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HYDROGEOLOGICAL RESEARCH AND TERRAIN CHARACTERIZATION ON A SECTION OF ROAD 2B SARAJEVO-FOČA, AREA OF FBiH

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ABSTRACT

Roadways are complex construction (line) facilities that have specific characteristics in terms of planning, design and execution of the route. Due to the length of the roads, many characteristics of the terrain such as lithological, hydrogeological, engineering geological and geomorphological change along the route, as a result of which different effects of endodynamic and exodynamic processes and phenomena occur on certain sections. This points to the necessity of an interdisciplinary approach when creating the conceptual and implementation project, in order to choose the optimal solution based on all the influencing parameters.

The route of the road that passes through the Entity of the Federation of Bosnia and Herzegovina, for the most part stretches along the valley of the Željeznica and Dobrinja rivers. The section is located at stations 0+000.00 – 3+250.00, and continues at stations 19+800.00 – 26+100.00, and the total length is 9,550 m'. The area of the studied terrain is located in the zone of the inner Dinarides of Bosnia and Herzegovina, where the pre-mountainous and moderate-continental climate prevails. The elevations of the terrain start at 505 m.a.s.l. in the part of the route near the Stupska petlje loop, and increase to an elevation of 535 m.a.s.l., in the part of Aerodromski settlement, while the second part of the section stac.19+800.00 – 26+100.00 is defined by elevations of 778 m.a.s.l. – 830 m.a.s.l.

Key words: hydrogeological characteristics of the aquifer, route of the Sarajevo-Foča road.

1. HYDROGEOLOGICAL CHARACTERISTICS OF THE TERRAIN IN THE TERRITORY OF THE FEDERATION OF BIH

Formations of Quaternary deposits (al,el-dl), Miocene formations (1M3) and carbonate rocks of the Middle Triassic (T21,2T1) participate in the structure of the terrain. The hydrogeological properties of the isolated units are predisposed by the lithological composition and porosity structure of the rocks that make up them.

On the section in question, the following rock categories were distinguished from the aspect of water permeability:

• permeable rocks i
• impermeable rocks.

Permeable rocks

Permeable rocks are classified based on their porosity structure into:

• permeable rocks of intergranular porosity (well-permeable and poorly water-permeable) i
• permeable rocks of cavernous-fissure porosity.

Well-permeable rocks of intergranular porosity are alluvial deposits (al) formed as a product of deposition of material during the flow of the Željeznica and Dobrinja rivers. They were built predominantly from gravel and sand, and to a lesser extent clayey particles.

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The underground water level is free, and depends on the water level of the Željeznica and Dobrinja rivers. From a hydrogeological point of view, they have the function of a near-surface aquifer of greater extent and shallower depth, and relatively fast and seasonally renewable water exchanges. The level of underground water in such an aquifer is free and directly depends on the water levels of the rivers.

Impermeable rocks

Waterproof rocks are presented at the station km. 0+000.00 and stac. km. 26+040.00 Exploratory drilling revealed impermeable formations represented by materials of marly clay and marl, and in the lower horizons by shale, clay and interlayers of sandstone, which represent a hydrogeological insulator through which surface water has no possibility of infiltrating deeper parts. It is important to note that even though shale forms impermeable rocks, they can be poorly impermeable, because it has been established that in some places between the stratification surfaces there is a permeable filling that allows water to flow, and they are also often tectonized and have fissure permeability.

Given that they lie directly below the alluvial and eluvial-deluvial deposits, they represent a podina hydrogeological barrier to the said deposits. There are no aquifers formed in them, but they can filter water, so springs of less abundance appear in places. Waterproof members build the terrain under poorly permeable and well permeable covers. Some exploratory wells did not enter this complex due to the depths of the exploration work planned in the program or deeper marl deposits in the investigated area, but it can be considered that at the defined stations, under the alluvial cover, there is a water-impermeable layer with smaller or larger oscillations in depth.

2. HYDROGEOLOGICAL CHARACTERISTICS OF THE AQUIFER

On the section of the road Sarajevo - Foča (Brod na Drina), at the current level of investigation, the presence of aquifers in permeable and poorly permeable rocks of intergranular permeability was determined.

Alluvial aquifer

It was formed in alluvial sediments developed along the Željeznica river valley. The aquifer is of the exposed type, with a variable thickness of 1.0 - 11.0 meters. The underground water level is free, relatively close to the surface of the terrain and usually conforms to the relief. Aquifers of this type have the characteristic of easy seasonal variability of yield, that is, water abundance. The filtration characteristics of alluvial aquifers are very good.

