

AN ASSESSMENT OF WATER RESOURCES USE IN THE TUNDJA RIVER BASIN

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Abstract

Probably our greatest global challenge is the shortage of water, because this affects food and energy production. Many places in the world just don't have enough water. This is partly due to climate change, but especially due to increasing urbanization. Cities are growing at staggering rates, and to find water requires travelling further and further away from the densely populated areas. This is not a sustainable situation. With the growing urban demand, groundwater levels are sinking, and this not only means that water supplies are drying up, but that the water quality is deteriorating, due to chemical changes in the soil layers.

Key words: water supply, water resources, water exploitation index

1. INTRODUCTION

Bulgaria is one of the poorest of water resources countries in the European Union. The average annual runoff depending on the humidity of the year varies between 9 and 24 billion m³ without taking into consideration the River Danube. The average annual amount per capita is about 2300-2500m³ (for Europe this value is 5300 m³). With the availability of these water resources Republic of Bulgaria is among the five poorest countries in water resources in Europe with Poland, Czech Republic, Belgium and Cyprus (Vassilev, V., P. Sarnev, 2011).

Nowadays in Europe, effective management of water resources is regulated by various EU directives, based on which each country should form its policy for management and protection of its own available water resources. Integrated management of water resources is one of the main objectives set by the Water Framework Directive of the EU.

A great number of papers of the European Environment Agency are aimed at improving the efficiency of water resources use and management. An objective of EU's Sixth Environment Action Programme (ended in July 2012, but many measures and actions launched under that programme continue to be implemented) requires monitoring the efficiency of water use by different economic sectors at the national, regional and local level. Protecting water resources and ensuring their ecological quality is a cornerstone of EU environmental policy.

Water resources in Bulgaria are highly irregular and unevenly distributed, both within the territory of the country and in different seasons of the year. In certain areas there is significant water deficit, which leads to seasonal and year round regime of water supply of the population (Draft Strategy for sustainable development of the Republic of Bulgaria).

In order to input an optimal model for water management by means of the water infrastructure and finding some opportunities for investments a National Strategy for management and development of water sector is created. It contains some policies of water management, their rational use and equitable distribution of the population, economy and ecosystems, as well as protecting and restoring the quantity and quality of water resources.

Inside the strategy is exposed the following summary evaluation: Generally the data for Bulgaria show that there is low water stress. The projected total domestic water consumption of 3,340 million cubic meters in 2035 (excluding hydro energy and nuclear power plants) is much less than the multi-year average internal water resource of 18,547 million cubic meters (excluding the Danube River) for the period 1974–2008. Prior to 1990, Bulgaria was considered to be close to the threshold of a water-

scarce country. Since then, abstractions have fallen drastically for both agricultural and industrial purposes, and today Bulgaria overall is non-stressed.

To identify whether the rates of abstractions in countries are sustainable over the long term here is used the Water Exploitation Index (WEI).

2. SUMMARIZED INFORMATION

According to the data of the National Statistical Institute (NSI) for the period 2000-2012 this index for our country is given in the following figure, where the threshold is 20% for the presence of water stress.

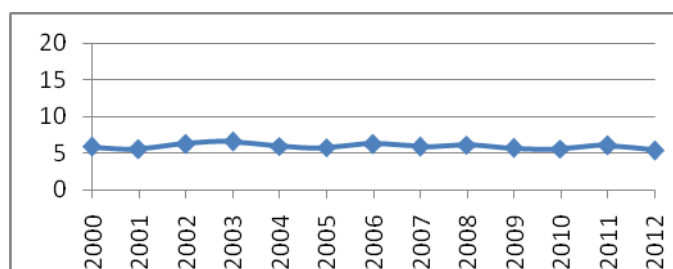


Fig. 1 Water exploitation index for Bulgaria (source NSI)

On the basis of information provided by the Executive Environment Agency (ExEA) Water exploitation index for Bulgaria including the Danube River is given on figure 2. (<http://eea.government.bg/bg/soer/2011/water/water1>)

