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CONSEQUENCES OF WATER ENGINEERING PROJECTS IN THE MOKAŠNICA RIVER BASIN (BOSNIA AND HERZEGOVINA)

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COMMUNICATION

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Abstract: The article deals with the state of utilization and protection of the water resources in the Mokašnica river basin (MRB) within the larger Mostarsko Blato catchment area (MBB). The authors present data on the Mostarsko Blato basin, provided through the analyses of the results of earlier research projects dealing with surface and groundwater flows, particularly related to the research carried out in the MRB. The previous water engineering works in the MRB have been analyzed for effects on the natural environment and the influence of such works on the regime of surface flow and groundwater aquifer geometry. In order to protect the area of the MRB from further devastation, the authors suggest some protective measures and due improvements. A special environmental protection study is necessary for better management of the MRB waters and the natural environment, including the analysis of the possibility of losing said water resources due to the implemented engineering interventions.

INTRODUCTION

The Mokašnica river basin (hereinafter: the MRB), covering an approximate area of 120 km^2, is the second largest and the second most important river basin of Mostarsko Blato (hereinafter: MB). The characteristics of the MB basin were examined before and during the 20th century in order to facilitate better protection from floods, to intensify agricultural production using irrigation, and lately in order to use the water for production of electricity. The Mokašnica River, its branches, wellsprings, sinking streams, estavelles, underground aquifers and other MRB features are seldom mentioned in reports on MB examination. Most research, according to reported data, pertained to the Lištice river basin, whose mainstay spring is the largest in the MB basin (hereinafter: the MBB).

The springs of Mokašnica and Lištica rivers are located northwest from MB, and their sinkholes (Orline for Mokašnica; Renkovača, Košina, Kabanica and Plitonje for Lištica) at the eastern edge of the MB plain. The Mokašnica and Lištica rivers flow almost parallel through their individual water beds from their springs to sinkholes. Dr. Polić used (color) tracers to show that the waters from the Lištica follow mainly flow toward the Jasenice spring, and those from the Orline toward the Arape and Miljačić Oko springs [12]. Every summer the Mokašnica dried up in its upper part of stream, along with its right incoming branches. Its two tributaries entering the MB field with their entire lengths, as well as the Mokašnica itself in its lower part of stream (from Biograci to the Orline sinkhole), used to have enough water to support life in them all year long [10].

Mokašnica was always functioning as an open drainage „sewer system" to a congruence of over 2000 homes with septic tanks, dunghills, farming land with crops being fertilized and protected. A lot of solid waste is being thrown away within the MRB without any care or control [3]. Earlier engineering research and interventions did not observe any environmental analyses related to the ecological aspect of the MRB or the MBB, nor the consequences on the quality and quantity of underground and surface waters in the MRB.

Natural sinkholes at the eastern edge of MB (Fig. 1) are insufficiently large in order to take in the large waters of the Mokašnica, the Lištica, the Crnašnica, the Orovnik, the Žvatić and numerous occasional streams appearing during the rainy season. As a result, a larger portion of MB gets flooded, and the waters from the above sub-inlets, get mixed forming an intermittent lake which was known to reach 40 km^2 in size [4]. In order to have shorter floods periods and smaller flooded area of the MB field, a tunnel was constructed for evacuation of large water masses. The tunnel is only partially used, because

