RIVER SOLINA (SALT RIVER) – HYDROECOLOGICAL CHARACTERISTICS

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Solina's watershed drains the surface waters from the southern slopes of Majevica Mt. and belongs to the wider area of the Spreča-Majevica subregion, in the northeast of Bosnia and Herzegovina. Solina is the right tributary of the Jala river, and its mouth is at Brčanska Malta in the urban zone of Tuzla.

Its name, like most others in the area of Majevica Mt., is associated with salt, just like city of Tuzla and the Jala river, where Solina ends. Solina is a smaller stream that is formed by headwaters of the weak surface streams and, flowing through the settlements, suffers from anthropogenic pollution, which at the mouth, looks more like a sewage channel than a natural watercourse.

Key words: river, watershed, morphometric indicators, hydroecological problems.

INTRODUCTION

The source of the Solina river is on the southern slopes of the Majevica mountain. Solina is the right tributary of the Jala river, and its mouth is at Brčanska Malta, in the urban part of Tuzla. Both streams are surface draining the salt deposits basins, which is indicated by the hydronyms of Solina according to the prefix of the word „sol“ and Jala, which in Turkish has the same meaning as Solina.

The city of Tuzla and wider area are characterized by a processes of urbanization, deruralization, industrialization and deagrarization (Stjepić Srkalović, et al, 2016), which has contributed to the pollution, degradation and devastation of this river.

Considering the natural-geographic characteristics of the Solina river basin, a clearer apprehension of anthropogenic activities in alteration of natural landscape is gained. The most significant landscape values that are influencing the potamological system are considered. In this context, the morphometric characteristics of the drainage basin were identified, which is one of the important elements of the morphological structure. Based on the existing maps, relief models were created in order to gain a clear representation of its catchment area. Given that potamological analyse require river regime data, which are not monitored, the same was done indirectly, relying on the isohyet indicators data.

The methods used in the paper are specific for a potamological researches and primarily the statistical, inductive, deductive and the method of generalization. In addition to these methods, the research involved terrain opservations too. Everything was accomplished with the application of QGIS and Golden Software Surfer 12 software package, which contributed to graphic quality of the paper.

GEOGRAPHICAL POSITION OF THE SOLINA WATERSHED

Morphostructurally, the Solina drainage basin belongs to the Inner Dinarides in the contact place between the Dinarides of Bosnia and Herzegovina in the south and Panonides in the north. The watershed, by its relief, belongs to the hills, mountains and basins of Northern Bosnia. This is especially true for its headwaters, while the lower part of the basin belongs to the relief of smoothly wave shaped part of the Sprečko polje (Fig.1.).

The Solina's watershed is characterized by its heterogeneous geological structure. It is part of the Tuzla's basin, which lies at the transit between the mountainous ophiolitic zone and the peripheral part of the panonids, which deposits neogene sediments. The geological structure reflects on the relief composition of the drainage basin; the headwaters are in ophiolites, and the lower part of the watershed is in the marls, clastites, sandstones, sands, sandy clays and fine gravel.

The tectonic movements that took place in the wider area of Tuzla's basin, had a great influence on the Solina's drainage basin as well. It is located between two major structural-tectonic units: Cretaceus-Paleogene clastites in the north and neotectonic units of the Spreča depression in the south. These tectonic units are spreading in dinaric direction.

