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Assessment of runoff within an experimental and representative hydrographical basin (Sebeș, Romania)

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Abstract: The hydrographical basin of the Sebeș River is situated in the west part of Romania, it has a small surface (124 km^2) and which is part of E.R.B. – European Network of Experimental and Representative Basins. The role of hydrographical experimental basins is to understand and to know the process of runoff formation into a small catchment (surface < 150 km^2), especially that in the context of climate change the small hydrographical basins will be affected first. It is important to understand which is the impact of the climate change on runoff from a small basin because even a small decrease of water discharge regime will increase the risk of water level falling below ecologically or economically required minimum flows or even of rivers drying up. This study focused on assessment of runoff from a long period of time (1964-2013) in a small hydrographical basin, an important step in the impact evaluation process of the different types of runoff (mean, maximum and minimum) on the surface of the small hydrographical basins within Banat hydrographical space.

Keywords: hydrographical basin, Sebeș River, mean runoff, maximum runoff and minimum runoff, water discharge.

1. INTRODUCTION

Acknowledging the hydrological regime of some rivers can solve practical problems that lead to the most rational use of water resources in a given hydrographical basin.

The correct understanding of the hydrological regime and the accurate identification of its spatial and temporal characteristics are very important because these are taken into account in the planning of the hydrographical scheme and hydrotechnical structure and in the water resources management activity of a hydrographical basin, for different periods of time (Dunca, Bădăluță-Minda, 2017).

The water discharge regime represents the variation of water discharge over time, during several months, seasons, years or decades. This varies according to the determining and conditioning factors of the discharge, such as the atmospheric precipitations, the air temperature and humidity, the flash floods, the morphological and geological structure of the hydrographical basin, the soil structure etc. (Arba, 2016).

The participation share of the various sources in the water supply of rivers within the hydrographical basin varies from one region to another, from one river to another or from one sector to another, being conditioned by the diversity of the physical and geographical factors, such as: the climate, the geological structure, the vegetation, the forestation coefficient etc. (Munteanu, Rodica, 1998).

Within the Banat hydrographical space located in the temperate area at the junction of the oceanic influences from the west, the polar ones from the North and the sub-Mediterranean from the South and South-West, on the background of the vertical zonality imposed by the Carpathian range, the superficial supply of rivers presents, generally, the same features thanks to the similar geographical conditions on the entire surface of the basin and, at the same time, to the obvious local differentiation according to the case (Arba, 2016).

The Sebeș hydrographical basin is situated in the west part of Romania, in the way of the oceanic masses of air and of the Mediterranean cyclones, as well as at a high average altitude, which give the area significant quantities of precipitations with direct influence on the water discharge (fig. 1).

This catchment is unfolding on the north-eastern unit of the Tarcu Mountains Group, from the Southern Carpathians, that is on Muntele Mic, which is bounded by the valleys of the Sucu and Bistra Mărului rivers to the southeast and east, by the valley of the Sebeș river to the south and west and by the valley of the Bistra river to the north.

The main river from this hydrographical basin, namely Sebeș, springs from Muntele Mic, having a 20,1 km long in closure profile and drains the waters mainly from the western part of this relief, on a relatively small total surface, only 124 km^2, which places this basin in the category of small basins.

The hydrographical basin of the Sebeș river is bordered to the north and east by the Bistra Mărului catchment, to the south with Șucu catchment and to the west with Timiș catchment, a hydrographical basin to which it is subordinated because in the area of Caransebeș, the Sebeș river flows into Timiș river.

