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# INTRODUCTION OF EFFICIENT SYSTEM FOR ACTIVE WATER LOSS MANAGEMENT AND MEASURING-CONTROL POSTS STANDARDIZATION IN WATER SUPPLY SYSTEM

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***Keywords:*** *active management, water loss, water supply system*

## ABSTRACT

The introduction of a system of active management of water consumption and losses in water supply systems is an extremely important task that enables the rational use of water resources and better environmental care. The funds invested in the active management system, in addition to saving water, also allow for reduced operational costs, which have proven to be very profitable in the long term period. Active monitoring and management system introduction is a complex multidisciplinary task that can be implemented in parallel with the upgrade or reconstruction of the water supply system. This paper presents the process of rationalization of new parts of the system that need to be built and, in parallel, the introduction of real-time monitoring and control system on the case study of water supply in the municipality of Doljevac. Special attention is paid on organization of measuring-control posts. Standardized posts shapes and dimensions have been adopted. Standardization of measuring and control equipment can enable easier interventions, comfort operator work and efficient equipment maintenance and service, which consequently results in shorter potential supply stoppages, quick interventions, making water loss minimized and raised consumer satisfaction.

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## 1. Introduction

Quality drinking water is without a doubt the most valuable resource, the availability of which in a certain area has a direct impact on the population's quality of life and the development of all economic sectors. The industrial and technological revolution of the last few decades has caused significant changes in the natural environment and increased the demand for water, while also increasing pollution of water resources. Current climate change, the higher density of large cities population, decline in the number of inhabitants and standard of living in smaller municipalities, along with the increasing temporal unevenness of the abundance and quality of water sources, create additional pressure on water resources.

The possibility of discovering and incorporating new sources of high-quality drinking water is an exhausted activity, because all high-quality sources have already been explored and activated, and connecting new sources of less abundance from greater distances is prohibitively expensive in terms of both construction and exploitation [1]. Connecting smaller systems to regional water supply systems aims to improve water balance in the areas they serve over time.

The theory of unlimited water resource availability has been proven unreal. Rational use of water resources with maximum protection of natural resources has become a priority task. Provided the existence of systems with extremely high levels of lost or irrationally used water, it has been demonstrated that active management of water consumption and inevitable losses in water supply systems is the primary task by which practically "new springs" are discovered precisely in lost and irrationally used volumes of water [2].

Active management and reduction of water losses in water supply systems requires planning for the implementation of a water supply system monitoring and management system during the design phase [3]. This activity necessarily requires initial (usually high) investments for the companies that manage it, as well as the reorganization of the companies themselves [4].

A well-established system of active management already in a short-term gives positive effects of reliable water supply, better utilization and availability of water resources [5]. Furthermore, the long-term return on investment will be increased by lowering the costs of water production and distribution, as well as business, increased consumer trust and satisfaction, and multiplied positive effects on the environment and water resources [6].

In this paper, an example of the development of the water supply system of the municipality of Doljevac within the regional water supply system "Brestovac-Bojnik-Doljevac" is shown [7], as well as the process of introducing a system of active management of consumption and losses in the design phase of the reconstruction of the existing part of the system, and connections with neighboring water supply systems. The entire regional system "Brestovac-Bojnik-Doljevac" was examined, a representative numerical simulation model of the system was created, and within it, the precise positions of the planned reservoirs and the required dimensions of the pipelines were optimized.

Pressure and consumption management measures, as well as the possibility of water balancing with the Niš water supply system, were simulated in the numerical model [7]. As a result, based on the actual circumstances in site, as well as the available resources and constraints, a system for monitoring and managing the water supply system in real time was developed, as well as the specification of the necessary equipment, software, personnel, and individual locations for data collection and active management [8].

## 2. Description of the water supply system in the municipality of Doljevac

The municipality of Doljevac is located in the valley of the South Morava River between the cities of Niš and Leskovac, with a total of 16 settlements and around 18500 inhabitants. Despite its development potential, the municipality of Doljevac is classified as underdeveloped. The exceptionally fertile land in the South Morava River valley, as well as its proximity to the corridor X and railway corridor from Hamburg to Athens, provides exceptional conditions for agricultural and economic activities.

The decrease in the number of inhabitants due to a lack of quality jobs and cultural activities, but also, to a large extent, due to underdeveloped infrastructure, is a major problem for the development of the municipality of Doljevac.

The main challenges in supplying the population with pure drinking water are a lack of local sources of potable drinking water and the absence of a developed water supply system in most municipalities. Doljevac's water supply concept was strategically based on bringing water from the accumulation Brestovac in the municipality of Bojnik. To manage the system, a joint public water supply company "Brestovac-Bojnik-Doljevac" was formed with the municipality of Bojnik. This water supply concept in the municipality of Doljevac is outlined in the Republic of Serbia's Water Management master plan [1] and planning documents (Fig. 1).

The construction of the regional system "Brestovac-Bojnik-Doljevac" was started about 50 years ago. The current system's construction level is relatively low in comparison to the planned one, which means that most of the built sites are still out of use or are used at significantly lower capacity than the designed one, causing premature aging and overstressing of the built part of the system, as well as serious and expensive technical problems.

The "Brestovac-Bojnik-Doljevac" water supply system was conceived as a temporary solution for settlements in the municipality of Žitorađa until the construction of the Toplički system with the accumulation "Selova" in the Kuršumlija municipality, which will not be completed in the near future for sure.

