SURFACE WATER RESOURCES ASSESSMENT METHODOLOGIES APPLICATION IN CASE OF VIT RIVER

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Abstract: The surface water resource determination is an important issue related to most reliable water management, which in some districts of Bulgaria in some periods are not enough. In this aspect, the present work is part of the effort to create an operational tool to assess the annual resource. Annual, because this is one of the periods of planning the water use, on the other hand annual averaging significantly simplifies the water balance equation.

There are several methods in world practice for this purpose: modeling the process *"rainfall – runoff"*; regionalization in typical water quantities depending on physico-geographic factors; balance approach. The first one require a serious resource of information and time, mainly used to analyze the impact of decay factors and climate change rather than on operational purposes. The method of hydrological regionalization is already operational in use, but as far as it is based on registered river flow, it is important to clarify the influence of anthropogenic factors. The water balance method is widely used for the purposes of the Water Framework Directive, both for the assessment of the water bodies' resources influenced by human activity, as well as for analysis of pressure and water stress, for water economic balances, for the management of water abstractions and river basins. It applies to WB category "lake" - large dams; WB with resource dependent on technological input from dams or derivations; WB with additional flow of water transfer, etc. *Vit* is one of the main bays in Northern Bulgaria, combining a mountainous, hilly and plain area, on average in area, presenting relatively well the characteristics of formation of the river flow. There are three significant dams, two irrigation systems, derivations and water transfers and a significant number of smaller consumers. In this sense, the basin is chosen as representative, with the opportunity to demonstrate the methods. The balance method is applied to typical sub-basins for the period 2015 -2017.

As a result, a hydrological evaluation of the surface water resource was made for the selected sub-basins based on the registered flow and the water balance assessment of the surface water resource for the same sub-basins. A comparison was made, conclusions were drawn about the advantages and disadvantages of the methods and their applicability in practice.

KEYWORDS: SURFACE WATER, RESOURCES, WATER MANAGEMENT, BALANCE APPROACH

1. Introduction:

Assessment of water resources is an important task, ensuring efficient and fair water management and ensuring objective long-term planning.

Water management in Bulgaria is carried out by the Ministry of Environment and Water, which maintains the register of consumers and annual gives specific quantities for the three options - normal, dry and wet year. Appropriate resource assessment places this regulation on an objective basis. After the year 2010 the resource assessments are carried out by NIMH/ National Institute of Meteorology and Hydrology/, based on the hydrological method, which will be discussed below. They are prepared on a yearly basis in the light of practical needs and also to avoid seasonal impacts on fluctuations in river flow. Most often estimates are made in the basins, which greatly facilitates calculations from a methodological point of view. Assessments may also be made for districts and administrative units, for example on the territory of Bulgaria, which require additional information on hydrological and meteorological parameters at the border of the area.

2. Methodology:

Three methods for resource assessments are generally used in practice. The first one, currently used in NIMH, is a hydrological method. It is based on statistical links between hydrological observations and other factors that form the river flow, for example: catchment area, average altitude, and others. This method gives assurance in assessments **[1]**, but is based on observations on the recorded runoff, which leads to additional checks on the riverbed with many anthropogenic violation.The second method is the water balance, which assesses the revenue and cost components of the water balance, requires significant amounts of information and, most importantly, for the actually consumed water masses**[2]**. In our country the method is used for individual regions and rivers where it is possible to meet the requirements for the volume and reliability of the input information **[3]**. The third method is quantitative modeling of the drainage process and requires the most information and human resources. It is usually applied in cases where the first two methods can not be used. In this article we will look at the application of the water balance method for the assessment of water resources to some borehole and we will compare the obtained results with those of the hydrological method. The water balance technology is detailed in the **[2]**.

We will use the Physical / Hydrological Balance Technology of formed, used and discharged water. It should be noted that this guideline also details the technology for water balance balancing as well as hybrid hydrological and economic balance linking both types of water information.