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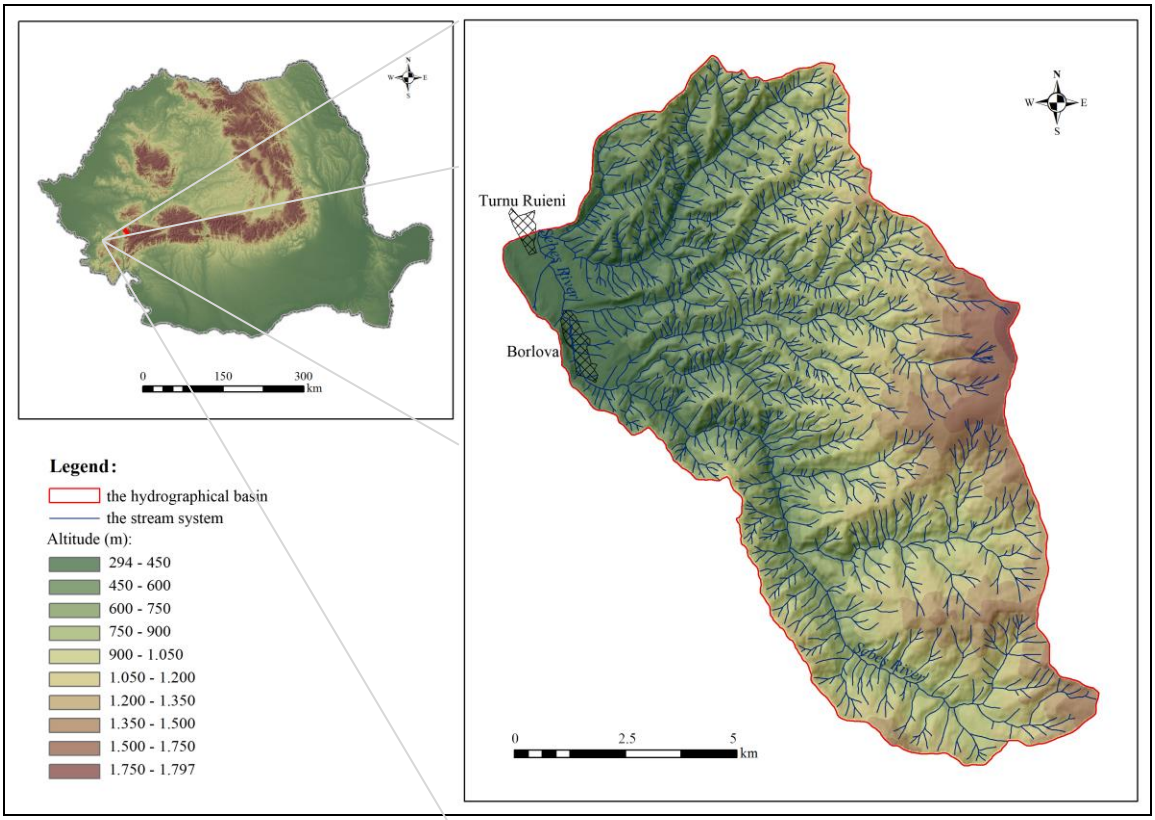

Figure 1. The experimental and representative hydrographical basin of the Sebeș river

The Sebeș catchment has a 815 m average altitude, with an altitude that rises from west to east, in the direction of general air mass movement, a small surface with an elongated shape in the south-east – north-west direction, a 444 % average slope and a 78 % degree of afforestation coefficient (Teodorescu, 2005).

The hydrographical basin of the Sebeș river is part of The European Network of Experimental and Representative Basins (E.R.B.), which is an scientific association of 20 European countries operating and managing well instrumented experimental and representative basins for hydrological and environmental research on a long term basis

This association was established in 1986, under the aegis of UNESCO, and has a very important role in understanding the process of runoff formation into a small catchment, like the Sebeș hydrographical basin is (surface < 150 km^2) (Teodorescu, 2003).

Romania joined this scientific network of experimental and representative hydrographical basins in 1993, with 5 small catchments (Fântâna Galbenă, Moneasa, Sebeș, Tinoasa-Vedea and Tinoasa Ciurea), which have undergone an intensive hydro-meteorological program.

Several hydrometric stations are distributed on the surface of the Sebeș catchment, which have an intense hydro-meteorological program thanks to this network. This allows an easier identification of the influences that rainfall and geological characteristics, relief, soil and vegetation have on hydrological regime of Sebeș river (Teodorescu, 2005).

Studies which focusing on measures of mitigates the extreme hydrological phenomena in small catchments are scarce, especially for Romanian territory. For this reason, studies on larger scales and storm water retention, which contains specific measures, are very important.