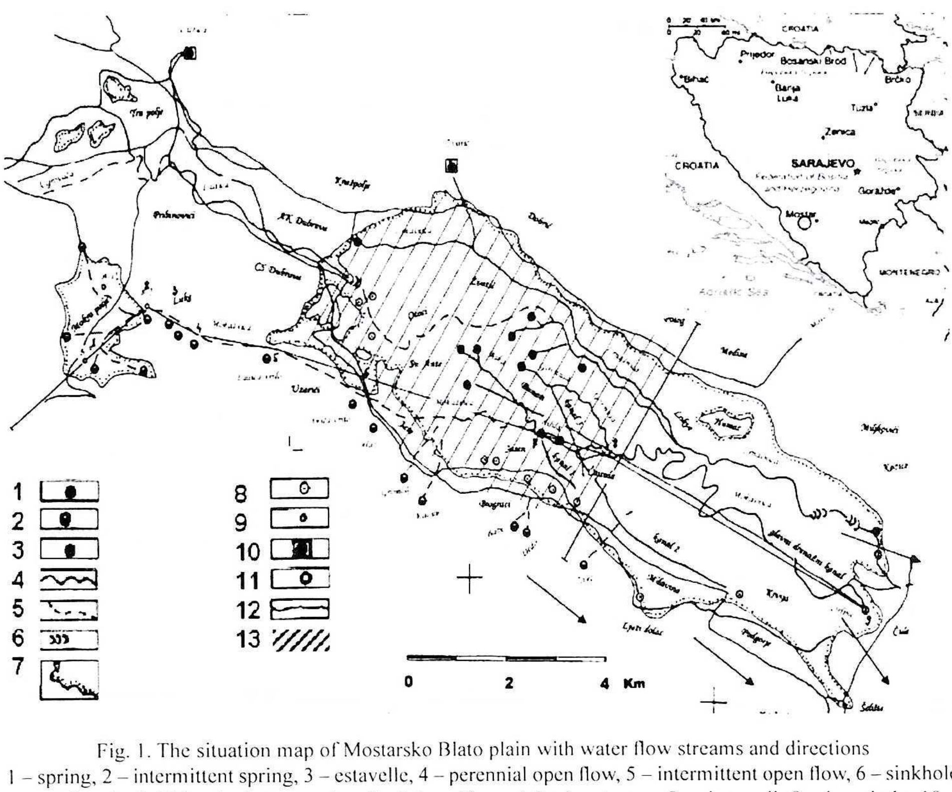

Fig. 1. The situation map of Mostarsko Blato plain with water flow streams and directions
1 – spring, 2 – intermittent spring, 3 – estavelle, 4 – perennial open flow, 5 – intermittent open flow, 6 – sinkhole zones, 7 – the field border between the alluvial aquifer and the karst zone, 8 – dug well, 9 – bore-hole, 10 – spring, 11 – sinkhole, 12 – canal, 13 – alluvial aquifer MB

of the limitation of the Jasenica River not being able to transport all water from the tunnel to the Neretva River. Conflicting opinions exist regarding the tunnel's effect on the environment in the MRB.

Inhabitants of the MRB are peasant who and get their water from some 2500 rain water tanks and numerous draw-wells found along the edges of the MB field. The largest number of water supply wells is constructed in the alluvial aquifer of the MRB, which earlier MBB projects chose to ignore. Rural households in the MRB, with their 1000-odd shallow wells, drain and consume from the alluvial aquifer more than 5000 m^3 water per day. In addition to the rain water tanks and shallow wells, the locals used to purchase water from private providers who transported it from other river basins – approximately 50000 m^3/year at 2–6 EUR/m^3.

Due to insufficient earlier research of the intermittent water springs in the MRB, the hydrogeological characteristic of the karst aquifers of the area is unknown. The demand for water and the prices are high in the MRB, and they continue to rise. There are no programs or concepts for investigation of groundwater aquifers near the intermittent springs, which are generally neglected. Therefore, the authors of this paper examined the largest portion of available data from earlier research in the MBB and gave their initial estimations on consequences of individual water engineering projects, i.e. activities pertaining to the change in quantity or quality of surface and underground waters. Results acquired through this research are presented here, along with the suggestions of improving environmental conditions and for revitalization of former water sources and perennial tributaries in the MRB.

WATER ENGINEERING RESEARCH IN THE MOKAŠNICA RIVER BASIN

Mokašnica is an intermittent river comprising many intermittent springs, carrying rain water and waste water to the river basin through the surface stream and a very complex system of underground canals. Only two water-measuring stations are placed in the MRB in order to control the surface dissipation. The older of them, and more regularly recording, is stationed in Jare (232.5 m a.s.l.), while the other is in Mokro (approximately 259 m a.s.l.). The purpose of the Mokro hydrological station is to control the surface water flow from the upper part (approximately 16.8 km^2), the highest part of the MRB. The average water flow is estimated at 0.425 m^3/s. The Jare hydrological station controls a larger portion of the MRB, an estimated 28 km^2. The average water flow in Jare station is 0.748 m^3/s. Regular measuring of precipitation is continually being performed only by the weather service station in Mostar. According to the water-measuring station in Mokro, the average value of water outflow (with precipitation of 1770 mm/year) would amount to 25 $dm^3/(s{\cdot}km^2)$, and to 27 $dm^3/(s{\cdot}km^2)$ according to the water-measuring station in Jare (Fig. 1). If we presume the average value of outflow for the entire Mokašnica river basin of 120 km^2 up the stream from the Orline sinkhole (223 m a.s.l.) to be 26 $dm^3/(s{\cdot}km^2)$, then the total average Mokašnica flow can be estimated at 3.12 m^3/s for the same annual precipitation value.

