

HYDROLOGICAL FEATURES OF THE ALLUVIAL STREAMS IN THE REGION OF ME IMURJE

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ABSTRACT

Criteria for assessing the state and for determining the characteristics of permanent change of surface waters – flowing waters, i.e. elements for determining the condition of the water are determined by the grades of the ecological status and the chemical status of water bodies (Decree on Water Quality Standards, NN 089/2010). According to the Regulation on Water Quality Standards, the ecological status of surface waters – flowing waters is determined by biological, hydromorphological elements, hydrological regime, chemical and physicochemical elements and biological elements (transparency, temperature, oxygen, conductivity, salinity, pH, m-alkalinity and nutrients). Previous research of the alluvial rivers in the region of Me imurje was very sporadic and insufficient. By calculating the average of the reference values of field measurements it is evident that the flow values by observing the average monthly minimal and maximal values of the average annual flow values are significantly higher for the Bistrec Stream when compared with the other investigated stream – the Stream of Boš ak. It is also evident that the mean annual flow rates and the mean monthly minimal and maximal possible values are significantly higher in the downstream part of the flow of both of the studied streams. The obtained research results of hydrological features of the alluvial Streams of Bistrec and Boš ak in the area of Me imurje are part of a complex scientific research with the aim of determining the chemical and physicochemical elements that accompany biological elements (faunistic features, particularly qualitative and quantitative composition of macrozoobenthos populations) as the basis for the assessment of water quality. This research was done on the basis of the results of our own research that was done in the Institute of Zoology of the Departments of Biology of the Faculty of Science at the University of Zagreb.

Key words: *alluvial streams, ecological status, hydrological features, water quality.*

INTRODUCTION

Much of the landscape of the region of Me imurje and its natural features were caused by the activity of the River Mura and the River Drava. Among other watercourses, mention must be made of the Trnava and a number of creeks and canals that belong to the catchment area of both rivers. A detailed research of the faunistic characteristics, especially the research of macrozoobentos, was done on the studied streams as a basis for the assessment of water quality.

The name of the watercourse of Bistrec refers to the alluvial stream between the village of Sveta Maria near Donji Vidovec and the mouth into the waters that end up in the River Mura not far from its mouth into the River Drava. It is 24.3 km long and belongs to the canals of first order and is the main recipient of the region of Lower Me imurje (Engineering Project Institute Zagreb, 1956). Water and their influence are very important for the area of the region of Lower Me imurje. In the area of the Me imurje County there are four basins: the basins of the River Mura and the River Drava, and the basins of the Stream Trnava and of the System Bistrec - Rakovnica. According to the Decision of the First Order Water Census (NN 79/2010), the Stream Bistrec - Rakovnica belongs to other larger water and canals, i.e. watercourses. All the waters with a catchment area larger than 200 km² and all those longer than 20 km are classified as watercourse. Many backwaters and watercourses have disappeared. They have become an integral part of the regulation of the Bistrec Stream and its tributaries. The Trnava, which has through history continuously changed its course under the influence of river sediment, has today been technically turned into a canal and been practically turned into two basins – the basins of the Trnava and of the Bistrec-Rakovnica. Surface waterflows mainly flow into the Bistrec – Rakovnica System and this happens via a lateral system whose main canals are Kopanec – Gorenjak and Veliki Berek. Only a small part of waters from the northern hydromelioration canal flow into the Trnava. The main canals of Kopanec – Gorenjak are connected with the Canal of Novi Kopanec. Today the course of the flow of the Trnava into the Mura is south of the area whose topographical name is Poljanec. Geologically it is a part of the older Pleistocene terraces. The composition of the substrate is dominated by gravels with sand and soil layers of dust and clay, whereas the southern part of the river terrace is covered with clay. Watercourses are fully regulated, and a protection embankment has been built for protection from the waters of the River Mura. The construction of the protection embankment prevents their flow into the River Mura, which used to be the basis of the unregulated status, and thus their course was diverted into the direction of the Trnava. Surface waterflows are continuously controlled by the institutions responsible for their maintenance. Watercourses are regulated canals formed for flood protection and drainage of surplus water from agricultural land. The most significant is the Muršak, with the function of lateral canals and as the recipient of rainwater. Since these are specific water ecosystems, together with an associated vegetation belt, they form natural, or in cases of significant regulation, nature-friendly areas that need to be protected from negative influences. In addition to technical interventions the worst impact on watercourses is done by the discharge of wastewater without pre-treatment into their waterchannels. Such interventions can reduce the quality and quantity of water as a basic parameter of the water biotope and they can destroy the ecosystem. The fall of groundwater has led to dryness of the old river beds of the Drava and of the old riverbed of the Bistrec. The drop of the bottom of the Bistrec and of the Rakovnica was selected as 0,6 ‰. In terms of hydraulics, this decline is advantageous because small water can reach a speed of about 0.30 m / s, and a large water does not exceed a speed of 1.0 m / s. Bistrec - Rakovnica – Jalše was chosen as the main

