Caspian J. Env. Sci. 2011, Vol. 9 No.1 pp. 81~95

CJES
Caspian Journal of Environmental Sciences

[Research]

Patterns of flow evolution in the central area of the Romanian Plain, Case study: the Calnistea Catchment (Romania)

A. Cocos[1], O. Cocos[2*], I. Sarbu[2]

1- Hyperion College, Bucharest, Romania
2- Faculty of Geography, University of Bucharest, Bucharest, Romania
** Corresponding author's E-mail: octaviancocos@yahoo.com*

ABSTRACT

This paper seeks to emphasize the flow variability in the Calnistea catchment by analyzing the local physiographic factors. The research has shown that the amount of precipitation that falls to the ground is low, the rocks in the region are soft, but highly permeable, gradients are gentle in most of the territory and vegetal cover is sparse and therefore cannot hold important amounts of water. Under the circumstances, the flow is controlled especially by precipitation, gradient and rock permeability, which largely explains the rather low values of the drainage density, as well as the frequency with which the rivers dry up completely. The moisture deficit of the summer season is compensated to a certain extent by the existence of a chain of ponds along the main streams. The situation could further be improved if local authorities will find the necessary financial means in order to excavate artificial channels to bring water from the neighboring catchments. Although the flow values are generally low, under exceptional synoptic conditions the heavy rainfalls can lead to the formation of flash floods that can damage settlements, transportation routes and crops. Consequently, it is necessary to build protection levees in the lowlands and to regulate the stream flow.

Keywords: *Calnistea catchment, Precipitation, Streams, Flow, Discharge.*

INTRODUCTION

Despite the progress that has been made so far in science in general, and in the forecasting of hydrological risks in particular, many regions of the world continue to be confronted with catastrophic hydrological events, which cause serious material damage and loss of human life. On the one hand, there are areas that are confronted almost every year with the unleashed rage of the floods that sweep away human settlements, roads, railways, bridges and power lines. On the other hand, vast areas are left without a drop of water, inasmuch as the rivers dry up, and consequently people have to face different problems, such as human migration, epidemic outbreaks and desertification. These undesirable phenomena can sometimes be attributed to natural causes, as for instance magnetic storms, solar eruptions or El Niño effect. Other times, however, those who must be blamed for are the people, because they alter the natural balance of the environment through reckless actions (massive deforestations, works that render the ground impervious, dyking and reclamation works, constructions that hinder the streamflow, and last but not least, the burning of fossil fuels, which leads to the intensification of the greenhouse effect).

In order to control these devastating events specialists from all over the world have been trying to determine as accurately as possible the relationships between the natural and anthropogenic elements of the catchments, how they interact with one another and how they manage to influence the surface and sub-surface flow. Besides, the "*design of water control structures, reservoir management, economic evaluation of flood protection projects, land use planning and management, flood insurance assessment, all rely on knowledge of the magnitude and frequency of floods*" (Rao & Srinivas, 2008, p. vii).

The analysis of flow variability in the Calnistea catchment is therefore rooted in this general effort. The understanding of the role of every single factor in the local water budget and the deciphering of the variation patterns of surface flow will be extremely important for the future development of the area.

DATA AND METHODOLOGY

In order to understand the conditions of flow formation on this territory we have firstly assessed the physiographic factors that influence to a higher or lesser extent this phenomenon. Thus, the study of geological features has been accomplished on the basis of geological maps of scale 1:50000 and the existing stratigraphic profiles for this region. To investigate the terrain features we have used topographic maps of scales 1:25000 and 1:50000, as well as aerial photographs of scale 1:50000, which have been supplemented by our own observations and mappings in the field. As far as the climatic conditions are concerned, these have been analyzed based on the statistical datasets provided by the weather stations within the catchment or lying in its immediate vicinity. Likewise, we have turned our attention to vegetation and soils, using for their analysis thematic maps of scale 1:100000, whose information has been updated by our own investigations in the field. After getting a comprehensive picture of the runoff controls, we have proceeded to an analysis of flow variability based on the datasets provided by the National Institute of Hydrology and Water Management, taking seriously into account Mallows ideas and his definition of statistical thinking (Mallows, 1998). In the case of maximum flow, a series of theoretical estimations regarding the maximum discharges with various probabilities of occurrence of the rivers in the Calnistea catchment have been done. The values have later been employed for the computation of the thickness of water layer that flows over the entire catchment, or some sections of it, as well as for the assessment of total water volume specific for the respective floods. We should note that the empirical discharge recurrence interval has been computed with the Weibull formula, whereas the computation of maximum discharges and the drawing of theoretical recurrence curve are based on Log-Pearson type III, which better fits the physiographic realities of Romania. The processing of all the information has been done in a modern manner, by using the computer and the Geographical Information Systems.

THE STUDY AREA

The Calnistea catchment lies in the southern part of Romania, within a major physiographic unit that goes by the name of the Romanian Plain (Fig. 1). This rather well populated territory has lately been confronted with long periods of drought, which on the one hand have made some rivers dry up completely and on the other hand have brought about a moisture deficit in the soil, with negative effects on the local crops. However, the region also experiences periods when heavy rainfalls lead to the occurrence of flash floods, which play havoc on households, roads, railways, bridges and power lines. Under the circumstances, it is necessary to understand the flow variability at the scale of the entire catchment, not only to be able to prevent the risk situations, but also to find the most efficient means to respond when such unwanted phenomena occur.

From the geological point of view, it is important to note that almost the entire region is capped by loessoid deposits of variable thickness. South of the Calnistea axis, these belong to Middle Pleistocene, whereas to the south they are newer, belonging to Upper Pleistocene. The floodplains and terraces are carved in Holocene formations, represented by loessoid deposits and coarse sediments (Ionesi, 1994). What is really important about these formations is their high permeability, which favors the rapid percolation of meteoric waters into the ground, thus hindering the runoff.

As far as topography is concerned, it is apparent that altitudes are very low. Thus, the highest elevation (204 m) is in the extreme northwest of the catchment, exactly on the divide, whereas the lowest elevation (46 m) corresponds to the confluence of the Neajlov. The largest hypsometric step is that of 50 – 100 m, which accounts for 65% of the whole area.

