GEOGRAPHICAL INSTITUTE "JOVAN CVIJIĆ" SASA **JOURNAL OF THE …**
Vol. 60 № 2 **YEAR 2010**

Original scientific paper 911.2:551.49

HYDROLOGICAL PICTURE OF NIŠAVA TRANS-BOUNDARY CATCHMENT

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Abstract: This work focuses on hydrographic and hydrological specific of Nišava River. It uses all hydrometric and cartographic information for the Bulgarian part of the catchment. Trans-boundary catchment of Nišava River includes four sub-basins, which are trans-borders too. There are a lot of karst areas in the river basin. The drainage density is 1.09 km/km^2. Water resources of Nišava River are 170 million m^3. They vary between 300.0 and 84.0 million m^3. The period of high water appears in March/April and finishes in June. The frequency of monthly maximum is biggest in April or May. The monthly minimum appears most often in September or October. Floods in the catchment of the river Nišava are most often in March, May and June. Some of the rivers lose its waters in the karst areas and dries up during the summer. The average number of days with ice is between 10 and 70. The chemical and ecological status of river water is good.

Key words: Nišava River, water resources, stream flow's regime

Introduction

There are 71 international river basins in Europe witch cover 54 % of total area (Wolf *et al*., 1999). One of them – Danube basin, includes some trans-boundary catchments between Bulgaria and Serbia – drainage basins of Timok River (right tributary of Danube) and Nišava River (right tributary of South Morava). There is a project for Timok River (Bilateral arrangements for a trans-boundary management of water resources, 2008) between Bulgaria and Serbia, but there not common hydrological investigations for Nišava River. In Bulgaria there are no purposeful studies on the river Nišava. Some aspects of the hydrological regime of the river were investigated by Blagojević *et al* (2007), Ninković *et al* (2009), Miljojković *et al* (2010). That's why this work presents some hydrographic and hydrological characteristics of Nišava River for the Bulgarian part of its basin. It is the first step towards the creation of a water cadastre for River Basin Nišava and step for a future integrated management of water resources. Trans-boundary cooperation is facilitated by the European Water Framework Directive and the Convention of UNECE.

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Data and results

Hydrographic information

Nišava River Basin is situated in western periphery of Bulgaria. It borders to the north with the River Basin Ogosta, to the east is in the vicinity of the Iskar River, to the south is separated from the Struma River through the main divide. Nišava River Basin in the Bulgarian part consists of the upper reaches of the river and its tributaries – Visočica, Gaberska and Erma (Figure 1). Catchment area of river Nišava is 1137.11 km^2.