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recipient of the entire drainage from the plain; it is continuously stationed, but it is divided into sections of rainfall areas. The intensity of rainfall has been calculated as a function of climate in relation to the duration of rainfall with the value of exhibits established in Me imurje (Vilerding, 1956). According to this formula the height function of the precipitation is its length, which means that it is linked to and independent of the size of the rainfall area. As it has been observed in the field, the focus of the problem is not in the taking of high waters that would flood the terrain by spilling over from the bed, but in the good drainage so that the arable land could be drained and that the water remaining in the ponds which could otherwise only disappear by evaporation would be taken away (Vilerding, 1956). Today the Bistrec-Rakovnica is a first order canal with a length of 24.3 km and is the main recipient of the region of Lower Me imurje whose mouth is a backwater channel of the Drava River close to the mouth of the River Mura into the River Drava.

The natural flow of the Boš ak Stream flows into the Trnava Stream (Mravinac, 1959). For the drainage of the areas of Domašinec, Gardinovec and Belica to the road Belica - Mala Subotica a project to dig the Boš ak Canal had been designed. According to this design the digging was done in 1960 and 1961. The current Stream Boš ak is 10.933 km long, a canal of second order and flows into the first order canal – Trnava 8 +697- km. According to the same Technical Report, from the mouth of the Boš ak into the Trnava near the Gradiš e Bridge 1 +450 to km route follows the natural flow of the bed with smaller alternations. It then leaves the old riverbed, cuts the pasture between Domašinec and Kvitrovec, comes under Domašinec, cuts the Domašinec - Tur iš e road and along the slope of the plateau continues all the way to Belice. All the way to the path Držimurec – Brickyard Belica the route has been laid over low lying meadows. A drop of the bottom of the canal, vertical alignment caused the fall of the terrain and getting the flow rate above the minimum so that no mudding of the canal could happen. The following declines were selected: from km 0.0 to 2.19 ... 0.50 ‰, from km 2.19 to 6.00 ... 0.90 ‰ and from km 6.00 to 9.64 ... 1.00. The slopes of the canal were taken in the 1 : 1,5 ratio due to the material in which the digging was done. The soil consists of middle-kernel, covered by a layer of sandy clay. The extension of the Boš ak Canal from km 9.605 to 10.9333; 1,330 m in length, was made later for drainage of low lying land and ponds along Belica, as because of heavy rainfall during the year the land was still being subject to excessive wetting and flooding. (Mravinac, 1965). The deline of canals, vertical alignment was chosen based on field conditions with 1.7 ‰, and it took into account the possibility of drainage of lowest depression and lowering of the groundwater.

According to the Regulation on Classification of Watercourses, for all all watercourses in Me imurje the border limit of the water quality has been prescribed as II. category, except for the Trnava which has been prescribed as III. category. It is believed that from the viewpoint of protection of watercourses such categorization has been objectively prescribed, with the exception of the Trnava, that would after the construction of wastewater treatment plant pass into the second category.

The physical and chemical tests of the watercourses of the region of Me imurje show that their quality in 1994 was significantly lower than prescribed. The worst situation was found in the Trnava beyond the mouth of the Lateral Canal and the Štrigova Stream. Apart from the industrial and household wastewaters the water quality of the watercourses in the Me imurje County has been damaged by the densely distributed agricultural lands that are usually cultivated all the way to their banks, which allows flushing of fertilizers and pesticides into the water. The agricultural land of the Upper Me imurje region is also associated with the problem of surface erosion of the arable land, whose fertile soil is washed down and deposited in the riverbeds and causes their mudding.