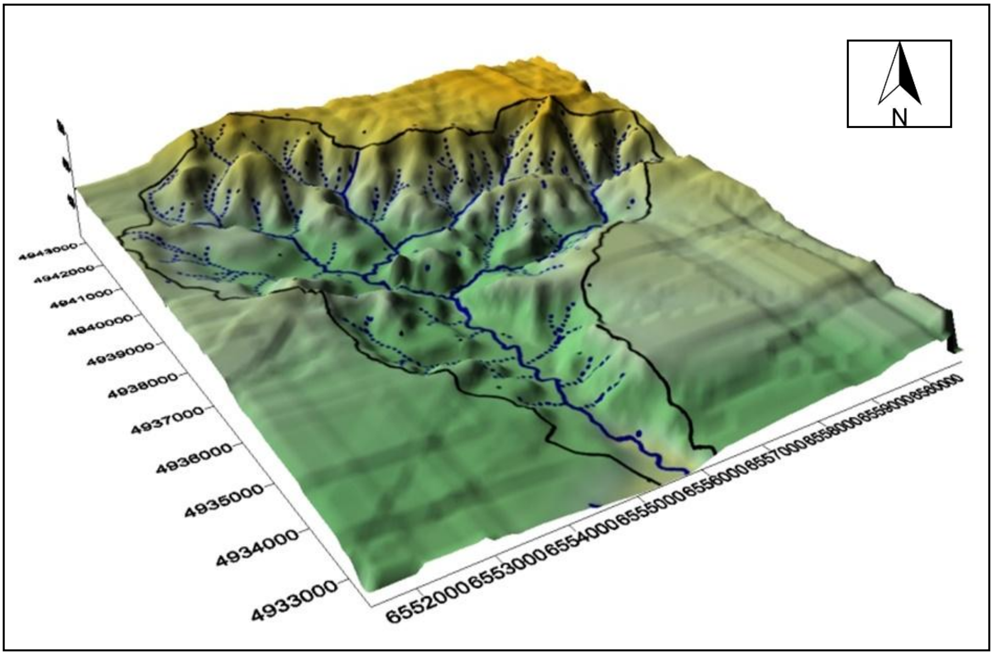

Fig. 1: 3D model of the Solina drainage basin

From the climate aspect, the Solina drainage basin belongs to the moderate-continental climatic type (Cfb), which is dominated by moderately warm and humid climates with warm summers, with an average annual isotherm of 9.9°C, and an average annual precipitation is 900 mm.

Big part of the Solina catchment area, especially in its submountain area, belongs to the territory of the city of Tuzla.

Several different types of soil can be found along the Solina river. The brownish soils on slates, brown medium-deep and deep soils on carbonate debris, brownish degraded soils on clays and loams, and gray carbonate and non carbonated soils on slates are prevailing.

The most of the drainage basin is anthropogenically conquered and usurped by techno-systems, and the most represented are urbanization and less and less agrarization. This is why hydro-ecological problems are reflected in the river system, especially in the talweg, where a large quantity of waste is deposited.

MORPHOLOGICAL CHARACTERISTICS OF THE SOLINA'S WATERSHED AND RIVER SYSTEM

Morphostructural characteristics

The morphostructural habitus of the watershed is composed by the upper in the Majevica submountain area and the lower, in the Sprečko polje. According to the attached model (Fig. 1) the drainage basin and river system are considered as simple, which is a characteristic of the gradual rise of the altitudes by the flow direction, from mouth to the source. The highest peak in the Solina watershed is Greda (803 m), while the lowest point is at the mouth of Solina in Jala (228 m). Such a simple watershed morphostructure is conditioned by hydrogeological relations, which form an aquiferous geological formation.