Such measures have to be adapted to the conditions in small catchments and evaluated with regard to the aim of ensuring minimum runoff and combating the maximum runoff. Measures differ with respect to such aspects as the effective volume, time scale, controllability and conflict potential.

The aim of this study is to analyse the runoff distribution in the Sebeș hydrographical basin, in order to evaluate correctly the water quantity of the rivers in this small basin and to find the appropriate measures to combat the extreme hydrological phenomena like droughts and floods.

2. METHODS AND DATA

The scale of the study area depends on: data needs availability of these data, study of methods, focus of the study and time constraints of the study which has to be achieved (Lazaro, 1990).

The time and space variation of the hydric potential of the hydrographical basin given may be characterised through the analysis of liquid discharge stages and through the parameters that define it.

Among these, the average discharge is the most important because it offers the possibility to know the hydric potential of the hydrographical basin at a multiannual average level.

The maximum and minimum discharge are important as well, warning, through the extreme values, that the river discharge regime may be not only beneficial but also damaging for economy if certain measures to predict the extreme hydrological phenomena are not taken (Arba, 2016).

The hydrologic data from the direct observations were collected, analysed, processed and interpreted, which allowed us to establish the parameters of the water discharge within Sebeș hydrographical basin.

We have used data strings and observations of the water discharges for a long period of time (1964-2012), in the analysis of middle runoff (monthly annual, seasonal and multiannual average values) and extreme runoff (maximum annual values and minimum annual values), coming from the main hydrometrical station within the basin (Turnu Ruieni), which is located on Sebeș river.

The Turnu Ruieni hydrometric station controls the surface of the entire surface within experimental and representative hydrographical basin of the Sebeș river, which is characterized by a radial decrease of the altitude from the Muntele Mic Peak (1802 m) which is located in the east on the main watershed, west, south and north-east (Teodorescu, 2005).

Using these hydrological data, we have been able to realize some detailed analyses of the Sebeș river's hydrological and morphological conditions, following a set of principles that comply the scientific standards and allow us to present them in an accessible format.

Regarding to the spatial and temporal distribution of Sebeș river hydrological regime we used several statistical methods for the analysis, processing and interpretation of the hydrological data collected from the Turnu Ruieni hydrometric station.

These methods allowed us: to calculate some primary and derived statistical indicators (arithmetic mean, standard deviation, coefficient of variation, etc.), to create specific tables that capture very well the numerical values of some analysed variables and to elaborate more types of graphical representations, useful for visualize, analyse and interpret the data.

3. RESULTS AND DISCUSSION

It is well known that for the proper understanding and assessment of water leakage from a small hydrographical basin it is necessary to use a long string of hydrological data.

In order to identify the characteristics of the hydrological regime, from the Sebeș basin, which has a small surface, we have used hydrological data over a long period of time, starting with 1964, since there were direct observations at the Turnu Ruieni hydrometric station, located in closure section on the Sebeș river and ending with 2012.

By analysing the runoff distribution in the Sebeș hydrographical basin, taking into account the coefficient of determination between the average altitude of the hydrographical basin and the normal supply sources quantity, we have found that there is a causality effect between the increase of the relief altitude and the increase of the superficial supply and the snow water supply.

In this part of the country the superficial supply sources have the largest share (> 50%) from the total discharge on the basin territory and a variable composition according to the ratio between the base sources: the melted snow and the rains, hence the rivers have a mixed supply source, with a different share according to the water quantity existing under one form or another.

For evaluating the medium water leakage on Sebeș river we have realized the variation hydrograph of annual middle water discharge over the period 1964-2012 (fig. 2).

Analyzing these values represented on hydrograph we can observe that the trend variation of the annual average values in relation with the multiannual average is slightly decreasing in the analyzed period of time, with decreasing values towards its end.