Although the system "Brestovac-Bojnik-Doljevac" is still under construction, the connection of the system with "Nivos" (Niš water supply system) has started. The water supply systems of Knežica, Ćurlina, and Perutina are already connected and supplied with water from "Nivos", and a direct connection in the area of the village of Belotinac is also planned for the two-way balancing of the required amounts of water between these two water supply systems.

The main parts of the initially planned system "Brestovac-Bojnik-Doljevac" are:

- Accumulation (artificial lake) "Brestovac";
- Transport reinforced concrete pipeline DN600;
- Water purification plant;
- Primary pipeline from Bojnik reservoir to Doljevac;
- Reservoirs Bojnik, Kosančić, Kutleš, Kočane and Klisura;
- Distribution network.

The dam and accumulation "Brestovac" on the Pusta river, raw water transport pipeline to the purification plant "Bojnik" (in the first phase capacity 100 l/s), primary pipeline Bojnik - Doljevac, distribution network in Bojnik, and certain settlements were completed among the planned facilities.

The accumulation "Brestovac", Fig. 2, was built on the Pusta river upstream from the village of Gornji Brestovac, about 10 km west of the village of Bojnik. It is situated 400 m above sea level at the foot of Mount Radan. The construction of the dam began in 1975, and filling of the reservoir in 1986. The surface area of the lake is 107 km$^2$, the useful storage capacity 4,1 million m$^3$ with an average discharge of 690 l/s.

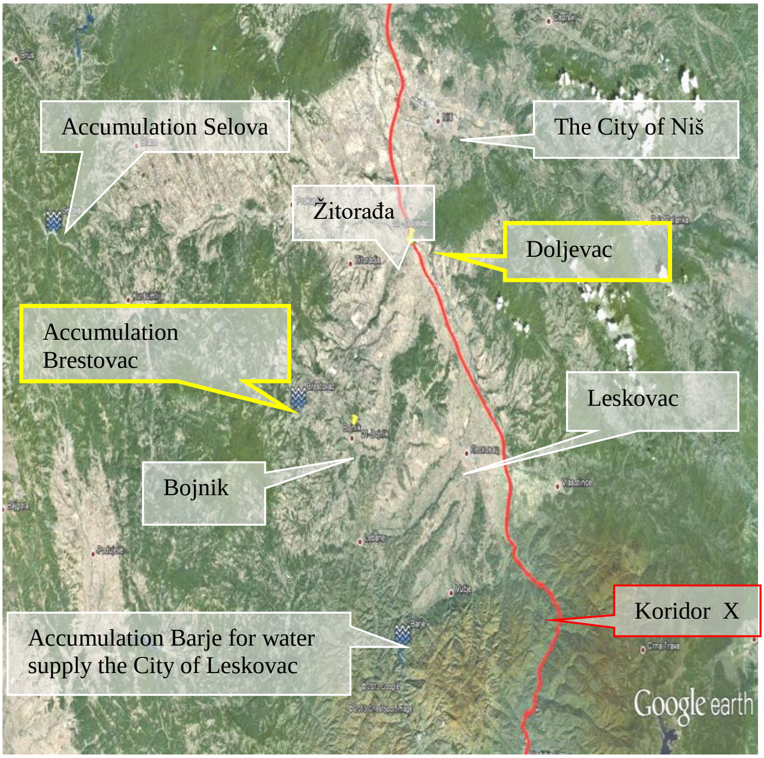



**Figure 1. Water supply system of Brestovac-Bojnik-Doljevac and location of neighboring water supply systems**

**Figure 2. Accumulation Brestovac**

A primary pipeline DN600 of reinforced concrete pipes with a length of 11 km was built from the accumulation Brestovac toward Bojnik. The pipeline's capacity is estimated to be 300 l/s for drinking water and 70 to 100 l/s for irrigation purposes [7].

The primary pipeline was built on the territory of the municipality of Doljevac to the intersection manhole on the right bank of the South Morava River, from which water is delivered to the Čečina settlement. Certain sections of distribution pipelines were built on the right bank of the South Morava River but were never connected to the "Brestovac-Doljevac-Bojnik" water supply system. So far, not a single planned reservoir has been built, which is one of the most significant matters, for both, the municipality of Doljevac's regular water supply and the potential development of the entire regional water supply system.

A strategically important point for Doljevac is the node "T40", which represents the entrance of the primary pipeline to the municipality of Doljevac. A chlorine station exists in node T40, behind which the system splits into two branches. The left, currently unconstructed branch should be used to fill the Kočane reservoir, the largest in the system, while construction of the right branch on the right South Morava bank should continue in accordance with the location of the future Klisura reservoir. The terrains configuration, the systems poor development and the low water consumption all contribute to the appearance of high pressures in node T40, around 8 bars. Due to high pressures, the equipment ages faster and leakage losses increase. The pipeline must be flushed frequently due to very small water velocities.

## 3. Hydraulic model of the system "Brestovac-Bojnik-Doljevac"

Water supply distribution systems are an essential part of the "Brestovac-Bojnik-Doljevac" water supply system, so the model is intended to include all of the settlements planned to be connected to the system in the municipalities of Bojnik and Doljevac, as well as 7 settlements in the municipality of the city of Leskovac. The settlements are grouped according to the associated reservoirs, none of which has been built and put into operation so far [7].