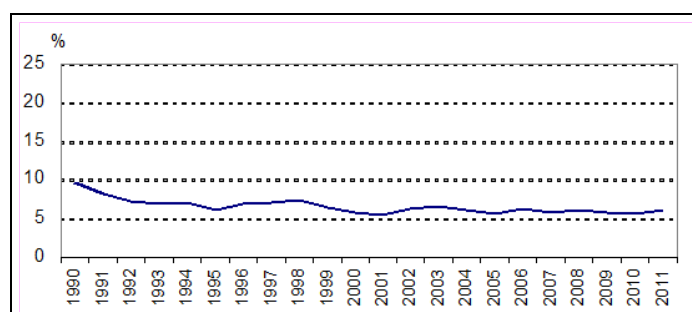


Fig. 2 Water exploitation index for Bulgaria including the Danube River (source ExEA)

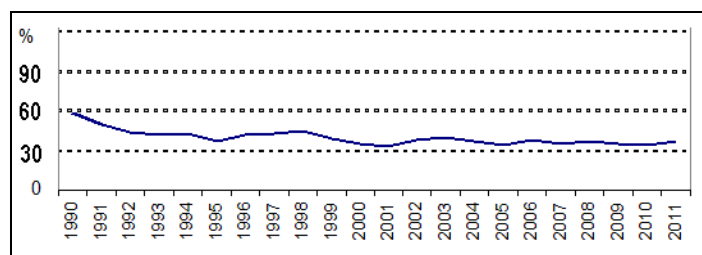


Fig. 3 Water exploitation index for Bulgaria excluding the Danube River

The focus is on the possible water use of the Danube River, in particular the impact on the water sector in Bulgaria. This impact is quite limited, but the water use of the Danube River has significant influence when calculating WEI for Bulgaria as it is seen from figures 2 and 3.

Danube is a joint river for European countries, but some infrastructure for use the Danube waters in the interior of Bulgaria is still missing. So, it is better to consider our fresh water resources without Danube.

3. BRIEF DESCRIPTION OF THE FEATURES AND CHARACTERISTICS CONCERNING THE TASK

With the view of this generalized assessment it should find the problematic areas with water scarcity in Bulgaria and give some solutions. For this reason it is necessary to analyze the water use on river basin level.

As a tool it is appropriate to use the simulation modeling of water resource systems. This practice is acceptable and more logical. Otherwise it is necessary to analyze, design and build quite elaborate schemes to transfer water. In this regard, this article discusses the use of water resources in a river basin. The aim is to show the strengths and weaknesses of possible analyzes and accordingly recommend appropriate indicators to assess the use of water resources including and expression of areas with significant vulnerability.

The analysis of the allocation of water resources through water resource systems and water resource balance (at river basin level) are tools of identification of deficits. Water scarcity and vulnerability are assessed by the ratio: abstraction - resource. (Georgieva, D., I.Ilcheva, 2014)

In this report the river Tundja basin is analyzed from hydrological and water resource system point of view. The necessary input information for the water resource system calculations is described such as data for river runoff, ground waters, water sources and withdrawals, water users and consumers, technical parameters of hydraulic works.

One of the most important water resource system (WRS) in Bulgaria was built in the basin of the river Tundja. It includes multiple water intakes and two large reservoirs with complex purpose. The reservoir cascade “Koprinka” -“Jrebchevo” is used to regulate the water in the basin of the Tundja River and contribute to the increasing complexity of water allocation and implementation of rational use of water resources. The management of reservoir “Jrebchevo” is related to the management of the reservoir “Koprinka”.

Data available at basin level on water uses helps to identify the main sources of water abstraction and consumption. They also help get an insight into geographical and sector differences. Aggregated data for Tundja river basin highlight the significant part of the agricultural sector in the overall abstractions compared to the public water supply and industry.

According to the requirements of the WFD some investigations are carried out related to the assessment of water demand satisfaction in different economic and climatic scenarios. Water resource system balances for Tundja River basins are developed (Nikolova, Kr., D. Shopova, 2006).

The water resource system balance represents a comparison between the available water resources and water demand of all water users and consumers.