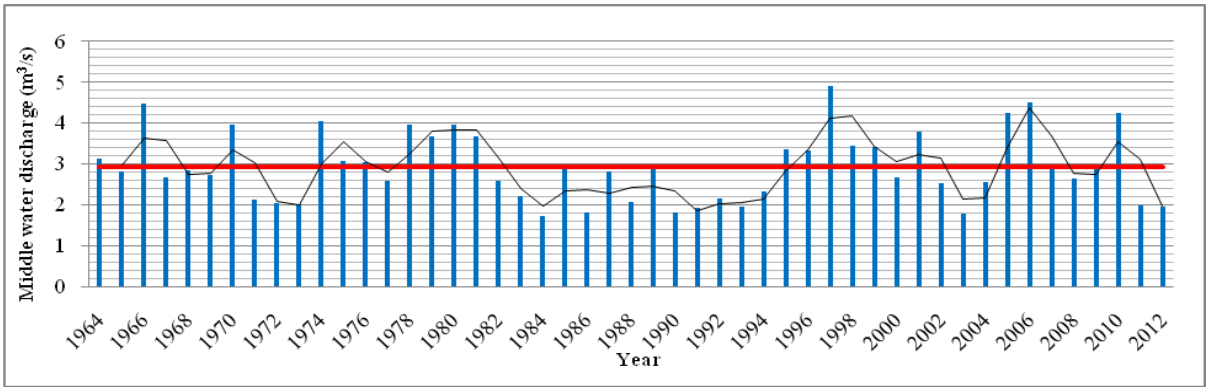

Figure 2. The variation hydrograph of annual middle water discharges at Turnu Ruieni hydrometric station (1964-2012)
Source: Data processed by the Banat Water Basin Administration (ABAB) Archives, Timişoara

The most important influence on the variation of the runoff from one year to another is determined by the variations of the annual quantities of precipitations and their manner of distribution during the year, and the nature of supply sources, the regulating effect of the Sebeș catchment, its surface, the slope and the average altitude exercise less significant changes on this type of regime.

The multiannual average discharge of Sebeș river sums up 2,91 m^3/s at the Turnu Ruieni hydrometrical station, located at 287 m altitude and downstream of Turnu Ruieni locality and closest to the confluence of the Sebeș river with Timiș river.

Analysing the variation in time of the annual average leakage and the relation of this parameter in comparison with multiannual average of runoff we can distinguish three types of years such as:

- 9 years with almost normal runoff (1965, 1968, 1975, 1976, 1985, 1987, 1989, 2007 and 2009);
- 17 years with rich runoff (1964, 1966, 1970, 1974,

1978-1981, 1995-1999, 2001, 2005, 2006 and 2010);
- 23 years with poor runoff (1967, 1969, 1971-1973, 1977, 1982-1984, 1986, 1988, 1990-1994, 2000, 2002-2004, 2008, 2011 and 2012).

The most significant annual middle water discharge was recorded in 1997 (4,67 m^3/s), when the runoff reached record values at Turnu Ruieni hydrometric station. In April 1997 have been occurred significant amounts of rainfall and have been recorded high values of air temperature, that have led to the sudden melting of snow and the increase in the amount of water transported by the Sebeș river.

The seasonal distribution of the runoff is determined by the way in which the main sources of water supply within the hydrographical basin of the Sebeș river, are combined during the year.

By analysing the seasonal distribution of the water average stock from the Sebeș river, we have found that spring is the season with the richest discharge, because of the relatively high quantities of liquid precipitations occurred and because of the water coming from the melting of snow accumulated during the winter.

During summer, the seasonal average water supply from the flowing waters decreases quite a lot due to the high temperatures that intensify the evaporation process, reason for which this season is classified in the category of seasons with the poorest runoff from the year.

Autumn is the season with the lowest contribution to the annual average volume on the river, although the precipitation quantities are almost double compared to the ones during winter.

In winter, the territorial distribution of the discharge is influenced by the oceanic climate, with consequences on the atmospheric precipitation quantity, fallen on the surface of the basin and on the thermal regime of the air.

Analysing the distribution of the monthly middle water discharge during a calendar year, it can be noticed that at the level of this experimental and representative basin, more exactly at Turnu Ruieni hydrometric station, is recorded: a maximum leakage of water in April, a main minimum leakage of water in October-November and a secondary minimum leakage of water in January.

The maximum runoff recorded in April is due to large amounts of water from fallen rainfalls and melting snow accumulated during the winter.

