SIMULATION OF HYDROGEOLOGICAL ENVIRONMENTAL DISCHARGE IN CASE OF INTERRUPTION CONSTANT OBSERVATIONS

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Abstract:

To successfully address a specific problem and draw conclusions in a study area, it's crucial to establish a robust monitorToing network that enables the collection of an adequate amount of data. Often, unexpected circumstances such as changes in conditions at observation sites, instrument malfunctions, and safety concerns are encountered in the field. In such situations, defining correlation links between all observation points becomes extremely important. This correlation allows us the termination of operation utilize data from other observation points to rectify deficiencies and obtain a comprehensive understanding of the situation on the ground, even when some data are missing or certain instruments are damaged. This is essential for proper research management and drawing reliable conclusions.

In the study area, the process of discharging the hydrogeological environment in a tunnel under pressured was studied, focusing on the period when the tunnel was out of operation. Due to technical issues, there was a discontinuation of continuous data monitoring at the outlet channel, resulting in a 14-day data gap. However, data analysis from piezometer PP-3 showed a correlation with the data from the outlet channel, enabling the filling of data gaps. These data were used for simulating the discharge of water from the hydrogeological environment.

Keywords:

Monitoring Network, Data, Hydrogeological Environment, Tunnel, Simulation.

INTRODUCTION

The most crucial segment in solving a specific problem in the field is collecting a sufficient amount of data to systematize and subsequently analyze it. Therefore, it is extremely important in the initial research phase to thoroughly analyze the study area (conduct preliminary research) and conduct field reconnaissance.

Artificial structures built in areas with different geological and hydrogeological characteristics interact with the natural environment [1]. These structures are very difficult to completely isolate in practice [2] [3]. The degree of interaction varies over different time periods, both during the construction of the structure and during its exploitation. A particular problem arises when an artificial structure such as a tunnel under pressure interacts with a geological/hydrogeological environment where complex conditions prevail, or where ground waters of different chemical characteristics exist.

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Based on knowledge of the geological, hydrogeological characteristics of the study area, as well as technical conditions and accessibility of the terrain, the most important basis for obtaining reliable data is the establishment of a good monitoring network. The monitoring network should cover all marked observation points, i.e., hydrogeological phenomena and objects (springs, piezometers), as well as the artificial structure (tunnel).

Although the monitoring network is well established and the observation period is defined with the same time intervals, in practice, unforeseen technical situations often occur, leading to interruptions in observations. In such cases, if there is a break in continuous observation at one observation point, it is possible to perform a simulation, i.e., filling in the missing data series based on the established good correlation with data obtained at another observation point.

2. STUDY AREA

The study area is located in south-eastern Serbia, central part of Stara Planina and territorially belongs to the municipality of Pirot. In this area was built artificial object – tunnel of HPP Pirot, 9093 meters in length which transports water under pressure. There are three piezometers along the route of the tunnel PP-1, PP-2 i PP-3 (fig 1).

The study area is mostly built up of carbonate sediments of the Triassic, Jurassic and Cretaceous ages. The Triassic deposits are represented by limestones, dolomites, conglomerates and sandstones, whilst the Jurassic deposits are represented by sandstones, clays, conglomerates and marble limestones [4].

Based on the structural type of porosity in the study area, all three basic types of aquifers have been identified - intergranular, fissured and karstic, lower or higher productivity.

Additionally, the presence of a complex hydrogeological system has been established in the study area, including local, intermediate and regional hydrogeological systems [5].

Forming a monitoring network in the study area to define the potential impact of the artificial structure - tunnel on the environment involved multiple measurement points (springs, rivers, tunnel and its the accompanying structures). Observations were carried out for 108 days and covered different tunnel operating regimes: operational mode (tunnel under pressure), tunnel out of operation ("draining" of the hydrogeological environment), and the establishment of the tunnel's operational mode again. One of the measurement points was the channel of the outlet structure where water levels, flow rates, and basic chemical parameters of water were measured.

3. RESULTS AND ANALYSIS

Due to technical issues, observations at the accompanying object of the tunnel - the outlet channel - were interrupted because of the redirection of the water flow emanating from the tunnel. Data from this observation point were crucial for the overall analysis as they defined the quantity of water "draining" into the tunnel from the hydrogeological environment. Based on the analysis of the monitoring results from the piezometer PP-3 located along the tunnel route (Fig 1), it was determined that this location exhibited the most intense connection between the tunnel and the hydrogeological environment [6]. As a result of the tunnel's termination of operation, i.e., the release of pressure in the hydrogeological environment, the groundwater level at PP-3 decreased by 43 meters [4].