Fig 1. The geographical location of the Calnistea catchment within Romania

Second comes the step of 100 – 150 m, which has a share of 28.7%, followed by the steps of 150 – 200 m, below 50 m and above 200 m, which hold together 6.3% of the area. Another important morphometric element is the gradient. At the scale of the entire catchment, its value is extremely low, of only $0^0 09'$, which is a typical value for a plain region. However, locally one can notice some higher gradients, which highlight the slopes of the valleys that scar the territory. The most extensive are the quasi-horizontal surfaces with grades ranging from 0 to 3^0. These account for 88.6% of the region and correspond to the flat interfluves, terraces and floodplains. On such areas, the water from rain or melting snow easily sinks into the ground or is quickly lost through evapotranspiration and consequently sheetflow and gully erosion are almost absent. The surfaces that dip 3 – 5^0 have a share of 7.6%. They lie on both sides of the Calnistea River, but are also found in the lower courses of the Glavacioc and the Milcovat. Other more compact areas with similar gradients are also present at the headwaters of the Valea Spetezei and in the Burnas Plain (on the right side of the Valea Porumbenilor and the Ismar). The surfaces with gradients of 5 – 10^0 account for 3.5% of the total area of the catchment and are specific for the accumulation glacises that lie at the base of the slopes and terrace scarps. The higher inclination of land makes gullying processes extremely active. But the highest grades are found on the river slopes. Although they totalize only 0.3% of the area, they manage to break the monotony of the plain landscape. Here and there, however, the gradients may reach 40 – 50^0, as it happens on the northern scarp of the Burnas Plain and especially at the junction of the Calnistea and Neajlov rivers. Surfaces with such gradients are also found along the Glavacioc and the Milcovat, as well as on both sides of the younger valleys that cross the Burnas Plain. The economic exploitation of these lands is somewhat hindered by gullying and denudation processes, as well as by superficial landslides (Cocos & Cocos, 2007).

The mean annual temperature specific for the Calnistea catchment is 10.4^0C. The graphs drawn on the basis of the datasets provided by the weather stations in the area reveal the fact that monthly mean temperatures have a normal evolution, describing an ascending curve from January to July and a descending curve from July to January. In summertime, the maximum values often exceed 40^0C, whereas in the cold winters they drop to 35^0 below the freezing point. At Videle weather station, which lies in the central part of the catchment, are recorded on an average 111 summer days (with temperatures above 25^{0}C), 43 hot days (with temperatures exceeding 30^{0}C) and 112 frost days (with temperatures below the freezing point). During these periods, superficial flow is very much diminished.

The most important control of the runoff regime is the atmospheric precipitation, which has values ranging from 541 to 660 mm. The pluviometric maximum occurs in June or July, when the advection of North Atlantic cyclones generates heavy downpours (79 mm at Videle). The pluviometric minimum is recorded in February due to the advection of the Siberian Anticyclone, which makes the mean values of precipitation drop to 31 mm. The highest amounts of precipitation fall in summer (186 mm) and the lowest in winter (112 mm) and fall (113 mm). During most part of the year, precipitation falls in liquid form, but the spring and summer rainfalls, with strong torrential character, are prevalent. Snow begins to show up in November, or in the cold years even at the end of October. The snow layer is usually 5 to 8 cm thick, but sometimes can exceed 10 cm. The highest mean multiannual thickness values of snow layer were recorded during the period 1970 – 1985 in the month of January (190 cm), whereas the lowest values were specific for March (3 cm). However, there are also some exceptions when in March the area was covered by a 70 cm thick snow layer. The years with abundant snowfalls bring about not only an intensification of the flow, but also an active percolation of water into the ground, which contributes to the replenishing of aquifers.

Initially, the study area was covered by forest and silvosteppe, but in the last 220 – 240 years, the vegetation has suffered drastic alterations because of the human intervention on landscape (Cocos & Cocos, 2010).

Consequently, the forest has almost completely disappeared and its place has been taken by agricultural lands and secondary grasslands. Only here and there, one can see a few remaining patches of the former forest, hardly reaching 11,459 hectares (which accounts for 6.5% of the area, in comparison with the situation at the end of the 18th century when the forests covered 50 – 60% of the catchment). At present, the vast areas devoid of vegetation are brought under cultivation. The artificialization of the vegetal cover is further enhanced by overgrazing, which encourages the proliferation of less valuable herbal species.

As far as the soils are concerned, these are not only very fertile, but also highly permeable, thus allowing water percolation to the detriment of the flow (Demeter, 1999).

RESULTS AND DISCUSSION

The investigated area stretches on 1748 km^2, which accounts for 0.7% of Romanian territory and 14% of the Arges catchment, to which it belongs. The distribution of the territory on the two banks of the Calnistea river is slightly different, the left bank being prevalent, with 984 km^2 (56%), whereas the right bank covers 764 km^2 (44%). The catchment is 91.4 km long and averages 19 km across, whereas the maximum width is 32 km. Its shape is rather elongated (Fig. 2), which encourages the gradual drainage of slopes, thus preventing the occurrence of high floods.

The total length of the river system with permanent and semi-permanent flow is 389 km, a value to which the Glavacioc (99 km), Calnistea (87 km) and Milcovat (45 km) rivers contribute significantly. Apart of these, there are also very short streams, with low discharges, like the Valea Taudor (1.7 km), the Valea Cuscrei (2 km), the Bratilov (2.2 km) and the Valea Casariei (2.3 km).

The permanent and semi-permanent streams of the left bank totalize 302.1 km, which is 77.7% of the total length of the river system, while the streams of the right bank have only 86.9 km (22.3%), especially due to the Ismar (23 km), Valea Porumbenilor (22.8 km), Valea Alba (13 km) and Suhat (13 km).

The average gradients of the streams depend on their length, as well as on the difference between the elevation at the headwaters and the elevation at the mouth. Generally, the gradients are low, because of the terrain features. Higher grades are found along the streams whose weak linear erosion force prevented them to attain an equilibrium profile with respect to the mainstream river. It is especially the case of the Valea Casariei (8‰), Valea Alba (6.9‰), Valea Cuscrei (6.5‰) and Valea Dreajului (5‰). The direct consequences of the existence of slope angles of 0.4‰ to 8‰ are the low velocity of water flow, the formation of swamps, the prevalence of lateral cutting and sediment deposition within the channel, as well as the frequent occurrence of meanders and secondary branches (Cocos & Cocos, 2005).