Because of the unresolved problems of sanitary landfills the watercourses of Me imurje are often used as a place for disposal of various wastes, and often they are used as a place for damping of excess unused agricultural crop protection materials and wastewater produced by washing of agricultural machinery. All these problems can adversely affect the biocenosis of the watercourses of Me imurje and can cause qualitative and quantitative impoverishment of their characteristic flora and fauna. Watercourses have largely lost their function as a habitat for water plants, invertebrates and vertebrates in that part of the basin of the River Mura, and their poor condition affects the very River Mura itself (Spatial Plan of the Me imurska County, 2001).

STUDIED AREA

Studied area is the joint creation of the Drava and the Mura, i.e. a common terrace and alluvia of the two rivers geologically represent the youngest Holocene, alluvial debris that drifted along the courses of the rivers Drava and Mura. Previous studies of alluvial rivers have been very sporadic and insufficient. Available are data on the monitoring of water quality that are conducted by the Croatian National Institute for Public Health or the Laboratory of Croatian Waters for the needs of Croatian Waters. These data include a detailed chemical analysis of water that in some streams are done two to four times a year and a saprobiological analysis in order to determine water quality. However, faunal analysis for many groups of organisms were to higher systematic categories. Within the projects of the Croatian Waters (Ecological Research of Inland Surface Waters in Croatia according to the Criteria of the WFD III. Macrozoobenthos as an Indicator of the Ecological Status of Rivers), and according to the Water Framework Directive (WFD 2000/60/CE), a more detailed research was done on the alluvial streams: the Zebec and the Bosut during 2006 and 2007 (Kerovec et. al., 2008.). They also conducted long-standing biological and ecological studies of drainage ditches along storage lakes on the River Drava (Mrakov i et al., 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010; Previši et al., 2007), which, however, are artificial habitats, but hydrologically they are very close to the natural alluvial streams. Geologically, the studied area represents the youngest Holocene, alluvial debris that drifted along the streams of the River Drava and the River Mura. Multidisciplinary research included all the elements, i.e. all the criteria for assessing the situation and determining the characteristics of a permanent change of surface water – flowing rivers. The status of water condition is determined by the assessment of the ecological status and chemical status of water bodies (Regulation on Water Quality Standards, NN 089/2010). According to the Regulation on Water Quality Standards, the ecological status of surface water – flowing waters is determined by biological, hydromorphological and chemical and physico-chemical elements that accompany the biological elements, the composition and abundance of aquatic flora, the composition and abundance of benthic invertebrates; the composition, abundance and age structure of fish fauna; hydromorphological elements, hydrological regime, morphological conditions, chemical and physico-chemical elements that accompany the biological elements (transparency, temperature, oxygen, conductivity, salinity, pH, m-alkalinity and nutrients).

This was a pioneering research of alluvial flowing waters in the region of Me imurje. Previous studies of alluvial rivers in the region of Me imurje were very sporadic and insufficient. By calculating the average of the reference values of field measurements it is visible that the flow values, observed by average monthly minimum and maximum values of the average annual flow values, are significantly higher for the Bistrec Stream compared to the other investigated Boš ak Stream.

The obtained results of the hydrological characteristics of the alluvial Stream Bistrec and the alluvial Stream Boš ak in Me imurje are a part of a complex scientific research study with an aim of determining the chemical and physico-chemical elements that accompany biological elements (faunistic characteristics, especially qualitative and quantitative composition of the macrozoobenthos populations) as a basis for assessing water quality. Our research study was based on the results of own research that was done in the Institute of Zoology of the Department of Biology at the Faculty of Science of the University of Zagreb.

THE ALLUVIAL STREAMS IN THE REGION OF ME IMURJE: THE BOŠ AK AND THE BISTREC

The natural course of the Stream Boš ak flows into the Stream Trnava (Mravinac, 1959). A project for the digging of the Canal Boš ak was designed for the drainage of the areas of Domašinec, Gardinovec, and the area from Belica to the Belica – Mala Subotica road. Following the project design the digging was done in 1960 and 1961. The current Stream Boš ak is 10.933 km long, represents a canal of second order and flows into the first order canal - the Trnava. Today the Bistrec (Bistrec-Rakovnica) is a first order canal that is 24,3 km long; it is the main recipient of the region of Lower Me imurje and its mouth is a backwater canal of the River Drava very close to the mouth of the Mura River into the Drava River (*Fig. 1*).