A detailed description of the existing water resource system and its peculiarities is given and some problems concerning the water management are defined (Niagolov, I., Kr.Nikolova, D.Shopova, 2007; Nikolova, Kr., D.Shopova, Kr. Kolcheva, 2007).

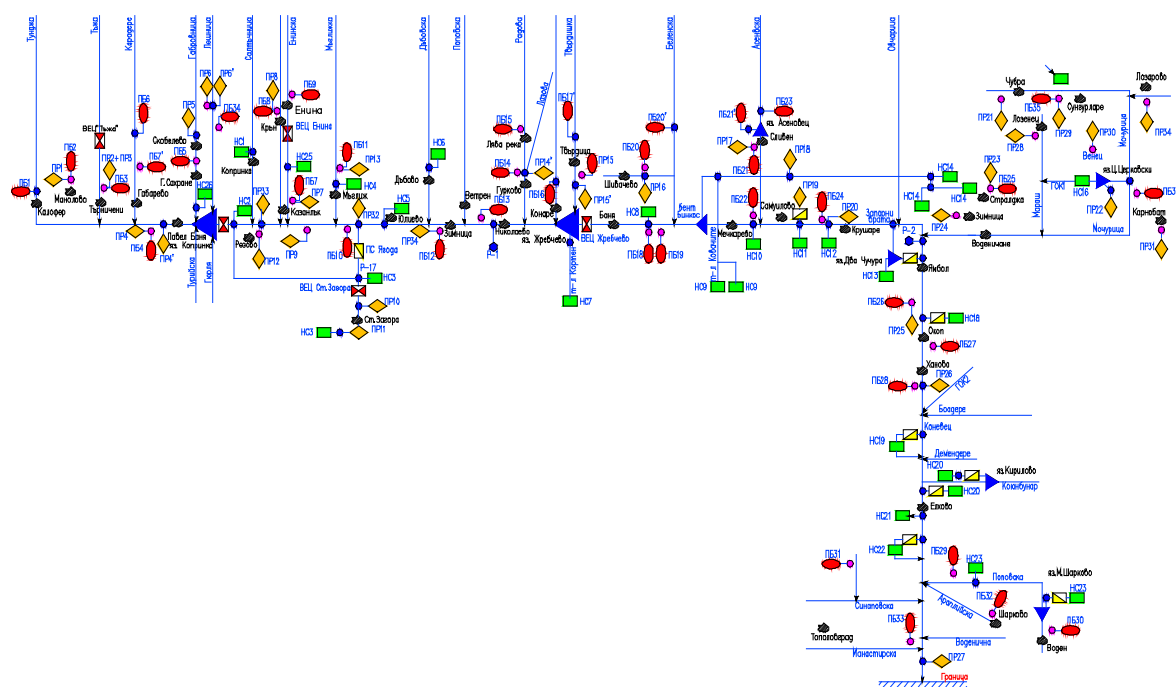


Fig. 1. Computational scheme of WRS of Tundja River

The simulation model SIMYL was used for balance calculation for the period from 1961 year to 2010 year. It is developed in National Institute of Meteorology and Hydrology and allocates water on the basis of priorities at given scheme of water use in the river basin.

A network flow model is created – the nodes indicate water reservoirs, water intakes, water users, etc. and the arcs are elements of the connections – river courses, derivations, channels, etc.

Computer program is based on the description of water resources scheme by network flow models. A distribution of water between the water users and water consumers is made taking into account the functional characteristics of the system “water source - water user“.

The obtained results are a set of data: reliability water demand satisfaction by years, months, volumes show for the first calculated period that almost water users' demands are satisfied. Several of them do not meet the normative reliability. Generalized indexes for satisfaction of water users and complete data base are obtained, which could be used for more detailed analyses.

