shown in Monthly Basis
Vertical Axis Represents Total Demand and Total Supply Flow Rate (m^3/sec/10days)

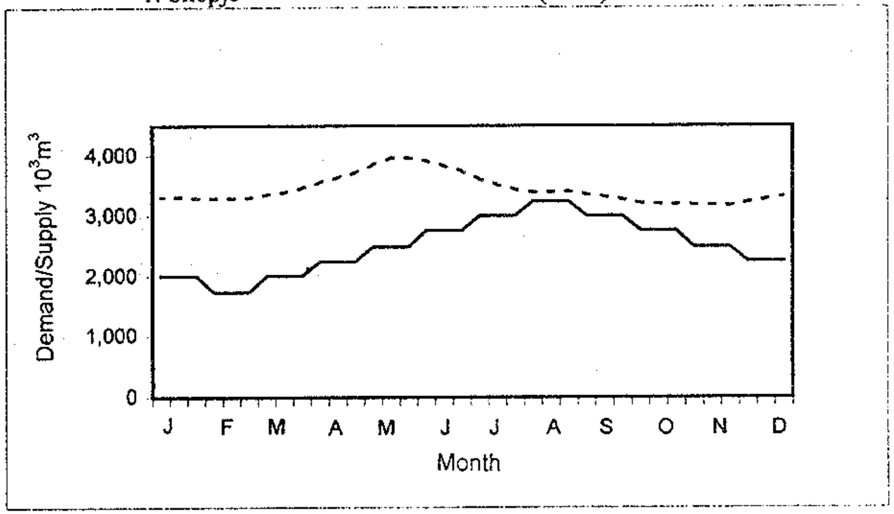
Annex 10

Water Demand and Supply Balance in Each Municipality

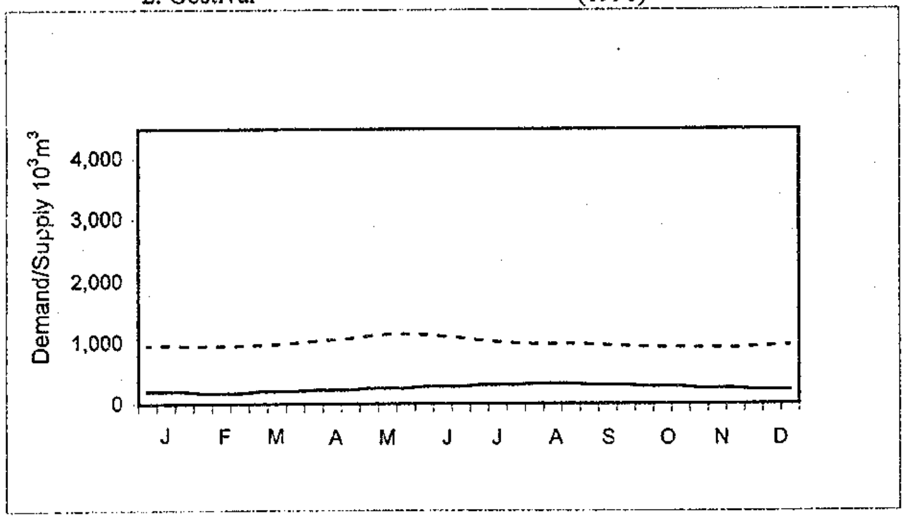
1. Skopje (1996)



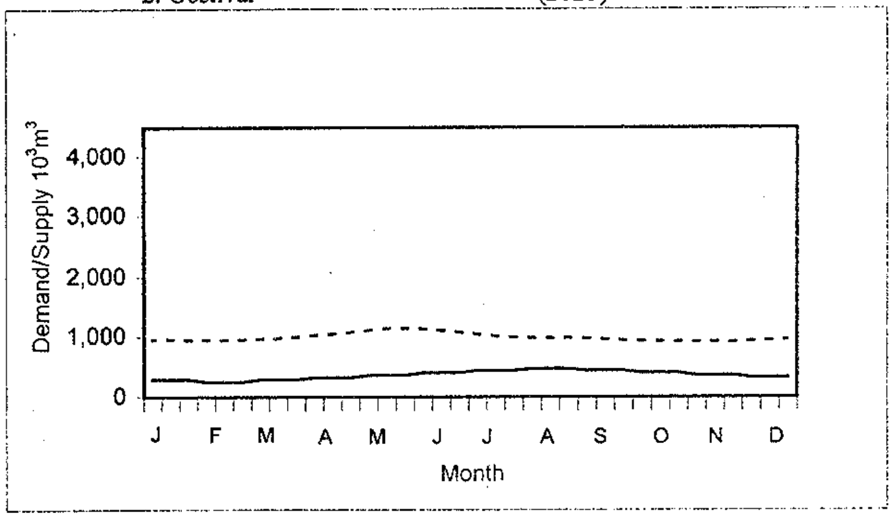
1. Skopje (2025)



2. Gostivar (1996)

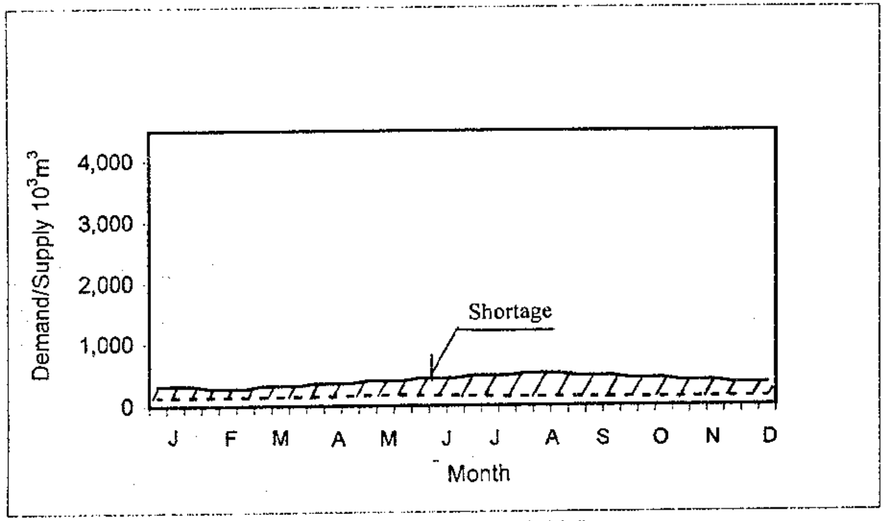


2. Gostivar (2025)

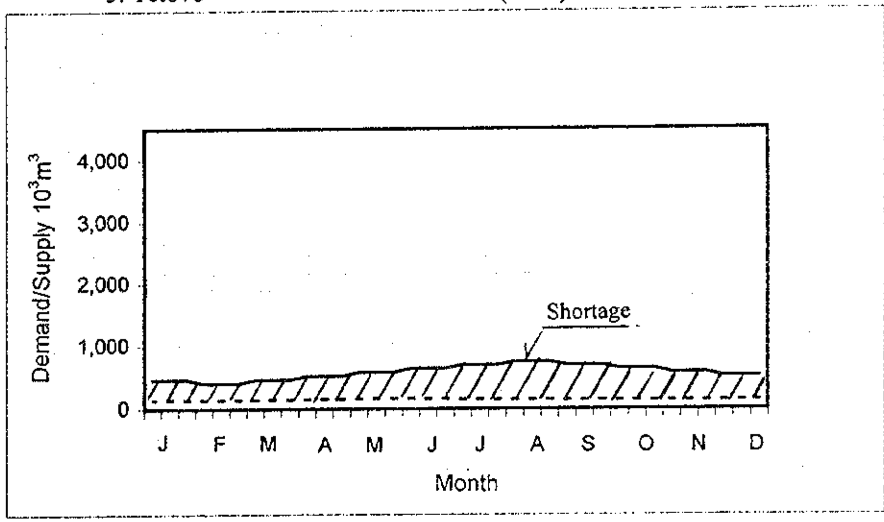


Balance between Water Demand and Supply in Skopje (1) and Gostivar (2) (No. in Former Municipality)
: No water shortage is estimated in both municipalities in 1996 and 2025

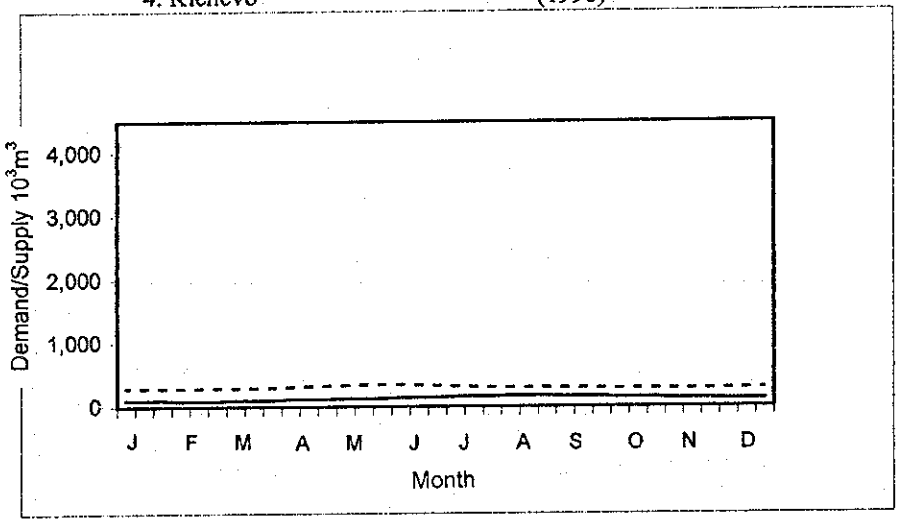
3. Tetovo (1996)



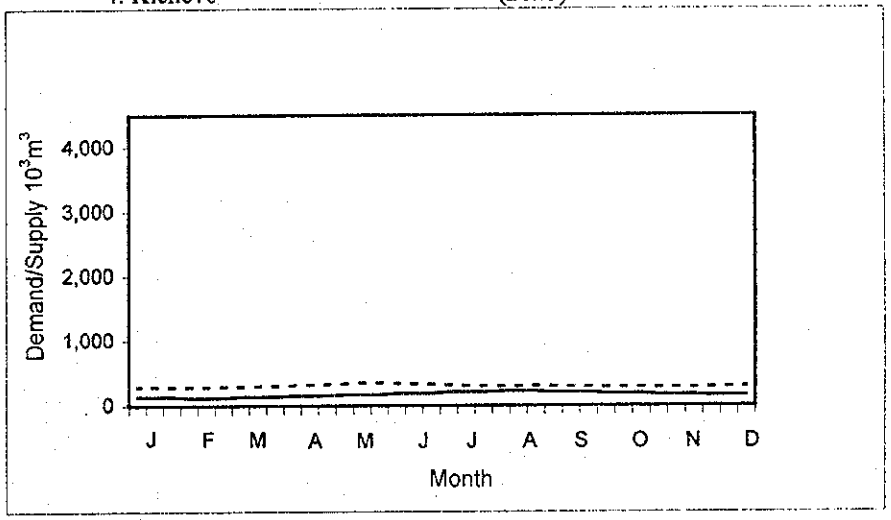
3. Tetovo (2025)



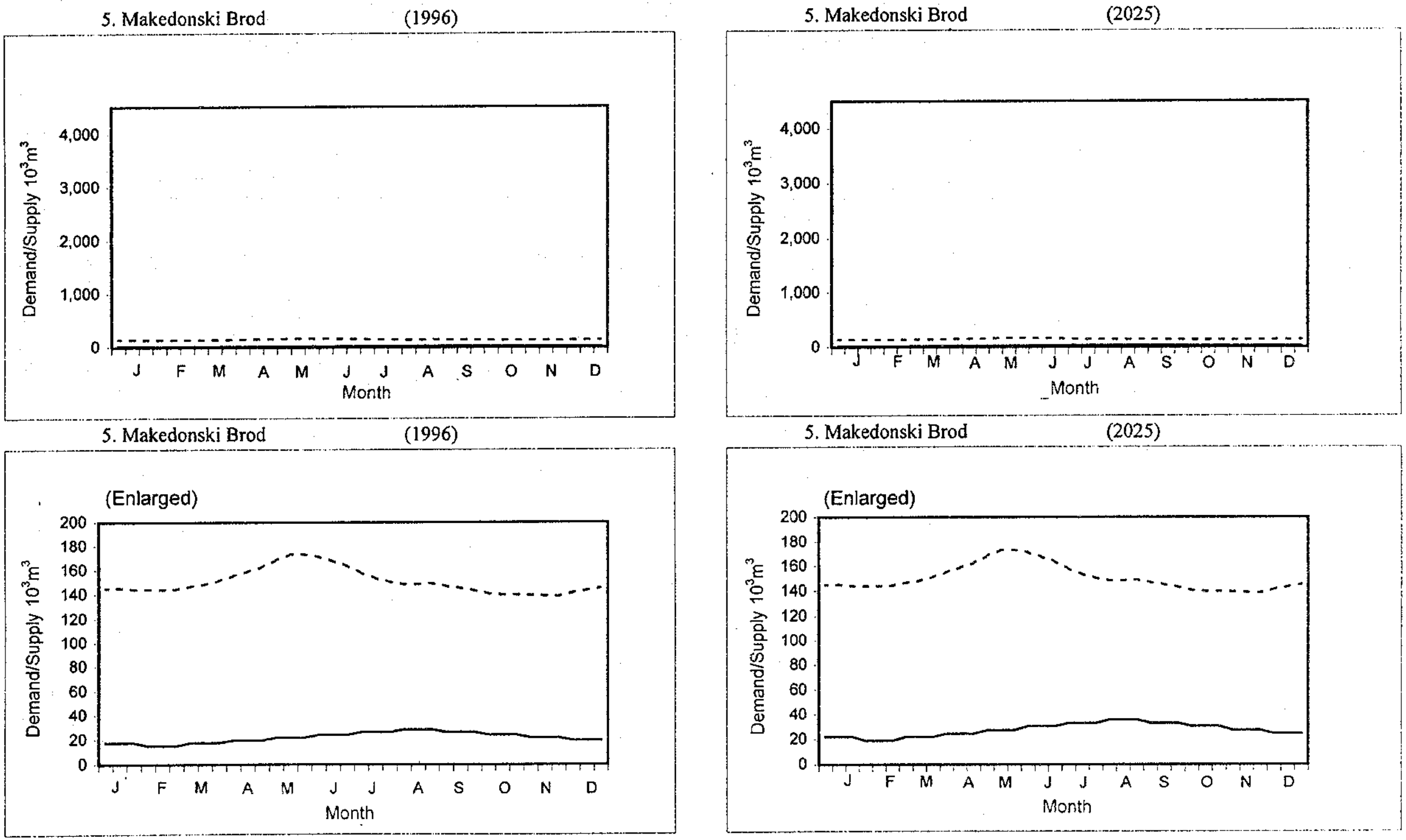
4. Kichevo (1996)