Initial water engineering research was performed by the Hydrotechnical Institute of the Technical Faculty in Zagreb during the early 1960's [4]. This and subsequent research was performed mainly in order to ensure the basis for designing hydro-melioration structures and other projects in the MBB. An earlier MB hydrological research program related to the hydro-power station on the Neretva (the Institute for Study and Development in Mostar) consisted in performing 18 hydrogeological boreholes in MB. The report of the results of these operations contains mostly geological and technical borehole profiles, without any data on hydro-geological parameters of the alluvial aquifer, changes in groundwater levels, etc. [7]. The basic 1:100 000 geological maps, Mostar and Metković sheets, and the hydro-geological map of the Neretva river basin at 1:200 000, gave valuable orientation data on the MBB. The MBB hydro-geological map at 1:25 000 [12] shows the geological data, sites of faults, the slip and folds, and presents much significant hydrogeological information, enabling us to determine the conditions and causes for majority of intermittent and permanent water-springs in the MRB.

By examining unpublished technical documentation, including the reports related to the melioration in the MRB available in Vodoprivreda (Water Management Co.), Mostar, the research of bauxite in Western Hercegovina, the water supply and, lately, the energy needs, the authors familiarized themselves with numerous hydrogeological characteristics of the MRB.

SURFACE WATERS

The Mokašnica begins in Mokro polje, between Mokro and Turčinovići villages, and disappears into the Orline sinkhole at the south-eastern end of Mostarsko Blato (Fig. 1). During the rainy season, numerous springs of water appear in Mokro polje, some representing estavelles. The upper route of Mokašnica is considered to be its largely hilly portion, approximately 8 km long, reaching from the spring at 260 m a.s.l. to the Jare water measuring station at 232.5 m a.s.l. This portion of the river bed has several occasional wellsprings, the largest of which are Lasića *vrelo* (Lučica) and Anića *vrelo*, offering water for longer periods than the upper springs in Mokro polje and Luke. Surface water in the occasional upper flow of Mokašnica is mainly used as water supply for cattle and for running one paddle-wheel mills. Some intermittent water springs water in the upper part of the MRB and on northern slopes of Trtla occasionally permit surface water to percolate into the muddy alluvial sand deposits, or *pržina*, and recharge the alluvial aquifer in the MRB. It is a natural way of drainage of underground karst aquifer into the MRB. It is assumed that a certain portion of water from the orographic MRB flows into lower permanent wellsprings in Studenci, Vitina and some springs in the Neretva Valley, which should be investigated. Permanent springs and water sources of two Mokašnica's (left) tributaries, Rika and Govnuša, and springs of water along the lower permanent Mokašnica flow (Bilila, Otok, etc.) are natural points of drainage of the alluvial aquifer at the Mostarsko Blato plain (AAMB). Quantities of water inflow along the permanent part of the Mokašnica flow were not measured, nor were the controlled quality of water present at that location – something that should be done as soon as possible.

Both left tributaries of Mokašnica, as well as Mokašnica itself, had enough water for cattle, fishing and irrigation of a limited number of lots even during the driest seasons, ranging from the Rika confluence up to the Orline sinkhole. Mokašnica in Biograci had several fresh water sources (Bilila, Otok) and several larger sources of water along the river (Buć, Modraš, Grumeničovac, Prokopica, kaluža), where high willows and other useful plants grew. These spots were important and popular locations (Bilila, Otok, Dubalj, Prokopica and Kaluža) for the people from more than 10 villages, who came to these locations to rest, relax, enjoy fresh drinking water, play sports, dance, participate in religious ceremonies, etc.

The water flow of the Mokašnica's lower end has made numerous meanders in the MB plain, causing a gentle slope without erosion. The relations between the lengths of the longer intervals along the meanders of the river flow and the shorter (straight) intervals, measured between characteristic points on the 1:10 000 scale maps are shown in Table 1. Mokašnica flow segments are 1.50 to 1.97 times longer along the meanders than the straight length measurements (Table 1). The average decrease of slopes at certain segments of the upper MRB ranges from 0.3 to 10.8, but in the lower portion segments are only 0.2–1.2 m/km (Table 1).