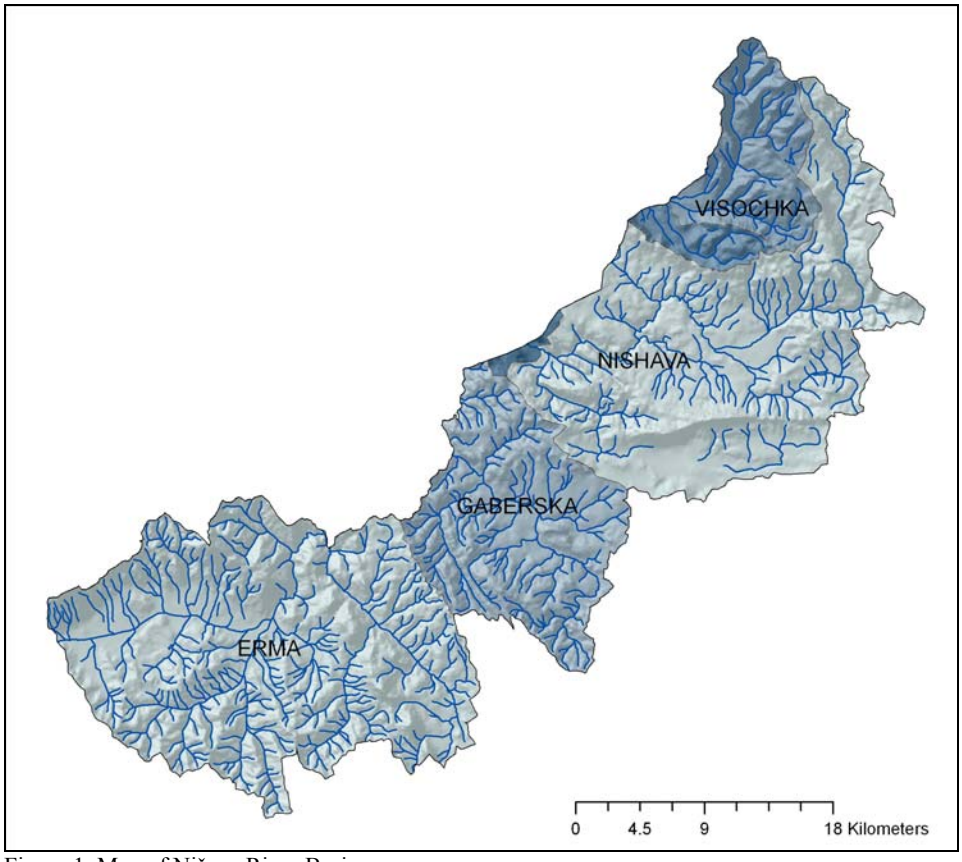

Figure 1. Map of Nišava River Basin

The total streams length is 1237.71 km (Table 1). The density of river network is 1.09 km/km^2 and varies between 0.85 and 1.30 km/km^2.

Table 1. Hydrographic data

River	Length (km)	Total streams length (km)	Catchment area (km^2)	Drainage density (km/km^2)
Nišava	97.0	335.27	395.31	0.85
Gaberska	35.6	240.06	194.12	1.24
Visočica	16.7	94.38	111.53	0.85
Erma	25.0	568.00	436.35	1.30
Nišava - total		1237.71	1137.11	1.09

Nišava starts from karst springs (with coordinates 43°10'N and 23°04'E) in southeastern slope of peak Kom[2]. It is named Ginska River in upper stream. Ginska River crosses karst area and accepts some small tributaries near by Razboishte - Dracula River, Stanyanska River, Cheparlenska River and some small streams, which dry up in summer. Ginska River turns sharply in the west under Poleglitsa (part of Gintsi). It gets water from Gubeshka River (right tributary), passes through Godech and gets name Nišava. Last tributary of the River Nišava is Yezhovitsa River (takes its source from Vishanski height) with its tributary Letnitsa River.

Visočica River starts from Berkovska planina (near Srebarna Peak - 1931.3 m) under the name Srebarna. The river runs to south, reaches the Zabarde region, enters the Visok depression and turns west at the village of Komshtitsa. Visočica River crosses the Bulgarian-Serbian border after few kilometers the village Komshtitsa. The river system includes small tributaries: from left - Kamarska River (L = 3.6 km, F = 4.7 km^2), Kuratska River (L = 6.85 km, F = 11.2 km^2) with its right tributary Sredna River (L = 4.3 km, F = 4.6 km^2) and Ranovtsitsa River, which flows into Visotchitsa outside of the border. The biggest right tributary is Barlka River.

Gaberska River and its left tributaries begin from Viskjar Mountain. It is called Povalirazka in the upper reaches. Gaberska River flows in the meridional direction, formed several meanders and change direction in northwestern. The river takes several small tributaries till village Gaber: from the left – Yalbotinska (Chekanska), Krushenska (Prevalska) and Sharbanitsa and from the right – Tabanska, Kalugeritsa and Tranavachka bara. It forms a small gorge before village Dragotintsi. River network of Gaberska River is dendritic drainage system.

[2] The beginning of Nišava, according to travelers in the past, is Ezovitsa River that starts near the city Dragoman (Irechek, 1974).

Erma River enters in Bulgaria near by the village Strezimirovtsi. Its river network includes small tributaries - Jablanitsa (L = 24.6 km, F = 140.0 km^2), Lishkovitsa (L = 15.5 km, F = 94.0 km^2), Zelenigradska River, Selska River, Bohovska River, Mramorska River, Businska River, Glogovishka River. Left tributaries spring from Rui Mountain. They are short. Right tributaries are longer and more continuous flow, but dry up in dry years in parts of its course. All spring from Kraishte.