The calculation scheme of the basin is made reflecting the river network with the direction of water movement, location of the physical structures, water abstraction points, connections between the separate objects and the way for water resources usage. Based on this scheme a network mathematical model (containing 192 nodes) is developed for WRS balance calculation. The obtained results are shown in table 1.

data	base variant				reliability, %			
node	Water users	Water demands	Initial volume in the reservoir	Average shortages	by volume	by years	by months	Index
1	W.S. 1	3521	0	80	97.73	79.55	96.59	0.466
20	W.S. 21	5809	997	23	99.6	93.15	99.05	0.032
29	W.S. 7	2001	3772	33	99.64	93.18	99.24	0.052
54	Ind. 28	9100	2217	25	96.75	86.36	98.11	0.145
69	Ind. 6	200	0	1	99.5	90.91	98.11	0.027
89	Ind. 14	1212	0	22	96.18	91.82	98.11	0.313
91	W.S. 17	10999	0	9	99.92	95.94	99.43	0.02
92	Fish. 3	1656	0	13	99.21	90.91	99.05	0.091
93	W.S. 20	4500	0	44	99.02	86.36	99.48	0.102
108	W.S. 36	3660	0	2	99.95	97.73	99.01	0.002
112	W.S. 25	4846	0	24	99.5	90.91	99.05	0.042
134	W.S. 37	44472	0	1159	97.39	77.27	94.98	0.639

Tab.1. Results of WRS balance calculation

4. USE WEI

As it is mentioned above in order to assess to what extent is water used the author adopted as a first stage the water exploitation index WEI. As a rule it represents "the mean annual total demand for freshwater divided by the long-term average freshwater resources. It gives an indication of how the total water demand puts pressure on the water resource. It also identifies those countries that have high demand in relation to their resources and therefore are prone to suffer problems of water stress"

$$WEI = \text{abstraction} / \text{resource} \quad (1)$$

For a given area and for a period - at least three approaches for calculating WEI are used:

$$\bullet WEI_1 = (\text{abstractions} - \text{returned water}) / \text{Renewable Water Resources} \quad (2)$$

$$\bullet WEI_2 = (\text{abstraction} - \text{returned water}) / \text{water resources for the period} - (\text{transferred water, change in storage}) \quad (3)$$

$$\bullet WEI_3 = (\text{abstraction} - \text{returned water}) / \text{long-term average water resources} \quad (4)$$

As WEI is dimensionless, the values on the right side of equality should be the same dimensions.

The aim is this index to assess the use of water resources in a given region and especially to show the degree of vulnerability of the process. Use the following rating scale:

- $WEI < 0.2$ - there is no "water stress"
- $0.2 < WEI < 0.4$ - presence of water stress
- $WEI > 0.4$ - presence of acute water stress (unsustainable use of water resources).

The warning threshold for the water exploitation index (WEI), which distinguishes a non-stressed from a stressed region, is around 20 % (Raskin et al. 1997). Severe water stress can occur where the WEI exceeds 40 %, indicating unsustainable water use.

All economic sectors need water for their development. Agriculture, industry and most forms of energy production are not possible if water is not available.

For the watershed of Tundja River as a whole, 50% of freshwater abstraction is used for energy production, followed by agriculture - 29%; public water supply – 12.5%; and industry – 8.5%. These sectors differ significantly in their consumptive use of water. Almost all water used for energy production is returned. In this research is accepted: 8% of the amount abstracted for agriculture, 25% of the amount abstracted for industry and 40% of the amount abstracted for public water supply is returned in the system.

5. RESULTS

The results of the estimation of WEI (with or without returned waters (RW) or the change of filling reservoirs (ΔS)) using the above expressions for the calculation of WEI of whole watershed of Tundja river at the monthly accounting period are given in the following figures.