Table 1. Lengths and slopes of certain segments of the Mokašnica, its left tributaries and the DDC

Intervals	Distance [km]		Meters above sea level [m a.s.l.]			Dip [m/km]	Meandering coefficient
	longer	shorter	start.	ending	diff.		
Mokro polje	2.00		260.0	259.4	0.6	0.3	
Ćužići	1.23		259.4	257.5	1.9	1.5	
Luke	0.48		257.5	256.0	1.5	3.1	
Uzarići Gornji	2.00		256.0	252.0	4.0	2.0	
Uzarići Donji	1.80		252.0	232.5	19.5	10.8	(water mill)
Total upper flow	7.51		260.0	232.5	27.5	3.7	
Jare/Biograci	2.85	1.90	232.5	229.0	3.5	1.2	1.50
Biograci	3.55	1.80	229.0	225.0	4.0	1.1	1.97
Blato Donje	11.25	6.50	225.0	223.0	2.0	0.2	1.73
Total lower flow	17.65	10.20	232.5	223.0	9.5	0.5	1.73
Deep drainage canal (DDC)	8.8		231	222	9.0	1.02	
Rika (tributary)	2.30	1.70	231.5	229.0	2.5	1.1	1.35
Govnuša (tributary)	4.20	2.50	229.5	225.0	4.0	0.95	1.68

In addition to the above mentioned water springs and two tributaries from the left side, the Mokašnica also has numerous water springs coming from the right: Anića spring, Blaž, Gromolj, Kaćun, Zelenikove Babe and Dedo, Zveč, and numerous springs in the alluvial sand deposits (Blatska *pržina*) along the southern margins of the MB plain, consumed by forest cutting, active lime production and goat herding.

It is well-known that the cutting of forests and reforestation of areas may cause changes in precipitation recharge of surface streams and the groundwater aquifer. Especially noted is the reforestation of areas in the United Kingdom, which caused an almost 20% decrease in the surface runoff [2]. Similar changes in surface runoff values were also determined through latest research results in Ireland [1]. Many changes occurred in the forestlands of the MRB during the last 40 years, but the adequate hydrological analysis of surface water quantities in the MRB was not possible because of the lack of necessary data related to forestland changes and hydrological data for the recent period.

GROUNDWATER

Groundwater has some important advantages over surface water. Most underground waters demand little or no cleaning before being used in households or by industry. That fact gives groundwater a large economic advantage with leading persons in various public institutions and industries. However, contrary to popular belief, groundwater is not infinite: once tapped out from the aquifer or contaminated, it requires decades or hundreds of years to replenish or cleanse itself [5].

Two significant groundwater aquifers are available in the MRB. The larger one – karstic aquifer exists in the carbonate rock, while the smaller one is found in the alluvial deposits of the MB plain and along the river and streams. The karstic aquifer was built by water-saturated cracked and cavernous limestone and (less permeable) dolomites, which are present in the entire river basin, at the surface and deeper, under the neogene and quaternary deposits. The alluvial aquifer contains water-saturated alluvial sand, gravel and crushed limestone (Fig. 2). The alluvial aquifer sits in the lower Mokašnica area, between the hydro-station in Jare and Kaluža, in the western part of Mostarsko Blato plain and along the southern edge of the low-lying portion of the MRB from Jare to Čule (Fig. 1).

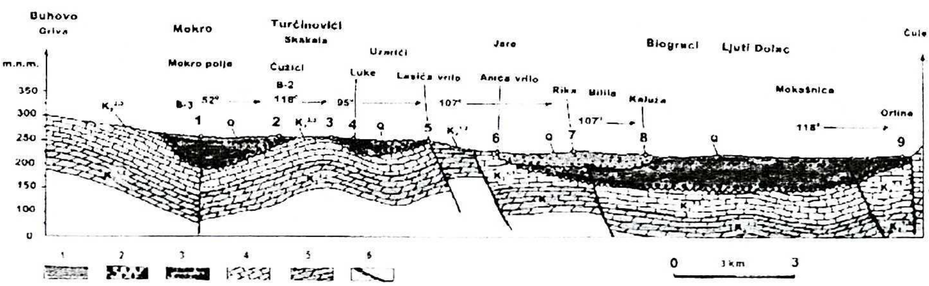

Fig. 2. Area profile along the Mokašnica river flow

1 – alluvial aquifer, 2 – karstified limestone, 3 – clay – silt, 4 – limestone, 5 – dolomite, 6 – slip-fault

Divides within the groundwater aquifers in the MRB carbonate rock and the groundwater in aquifers of the neighboring river's basins, the Lištica to the north, the Lukoć to the south, the Neretva to the east and the Topola to the west, are yet to be investigated. Appearances of the intermittent karst water springs at various elevations in the MRB are proof of changes in groundwater levels, as is probably the position of the groundwater divide in the carbonate rock. The groundwater level in the alluvial aquifer features lesser changes during the rainy and dry seasons in relation to groundwater level changes in the MRM karst aquifer.