4. Kichevo (2025)

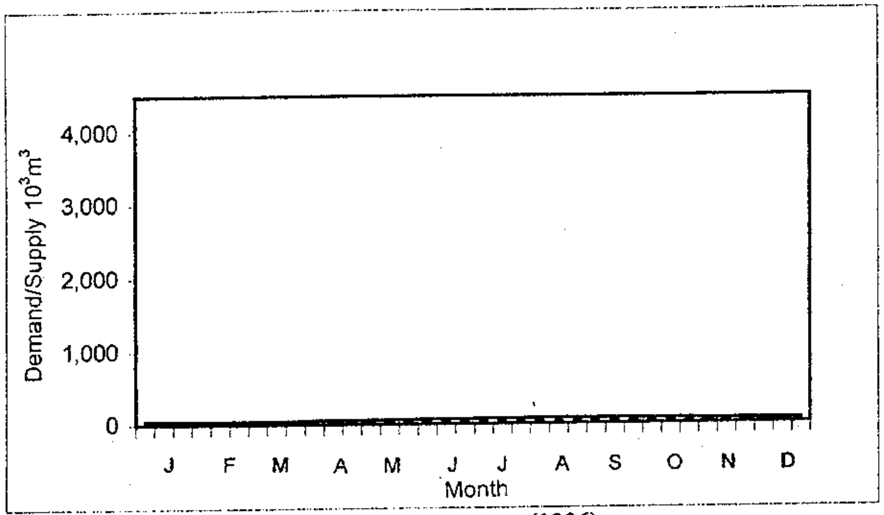


Balance between Water Demand and Supply in Tetovo (3) and Kichevo (4) (No. in Former Municipality)
: Water shortage is estimated in Tetovo through the year in 1996 and 2025
: while, no water shortage in Kichevo in 1996 and 2025

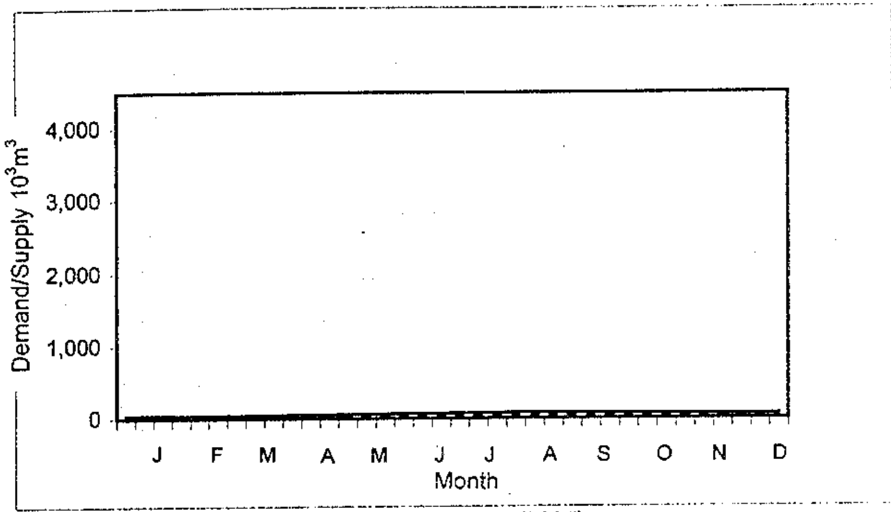


Balance between Water Demand and Supply in Makedonski Brod (5) (No. in Former Municipality)
: No water shortage is estimated in Makedonski Brod in 1996 and 2025

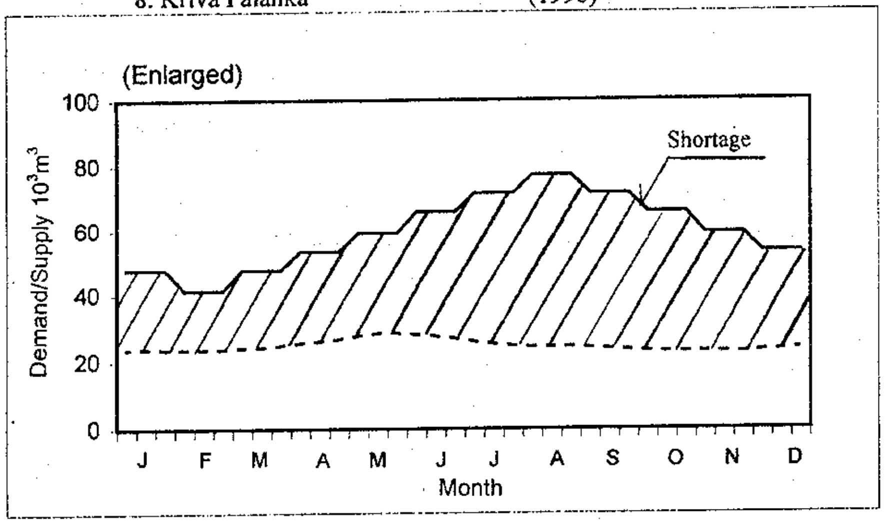
8. Kriva Palanka (1996)



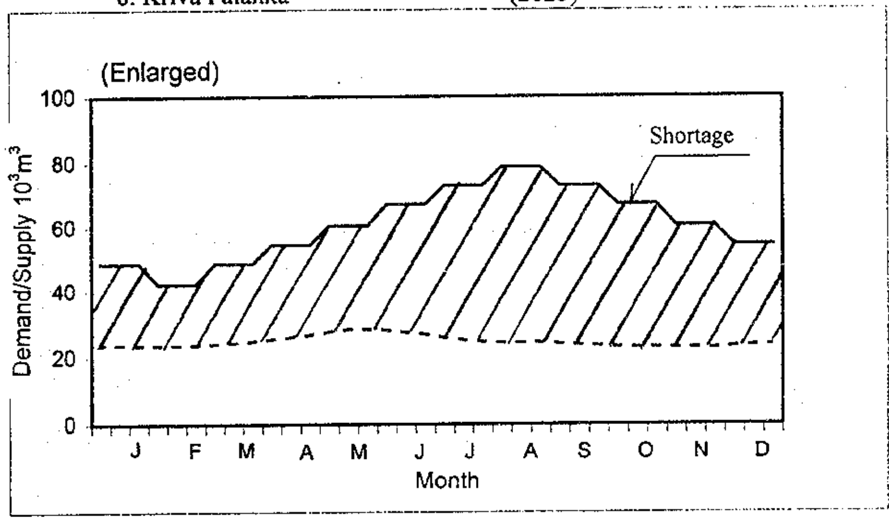
8. Kriva Palanka (2025)



8. Kriva Palanka (1996)

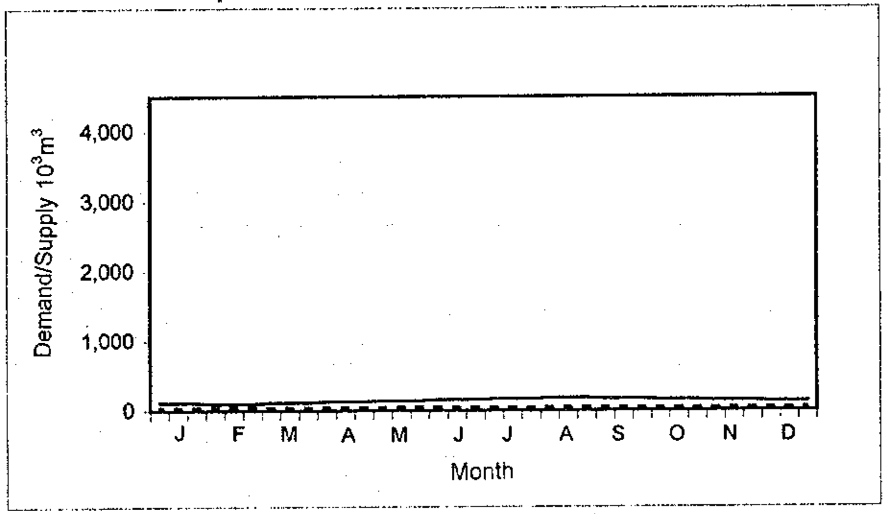


8. Kriva Palanka (2025)

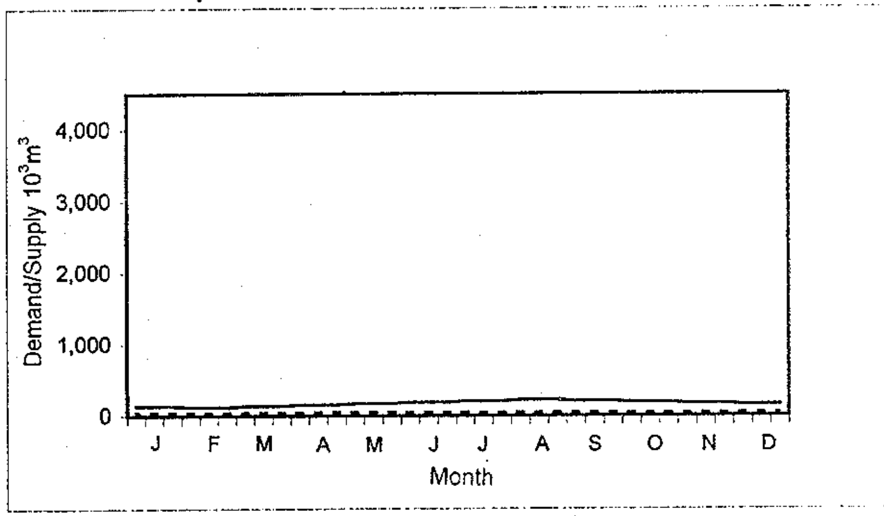


Balance between Water Demand and Supply in Kriva Palanka (8) (No. in Former Municipality)
: Water shortage is estimated in Kriva Palanka through the year in 1996 and 2025

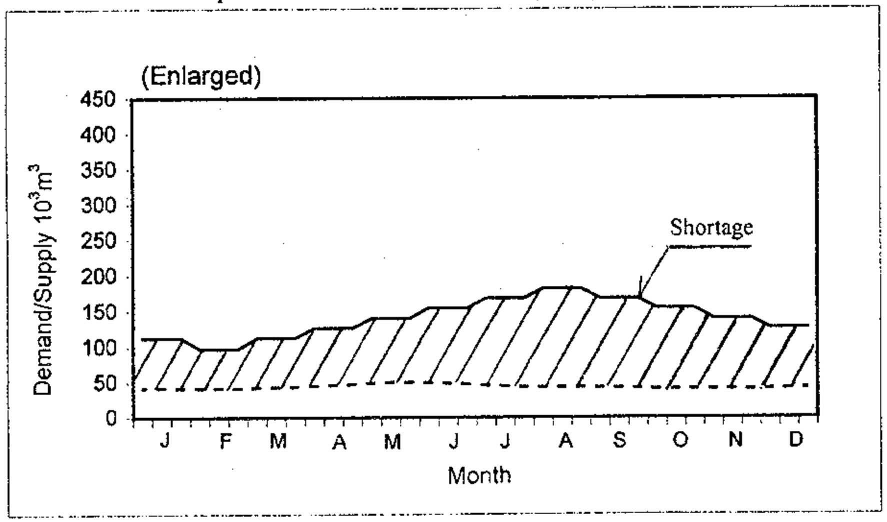
11. Shtip (1996)



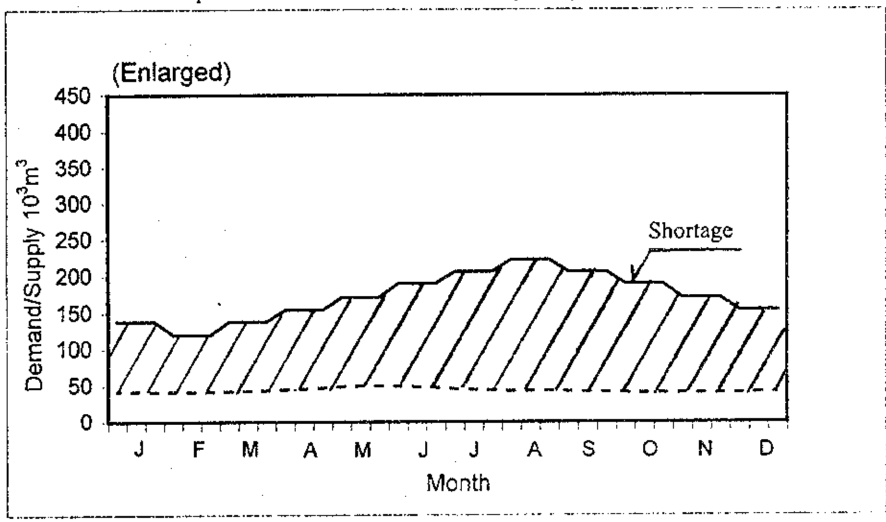
11. Shtip (2025)



