International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:13, No:3, 2019

Calculation of Water Economy Balance for Water Management

Vakhtang Geladze, Nana Bolashvili, Tamazi Karalashvili, Nino Machavariani, Ana Karalashvili, George Geladze, Nana Kvirkvelia

***Abstract*—**Fresh water deficit is one of the most important global problems today. It must be taken into consideration that in the nearest future fresh water crisis will become even more acute owing to the global climate warming and fast desertification processes in the world. Georgia is rich in water resources, but there are disbalance between the eastern and western parts of the country.

The goal of the study is to integrate the recent mechanisms compatible with European standards into Georgian water resources management system on the basis of GIS. Moreover, to draw up water economy balance for the purpose of proper determination of water consumption priorities that will be an exchange ratio of water resources and water consumption of the concrete territory.

For study region was choose south-eastern part of country, Kvemo kartli Region. This is typical agrarian region, tends to the desertification. The water supply of the region was assessed on the basis of water economy balance, which was first time calculated for this region.

***Keywords*—**GIS, water economy balance, water resources.

I. Introduction

WATER is a vital element of our environmental essential for existence of all living species human beings inclusive. Georgia has a reach water resources, however, it is unequally distributed, which creates a gap between the amounts of available and consumed water. Water consumption is four times lower in the east Georgia, which is considered to be main water consumer part of Georgia, compared to the West. In West Georgia, South and South-East parts are suffering from the most difficult conditions because during low water level periods water flows of the rivers are often lower than environmental minimum. Considering climate changing process, we predict that freshwater availability problem will become more serious in time. We chose Marneuli Municipality from the south part of East Georgia as a pilot region. Nowadays, in Georgia water resources are managed by administrative principle. The administrative model cannot ensure effective water management considering the needs of water consumers' as well as environmental protection interests. Therefore, there is a need for the shift to pound manageable water consumption. At the same time, Kvemo Kartli's administrative-territorial division model perfectly illustrates the specificities of the region's natural and socio-economic conditions.

The development of approximate water economy balance is necessary for establishing water resources management system. Based on water economy balance appropriate program and data will be selected and the territory of the reservoir will be divided into manageable units - water economy sections. Water Economy Balance is the part of basin water and it is used to determine water supply from the water object and other water consumption parameters. Water economy balance can be used for multi-year goals as well as for certain periods (such as arid-climate year, vegetative season, etc.). As a rule, maximum of water-consumption indices and the 95% of water supply (Practically guaranteed runoff, shallow year) is taken into account for developing water economy balance.

There are four main water economy balances: 1. Statement developed using on the data from the previous year. It is used to analyze the activities related to water economy, to determine the loss of non-production water and to decide the ways for saving water resources. 2. Operative Water Economy Balance, which has a main goal to conduct operational management of hydroelectric-engineering systems within the mean future (year, quarter, month, decade). 3. Perspective Water Economy Balance, which is used to develop long-term plans (5-20 years) for water resources of developing scheduled economy. 4. Scheduled Water Economy Balance that is the middle point between reporting and perspective periods, which gives us opportunity to plan stepwise perspective Water Economy Balance. In the following article, we discuss multi-year water economy balance.

To evaluate water supply, environmental flow should also be computed asides water economy balance. an environmental flow is the minimum amount of water, including water regime, water quality, and water level, which is necessary for securing freshwater ecosystems, vital human means, and welfare. an environmental flow is highly inconsistent multi-factor quantity. The stages of its computation are still on an initial level. Since limited the data is available, computing environmental flow is difficult and requires relevant education, experience, understanding and scientific intuition asides competence. Enough data and information for computing environmental flow are rarely available. In this case, prevention principle

Nana Bolashvili is with the Vakhushti Bagrationi Institute of Geography at Ivane Javakhishvili Tbilisi State University. 6, Tamarashvili str., 0177, Tbilisi, Georgia (phone: +995 577 84 83 14, e-mail: nana.bolashvili@tsu.ge).

Vakhtang Geladze, Tamazi Karalashvili and Nino Machavariani are with the Vakhushti Bagrationi Institute of Geography at Ivane Javakhishvili Tbilisi State University. 6, Tamarashvili str., 0177, Tbilisi, Georgia.

George Geladze is with The National Environmental Agency, 151 Agmashenebeli av., Tbilisi, Georgia.

