OPTIMIZATION OF THE WATER MANAGEMENT IN THE VEĽKÁ DOMAŠA RESERVOIR

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ABSTRACT

The hydraulic structure Veľká Domaša, had been built on the Ondava River from 1962 to 1967. The purpose of the reservoir with the volume of 187.5 mil. m³ is water accumulation for industry, agriculture, flood control, hydropower and improvement of flow rates downstream the dam. Additional purposes are recreation, water sports and tourism. Due to the high variability in flow rates, the reservoir was designed for multiannual cycle of regulation. In the first decades, after the commissioning of the hydraulic structure, the supply volume indicated a reserve. In the 1980s, during the drought, it was considered to expand its purpose to drinking water supply for population. At present, due to climate change, the importance of multiannual cycle of regulation of the reservoir is proved. However, the increased variability of the water level in the reservoir is perceived negatively by the public, because exposed sediments limit recreation conditions during periods of low water level in reservoir. The paper discusses the operation optimization possibilities of the hydraulic structure and revision of the previous connection with the water, other reservoirs and with the environment.

1. DESCRIPTION OF THE WATER STRUCTURE

Accumulation reservoir Veľká Domaša was created by damming the valley of the river Ondava at the 71.565 river kilometer by a heterogeneous embankment dam with an inclined internal sealing. Stabilizing parts of the dam were made from alluvial gravel. Sandy loam materials with single-layer protective filter at the point of contact with the stabilizing zones were used as sealing material. Sealing of the dam is founded in the bedrock by a wide cut-off and a concrete grouting gallery. From this concrete grouting gallery, a grout curtain was built within the area of alluvial plain to the depth of 20 to 25 m. Dam crest is 165.10 m a.s.l. and 7.0 m wide. At the level of the alluvial plain, the dam is 166.7 m wide. Maximal height of the dam above terrain is 25.4 m. Maximal height above the foundation base is 35.0 m. Upstream slope of the dam fluctuates from 1:2 below the dam crest to 1:3 at the upstream toe of the dam. Cubic capacity of the local materials (alluvial gravel and sandy loam materials) built into the body of the dam is 660 thousand m³. (Bednárová et al., 2010)

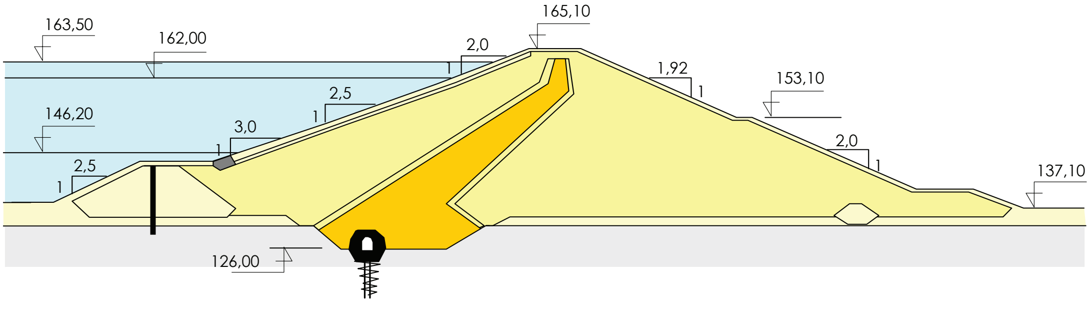

Figure 1 : Cross-section of the dam

The purpose of the dam is being fulfilled by the appurtenant structures. These include intake structures, bottom outlets and an emergency spillway. All intakes from the accumulation reservoir go through the intake tower, which is a in the compound appurtenant structures at the upstream toe of the dam.

At the downstream toe of the dam in the alluvial plain is a hydropower plant with two Kaplan turbines with a flow rate of 2 x 25 $m^3.s^{-1}$. Hydraulic head is between 12.7 and 30.4 m. Designed output of the peak load hydropower plant is 12.4 MW. Duration of the peak is influenced by the desired outflow from the reservoir and by the capacity of the compensating reservoir Malá Domaša (1.03 mil. m^3). It is a part of the hydraulic structure and regulates the stream flow of Ondava River downstream the hydraulic structure.