11. Shtip (1996)

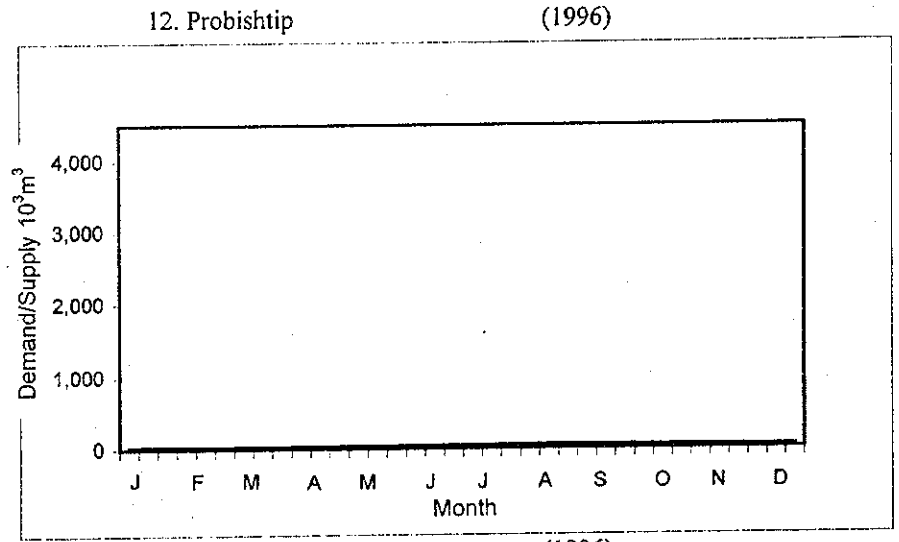


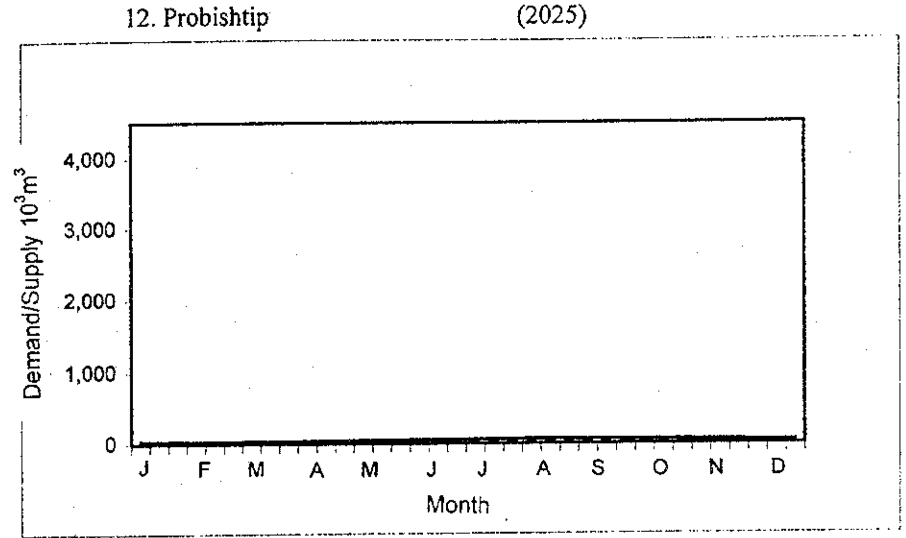
11. Shtip (2025)

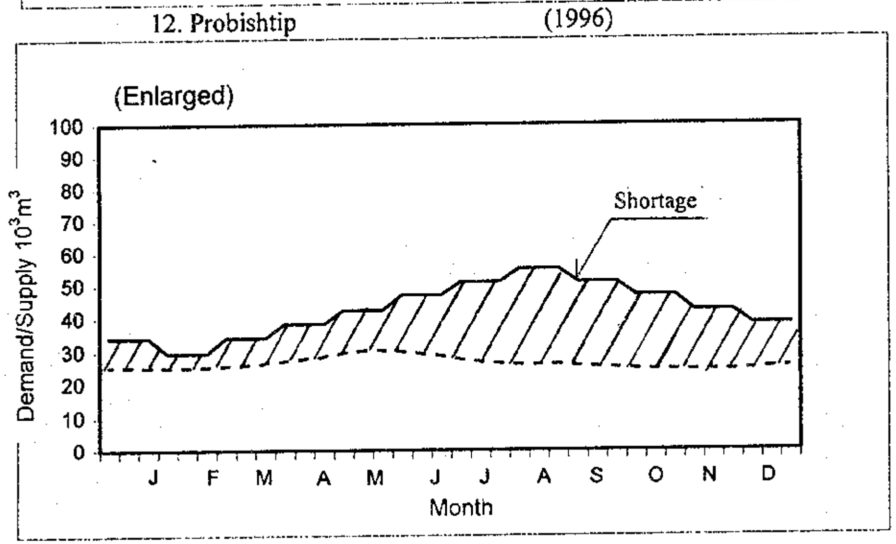


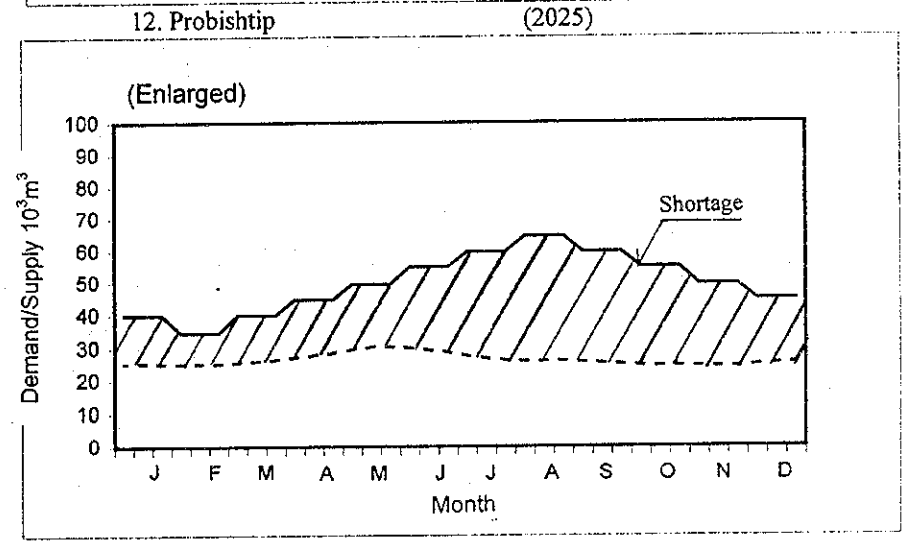
Balance between Water Demand and Supply in Shtip (11) (No. in Former Municipality)

: Water shortage is estimated in Shtip through the year in 1996 and 2025



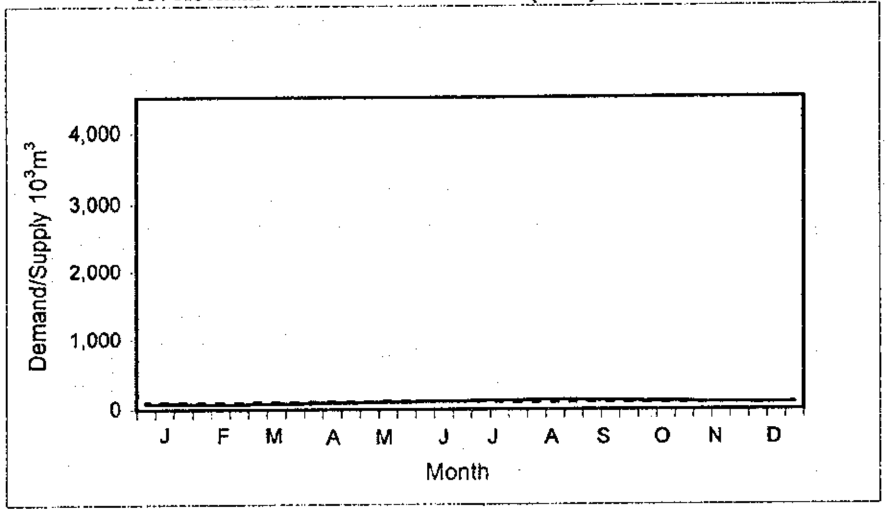




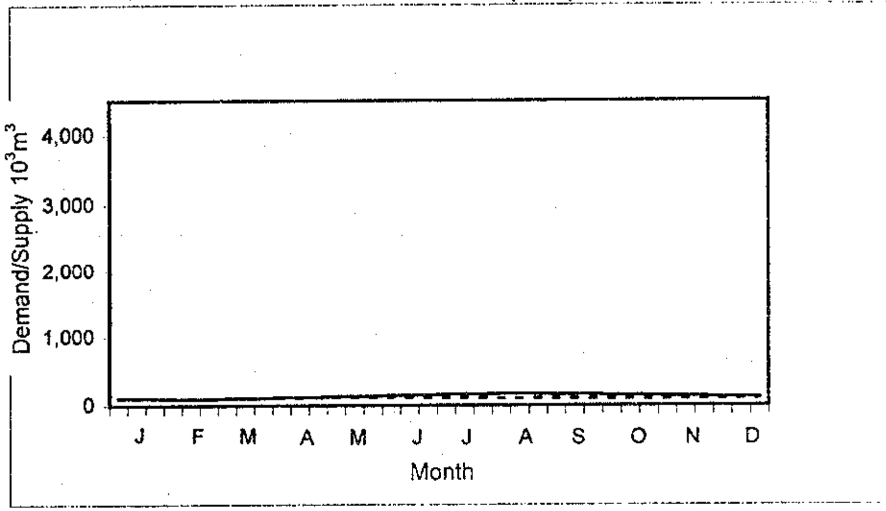


Balance between Water Demand and Supply in Probishtip (12) (No. in Former Municipality)
: Water shortage is estimated in Probishtip through the year in 1996 and 2025

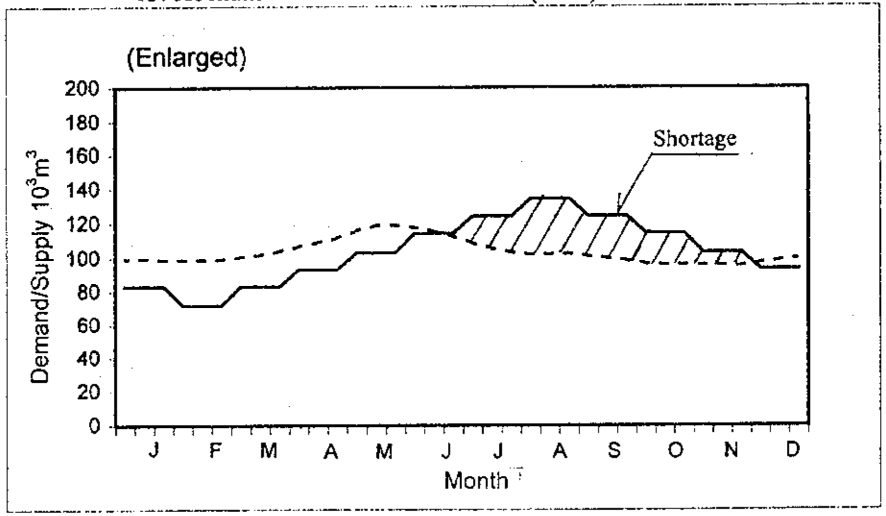
13. Kochani (1996)



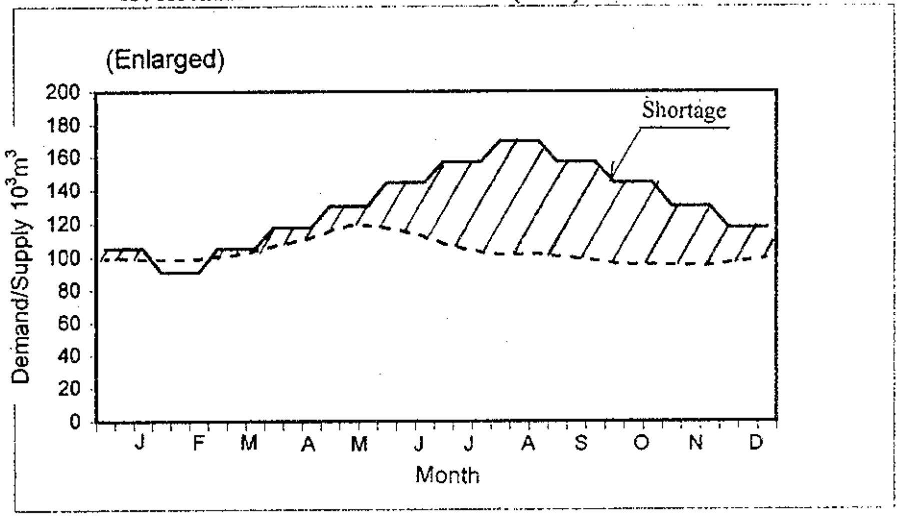
13. Kochani (2025)



13. Kochani (1996)

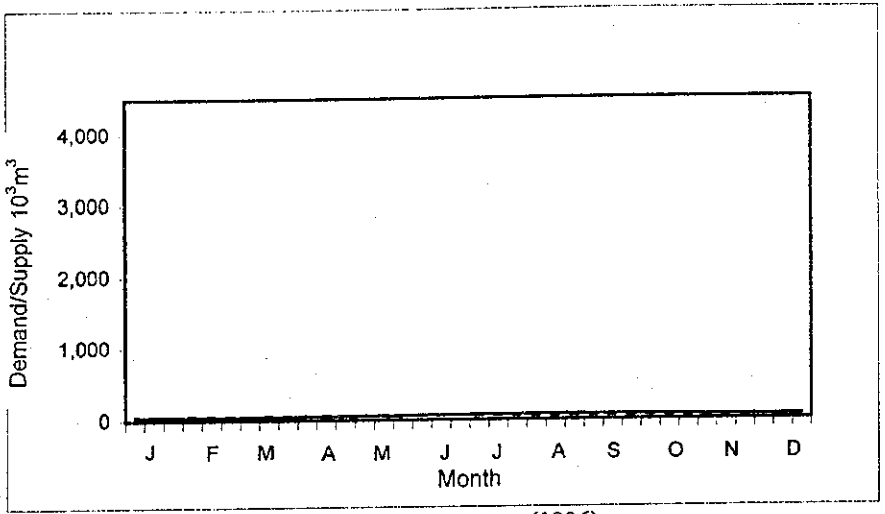


13. Kochani (2025)

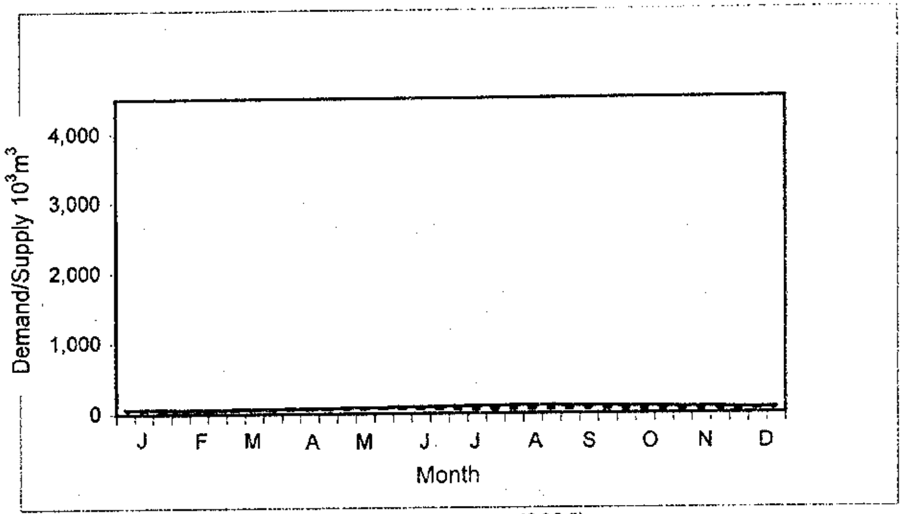


Balance between Water Demand and Supply in Kochani (13) (No. in Former Municipality)
: Water shortage is estimated in Kochani seasonally in 1996 and 2025