These sources are fed by the rivers Željeznica and Dobrinja, with which they mostly have a good hydraulic connection, and only seasonally, with a small part from the hinterland, the alluvial aquifer is fed by occasional stream tributaries. The aquifer is recharged by the river Željeznica, with which, in some places, it has a good hydraulic connection. Favorable filtration characteristics and aquifer recharge conditions enable the formation of underground water reserves. It is important to mention that due to the exposure, the relatively small depth to the groundwater level and the hydraulic connection with the Željeznica river, the intergranular porosity aquifer has less favorable conditions for protecting groundwater from pollution.

Eluvial-deluvial aquifers

In addition to the mentioned alluvial aquifer, the presence of near-surface aquifers of greater distribution and shallower depths within the framework of eluvial-deluvial formations was also determined. Like the previous ones, they are characterized by intergranular porosity, and along the route they were noted at the exploration well B-12 and they are open type, of variable thickness.

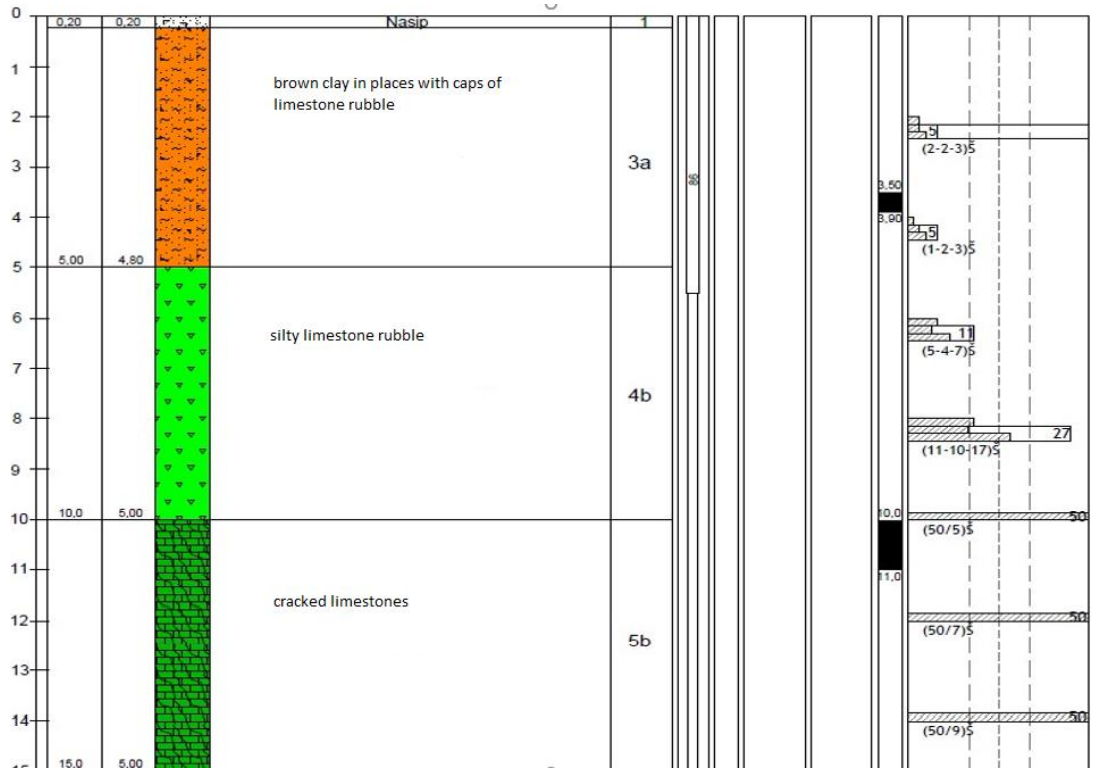

Figure 1. Lithological profile of well B - 12

The groundwater level is also free and relatively close to the surface. Replenishment is mainly related to the infiltration of precipitation and the melting of the snow cover.

Discharge is in a wider area via a number of smaller occasional sources, or diffuse discharge in the form of pistevins or along the river course of the Željeznica, i.e. alluvial formations. Weak filtration characteristics, low power and recharge conditions of these aquifers of intergranular porosity do not allow the formation of a significant volume of underground water reserves. For these reasons, groundwater is not used for water supply purposes, and protection measures are not foreseen, nor are they applied.

Aquifer of fissure-cavernous porosity

The fissure-cavernous porosity aquifer within the Anisian limestones has a small distribution, and represents a local aquifer within the Triassic impermeable complex. Karstified limestones were found in the exploration well B-12 and BZ-16. At station 19+800 – 24+750, a large number of small streams fed from limestone local aquifers were found.

