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Geological Characteristics and Density of the Una Water System as a Factor of Spatial Planning, B&H

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Abstract: Geological structure has a significant effect on maintenance of rainwater on surface and its absorption into the underground. The depth of erosion processes and cutting of river valleys depend of it. Geological factors play an important role in the movement of groundwater. They determine the conditions of formation of groundwater, its position and speed of movement, depth of hydrological insulators and character of hydrological collector. Among other things, hydrogeological relations affect the density of the water system. Geological structure may be a limiting factor when it comes to planning and determining the purpose of the space, and as such, it largely affects the functionality of spatial planning. The highest population density in the area of Una basin is on those parts which are mainly consisted of watertight rocks with higher density of water system.

Keywords*: geological structure, density of water system, spatial planning, river Una*

Introduction

As an element of the environment, water has a wide representation in all types of spatial and urban plans. It is an essential element of development in each area and it directly affects livelihoods. In the context of spatial planning, its general and specific impact as surface water and groundwater is analyzed. The level of hydrological research is determined by the type of spatial plans which are analyzed. Among other aspects, spatial plans need to consider all the "inventory" of surface and groundwater in a particular area, their type, nature and disposition. This paper aims to analyze the geological structure and, in association with that, river system and the density of water system in the basin of river Una. Una basin supplies water to river Sana and is a part of the Black Sea basin. It borders with the following basins: Vrbas and Pliva in the east and southeast, Cetina, Krka and Zrmanja in the south and southwest, Korana and Glina on the northwest, Sava River basin in the north, and its west groundwater are flowing towards Gacko Polje.

Different information on the area covered by the Una basin can be found in the literature. Mostly it is cited that Una basin, as a whole, covers 9.640 km^2, of which 9.368 km^2 in Bosnia and Herzegovina, of which 5.020 km^2 on the territory of the Federation of Bosnia and Herzegovina. Most of this data is linked to the orographic or topographic watershed, which does not make the actual watershed between adjacent basins and basin of Una and should be treated with caution, due to the prevailing terrain with aquifers of fracture - cavernous porosity. Specific and accurate watershed, including the surface of the basin, is difficult to determine until the direct hydro-geologic studies in the area of the basin are performed. In recent period, this kind of research was conducted in the western and south-western part of the watershed. As the basis of this study, we used a hydro-geologic map of the former Yugoslavia, sheets Zagreb, Sarajevo and Dubrovnik, scale 1: 500.000, with certain changes that are caused by recent studies, since hydro-geologic maps of larger scale have not been made for this area. Based on the aforementioned maps and amendments, we singled out the basin of river Una (as measured from the maps in ArcGIS 10.2., ArcMap) with an area of 9.979,5 km^2.

General stratigraphic complexes in the basin

Due to its spatial coverage, but also the direction of stretching and large altitude differences, area of Una basin is characterized by a very complex geological and lithological composition. This is a direct result of long and complex geological history and complex geotectonic movement. Almost all geological formations are represented in the analyzed area. Stratigraphically, creations of Paleozoic, Mesozoic and Cenozoic sediments alternate in this area. The thickness of sedimentary cover on the

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analyzed area is different going from south to north. According to geophysical data, in the outer parts of the Dinarides, the thickness of the sedimentary cover varies from 8-13 km. In the contact area of Bosnian flysch and ophiolite Dinaric zone, the thickness is reduced to 8-10 km, while in the southern part of the Pannonian Basin sediment thickness is only 4-5 km. During the analysis of the geological composition of the terrain, geological map of scale 1:500,000, and R 1:100 000, sheets Bihac, Kostajnica, Bosanska Krupa, Prijedor, Banja Luka, Kljuc, Drvar, Glamoc, Udbina and interprets of these sheets were used.