Due to high variability in flow rates of Ondava River ($Q_{max}/Q_{min} > 500$) and morphological conditions allowing sufficient volume for water storage. The reservoir was designed for multiannual cycle of regulation, which in practice means that the cycle of filling and emptying of the reservoir exceeds one year. Even during years with low precipitation, when the reservoir is not necessarily filled to its maximum operating water level, the water management of the reservoir is not impeded in any way.

Projected reservoirs total volume is 187.5 mil. m^3 at the maximum retention level of 163.50 m a.s.l., but current reservoir capacity is approximately 178 mil. $m^{3.}$ Reason for this decrease is mainly reservoir sedimentation during more than 50 years of reservoir's operation.

2. WATER STRUCTURE MANAGEMENT

Function of the reservoir (controlled augmented discharge and hydropower production) is provided for by an active storage of 140.222 mil. m^3, flood control is carried out by retention storage of 20.756 mil.m^3 (above the maximum operating water level of 162.00 m a.s.l.). The remaining 17.305 mil. m^3 from the total storage volume of 178 mil. m^3 is a permanent storage (below the maximum operating water level of 146.20 m a.s.l.).

Reservoir was originally designed to guarantee minimum discharge of $Q_z = 5.9$ $m^3.s^{-1}$ into the Ondava River downstream the hydraulic structure. During the first three decades since the start of its operation in 1967 Domaša had been able to fulfill this role by a significant margin. That is why the 1980s – years of very low precipitation – saw plans for increasing the water take-off from the reservoir and for using this extra water as drinking water supply. These had however never been carried out. One of the reasons behind this were complications regarding protection zones of the water resource.

Effects of climate change grew more protuberant at the turn of the millennium. First period significant in this regard came in 2002 and lasted until 2004. Due to low water inflow in March 2003 the water level decreased to an all-time low (152.65 m a.s.l.). Although there was a partial increase of water flow in spring due to snow runoff in the basin, the water level began to decrease again and at the beginning of February 2004, the level reached a new all-time minimum of 149.97 m a.s.l. This happened despite recent changes in handling regulations due to the water no longer being needed for irrigation. Minimum guaranteed flow downstream the water structure was decreased by 1 $m^3.s^{-1}$, i. e. from $Q_z = 5.9$ $m^3.s^{-1}$ to 4.9 $m^3.s^{-1}$. In the same year (in august 2004 after a summer flood) the water level in the reservoir reached an all-time high 162.95 m a.s.l. (Fig. 2), which was paradoxical but could also be credited to the increasing hydrological extremes (Kolesarova, E. et al., 2019).