Most rivers in catchment of Nišava are small by length and catchment's area. Exceptions are Gaberska River and Erma River, which are medium and Nišava River, which is medium big (Sarafska, 2000).

Catchment area of river Nišava includes some morfographic units – south slopes of Berkovska Mountain (2016 m), Viskjar Mountain (1077 m), Zavalska Mountain (1403 m), Straza Mountain (1389 m), part of south slopes of Rudina Mountain and Znepole valley (770 m). The lowest point – 590 m, is the confluence of the Jablanitsa River into the Erma River. The climate of Nišava basin is typical continental. The coldest month is January, with negative temperature, the warmest month – July (Table 2). The average annual rainfall is above 1000 mm in the mountainous part and 600 mm in the valleys. There are between 40 days (Kraiste) and 120 days (Balkan Mountain) with snow coverage in the catchment.

Table 2. Climatic characteristics of the river basin Nišava

Station		Months												An.
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Petrohan	T °C	-5.0	-4.2	-2.0	3.6	8.5	12.0	14.0	14.2	10.6	6.2	2.0	-2.0	4.8
	P mm	73	69	75	109	156	153	99	71	78	92	97	85	1157
Tran	T °C	-3.3	-0.8	2.9	8.4	13.3	16.0	18.0	17.2	13.5	8.8	4.6	-0.7	8.2
	P mm	41	38	36	51	73	84	56	42	41	50	51	47	610

Rainfall is between 7.0 and 31.5 l/s/km^2. It is the highest in the catchment of Visočica and Ginska River and about 7-10 l/s/km^2 for Erma River. Rainfall increases with increasing altitude of river basin (Figure 2). The line is nonlinear.

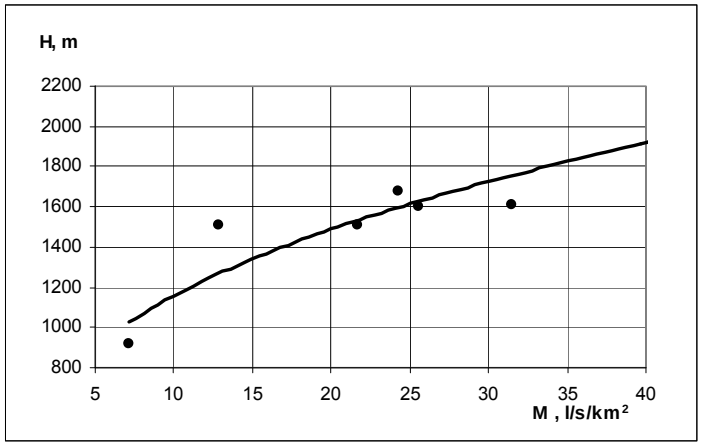

Figure 2. Relationship between elevation and rainfall

There are some karst areas in Nišava catchment – Nisavski, Gaberaski, Ponorski, Ljubashki, Trunski (Antono, 1961, Benderev *et al*, 2005). Nišavski karst basin is developed in dolomite limestone from the middle Triassic. There is shallow water circulation. Sources are highly variable regime. Among them are greater in those Komshtitsa (10-100 l/s), Ropotski (50-150, 5-30 l/s), Zlidolski (50-500, 15-40 l/s), Godečki (10 l/s), Vrelo (60-1000 l/s), Drakon (30-60 l/s), Lopushna (30-50 l/s). Gaberski karst basin is developed in limestone of the Upper Jurassic. It is with deep water circulation. The springs are a constant flow upward – Toplika - near village Nesla (50 l/s) and Vreloto (80-120 l/s) and etc. Lyubashki karst basin gives springs near by village Bankya (85-157 l/s) and village Zeleni vir (80 l/s). Resources of karst water (the sum of estimated average flow of the springs) and operational resources (the sum of minimum flow to the same sources) are similar (Table 3).