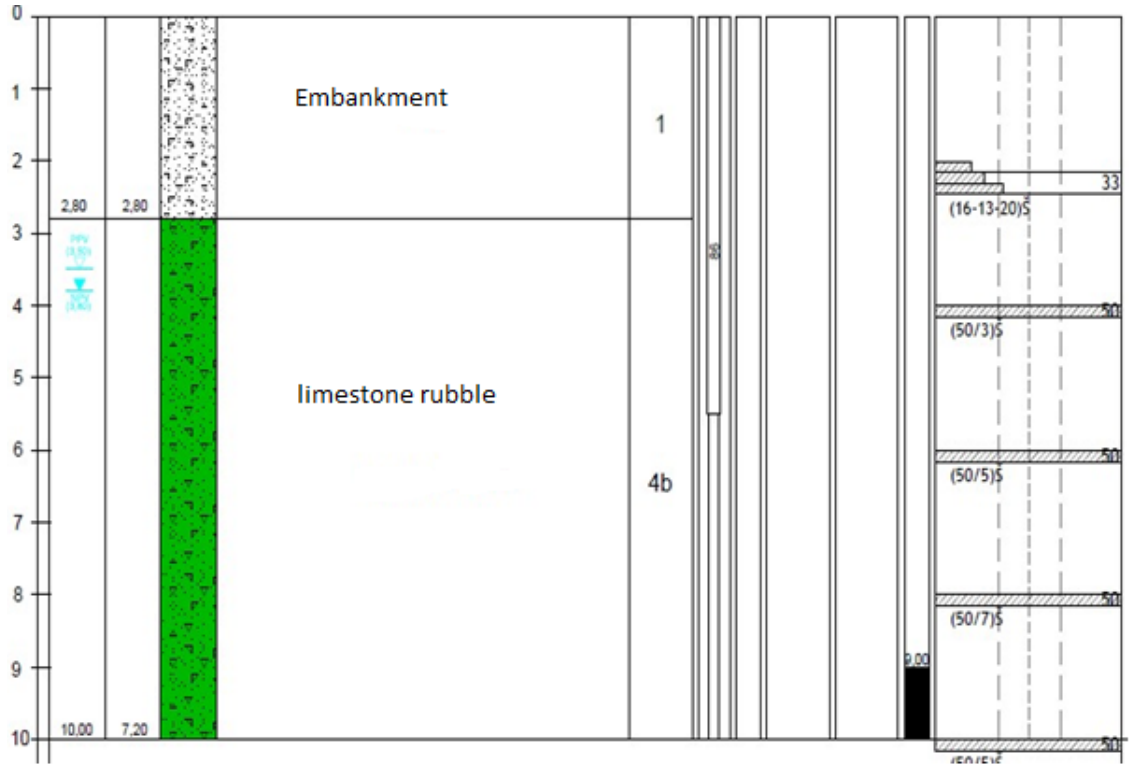

Figure 2. Lithological profile of the BZ - 16 well

3. INSTALLATION OF PIEZOMETER STRUCTURE

In two exploratory wells along the route, piezometer constructions made of plastic 10 bar pipes Ø50, 8mm (2") were installed, which in the zones of groundwater level oscillations were perforated in the necessary lengths. On all piezometers, a concrete protective block was made and a clearly written mark. Tops ("mouth") pipes are protected by a suitable metal screw cap and padlock.

Figure 3. View of the built-in protected piezometer

Measurement of underground water level

During the implementation of investigative works in the field, the occurrence of underground water (PPV) was monitored, which was noted in 15 investigative wells, as well as the level of underground water

measured 24 hours after the end of each investigative work. Since the Stup - Foča section stretches through the alluvial sediments of the Željeznica River, in a large number of exploratory wells, the installation of a column was used, after the extraction of which there was a collapse in the gravel and sandy horizons.

In addition to table 1, which shows the occurrence of underground water and the level of underground water that was ascertained during exploratory drilling, piezometers were installed in two exploratory wells, which were used to measure the oscillation of the underground water level, in the period after drilling.

Table 1. Presentation of the well mark and the level of underground water, during several months of measurement

Well mark	Depth	Groundwater level	Occurrence of undergroud water (PPV)	Well mark	Depth	Undergroud water level	Undergroud water occurrence (PPV)
B-1	10,00	-	-	BZ-4	8,00	-4,20	-3,10
B-2	10,00	-7,50	- 7,50	BZ-16	10,00	3,80	3,50
B-11	7,00	-	-	BP-1	15,00	-	-
B-12	15,00	-	-	BP-2	20,00	-	-
B-13	7,00	-2,10	-2,10	BM-1	10,00	zarušeno	-3,70
B-14	7,00	-	-	BM-2	15,00	-3,50	-3,00
B-15	7,00	-	-	BM-3	16,70	-4,10	-5,00
B-17	7,00	-	-	BM-4	10,00	zarušeno	-2,40
B-18	7,00	-	-	BM-6	15,00	zarušeno	-3,70
BZ-1	8,00	zarušeno	- 4,30	BM-8	10,00	zarušeno	-4,30
BZ-2	8,00	- 3,00	- 3,00	BM-30	20,00	1,90	1,90
BZ-3	8,00	-4,50	-4,00	BM-31	20,00	1,90	1,90

Bušotina/dubina (m)	Datum i NPV (m)				
	21.09.2022	19.10.2020	26.11.2020	25.12.2020	25.01.2021
BM-3 (16,70)	-4,10	-4,50	-4,60	-4,40	-3,80
BM-30 (20,00)	-	-	-1,90	-1,60	-1,50

4. ASSESSMENT OF THE RISK OF GROUND AND SURFACE WATER POLLUTION

Taking into account the hydrogeological categorization of rocks and their function, two categories of terrain can be distinguished in relation to the assessment of the risk of groundwater and surface water pollution, namely:

• low risk zone i
• high risk zone.

