The Ljubljanica river and the Gradašćica river case study and monitoring

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ABSTRACT: The present research is part of the URBEM (Urban River Basin Enhancement Methods) EU 5th framework project for implementation of the WFD in the urban river environment (http://www.urbem.net/).

The relationship between a developing urban environment and water is manifold. Water is the source of life and a city cannot function properly without a modern and safe water supply. However, water may pose a direct threat to human lives by ways of pollution and floods. Furthermore, water is a major basis for an array of economic civic activities: shipping, sailing, fishing and the use of water force. And importantly, water in built-up city areas provides a means of staying in touch with nature and enables a unique design of man-friendly urban environment.

The present paper aims at presenting the urban Ljubljanica River from Ambrož Square to the Špica with the Gradaščica stream to the bridge in Riharjeva Street and the Mali Graben, set as case examples of good practice in managing urban water body regimes. After 1990, water quality in the Ljubljanica River started to improve, this being the basic condition for several riparian activities, especially recreational activities. An improved water quality has enabled navigation for tourist needs, which has been developing gradually. The problem remains the insufficient bank regulation and a general disorganization of activities.

What remained was fishing managed by fishing societies. Owing to the demands and needs of the Dolomiti fishing society, a successful revitalization of the Mali Graben channel with transversal weirs was carried out. The weirs raised the water level in the channel, increased its volume, and formed several river pools and rapids, and thus enabled an increase of fish population by 50 %.

KEYWORDS: urban environment, urban river, improved water quality, URBEM project

Introduction

The Ljubljanica and Gradaščica rivers were chosen because of their originally beautiful, man-friendly and functionally arranged banks designed by architect Jožef Plečnik. Standing out are the sluice gate, fish market, the Three Bridges and the embankment around the Three Bridges, Trnovo Pier and the Gradaščica embankment between the Trnovo church and the bridge on Riharjeva Street. The Ljubljanica water regime on the particular reach is managed by a gate at Ambrož Square that regulates the low-flow channel. Without the gate, during low flow periods the flow in the paved channel charged with urban alluvial deposits would have been narrow and shallow. The Mali Graben has been chosen because of its transversal structures that enhance channel discharge capacity and form river pools and riffles.

The development of the city core of Ljubljana and the Ljubljanica River management dates back to the time of ancient Greece and Rome, when the ancient city of Emona was settled. Unfortunately, there are no maps from the time available, however, the position of

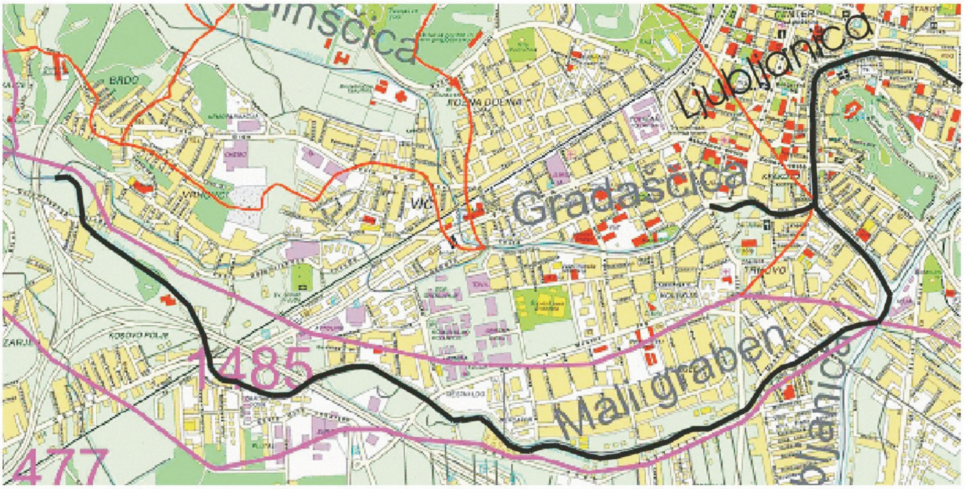

Figure 1. Streams and the surrounding area of the case study site.