Table 3. Resources of groundwater

Hydrogeological unit	Type of groundwater	Natural resources		Operational resources	
		l/s	$m^3 \cdot 10^6$	l/s	$m^3 \cdot 10^6$
Dragoman field	alluvial	30	1.0	30	1.0
River Terrace Nišava	alluvial	10	0.3	18	0.5
River Terrace Gaberska	alluvial	15	0.5	25	0.8
River Terrace Erma	alluvial	100	3.0	130	4.0
Nišava karst area	karst	1000	31.5	400	12.6
Gaberska karst area	karst	230	7.2	130	4.1
Ljubashka karst area	karst	200	6.3	150	4.7
Trunska karst area	karst	50	1.6	50	1.6
All		1635	51.4	933	29.3

Water temperature of those springs is 17-18 ^{o}C. Trunski karst basin includes some small carbon bodies. Its bigger spring is "Transka banja" (50 l/sec). Chemical composition of karst water was hydro-calcium-sodium and mineralization is less than 1 g/l (Table 4).

Table 4. Mineralization and chemical composition of the karst water

Spring	Mineralization (g/l)	Ion composition					
		Cations			Anions		
		Na+K	Ca^{2+}	Mg^{2+}	Cl^{-}	SO_4^{2-}	HCO_3^{-}
Komshtitsa	0.4	4.76	66.1	10.9	3.55	8.60	243.85
Ropot	0.4	15.10	54.1	13.4	3.55	13.2	254.50
Vreloto	0.6	10.3	102.2	21.3	6.21	15.60	397.35
Drakon	0.6	9.1	105.2	15.2	8.87	18.50	385.4
Zlidol	0.5	19.5	45.1	7.3	1.77	5.80	215.0
Vrelo (Berende)	0.7	31.51	102.2	21.3	6.21	5.30	459.45
Lopushna	0.4	15.40	61.1	25.5	4.44	9.10	311.10
Vrelo (Banja)	0.6	11.43	69.0	45.6	8.77	23.46	420.90
Toplika (Nesla)	0.5	22.13	53.0	32.0	7.09	37.86	314.15

Source: Antonov (1961)

There aren't a lot of anthropogenic activities in the river basin of Nišava. The settlements in the catchment are 97: 3 small towns (Dragoman, Godech and Tran) and 96 villages. Cities have not treatment plants for effluents. The environmental impact of the mining activity is biggest for Stanjanska River and a section of Gaberska River. Mihaylova *et al* (2009) has fixed small areas with vulnerability of karst water – in catchment of Ginska River (around village Gintsi) and region of Dragoman marsh (karst wetland). The reason is agriculture. Waters of Erma River is discharged into a dam "Yarlovets" (W – $5.91.10^6$ m^3) through the channel.

Drainage Basin of Nišava River is water body BG1NV200R001, of the catchment of Erma - BG1ER100R001 (according to the requirements and methodologies of the Water Framework Directive 2000/06/EC)

Hydrological characteristics

The base of this investigation is dates from hydrometric monitoring network of Nišava river basin in Bulgaria. The period of observation is short for the most of the stations (Table 5). This study uses all hydrometric information, regardless of short periods of observation.

Table 5. Information of stream gauge stations

River - Station	Length from source (km)	Area (km^2)	Average elevation of catchment (m)	Observation period	
				Opening date	Closing date
Erma - Tran	35.80	358.0	919	25. X 1935	continue
Erma - Strezimirovtsi	25.40	117.0		20. IX 1961	31.XII 1967
Jablanica - Sekiritsa	17.60	133.0		19. IX 1961	31.XII 1967
Ginska - Boishte		9.90	1681	18. VII 1949	continue
Ginska - left trib. Boishte		2.74		2. X 1953	continue
Nišava - Kalotina	36.5	267.0		1. IX 1966	continue
Visočica (Srebarna) - 8 km above Komshtitsa	3.40	5.40	1611	14. VII 1950	30. XI 1956
Visočica (Srebarna) - near by Komshtitsa	8.70	49.4		8. IX 1961	31. XII 1967
Kamarska - Komshtitsa	3.40	4.60	1603	9. VIII 1950	17. IV 1953
Kuratska - Komshtitsa	5.60	10.10	1511	17.VIII 1950	17. IV 1953
Sredna - Komshtitsa	4.10	4.60	1509	11. VII 1950	30. XI 1956

The mean annual runoff is between 0.10 m^3/s (Sredna River) and 2.57 m^3/s (Erma River - Tran) or between 3.2 and 81.1 million m^3 (Table 6).