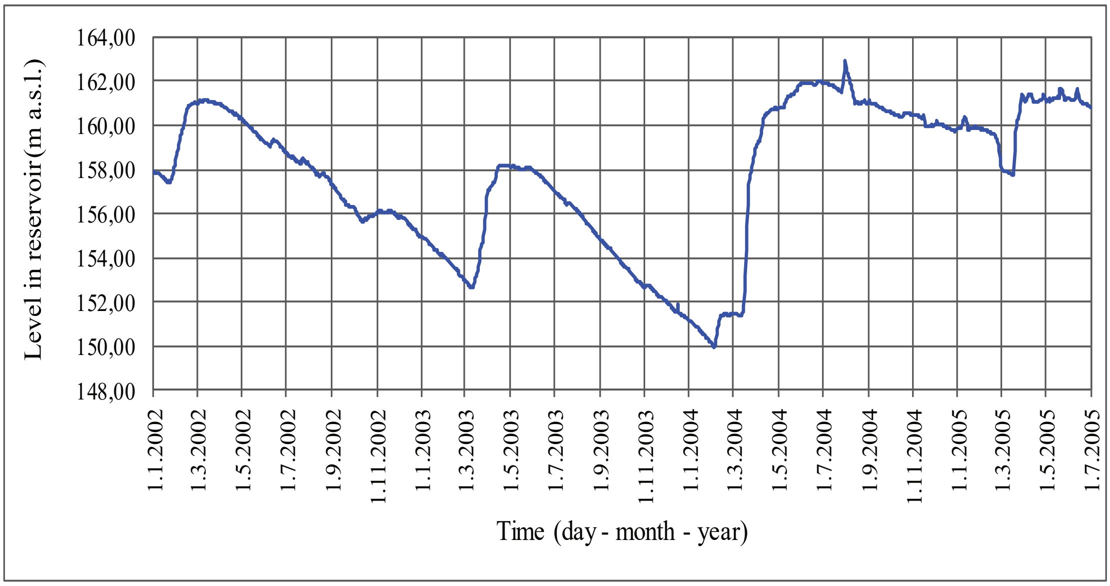

Figure 2 : Water level in the reservoir from 2002 to 2004

The situation reversed in years 2010–2013. An extreme flood came in June 2010, records show an all-time high of the water inflow and an all-time low of the water level (163.11 m a.s.l.), then began a long-lasting drought. As a result of a low precipitation period, the water level in the reservoir kept decreasing until April 2012 (150.54 m a.s.l.), or rather until February 2013 (151.86 m a.s.l.). Levels near maximum operating level were not reached until the second half of the year 2013 (Fig. 3).

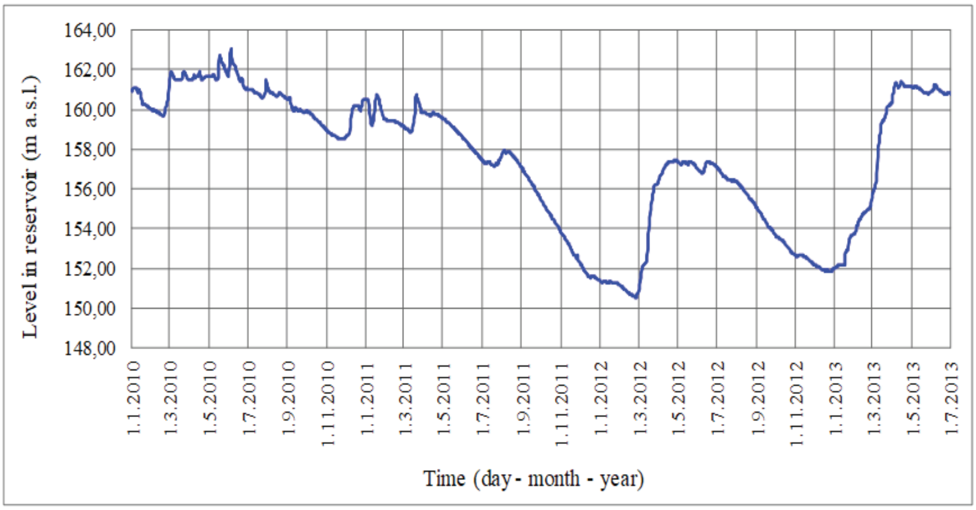

Figure 3 : Water levels in the reservoir from 2010 to 2013

The pressure from the public and the state authorities to slow down the water level decline grew stronger during this dry (low precipitation) period. This was because of the requirement to use the reservoir for recreational purposes. As a result, new handling regulations were brought into practice. Based on the previous experience new regulations for winter operation (from November 1 till March 31) were implemented. This meant a decrease of the water outlet from 4.9 $m^3.s^{-1}$ to 3.5 $m^3.s^{-1}$. The conditions of the lowered discharge were given by the level of water in the reservoir. The main requirement was for the reservoir to hold enough water to eliminate the risk of hydrological deficit and disruption of the ecological stability of the stream.

2.1 Impact of the reservoir on the outflow downstream the dam

Impact of the reservoir management on the hydrological regime of the river Ondava downstream the dam may be illustrated by the exceedance probability curves of discharge, or rather by the dependencies - $Q_p = f(P)$ and $Q_o = f(P)$, where Q_p is the water inflow to the reservoir, Q_o is the water outflow from the reservoir and P is the probability of occurrence.

For an illustration we present the results of the past 15 years of the hydraulic structure operation. Fig. 4 shows the documented dependencies $Q_p = f(P)$ and $Q_o = f(P)$ using the values of average annual discharge. The results show that the impact of the reservoir operation on the flow in the stream channel is miniscule. It is worth noticing that the reservoir outflow is higher than water inflow, which is due to the multi-annual cycle of regulation.