Figure 1. Position the basin and river system of the Una

Paleozoic rocks, as the oldest ones, are a part of the Sana - Una and Kljuc Paleozoic, which are two of six Paleozoic areas of Bosnia and Herzegovina. In the Una basin, the rocks of Sana - Una Paleozoic stretch of Una's right tributaries: Vojskova, Cadjavica and Vidorija in the northwest, and in the area of Bosanski Novi - Piskavica - Bronzani Majdan - Kozica Valley - Sanski Most - Budimlic Japra - Rudice (Una Valley) - Bosanski Novi. Kljuc Paleozoic includes the area around the town Kljuc and it's generally made of Permian-Triassic formations. Part of the Una river basin in the northwest, more precisely, the right side of the basin of Zirovnica belongs to Banija Paleozoic. The border between the Banija and Sana - Una Paleozoic is the river Una. Paleozoic rocks are bordered by the Mesozoic formations, except in the area of Kamengrad basin and Prijedorsko-Omarsko Polje, where younger deposits of Cenozoic age are sedimented over Paleozoic. Formations of Una - Sana Paleozoic are mainly low permeable and impermeable rocks which have the function of hydro-geologic insulator, which caused the formation of a dense network of surface streams in this area. Mesozoic sediments are most prevalent in the Una River basin. Triassic, Jurassic and Cretaceous with almost all its epochs and floors are developed in the area that includes the geotectonic, a higher limestone - dolomite zone of high karst. Early Triassic formations, in their classic facial development of werfenian layers, are widespread in all the structural - facial units. Middle Triassic has a great widespread in this area and is of the dominant carbonate development Middle and Late Triassic were not possible to separate in some parts of the basin, and are shown together. Late Triassic was developed in dolomite facies and megalodon limestones with dolomites, with the thickness of 300-700 m and also in facies of ash-gray layered dolomite with the thickness of 900 and 1000 m.

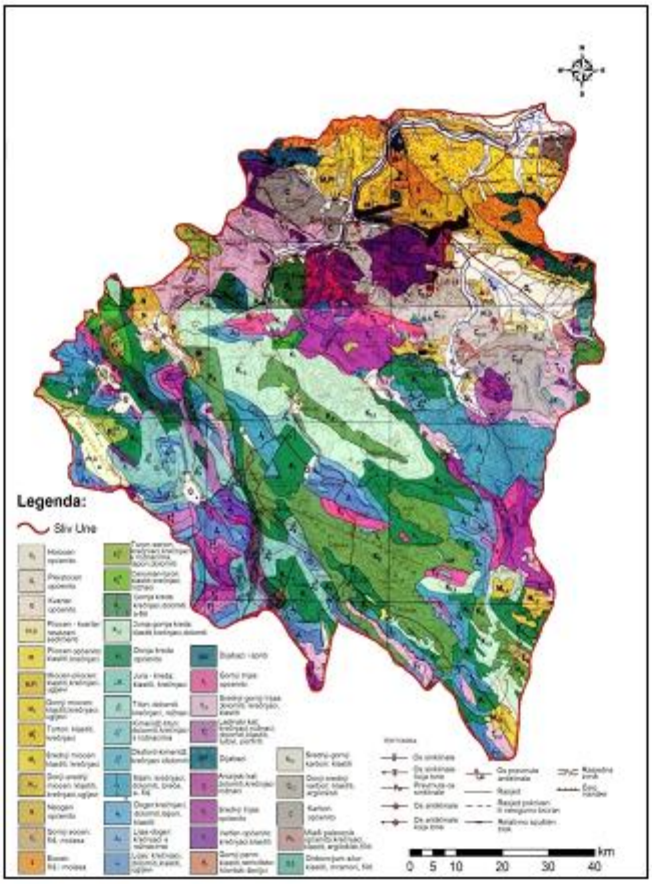

Figure 2. Geological map of the Una river basin

In the area of the Una basin, Jurassic formations make deposits of Liassic, Dogger and Malm (which are not dissected in specific localities) and tectonised ophiolitic mélange. Tectonised ophiolitic mélange is part of the Central Ophiolite zone, and within the basin area of the Una it is registered on Basic Geological Map sheets of Kostajnica and Prijedor. Creations of this formation represent a paleo-relief with younger tertiary sediments, tectonically separated from the Eocene flysch and Triassic sediments, while Miocene sediments often lie discordantly across them. At the end of the Early Jurassic, an undersea trench is formed in these terrains, as well as in the other parts of the Internal Dinarides. During this period, in the most part of Internal Dinarides, Jurassic-Cretaceous flysch is deposited, while a carbonate regime of sedimentation with deposition of dolomite and limestone with ellipsactinias continues in the basin of river Sana. Limestones are reddish brown in color, with a distinct stratification, and with the highlands of masked karst formations. In the area of Una basin, Lower Cretaceous was found, which is in some places dissected into two super-positional packages, then with a transition layer between the lower and upper Cretaceous and with an Upper Cretaceous in flysch facies.