This phase of runoff is the most important phase of the runoff regime, because of its characteristics and the weight of the destructive effects that floods can cause, which must be taken into account in the design of water courses, both in the design and execution and the exploitation of hydro-technical constructions from a hydrographical basin.

The study of the maximum runoff from the main hydrometric station on the Sebeș river, as well as the distribution of these values according to genesis, was carried out on the basis of the comparative analysis of the variations that the climatic and hydrological elements has during 1964-2012.

Calculating the deviation of the annual maximum values from the multiannual average value we identified three situations as follows:
- 5 normal years without deviation (1968, 1971, 1972, 1979 and 1981);
- 17 years with a positive deviation (1965, 1966, 1969, 1970, 1973, 1974, 1978, 1980, 1989, 1997, 1998, 2000-2002, 2005, 2006 and 2010);
- 27 years with a negative deviation (1964, 1967, 1975-1977, 1982-1988, 1990-1996, 1999, 2003, 2004, 2007-2009, 2011 and 2012).

Some of these years (1966, 1970, 1975, 1978, 1980, 1991, 1993, 1997, 2000 and 2005) had an extremely rich atmospheric precipitations which together with suddenly melting of snow layer, generated the increase of water discharges and significant flash floods in the Banat hydrographical space (Arba, 2013).

By analyzing the maximum runoff on the Sebeș river and its variation over time, we noticed that the most important years, in which the highest values were recorded, well above the multiannual average of the annual maximum values, were recorded in: 1980 and 1970, the same years in which happened significant floods in this hydrographical basin, but also in other regions of the country (fig. 3).

In 1970 the floods affected almost all of the country, including the western part of the country. On the Banat rivers, the recorded flood water discharge were not so high, but they caused significant floods, especially in lowlands, which compromised some rural and urban localities and agricultural crops on large areas of land (Arba, 2010).

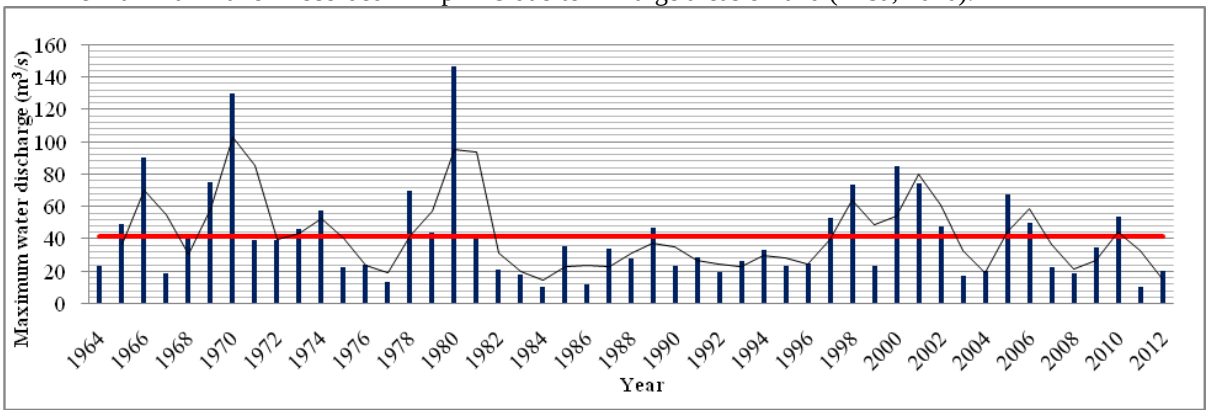

Figure 3. The variation hydrograph of annual maximum water discharges at Turnu Ruieni hydrometric station (1964-2012)
Source: Data processed by the Banat Water Basin Administration (ABAB) Archives, Timişoara

The floods which general occurres on the rivers from Banat region are a frequent natural phenomenon and an analysis of them over an interval of about 250 years reveals that the periodicity of the major floods is about 30 years and thare are cases when these extreme hydrological phenomena occur at intervals only a few years (Arba, 2016).

Within this region most of the flash floods occur in the spring season, when the snow layer melts suddenly or when significant rainfall produce or when several factors combine, such as those mentioned before, which together lead to the occurrence of mixt flash floods (Arba, 2010).