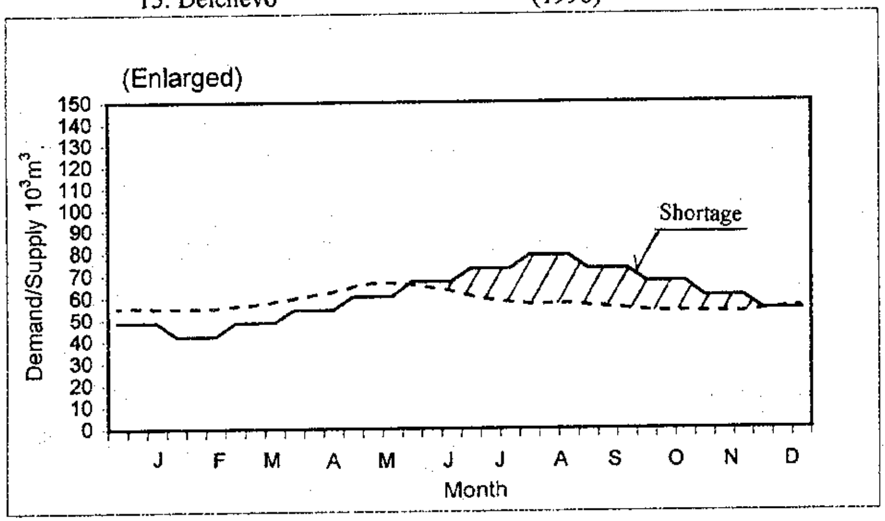
15. Delchevo (1996)



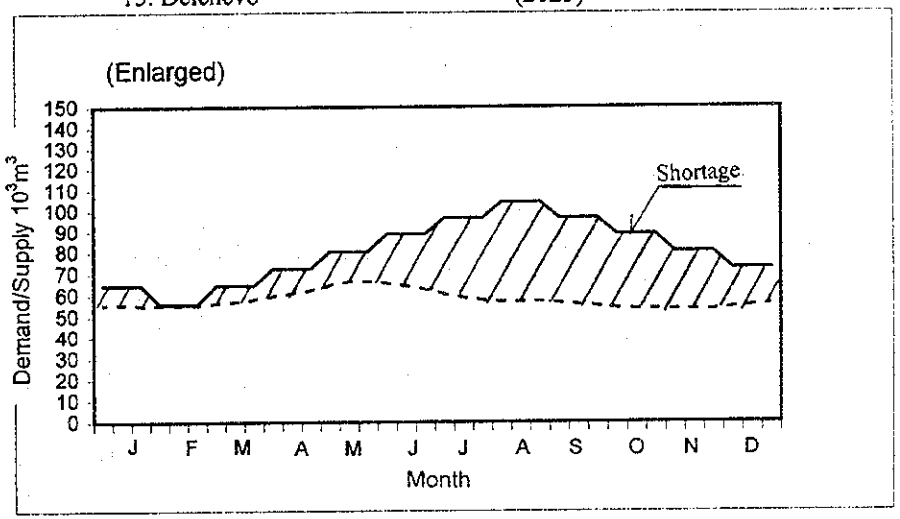
15. Delchevo (2025)



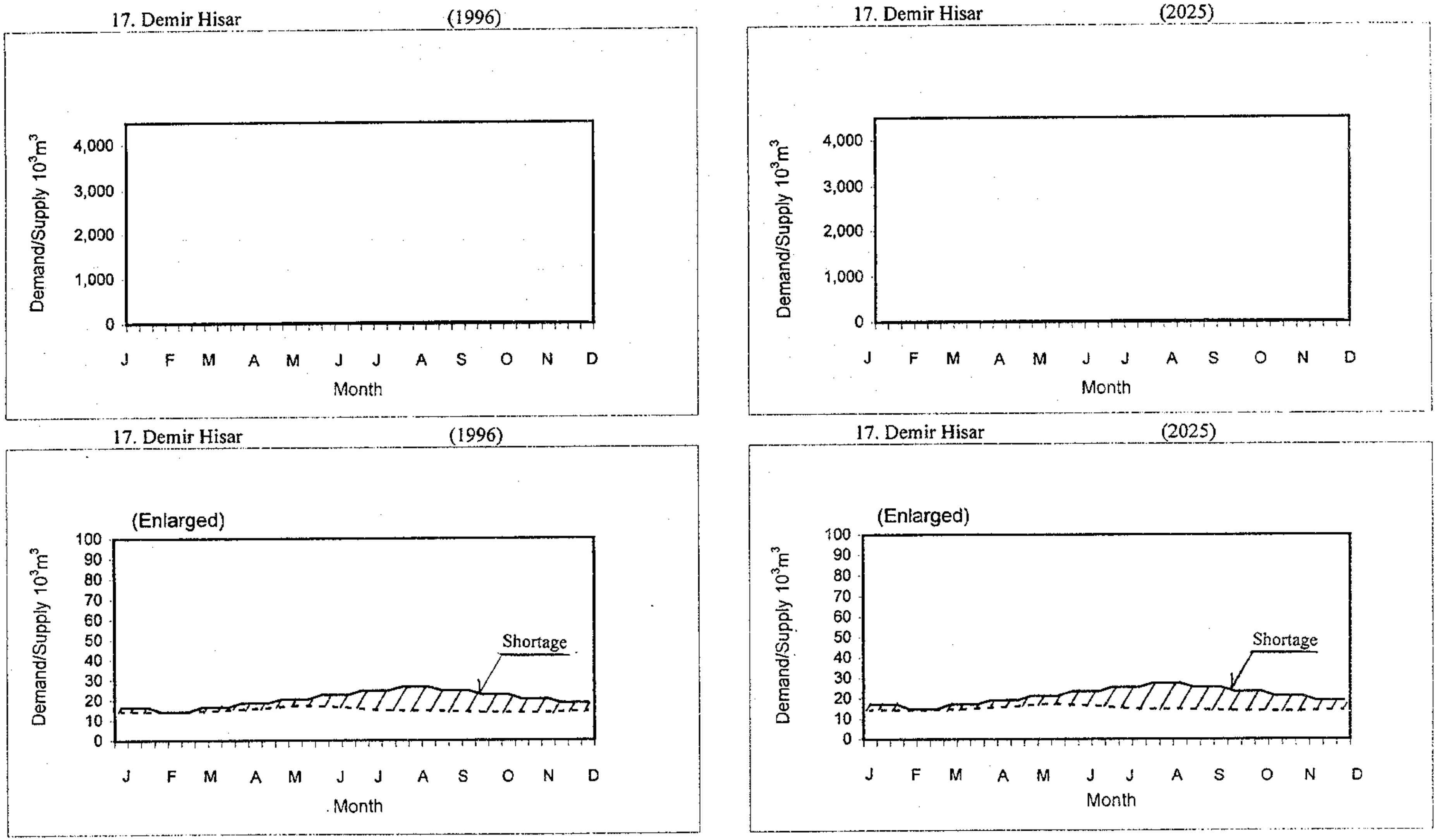
15. Delchevo (1996)



15. Delchevo (2025)

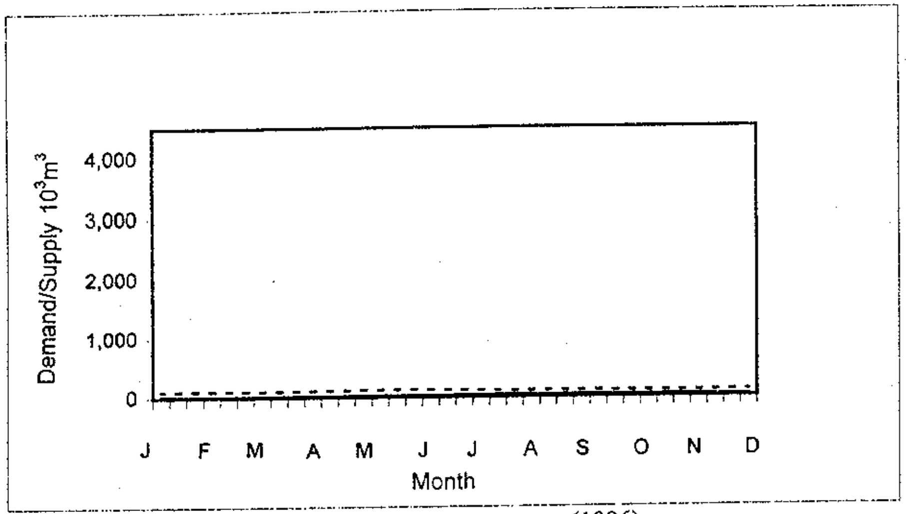


Balance between Water Demand and Supply in Delchevo (15) (No. in Former Municipality)
: Water shortage is estimated in Delchevo seasonally in 1996 and 2025

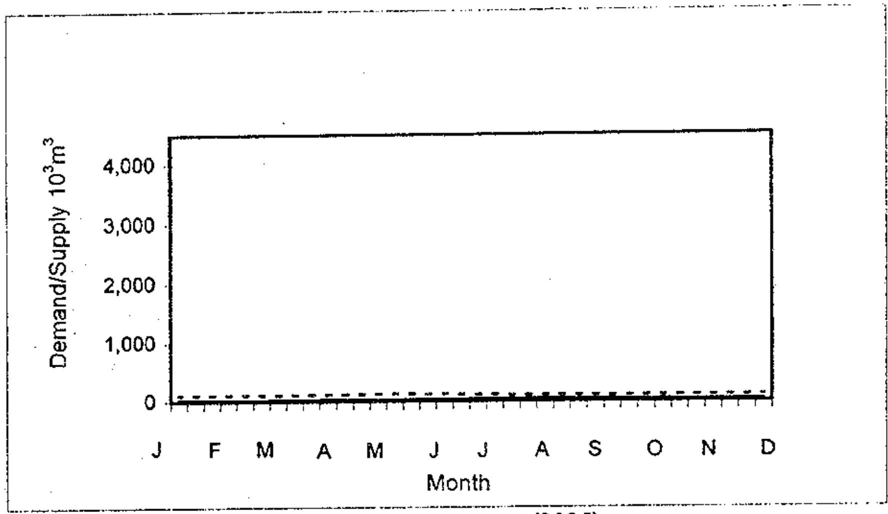


Balance between Water Demand and Supply in Demir Hisar (17) (No. in Former Municipality)
: Water shortage is estimated in Demir Hisar seasonally in 1996 and 2025

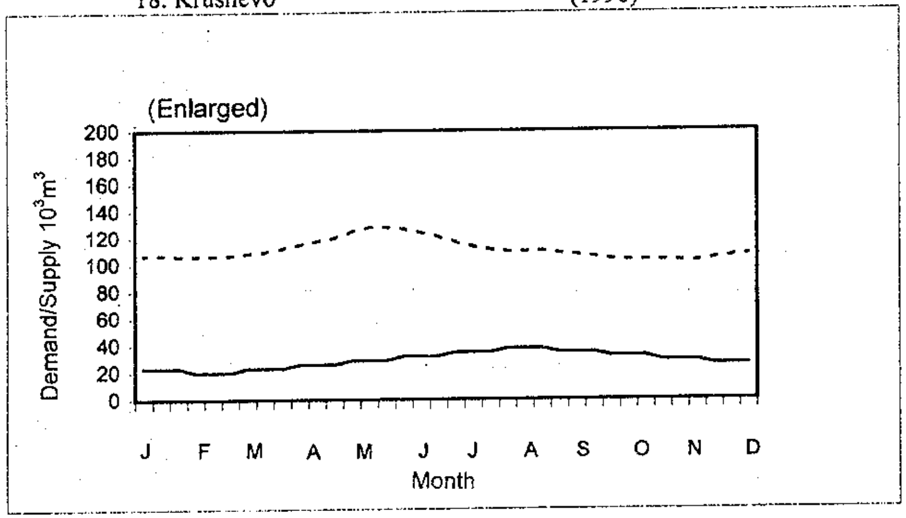
18. Krushevo (1996)



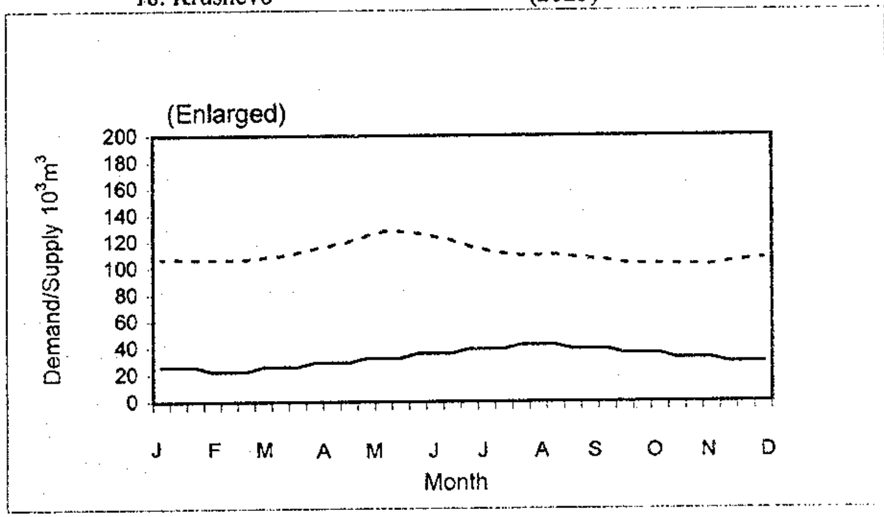
18. Krushevo (2025)