The deposits of the lower and upper Cretaceous are not dissected in some places, and were marked as lower-upper Cretaceous. They are presented with limestones and dolomites, so that the package begins with layered and banked, greyish and yellowish dolomites, over which light gray to white limestone are found. They are often found in the basement of bauxite deposits, such as for example in the area of Lipa, Lastva and Suvaja. Upper Cretaceous in the area of Una basin occurs mainly in two developments: carbonate and flysch. In the form of flysch sediments, general Cretaceous was discovered in the upper reaches of Japra and Bistrica, and on Kozara, where flysch is mostly of carbonate composition with subordinate sand components. Carbonaceous development of Upper Cretaceous is presented mostly with limestone, and then subordinately with dolomites, marl limestones, conglomerates, breccia and marl. Cenozoic formations largely built the lower part of basin of the Una, although they are represented in other parts of the basin in the form of Neogene freshwater basins. Neogene freshwater deposits play an important role in the structure of the Dinarides. They were built after the uplift of morphostructures during Eocene deformation phase. There are a large number of freshwater pools with different sizes in the area of Una basin, with coal deposits or without them. Among the important ones are:

- Neogene basins: Glamoc, Bihac, Drvar;
- Sana-Kamengrad Neogene basins;
- Neogene basin Ljesljani - Knezica - Kozarac.

The Quaternary in the catchment area of the Una is presented with various clastic sediments. These deposits were found in fields and their circumference and river valleys. They consist of talus slope deposits, proluvium, screes and slope breccia, quartz sand, marsh and lake sediments, river terraces, alluvial deposition and travertine. The largest percentage share in terms of spatial coverage, are creations of Lower Cretaceous (K_1), in amount of 16.4 %. They are made of boulders to thick layered limestone, of dolomites, limestone breccia and chert. In addition to these rocks, a significant share refers to deposits of the Upper Jurassic (J_3). Massive, banked reef limestones with subordinate participation of dolomites cover 9 % of the basin. A Quaternary deposits (Q) which are well-permeable, also have a significant proportion in the geological structure of the terrain, about 10 %. Paleozoic (C, P, PT), and the Triassic (T_1, T_2, T_2^2, $T_{2,3}$, T_3), impermeable rocks cover approximately 25 % of total analyzed area.

During the analysis, we have selected over 40 different stratigraphic units, reflecting the complexity and specificity of the terrain, and thus the complexity of the geological, hydro-geologic and hydrological relations in this area. Paleozoic formations on the territory of the basin of the Una participate with 7.8 %, Cenozoic with 21.8 %, while the Mesozoic formations are the most represented with the share of 70.4 %. Lithological composition the rocks, their location of depth of the watertight layers greatly affect the conditions of accumulation in the basin and runoff of ground waters that feed the main stream of the Una. In the loose rocks, such as alluvial deposits in the river valleys, significant amounts of water are accumulating. One part of these waters comes directly from rainfall, while the other is drained from the flow through the coast. This accumulated ground water is later returned in the river, filtering through the side of banks. In the Una, Quaternary deposits, presented with various clastic sediments, well-permeable, cover about 97 % of the total area in the zone to 100 m above sea level, and 47 % of in the area of 100 to 200 m. Alluvial deposits are the most widespread lithological member of the Quaternary. They are represented in all river and stream valleys and fields, and hypsometrically dominate the area from 600 to 700 m.

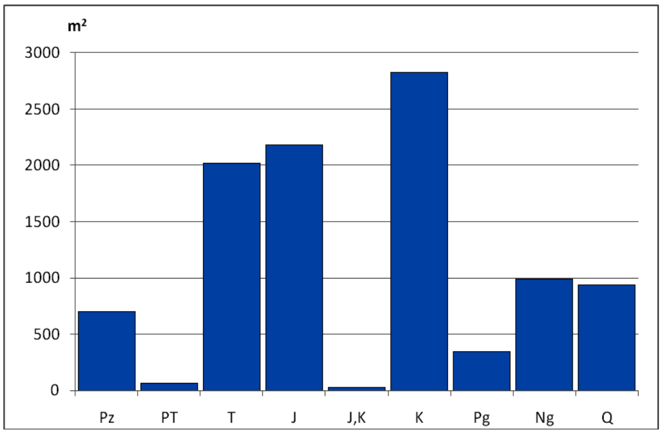

Figure 3. The spatial coverage of basic stratigraphic complexes in the Una river basin