Data strings which contains the annual maximum water discharge can be the basis for calculating and tracing the curves with different probability of overtaking, very useful in flood defence activity.

For the Turnu Ruieni hydrometric station, which is situated on Sebeș river the maximum values of water discharge with various assurances are: 227 m^3/s with 1 % insurance, 185 m^3/s with 2 % insurance, 119 m^3/s with 5 % insurance and 81,9 m^3/s with 10 % insurance (Teodorescu, 2005).

In a small hydrographical basin like as the catchment of the Sebeș river, the floods and their destructive effects have been amplified by massive deforestation and by the improper exploitation of multiple surfaces and soil erosion respectively (Bădăluță-Minda, Dunca, 2017).

The minimum leakage of water is a basic feature of the river's hydrological regime, which means the smallest quantity of water passing through a river drain section over a reference period (one day, one month, one season, one year or several years), according to which this phase of the regime may be several types, namely: daily, monthly, seasonal, annual or multiannual (Zăvoianu, 2007).

Assessment of leakage water during periods with low waters is very important because these periods can have negative consequences on water supply to the population, industry, irrigation systems and maintaining the integrity of aquatic ecosystems.

In Romania the minimum leakage of water occurs in winter when the average daily air temperatures drop below 0° C, but also the summer, because of low frequency of rainfalls from August to September, because of high air temperature, because of increased and accentuated evaporation, as well as because of the maximum depletion of reserves from the undergound waters.

At the level of one calendar year, we found that in the experimental and representative hydrographical basin of the Sebeș river occures two periods with small waters, as follows: a period of small waters in summer-autumn, due to high evapotranspiration, reduced atmospheric precipitation and water supply of rivers from the depleted underground waters and a period of small waters in winter, which are the consequence of solid precipitation and accumulation in the snow layer.

The average duration of summer and autumn small waters from hydrographical basin of the Sebeș river, which is part of the Timiș hydrographical basin, is maintained between 75 and 85 days per year, being significantly higher in the western and central part of the basin than in the eastern part, where convective rains and lower temperatures favor the formation of superficial runoff (Arba, 2016).

The minimum leakage of water from winter season is due to dry and prolonged periods from autumn season, due to solid precipitations, like as snowfalls and due to negative air temperatures that can last for a long time, favoring the development of frost phenomena, or even total freezing of rivers which have a lower water discharge.

The variation of the annual minimum water discharges at Turnu Ruieni hydrometric station reveals that the years with the lowest minimum water discharges on Sebeș river are: 1965, 1986, 1987 and 2000 (fig. 4).

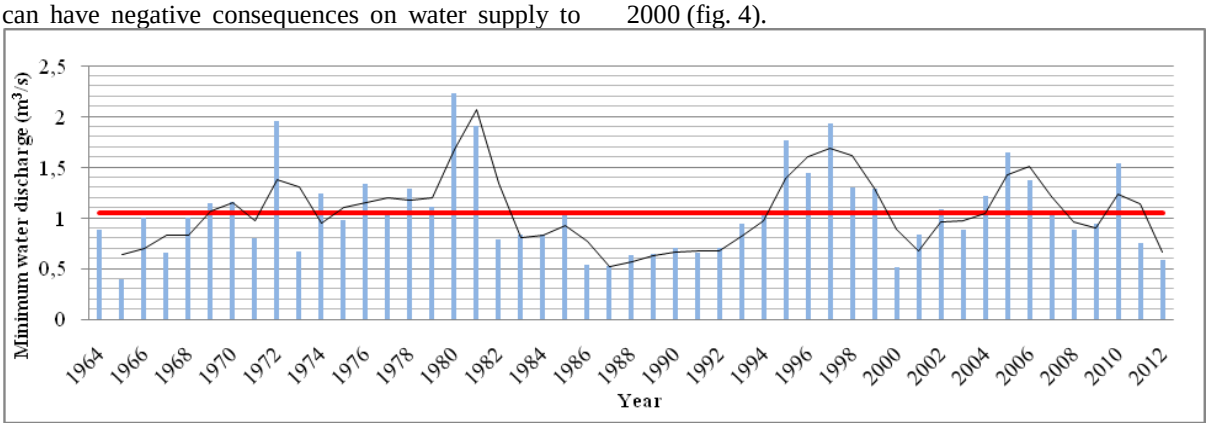

Figure 4. The variation hydrograph of annual minimum water discharges at Turnu Ruieni hydrometric station (1964-2012)
Source: Data processed by the Banat Water Basin Administration (ABAB) Archives, Timişoara