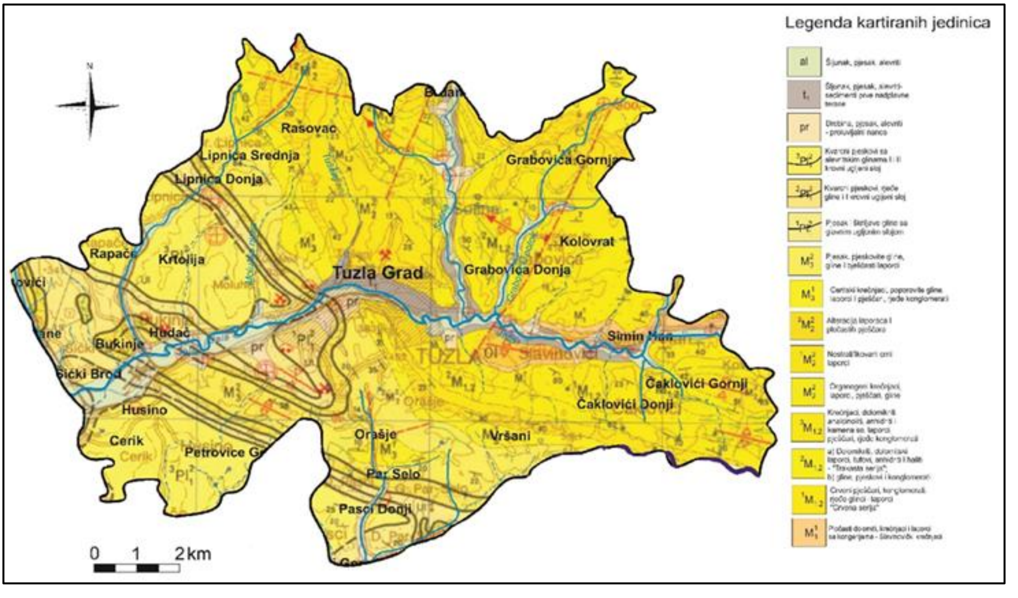

Fig. 2: Geological map of the Tuzla's urban area (Čičić, 1988)

The oldest structures belong to the Tuzla's lower Miocene formations in which organogenic limestones are prevailing ("slavinovićki" limestones and dolomites) with sporadic marls. Above them, the clasts were deposited with characteristic reddish colored sandstones and conglomerates, building the "red" series. The continuation of the sedimentation cycle is made of a "trakasta" series, where the salt formation with accompanying dolomite, anhydrite and tufts are developed. The organogenic limestones, clays, marly clays, sands and subsidiary conglomerates are belonging to the youngest Miocene products.

The development of the lower Pliocene is characterized by the deposition of several seams of lignite (main, base and top seams). Vertical development of the Pliocene formation has the characteristics of rhythmicity: quartz sand, clays (slate and alevrite) and lignite. Quaternary formations were developed along the streams in the form of proluvial depositions (debris) and as precipitated terrace and alluvial sediments (sand and pebbles) (Fig. 2). All the above-mentioned formations are water impermeable and form predominantly the surface river network.

Morphometric characteristics of the Solina's watershed and river system

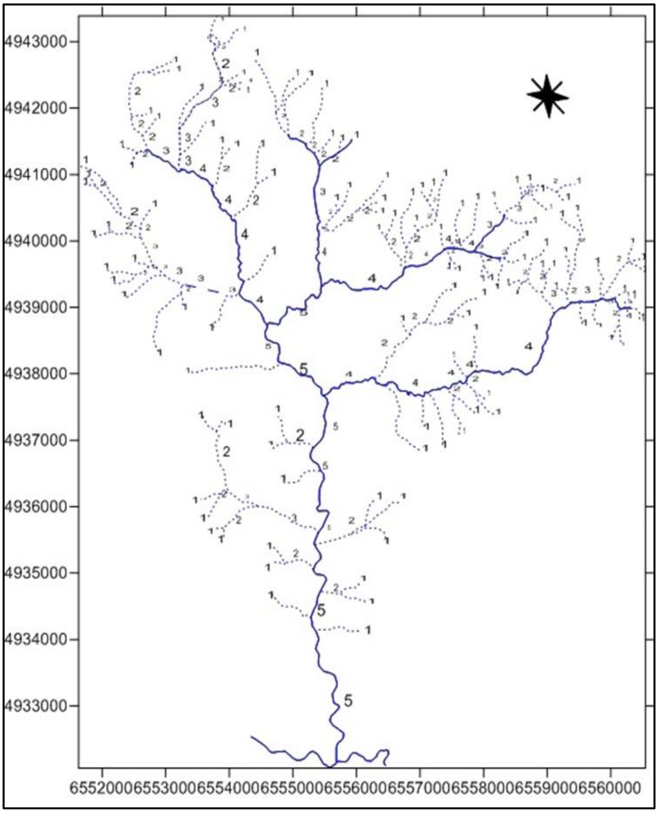

Fig. 3. Ranking of the tributaries in the Solina drainage area according to Strahler

The Solina river watershed is situated between geographic coordinates of 6' and 9", and the watershed width is defined by the 5' and 53" of geographic coordinates. The Solina river drinage basin cover a surface of 47.9 km^2.