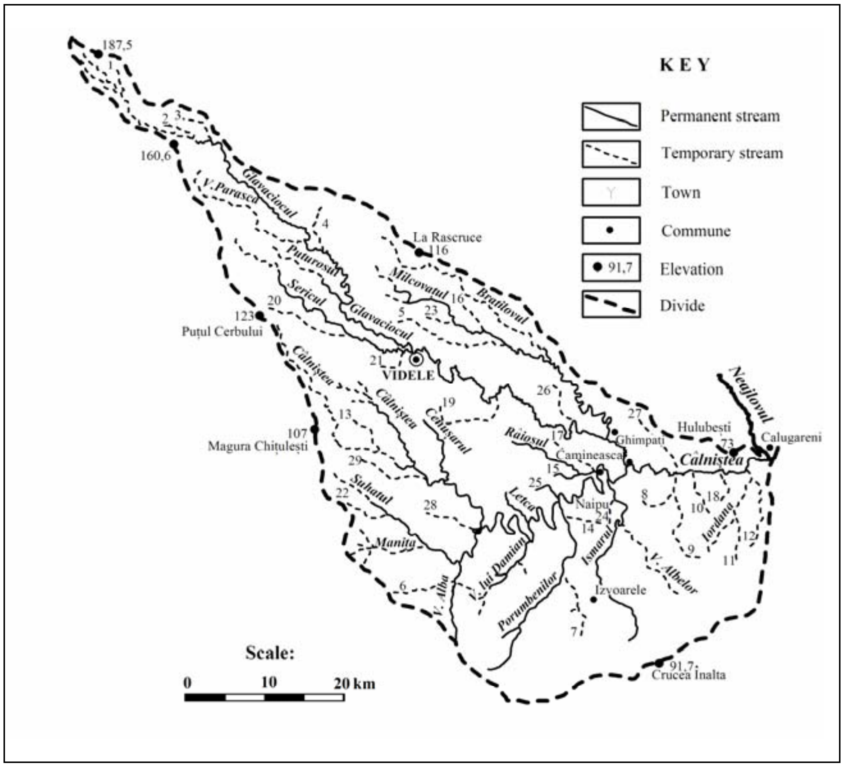


Fig 2. The Calnistea river system

The figures on the map stand for: 1. Glavaciocul Mare; 2. Fataceni; 3. Balaban; 4. Valea de Margine; 5. Cosoaia; 6. Putul Butii; 7. Silistea; 8. Valea Rotundu; 9. Valea Racul; 10. Valea Viilor; 11. Valea Campul Ascuns; 12. Valea Bujorescului;13. Valea Mutului; 14. Valea Bacanului; 15. Valea Casariei; 16. Valea cu Corn; 17. Valea Cucuiului; 18. Valea Neagra; 19. Valea Dreajului; 20. Valea lui Margarit; 21. Valea Muscalului; 22. Valea Putul lui Andrei; 23. Valea Rece; 24. Valea Seaca; 25. Valea Cuscrei; 26. Valea Helesteele Diaconului; 27. Valea Spetezii; 28. Valea Taudor; 29. Valea Botoroaga

The Calnistea River has a mean flow gradient of 0.6 m/km. In the upper sector, the valley is barely visible on the first six kilometers or so, but then begins to deepen into the loessoid deposits of the plain, thus getting here and there a "canyon" appearance (0.5 km across and with steep slopes, 20-22 m high). More than half of this stretch is dry, because the downcutting has not reached the groundwaters yet. Only downstream of Stejaru village one can see a thread of water flowing lazily on the valley bottom. In the middle sector the valley is still narrow, but near the confluence with the Glavacioc, its main tributary, it gets larger, inasmuch as the two rivers have managed to cut a small confluence floodplain. Along this stretch, the gradient is extremely low and as a consequence, the water oozes gently or even stagnates on the flat bottom, which explains the existence of the pools and swamps. The lower sector of the valley lies downstream the confluence with the Glavacioc. Here, the valley becomes asymmetrical, because the right bank is high and the left one is low. At the same time, the valley is much larger, the floodplain reaching 2 km across.

The Calnistea River has 18 first-order tributaries, of which the most important ones are the Glavacioc (on the left) and the Ismar and Valea Porumbenilor streams (on the right).

The Glavacioc valley has a mean flowing gradient of 1.1 m/km. Between the headwaters and the Glavacioc village it is narrow and dry, but immediately downstream the village the existence of some springs with significant discharges make the river acquire a permanent flow.

Consequently, on selected stretches, the valley widens up to one kilometer and deepens by 26 m. Between Videle and Crevenic the course of the river is winding and splits into several branches. Downstream of Crevenic and as far as the confluence with the Calnistea the valley gets larger and larger as the floodplain begins to accompany the watercourse. Likewise, discharges are much higher, due especially to the contribution of the Milcovat, which is the most important tributary.

The Ismar valley has a mean gradient of 1 m/km. It is carved into the loessoid deposits of the Burnas Plain, which makes it resemble a small canyon. The flow has a temporary character, except for the lower stretch, where the stronger downcutting has reached the groundwaters. The long gradient in the long profile and the human interventions have turned the stream into a chain of small pools and impoundments.

As far as the Valea Porumbenilor is concerned, it has rather similar features with the Ismar valley, namely low gradients in the long profile, steep slopes, with maximum heights of 26 m, which render it a "canyon" appearance, and a maximum width of only 1.3 km.

The other first-order tributaries are less important as they are much shorter and have a temporary flowing regime. Of the second order tributaries, the most important are the Milcovat, Sericu, Parasca and Suhat streams, which do not differ markedly from the general features described above.

The assessment of flow variability in the Calnistea catchment has been accomplished based on the data recorded at the three gauging stations in the area, namely Videle and Crovu on the Glavacioc and Stoenesti on the Calnistea. The most important of them is the Crovu station, which has been in operation since 1962. However, despite the fact that the time span is enough for a pertinent analysis we have preferred to extend theoretically the mean discharges back to the year 1950 on the basis of the correlation with the average precipitation fallen each year over the catchment. Under the circumstances, this station can be considered representative for the Calnistea catchment and therefore it has been used to extend the datasets recorded at Videle and Stoenesti, inasmuch as the intervals of observations have been shorter.

The **mean multiannual discharges** for the three hydrometric stations within the catchment have been determined on the basis of the mean annual discharges for a period of 54 years. The respective values show that at Videle the mean multiannual discharge of the Glavacioc is very low, only 0.69 m^3/s, which is understandable if we take into account that the station is placed in the middle stretch of the river and the drained area amounts only to 220 km^2. Downstream, near the junction of the Calnistea, thanks to the contribution of the Milcovat, its main tributary, the discharge reaches 1.1 m^3/s.

On the Calnistea River, at Stoenesti gauging station, the mean multiannual discharge is 2.95 m^3/s. This is a rather low value if we take into account the drained area of 1,644 km^2, which confirms the high aridity of the entire region.