the city was harmonised with the position and water regime of the then water bodies of the Ljubljanica and Gradaščica that were equipped with structures for navigation and bridges. Major floods were registered in 1190, 1537, and 1599. A first major intervention into the Ljubljanica water regime in the respective section was the building of the Grubar channel that diverted the flood flow past the city core. The construction took place between 1773 and 1780. Major floods were registered in 1190, 1537, and 1599. The position of riparian structures is evident from Austrian army maps dating back to the end of the 18th century (1763–1787), Figure 2.

Figure 2. Austrian army maps of Ljubljana (Rajšp and Ficko, 1996).

Navigation on the Ljubljanica River was essential in the development of the medieval Ljubljana. Navigation was first mentioned in 1092, Uhlir 1956. With the development of railway in the mid-19th century, navigation lost its meaning and in fact died out completely. However, street names in Trnovo (Little and Great Boat St.) and embankment names (Trnovo Pier) still bear witness of the importance of navigation.

The Ljubljana city development was badly interrupted by the 1895 earthquake that caused severe damage, but admittedly enabled the urban reconstruction of the city, which gradually transformed from an extended village into a modern European city (Uhlir 1957). In 1924, there were great floods of the Gradaščica in the Vič area in the Ljubljana suburbs. Due to settlement needs, there were extensive works on the Gradaščica regulation. The Ljubljanica River training was additionally enhanced after the 1933 flood that damaged the city core as well. An integral channel fortification encompassed also regulation works of the urban sewerage system, which put a stop to a free discharge into the channel, which had caused unpleasant smells with the low water level.

After World War II works on the gate at Ambrož Square came to an end and no further alterations ensued. The 1950–1990 period was marked by worsening of the water quality in the Ljubljanica due to urban development of the catchment. The water failed to meet bathing water criteria and, consequently, the Špica baths closed down. Additionally, small-sized watercourses at the city edge were polluted; the open sewerage system had changed them into sites of filth and rats. Thus, a much needed regulation of the urban Gradaščica and Glinščica channels followed in 1974. Today, their channels have been narrowed into tight channels made of concrete and rather resemble an open sewerage system as opposed to a natural watercourse.

The sewerage system of Ljubljana (mixed system and waste water sewerage system), which originated from the Roman times, developed with the dynamics shown in Table 1 and Figure 3.

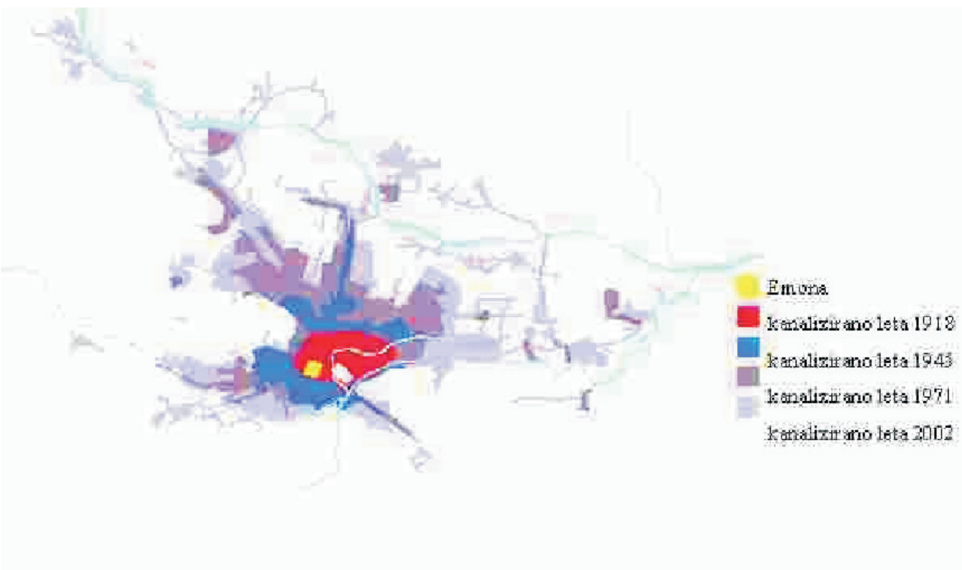

Figure 3. Sewerage system.