MATERIAL I METHODS

RESEARCH AREAS

The Bistrec Stream and the Boš ak Stream are in the County of Me imurje. It is important to note that they both spring in the alluvial deposits along the left bank of the River Drava. The Boš ak flows into the Trnava that flows into the River Mura.

The Bistrec joins with the Stream Rakovnica and flows into the Drava River in the area of Veliki Pažut. Both streams are characterized by a pluvial (rain) flow regime, with maximum water levels after heavy rainfalls, especially in the autumn and spring. Research conducted last year found that the Stream Bistrec contained large amounts of heavy metals (chromium, lead, cadmium). The reason for this is the load of the Stream Bistrec with wastewater and the damage caused by the village of Donji Kraljevec.



Figure 1: A map of the County of Me imurje with research stations on the streams

Legenda: BI – station Bistrec I, BII – station Bistrec II, BoI – station Boš ak I, BoII – station Boš ak II

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The research study was conducted at four sites: Bistrec I, Bistrec II, Boš ak I and Boš ak II (see Fig. 1). Macrozoobenthos sampling and the measurements of physical and chemical parameters were taken in the period from April to September, 2010: April 15th, May 27th, July 13th, August 9th, 09th 08t and September 16th.

Bistrec I (see Fig. 2)

Sampling was carried out at 148 m above sea level at coordinates N 46 ° 22 '207" E 016 ° 41' 128" that were measured by using GPS. The bottom is gravel-sand with plenty of macrovegetation.



Figure 2: Bistrec

The spring itself of the Stream Bistrec is directly close to it The Economic Zone North Prelog was built seven years ago. (see Fig. 3 and 4).



Figure 3: The spring of the Stream Bistrec



Figure 4: The Economic Zone North Prelog

Bistrec II (Fig. 5)

Sampling was done at the GPS coordinates of N 46 ° 20 '300" E 016 ° 48' 529" at 129 m above sea level. The bottom is gravel (80%) - sand (20%), muddy, sandy-clay, with a lot macrovegetation.



Figure 5: Bistrec II

Figures 6 and 7 show the Stream Bistrec just before the mouth of the River Mura and River Drava respectively.



Figures 6 and 7: The Stream Bistrec just before the mouth of the River Mura, Kotoriba

Boš ak I (see Fig. 8)

Sampling was carried out at coordinates N 46 ° 20 '300" E 016 ° 48' 529" at 153 m above sea level. The bottom is dominated by gravel (70%) and pebbles (30%).



Figure 8: Boš ak I

Boš ak II (*see Fig. 9*)

The sampling site is at the GPS coordinates of N 46 ° 25 '742" E 016 ° 35' 837" and 151 m above sea level. The bottom is gravel with addition of sand and with the presence of macrovegetation.



Figure 9: Boš ak II

CLIMATE OF THE RESEARCH AREA

Mean values of temperature, precipitation and their annual fluctuations determine climatic regions of Croatia that at the same time also represent the basic climatic and ecological areas. According to the globally accepted criteria for climatic classification systems¹ (W. Köppen), most of the Croatian territory includes moderately rainy (type C), while only high mountain regions have a snowy forest climate (type D). However, for the small Croatian territory, most significant are sub-varieties of type C, because the differences in climate between the lowland and highland Croatia are more apparent towards the coast. Basic features of the climate types and subtypes are related to the standard period between 1961-1990.

The entire Pannonian and Peri-Pannonia area, and therefore the studied area, are characterized by the sub-varieties of the type C climate and it is moderately warm and humid climate with warm summers (CFB) (in the earlier period it was classified as colder climate CFC) that is dominant over most of Croatia. Mean January air temperatures range from -2 to 0 °C and mean July temperatures range from +18 to 22 °C. The rainfall is quite evenly distributed throughout the year, with spring and autumn peaks. In this climate the differences between the seasons of the year are most developed and expressed. At the beginning of summer and spring rainfall is convectional and autumn maximum is related to cyclone passages. Snow remains differently long on the ground, usually up to 40 days per year. For example, the mean annual temperature for the city of Varaždin is 10.1 ° C, the total annual number of hours of sunshine is 1997.1, while the total annual rainfall is 870.0 (mm). Total rainfall is distributed in the following way: from April to September it is 516.5 mm, and from October to March it is 353.5² (Kiš-Novak, 2007).