The **mean annual discharges** vary with the amount of precipitation fallen each year on the catchment's territory. By analyzing the range of data, one can find out that on the Glavacioc the highest discharges were 2.02 m^3/s at Videle and 3.31 m^3/s at Crovu, both values recorded in 1970, while the lowest discharges barely reached 0.142 m^3/s and 0.232 m^3/s respectively, in 1950. On the Calnistea, at Stoenesti, the mean annual discharges ranged from 0.567 m^3/s to 10.3 m^3/s, the characteristic years being the same as in the case of the Glavacioc. This confirms once again the homogeneousness of the local geographical conditions, which largely explains the good correlations among the three hydrometric stations.

By analyzing the mean annual discharge hydrographs one can notice a common pattern of flow evolution above and below the mean multiannual discharge. Thus, at the level of the entire catchment, irrespective of the stretch where the recordings were made, one can notice rainy periods (1953-1956, 1969-1973, 1978-1980) and dry intervals (1950-1953, 1957-1966, 1974-1978, 1987-1996, 2000-2003). From time to time, the discharges were close to the mean multiannual flow or even had the same values (the so-called characteristic years from the hydrological point of view).

The position of the gauging stations

within the catchment allows the estimation of the mean discharges of the Milcovat, as well as of the Calnistea upstream of the confluence with the Glavacioc. Thus, the Milcovat discharge varies from 0.007 m^3/s (in 1965) to 1.29 m^3/s (in 1970), while the Calnistea, without the Glavacioc contribution, has a mean annual flow that ranges from 0.335 m^3/s (in 1950) to 6.99 m^3/s (in 1970).

The annual variability of meteorological factors is mirrored by the distribution of the mean monthly discharges (Fig. 3). Thus, for the three hydrometric stations in the region the highest flow values occur in March (1.69 m^3/s at Videle, 2.68 m^3/s at Crovu and 6.88 m^3/s at Stoenesti) and February (1.27 m^3/s, 2.03 m^3/s and 5.04 m^3/s, respectively). These are determined especially by snow melting, but also by the fairly significant liquid precipitation that falls in early spring. As far as the minimum discharges are concerned, they are specific for August (0.24 m^3/s at Videle, 0.39 m^3/s at Crovu and 1.26 m^3/s at Stoenesti) and September (0.26 m^3/s, 0.42 m^3/s and 1.37 m^3/s respectively), when precipitation is scarce (Cocos, 2006).

The participation of every season to the total water volume that flows during a year is somehow similar for the three hydrometric stations (Table 1). The highest values of the mean seasonal flow are specific for spring (38.06% at Videle and 38.45% at Crovu on the Glavacioc and 37.6% at Stoenesti on the Calnistea) and winter (31.04% at Videle, 30.67% at Crovu and 29.18 at Stoenesti). By contrast, the lowest participation is recorded in fall (13.44% at Videle, 13.77% at Crovu and 16.33% at Stoenesti) and summer (17.46%, 17.11% and 16.89% respectively), as a result of long droughts and intense evapotranspiration.

The cloudbursts and the sudden melting of snow cover induced by the persistence of higher temperatures result in a considerable increase of discharges and water levels on the main rivers in the Calnistea catchment. Consequently, they overflow their banks generating floods the size of which is strongly influenced by catchment shape and physico-geographical factors (terrain gradient, soil permeability and degree of vegetation cover). Unfortunately, however, floods often have a strong negative impact on the settlements, transportation routes, economic facilities and crops, which is why the analysis of the maximum flow and the prediction of flood occurrence has become a major necessity.

The maximum discharges show significant variations from year to year. Thus, the highest values recorded so far amount to 94.7 m^3/s on the Glavacioc and 195 m^3/s on the Calnistea (both values recorded on March 24, 1973). By contrast, the lowest maximum values were observed on the Glavacioc in 1994 (0.94 m^3/s on July 17) and on the Calnistea in 1989 (3.12 m^3/s on September 8).

The monthly variation of maximum flow is controlled by the climatic features of the investigated area. Thus, the high waters are specific for the interval February – April and to a lesser extent to July and November. In the rest of the year, the high values occur sporadically, either because of the sudden winter warming events (especially in January), or because of the showers generated in May, June and September by the local or regional synoptic conditions.

For the Romanian territory, the empiric flow distribution is plotted with the Weibull's formula, while the calculus of the maximum discharges and the drawing of theoretical stochastic curve are based on log-Pearson type III distribution, which is the most convenient for the geographical conditions of the country (Drobot, 1997).

The maximum water discharges with various occurrence probabilities must necessarily be studied, as they are extremely important for the engineering works and transport infrastructure, as well as for the village dwellers and economic activities. The assessment of maximum flow can be accomplished both through empirical methods, based on the data recorded at the gauging stations, and through theoretical methods, which employ formulas that rely on various hydrological parameters. If the former give us a short-term image (between 2% and 98%), the latter allow us to forecast the occurrence of maximum discharges with much lower probabilities (0.1%, 0.3%, 0.5% and 1%).

For water management activities, knowing the discharges with occurrence probability of 1% is extremely important. From this standpoint, we can assert that the highest values are specific for the Calnistea, upstream the junction of the Neajlov (340 m^3/s), and the lowest for some petty affluent streams, namely the Calnistea brook and Cenusarul (both with 55 m^3/s).

As far as the Glavacioc is concerned, upstream the junction of the Calnistea its discharge is pretty high (215 m^3/s) in comparison with other tributaries of the trunk river (Raiosul 60 m^3/s and Valea Alba 80 m^3/s).