Table 6. Annual stream flow

River-station	Annual stream flow (m^3/s)			C_v	W $m^3 \cdot 10^6$
	Q_{max}	Q_{av}	Q_{min}		
Erma - Tran	4.67	2.57	1.01	0.34	81.1
Erma - Strezimirovtsi	1.52	1.07	0.67	0.29	34.0
Jablanica - Sekiritsa	1.62	1.06	0.36	0.38	33.5
Ginska - Boishte	0.41	0.24	0.08	0.25	7.7
Ginska - left trib. Boishte	0.32	0.11	0.05	0.52	3.5
Nišava - Kalotina	3.47	2.00	0.91	0.31	63.4
Srebarna - 8 km above Komshtitsa	0.25	0.17	0.10	0.29	5.4
Visočica (Srebarna) - near by Komshtitsa	0.82	0.55	0.15	0.36	17.5
Kamarska - Komshtitsa	0.07	0.11	0.17	0.45	3.4
Kuratska - Komshtitsa	0.09	0.13	0.16	0.27	4.0
Sredna - Komshtitsa	0.05	0.10	0.13	0.27	3.2

The coefficient of variation 0.19 – 0.37, shows small fluctuations for the mountainous rivers and big fluctuations for the lower stream of Erma and Nišava. The annual water volume of Nišava River is $173 \cdot 10^6$ m^3 (Table 7). It varies between $304 \cdot 10^6$ m^3 in abounding in water year (5 %) and $83.6 \cdot 10^6$ m^3 in dry year (95 %). The most part of water resources belong to Erma River (Table 7).

Table 7. Annual volume of stream flow

River	W $m^3 \cdot 10^6$	W $m^3 \cdot 10^6$				
		5 %	25 %	50 %	75 %	95 %
Erma	101.0	181.0	131.0	97.8	50.4	44.2
Nišava	72.4	123.0	90.8	69.4	42.6	39.4
Nišava - total	173.4	304.0	221.8	167.2	93.0	83.6

The river regime includes short period of high water (April – June) and long period with law water (July – October and January – March) in mountainous river basin (Figure 3). The water level begins to rise from January and finishes in June for lower Stream of River Nišava and River Erma.

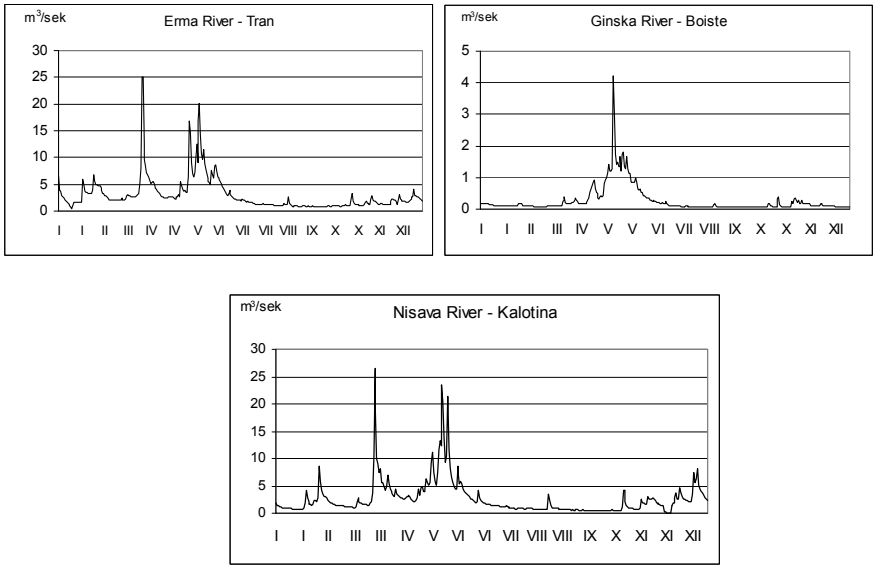

Figure 3. Daily discharges for year 1980

There is another approach for the analysis of hydrological regime. This is the so-called water-balance year defined as period with beginning from month when the high water starts (Hristova, 2000). This method shows up very well the period with high water (the period when monthly flow is above annual flow) and the period with law water (the period when monthly flow is bellow annual flow). By this way hydrological cycle includes only two flow's phases. Exceptions are the river basins with developed karst - their hydrological cycle includes three or four flow's phases (Figure 4). The water-balance year begins in February for Erma River and for lower basin of the Nišava (Figure 4). The period with high

