Proposal of Prevention Measures Against Drought in Urban Areas

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Abstract. The creation of the adaptation strategy on impacts of the climate change in urban area comes out from assumption that the adaptation is not just a single shot but a cyclic dynamic process which has to be systematic and coordinated taking into account the necessity and effectiveness. Those cities which are or will be able to integrate the adaptation into planning process will better resist to reality which is affording the new period of climate change. One of those cities is the Trnava City in Slovakia. The analysis of the present climate change in the Trnava City and its surrounding assumes growing trend of temperature increase during the year and especially the increased extremeness. The combination of temperature and precipitation trends will affect the soil moisture and changes of run-off regimes of rivers. The main goal of proposal of water retention measures on the Trnavka River flowing through the city is the improvement of the water level by retaining the water what should attract public places and to cool down the air in the residential area of the city. The research was concentrated on evaluation of possible realisation of such water retention measures from water quantity and quality point of view. The solution consisted in design of several inflatable rubber weirs, its analysis and prognosis of water level and discharge regime in the Trnavka River using mathematical modelling connected with field measurements and updated detailed geodetic survey.

1. Introduction

The proposal of water retention measures on the Trnavka River, which flows through the Trnava City, Slovak Republic, is a part of the Trnava Adaptation Strategy on the Impacts of the Climate Change – Waves of Heat. This strategy, adopted by the Trnava City Council in 2015, was prepared as a part of the Cities Resistant to Impacts of Climate Change – the Trnava Inspiration, which was supported by the Swiss-Slovak Cooperation Program within the European Union [1]. An important factor in the cooling of the territory during the heat is the good circulation and exchange of air between the urbanized environment of the city and its surrounding. The cooling factor mitigates the impact of waves of heat in overgrown urban districts and improves air quality in cities. Water retention in the territory of Trnava, as one possibility maximizing the cooling wind flows from the water courses, is an important part of the mentioned strategy.

The Trnavka River springs up in the Small Carpathians and flows across the city in a regulated riverbed. In the past, there was a gate slide (figure 1) located over the city, which was removed in 2013.
due to the state of emergency. The local authorities are currently thinking of re-building of such elements so that, in addition to making public places more attractive, the water will be retained in the city area and also the air in the vicinity of the stream will be cooled down.

![Figure 1. The gate slide on the Trnavka River (removed in 2013)](image1)

![Figure 2. The Trnavka River with remains of the toilet paper after the rainstorm (October 2017)](image2)

The aim of the research is therefore the proposal of such measures for water retention which will not adversely affect other functions of the Trnavka River (e.g. the effect of the backwater on the functioning of the sewerage network chambers in Trnava, the transition of the flood wave and the level of the groundwater in the adjacent area of the Trnavka River) and at the same time will contribute to the improvement of the water level regime, which should lead to incensement of the purity of the stream. The stream is polluted and smells due to the relieved sewage after each rainstorm, which is the subject of numerous complaints by citizens (figure 2). The design of the water retention measures should therefore take this fact into account.

2. Materials and methods
The basic method used to achieve the above defined goals of the research is the mathematical modelling method. The problem of the design of water retention measures for the Trnavka River was solved by a numerical model in the HEC-RAS software [2], which serves for the analysis of the water flow in rivers.
The methodology can be summarized in the following steps [3]:

1. Determination of the objectives of the model as the purpose of the model decides about appropriate mathematical equations, as well as the appropriate software for solving the given task (described above).
2. Creation of a conceptual model of the system consisting of the collection and processing of all available background materials in order to obtain the natural conditions of the studied area. During this phase, the field measurements were conducted.
3. Definition of a numerical model for the area of interest. During this phase, the conceptual model is modified into a model suitable for modelling.
4. Calibration of the model based on the field measurements.
5. Model forecast that predicts the system's response to the future events. The model calculates with the calibrated parameter values, except for those that are expected to change in the future. The uncertainty in the forecast results from the uncertainty of the model calibration and the inability to estimate the exact values of the entered parameters.

It should be mentioned that a model is a simplified representation of a complex system in which physical processes are described indirectly through mathematical equations. Even when modelling with individual attempt, deviations from the reality may occur.

2.1. Field measurements

The purpose of field measurements (figure 3) was to obtain the geodetic survey of the channel (and near the vicinity of the riverbed) (figure 4) and the hydraulic parameters of the riverbed, which are necessary for the design of the water retention measures. Field measurements were realized in two phases. Besides this stages, the chemical-physical research along the Trnavka River was conducted, which served as the answer of if the stream is chemically contaminated or not. The actual values of the chemical-physical properties of water are presented in [4].