The hydraulic model of the "Brestovac-Bojnik-Doljevac" water supply system for the planned condition was developed using the following assumptions:

- That all of the major components of the "Brestovac-Bojnik-Doljevac" system will be completed;
- That the primary pipeline between Bojnik and Doljevac will be reconstructed;
- That there will be a link with "Nivos" and a water exchange;
- The possibility of water supply Žitorađa and the surrounding settlements.

The entire system is based on the supply from the primary pipeline, from which the subsystems are separated and organized in accordance with the planned reservoirs. To balance consumption, the reservoir "Kočane" – the largest in the entire system – and reservoir "Klisura" are planned to be built in the municipality of Doljevac.

The calculations were performed on the system's mathematical model using the Epanet 2.0 software package. Following a survey of demographic trends, water needs analyses were performed, followed by a volume check of reservoirs and main pipelines. Dimensioning and capacity checking of the planned facility were performed for the estimated consumption values, whatever, for the operation of the system in its current state as well as the operation of the fully constructed system.

### 3.1. Specific consumption per inhabitant

The state of the "Brestovac-Bojnik-Doljevac" system is a clear example of how a system that was started but not fully developed results in irrational operations and ongoing water quality issues in the distribution system due to low water discharges.

According to outdated projections, specific consumption was set at 600 liters per inhabitant per day, which confirmed to be an extremely high and irrational value. Considering the decrease in population, it was discovered that many parts of the system were over-dimensioned [7].

Water demand analysis is shown in Table 1 [7]. These data look much more realistic, especially considering that water must be saved because water resources are scarce.

**Table 1. Water demand analysis**

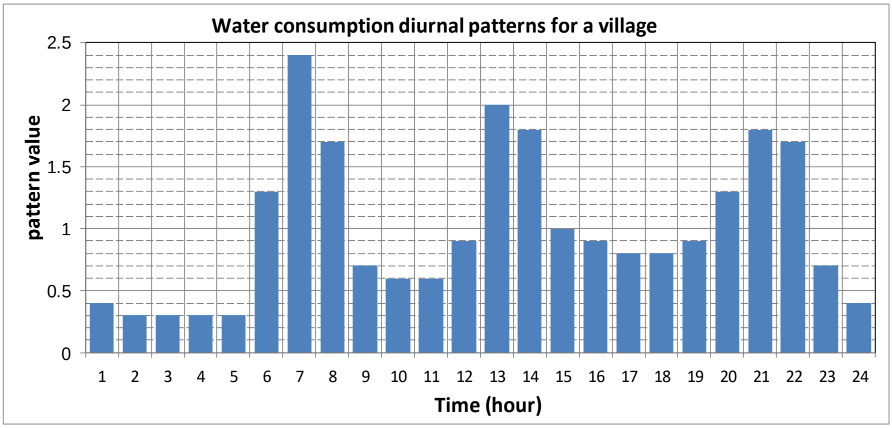
| | Demand (l/s) | Specific demand $q_s$ | Maximal daily specific demand $q_{s,max,daily}$ |
|---|---|---|---|
| Citizens | 150 | 250 lit/capita/day | 1,8* $q_s$ = 450 lit/capita/day |
| Industry | 50 | | |
| Institutions | 20 | | |
| Water loss | 30 | | |

The dimensions of the primary pipelines and pipelines toward the reservoirs were checked based on the estimated specific consumption. The volume of the storage reservoirs are designated based on the adopted specific consumption for the needs of subsystem users, with fire protection and mandatory water reserves.

## 3.2. Diurnal patterns

Consumption diurnal patterns for village-type settlements were used. In this case, the midday consumption peak, i.e. consumption twice as high as the average during the day, occurs at noon (12-1 p.m.), so when analyzing the system under maximum daily consumption conditions, this value is used as the standard for checking the dimensions of the pipeline diameter [7].

In the analyses, the highest consumption peak occurs between 6 and 7 a.m., when the coefficient of consumption in relation to the average value of consumption during the day is increased 2,4 times (Fig. 2). It is unrealistic to expect such high consumption values for a variety of reasons, but it is advisable to test the system's response in emergency situations.




| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,4 | 0,3 | 0,3 | 0,3 | 0,3 | 1,3 | 2,4 | 1,7 | 0,7 | 0,6 | 0,6 | 0,9 | 2,0 | 1,8 | 1,0 | 0,9 | 0,8 | 0,8 | 0,9 | 1,3 | 1,8 | 1,7 | 0,7 | 0,4 |

**Figure 3. Adopted diurnal water patterns**

### 3.3. Introduced settings in the water supply system mathematical model

Certain changes were made to the system's topology in comparison to the previously prepared documentation, primarily concerning the location and elevation of the Kočane reservoir, which has a direct impact on the dimensions of the inlet and outlet pipelines [7].

The Kočane reservoir was designed as a two-chamber one with reduced dimensions $V$=2×1000 m$^3$ instead of 2×1600 m$^3$; elevations of bottom 249 m, and spillway 253 m. Its bottom is 11 m lower than designed (260 m) in the original Detailed Project of the Kočane reservoir in 1975. Because of the reservoir lower location and shorter connecting pipelines, the diameter of the supply pipe can be reduced from what was originally planned (DN450). The Kočane reservoir still has sufficient reserves for a future connection to Žitorađa. The supply pipe from the T40 chlorine station to the reservoir is DN300 mm (ductile casting), and a DN350 mm pipe for water flow towards the consumption area is provided.