water is 5 months (February – June) and the period with law water is 7 months (July – January). The volume of water during this period is between 63.2 % (Nišava - Kalotina) and 66.7 % (Erma - Tran) from annual volume of the river flow.

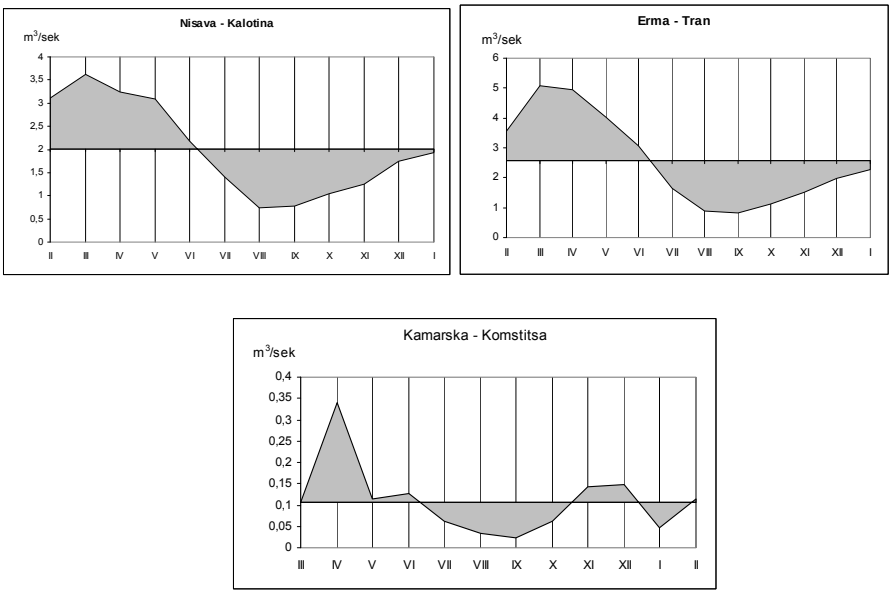

Figure 4. Hydrographs for water-balance year

The water-balance year begins in March for Ginska River and for Visočica (Srebarna) and its tributaries (Figure 4). The period with high water begins from March and finishes in June. Exceptions are Kamarska River and Kuratska River. The period with high water appears two times for Kamarska River: March – June and November – December (Figure 4). Monthly flow is above annual flow during period March – June and in December for Kuratska River.

Distribution of mean monthly discharge is studied through the hydrological year, which started for Bulgaria in November. Maximum of monthly stream flow appears in March for Erma River (Table 8, Figure 5). Its frequency is between 50 and 66 %. The volume of river flow during this month is 16.4 – 21.4 % from annual flow. March and June are the months with most floods. Duration of floods is between 24 and 160 hours. Absolute maximum is 180 m^3/s. It is registered on 22 June 1944. Monthly minimum for Erma River comes in September. It appeared in some years and in August, rare in October. Its percentage from annual volume of river flow is 0.9 - 2.7.

March is the month for maximum of river runoff for lower catchment of Nišava River. Then pass about 15 % from annual river flow. The biggest monthly flow for Ginska River is in May. Its frequency is between 47.6 % and 61.3 %. May is the month with most of the flood for this river. Duration of floods is between 23 and 96 hours for Ginska River and 30 - 119 hours for Nišava River. Absolute maximum is 19.8 m^3/s (16 June 1961) for Ginska River and 83.5 m^3/s (12 July 1970) for Nišava. The monthly minimum river flow is in January for the mountain watershed and in August for the lower river basin of Nišava (Table 8).