The greatest impact of geological structure on runoff of precipitation in basins with larger or smaller areas exposed to the process of karstification, as is the case in the Una basin. This effect is most intense in the lower part of the basin, where there is no large number of surface watercourses. There are distinct streams with deep cut valleys of canyon type in this area. Precipitation waters quickly sink through the numerous cracks and form underground streams, which then surface in the form of abundant karst springs. The evaporation of precipitation is slight and underground runoff is strong. In this part of the basin, both in the horizontal and the vertical profile, the highest representation have formations of Upper Jurassic (J_3) and Lower Cretaceous (K_1). Throughout all hypsometric zones, except in the zone up to 100 m, these well water permeable rocks affect the runoff of precipitation and its filtering into the interior. In addition to these creations, in almost all hypsometric levels, there are also limestone and dolomite rocks of the upper Triassic (T_3), Lower Jurassic (J_1) and Upper Cretaceous (K_2).

Hydrogeological complexes in the basin per altitude zones

In basins that are built on hydrological insulators precipitation waters are retained on the surface and thus, under other favorable conditions, they affect the surface run-off, while surface runoff is limited and transferred to the underground in the areas where the catchment is built on hydrological collectors (Spahić, 2000). This mainly refers to karstified carbonate part of the basin, which affects the disorganization of the surface in the underground runoff. Also, the participation of karst retention depends directly on the area covered by carbonate geological formations, or the degree of karstification of these rocks. In the Una basin they include significant areas and precipitation waters are infiltrated through cracks in the karst underground to hydrological insulators. After the precipitations fill the karst hydrological recipients, runoff in the basin is mainly surface and karst springs abundantly supply surface waters. According to Spahić, M. (2013), an underground runoff reduces the waste of precipitation waters, especially evapotranspiration, and groundwater in the wells and springs are therefore very abundant, with an average of more than 5 m^3/s. Great variety of lithological composition, different tectonic processes through the geologic history, geomorphic characteristics of the terrain and meteorological factors and elements are affecting the complexity of hydrogeological relations in the Una basin. Seven hydro-geologic units are allocated in the area, with a variety of permeability and transmissivity:

1. aquifers of crevice-cavern porosity,
2. highly karstic aquifers,
3. hydro-geologic complexes mostly without aquifers,
4. aquifers of intergranular porosity,
5. aquifers of crevice porosity,
6. non-water-bearing rocks without aquifers and
7. hydrogeological complexes with aquifers of composite porosity.

First, the largest and the most important unit, covers terrains with aquifers of crevice - cavernous porosity. These are well permeable rocks, which participate with 34.1% within the total surface coverage basin of the Una. These terrains are characterized by very good permeability and transmissivity, water abundance, the flow of underground waters through privileged directions and underground channels, and concentrated runoff of underground waters in discharge zones of aquifers with the an emergence of strong karst springs, such as well of the Una. The terrains built of Mesozoic carbonate, in whose interior a very heavy accumulation of underground waters are formed, are characterized by the absence of surface flows, and the multitude of surface and underground karst formations. The bodies of underground waters in this area are of high discharge (occasionally a few m^3/s) with very favorable terms of recharge and discharge. Extremely karst aquifers, represent a second unit in spatial coverage, with 20.4 % of the area. They consist of porous rocks, banked and layered limestones and dolomites. Almost the same area is covered by the third unit, represented by waterproof rocks. It is a hydro-geologic complex, which is largely without aquifers, that includes 1956.5 m^2 of the basin area. Aquifers of intergranular porosity, with good water permeability, are presented with the rocks with the best hydro-geologic characteristics with the most important reservoirs of underground waters, and those participate with 10.3 % in the total catchment area. They are formed in the Quaternary sediments of the lowest river terrace, where aquifers of intergranular porosity are represented with gravel deposits with weathered porous travertine. Very favorable conditions for aquifers recharge with waters of rivers Una and Sana allow the formation of groundwater bodies of high discharge. Non- water-bearing rocks without aquifers include 830.2 m^2 of the basin area of Una, and they are made of impermeable rock mass.