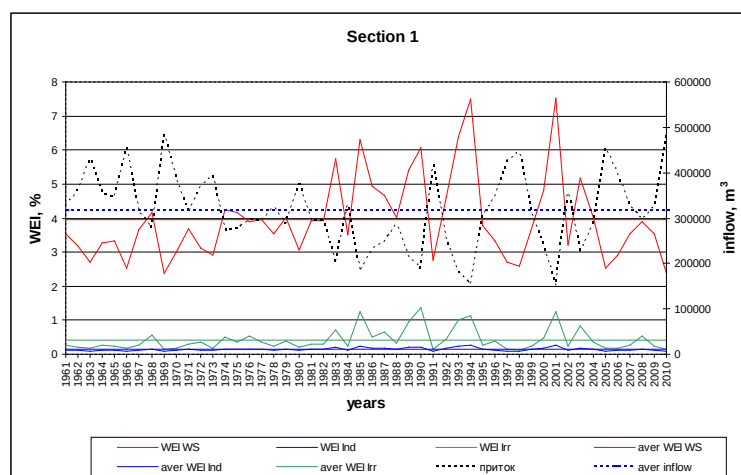


Fig.2 from the beginning of the river to the reservoir “Koprinka”

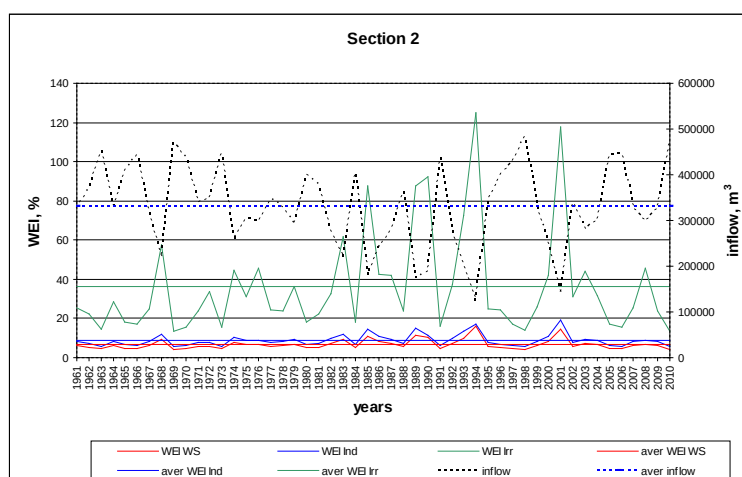


Fig.3 from the reservoir “Koprinka” to the reservoir “Jrebchevo”

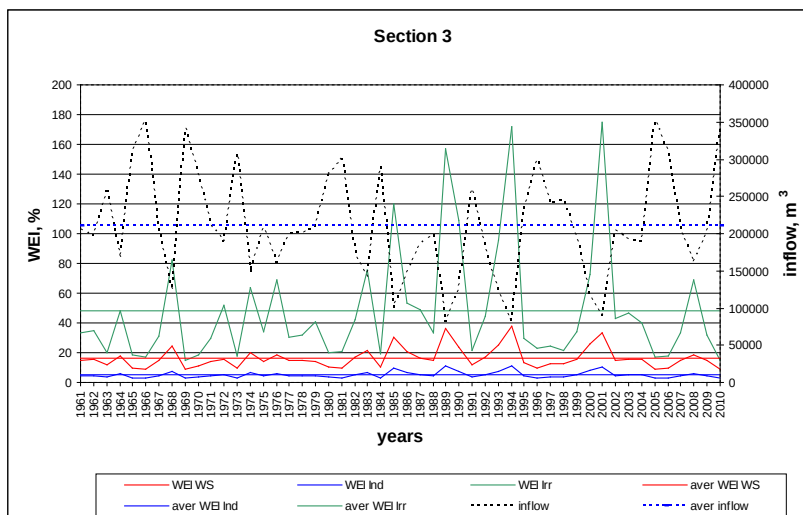


Fig.4 Section 3 “reservoir “Jrebchevo” - before inflowing Mochuritsa River”