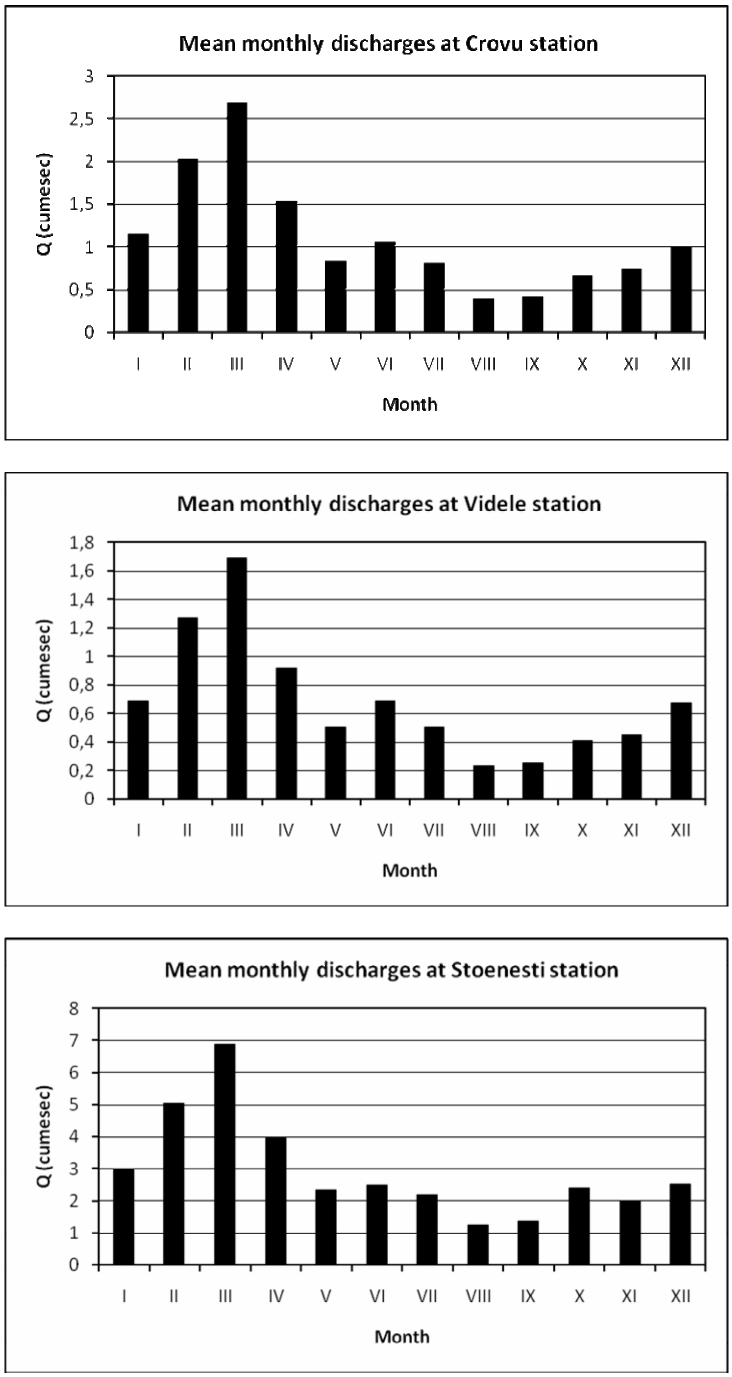


Fig 3. The march of the mean monthly discharges at the three gauging stations in the Calnistea catchment

Under the circumstances, the highest water volumes flow on the Calnistea (77.5 m^3/s) and the Glavacioc (43.3 m^3/s), but the thickness of water layer that flows over the Calnistea catchment is smaller (44.5 mm) than that of the layer that flows over the Glavacioc river basin (65.5 mm).

Expressing the maximum discharge with occurrence probability of 1% in the form of specific liquid maximum discharge (in l/s/km²) one can notice that the highest values correspond to the smaller catchments (Cenusarul 1341.4 l/s/km², Calnistea brook 1309 l/s/km² and Raiosul 1090 l/s/km²). Compared to those, the Glavacioc and Calnistea have much lower values, of 325.7 l/s/km² and 195.06 l/s/km² respectively.

Table 1. Seasonal flow distribution in the Calnistea catchment

River	Gauging station	Mean seasonal flow Percent of the mean annual volume			
		Spring	*Summer*	*Fall*	*Winter*
Glavacioc	Videle	38.06	17.46	13.44	31.04
Glavacioc	Crovu	38.45	17.11	13.77	30.67
Câlniştea	Stoeneşti	37.60	16.89	16.33	29.18

Floods are natural hazards that occur after heavy rainfalls, which sometimes overlap the snow melting process, thus generating high discharges in a very short time. In the Calnistea catchment, systematic observations on floods have been done only at Crovu station on the Glavacioc. Here, the highest flood recorded so far occurred between March 19 and 28, 1973. It reached a peak discharge of 94.7 m³ and totaled a water volume of 26.3 million cubic meters. The flood hydrograph is rather symmetric (Fig. 4), inasmuch as the rising and falling limbs are nearly equal (110 hours and 111 hours respectively). In other words, almost five days in a row the water level rose continuously, and for the next five days it dropped to a value lying close to the normal level, which corresponds to a discharge of 9.41 m³/s.

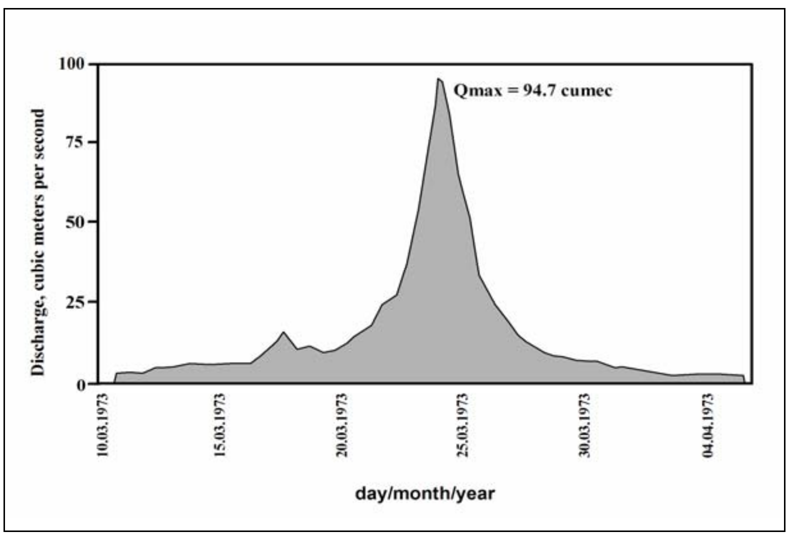


Fig 4. Discharge hydrograph of March 19 – 28, 1973 for Glavacioc River

Another important flood occurred at the same gauging station within the interval October 9 – 14, 1972. It began from a base discharge of 18.4 m³/s a reached a peak of 88.8 m³/s. Even though it lasted only 120 hours, the water volume that flowed through the cross-sectional area was 20.7 million cubic meters and the thickness of water layer was 32.2 mm. If this flood comes second in terms of maximum discharges, the flood of March 7 – 13, 1984, comes second in terms of the total water volume that flowed through the cross-sectional area (33.8 million cubic meters). This can be explained by the significant value of maximum discharge (75 m³/s), but especially by the longer duration (155 hours) and the slower recession pace (122 hours).