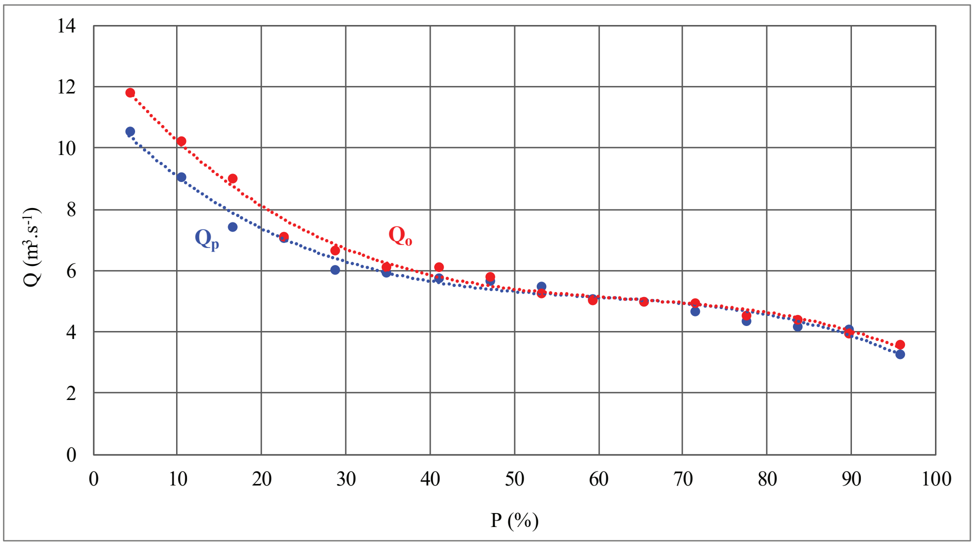

Figure 4 : Exceedance curve of average annual discharges from 2004 to 2019

Redistribution of outflow from the reservoir is more visible in the analysis performed on a set of average monthly discharges (Fig. 5)

Monthly inflows averaging above 5 $m^3.s^{-1}$ and with a 40% probability of occurrence were being reduced, while those smaller than 5 $m^3.s^{-1}$, with 60% probability, were controllably increased in accordance with handling regulations, in order to achieve optimal ecological flow downstream the dam, ranging between 4.9 $m^3.s^{-1}$ and 3.5 $m^3.s^{-1}$. The impact of the reservoir on the outflow conditions downstream the dam is therefore undisputedly positive.

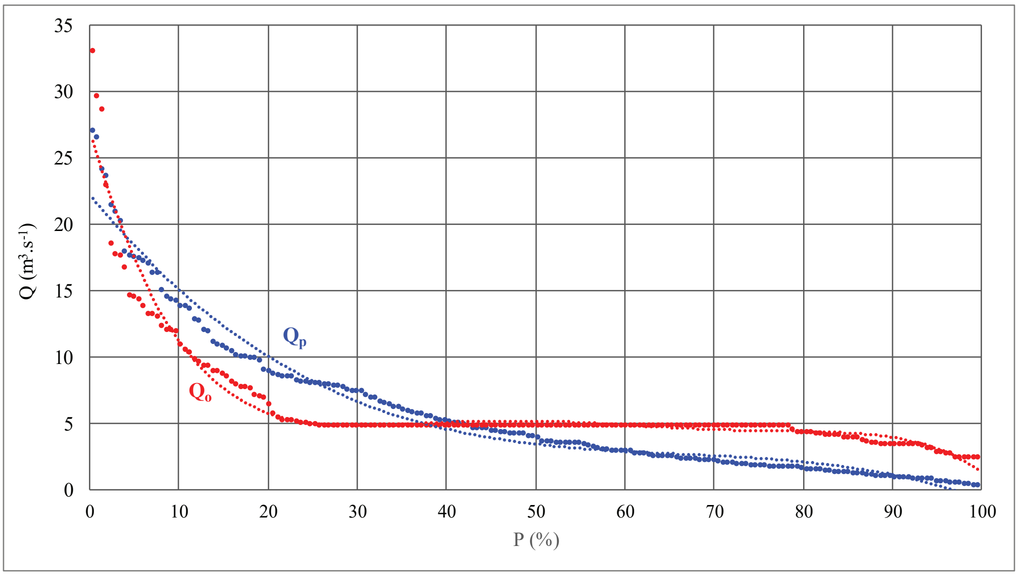

Figure 5 :. Exceedance curve of average monthly discharges from 2004 to 2019

$Q_p = f(P)$ a $Q_o = f(P)$ offers a more detailed insight into the positive function of the dam. For results of this analysis for the 2004–2019 period see Figure 6.