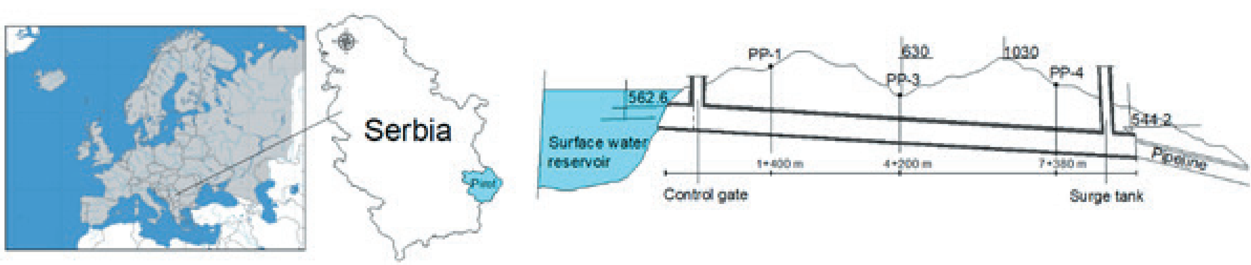

Figure 1. Geographical location of the study area with the tunnel scheme with accompanying objects and the location of piezometers [4].

Monitoring the water level changes discharged through the outlet channel began two days after the closure of the control gate and the termination of the operation of the tunnel. Just two days into the measurements, there was a redirection of the water flow, and the sensors remained dry for 14 days. After resolving the technical issues, the flow was redirected back to the outlet channel until the tunnel was closed again and put back into operation (Fig 2).

The initial tunnel dewatering period at the outlet channel reflects recession conditions that unfold exceptionally rapidly. During this phase, water drainage occurs from the rock mass after the tunnel closure and pressure relief within the tunnel. The drained water comprises partly groundwater and water pressurized within the rock mass when the tunnel operates under pressure. Following a period of relatively intense recession, there is a stabilization of water levels, or flow stabilization (discharge from the tunnel), with the appearance of various peaks. These peaks may indicate different hydraulic conditions of water drainage from the rock mass, i.e., different sections within the tunnel.

The second observation period indicates a relatively stable tunnel drainage regime with a rising trend, which was a result of changes in groundwater conditions, namely, the inflows of newly infiltrated water.

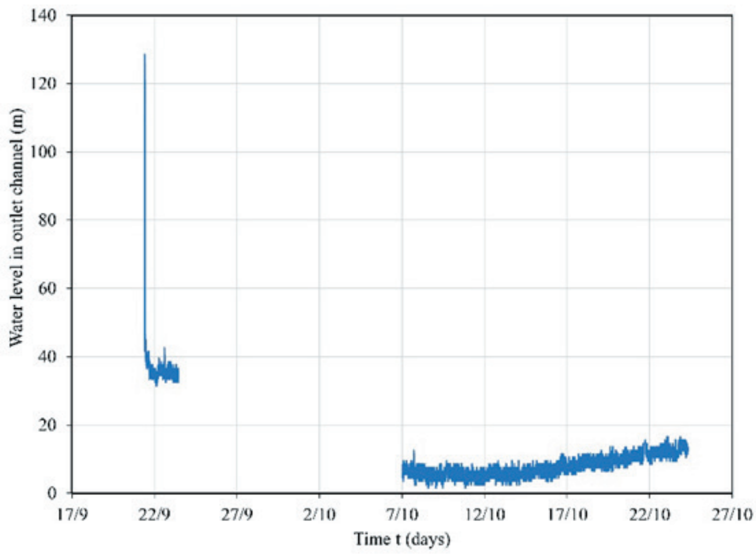

Figure 2. Water level on the outlet channel (observation interval 2 minutes).