In our case, the physical process of surface water formation is described as a result of the balance of the precipitated water revenue and the flow for the formation of the river runoff, underground and groundwater and the cost of evaporation, realized by various mechanisms, by the surface detention plants ***(Ei)*** from the soil and others. Direct determination of evapotranspiration is practically not possible. The rainfall is a feature with large spatial variability, but there are a significant number of measurements in the flatlands, and in the foothills and mountainous parts of the catchments they are insufficient. With relatively good accuracy, the river flow is observed. As far as annual resource assessments are concerned, the influence of sub-surface and underground runoff can be neglected. Our efforts will be focused on the more precise determination of the surface water component - river runoff, by assessing the anthropogenic impact of water users on the change of natural flow regime. This will be done for selected / to the configuration of consumption /, sub-basin from selected river basin.

3. Pilot basin selection

The selection of the pilot basin was realized in view of the following requirements: average for the country area of the catchment (3 - 5 thousand sq. km), various relief, flat, hilly, mountainous, presence of significant consumers whose impact on the water balance on an annual basis the presence of basic hydrometeorological observations of significant duration can be neglected. Pursuant to these requirements, for the purposes of this study, it was selected *Vit* as pilot basin with a catchment area of 3225 km^2. In the valley there are 5 hydrometric stations with a significant observation period (***Fig.1***), in the figure are shown the three main reservoirs, significant in terms of the annual water balance. **[1]**

It also shows the river network and the main reservoirs, the Sopot reservoir with a catchment area of 76 km and a derivation to *Lesidrenska* River with a similar area; the *Gorni Dabnik* reservoir with a derivative to the *Vit* River from the Boazas water catchment, as well as a smaller *Telisch* reservoir. In the valley, there are other smaller reservoirs, whose impact on the annual water balance is neglected. They are shown at ***Figure 1***.

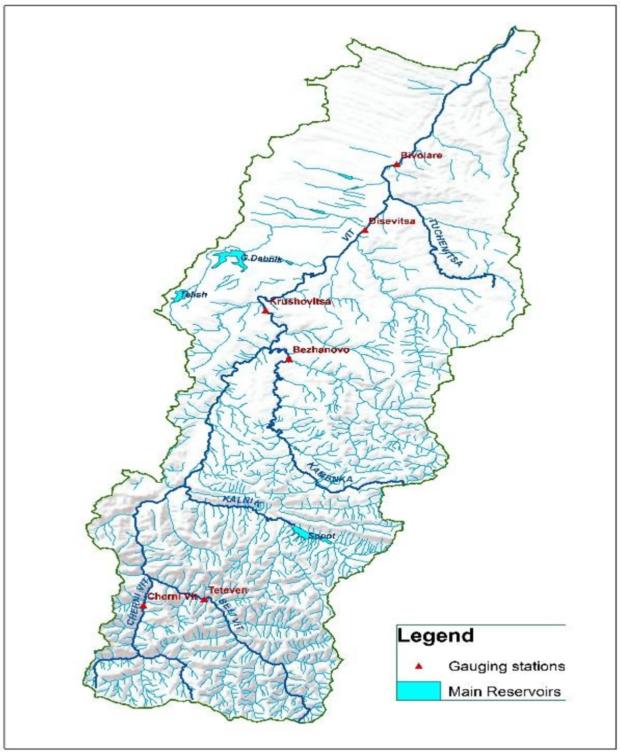

Figure. 1. *Vit River basin, hydrometric network, main reservoirs and derivation, significant for the annual water balance.*

As far as the idea is the application of the water balance approach for surface water assessment and comparison with the results of the hydrological approach, two sub-basins were selected in the *Vit* River where there are direct observations of the river inflow. One is the water catchment area of the Sopot Reservoir at the top of the valley.

The second one is the sub basin of Vit next to gauging station in the village of *Disevitsa*. The period for which the resource assessment has been made is selected in view of the actual of the assessment and the availability of information about the water used by the main users, obtained from Irrigation Systems Co. **[4].** A three-year period 2015-2017 was chosen as representative.