Rain water infiltrates and percolates into the karst aquifer and flows through complex, difficult to follow paths; therefore, it is very difficult to determine the exact process of groundwater recharge, its flows, accumulations and springs. The karst groundwater aquifer in the MRB has not been closely investigated. Only 3 groundwater investigation boreholes were made in Mokro polje, but the groundwater level (GWL) was not systematically monitored, nor were water samples regularly taken in order to control water quality. Intermittent water springs on the northern slopes of Trtla in the MRB are natural phenomena, with no record of appearances and durations, quantity and quality controls, or any other physical and chemical characteristics of their water samples.

The most significant alluvial groundwater aquifer is the one found in the western part of the MB plain (the AAMB). It used to be recharged by precipitation through direct soil infiltration and percolation into alluvial sandy gravels, and indirectly through the contact of the AAMB with the karstic aquifers. During rainy seasons, the alluvial aquifer is also recharged by the neighboring Lištica water stream. The alluvial aquifer is naturally drained through springs in the MRB along the river banks during its surface flow over the alluvial sandy gravel. Traditional water springs along the Mokašnica River (Bilila and Otok) and the numerous dug shallow wells in the MRB were an excellent supplementary rural water supply when their traditional rain water tanks dry out during dry season.

WATER ENGINEERING PROJECTS

Until the mid-20th century, water belonging to the permanent part of the Mokašnica water stream was used mainly as a water supply for cattle, smaller agricultural lots, fishing, washing clothes and, to a lesser extent, for domestic use. There was no conflict among the users because there were unwritten rules in place where the fishermen muddled the water only downstream from the locations where the water was used for cattle and washing clothes. Smaller water engineering projects were designed, realized and used in the MRB before the 20th century as well. Local population used to dig shallow wells a few meters deep and drew up water for vegetables and other domestic use (in Odanci), or divert water from the Mokašnica stream toward their land. During the 20th century, the local government and the authority in charge of water sources began to design more expensive and more complex water engineering projects, which were not maintained at all. Individual MBB projects have significant negative effects on the MRB, as witnessed by the following examples:

1. A small group of households in Biograci constructed a weir (small earth dam) at Bilila, on the permanent flow portion of Mokašnica in order to divert water for irrigation. They also constructed a water course to transport diverted water toward the south-east in order to flood their agricultural land. This project had several positive effects, but the dug water course was a hindrance for cattle carriages, horses and people passing through the cut-off area. This first soil dam was active for a very long time, since its users reconstructed it every year and took good care of it. Later, the local government constructed a concrete dam on the same location at Bilile, but it did not last long because no-one knew how to maintain it.
2. A larger group of households from Ljuti Dolac village built two earth dams in Biograci, the main one at Kaluža (on the Mokašnica river, downstream from Bilila), and the second one in the middle of the permanent stream of the left Mokašnica's tributary, plus the construction of new canals across the field towards the south-east edges of the MB plain. These structures drew their water from the original permanent stream of Mokašnica leading toward the agricultural plots in Ljuti Dolac, without consent from the Biograci villages, i.e. the owners of the land. It caused numerous negative consequences.
3. It is well-known that the natural sinkholes cannot evacuate larger inflow of water during heavier rains in the MBB, where the hundred-year waters calculation is $Q_{100} = 360\ m^3/s$ and that of the fifty-year waters $Q_{50} = 137\ m^3/s$ [4]. Therefore, a tunnel was constructed to evacuate the flood waters from the lowest point of the MBB (222 m.a.sl.) into the Jasenica river. The tunnel can receive only 40% of larger inflows,

since it is limited by the flow-through capacities of the Jasenica River [10]. The environmental consequences of this tunnel in the MRB should be studied and estimated as soon as possible.