The basin development coefficient is 1.04 and shows a basin's large similarity to the circle. From the hydrological point, this is very advantageous, because the rainfalls get fast into some of the watercourses in the Soline hydrographic system. The length of the Solina's watershed is 7.22 km, which points to the fact that the flood waters reach relatively quickly to the riverbed. The average width of the basin (Bm) obtained by the division of the basin area (F) with its length (Ls) is 6.63 km. Given that the average width of the Solina basin is close to its length, it is very advantageous for evenly inflow of rainfalls, without water losses, to the main hydrographic system of Solina. The increased water level on the Solina river lasts for as long as the inundation lasts, because the catchment area is not abundant for long-lasting rainfall waters after inundation season.

The Solina river drainage basin is quite asymmetrical. The right side of the basin is less diverse due to the geological substrate, which influenced the narrowed relief structure, while the left watershed surface is more indented and its surface is 32.8 km^2 and is almost fo a half bigger than the right - 15.1 km^2. The basin asymmetry coefficient is 0.008.

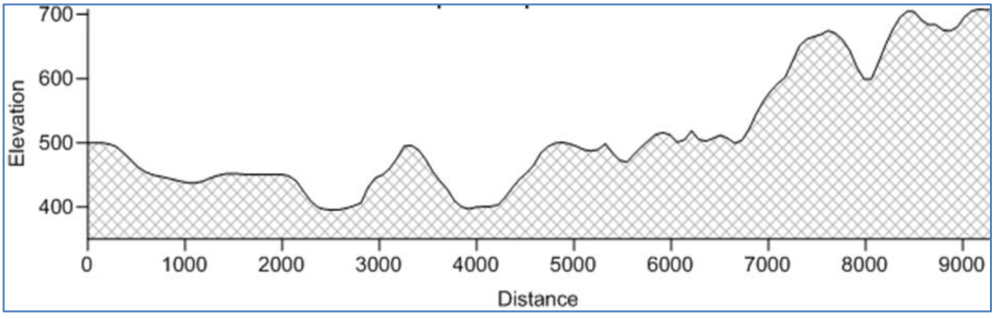

Fig. 4. Transverzal profile of the Solina river which shows significant relief unevenness

The basin asymmetry was reflected on the river network density in the Solina river system. There is a greater river network density on its left, compared to the right watershed surface, which is clearly noted in Fig. 3.

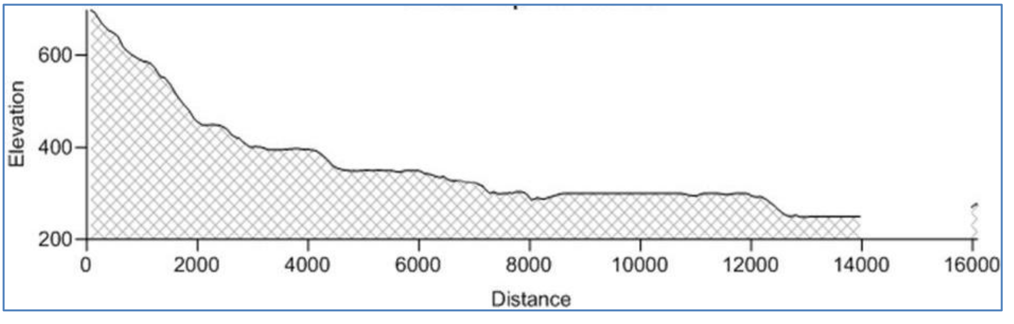

Fig. 5. Longitudinal profile of the Solina river

The transversal profile in the widest part of the Solina basin shows the complete vertical indentation in its east-northeast part and a predominant horizontal diversity in the west-southwestern part of the basin. This shape of relief was primarily influenced by geological substrate; the ophiolites in the east-northeast, and the more present neogene sediments on the other side of the basin. According to the attached profile, there is considerable horizontal indentation and somewhat smaller vertical dissection. Vertical dissection moves on a scale not more than 350 m (Fig. 4).