18. Krushevo (1996)



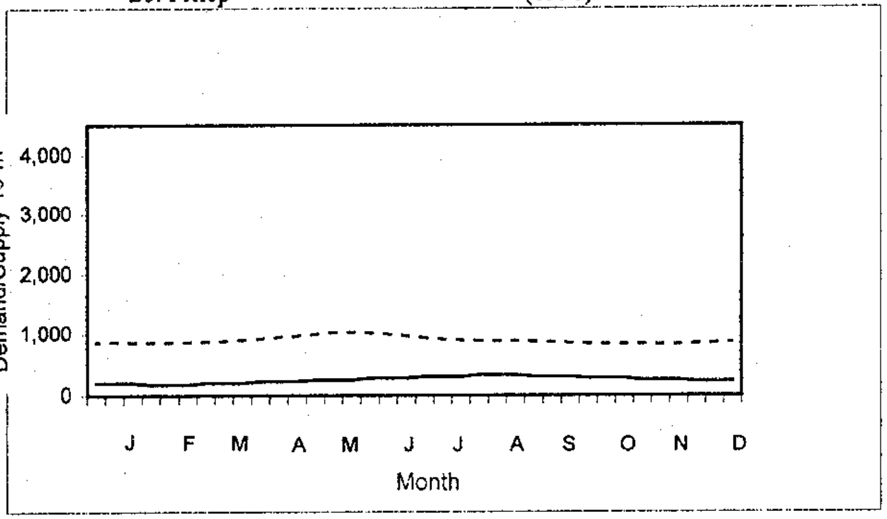
18. Krushevo (2025)



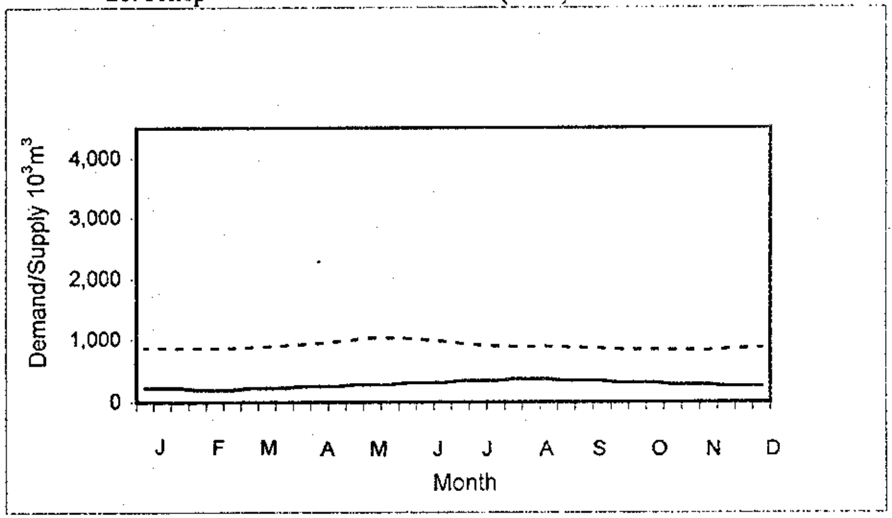
Balance between Water Demand and Supply in Krushevo (18) (No. in Former Municipality)

: No water shortage is estimated in Krushevo in 1996 and 2025

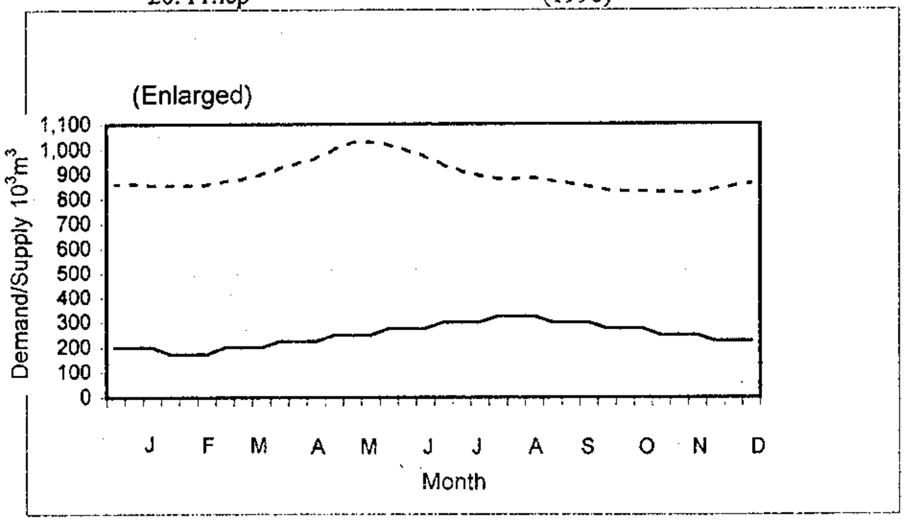
20. Prilep (1996)



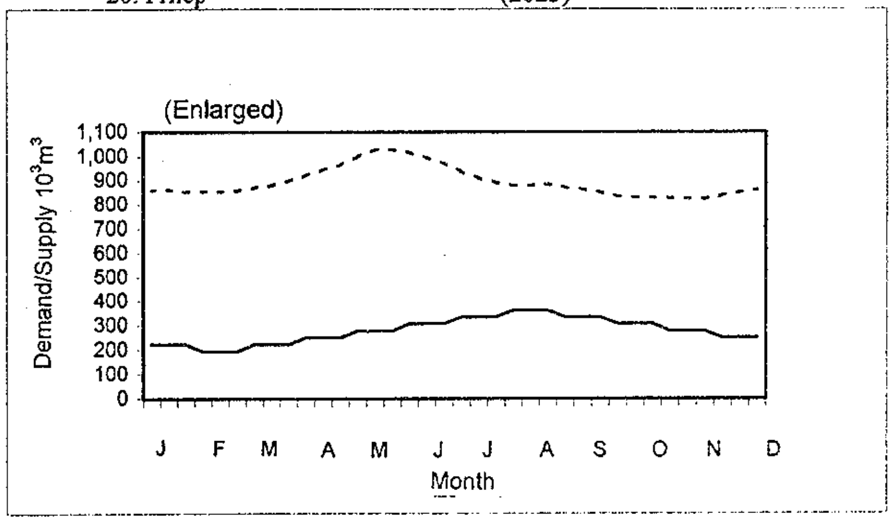
20. Prilep (2025)



20. Prilep (1996)

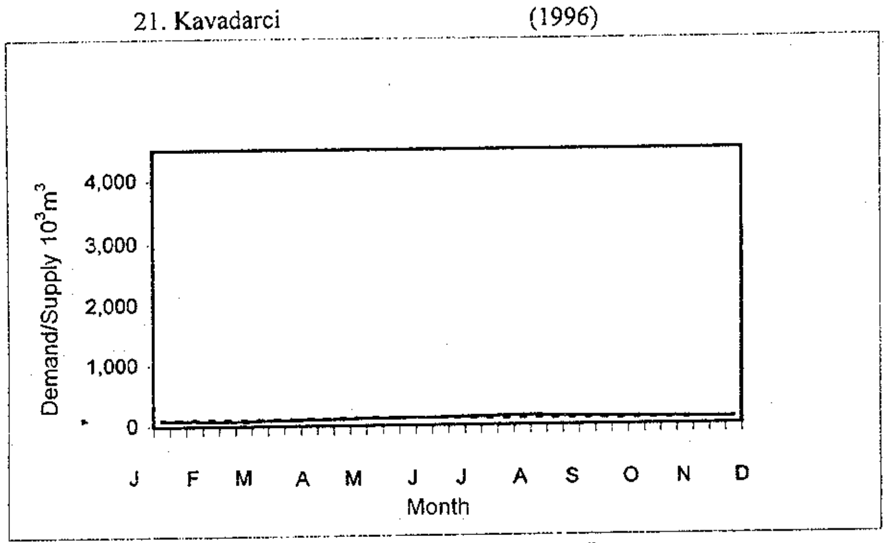


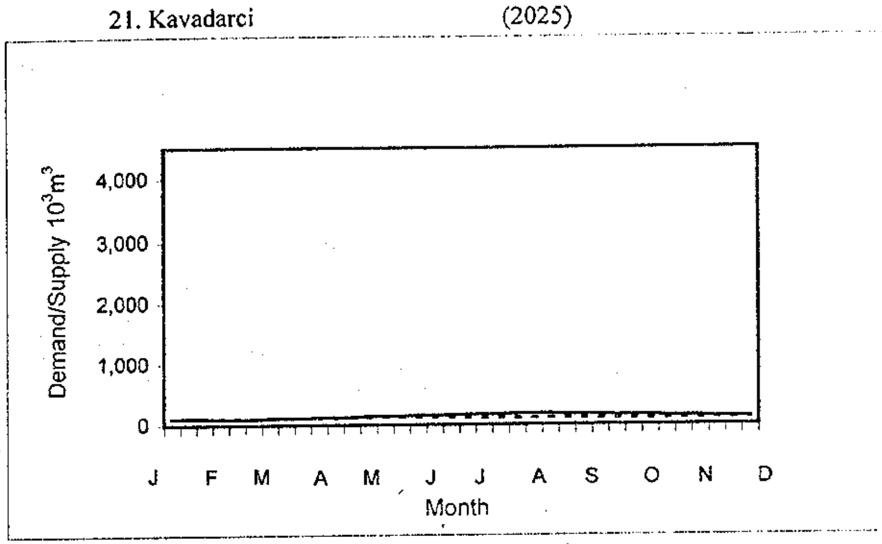
20. Prilep (2025)

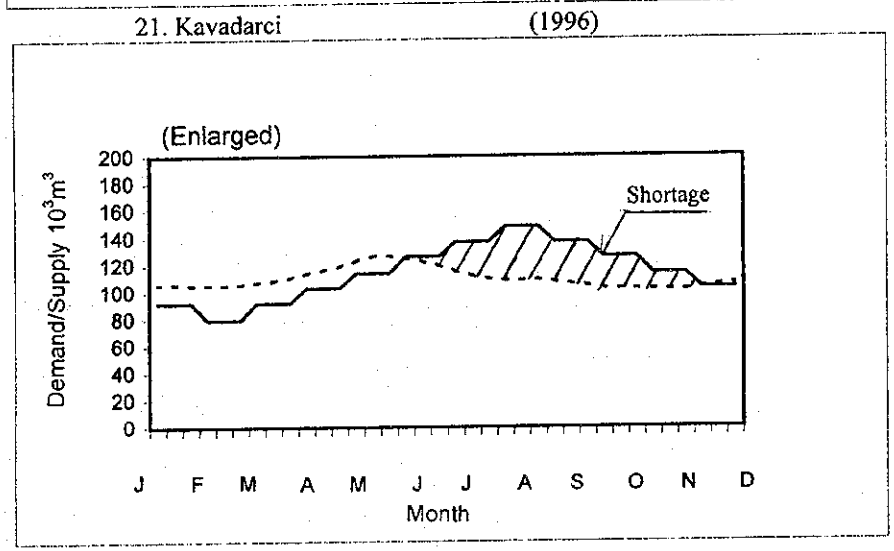


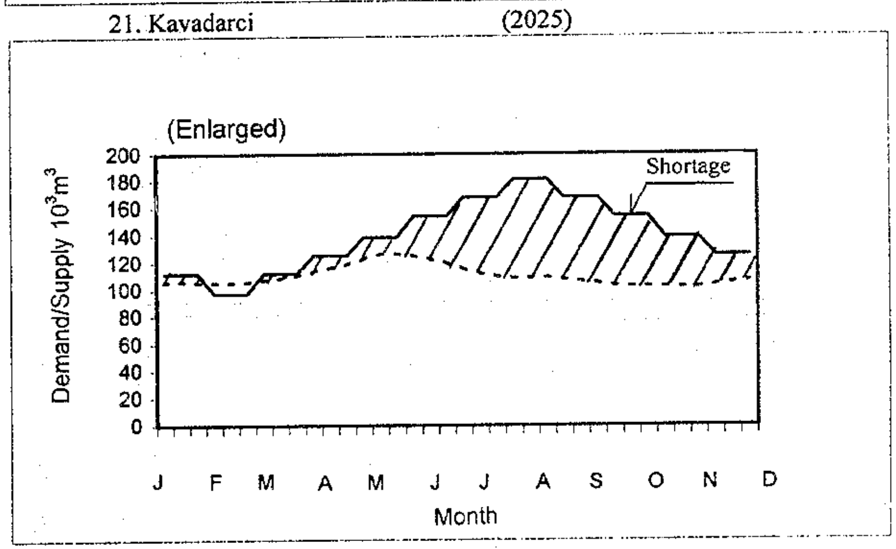
Balance between Water Demand and Supply in Prilep (20) (No. in Former Municipality)