The volume of the still unbuilt Klisura reservoir was reduced from the previous planned 1300 m$^3$ to the optimal 1000 m$^3$ with a bottom elevation of 250 m and an overflow at 254 m.

### 3.4. Results of hydraulic calculations

Hydraulic calculations were performed over a five-day period for two scenarios: average daily and maximum daily consumption.

The calculation results show that a daily periodic state is established in the system. By examining the water balance in the "Brestovac-Bojnik-Doljevac" system, it is possible to conclude that more water can be produced at the purification plant than consumed. The quantities of water that can be forwarded to NIVOS on a day with medium consumption are 60 – 70 l/s.

All the reservoirs work well, they empty and fill, except for the "Bojnik" reservoir, which is full almost all the time on a day of average daily consumption, because the high pressure in the network and the large-diameter supply pipe allow it to be filled very quickly.

The "Kočane" reservoir's location ensures adequate pressures in the distribution network. In hydrostatic conditions, pressures in the system's lowest parts can reach 5,9 bar. When designing the secondary network in certain settlements, it is essential to correctly dimension the pipeline diameters due to the pressures at the network's end points, which are decisive for the dimensioning of the branched type of network.

The reservoirs of Kočane and Klisura fill and empty in a 24-hour cycle up to the mandatory reserve (adopted at 0,5 m water level in the reservoir).

These two reservoirs operate in opposite phases, Fig. 4. The Klisura reservoir has the lowest occupancy when the Kočane reservoir is completely full. The water level in the Klisura reservoir is at its lowest level at the time the inflow into the Kočane reservoir is closed. At that point, the inflow into the Klisura reservoir begins to increase, reaching a peak when the Kočane reservoir is emptied.

This phase relationship is a result of the hydraulic connection, because the pipeline at node T40 forks into two connections that go directly to these two reservoirs. As Kočane reservoir is closer to the node T40, it gets full faster, i.e. the inflow into it is greater than the inflow into the Klisura reservoir for the adopted dimensions of the pipeline, so it dictates the operation of the Klisura reservoir, Fig 5.

All of the system's reservoirs have a daily rhythm of filling and emptying. The calculated level change in the Kočane and Klisura reservoirs in a five-day consumption period with $Q_{\max,day}$ is presented in Fig. 6. When examining the dimensions of the Kočane reservoir and supply pipelines, as well as the Klisura reservoir, it is important to note that even at maximum daily consumption, the 24-hour rhythmicity of the Kočane reservoir's operation is noticeable.

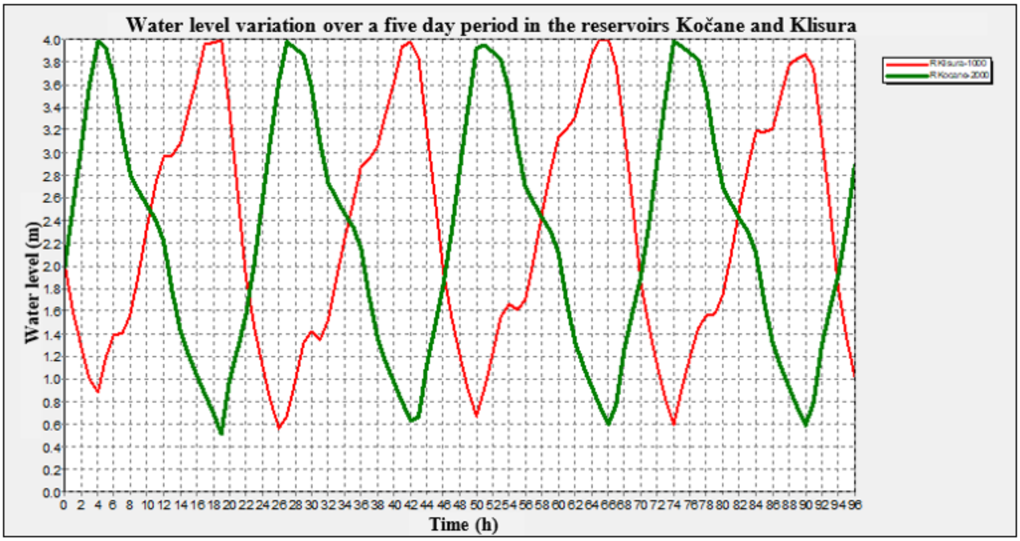



**Figure 4. Changes in water level in the Kočane and Klisura reservoirs over a five-day period for consumption in the system $Q_{mean,day}$**