The river basin density coefficient is consistent with the general natural-geographical conditions in the basin and is 0.91. This data suggests that the rainwaters inflow from the catchment area to the Solina river system is advantageous. The oval character of the river basin is also evidenced by the river watershed development coefficient of 1.3.

The headwaters of the Solina river is at an altitude of 736 m, and its mouth at 228 m, so the total drop of the river is 508 m. The average drop is 70.36 m/km or 70.4‰. The largest drop of the riverbed is in headwater area and it amounts to 80.2‰, and the smallest in the middle part of the river and averages up to19.5‰ (Fig. 4). According to the attached profile, it is clearly that it's longitudinally stepwise, formed on the normal longitudinal profile of the upper flow and inversed in the middle and lower talweg. This sector is also distinguished by its gradual features, affected by erosionally resistant geological substrate.

The increase of the Solina river drops in its lower part at the mouth, can only be explained rationally, by the neotectonic sinking and the faster erosion incision of the Jala river, because of the greater amount of water, compared to the Solina.

Fig. 6. Artificially arranged Solina's riverbed just before rivermouth in Jala

RIVER SOLINA'S REGIME

The river regime consideration, which includes water levels and flow categories, due to the lack of the potamological monitoring, was only possible indirectly. Since under hydrogeological stable conditions, the river regime mostly depends on precipitation, it was necessary to bring it in correlation with the sustainable course of the Solina river.

The pluviometric and thermic relations, presented on the climate chart (Fig. 7), are relevant for the the calculations, related to the flow and flow out regime.

The annual rainfalls in the entire Solina drainage basin averages about 900 mm/m², which is 43.2 x 10^8 liters. Of this total amount of precipitation in the Solina river system flows in about 70% of the precipitation water, which amounts to 30.2 x 10^7 liters. If this amount of rainwater from the basin is converted into m³ and distributed throughout the year,

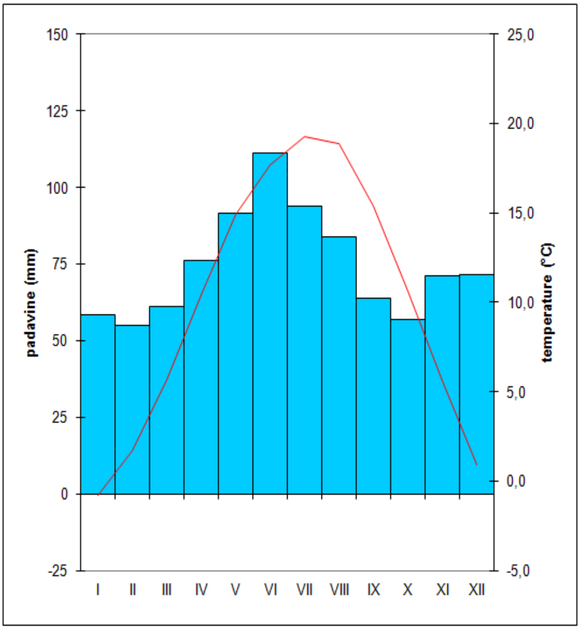

Fig. 7. Climate-diagram for Solina's drainage basin

then the total inflow and flow of the precipitation through the cross-section profile of the riverbed is 0.96, or 1 m³/s of water. This is just the average flow of the Solina river.

Over the years the flow varies, in the same ratio as there is a difference in the precipitation regime. As a result, the flow increases during the seasons and the maximum occurs in the hydrological spring, when the amount of extracted rainfalls is significantly increased, so the water level and the flow rises for almost a half of its height. Likewise, at the time of the hydrological minimum, which occurs during the summer and fall, the inflow is noticeably reduced, and minimally water levels are regularly observed.

The extremely high water levels occur when the snowfalls are combined with spring rainfalls and a high water levels occurs, which can be 8 times higher than the average.