Table 1. Development of sewerage system of Ljubljana.

Year	Length (km)	Channelled area (km^2)	Sewage system density (km/km^2)
1917	28	4,97	5,63
1945	105	10,76	9,76
1971	300	24,63	12,18
1985	593	45,61	12,99
2001	755	65,76	11,48

What remained was fishing managed by fishing societies. Owing to the demands and needs of the Dolomiti fishing society, a successful revitalization of the Mali Graben channel with transversal dams was carried out. The dams raised the water level in the channel, increased its volume, and formed several river pools and rapids, and thereby enabled an increase of fish population by 50 %.

After 1990, water quality in the Ljubljanica River started to improve, this being the basic condition for several riparian activities, especially recreational activities. An improved water quality has enabled navigation for tourist needs, which has gradually started to develop. The problem remains the insufficient bank regulation and a general disorganization of activities.

Measurements

The entire area of the relevant water bodies was recorded with a digital camera and a unified base of recordings linked into a map. Thus a basis was provided for monitoring the changes and assessment of landscape characteristics, including amenity. The data on sewerage network, hydrological studies and design projects for the objects built in the given field were collected.

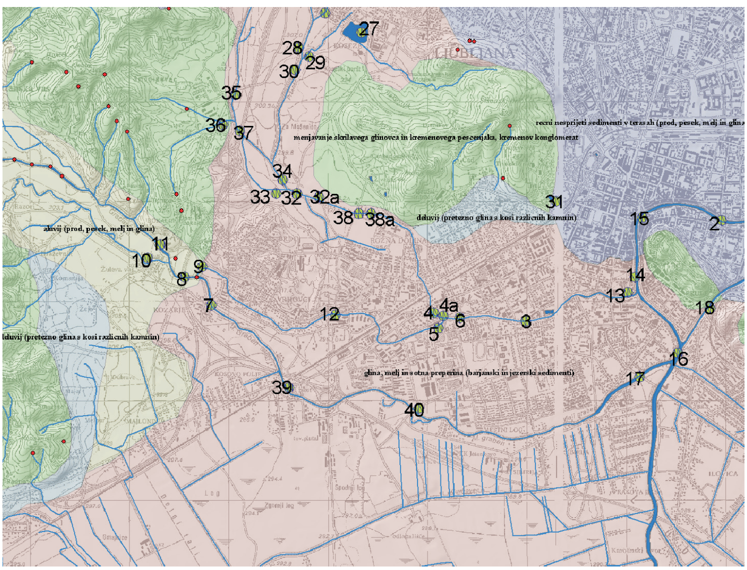

Figure 4. Points (sites*) of measurements with multiprobe.

The state and the city perform the monitoring of water quality on 3 profiles of the Ljubljanica and on 5 profiles of the Mali Graben and other water bodies. The monitoring has been under way since 1998. The data include physical and chemical characteristics of water and biota. Besides the official monitoring, the measurements with the Hydrolab multiprobe have been in progress. The probe enables the measurements of: conductivity, depth, dissolved oxygen nitrate, pH, TDS, ORP and temperature. Besides the occasional measurements with the multiprobe, several continuous measurements of the parameters were carried out, by data collection at few-minute intervals, Figure 4.

Furthermore, on the streams an additional automatic weather station was placed, as well as five rain gauges, and three Doppler instruments for measurements of velocity, temperature and pressure. In the profiles with the installed instruments, discharge measurements were also performed.

Results

The analysis of the data of the sewerage network has shown several spillways of the sewerage system and individual objects that are still not connected to the sewerage network, Figure 5. Besides the sewerage system and run-off from the roads and other urban areas, two hot spots were identified in the Glinščica river basin: the Zoo, and the Koseški bajer pond.