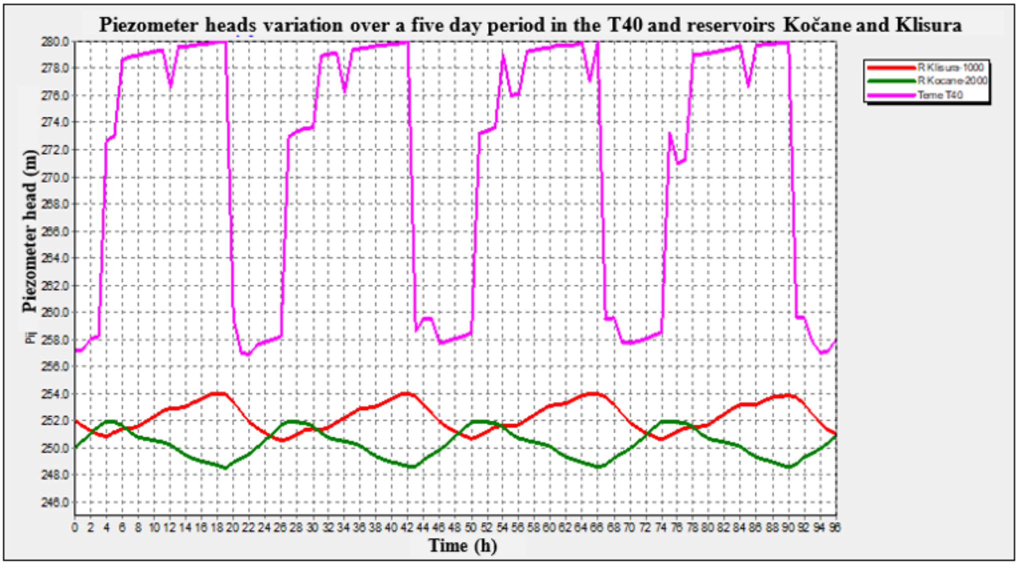



**Figure 5. Piezometer elevation change in T40 and Kočane and Klisura reservoirs during a five-day period for consumption in the system $Q_{mean,day}$**

Pressures at the ends of the network for maximum daily consumption enable a stable supply at the ends of the network. Under these conditions, water supply of 18 – 25 l/s toward "Nivos" is also possible.

Calculated hydraulic pressure variations at node T40 as well as the water levels in the Kočane and Klisura reservoirs are shown in Fig. 7. As the largest reservoir in the system, the Kočane reservoir has a dominant influence on the system. If the supply to the Kočane reservoir is turned on at node T40, the pressure drops from 80 to 40 meters (from 8 to 4 bars).

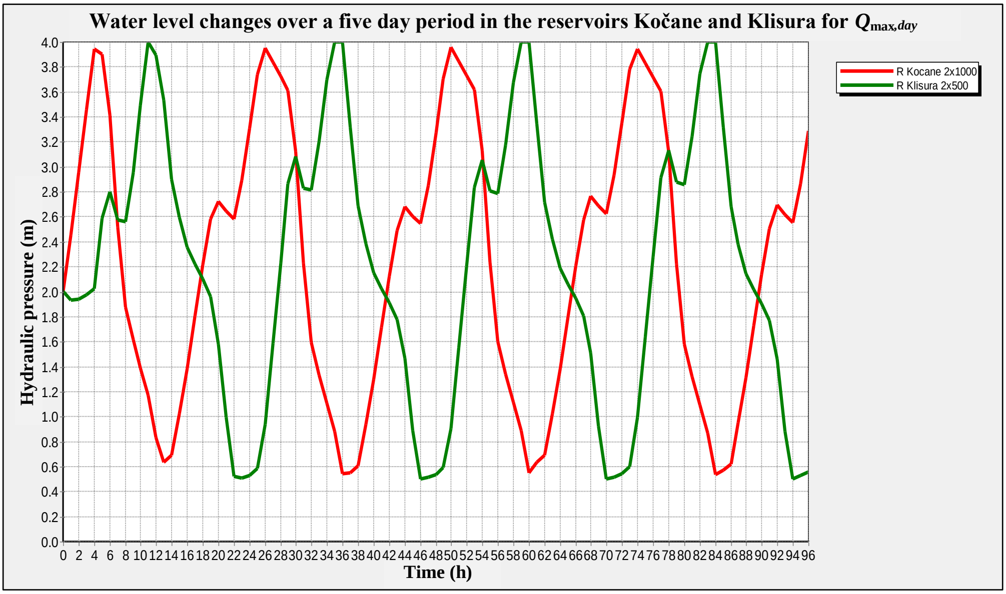



**Figure 6. Water level change during a five-day period in the Kočane and Klisura reservoirs for consumption in the system $Q_{max,day}$**