4. Registered users and anthropogenic factors

Information on registered users in the Vit River is received by the MOEW - BDDR **[5]** and IS Co.**[4]**. Information from the BDDR contains a description of the users on certain parameters, an annual limit of the allowed water use. We did not have information about actual water use for 2015-2017. Such information was available only to the sites of the IS EAD.

The information for the different users was merged into ***Table 1*** against the purposes of water use and is shown in ***Figure 2.*** The merger is done according to the classification of the BDDR, and the significance to the annual water balance is assessed according to the type of water consumption.

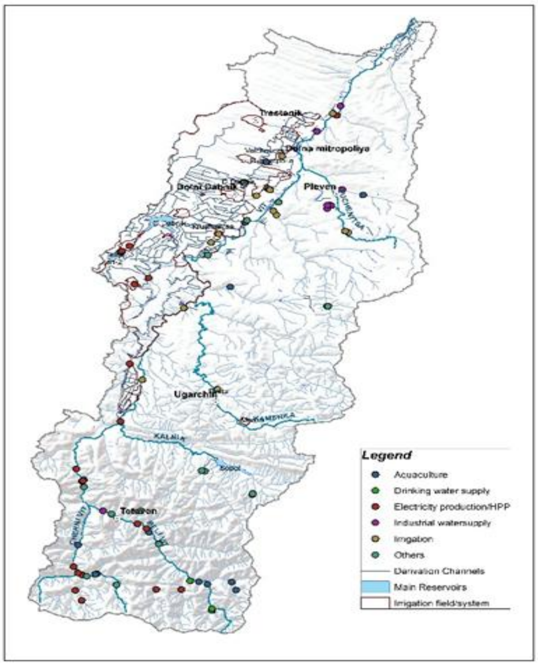

Figure 2. *Registered water use*

There are two main types of users. One has a significant anthropogenic impact on the annual water balance. This is irrigation, where part of the river effluent evaporates from irrigated areas and plants. In the same way we take into account the loss of evaporation from the large reservoirs. Other groups of users have no significant impact on the annual water balance. These are, for example, power stations, aquaculture, water supply - drinking and industrial, etc.. For them we will consider that the water used is transferred instantaneously without loss back to the point of water abstraction. It should also be noted that allowing annual water consumption limits far exceeds actual water consumption. In support of the above we will say that the constructed facilities have a total capacity of about 200 million m3, the annual irrigation limits are about 19 million m^3 and the actual water consumption for irrigation for the period 2015-2017 declared by the IS EAD does not exceed 2 million m^3 per year. As long as the consumed water from smaller users is used for the second and third time by other downstream users, the annual limits shown in Table 1 can only be used as a guide to the scale of consumption. The last one becomes very clear by analyzing the annual sum of the limits for such water consumption purposes as electricity and industrial water supply.

In these two groups, about 50 users have a permitted limit exceeding at least three times the resource of the river basin. It is clear that in the production of electricity, water is used repeatedly, using the differences in altitude in the basin. (For example: In the upper reaches of the Vit River, after the White and Cherni Vit valves, there are seven HPPs that produce the same water.)

Users which influence on the annual water balance might be neglected	**Annual water use limit, $[10^6 m^3]$**	**Numbers in the group**
Aquaculture	6,659	20
Electricity production / HPP	1550,	29
Irrigation	19,196	26
Industrial watersupply	57,089	15
Drinking Water supply	3,200	3
Others	7,667	20

Table 1. Registered water users by purpose of use annual limits

5. Results

For the application of the hydrological method two types of relation are used between the observed water quantities to the selected hydrometric stations and the corresponding water basins areas. For the resource assessment to the *Disevitsa* sub basin, the information from four hydrometer stations in the middle and downstream of the *Vit* and *Osam* Rivers is used. Four regression relations have been created. The first one is with data from 1981-2012 **[1]**, while the other three are for each of the years 2015-2017, the statistical relations have a very high correlation coefficient above 0.95 and are similar in their tendencies, showing stability of the obtained results, ***Figure 3***. Similarly, the regressional dependencies for the assessment of the Sopot sub-basins were created using data from gauging station in the mountainous part of the *Osam* and *Vit* Rivers. The resource estimates identified with these dependencies are listed in the second column of ***Table 2*** as annual water tables. When assessing the resource to this sub-baisn, *Kalnik* area was used, representing the reservoirs own catchment. It should be noted that there is a derivation channel between the *Lesidrenska* River and the Sopot reservoir, increasing the flow to the reservoir, but we do not know when this derivation is used.