: No water shortage is estimated in Prilep in 1996 and 2025

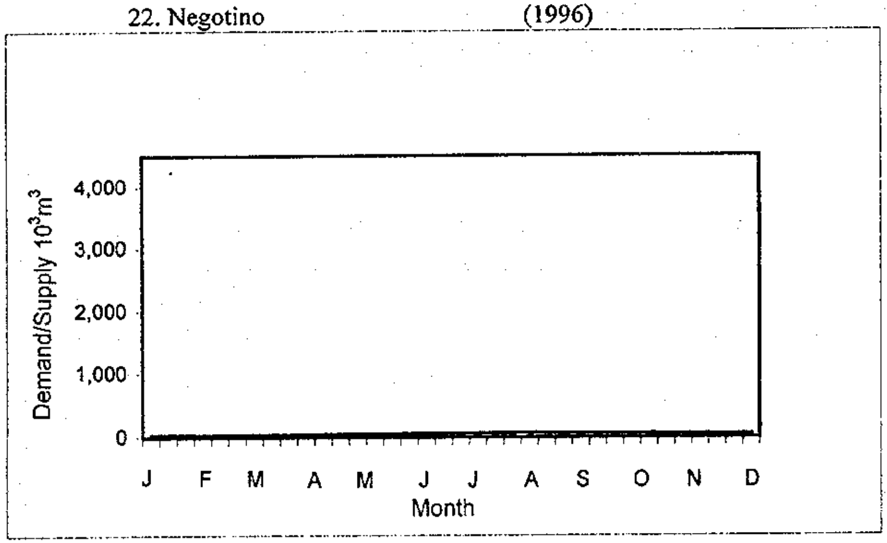


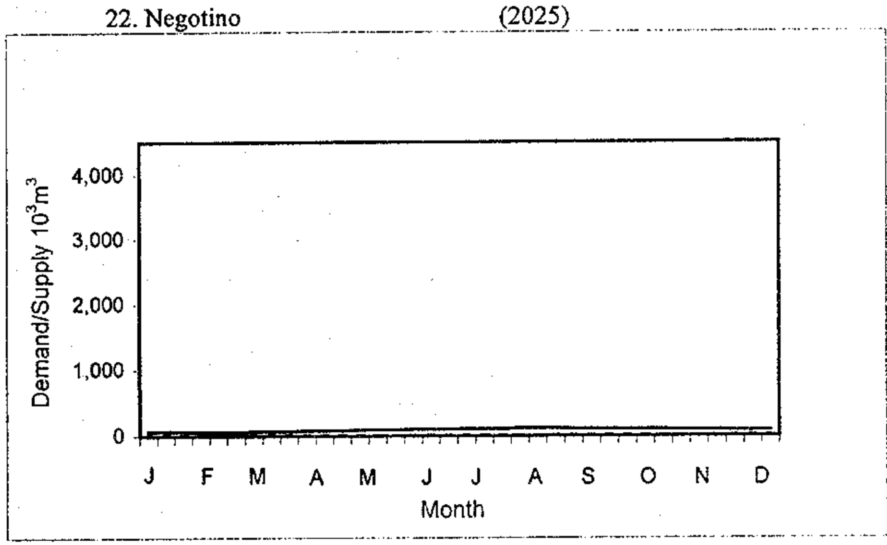


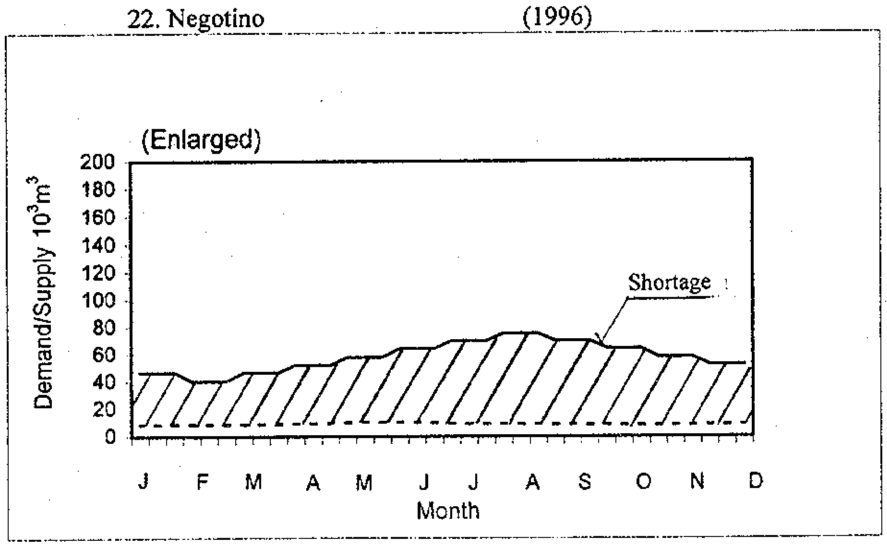


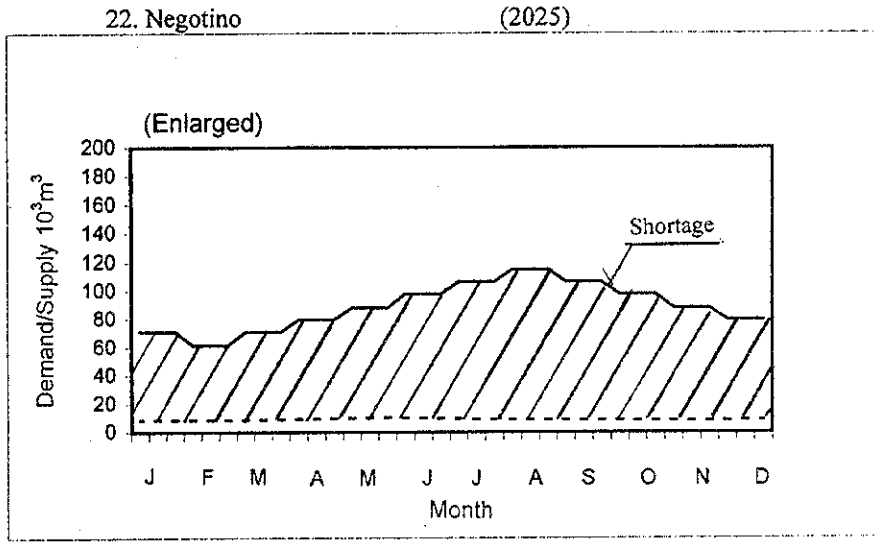


Balance between Water Demand and Supply in Kavadarci (21) (No. in Former Municipality)
: Water shortage is estimated in Kavadarci seasonally in 1996 and 2025



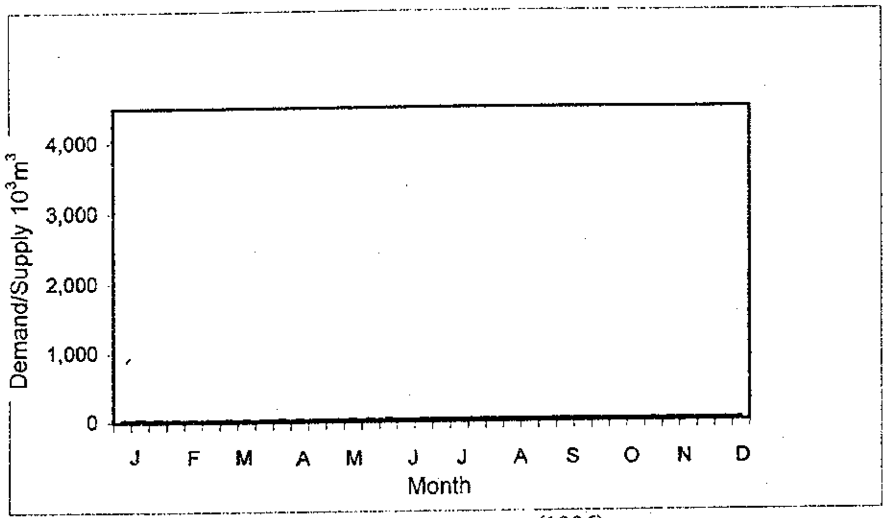




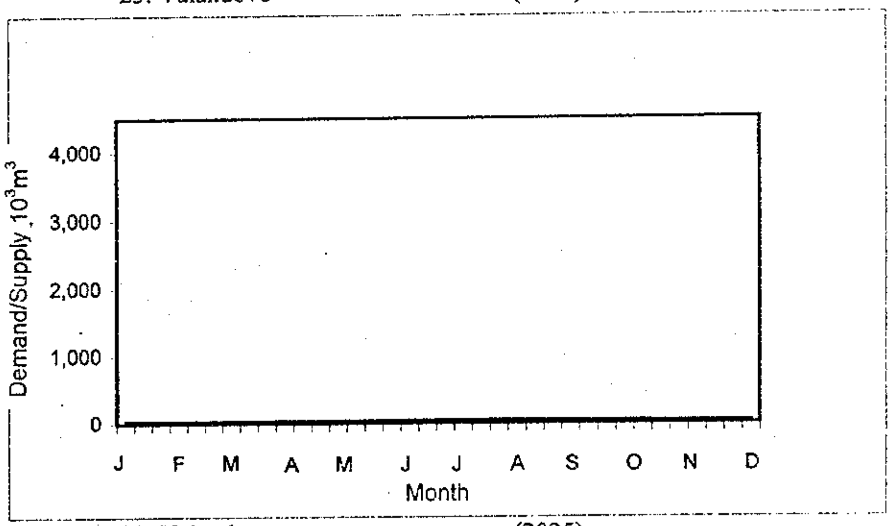


Balance between Water Demand and Supply in Negotino (22) (No. in Former Municipality)
: Water shortage is estimated in Negotino through the year in 1996 and 2025

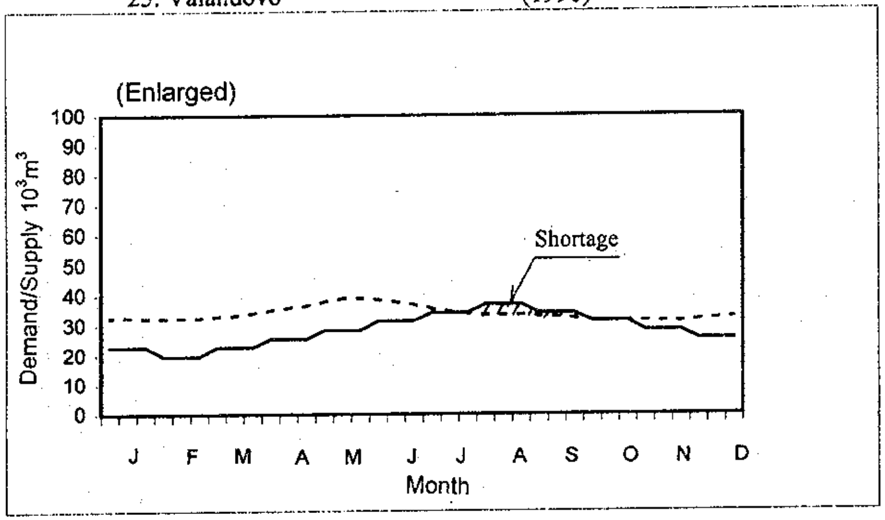
23. Valandovo (1996)



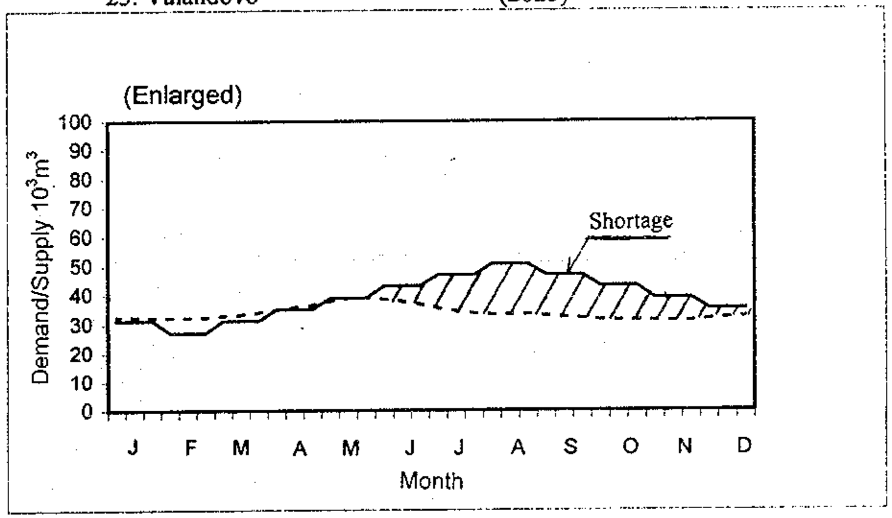
23. Valandovo (2025)



23. Valandovo (1996)

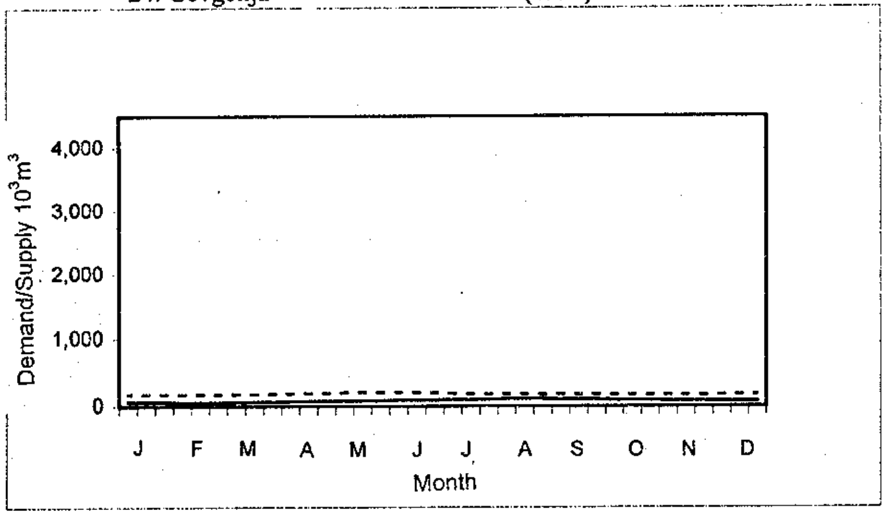


23. Valandovo (2025)

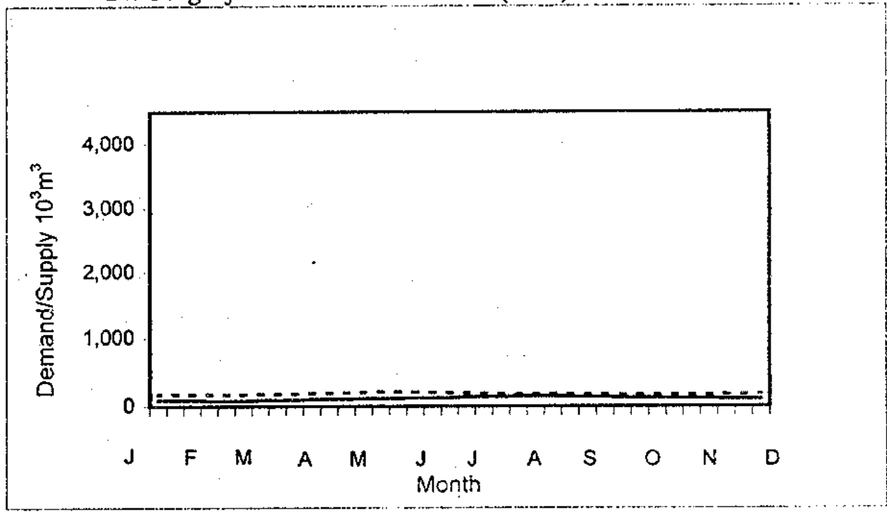


Balance between Water Demand and Supply in Valandovo (23) (No. in Former Municipality)
: Water shortage is estimated in Valandovo seasonally in 1996 and 2025

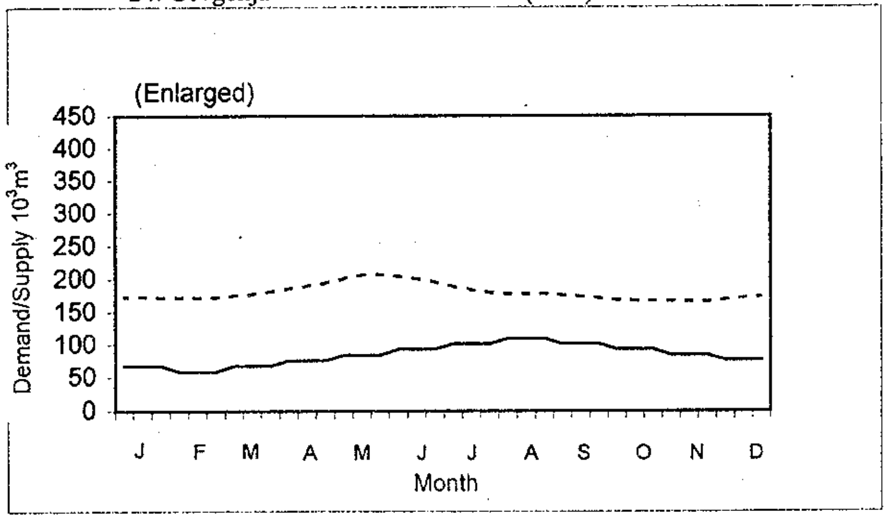
24. Gevgelija (1996)