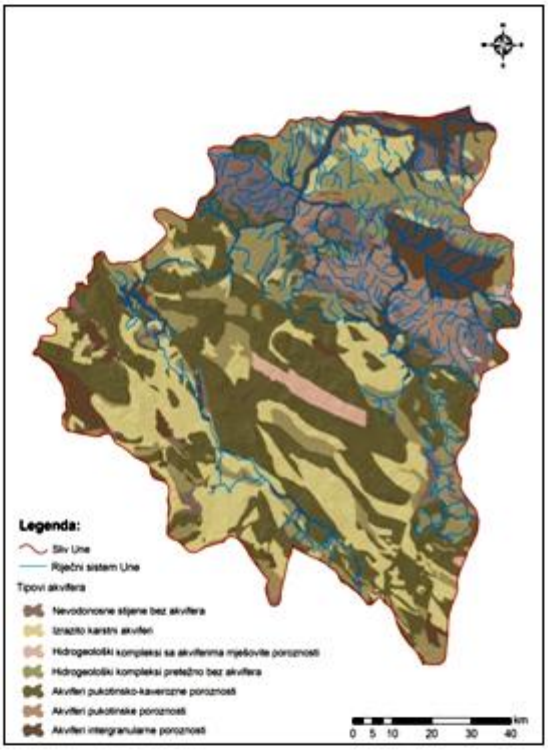

Figure 4. Types of aquifers in the river basin area of the Una

Table 1. Percentage share of aquifer types per altitude zones

Aquifer type	Aquifers of intergranular porosity	Aquifers of crevice porosity	Aquifers of crevice -cavern porosity	Hydrogeological complexes mostly without aquifers	Hydrogeological complexes with aquifers of composite porosity	Highly karstic aquifer	Non-water-bearing rocks without aquifers
0-100	0.00	0.00	1.26	1.90	96.84	0.00	0.00
100-200	4.14	13.96	16.95	52.49	7.94	0.03	4.49
200-300	10.27	30.94	19.03	11.38	12.63	0.79	14.96
300-400	28.16	32.53	10.81	2.64	12.63	0.50	12.73
400-500	34.19	25.46	9.50	1.22	17.40	0.44	11.79
500-600	36.03	19.90	7.49	3.24	28.18	0.72	4.44
600-700	39.58	17.85	2.64	13.55	25.37	0.50	0.51
700-800	53.28	13.91	3.20	3.11	25.90	0.49	0.11
800-900	52.89	13.27	2.28	1.26	28.00	2.29	0.01
900-1000	52.13	15.05	1.17	2.69	26.20	2.76	0.00
1000-1100	54.19	12.54	1.40	0.20	26.19	5.48	0.00
1100-1200	51.71	8.91	1.99	0.21	29.80	7.38	0.00
1200-1300	51.83	9.46	1.02	0.13	33.42	4.14	0.00
1300-1400	46.76	4.67	0.49	0.00	44.89	3.19	0.00
1400-1500	41.04	3.68	0.06	0.00	51.78	3.44	0.00
1500-1600	32.68	2.11	0.00	0.00	63.17	2.04	0.00
1600-1700	26.33	1.74	0.00	0.00	71.93	0.00	0.00
1700-1800	36.31	1.55	0.00	0.00	62.14	0.00	0.00
1800-1900	18.03	0.00	0.00	0.00	81.97	0.00	0.00
1900-2000	0.00	0.00	0.00	0.00	100.00	0.00	0.00