It is hence undisputable that the dam has an exceptionally positive effect on the optimal ecological stream discharge in the river Ondava. Taking into consideration the optimal ecological stream flow ranging from 4.9 $m^3.s^{-1}$ to 3.5 $m^3.s^{-1}$. The highly beneficial ecological effect of the reservoir Veľká Domaša is evident in summer and autumn months. If there were not affected discharge by the reservoir, the water deficit in the river Ondava basin would be extreme. E.g. from July to October the lack of ecological discharge (Q_p from 4.9 $m^3.s^{-1}$ to 3.5 $m^3.s^{-1}$) would manifest itself with 70-90% probability of occurrence, or with 40-60% probability of occurrence in November and December. A positive effect of the reservoir on the outflow downstream the dam could also be expressed by the Q_p and Q_o values with a probability of occurrence of 90 and 95%. (Fig. 7, 8)

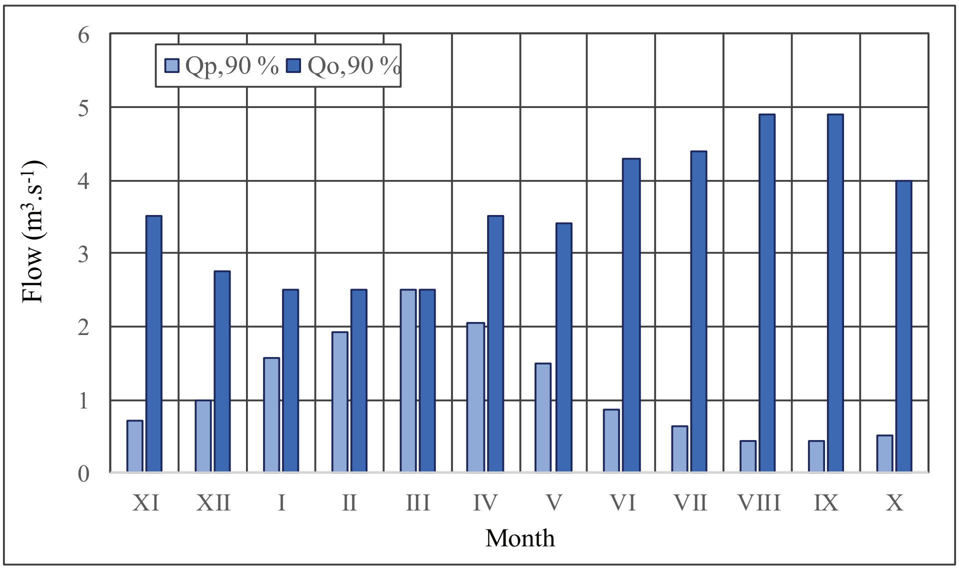

Figure 7 : Inflows to the reservoir (Q_p) and outflows to the stream channel downstream the dam (Q_o) during respective months (2004–2019) for P=90%