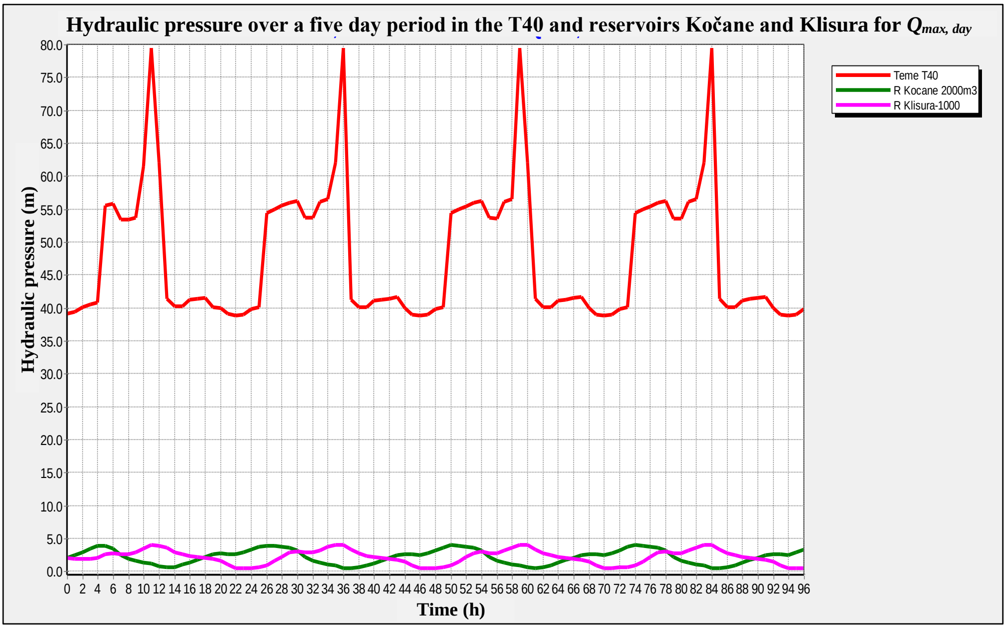



**Figure 7. Pressure variation at node T40 and reservoirs Kočane and Klisura over a five-day period for consumption in the system $Q_{max,day}$**

Changes in piezometer heads at node T40 are significantly greater for maximal than for mean daily consumption (Fig. 7). The piezometer head at T40 ranges from 239 m to 281 m, indicating that the Kočane reservoir has the greatest influence on the height of this elevation, which lowers the elevation by 42 m when the inflow is turned on.

## 4. Concept of the water supply active management system

One of the most important development plan and maintenance of the supply system is reaching the set goals of its efficiency, as well as the establishment of a system of active management of the water supply system. In order to reduce water losses to the lowest possible level and provide users with the highest possible quality of water supply service, it is necessary to establish a system of continuous monitoring and management, install the necessary measuring and management equipment, and establish protocols of management actions.

The basic concept used in the design of the monitoring and control system can be described in the following manner [8]:

- The command and control center (CCC) was installed in Bojnik, in the premises of the water factory. In CCC via computer, the user should have the ability to display the current state of the system and measured values, the ability to choose different management methods, issue commands to turn on and off pumping units, control electro-valves, change equipment parameters in manual and automatic operation, as well as view the history of events and measured values (databases).
- One monitoring center (MC) will be established in the municipality of Doljevac, with the same capabilities of displaying and reviewing the system's status and history, but with no or limited management rights.
- The installation of SCADA software with the required number of connections for the existing system as well as future expansions of the water supply system until the final construction is planned for the monitoring and management of the distribution controller.
- All pumping units in the system will be managed automatically, and frequency regulators will be installed to regulate engine revolutions based on input and output parameters.
- In all reservoirs, continuous measurement of inflow and outflow, measurement of water level in chambers, and automatic control of electric valves on the inlet and outlet are planned.
- Unauthorized entry signaling is provided on all separate facilities for equipment accommodation (manhole and other separate facilities).
- For communication with CCC and MC, observation and control points in separate facilities use a wired connection for signal transmission or a low-power GSM/GPRS modem with an antenna.
- The installation of a battery power supply system is planned for detached buildings where there is currently no possibility of connection to the power system, while leaving the option of installing a connection from the power network and hybrid power supply.
- Manholes for housing the equipment are made of waterproof concrete and are impervious to water and moisture. The manholes must be of adequate size and comfort for workers to enter and perform inspection, servicing, or replacement of equipment.
- The monitoring and control equipment is maximally typified, making spare parts and servicing easier to obtain.

### 4.1. Command and observation center

At the command and observation post, a newer generation computer with a large diagonal monitor would be installed for visibility and, if necessary, to allow a larger number of people to directly view the system status.

Command actions can be issued remotely from the command and control center. CCC command actions are mostly issued when there is a need to change a regime that is not defined at local measuring points, or when there is a need to change parameters and limit values that are programmed at an individual measuring control point, as well as intervention actions when there are breakdowns, unforeseen circumstances, or outages of equipment from the function.

SCADA software should be installed on the computer at CCC as a platform that is maintained, adapted to system changes, and upgraded by establishing new measuring points into the system over time.

It is planned to purchase and install the SCADA platform for the entire developed system, with missing parts added and connections developed with other municipalities and systems. The planned MC in Doljevac differs from the CCC only in that it lacks the ability to issue direct command actions, but it has full observation rights.

### 4.2. Organization of measuring and control posts

Measurement and control points are organized according to the principle of measurement zones (DMA), where areas in the system are limited in which the current flow rate can be measured, as well as cumulative deliveries, pressure values at characteristic points in the system, isolation of parts of the system in the event of a breakdown or the need for intervention on part of the system.

Measurement control points are connected to some of the existing facilities (built manholes, reservoir, pumping station), or new manholes are planned to be built.

The reconstruction of the existing manholes is planned, as well as the construction of new conditional manholes in which measuring and control equipment, an electrical power supply system, a control and communication unit (PLC) and an alarm system for reporting the case of unauthorized entry into the area of the measurement site would be placed in case of protection against vandalism.

At the measuring and control points located in the shafts, it is planned to install a flow meter, a shut-off device with an electric drive, and a pressure gauge. In the reservoirs, flow meters on the supply and drain, probes for measuring the level and shutting off the system's water inflow or outflow. In pumping stations, a flow and pressure meter and a frequency modulator to optimize the operation of pumping units and reduce the risk of hydraulic hammer.