From the Ljubljana zoological garden, there are two outflows with little water. Most water has occurred during storms, when the storm water from Rožnik flowed into a system of lakes, on the right side from the entrance into the Ljubljana Zoo, in the direction towards Rožnik, while the overflow structure drained water into the Glinščica. All

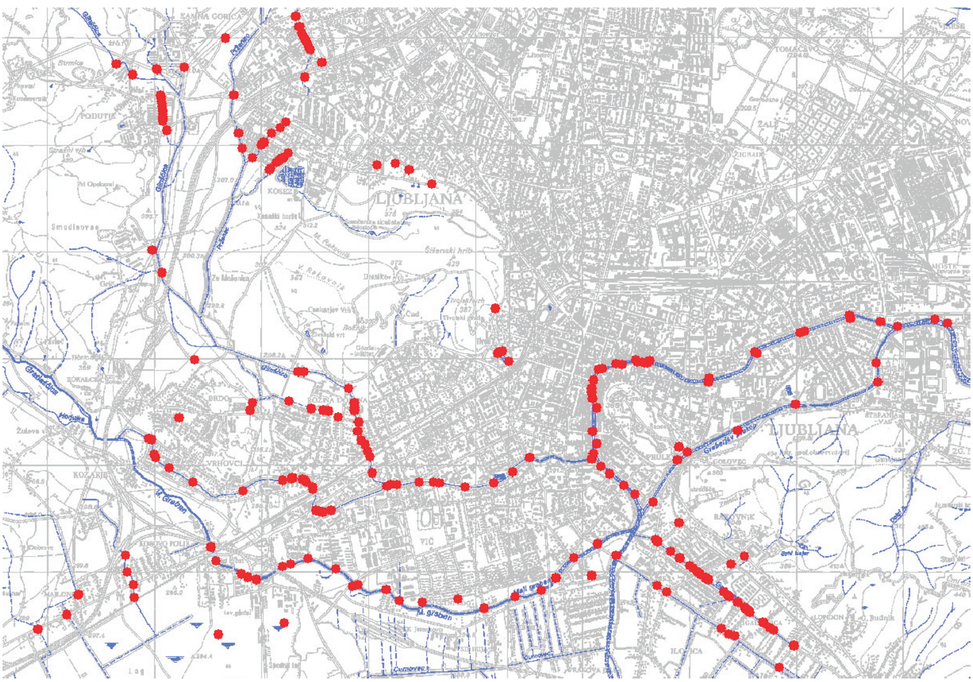

Figure 5. Sewage overflows.

ponds are limited with the elevation of the upstream water, and the surplus of water drains under the overflow system in two spillways into the Glinščica. On both outflows, increasing organic water pollution is to be expected, since the water flows in from the ponds inhabited by different species. In planning the future management of the Glinščica stream on the outflow sections, one needs to consider how to affect the water quality downstream as little as possible.

The Koseški bajer pond is a pond with a surface of 3.8 ha and with an average depth of 3.4 m. The pond is part of a clay quarry pit of the former brickworks, the rest of the pit is filled with different waste and in fact serves as a disposal facility. The Koseški bajer maintains high groundwater surface in a gentle slope rising towards Mostec. The water level in the lake is at 303.52 m and is determined by the outfall in the form of overflow (GEOTEC, 1999). In dry periods the water level may fall for more than 10 cm.

The upper part of the bank was fortified with Salix, elsewhere swamp vegetation was initially planted. According to the rules of sports fishing, fishermen introduced the communities of indigenous fish species, i.e. of rudd (*Scardinius erythrophtalmus*), carp and catfish (*Silurus glanis*), which integrated naturally into the life of the pond. In the course of years diverse flora and fauna developed in the Koseški bajer pond (Spazzapan et al., 2001). In 1984 the pond Koseški bajer was by a special decree included among natural heritage in need of protection. The decree lays down a safety regime as valid for a landscape park.