In the case of the Calnistea River, flood observations made at Stoenesti station have been irrelevant, inasmuch as the floodplain is very large and, besides, there is a small branch that collects the waters coming from the right side of the valley diverting them downstream the hydrological staff. Although on this stretch water level rose high in1972 and 1975, the information provided by the locals suggest the flood of 1951 had been much higher. However, the two more recent floods were recorded upstream the junction of the Glavacioc, where terrain configuration and channel characteristics are much more convenient for gauging. The data recorded have allowed us to draw the discharge hydrographs for the two floods, have revealed a common pattern of evolution.

At the scale of the entire catchment, it is apparent that most frequent floods occur in March, October, June and July

The rising limbs and the total duration of flood events can be analyzed from the perspective of their relations with the river lengths and the surface area of the catchments lying upstream the gauging sections. Such a regression analysis will provide us with a simplified view of the relationship between the selected variables (Rogerson, 2001). From this point of view, one can notice that for the Calnistea catchment the correlations between the maximum flow parameters (the rising limb on the one hand and flood duration on the other hand) and the lengths of the river channels are much more relevant than those between the former and the drained areas (Fig. 5 and 6). This can be seen not only from the scatter of data points, but also from the values of the mean square error, which are lower in the second case (0.67, compared to 0.92 in the first case).

What is important to note, however, is the fact that sometimes flood waves can be enhanced by the breech of the dams. This can have a negative impact on the other dams lying downstream, which in their turn can fail, bringing about havoc to the adjacent settlements. In some cases, the bad management of these impoundments is responsible for material damage and loss of human lives. For instance, the people who own the lakes often refuse to empty the reservoirs in order to absorb the flood wave. The reason for this behavior is the fact that they are engaged in fish breeding and consequently cannot afford to lose completely their production, as long as there are no clear regulations regarding the compensation of their losses. Likewise, the local authorities are often confronted with a technical problem arising from the fact that emptying valves get stuck for not being used for a long time. Thus, levees are overtopped or pierced and waters rush into the flat fields destroying settlements, roads and crops.

From this point of view, a serious situation occurred in 2005, on the Sericu River, when the break of a dam had a domino effect that propagated downstream. This was further amplified by the shallow valley stretches, which did not have the capacity of evacuating such huge amounts of water in a short time (Grecu et al., 2010).

In some years, discharges drop significantly because of the low amounts of precipitation and consequently the rivers become mere threads of water flowing lazily through their sediments. In summer, the phenomenon is further enhanced not only by the intense evapotranspiration, through which significant amounts of water are lost every day in the hot air, but also by the gentle slopes that make the waters stagnate on certain stretches (Pisota, 2000).

The analysis of the annual variation of minimum discharges of the Glavacioc and Calnistea rivers shows that at Crovu station the lowest minimum occurred on August 10, 1996 and it was as low as 0.019 m^3/s, while at Stoenesti it was observed much earlier, on June 28, 1974 and was a little bit higher (0.09 m^3/s). On the Glavacioc, the amplitude of variation of the minimum discharge on a range of 31 years of analysis has been 0.35 m^3/s, whereas on the Calnistea the value has been much higher, reaching 1.63 m^3/s.

The mean monthly variation of minimum discharges emphasizes that the lowest values are frequently recorded on the Glavacioc in August and September and on the Calnistea in July and August, due to the low amounts of precipitation and to the intense evapotranspiration specific for this part of the year.

In the dry years, the flow stops completely and river channels turn into a chain of pools. Such a situation occurred on the Glavacioc in the interval July-September 2000. However, the two main rivers rarely dry up, which means the underground feeding is rich enough to maintain a thin thread of water even under the harsh semi-arid climate of the southern part of Romania. Yet, this is not true for the other streams as well, which, having no connection at all with the aquifers or failing to capture them properly, are at the mercy of climatic conditions (Pisota & Moisiu, 1975). Consequently, they dry up in summer and early fall.

CONCLUSIONS

The low amounts of precipitation, the high evapotranspiration values and the low feeding of the rivers by emerging groundwaters explain the reason for which the streams in the Calnistea catchment generally have low discharges and why many of them dry up in the droughty summers. In order to prevent the risk of occurrence of such unwanted events people have been compelled to build up earth dams across the valleys to create ponds. Consequently, at present the Calnistea catchment shelters 61 such bigger or smaller reservoirs, which beside their hydrologic importance make the climate of the surrounding areas milder and, at the same time, serve as recreational areas for the locals. The discharge compensation is necessary in order to meet the demands of population and economy. This can only be ensured through the excavation of some derivation canals with the purpose of bringing water from the adjacent catchments (Pisota & Cocos, 2003).

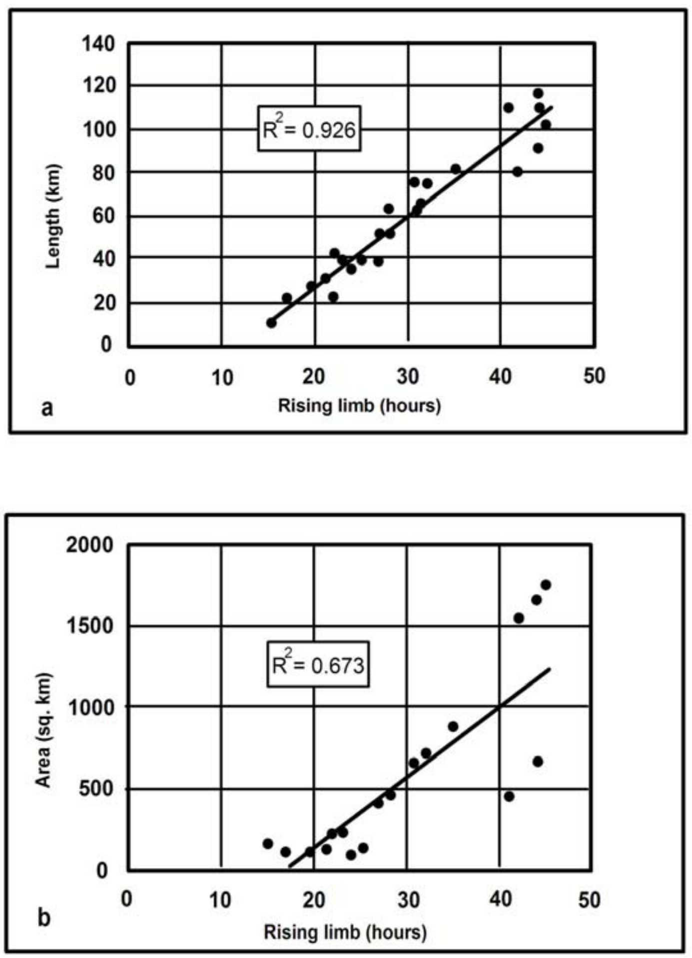


Fig 5. Correlations between the rising limb of the floods and the length of the rivers (a) and the catchments' area (b), respectively
(R^2 = mean square error of the regression line)