Ana Karalashvili is a master student of Tbilisi State University, 1, Chavchavadze av., Tbilisi, Georgia.

should be used when the river is maintained with a distinct amount of water.

II. Study Area

Kvemo Kartli has been taken as the region under study. Its area is 6.5 thousands of square km (that is 9.3% of the country territory). There are 347 settlements – 7 cities, 6 towns and 334 villages.

The hydrography network of Kvemo Kartli is represented with trans-boundary river Mtkvari and its tributaries; 15 lakes are used for recreation, irrigation and fishing purposes; 6 reservoirs are used for fresh water supply, power and irrigation purposes. There are mineral, sulphur and thermal springs [1].

Tbilisi – the capital of country is located next to Kvemo Kartli region. The nearby Azerbaijan and Armenia republics, Tbilisi international airport, high level of urbanization, transport and power corridors, etc., favor development of the region. Its natural conditions are most favorable for agricultural purposes with 2-3 harvests per year that stipulate for high competitiveness of the region in comparison with other ones. Different branches of industry such as mining, metallurgy, chemical production of cement and construction materials, ceramics, glass, etc., along with power generation plants are the most active water consumers in the region.

Water economy balance was computed using the example of Marneuli Municipality. Marneuli Municipality is located in the east of Georgia. It is bordered by Bolnisi Municipality to the west, Gardabani Municipality to the north-east, Tetri Tskharo Municipality to the north, and the republics of Armenia and Azerbaijan to the south.

The area of the Municipality is 935 km^2 with the population of 120 000 people. The index of population density of Marneuli (128 person/km^2) is much higher than the mean index of Georgia (67 people/km^2). There are 72 settlements in the Municipality, including 1 city, 1 town and 70 villages.

River Mtkvari flows in the East border of the municipality. Among other rivers, Khrami and Algeti are worth to mention. The river Khrami flows from Bolnisi, whether, the river Algeti flows from Tetristkaro Municipality. Both rivers are the right tributaries of the river Mtkvari. Among the tributaries of Khrami, the most important river in the municipality is Debeda, which starts from the east slope of Javakheti ridge. Mean multi-year expense of the river is 29.7 m^3/sec by the village Sadakhlo. Among the tributaries of Debeda, the river Banoshistskali (length – 20.4 Km) is the most important. It starts from North slope of the Loki ridge. The main tributary of the river Banoshistskali is the river Budadzori. Among the tributaries of the river Khrami, we can mention river Shulaveri (length – 39.5 Km). There is a lack of the lakes in the municipality.

In Marneuli Municipality only 10% of total water resources are formed, while water consumption level is more than a half (55%) inside the region.

80% of the total population is employed in agriculture (plant-growing and cattle-breeding), which is the main area of economics. Among other fields of economy market-gardening, employment in Organic Recycler factories and small business remain to be important.

The relationship between multi-year river flows and mean weighted height can be described by two regularities and contains the ponds of the river Khrami and the river Algeti. By homogeneity of inter-annual distribution of flow, we can divide the municipality into two regions: lower part of the rivers Khrami and Debeda and the river Algeti.

The variability of river's annual flow shows a high level of synchronicity. The flow variability regional correlation coefficient is up to 0.80 and shows minor asynchronicity during extreme availability (< 5 %, and > 95 %) only.

The formation of river's maximum flow shows homogeneity and can be described by single regional empirical regularity.

III. Method

Water economy balance expresses the ratio of territory's water resources and its consumption. Water supply of the territory is assessed based on the analysis of Water economy balance's components of and structure. Usually, the indices of water economy balance (up to 15) are diversified by its types. Considering natural environment and data, only 5-8 indices can be taken into account. Usually, the water economy balance indices are presented in volume units of water [2].

The main indices of Marneuli Municipality water economy balance are following:

1. Local flow (formed in the territory of analysis) – was computed using mentioned Q=F(H) rule;
2. The upper flow of the river coming from the next neighborhood (given).
3. Full flow – the sum of 1 and 2 measurements (sum begins from the source), which is natural (background) flow excluding water consumption and territorial diversification of the flow.

Expenditural part of balance:

1. Volume of total water consumption in the territory of analysis (measured, computed) as well as its diversification by branches;
2. Territorial diversification of the flow.

While computing water economy balance, the volume of returned/unreturned water should also be considered. This shows the odd between water intake and water consumption. It is worth to mention that the volume of returned water and its quality might importantly correct water economy balance.