The hydromorphological features of the Koseški bajer enable rapid eutrophication processes. A yet bigger problem is the influence of anthropogenic origin. The level of the anthropogenic eutrophication is so high that the changes that would because of natural eutrophication normally reflect no sooner than in several centuries or more will reflect in several decades. Poor quality water affects the entire flora and fauna and at the same time limits or even disables the uses and activities connected with the pond. Notably, the Koseški bajer is an endangered water body. In a fairly small area different interests have collided, thus a proper planning in terms of area development and management of the pond is necessary, considering the interests and views of landowners with regard to the management.

The hydrographic network of the Ljubljanica, Gradaščica, Glinščica and Mali graben water bodies was analysed by GIS guidance Vogt at all, 2002. The data of the analysis are shown on Figure 6. The area in question was split into 5 types.

The regulation works in the Mali Graben were carried out between 1984 and 1986. There were several thresholds built in the river made by boulder and however no concrete walls and the living conditions remained favourable, bringing but a few changes for fish species. The catch of the nase (*Chondrostoma nasus*) and of the Danube roach (*Rutilus pigus virgo*) significantly increase after the regulation.

The measurement of ammonium content in the water is presented in the diagram, Figure 7. The measurements have been made in the sections of the Ljubljanica River before the city (LJ1), after the inflow of the Mali Graben (LJ2), and in sections of the Gradaščica before the city border (Gr1) and before the outflow in the Ljubljanica River (Gr2), and the Mali Graben before the outflow (MG). Generally, in the last ten years water quality of rivers in Slovenia has tremendously improved and the high values of ammonia from 1997 did not occur later on. The data from the 1998–2004 period have not produced significant changes. Furthermore, the Gradaščica River before the city border has constantly been of a much better quality than in the outflow in the Ljubljanica River. Also, the Mali Graben is more polluted than the Gradaščica.

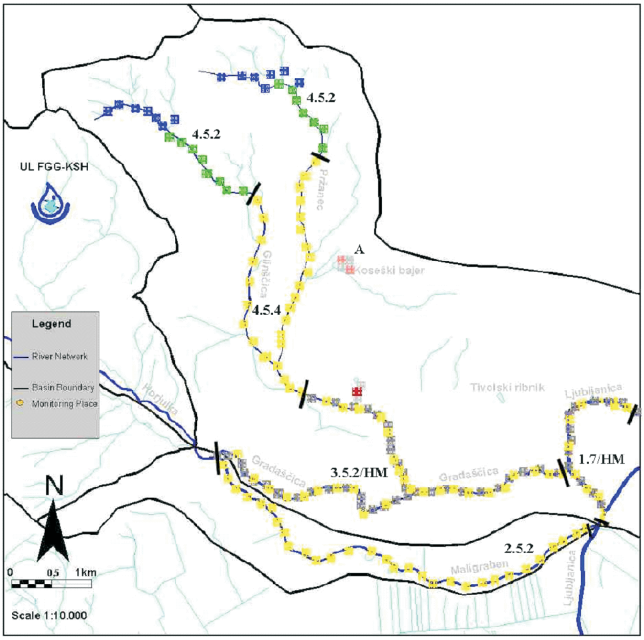

Figure 6. Water body types.

The measurements of dissolved oxygen in the Gradaščica river by the Hydrolab probe are presented on Figure 8. The numbers given in the legend are signs of cross sections presented in Figure 4. The continuous measurement by multiprobe in cross section 3 of the Gradaščica river is illustrated on Figure 9. Daily changes in nitrates are significant and could not be recognized without continuous measurements.