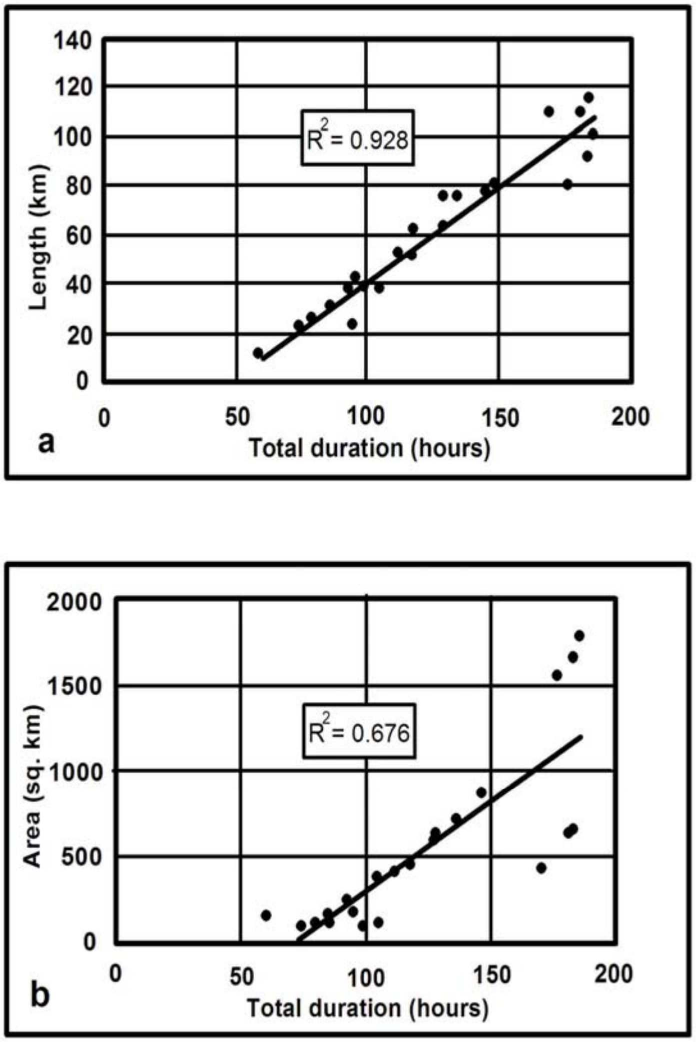
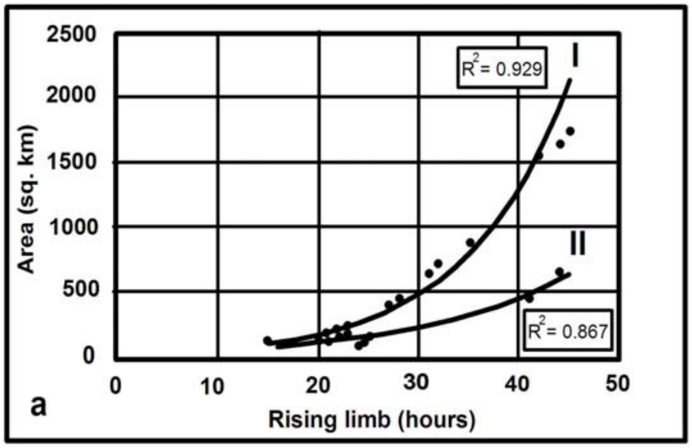


Fig 6. Correlations between the total duration of floods and the length of the rivers (a) and the catchments' area (b), respectively (R^2 = mean square error of the regression line)

In this respect, greater priority should be given to the accomplishment of two artificial channels, one between the Dambovnic and the Glavacioc and the other one between the Glavacioc and the Calnistea.

The Dambovnic – Glavacioc derivation canal will be meant to divert part of the Dambovnic waters in order to feed and enlarge the ponds lying along the Glavacioc. The intake facility should be placed upstream of Fierbinti, at an elevation of 150 m, and the derivation canal, 5.2 km long and capable of ensuring a gravitational flow with a mean discharge of 17 m^3/s, should reach the Glavacioc channel at an elevation of 146 m. From that point, a stepped channel will need to be created in order to bring the water to the level of the Catunu pond (139.5 m).

The Glavacioc – Calnistea derivation canal will allow the discharge compensation of the Calnistea River by supplementing the amounts of water within the ponds that string along the valley. The canal should start at the Blejesti reservoir, then will have to cross the Sericu valley and finally will end up in the Calnistea channel. Because of its length, the canal will probably be confronted with important water losses. In order to deal with this problem the authorities will have to reinforce it with concrete. As with the previous derivation canal, the water will also flow gravitationally, but the discharge will be lower (about 12 m^3/s).



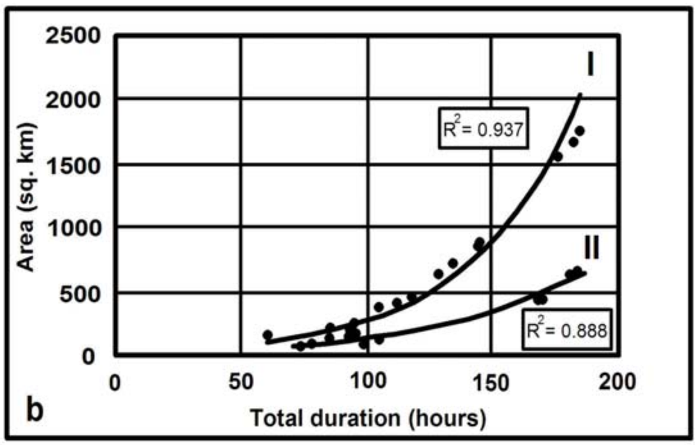


Fig 7. Correlations between the catchments' area and the rising limbs (a) and the total duration of floods (b), respectively
(R^2 = mean square error of the regression line)
I – regression line for Calnistea catchment II – regression line for Glavacioc catchment

Beside these two hydrological engineering works, the local authorities could also take into account the possibility of pumping water from the Danube all the way up to the Botoroaga pond and from there farther away as far as the Blejesti reservoir. However, the cost of this project will certainly be high and this could turn into a major obstacle inasmuch as Romania is passing through a serious economic depression.