The data of measurements on unreturned water is rarely unavailable. In this case, it is advisable to use the mean measurements (1990-2010) for Georgia. According to this data, in the east of Georgia returned water consumption by agricultural branches, accounts following: for irrigation – 90%, for living-communal agriculture – 29%, for industry (excluding energetics) – 48%, agricultural water supply – 72%. These data were obtained by the specialists of „SAKTSKALPROEKTI". The measurements were made based on information from the 80s which was extrapolated till 2011. It should be considered that during this time almost all fields of agriculture functioned normally in Georgia.

Based on mentioned characteristics, one of the most complex characteristics of water economy balance was computed – (usable) water resource which is the sum of local water and given water from next neighborhood, and returned water.

In Georgia, still hydrological method is used for assessing expenditure of environmental protection [3]-[5]. The main disadvantage of this method is its low environmental consideration since it only takes into account statistical characteristics of water expenditure and ignores complex interferences between river and ecology. Moreover, the method does not take into account the type of the river, regime, seasonal expenditures, multi-level variation of river flow, and, most importantly, various environmental, social and cultural-recreational (for example, preservation of waterfall) factors. Environmental minimum is defined as 10-12% of multi-year water expenditure. Asides that, environmental expenditure is much less compared to results got from other, more complex methods.

Proposed new methodology for investigating environmental expenditures in Georgia was developed in frames of US Agency for International Development project. It is based on the methodologies developed for Austria and Connecticut in the USA. Both approaches are widely used in many countries and it is usually mandatory by legislation. This methodology was chosen for Georgia because there are similarities in natural resources, water ponds, and river types between Georgia and mentioned state and country. The proposed methodology is quite complex and includes 14 main stages. Moreover, it has some limitations and does not provide an immediate analytical assessment of environmental expenditure.

The mentioned methodology cannot be completely applied to Georgia considering the fact that capacities and practices of assessing environmental expenditures are still on its starting point in Georgia. The lack of relevant data is also an important obstruction [6], [7].

To find a relevant methodology for Georgia, different European approaches were also discussed. Based on the analysis we can conclude that meaning of environmental expenditure is defined by mean multi-year expenditure among 25%-50%. Therefore, the meaning of environmental expenditure in Kvemo Kartli is 25% of multi-year flow.

Based on analysis of integral curves of annual river flows, hydrological characteristics calculation is 1951-92.

Using modern high-resolution terrain digital model, we calculated morphometric elements (space, mean weighted height, etc.) for Marneuli Municipality and its rivers. Using mentioned characteristics and Q= F(H) rule of the relation of flow and mean height of pond, the precise multi-year flow of certain ponds was calculated.

Marneuli Municipality is served by Khrami-Debeda Irrigation Service Center (Irrigation area 12 673 ha, water intake - 156 million M^3) which is located in the city Marneuli and involves 14 irrigation systems. While developing water economy balance, to calculate irrigation water consumption, we used updated data of agreed technical regalements provided by the mentioned service center.

Water economy balance [1], [2], [8], which represents subtraction of available water resources and total water consumption, could be displayed:

$$B_n = B_{n-1} + Q_n - A_n + C_n \qquad (1)$$
$$B_n \geq G$$

where, B_n – water economy balance in n- section, Q_n – water income between the sections, A_n – water intake between the sections, C_n – returned water between the sections, G - environmental water discharge.

The results of water economy balance are following: Shortage of water resources/reserves and following given (transited) flow to water economy section.

Main results of calculations of Marneuli Municipality water economy balance and its structure is given in the table (Tables I and II) by rivers as well as for the whole municipality.

There is a tensed situation when the term 1 is not present – flow left in the river (given to the neighbor municipality) is less than the environmental minimum or is close to it and the corresponding water economy section is on demand.

To analyze the structure of Water Economy Balance, we suppose, that different types of coefficients are more efficient compared to the absolute data. To assess the profitability of Water Economy Balance, we used following coefficients: Water Economy Balance Coefficient that is the ratio of the Water Economy Balance to the Environmental Minimum; Water Consumption Coefficient – ratio of Local Flow to Full Water Consumption; Potential Water Consumption Coefficient – ratio of available flow to the Full Water Consumption.