Low risk zone

The zone of low risk of underground and surface water pollution is separated in the parts where the route stretches along the terrain built of impermeable and poorly permeable dusty - sandy clays of eluvial-deluvial cover. It is separated between stations:

• station km 19+800 – 20+390,
• station km. 21+850-22+200,
• station km 23+500-23+670,
• station km 25+290-25+550.

It is estimated that a milder protection regime should be applied in this zone, with the recommendation that absorbent devices for drainage of water from the road, masts and the like, be disposed at optimal positions along the route.

High risk zone

The zone of high risk of underground and surface water pollution is separated in the terrain built of water-permeable rocks of intergranular porosity, that is, in alluvial deposits, and of well-permeable rocks of fissure-cavernous porosity. It is separated between stations:

- station km 0+000.00 – 3+250.00,
- station km 20+390.00 – 21+850.00,
- station km 22+200.00-23+500.00,
- station km 23+670.00-25+290.00,
- station km 25+550.00-26+100.00.

The rocks that make up the terrain in this zone have the hydrogeological function of aquifers of greater distribution, and are registered water bodies used for water supply.

For these reasons, protective measures appropriate to the high risk of pollution must be recommended. In any case, the solutions must be based on the conditions to accept all rainwater from the surface of the road and the connection loop facility, as well as seepage-drainage water from the trunk of the road that may be polluted by oil derivatives, as well as during incident pollution, and must be removed through a watertight sewer outside the source zone and treated with appropriate purification devices before entering the recipient. Also on this section, in addition to the hydrogeological characteristics, unwanted effects and risks of groundwater and surface water pollution that may arise as a result of incident situations, i.e. damage to passenger vehicles, or vehicles transporting liquid and solid materials must be anticipated. The risk of groundwater and surface water pollution is not the same, and special attention should be paid to sensitive and critical moves, regardless of which risk zone they are in.

Within the isolated risk zones of groundwater and surface water pollution, the following protective measures can generally be proposed:

- in the high-risk zone, engineering-geological rigorous protection measures and conditions for water purification from the well are proposed with the application of project solutions that include a closed drainage system, with purification to the prescribed quality level and complete drainage;
- in the low risk zone, milder protection measures with the so-called open drainage system, whereby mechanical water purification is not excluded. This does not imply drainage from the highway without control, and it is necessary to foresee technical solutions for additional water purification, especially on critical sections or sections that are determined to be places of potentially higher risk.

CONCLUSION

On the basis of extensive hydrogeological and other works carried out in the zone of the route of the planned road in the territory of FBiH, especially the data of groundwater level measurements during the implementation of exploratory drilling, starting from March to July 2022, a series of very significant analyzes were carried out on the basis of which concrete conclusions.

In the area of the Bogatići tunnel - which is located between stations 0+797.00 – 0+896.50 in a length of 99.50 meters, the basic hydrogeological conditions of its construction were analyzed based on the data of the hydrogeological characteristics of the wider area. It was assessed that groundwater is not a significant influencing factor on the engineering-geological conditions of construction. In the excavation of the Bogatići tunnel, in the limestone, maximum short-term inflows of water up to about 1l/s are expected during wet periods. The conditions for foundation of bridges and overpasses, depending on the adopted method of foundation of pillars, are different. In the case of foundations of pillars by excavation in alluvial deposits, inflow of water from rivers is expected. The maximum inflow into the foundation pit can be 10-20 l/s depending on the water level of the rivers in the section, the dimensions of the excavation, the distance from the river, etc. A significant influence of underground and surface water on the conditions of the foundation of the pillars is not expected, especially in the dry period.

In the open part of the route, the influence of underground water on the excavation of the foundation of the embankment practically does not exist, which is evident when looking at the hydrogeological section of the terrain. Groundwater was registered in only a few wells during drilling. Difficult construction conditions are expected in the zone of occasional flows that plunge along the route of the current road, that is, if excavations are made to enter the karst channels during periods of heavy and prolonged rainfall.

From the above, it can be concluded that the hydrogeological issues, that is, the conditions for the construction of the road route are not unfavorable from the aspect of the negative influence of groundwater.

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