Infiltration of atmosphere waters is very slow, and these terrains are characterized by a very dense hydrographic net of surface flows. These are mostly Paleozoic rocks and Lower Triassic formations. Aquifers of crevice porosity (carbon deposits and Jurassic diabase - chevron formation) and hydro-geologic complexes with composite porosity aquifers (Jurassic-Cretaceous and Upper Cretaceous formations), have the lowest participation in the total area of the basin, only 7.3 %.These hydro-geologic relations in the basin have influenced the formation of surface water system and high yield wells and springs. The participation of individual types of aquifers in each of the surveyed hypsometrical zones is of a particular importance. Water permeability of rocks directly affects the contact of water in streams with each altitude zone and then the total participation in flow of Una. In the zone of 200-300 m, which covers the largest area in the basin, the most common are aquifers of fracture porosity which have weak water permeability or are watertight. In addition to these, hydro-geologic complexes mostly without of aquifers and aquitards stand out as waterproof, which make a total of about 57 % of the area of this zone, which causes more dense surface water system, and large surface inflow from these hypsometric levels. Similar relations, with the participation of various waterproof of aquifers, are in zones 100-200 m and 300-400 m, which participate with about 40 % in the of the basin area. In the area above 400 m above sea level, aquifers of intergranular porosity and hydro-geologic complexes with mixed porosity aquifers that are characterized by good water permeability dominate in all areas. Given that this is almost 60 % of total catchment area and favorable conditions of recharge of aquifers with water, forming bodies of groundwater of high discharge is enabled.

Density of Una water system as a factor of spatial planning

Geological structure may be a limiting factor when it comes to planning and purpose of the space, and as such it largely affects the functionality of spatial planning. The highest population density in the basin of Una is in those parts which are mainly consistent of watertight rocks with higher density of water system. The density of water system is expressed by the abundance of rivers in the basin area or length of all flows per one km^2. If the density of river network is analyzed through the ratio of the total length of the watercourse of all ranks and surface, 0.4 m of water flow per km^2 is obtained, if we consider only permanent water flows, and 1.02 m/km^2 if the ratio includes the total length of permanent and temporary water flows. The lowest density of river networks is in karst areas, where surface flows are disorganized in karst underground with swallow holes.

The density of the river network with the same other physical geographical factors in the basin increases the runoff of precipitation in watercourses. If the density of river network is greater and if the river valleys are deeper, watercourses are draining the land and water-bearing horizons intensively. The value of the length of runoff, equal to half inversely proportional to the size of the density of river network is 0.51 m/km^2 for the basin of Una. Due to the geological structure of the terrain and the deployment of aquifers, very uneven density of the river network in the Una basin can be seen.

The area of these formations is characterized by a very dense network of surface streams, and these are mostly Paleozoic rocks and Lower Triassic formations, represented in the central and northern parts of the basin. The main hydro-geologic role of Paleozoic sediments is to make the impermeable floor to limestones (or to individual layers of Neogene) and to direct the groundwater to the discharge bases. Hydrographic system of the river Sana makes the hydrographic backbone of the eastern part of the Una basin. Terrains with aquifers of crevice - cavernous porosity and distinctly karst aquifers, which are characterized by very good permeability and transmissivity, water abundance, the flow of underground waters through underground channels and emergence of these waters in the form of strong karst springs, as well as the absence of surface flows, include mainly the southern and central part of the basin.

In the formation of surface river network the most significant are non-water-bearing rocks without aquifers. Mostly non-carbonate geological structure caused a very widespread and diffused surface hydrographical network in this part of the basin. It is formed gradually from a number of smaller surface flows from the source crest, on water bearing rocks in the area of the southeastern slopes of Grmec and southwestern slopes of Dimitor. The upper part of the basin and the valley of the river Una until Bihac lacks with surface tributary hydrographic systems. Hydrographic network is homogeneous, and basically made of stream and valley of the river Una. Part of the basin downstream Bihac, due to changes in geological structure and greater participation of sedimentary-metamorphic, and then the Molase complex, has a more developed river network, with numerous tributaries, especially in the lower part of the basin and the valley of the Una. River Unac is formed gradually, from the source crest, and all the way to the town Drvar basin is characterized by surface tributaries, and, in this connection surface river network is present. From Drvar to the mouth of the river Una, Unac has a typical karst features. The lower part of the river does not have surface inflows, but it's mainly fed with water from wells and springs. Water quality greatly decreases downstream on Una from Novi and on Sana from Prijedor, while the upstream of these areas, water is mainly I and II quality. At upper, or the southern part of the basin, karst terrains are widespread, dominated by hypsometrically higher level with a large amount of precipitation. Water that is excreted in the form of precipitation, filters into the underground due to a well-permeable aquifers and circulates towards the zones of accumulation, where it accumulates and runs on the surface in the form of springs of high discharge. Springs directly fed Una with water, resulting in the need to protect and preserve the transit waters by altitude zones.