The measuring control center will be supplied with electricity from the power grid wherever possible. Battery power and solar panels will be installed in areas where this is currently not possible.

The site on which pipeline reconstruction and manhole construction or reconstruction are taking place is owned by the government (9 measuring control posts), while 2 measuring control posts will be established by the reconstruction of existing manholes on private plots (there is already a record of the existence of public utility facilities).

### 4.3. Criteria for the organization of individual measuring and control places

Criteria of the organization that were set during the installation and arrangement of measuring and control places:

- The measuring control point must be clearly visible and accessible.
- In order to ensure the precision of the measurements performed in a homogenized current field, the measuring control point must have a clearly defined space for placing the measuring control equipment, as well as a length in front of and behind the flow meter of at least 5 sizes of pipe diameter.
- Internal lighting is required inside the manhole in order to securely access, maintain equipment, or carry out interventions.
- Inside the manhole, an electrical cabinet and a control cabinet should be installed.
- The manhole entrance is designed to make it easy to enter, bring in, and remove the essential tools and equipment.
- In the event that flow meters or control valves must be removed, the section of the pipeline in the manhole is limited by two butterfly double eccentric valves with manual operation. It is required to install a removable assembly piece so that the equipment can be easily removed and reassembled, i.e. using force to remove the equipment is unnecessary and inappropriate.
- A typical manhole with measurement and control equipment has net dimensions of 3×3,5×2 m and an entrance of 1×0,70 m.
- The equipment is maximally standardized, with two-way electromagnetic flow meters of 200 mm and control valves being used; this approach allows easier servicing, maintenance and the procurement of a small number of spare pieces of equipment; while one device is on service or maintenance, another device of the same dimensions can be placed in its place, without stopping the functioning of the system.
- Manholes were placed wherever possible on public land to enable access and reduce potential damage (e.g. crop damage during interventions), as well as near the low-voltage network from which the electricity connection can be made.
- Where it is impossible to avoid the construction of a manhole on private property, interventions are carried out by reconstructing existing manholes to reduce the occupation of private areas.
- Every manhole has a small well built into the bottom plate, and the slope towards it has a 1 % fall. A small mud pump is installed in the well, with floats that control the pump's operation. In order to ensure that the equipment has stable and optimal microclimatic conditions for operation throughout the year, the pumps are activated in the event of water penetration into the manhole, possible damage to the installations in the manhole, or during interventions.
- The entrance to the manhole is secured by a lockable steel cover that acts as a canopy over the opening, preventing rainwater and external water penetration.
- A ventilation curved pipe and protection of entering insects and reptiles is placed on the manhole.
- A 50 mm FF piece is inserted through the manhole wall to allow the mud pump to evacuate the water that has accumulated in the manhole.
- A protective panel fence with a gate has to be placed on the manhole to prevent unauthorized entry into the manhole space.
- Unauthorized entry sensors must be installed at the manhole's entrance, alerting the CCC and the observation center to any attempted break-in.
- In all places where possible, an electricity connection should be provided near the low-voltage network. Wherever a low-voltage network is not available, the installation of a solar panel and a battery unit is planned (few locations).

- On the roof of the manhole, an antenna support with a minimum height of 2,50 m made of profiled steel sheets has to be installed; this height acts as a deterrent to potential vandalism.
- On fenced manholes, a sign prohibiting unauthorized access has to be posted.
- The construction of measuring points was prioritized, and the choice was made for construction in the first phase, so that the monitoring and management system's functionality is fully enabled. Other measuring points will be built in later stages of system development, and it is recommended that they be typical and easily integrated into the overall SCADA system.

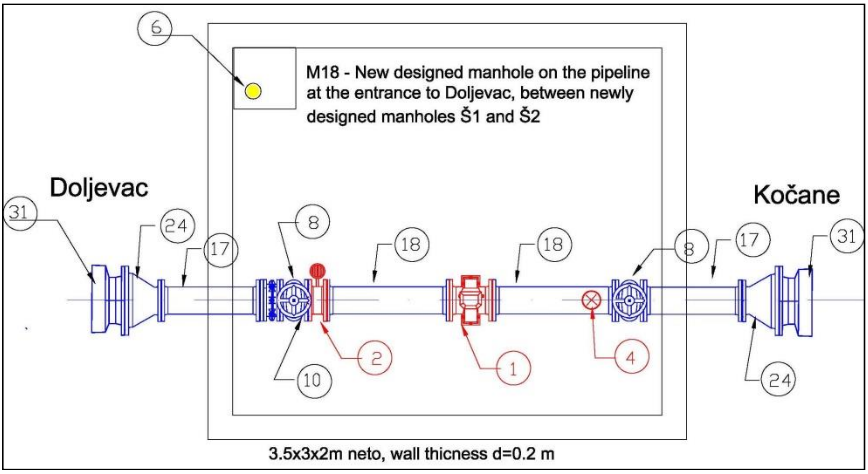



**Figure 9. Schematic design of the M18 measuring control station [8]**

Figure 9 depicts a schematic view of the M18 measuring and control station, and Table 2 describes the measuring and control equipment for installation.