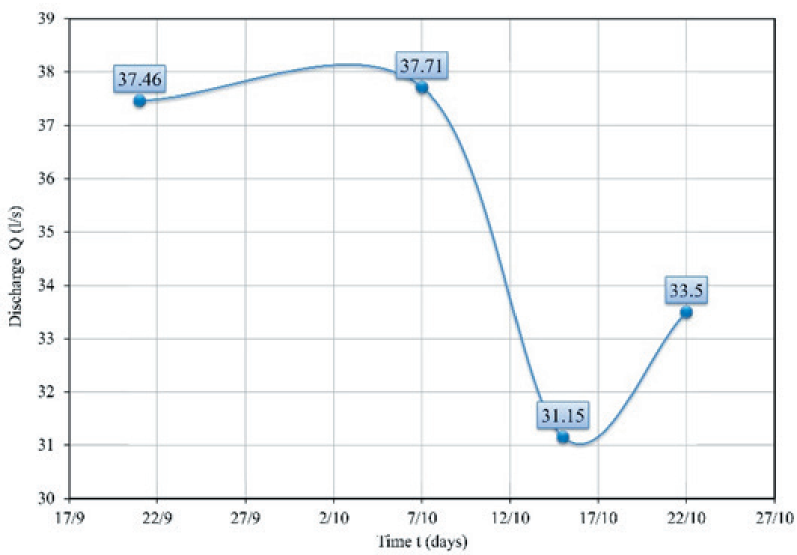

Figure 3. Discharge Q (hydrograph) on the outlet channel.

In addition to continuous monitoring of water level changes at this measurement point, flow measurements were also conducted (Fig 3).

Due to the lack of data during a significant observation period of 14 days and the initial moment when water suddenly emerged in the channel, which is only a data point related to that moment and does not capture the dynamics of draining the hydrogeological environment, the 2-minute water level data in the outlet channel were aggregated to daily observation intervals to obtain a better analysis (Fig 4).

By analyzing all the collected data throughout the entire research period, it can be noted that the highest volume of water enters the tunnel from the hydrogeological environment in the zone of piezometer PP-3 [4] [5]. Based on this fact, this observation point served as a reliable source for filling in the missing data in the outlet channel. A good correlation/curve (Fig 5) was established between the data on the groundwater level changes in PP-3 and the observed data in the outlet channel, which served as the basis for further filling in missing data (forming a new curve) and their simulation. Daily data on groundwater levels in PP-3 and levels measured in the outlet channel were used for forming the correlation curve and further calculations.

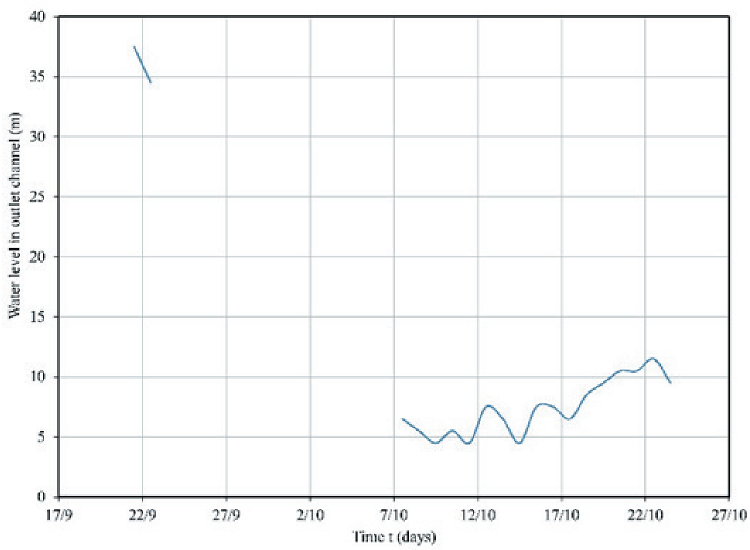

Figure 4. Water level on the outlet channel (observation interval 1 day).

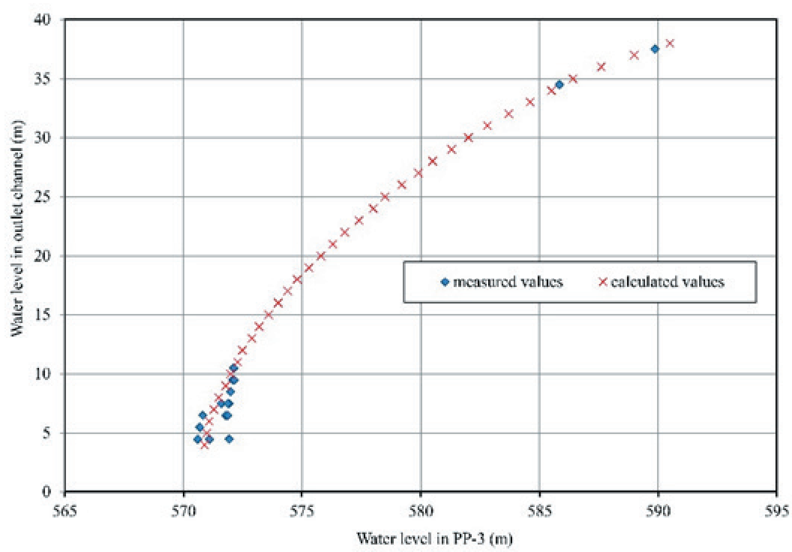

Figure 5. Diagram of measured and calculated water levels on the outlet channel and piezometer PP-3.