¹ <http://www.unizd.hr/odjeli/geografija/Geoadrija/Geo%208-1/Segota-Filipic%208-1.pdf>

² http://www.crometeo.info/crometeosite/index.php/index.php?module=pagemaster&PAGE_user_op=view_page&PAGE_id=7&MVN_position=5:5

RESULTS

HYDROLOGICAL FEATURES OF THE STUDIED FLOWING WATERS

The flow rate Q (L/sec) for the studied flowing waters in the period between 2005 and the end of 2010 that was obtained by calculating the average according to the reference values of field measures of Croatian Waters and the Bio-Institute (Figure 10).

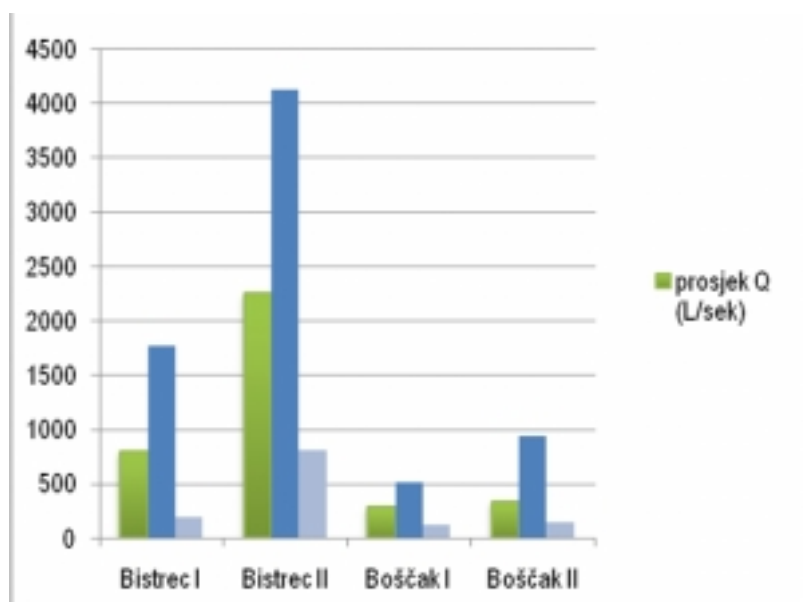


Figure 10: Flow rate values Q (L/sec) in the period between 2005 and the end of 2010 (Croatian Waters, Varaždin; VS Bio-Institute akovec)

It is evident that the values of the flow, observed by the average monthly minimum and maximum values and the average annual flow values, are significantly higher for the Stream Bistrec than for the other investigated stream – the Boš ak. It is also evident that the mean annual flow rates and mean monthly minimal and maximal values are significantly higher in the downstream part of the flow of both studied streams.

According to the available data on non-systematic measurements of the flow in the period from 2005 to 2010, large fluctuations were noted in flow during some years. They largely depended on the general hydrological conditions that significantly differed from year to year. But generally, we can say that the biggest flows in both streams were recorded mainly in the spring, during the months of March and April, and occasionally in June and December. As expected, the smallest flow rates were recorded in the summer and early autumn period, i.e. from July to September.

The minimal flow value Q (L/sec) in the period from 2005 to 2010 for the Stream Bistrec was 190.3 at the station Bistrec I and 811.7 for the station Bistrec II (September 9th, 2007). The maximal flow value Q (L/sec) in the period from 2005 to 2010 for the Stream Bistrec was 1764.9 at the station Bistrec I and 3818.3 at the station Bistrec II (June 16th, 2005)(Kiš-Novak, 2012).

The minimal flow value Q (L/sec) in the period from 2005 to 2010 for the Stream Boš ak was 116.6 at the station Boš ak I and 144.3 at the station Boš ak II. (June 16th 6). The maximal

flow value Q (L/sec) in the period from 2005 to 2010 was 461.76 at the station Boš ak I and 840 at the station Boš ak II on the same date (June 16th, 2005)(Kiš-Novak, 2012).

CONCLUSION

Watercourses are regulated canals that have been formed for flood protection and drainage of surplus water from agricultural land. Since these are specific aquatic ecosystems that together with associated vegetation belt form natural or, in cases of significant regulation, nature-like areas, they need to be protected from negative influences.