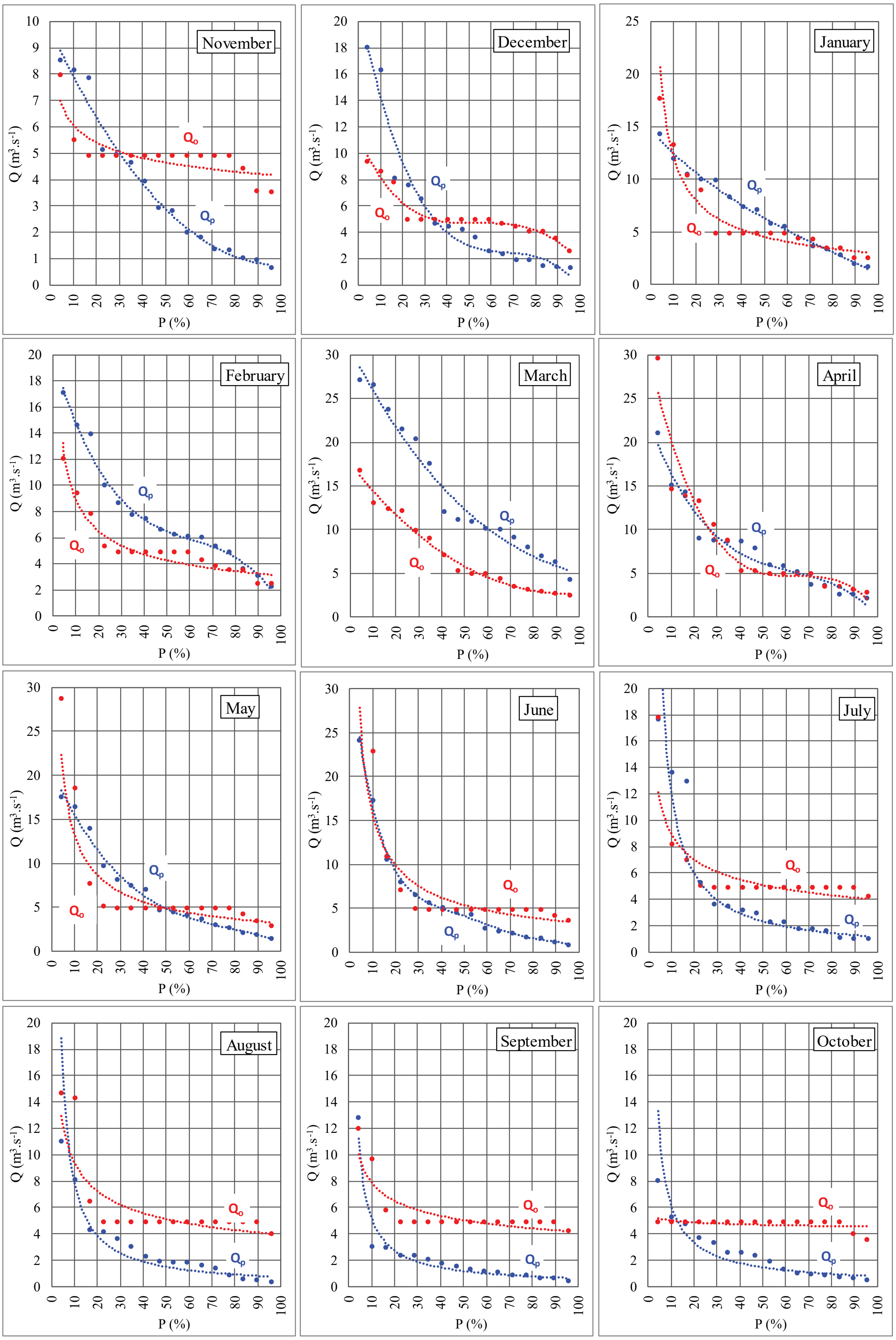

Figure 6 : Exceedance curves of average monthly discharges for respective months from 2004 to 2019

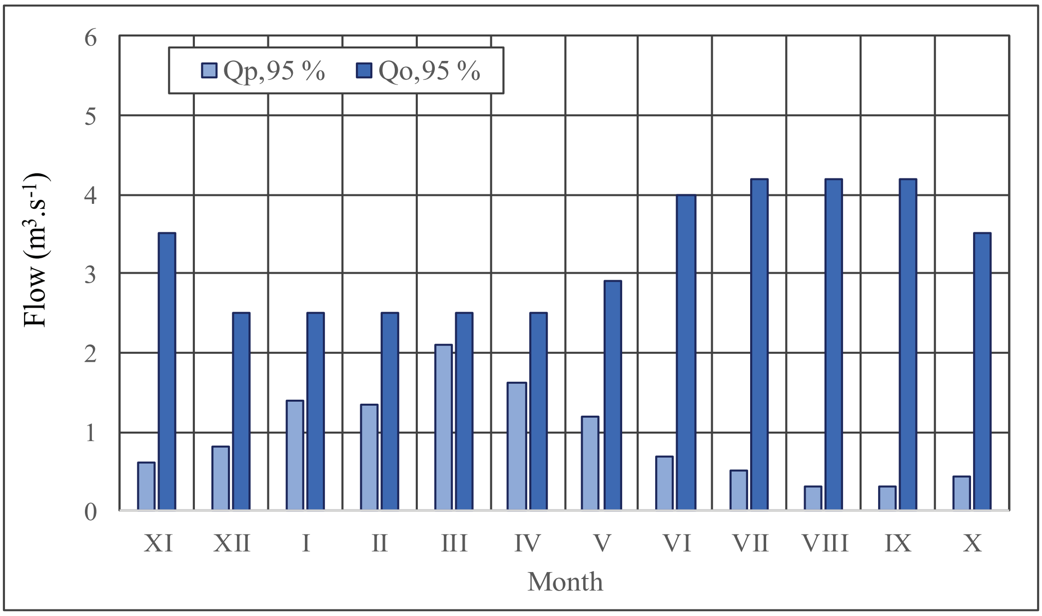

Figure 8 : Inflows to the reservoir (Q_p) and outflows to the stream channel downstream the dam (Q_o) during respective months (2004–2019) for P=95%