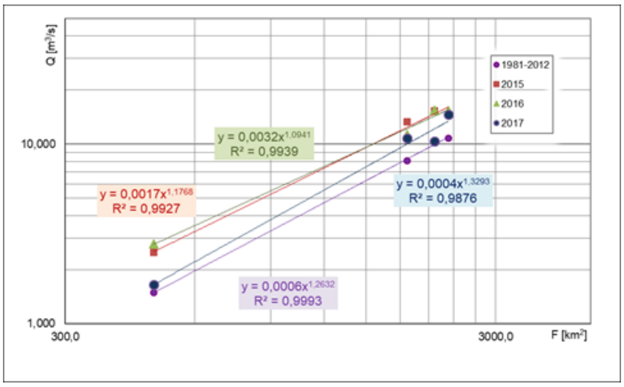

Figure 3. Regression of discharge versus watershed area for gauges downstream *Osam* and *Vit* Rivers

The data on the balance of *Sopot* reservoir and the measurement of the registered runoff from gauging station in the village of *Disevitsa* are used in the application of the water balance method. The following assumptions have been made: for the sub basin *Sopot* we will consider that the resource is equal to the total inflow to the reservoir; we will assume that the resource is equal to the recorded run-off from the gauging plus the evaporation losses from the reservoirs of the main reservoirs plus the irrigation water used, reduced by the return water.

We will consider that the evaporation from the reservoir is a loss of river flow. Similarly, irrigation water is transfer of river flow of evaporation as part of these waters passes through shallow groundwater back into the river network, which we call return water. We will consider that the return water is 30% of the quantity of water for irrigation. **[6]**.

The losses from evaporation of the three dams and the water used for irrigation are from the information of IS Co. **[4]**.

The comparison of the results of the two Sopot sub-basins methods shows significant differences without observing a equal tendency of these differences. A preliminary analysis of the data from 20 rain stations in the area confirms the high water level in 2015 recorded by hydrometric stations. The big difference between the balance and hydrological estimation of 2015 can only be at the expense of the work of the *Lesidrenska* derivation. The additional verification of the accumulated volumes of the Sopot reservoir also shows that it was nearly full at the end of 2014. Probably the *Lesidrenska* derivation was excluded in 2015 to prevent the dam from being overflowed.

The results of the calculations are shown in the last column of **Table2**.

Sub basin	Year	Hidrologic method	Water Balance method
Sopot	2015	60,904	30,527
	2016	39,573	54,108
	2017	52,157	47,132
Disevitsa	2015	492,321	484,003
	2016	488,033	510,595
	2017	377,937	480,246

Table 2. Annual Resources evaluation 2015-2017

This may explain the fact that in the next two years, 2016 and 2017, the water balance method shows values comparable to the hydrological.

For the *Disevitsa* subbasin, the results of the two methods are similar to a noticeable unidirectional trend of higher values of the water balance assessment. Differences between the two methods can be obtained for two reasons: 1) in the case of a poor correlation between the runoff and the area, the value of the recorded runoff in the station could differ significantly from the calculated equation; 2) In case of large losses of evaporation and irrigation, the differences between the recorded and the water balance calculated river flow will be significant.

6. Conclusion

The assessment of water resources in the water balance method is, in principle, preferable because the effect of anthropogenic factors on the river flow is eliminated. The calculations made show that the assessment of the surface water resource by this method is close to that obtained by the hydrological method currently applied in our country. The application of the water balance method requires a considerable amount of information, resources and time, and is more likely to be the case for research tasks. For the application of the water balancing method for operational purposes, it is necessary to provide information on the current water consumption available for a small number of cases.

7. Literature:

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