4. The Water Sources Management Office in Mostar designed and constructed a deep, steep drainage canal (DDC) in the lower Mokašnica area during the early 1970's. The excavated material during the construction of the DDC was transported and buried the original streams of the permanent river Mokašnica and its left tributaries. This material covered up the permanent drinking water springs along the Mokašnica (Bilila, Otok and others), where masses were held even during the driest weeks of the year. The village people from Ljuti Dolac, Biograci and Jare used to drink water there use it for their cattle and gardens, learned to swim, had fun, transported water from the springs for the domestic use, and also fished conger eels, crabs, frogs, etc. The construction of the DDC began at the centre of the spring zone (230 m above sea level) of the left Mokašnica's tributaries, and ended in the lowest area of the MB plain, in the zone of sinkholes (223 m a.s.l.). The construction of the DDC caused harmful reduction of the GWL in the AABB of more than 1 m.
5. As designed and approved by the Water Sources Management Office in Mostar, a massive gravel excavation commenced during the 1970's, starting at the Lištica river bed – very near to the Mokašnica river and the springs of its 2 left tributaries (AAMB). Although this massive excavation of gravel from the AAMB was ordered by 'responsible' designers, it caused additional degradation of the river bed and a very damaging decrease in GWL of AAMB in the area of permanent water springs.
6. Higher water consumption by the local population in the MRB demanded deeper excavation of their wells, the installation of more powerful pumps, and intensification of capturing more water from the relatively thin AAMB, in order to supply the households and gardens during the entire year. Majority of private wells are in the MRB and a smaller number of wells in the Lištica river basin.
7. The inhabitants of Biograci and Ljuti Dolac villages initiated and performed the excavating of the buried river Mokašnica from Bilila to Kaluža in the late 1990's. After this excavation, the permanent water flow was established again, but the surface water levels were significantly lower than before; no well-known water springs (Bilila and Otok) were recorded since the GWL was lowered due to the steep DDC, excavation of gravel and intensified AAMB drainage because of deeper wells.
8. A civil work contractor from Uzarići village obtained a permit to excavate the gravel and sand from the precious AAMB near the zone of previously active springs of the Mokašnica's permanent tributaries. These excavations lowered the bed of the Lištica River and the GWL in the precious AAMB.
9. Another private (amateur) group from Uzarići village constructed a low dam in the Lištica river bed, near the previously mentioned spring zone of the Mokašnica's tributaries. This dam was made with stone blocks driven in from elsewhere, and filled up with local soil using a bulldozer. The works were performed without an approved design and without expert supervision, but the GWL in the AAMB was raised a few decimeters at least.
10. Special threat to the natural environment in the MRB are numerous illegal dumps, the growing number of large warehouses for fuel, lubricants and other industrial and agricultural materials found in the MRB. An estimated 2000 liquid-manure pits,

1500 septic fills and numerous underground fuel and lubricant tanks can be found in the area [3]. The largest, already filled public dump was located on the largest underground aquifer, on water-permeable terrain of the karst aquifer called „Krtine", also containing several illegal landfills. Illegal landfills are numerous, the largest of which is Čajsula, found in the area of the most used underground aquifer in the MRB, is situated in the most delicate of locations, because it stands on the open AAMB in the MRB, where illegal excavation occurs for the construction needs in Ljuti Dolac and Biograci villages.

The quality of surface water and groundwater depends on various factors [6]: quantity of precipitation, evaporation intensity, chemical make-up of precipitation, the soil and the rocks through which the water flows, soil additives for purposes of fertilization and protection from weed and other damaging effects, materials let out from the industrial plants and various other facilities, and from the community. Peterson and Wollheim reported [8] that even the smallest surface water flows may remove 50% of nonorganic nitrogen taken in by the stream. Therefore, the disappearance of the permanent surface water flow in the MRB presents an immeasurably high damage to the environment.

CONCLUSIONS

Obligatory protocols have been proclaimed, and numerous institutions established within the United Nations system and the European Union, for the implementation of adequate measures of protecting the natural environment and revitalization of endemic and endangered species. Unfortunately, the reliable necessary data regarding the changes in the natural environment, quantities and qualities of water and soil in the MRB is not available. Therefore, it is difficult to plan effective protection activities aimed at revitalizing the natural environment, and adequate measures against further damages of the environment. To estimate realistic data related to changes in the natural environment, a necessary program of investigation should be implemented.