There are two maximums of monthly streamflow in watershed of Visočica (Srebarna) – April and December. Monthly maximum in April is very stable –its frequency is 50 - 83 %. Kamarska River and Kuratska River have two monthly maximum of river flow too and in the same months (Table 8). Exception is Sredna River – maximums of streamflow appear in April and October. Catchment area of river Visočica is different and for the monthly minimum river flow. August and February are months for monthly law water. There are two monthly minimum streamflow in catchment of Kuratska River, but in September and January. Reason for this distribution of discharge in the average year is karst.

There are three types hydrological regime in Bulgaria: Mildness-continental type – with spring high water, summer-autumn low water and transitional water during winter; Continental-Mediterranean type – with winter-spring high water and summer-autumn low river flow; Transitional type – with spring-summer high water and increase in stream flow during November and December, steady low water from July (August) till October and winter low water (Hristova, 2003). The rivers from Nišava catchment belong to Mildness-continental type: Erma River and its tributaries – to first sub-type (with equal duration of the high water, the low water and the transitional water, which are four months); Ginska River and Visočica River – to second sub-type (with high water, which are five months, short low water and transitional water from November till February).

Table 8. Monthly distribution of river flow in Nišava river basin

River-station		Months											
		XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X
Erma - Tran	m^3/s	1.52	1.97	2.27	3.55	5.07	4.95	4.01	3.05	1.66	0.89	0.84	1.12
	%	4.9	6.4	7.3	11.5	16.4	16.0	13.0	9.9	5.4	2.9	2.7	3.6
Erma - Strezimirovtsi	m^3/s	0.54	0.75	0.92	1.32	2.17	2.72	1.69	1.25	0.67	0.28	0.27	0.36
	%	4.1	5.8	7.1	10.2	16.6	21.1	13.1	9.7	5.2	2.2	2.1	2.8
Jablanica - Sekiritsa	m^3/s	0.34	0.96	1.55	2.61	2.71	1.78	1.01	0.97	0.41	0.18	0.12	0.13
	%	2.6	7.5	12.1	20.5	21.4	13.9	7.9	7.6	3.2	1.4	0.9	1.0
Ginska - Boishte	m^3/s	0.16	0.16	0.13	0.12	0.18	0.49	0.62	0.38	0.25	0.15	0.14	0.14
	%	5.4	5.0	4.2	4.2	6.2	16.4	21.8	13	8.8	5.3	4.9	4.8
Ginska - left trib. Boishte	m^3/s	0.08	0.08	0.07	0.06	0.09	0.20	0.26	0.16	0.12	0.07	0.08	0.08
	%	6.2	5.7	5.2	4.7	6.5	14.7	19.2	11.7	9.2	5.5	5.6	5.8
Nišava - Kalotina	m^3/s	1.25	1.73	1.94	3.12	3.61	3.23	3.06	2.2	1.4	0.73	0.77	1.05
	%	5.2	7.2	8.1	12.9	15.0	13.4	12.7	9.1	5.8	3.0	3.2	4.4
Visočica (Srebarna) - 8 km above Komshtitsa	m^3/s	0.15	0.16	0.12	0.09	0.17	0.48	0.38	0.17	0.10	0.07	0.06	0.10
	%	7.3	7.9	5.9	4.3	8.4	23.2	18.4	8.3	4.9	3.5	2.9	5.0
Visočica (Srebarna) - near by Komshtitsa	m^3/s	0.25	0.16	0.33	0.36	1.02	2.32	1.24	0.45	0.16	0.001	0.09	0.03
	%	3.9	2.5	5.1	5.6	16.0	36.2	19.3	7.1	2.5	0.002	1.4	0.4
Kamarska - Komshtitsa	m^3/s	0.14	0.15	0.05	0.11	0.11	0.34	0.12	0.13	0.06	0.03	0.02	0.06
	%	10.6	11.3	3.5	8.6	8.0	25.8	8.8	9.5	4.7	2.5	1.9	4.8
Kuratska - Komshtitsa	m^3/s	0.10	0.16	0.09	0.07	0.15	0.37	0.19	0.14	0.09	0.04	0.05	0.0
	%	6.4	10.5	6.3	4.9	9.7	24.3	12.3	9.3	5.7	2.6	3.2	4.8
Sredna River - Komshtitsa	m^3/s	0.06	0.09	0.09	0.08	0.12	0.21	0.19	0.12	0.06	0.04	0.06	0.10
	%	5.2	7.3	7.1	6.5	10.1	17.3	15.5	9.6	4.7	3.5	4.8	8.4