The following Table I shows the data regarding Water Economy Balance and estimates of its structure for river ponds and for the whole municipality. Based on the following data, the schematic map was developed. As you can see from the table, all of Water Economy Balance coefficients are significantly lower for Marneuli Municipality compared to the same indices of the other Municipalities of Kvemo Kartli, excluding Gardabani.

TABLE I
MARNEULI MUNICIPALITY WATER ECONOMY BALANCE AND ITS STRUCTURE, MILLION M^3

River, Municipality	Local Flow	Full Flow	Full Water Consumption	Returned Water	Accessible Flow
River Algeti	16,7	128	44,5	10,3	76,5
River Khrami	103	941	245	7,4	762
Marneuli	120	1069	290	17,7	838

Water supply Map expresses that highest water supply is in Tsalka, while lowest is in Bolnisi Municipality.

Annual Population Water Supply Map shows the necessary volumes of water supply – 500 Liter a day. As you can see from the map, highest amount of water is needed for Marneuli Municipality, while lowest amount of water is needed for Tsalka Municipality.

It is important to mention that in Georgia standard norms of water consumption per person are not yet established. In previous standards, these norms were following: in the city 450-

500 Liters/day-night, in the villages 100-300 Liters/day-night. Within "enlarged, perspective norms" these indices for cities are 300 Liters/day-night and for villages – 150 Liters/day-night. To calculate water consumption on a person, we used old norms: for city inhabitants – 500 Liter/day-night and for village inhabitants – 300 Liter/day-night.