Although the mean multiannual discharges of the rivers in the Calnistea catchment are generally low, under exceptional synoptic conditions, they overflow the banks causing havoc to agricultural lands and jeopardizing the settlements and transportation routes within the floodplains. The highest floods occur on the Glavacioc and Calnistea rivers, which together may affect a total area of 6,900 hectares (3,600 ha along the Calnistea and 2,300 ha along the Glavacioc). Even though the ponds in the area can store a total water volume of 8,924 million cubic meters in comparison to the normal retention level, the exposed areas should be further protected by local levees. The most important flood control dyke is the one lying in front of Hulubesti, on the left bank of the mainstream river. With a length of 8.5 km the dyke protects about 2000 hectares that are prone to flooding.

As far as the prediction of flood events is concerned, the estimation of rising limb and the total duration of flood events must rely especially on the correlation plots that show mean square errors close to unity. If separate correlations were made for the Glavacioc and Calnistea catchments, we would observe that exponential trendlines better fit the datasets referring to the surface areas, because the mean square error in this case is close to unity (Fig. 7). This means it is advisable to determine the rising limbs and total duration of floods in relation with the surface area, separately for each of the two important catchments.

ACKNOWLEDGEMENTS

We would like to acknowledge the late Dr. Ion Pisota, Dr. Petre Gastescu, Dr. Ion Zavoianu and Dr. Liliana Zaharia for their invaluable assistance. We are also grateful to the institutions that provided the necessary data and information on which this paper is based upon: the National Institute of Hydrology and Water Management, the National Administration of Meteorology, the "Apele Romane" National Company, Aquaproiect S.A. and the Institute of Geography of the Romanian Academy. Appreciation is also extended to Dr. Laura Comanescu, Dr. Gabriela Manea and Dr. Alexandru Nedelea for their useful comments on the draft of this paper.

REFERENCES

Cocos, A. (2006) Analiza scurgerii medii lichide in bazinul hidrografic al raului Calnistea, *Comunicari de Geografie*, vol X, Editura Universitatii din Bucuresti, pp. 267-272.

Cocos, A. and Cocos, O. (2005) Particularităţile reţelei de văi din bazinul hidrografic al râului Câlniştea, *Comunicări de geografie*, vol. IX, Editura Universităţii din Bucureşti, pp. 311-316.

Cocos, A. and Cocos, O. (2007) Cartographic Analysis of the Relief in the Câlniştea Catchment, *Analele Universităţii de Vest din Timişoara*, Geografie, vol XV, pp. 27- 40.

Cocos, A. and Cocos, O. (2010) Romanian agriculture in the post-communist era, *The Pennsylvania Geographer*, vol. 48, no. 1, pp. 55-63.

Demeter, T. (1999) *Valea Argesului – sectorul mijlociu si inferior. Studiu pedoclimatic*, Editura Universitatii din Bucuresti

Drobot, R. (1997) *Bazele statistice ale hidrologiei*, Editura Didactică şi Pedagogică, Bucureşti

Grecu, F., Zaharia, L., Ghita, C., and Vacaru, L. (2010) The Dynamic Factors of Hydrogeomorphic Vulnerability in the Central Sector of the Romanian Plain, *Metalurgia International*, special Issue no. 9, Editura Stiintifica, Bucuresti.

Ionesi, L. (1994) *Geologia unitatilor de platforma si a orogenului nord Dobrogean*, Editura Tehnica, Bucuresti

Mallows, C. (1998) The zeroth problem, *American statistician* 52, I: pp. 1-9

Pisota, I. (2000) Cateva observatii hidrologice asupra raurilor din Campia Romana, *Comunicari de Geografie*, vol. IV, Editura Universitatii din Bucuresti, pp. 221-230.

Pisota, I. and Cocoş, O. (2003) Unele observaţii hidrologice referitoare la bazinul râului Neajlov, *Comunicări de Geografie*, vol. VII, Bucureşti, pp. 183-188.

Pisota, I. and Moisiu, C. (1975) Cateva observatii asupra fenomenului secarii apelor pe unele rauri din Campia Romana, *Realizari in Geografia Romaniei*, Bucuresti.

Rao, A.R. and Srinivas, V.V. (2008) Regionalization of Watersheds: An Approach based on cluster analysis, *Series Water Science and Technology* Library, Springer Publishers

Rogerson, P.A. (2006) *Statistical Methods for Geography*: A Student Guide, Sage, London, UK

(Received: Dec. 7-2010, Accepted: May. 17-2011)

الگوی پراکنش سیل در نواحی مرکزی جلگه رومانی: مطالعه موردی حوزه آبخیز Calnistea(رومانی)

آ. کوکوس، او. کوکوس، ی. ساربو

چکیده:
این مقاله جستجو می کند تا قابلیت تغییرپذیری جریان در حوزه آبریز Calnistea را از طریق تجزیه و تحلیل فاکتورهای مربوط به جغرافیای طبیعی محل تاکید کند. تحقیقات نشان داده است که مقادیر بارش های نازل شده به زمین کم است صخره ها در این ناحیه نرم هستند ولی نفوذ پذیری بسیار بالایی دارند. شیب زمین در اغلب نواحی ملایم است و پوشش گیاهی کم پشت است و بنابراین نمی تواند مقادیر مهمی از آب را نگه دارد. تحت این شرایط، جریان خصوصاً توسط بارش، شیب و نفوذ پذیری صخره ها کنترل می شود که تا حد زیادی مقادیر نسبتاً پایین تراکم زهکشی را همراه با فراوانی آن توصیف می کند که سبب می شود رودخانه ها بطور کامل خشک شوند. این کمبود رطوبت در فصل تابستان تا حد زیادی توسط وجود زنجیره ای از استخرها در امتداد جویبارها (آبراهه های) اصلی جبران می شود. اگر مسئولان محلی توانایی اقتصادی لازم را برای حفر کانال های مصنوعی برای آوردن آب از حوزه‌های آبریز مجاور پیدا کنند، این وضعیت می تواند بهبود پیدا کند، اگرچه مقادیر جریان بطورکلی کم است. تحت شرایط سینوپتیک خاص، بارش های سنگین می تواند منجر به تشکیل سیل های ناگهانی شود که می تواند مناطق مسکونی، جاده های حمل و نقل و محصولات را خراب کند. در نتیجه لازم است که خاکریز های حفاظتی بر روی زمین های پست ساخته شود و جریان جویبارها تنظیم شود.