Based on the formed new curve, the missing dataset was filled in, simulating the draining period that would be recorded at the outlet channel and so enabling a realistic view of groundwater discharge into the tunnel (Fig 6). This method of simulating the draining process of the hydrogeological environment during the tunnel maintenance period showed a strong correlation between real groundwater level data in piezometer PP-3 and simulated data at the outlet channel (Fig 7), with a coefficient of determination of R2=0.96.

The large oscillatory changes in the water level in the outlet channel during the measurement period, as well as their absence during the non-measurement period (simulation), are due to frequent tractor passes through the outlet structure, which caused fluctuations in the water levels in the channel itself. For this reason, a correction was made to the observed and calculated data by averaging every third data point, aiming to nullify this effect (Fig 8).

After averaging the values and analyzing the obtained water level graph in the outlet channel, it can be observed that after a recession period lasting 22 days, there was a rise in the water level. This indicates an increase in inflow into the tunnel from the hydrogeological environment due to newly infiltrated water formed during the observed rainy period.

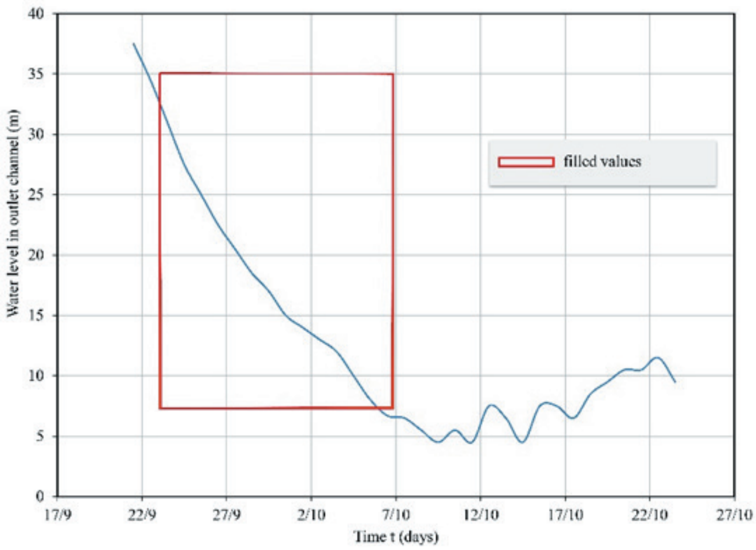

Figure 6. Filled values of the water level on the outlet channel.

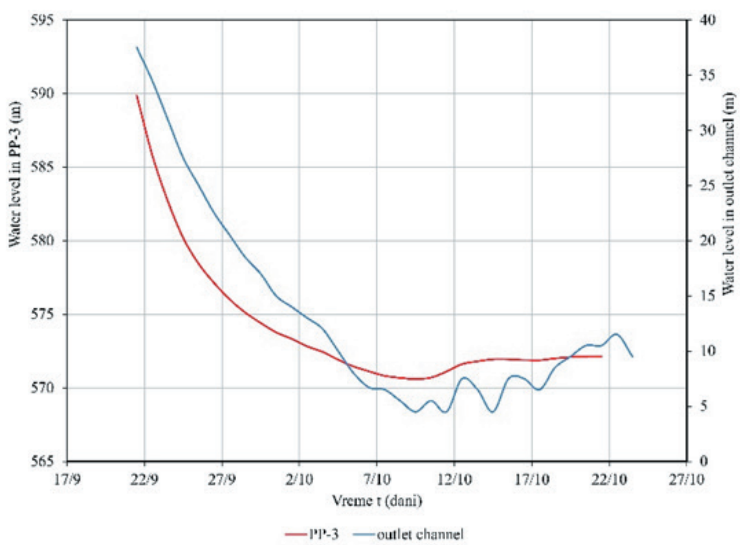

Figure 7. Diagram of real values of water level in PP-3 and the filled sequence on the outlet channel (interval 1 day).