2.2 Reservoir water management

Given the current frequency of hydrological extremes the multiannual cycle of regulation is of upmost importance. This is however intertwined with a greater water level variability in the reservoir, which is in concordance with the original project plans. Local representatives however pressure the reservoir administration to act in fear that the reservoir will not fill up sufficiently with snow runoff, or rather that the water level will descent before the summer holidays. They wish that the maximum operating water level would be maintained because of significant investments into tourism in this area. A good water access during the summer holiday season is required to reach the desired tourist numbers.

This brings us to the question: Is the main purpose of the reservoir flood control, affected discharge and hydroelectric power production or is the reservoir primarily meant for recreation? Can it still be called water management, if the water management function of the artificial water reservoir is suppressed and the possibilities and capacity of the reservoir are not fully used in order to create a good recreational experience? Such an approach prevents from an adequate utilization of the reservoir in the true water management sense. E.g. the flood retention storage and the active storage cannot be properly combined and utilized to take flood control measures or in case of higher discharges, water cannot be only released without being used for power-production, since the active storage is already full.

Regarding this mater, the reservoir administrator already ordered an expert study from the Water research institute during the drought of 2013. The aim of the study was to assess present procedures of handling (including irregular handling), determine hydrological changes in the basin during the recent years and propose changes to the handling regulations. According to the study, the current capacity of active storage allows for improvement of discharge to 4.9 $m^3.s^{-1}$ while the reservoir still maintains its versatility. The study allows for a temporary decline of emptying of reservoir to 4.25 $m^3.s^{-1}$ in case the water level decreases below 155.00 m a.s.l. and to 3.5 $m^3.s^{-1}$ in case the water level decreases below 152.00 m a.s.l. A drop in the emptying of reservoir should however not be permitted during summer season, when such low discharge would not allow for a good ecological water conditions in Ondava downstream of the dam (Benicky, J., 2013).

The study also specifically stresses the importance of flood control function of the reservoir, stating that "the third sector cannot dictate the operating conditions of strategic structures of the first sector" and a research in flood routing suggests that a so-called set-out water level of 160.00 m a.s.l. should be introduced here. A very precise prognosis of reservoir inflow is needed in order to implement such emptying of reservoir.

3. CONCLUSIONS

This paper focuses on the search for optimal water management solutions based on reassessment of priorities including water needs and local environmental impact.

A definitive answer to these problems and a long-term decision regarding the water management could solve the current situation. The water level as of January 1, 2020 is "only" 156.98 m a.s.l. Such water level is acceptable (active storage capacity is at 58%) regarding the water management function of the reservoir. There is, however, no snow reserve in the basin. The current water level is low despite the irregular handling which has been in effect since spring 2019. The irregular handling has been set up by the water-right authorities after pressure from local representatives and is used to this day. Reservoir discharges were 3.5 $m^3.s^{-1}$, 2.9 $m^3.s^{-1}$, or 4.2 $m^3.s^{-1}$. Without intensive precipitation, the water will in 2020 be well under the level expected by the recreational facility operators and tourists.

It is undisputable that the artificial water reservoir Veľká Domaša has over the years become an essential and distinct part of the local land. Its construction caused numerous changes to the lives of the local residents. People from neighboring regions gradually adjusted to this change and started founding businesses around the newly created body of water. They have yet to come to terms with climatic changes that in their opinion lead to trends jeopardizing their businesses. This is however in hands of regional authorities rather than water managers (Fig. 9).

Figure 9 : Veľká Domaša dam

First impulse to develop recreational facilities is – without any question – water. These facilities should however be more versatile and have other purposes than only the water reservoir. This would make them less dependent on the water level and more attractive outside the summer season as well.

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