Calculating the deviation of the annual minimum values from the multiannual average value we identified three situations as follows:

- 7 normal years without deviation (1966, 1968, 1977, 1985, 1994, 2002 and 2007);
- 18 years with a positive deviation (1969, 1970, 1972, 1974, 1976, 1978-1981, 1995-1999, 2004-2006 and 2010);
- 24 years with a negative deviation (1964, 1965, 1967, 1971, 1973, 1975, 1982-1984, 1986-1993, 2000, 2001, 2003, 2008, 2009, 2011 and 2012).

Although within Sebeș hydrographical basin is recorded two seasons with small waters during each year and even if about half of the analysed years had a negative deviation, it should be pointed out that in this hydrographical basin does not generally recorded

the draining phenomenon of the rivers.

In both periods of low waters produced in the course of the year, the water supply of the rivers takes place exclusively from the ground waters aquifers, which thus implies a variation within relatively small limits of the specific water discharges.

4. CONCLUSIONS

The water resources from the experimental and representative hydrographical basin of the Sebeș river are quite rich and are represented by both surface waters, such as flowing waters and lakes, as well as by the ground waters.

The Sebeș hydrographical basin is situated in the west part of Romania, in the way of the oceanic masses of air and of the Mediterranean cyclones, as well as at a high average altitude, which give the area significant quantities of precipitations with direct influence on the water discharge.

This hydrographical basin is part of European Network of Experimental and Representative Basins (E.R.B.) and has an important role of understanding the process of runoff formation into a small catchment from this part of our country.

The hydrological regime of the Sebeș river (daily, monthly, seasonal, annual and multiannual) is strongly influenced by the variations of the climatic phenomena, demonstrating once again the very close relationship between the meteorological and the hydrological parameters.

Analyzing the annual middle water discharge for a long period of time (1964-2012) we observed that the variation of the annual average values in comparision with the multiannual average value is slightly decreasing. This decreasing trend, especially towards the end, can be attributed to the global climate change, which primarily affects the small hydrographical basins.

By the analyses of the annual average leakage and the relation of this parameter in comparison with multiannual average of runoff we can distinguish three types of years such as: 9 years with almost normal runoff, 17 years with rich runoff and 23 years with poor runoff.

Calculating the deviation of the annual maximum values from the multiannual average value we identified three situations as follows: 5 normal years without deviation, 17 years with a positive deviation and 27 years with a negative deviation.

This phase of runoff is the most important phase of the runoff regime, because of its characteristics and the weight of the destructive effects that floods can cause, which must be taken into account in the design of water courses, both in the design and execution and the exploitation of hydro-technical constructions from a hydrographical basin.

The floods which general occurres on the rivers from Banat region are a frequent natural phenomenon and an analysis of them over an interval of about 250 years reveals that the periodicity of the major floods is about 30 years and thare are cases when these extreme hydrological phenomena occur at intervals only a few years (Arba, 2016).

Calculating the deviation of the annual minimum values from the multiannual average value we identified three situations as follows: 7 normal years without deviation 18 years with a positive deviation and 24 years with a negative deviation.

Although within Sebeș hydrographical basin is recorded two seasons with small waters during each year and even if about half of the analysed years had a negative deviation, it should be pointed out that in this hydrographical basin does not generally recorded the draining phenomenon of the rivers.

From a climatic point of view, the western region of the country, where the hydrographical basin of Sebeș river is located, dominated by moderate oceanic influences, records a relatively low frequency, duration and intensity of the drought and dryness phenomena, compared to other parts of the country, but the frequency of the extremely humid periods is higher than in other parts of the country.

The years with precipitation deficit as well as the rainy ones, having a climatic record feature, should not be neglected, because they represent important climatic risks, especially for economy.

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