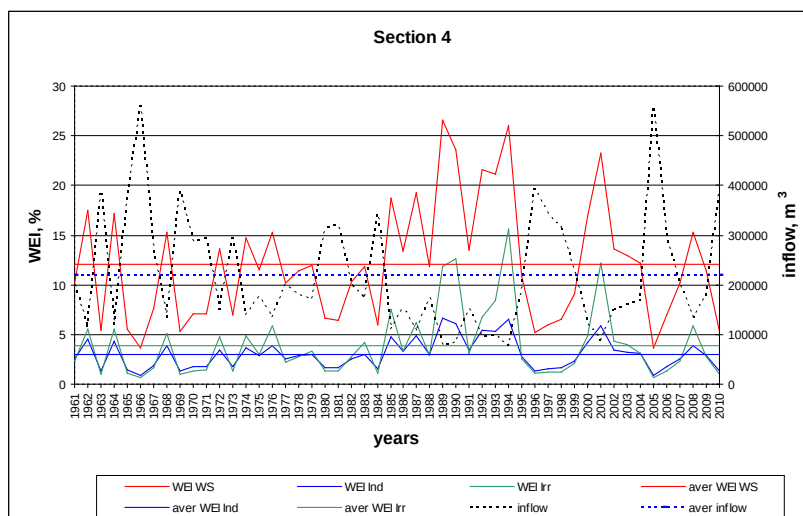


Fig.5 section 4 “Mochuritsa River-Yambol town”

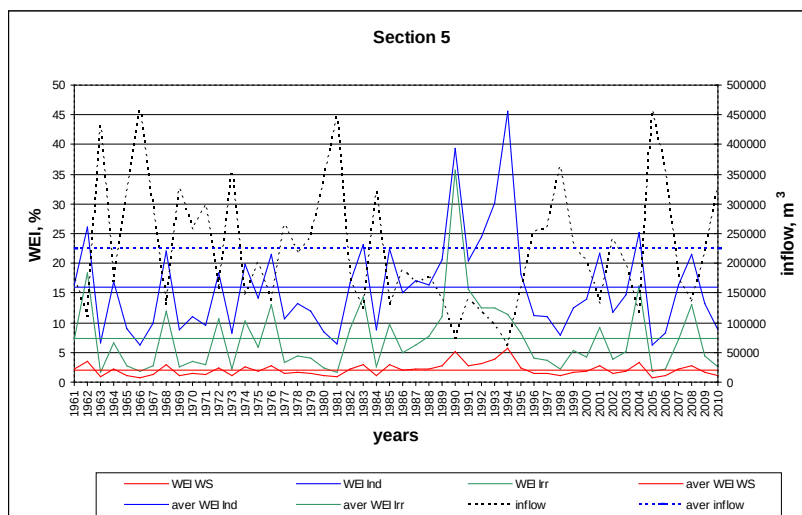


Fig.6 section 5 “Yambol town - boundary”