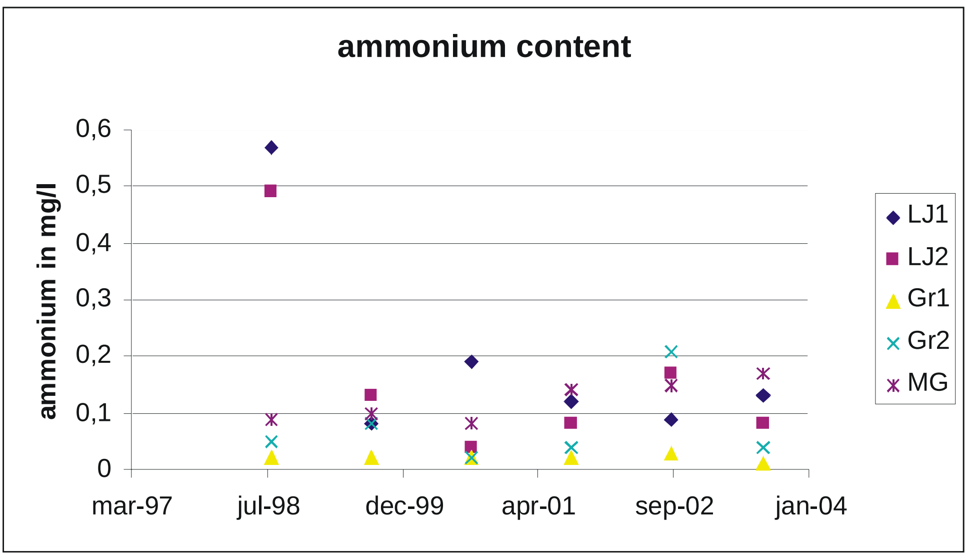

Figure 7. Amonium conntent in the water.

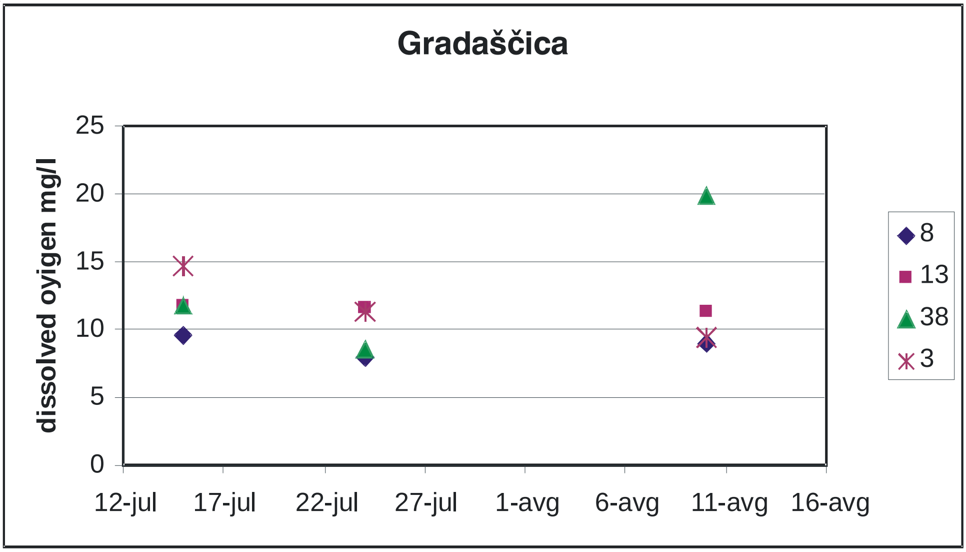

Figure 8. Dissolved oxygen in the water of the Gradaščica and Glinščica rivers.