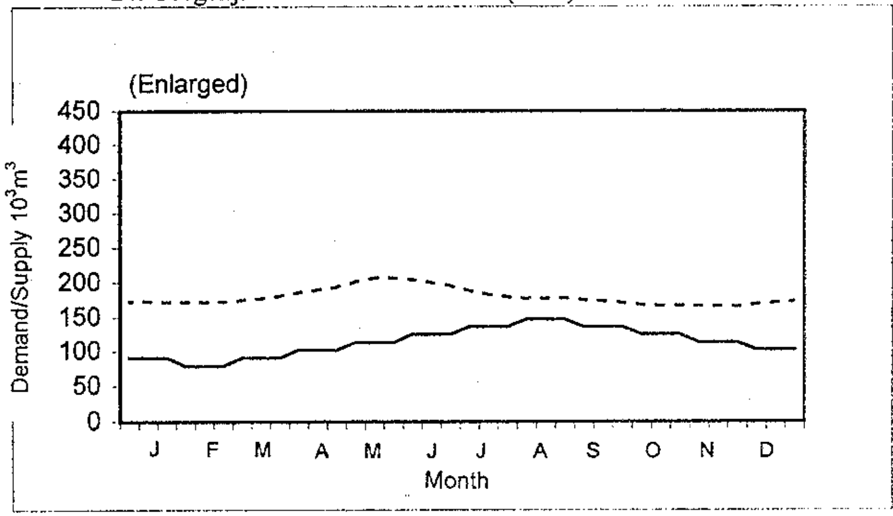
24. Gevgelija (2025)



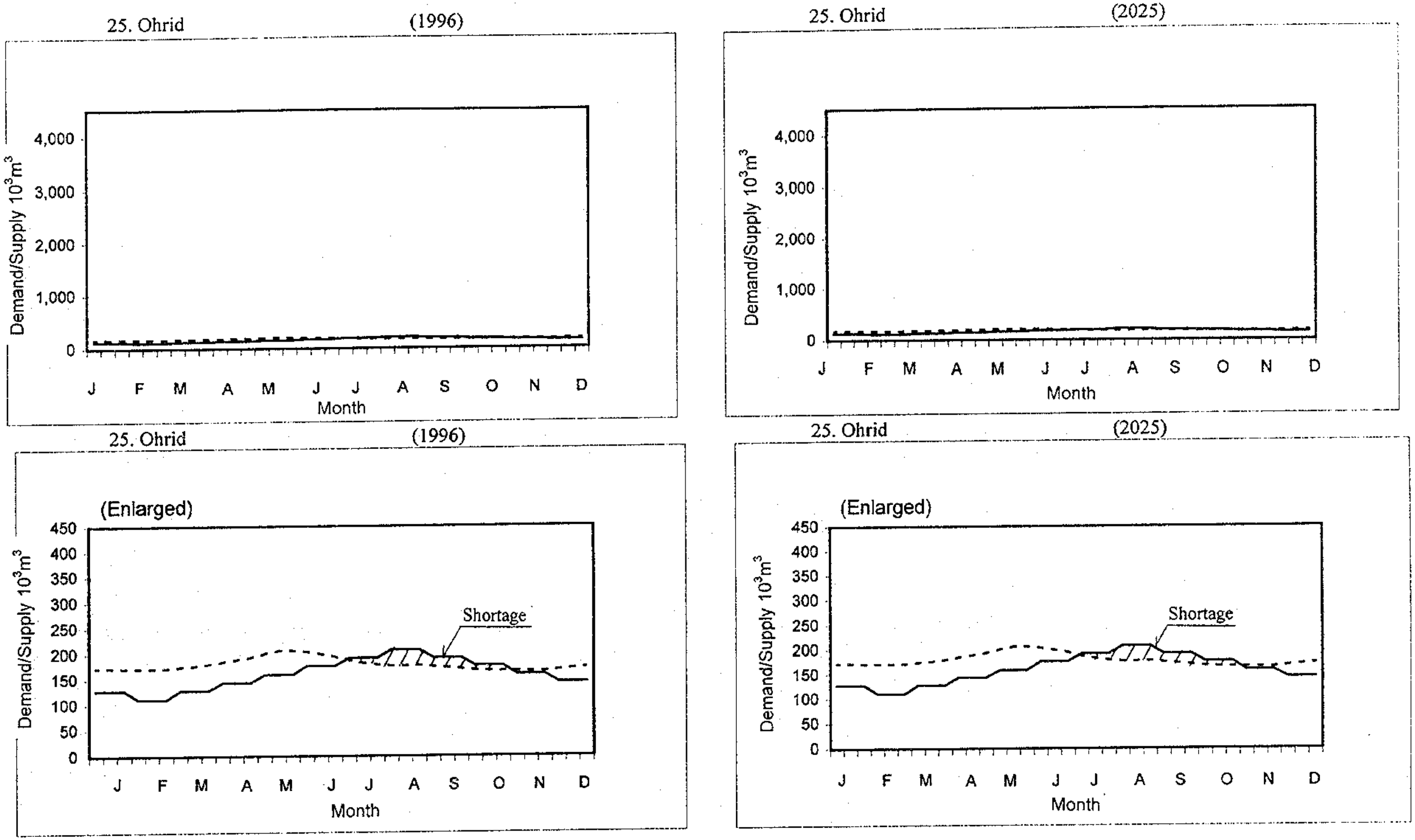
24. Gevgelija (1996)



24. Gevgelija (2025)

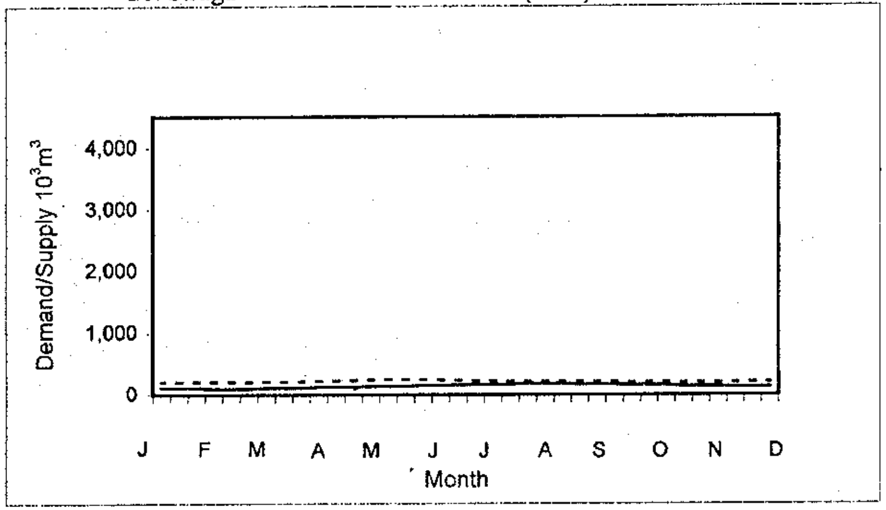


Balance between Water Demand and Supply in Gevgelija (24) (No. in Former Municipality)
: No water shortage is estimated in Gevgelija in 1996 and 2025

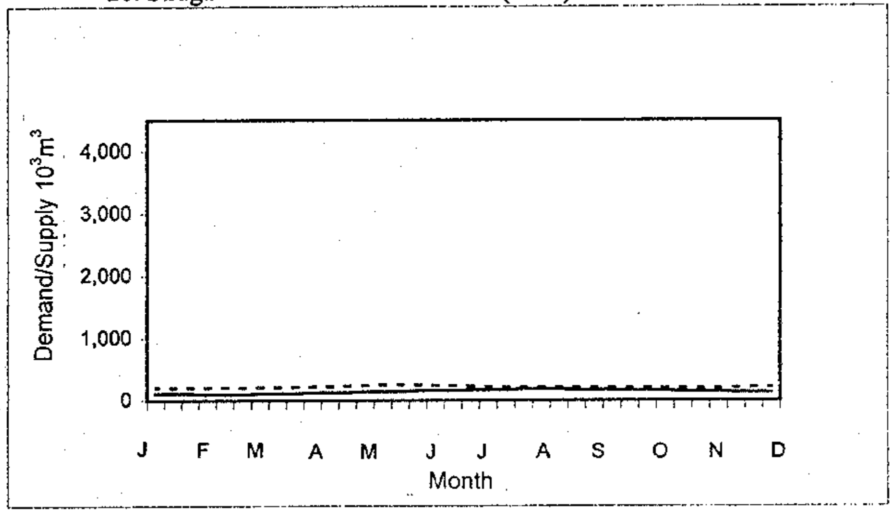


Balance between Water Demand and Supply in Ohrid (25) (No. in Former Municipality)
: Water shortage is estimated in Ohrid seasonally in 1996 and 2025

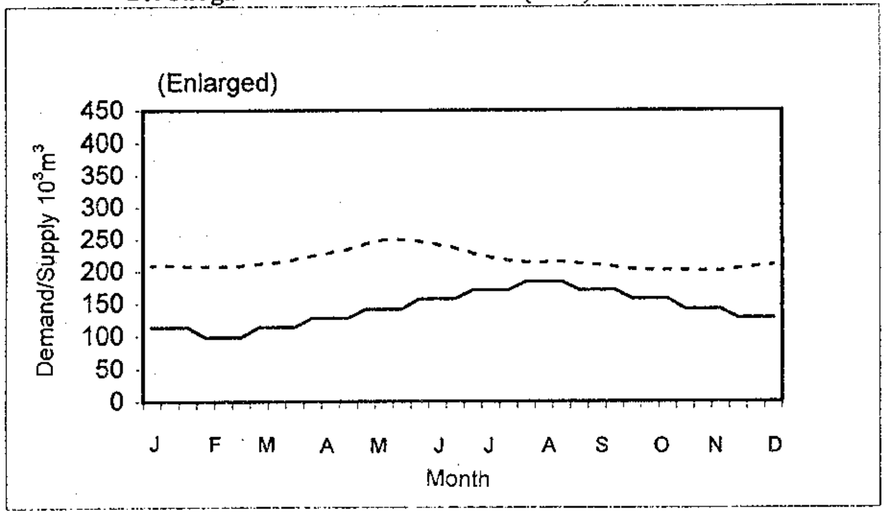
26. Struga (1996)



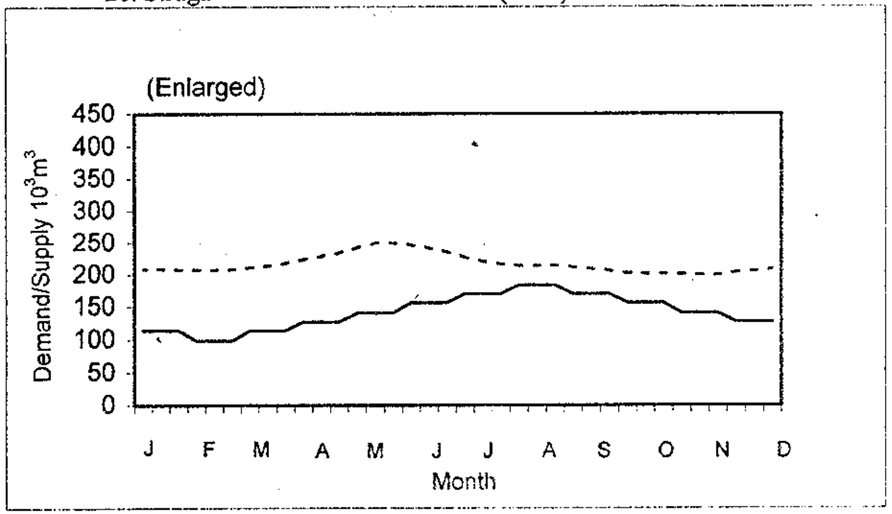
26. Struga (2025)



26. Struga (1996)

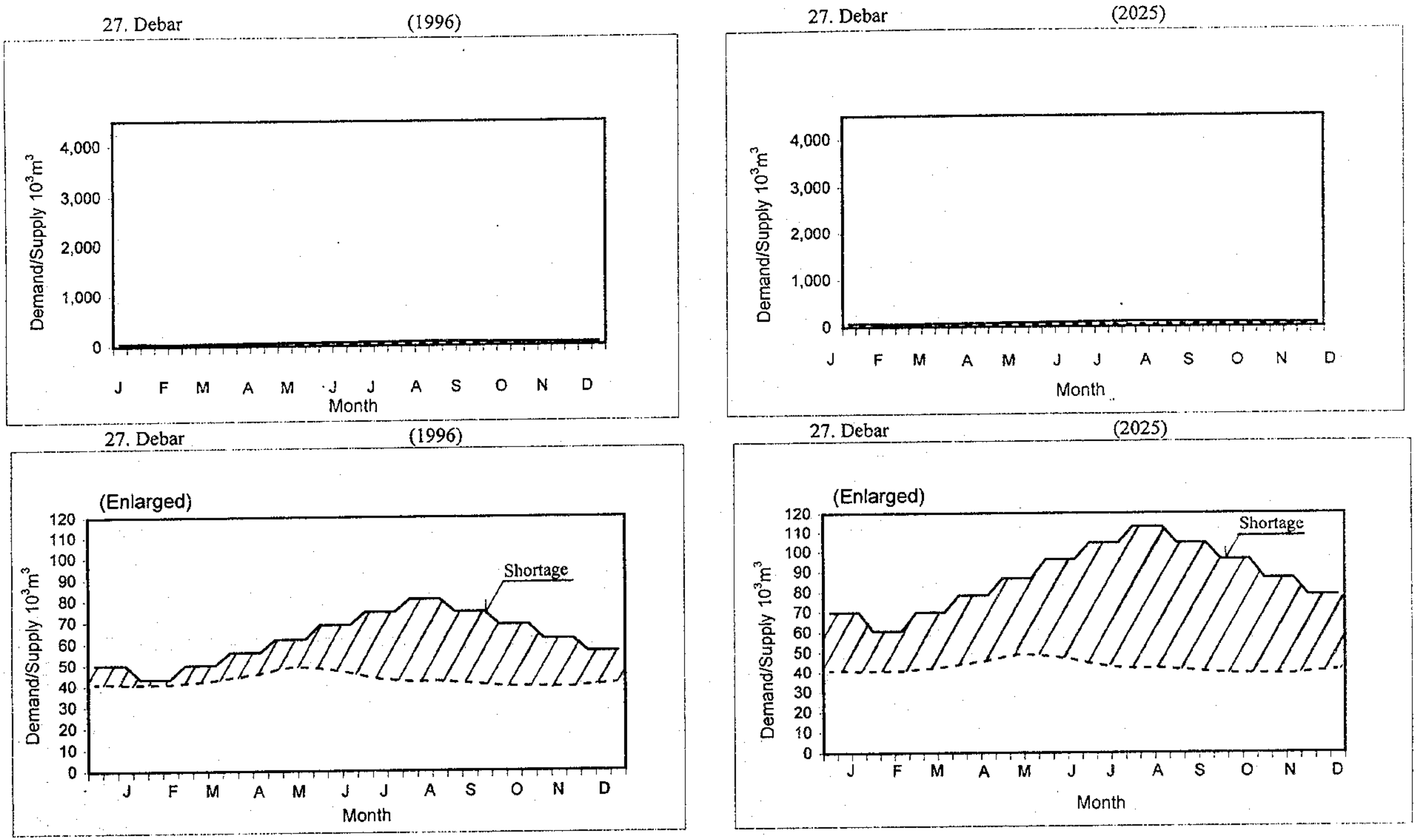


26. Struga (2025)



Balance between Water Demand and Supply in Struga (26) (No. in Former Municipality)