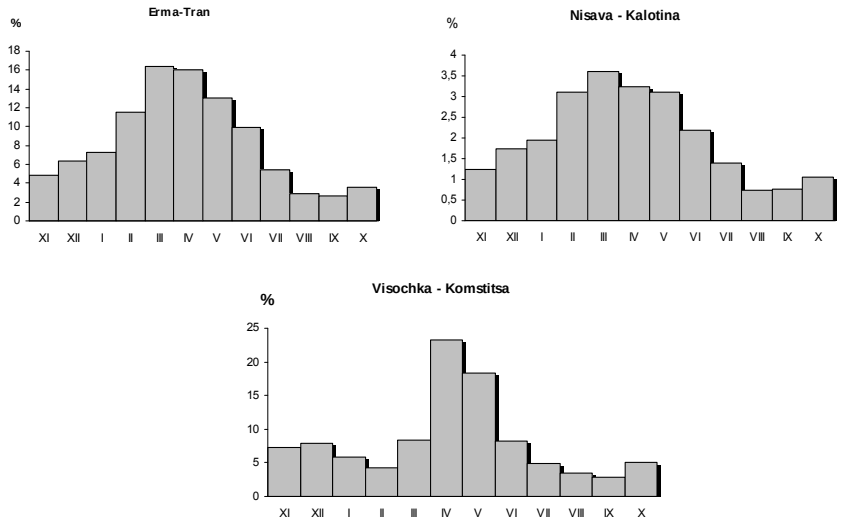

Figure 5. Mean discharge regime

Distribution of river flow truth hydrological seasons[3] shows predominating of spring stream flow (Table 9). This fact is evidenced by the values of the relation between water volumes of the winter (Kw_w) and spring (K/w_s) river runoff. Coefficient Kw_w/w_s is 0.22 (Visočica - Komshtitsa) – 0.84 (Jablanica - Sekiritsa). Its value includes catchment of Nišava in continental hydrological region.

Table 9. Seasonal distribution of river flow (%)

River - station	Hydrological season			
	Winter	Spring	Summer-Autumn	Kw_w/w_s
Erma - Tran	29.5	55.4	15.1	0.53
Jablanica - Sekiritsa	42.7	50.7	6.6	0.84
Ginska (Nišava) - Boishte	20.2	56.7	23.1	0.35
Nišava - Kalotina	33.3	50.2	16.5	0.66
Srebarna - 8 km above Komshtitsa	25.3	58.3	16.4	0.43
Visočica - Komshtitsa	17.1	78.5	7.4	0.22
Sredna River - Komshtitsa	26.2	52.4	21.4	0.50

[3] There are three hydrological seasons in Bulgaria – winter (XI – II), spring (III – VI) and summer-autumn (VII – X), defined by Panajotov and accepted for researching.

Conclusion

Catchment of Nišava River includes four cross-border sub-basins and two water bodies (defined by the Water Framework Directive). Its water resources are $173 \cdot 10^6$ m^3, of which $51.4 \cdot 10$ m^3 are groundwater. Almost half of water resources are formed during March –June – period of high water and of risk of flooding. The Nišava river water quality status is good. Water resources which have used for irrigation and water-supply are less than their natural volume. It is important for water consumptions in Serbian part of the catchment. Basis for future cooperation in water management of Nišava River is Cross-border Cooperation Programme between Bulgaria and Serbia, 2007 – 2013 which was approved by the European Commission on March 25, 2008. The program includes specific measures for the development of infrastructure concerning environmental issues such as small-scale infrastructure for pollution prevention, waste management, floods and erosion prevention.

Manuscript submitted on 18 June 2010; accepted on 11 October 2010.

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