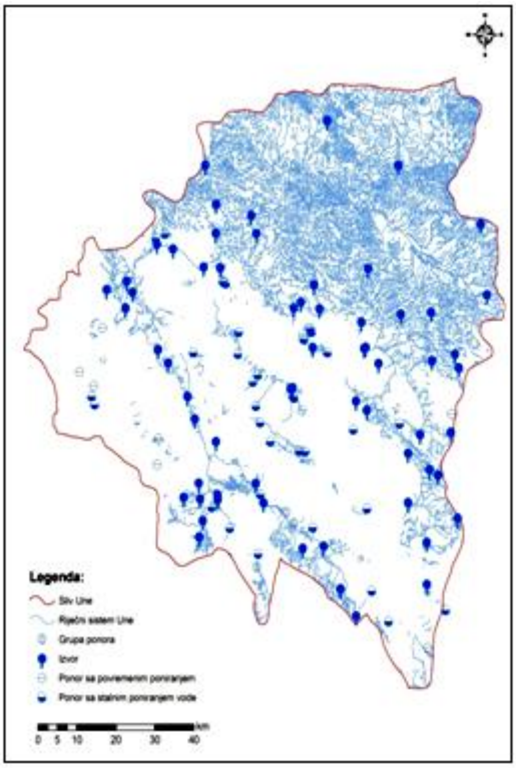

Figure 5. Una basin with significant hydrogeological objects

Conclusion

The study of hydrological characteristics is of great significance and impact on the proper organization and arrangement of space. During spatial planning, it is especially important to handle all attributes of surface river flows that make the river system in a given area. Geological structure may be a limiting factor when it comes to planning and purpose of the space, and as such largely affect the functionality of spatial planning.

The largest percentage share in the territory of the Una river basin, are well permeable rocks with 66.4 %, then waterproof with 27.9 %, while the low permeable to waterproof rocks have the lowest participation in the area, only 5.7 %. These hydro-geologic relations in the basin have influenced the formation of surface river network and high yield wells and springs.

The highest population density is in those parts of Una basin which are mainly represented with watertight rocks with higher density of river network. Mostly non-carbonate geological structure caused a very widespread and diffused surface hydrographical network in the basin of Sana, while part of the basin of the Una, downstream Bihac, due to greater participation of sedimentary-metamorphic, and then molase complex, has a more developed river network, particularly in the lower part of the basin and Una valley.

The results of the analysis of geological structure and density of the river network, and in this respect the river regime of balance and water basin have wide applications. Among other, these results can be applied to solve problems of water management, preparation of spatial plans, economic planning and other forms of economic activity. Also, these results are important for practical application in determining the secondary waters to the river where there is no hydrological observations and measurements, to determine the components of the water balance and hydrological forecasting, then the design of the network layout of the altitude of meteorological and hydrological monitoring, especially in the protection of waters from pollution with its classification according to the altitude zones.

Summary

The study of hydrological characteristics has great significance and impact on the proper organization and arrangement of space. In spatial planning process, it is especially important to handle all qualities of surface water courses in a certain area which are making its river system. Geological structure may be a limiting factor when it comes to planning and use of the area, and as such, it largely affects the functionality of spatial planning.

The largest share, in the territory of the Una river basin, are well permeable rocks with 66.4%, then waterproof with 27.9 %, while the low permeable and waterproof rocks have the lowest participation in the area, only 5.7 %. These hydro-geologic relations in the basin have influenced the formation of surface water system and high yield of its wells and springs. Parts of Una basin with the biggest percentage of watertight rocks and higher density of water system, have the highest population density. Mostly non-carbonate geological structure caused a very widespread and diffuse surface hydrographic network in the basin of Sana'a, while part of the basin of the Una downstream the town due to greater participation of sedimentary-metamorphic, and then molase complex, has a more developed water system especially in the lower part of the basin and valleys of the Una.

The results of the analysis of geological structure and density of the water system, and in this respect the river regime of balance and water basin are widely used. Among other, this study can be applied to solve problems of water management, physical planning, economic planning and other forms of economic activity. Also, its practical application, these results can be found in the determination of secondary water to the river where there is no hydrological observations and measurements, to determine the components of the water balance and hydrological forecasting size, then the design of the network layout height of meteorological and hydrological monitoring, especially in the protection of water of pollution with its classification according to height zones.

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