The permanent Mokašnica's flow and its two permanent tributaries with numerous intermittent streams drained the MRB, which was the home for numerous animal species, abundant vegetation and featured large annual fish growth before the arrival of water engineering activities. Eight out of nine hydrotechnical interventions in the MRB reduced the value of its natural environment. The increasing number and types of pollutants also increased the risk of polluting the soil and water in the MRB. The AAMB, intensively used for the rural water supply, was badly damaged, and if this is to continue, this precious aquifer may be depleted and even dry up. The burying and the drying-out of the permanent water streams with meanders shortens the surface water flow in the MB plain, and lowers the possibility of natural cleansing of water before sinking in the Orline sinkhole. This, in turn, can present a significant risk to the quality of groundwater and surface water in the lower Neretva river basin, and this situation should be systematically monitored and appropriate safety and protection measures applied. Therefore, an adequate investigation program is necessary in order to design and implement the needed revitalization activities.

The consequences of earlier noted water engineering projects in the MBB are as follows:

It has been estimated that the construction of the soil dam on Bilile and the Biograci canal had no negative effects on the lower water stream. The water quantity downstream from the dam was replenished due to underground waters below the dam and strong springs of water downstream from the dam; therefore, the biological need for the river bed downstream from Bilile was fulfilled [11]. The Bilile dam and the canal protected the water levels in a greater portion of the alluvial aquifer, so less energy was being spent to lift water from shallow wells.

However, negative environmental effects occurred due to the diverting of entire flow of the Mokašnica using dams at the Mokašnica in Kaluža and the Govnuša in the middle of the stream by villagers from Ljuti Dolac. Water was taken using man-made canals to transport this water in Ljuti Dolac in order to irrigate the agricultural land. All the water downstream from these dams in Kaluža to the Orline sinkhole dried up, doubtlessly destroying numerous plant and animal life. The scope of these damages needs to be re-examined using adequate rational projects [11].

The construction of the canal definitely decreased the flooded areas, the duration of floods in the MRB, the duration of the geese hunting season, as well as the duration of the use of boats for transport of goods and people over flooded areas. The construction of the canal also encouraged irresponsible issuing of water-supply office permits for the construction of various objects at lower elevations in danger of possible floods. The consequences the canal had on flora and fauna in the MBB, and the general environmental effects on the quality of life in the MBB are yet to be investigated.

The construction of the steep DDC lowered the groundwater level in the valuable alluvial aquifer for more than 1 m. This decrease of the groundwater level and burying the original permanent streams caused the drying out of all water springs and natural river flows, as well as earlier canals in the MRB. The disappearance of permanent water springs and water streams in the MRB also meant the disappearance of fish species such as *prikanac*, conger eels, frogs and numerous other species; water could no longer be used for supply, recreation, fishing, there were no new willow branches for basket weaving (*krtole*), etc., and no one 'competent' offered a reason or an explanation to the local populace for this direct and all-too-real loss.

The excavation of the shortest course of the buried Mokašnica River from Bilile to Kaluža, caused some erosion by surface waters during rainy seasons. If additional deeper wells were to be dug and more powerful pumps used, the excavated portion of the Mokašnica River would dry up during dry seasons. Further deepening of the river bed may cause additional lowering of groundwater levels in the AAMB and in all private wells in the MRB, presenting danger for total characteristics of the alluvial aquifer in MB.

Uncontrolled excavation of gravel and sand in the area formerly occupied by springs of permanent tributaries of the Mokašnica caused a quicker degradation of the river bed and the lowering of the groundwater level in the alluvial aquifer for another meter, maybe more during certain periods of the year. The consequence of this is drying-out of the more shallow private wells, their deepening and a greater expansion of energy used for raising the groundwater.

A low dam on the Lištica River in the area near the former permanent springs of the two Mokašnica's tributaries was constructed by locals from the Uzarići village. The dam was not professionally designed and did not have an experienced expert to implement and supervise the works. It caused the GWL to rise 0.50 m in the MRB. This rise of GWL is a positive effect of this first low dam, but it was not enough to facilitate the return of the important water springs. When these works were performed, the owner of the dam was advised to engage local experts to monitor the hydrogeological changes in the area, and perform the necessary evaluations in order to recognize the total impact of this first low dam in the MBB. The results of such evaluation may help to prepare a relevant guide to designing, locating and constructing any additional necessary structure(s) which may spearhead the rise of the GWL, initiate the return of the lost water springs and generally offer other positive benefits to the location.

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