In addition to technical interventions, the worst impact on watercourses is done by the discharge of wastewater without pre-treatment into them. Such interventions reduce the quality and quantity of water as a basic parameter of the water biotope and destroy the ecosystem.

This research is a pioneering research study in the area of alluvial rivers in the region of Me imurje. Previous studies of alluvial rivers in the region of Me imurje were very sporadic and insufficient. By calculating the average of the reference values of field measurements, it is evident that the flow value, observed by average monthly minimum and maximum values of the average annual flow values, are significantly higher for the Stream Bistrec when compared with the other investigated stream – the Boš ak (Kiš-Novak, 2012). It is also evident that the mean annual flow rates and mean monthly minimal and maximal values are significantly higher in the downstream part of the flow of both of the studied streams. Hydrological characteristics, hydrological regime of water, is just one of a number of elements needed to determine the ecological status of surface water that accompany physico-chemical and biological elements. Based on physico-chemical parameters, it has also been found that there are certain differences between the studied streams. The Stream Bistrec shows significantly higher values of electrical conductivity, and according to this indicator falls into the water of second order (Kiš-Novak, 2012). Higher values of Ni, Pb and nitrate in relation to the Stream Boš ak have also been found (Kiš-Novak, 2012). The water of the Stream Boš ak shows a more deteriorating situation in terms of value of KPK5, Cr, nitrate, total nitrogen and ortho-phosphate in relation to the Stream Bistrec (Kiš-Novak, 2012). The results of the conducted research study show a relatively good hydromorphological status of the streams (*Fig. 11*). The reliability of the obtained results need to be further improved with research results in a new follow-up planned cycle.

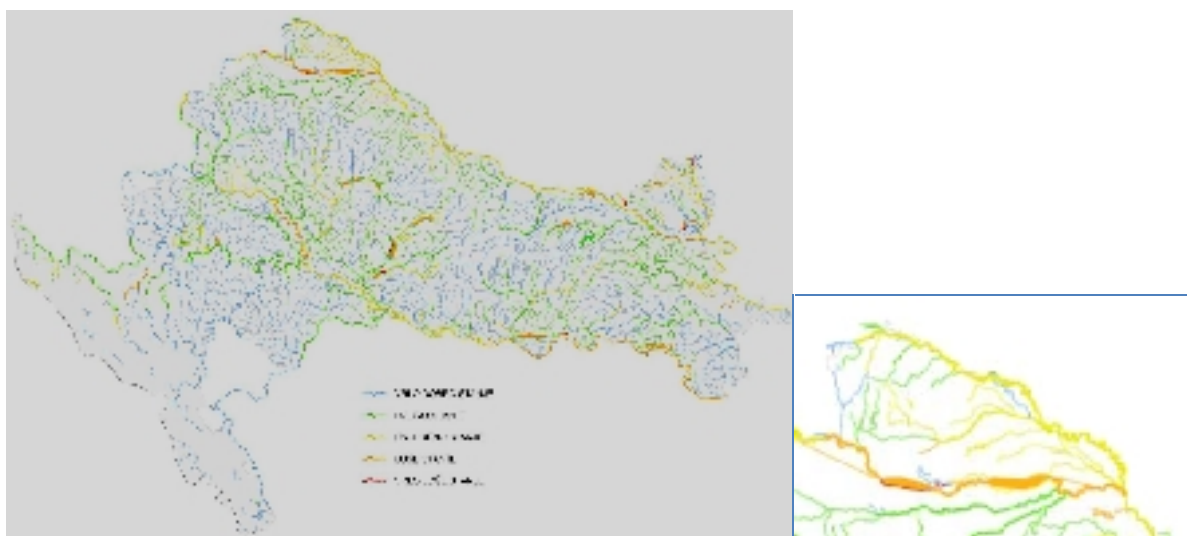


Figure 11: General hydromorphological status of waters in the Republic of Croatia (larger map) and in the Međimurje County (smaller map)

Classification status of flowing watercourses supports physical-chemical quality elements and the hydromorphological quality elements. General hydromorphological status of water is based on the quantity and dynamics of water flow, relation to groundwater, longitudinal continuity, lateral continuity, regulation, width and depth, structure and sediments as well as the structure of the river bank belt. (Filipovi, Barbalić and Kardej De Villa, 2011).

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