![Figure 3. Measurements using the GPS and Flo-Mate (December 2017 and February 2018)](image)

During the first phase (8th – 9th December 2017) of the field measurements, the topographical and altitudinal data of the Trnavka River (i.e. 27 cross sections and the 3.06 km long longitudinal profile), the location of 29 outlets of the sewer system, 5 bridges and other objects located in the channel or above it were measured using the GPS and the universal measuring station.

The aim of the second phase, realized on February 9, 2018, was the measurement of data required for the calibration of the numerical model (i.e. the discharge of water and corresponding water level altitudes) and additional survey needed for the model geometry. The Flo-Mate was used for measuring the water flow velocities from which the actual discharge was later determined. Based on this
measurements, the roughness coefficient (as the main calibration parameter) was subsequently adjusted in the model calibration process.

Figure 4. The model geometry in 3D view

Figure 5. Suggested profiles for the positioning of inflatable rubber weirs (source: googlemaps)

3. Results and discussions
For the water retention in the Trnava City, the two floating structures were design in the first stage of the research. Later a third structure was added (figure 5) [5]. The inflatable rubber weirs were chosen because of their benefits, including the simplicity in the terms of building and maintaining of such a
construction. Also the automatic control of the amount of the falling water is very convenient. The height of the weirs has been dimensioned so that the outlets from the sewer system are not clogged at the minimum flow discharge in the riverbed, which flows through the riverbed almost during the whole year. The value of such flow discharge is 0.2 m\(^3\).s\(^{-1}\), which represents the flow discharge from the Boleraz water reservoir (located above the city) and the addition of inflows.

The profiles were chosen on the basis of a good accessibility for the construction and the subsequent maintenance of the water structures. In the first profile (figure 6), there is also possibility for using the already existing rigid bottom structure (from the gate slide removed in 2013). The height of the fully-covered weirs ranges from 1.00 m (first profile) to 0.6 m (second profile, figure 7). The height of the third inflatable rubber weir (figure 8) was designed to be 0.75 m.

**Figure 6.** The first profile nowadays and with the visualization of the inflatable rubber weir

**Figure 7.** The second profile nowadays and with the visualization of the inflatable rubber weir
After the construction of the water retention measures, the volume of the retained water will change as follows (table 1):

**Table 1.** The comparison of the volume of retained water before and after the construction of the water retention measures

| Discharge [m$^3$.s$^{-1}$] | Volume (before) [m$^3$] | Volume (after) [m$^3$] | Difference [m$^3$] |
|-----------------------------|-------------------------|------------------------|-------------------|
| 0.10                        | 1 200                   | 6 830                  | 5 630             |
| 0.20                        | 1 770                   | 7 360                  | 5 590             |
| 0.30                        | 2 220                   | 7 800                  | 5 580             |
| 0.40                        | 2 630                   | 8 200                  | 5 570             |
| 0.50                        | 3 000                   | 8 550                  | 5 550             |
| 0.60                        | 3 360                   | 8 880                  | 5 520             |
| 0.70                        | 3 700                   | 9 210                  | 5 510             |

4. **Conclusions**

The proposal of water retention measures in the Trnava City was solved as a part of the Trnava Adaptation Strategy on the Impacts of the Climate Change – Waves of Heat from 2015. These measures are based on the construction of three inflatable rubber weirs on the Trnava River. The main purpose, in addition to making public places more attractive, is that the water will be retained in the city area and also the air in the vicinity of the stream will be cooled down during the heat. At the same time, the measures should contribute to the improvement of the level regime and also to the flushing of the riverbed, thus increasing the purity of the stream after each rainstorm.

The design was performed using the HEC-RAS software and was based on the updated geodetic survey conducted in the area of interest during December 2017 and February 2018.

The three suggested profiles have good accessibility for the construction and the subsequent maintenance of the water structures. There is also possibility for using the already existing rigid bottom structure in the first profile, which is the remains of the gate slide removed in 2013 due to the state of emergency. The height of the fully-covered weirs has been dimensioned so that the outlets from the sewer system are not clogged at the flow discharge of 0.2 m$^3$.s$^{-1}$, which represents the discharge from the Boleraz water reservoir (located above the city) and the addition of inflows in the riverbed. This is also the value of the flow discharge which flows through the riverbed almost during the whole year.
The differences in the volume of water retained show, presented in table 1, that after the construction of the water retention measures, the volume of water will rise at about 5,000 m$^3$. This fact should help with maximizing the cooling wind flows from the water courses and thus provide a good circulation and exchange of air between the urbanized environment of the city and its surrounding.

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