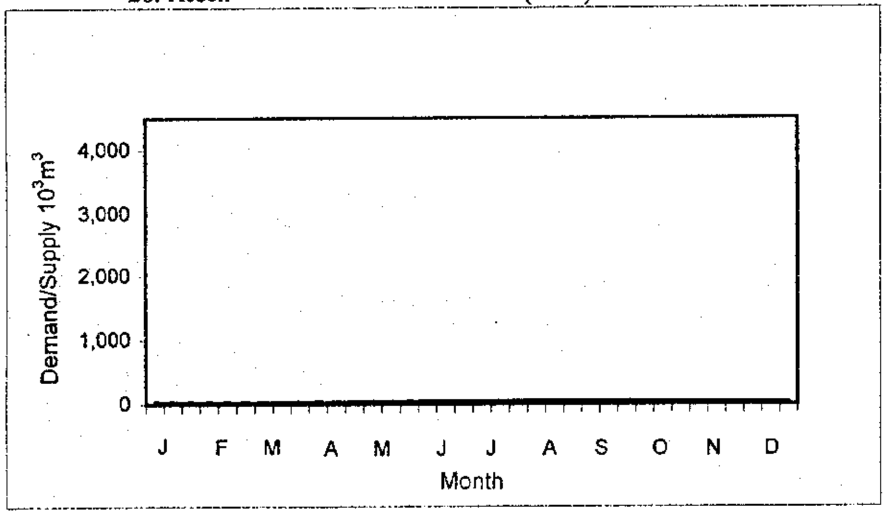
: No water shortage is estimated in Struga in 1996 and 2025



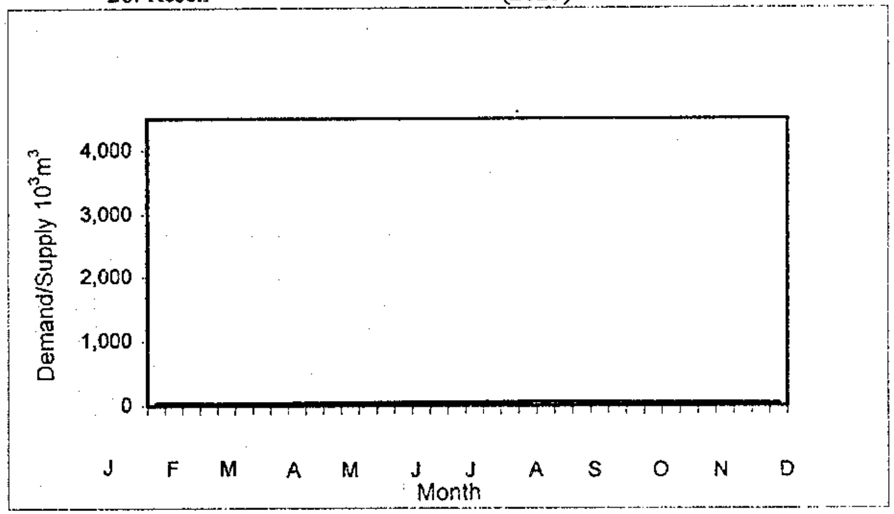
Balance between Water Demand and Supply in Debar (27) (No. in Former Municipality)

: Water shortage is estimated in Debar through the year in 1996 and 2025

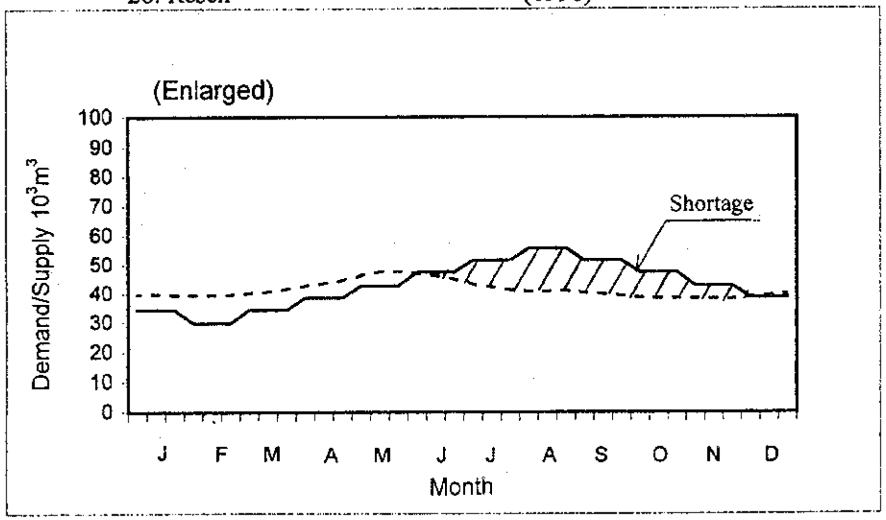
28. Resen (1996)



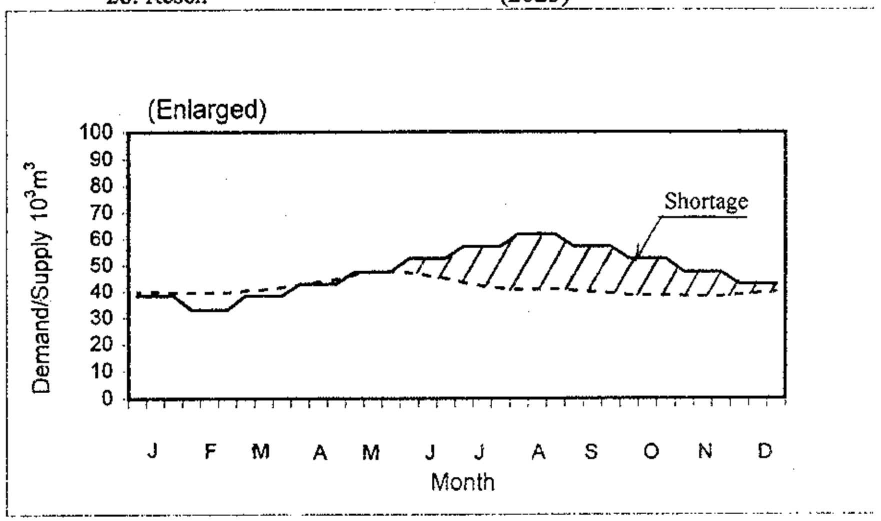
28. Resen (2025)



28. Resen (1996)

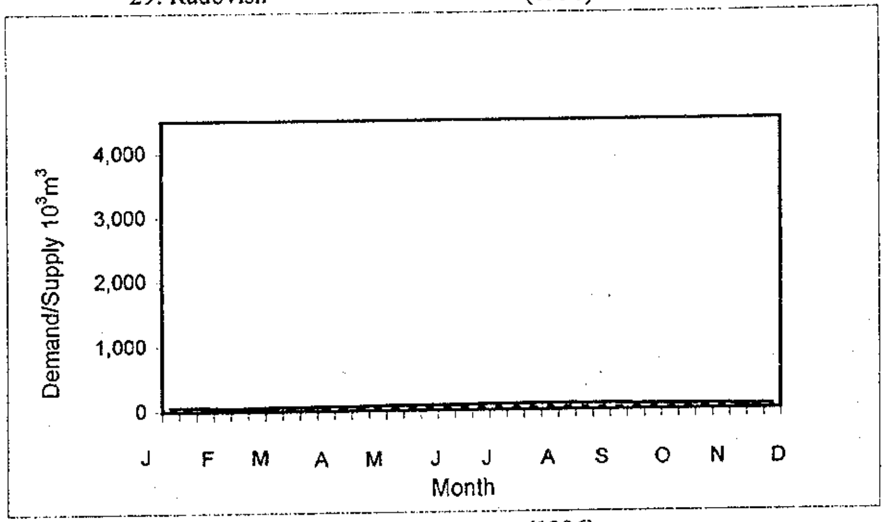


28. Resen (2025)

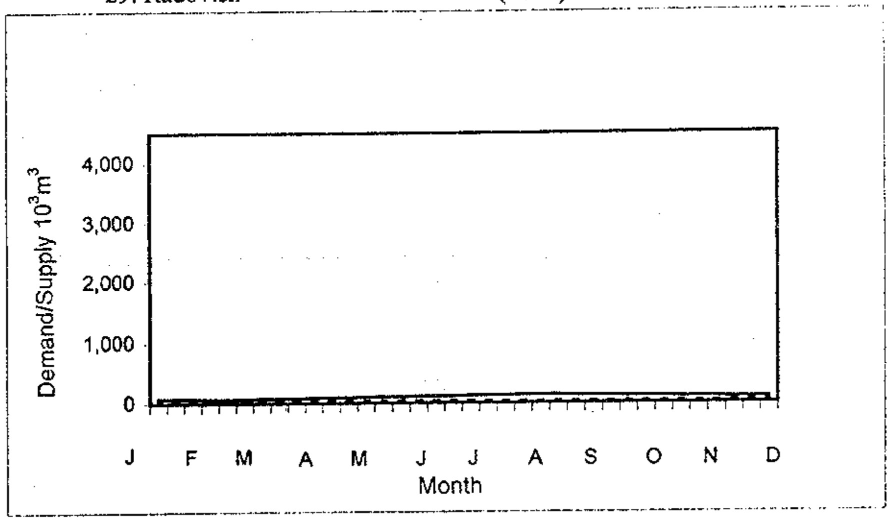


Balance between Water Demand and Supply in Resen (28) (No. in Former Municipality)
: Water shortage is estimated in Resen seasonally in 1996 and 2025

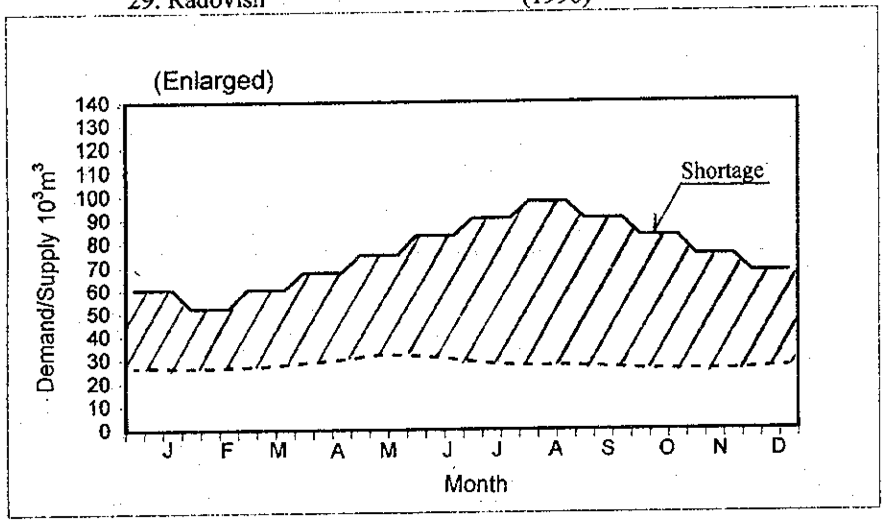
29. Radovish (1996)



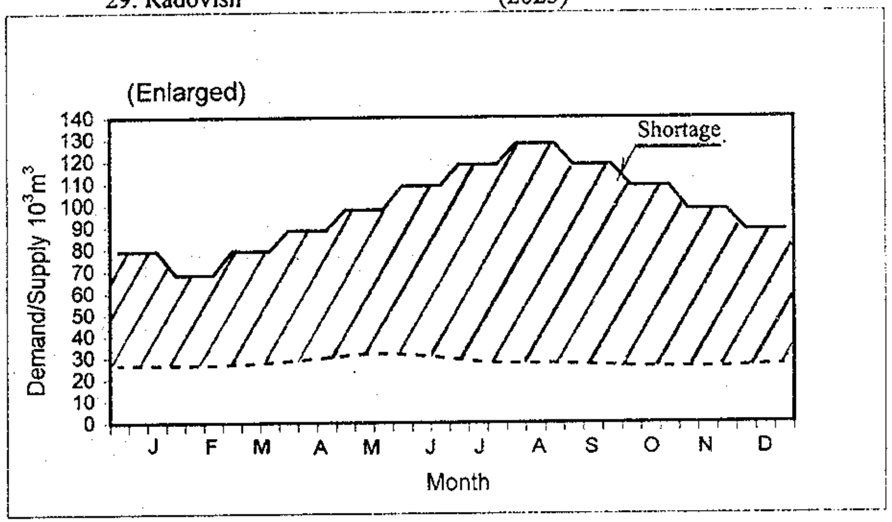
29. Radovish (2025)



29. Radovish (1996)



29. Radovish (2025)



Balance between Water Demand and Supply in Radovish (29) (No. in Former Municipality)
: Water shortage is estimated in Radovish through the year in 1996 and 2025