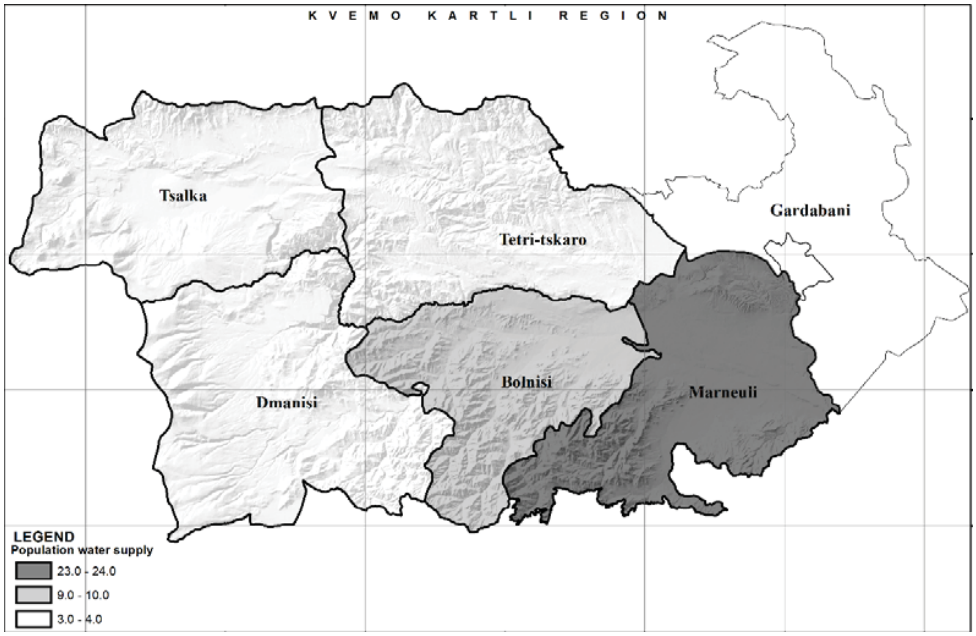

Fig. 1 Population water supply

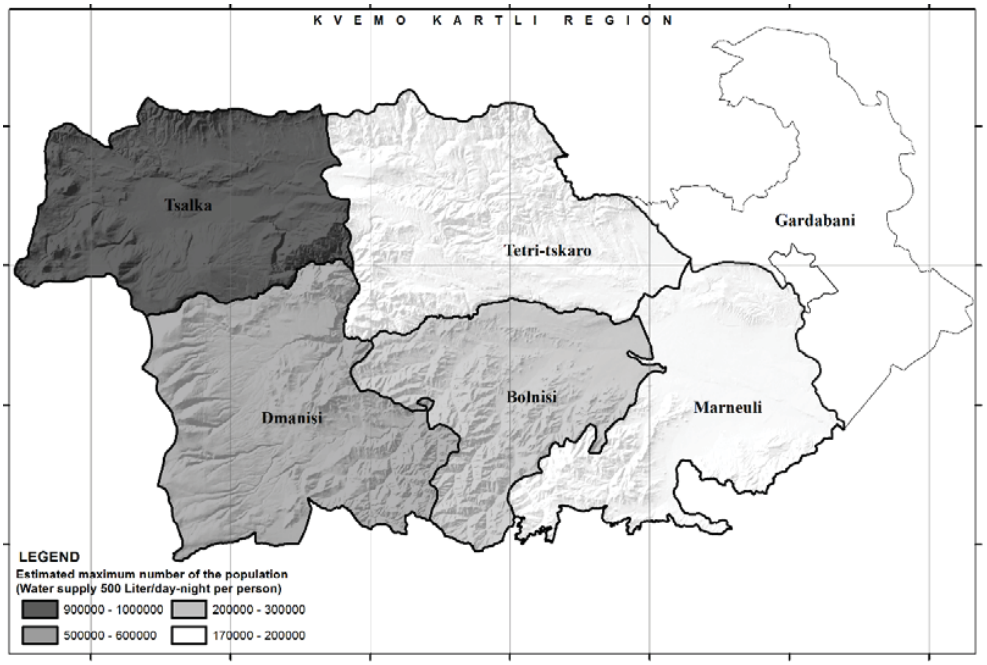

Fig. 2 Estimated maximum number of the population (Water supply 500 l/day-night per person)

Using local annual flow, the map of water supply for maximum number of the population (Fig. 2) was also developed (500 Liter a day on a person). Based on the map we can conclude that in Marneuli and Tetri Tskaro only 20%-30% of the population can maintain local water resources. At the same

time, the Municipalities of Tsalka and Bolnisi can supply water for 20-22 times more people.

In the following electronic table, by updating/manipulating the Water Eonomy Balance compilers (Local Flow, Water Supply, Returned Water, Environmental Minimum, etc.), we can calculate new versions of Water Economy Balance and create alternative plans. It is likely that some changes will be made in the calculation of mentioned indexes and, therefore, in the thematic maps after developing Water Economy Consumption for Khvemo Kartli considering water consumption characteristics of specific areas of agronomy.

IV. Conclusion

All coefficients of Marneuli Municipality water economy balance profitability are much less compared to other municipalities of Kvemo Kartli.

The most dramatic water economy situation is that a part of the municipality that includes the pond of Algeti River. Here, the volume of local flow is minimal (16.7 million m3) in the whole region. Furthermore, among accessible water, the most important ones are the shares of water given from Tetri Tskharo Municipality and returned water. In the mentioned pond, all coefficients of water economy balance structure are minimal for the region. Moreover, this is the only pond where water economy coefficient is less than one. This means that environmental flow is involved in water consumption process.

Acknowledgment

The study is funded by Shota Rustaveli National Scientific foundation (grant #216916), leading organization is Ivane Javakhishvili Tbilisi state University.

References

[1] Geladze V., Bolashvili N, Machavariani N.., Karalashvili T. (2013) Inner waters, *Geography of Georgia,* Tbilisi, p.110-124.

[2] Methodology for calculating water management balances of water bodies, (2007), Moscow.

[3] Geladze V., Bolashvili N., etc. Assessment of Water Resources and Inculcation of Controlled Water Consumption System. *https://www.waset.org/abstracts/65602.*

[4] Geladze V., Bolashvili N., Karalashvili T., Machavariani N. (2016) Geographical Information System for Sustainable Management of Water Resources, *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering Vol:10, No:3, http://waset.org/publications/10004830/geographical-information-system-for-sustainable-management-of-water-resources*, 21-22.03.2016.

[5] Bolashvili N., Geladze V., Karalashvili T., Machavariani N. (2015) Efficient use of water resources in Agriculture. Elsevier, Procedia Environmental Sciences 29 (2015) 107 – 108.

[6] On the approval of methodological guidelines for the development of schemes for the integrated use and protection of water bodies, 2007, Order N 169, Moscow.

[7] Kolesnikov V.I (1992). Ecology and water relations of Georgia, Metsniereba, Tbilisi.

[8] Vladimirov L., Gigineishvili G., Javakhishvili A., Zakarashvili N. (1991) The water balance of the Caucasus and its geographical regularities, Tbilisi, p.145.