**Table 2. Specifications of equipment and fashion pieces on the M18**

| Measuring & control post | | Piece |
|---|---|---|
| 1 | EM – electromagnetic flow meter 200 mm | 1 |
| 2 | RV – Regulating valve with electromotor 200 mm | 1 |
| 4 | Pressure gauge | 1 |
| 6 | Pump for water pumping out of the post | 1 |
| 8 | Butterfly double eccentric valve | 2 |
| 10 | Mounting/dismounting device 200 mm | 1 |
| 17 | FF200 – 800 mm | 2 |
| 18 | FF200 – 1000 mm | 2 |
| 28 | Flange adapter 200 mm | 2 |
| | FF200 – 400 mm – during construction | 1 |
| | Mounting/dismounting device 200 mm – during construction | 1 |
| | PLC complete with cabinet | 1 |
| | Solar panel cell with battery and electoral cabinet | 1 |

## 5. Expected effects of installation of measurement and control posts and equipment

The described method of system organization and operation requires system investments, but it has significant positive short-term and especially long-term effects:

- In the case of a failure, the system will automatically detect, notify, and take steps to shut down parts of the system in order to prevent unnecessary large losses of water from the system; in the event of a pipe failure, especially if it occurred in inaccessible places, in the current conditions it is necessary to go out into the field and manually close the shutters; the main pipelines in Doljevac's public water supply system have high pressures of around 8 bar in many places, so large amounts of water can leak out and cause major damage to the infrastructure, so the fast intervention is a very important factor.
- Disconnection of the parts of the system closest to the breakdown, so that larger parts of the system are not disconnected, which would unnecessarily disrupt the orderly water supply of consumers in parts of the system where this is not required; additionally, after the intervention and removal of the fault, a large part of the system must be flushed, resulting in additional unnecessary water losses.
- It is possible to determine the true physical losses of water in the system by creating a database of collected data, which are the result of minor leaks that are not visible.
- System management can be based on pressure and consumption, which enables active management of water losses in the system, by regulating pressures at control points during the day. Considering that it is mainly a rural area, the water consumption is objectively much lower at night than during the day, so the pressures in the network are higher at night than during the day, and the leakages from the system are also higher; the programmed management of pressures during the day directly affects both the reduction of lost amounts of water due to leakage, as well as the number of breakdowns that occur in the system due to the aging of the pipe material, i.e. the life of the infrastructure is extended and the number of interventions is reduced.
- By determining the degree of losses by zone, the need and established priorities and justification for the reconstruction of parts of the system can be determined.
- Many more advantages: rational use of limited water resources, water supply orderliness, lowering the risk to consumers health, extending the life of the infrastructure, reduction of expenditure for water production, etc.

## 6. Conclusion

The implementation of monitoring and active management systems in water supply systems is a necessary activity in order to sensibly utilize current water resources by monitoring and regulating consumption and losses in real time. This activity can be done simultaneously with the construction, extension, or reconstruction of the water supply system.

The project process of introducing active management is demonstrated using the example of the extension and reconstruction of the municipal water supply system of Doljevac, which functions as part of the regional water supply system "Brestovac-Bojnik-Doljevac". This insufficiently built and oversized system has a number of issues because the pressures in the system are too high, resulting in frequent breakdowns and significant losses of water from the system due to leaks, and due to low velocities water also being used for flushing the system.

The realistic values of the specific water consumption were determined during the revision of the concept and the re-design of the unbuilt parts of the system, and the unbuilt parts of the system were dimensioned with a realistic demographic projection.

The hydraulic analyses performed on the simulation model of the entire “Brestovac-Bojnik-Doljevac” water supply system justified the newly adopted reservoir storage volumes, which were calculated on the basis of specific consumption and required reserves. The dimensions of the connecting pipes to the reservoir were checked using hydraulic calculations, and the results confirm the correctness of the adopted diameters.

All reservoirs in the regional system operate on a 24-hour cycle of filling and emptying. Special attention is paid to the reservoirs Kočane and Klisura, which are located in the municipality of Doljevac. The Kočane reservoir, as the largest in the system, has a significant impact on the overall system’s operation.

To maintain the positive effects of project solutions, it is necessary to begin developing the project of active management of the water supply system as soon as possible, even before beginning construction of the reservoir.

The installation of the command and control center in Bojnik, the observation center in Doljevac, and the SCADA system, as well as 11 measurement and control points, are planned for the first phase. Two measuring and control places are formed in the reservoir under construction Kočana and the existing CS Rusna.

Existing manholes must be rebuilt to form two measurement and management posts, while new manholes will be built on publicly owned land to form nine measurement and management posts.

The measuring-control posts are designed with comfortable entry and installation conditions for construction, mechanical, and electrical equipment, as well as protection from natural disasters and vandalism.

In order for the system to be efficient in operation, easy to maintain, and expandable, the measuring points and equipment were standardized, so that, for example, at all measuring points, electromagnetic flow meters DN200 mm and the same or similar control electrovalves has to be installed.

At the measurement and control points, spare eqiupment pieces are also left so that in the event of removing the equipment for servicing, a hydraulic connection and uninterrupted water supply can be established.

Investments in the implementation of the active management system require capital for the municipality of Doljevac, so the first phase will be funded by donations. The expansion of the water supply system and the implementation of an active management system are expected to have a positive impact.

The system of active management is essential for the quality of life and development of the municipality of Doljevac. Therefore, it is very important to build quality infrastructure, install and connect equipment and introduce the management system as planned, and over time to approach the next phase of expansion of the water supply system, an inseparable part of which is the system for active management of water consumption and losses.

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