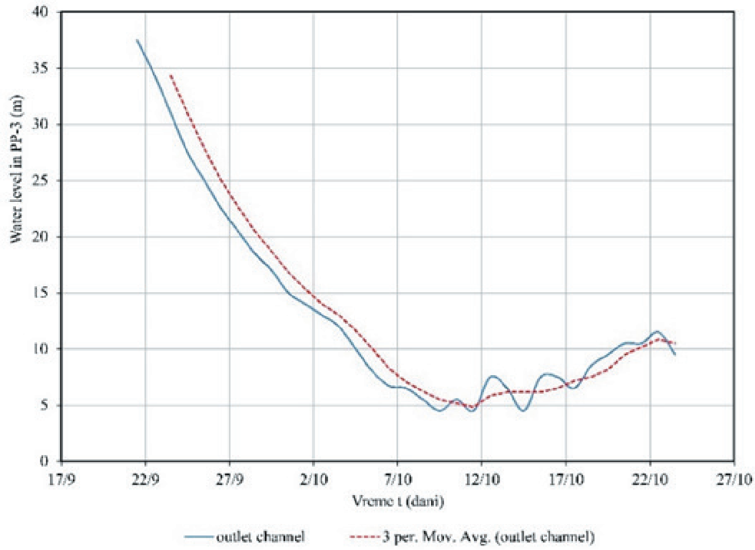

Figure 8. The correction of the entire period (observed and calculated) of water level values in the outlet channel involves averaging every third data point.

By measuring discharge at the outlet channel, it further indicated that in the fourth series of measurements, there was an increase in the discharge rate compared to the third series by 2.35 l/s. This is another confirmation of the increase in water inflow into the drained tunnel.

4. DISCUSSION

In practice, monitoring networks often do not function as intended in theoretical or planning processes. Frequently, it is not feasible to install instruments at observation points due to malfunctions or water redirection, as in this case. However, the existence of a good monitoring network enables the filling of missing data based on others if there is a strong correlation.

In the study area, the possibility of correlation with another measurement point was facilitated by the exceptional response of piezometer PP-3 to the operational pressure in the tunnel. This was particularly pronounced under conditions of tunnel discharged when a recession period occurred, leading to drainage of the hydrogeological environment.

The dependency curve between the data of two observation points, in this case, the continuous series of water levels in piezometer PP-3 and the interrupted series of levels at the outlet channel, provided the opportunity to fill in the gaps, or simulate missing data. The physicochemical parameters of groundwater at both of these observation points also indicated that the largest volume of water in the tunnel was draining from the zone of piezometer PP-3. This was another confirmation that this object was the most representative for the simulation process.

5. CONCLUSION

Every obtained data point is important and can be used to enhance the overall data analysis and draw conclusions in the process of solving a specific problem. For this reason, it is crucial to design and set up the monitoring network in the field effectively. Often, there are challenges such as equipment shortages to cover all measurement points, technical reliability of the equipment, and safe installation for continuous monitoring. Accessibility of the terrain being investigated is also a common issue. All of these factors need to be considered in logistics and decision-making regarding which locations are a priority.

In the process of investigation, it is important to collect as much data as possible, but conclusions should only be drawn through their analysis and mutual correlation, or comparison. In the specific case, the application of comparative analysis between two observation points and the existence of good correlation enabled the filling of datasets that were lost due to technical issues in the field.

6. REFERENCES

[1] Q. Li, R. Qian, J. Gao, J. Huang "Environmental impacts and risks of bridges and tunnels across lakes: An overview", *Journal of Environmental Management, Elsevier*, Vol. 319, October 2022

[2] P. Milanović "Karst Istočne Hercegovine i Dubrovačkog priobalja", Beograd, Srbija, 2006, p.362

[3] J. Kovačević "Savremeno građenje u podzemlju" AGM knjiga, Beograd, Srbija, 2014, p.679

[4] M. Čokorilo Ilić, A. Mladenović, M. Ćuk, I. Jemcov "The importance of of detailed groundwater monitoring for underground structure in karst (Case study: HPP Pirot, Southeastern Serbia)", *Water 2019*, Special Issue: Hydraulic Behavior of Karst Aquifers, 11(3), 603, 2019

[5] M. Čokorilo Ilić, M. Ćuk, A. Mladenović, I. Jemcov "Definisanje kompleksnog hidrogeološkog sistema na primeru hidrotehničkog tunela HE Pirot", 17. Kongres geologa Srbije, Zbornik apstrakata, Srpsko geološko društvo, 2018, pp.522-525

[6] M. Čokorilo Ilić, A. Mladenović, M. Ćuk, J. Radosavljević, J. Šišović, I. Jemcov"Analiza uticaja tunela HE „Pirot" na kvantitativne karakteristike podzemnih voda", Zbornik 8. Simpozijuma o zaštiti karsta, Pirot, 2018, pp.7-17