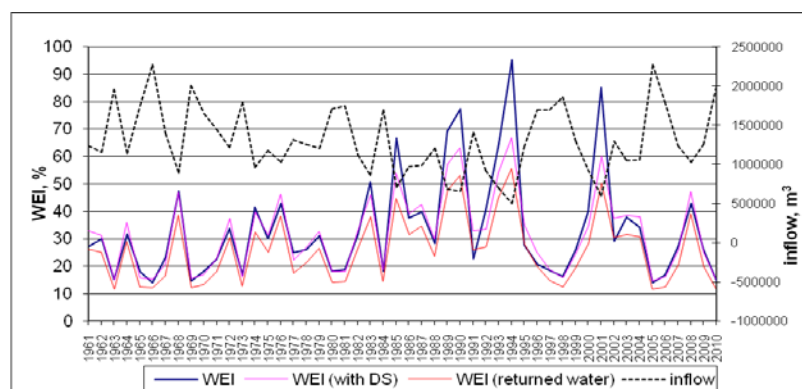


Fig. 7 WEI for the entire watershed of Tundja River and all consumers

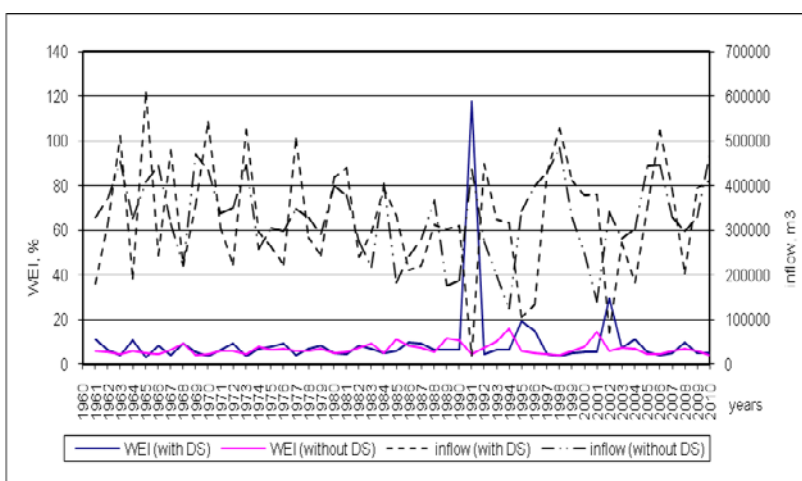


Fig. 8 WEI for the section 2 of Tundja River and consumers for public sector

As mentioned above WRS of the Tundja River includes the reservoirs cascade “Koprinka” - “Jrebchevo”. WEI_2 determined by formula (3) is estimated, where ΔS (change of storage capacity) for both reservoirs are calculated (figure 8). It should be taken into consideration that ΔS is a result of specific management of these reservoirs done by the dispatch schedules.

The return waters change significantly the value of WEI. The problem is that a small part of the return waters can change the usable water resource.

The main problem is to establish areas with lasting shortage or with a high degree of vulnerability. This should be done by sector and unlikely be caused by summarizing evaluations (figures 2-6).

The character of the curves is the same and the marked displacement is due to the priority in satisfying the needs.

As is known, the satisfaction of irrigation consumption has a lowest priority, it is obviously from the figures showing the water consumption separated by sectors (figures 2-6).

It is clear that the problems of water scarcity for satisfaction some specific needs are local. This is associated with a variety of circumstances: 1. insufficient water sources; 2. Great amount of concentrated consumption; 3. Lack of (or insufficient) regulated volumes to overcome the first and second circumstances.

From the computational point of view WEI represents balance of waters. The numerator includes the expenditure side of the balance sheet and the denominator - the income.

In different forms of calculation the numerator includes except abstraction and the return water as well, in the denominator - water resources for the given period as well as a change of storage filling. Therefore appear quite uncertainties and the resulting estimates can not reflect the realistic situation of water resources utilization in a given area.

CONCLUSIONS

The climate changes that occur now require very much optimal use of the limited water resources and clear policy of water management which satisfies our nation and future.

Optimal provision of population and economics with the needed quantity and quality of water, provision of enough natural water for ecosystems reproduction and development taking into consideration the basin management of trans-boundary rivers under the climate changes and guarantee the national interests and the ecology sustainability of affected ecosystems.

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REFERENCES

Georgieva, D., I. Ilcheva, 2014, Assessment of water resources vulnerability and hydrological drought management under different climate scenarios, Jubilee International Conference: Science & Technic. 65th anniversary Faculty of Hydraulic Engineering and 15th anniversary Hydraulic Engineering in German, UASG, 6-7 November 2014, Sofia, Bulgaria

Niagolov, I., Kr. Nikolova, D. Shopova, 2007, Some results of the water resource system balance of the Tundja river basin, J. of BULAGUA, No4, Sofia, Bulgaria

Nikolova, Kr., D.Shopova, Kr. Kolcheva, 2007, Hydrology and water resource system analysis of the Tundja river basin, Proceedings of the 2-nd international conf. with technical exhibition on water resources, technologies and services "BULAQUA 2007", 6-7 June, Sofia, Bulgaria

Raskin, P., P.H.Gleick, P.Kirshen, R.G.Jr Pontius, K. Strzepek, 1997, Comprehensive assessment of the freshwater resources of the world, Stockholm Environmental Institute, Sweden. Document prepared for UN Commission for Sustainable Development 5th Session 1997 - Water stress categories are described on page 27-29.

Vassilev, V., P. Sarnev, 2011, Status and Problems of construction of started and unfinished reservoirs in Bulgaria - International Conference: Science & Technic., UASG, 18 February 2011, Sofia, Bulgaria