GEOECOLOGICAL PROBLEMS IN SOLINA DRAINAGE AREA

The relatively low water levels and small flows do not have enough power to transfer the dragged sediments and to dilute the anthropogenic, biological and chemical waste. Because of this, the riverbed of the Solina river, has been overloaded with anthropogenic waste up to increased levels for a long time. Apart from solid waste, the Solina water is overly polluted by chemical and biological agens, which is a potential danger to the health and economic prosperity of all residents in this area.

According to the laboratory analysis carried out by the Water Resources Agency of the Sava river, the water of the Solina river basin is of extremely poor quality. The main causes of this pollution is the discharge of wastewater into watercourses without prior treatment, the disposal of solid and liquid waste directly into the river and the induction of agricultural pesticides into watercourses. Agriculture and the salt mine "Tetima", which bring significant income to many families inhabited in the basin, are also endangering the water in the river, where from the quality extremely decreases.

The wastewater are discharged into septic tanks or directly into watercourses, which presents a major problem for aquatic ecosystems. Home cleaning agents, which are used in the households, have a high content of chemicals that penetrate the surface and groundwater and have a harmful effect on water quality. The rinsing of fertilizers, pesticides and herbicides from the upper horizons of the soil in the area of the Solina river basin also contributes to the increased presence of the toxic substances in these waters. The additional damage is made when this polluted water is used by farmers for irrigation or in households. Gasoline, motor oil, and wastewater from petrol stations and tank cleaning are another source of dangerous pollution.

Inappropriate treatment and disposal of solid waste on wild dumps, often located near the watercourse and direct disposal of waste into the river, besides it's appearance, is a source of very harmful, health hazardous contaminations. These problems are further complicated by the fact that the Solina river basin is very populated, with frequent occurrence of illegal and unplanned constructions.

Fig. 8 and 9. Smaller tributaries of the Solina river are carrying chemical pollutions, which is a rare phenomena

The economy and industry development, on the one hand is advancing, it brings the economic development and population employment, but on the other hand, it creates a great danger of pollution. The wastewaters from production processes often contain very dangerous, toxic substances and chemicals, that by direct discharge into the watercourse, without prior purification treatment, causes constant water pollution, i.e. destroying flora and fauna and affecting the population that use that water.

CONCLUSION

The source of the Solina river is on the southern slopes of the Majevica mountain. Solina is the right tributary of the Jala river, and its mouth is at Brčanska Malta, in the urban part of Tuzla. Both streams are surface draining the salt deposits basins, which is indicated by the hydronyms of Solina according to the prefix of the word „sol“ and Jala, which in Turkish has the same meaning as Solina.

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If the amount of rainwater from the drainage basin is converted into m^3 and distributed throughout the year, then the inflow and the flow of the precipitation through the cross section of the riverbed is 0.96, or rounded, 1 m^3/s of water. This is just the average flow of the Solina river.

Over the years the flow varies, in the same ratio as there is a difference in the precipitation regime. As a result, the flow increases during the seasons and the maximum occurs in the hydrological spring, when the amount of extracted rainfalls is significantly increased, the water level grows and the flow arises a half of its height. Likewise, at the time of the hydrological minimum, which occurs during the summer and autumn season, the inflow significantly reduces, and water levels are at the minimum.

Extremely high water levels occur when snowfalls are combined with spring rainfalls and a high water level occurs, which can be 8 times higher than the average ones.

The bigger part of the basin is anthropogenically conquered and usurped by technosystems, most of which are urbanization and less and less agrarization. Because of this, there are hydroecological problems, that are reflected on the river system, especially the talweg, where a large amount of waste is deposited.

The relatively low water levels and small flows do not have enough power to transfer the dragged sediments and to dilute the anthropogenic, biological and chemical waste. Because of this, the riverbed of the Solina river, has been overloaded with anthropogenic waste up to disturbing borders for a long time. Apart from solid waste, the Solina water is overly polluted by chemical and biological agens, which is a potential danger to the health and economic prosperity of all residents in this area.

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