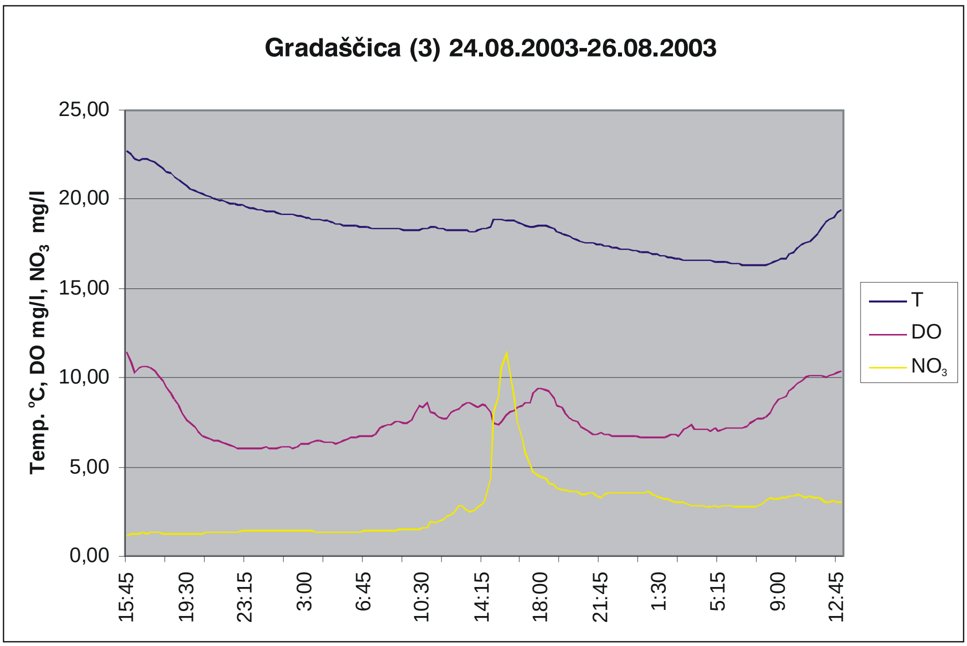

Figure 9. Continuous measurements in cross section 3.

The measurements of velocity, water level and temperature created by the Doppler instrument in cross section 3 of the Gradaščica river are presented in Figure 10. There is evidence of a clear and strong impact of urbanisation to the hydrograph produced by 34 mm of rainfall.

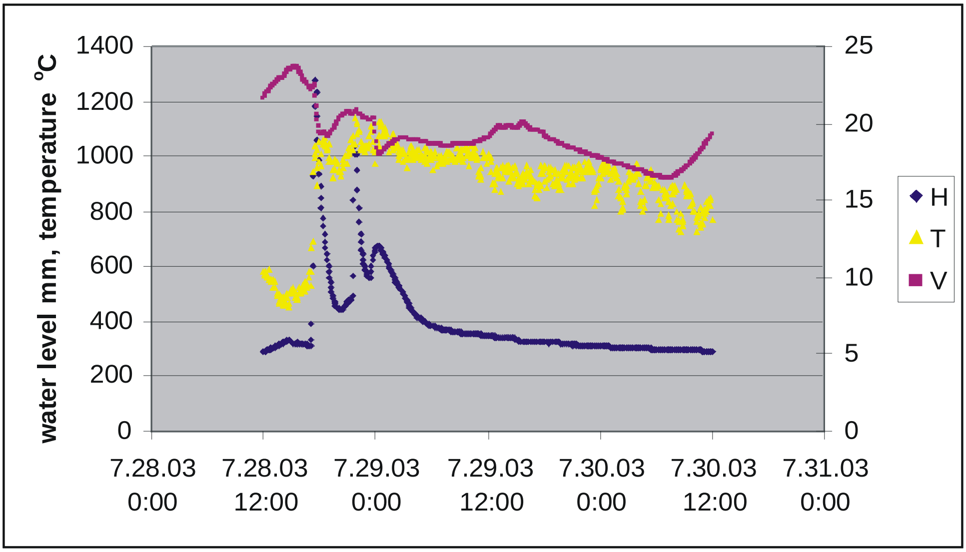

Figure 10. Measurements of velocity, temperature and depth of water in cross section 3.

Conclusion and recommendation

The urban river development has proven to be a highly complex, long term process and it will remain so in the future. The understanding of the processes calls for many field measurements, modelling, data mining and analyses. Only part of the work is presented in the paper.

The new sophisticated instruments for measurement of physical and chemical characteristics of water are powerful and give additional oportunity in understanding the processes that occur in an urban watershed.

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