Hydrological changes of the Mura River in Slovenia, accompanied with habitat deterioration in riverine space

Lidija Globevnik[1], Mitja Kaligarič[2]

[1]University of Ljubljana, Faculty of Civil Engineering and Geodesy, Hydrotechnical Department, Jamova 2, Ljubljana, Slovenia; lidija.globevnik@guest.arnes.si
[2]University of Maribor, Faculty for Education, Department for Biology; Koroška 160, Maribor, Slovenia; mitja.kaligaric@uni-mb.si

Introduction

The Mura River (380 km), the tributary of the Drava River (Sava, Danube) is a transboundary river, flowing from Austria to Slovenia and Croatia. Historical development of hydro-electric power plants in Austria, channel straightening and other engineering of the channel for flood protection have altered the hydrological and sediment transport regimes in the Slovenian section of the river. The channel bed of the upper part of the Mura section in Slovenia has deepened and this has affected low to medium flow levels. Enlargement of the main channel and reduction in connectivity with the floodplain area between the flood protection dykes were additional causes for reduced flood frequency and groundwater level lowering. However, the main channel in Slovenia flows within a floodplain up to 1 km wide bounded by flood protection banks. This flood plain comprises many old meanders, oxbow lakes and flood forest areas. Reduced flood frequency and groundwater level lowering is indicated in a reduction in natural tree species in flood forest areas and an increase in the number of alien species. The above problems coupled with the intensive drainage of wetland areas for agriculture that has been carried out in the past has caused the general decline in diversity of wetland habitats and species in the riparian forest of the inner Mura. We evaluate hydrological changes of the section (1); give the draft historical reconstruction of the river flow and riparian space (2); show the habitat types and their degradation rate on a small pilot area (3).

Description of the area

The Mura River is the largest tributary to the Drava River, the largest Danube tributary. It springs 1898 m above see level in the eastern edge of the Lower Tauren Alps in Austria and inflows to the Drava River on Croatian – Hungarian border. It catchment is 14304 km^2 large. More then half of the catchment belongs to Austria, while the lower part of the Mura lies in Slovenia (1393 km^2), Croatia (987 km^2) and Hungary (1911 km^2). The length of the Mura is 444 km. The hydrological regime depends on snow melting season in Austria that causes usual higher water flow in spring (March – May). In the winter period (October – March) the low water regime prevails. The average water discharge in the lower section is 170 m^3/s (Cmurek, Slovenia). The highest water peak (1357 m^3/s, Cmurek, Slovenia) can be more than 30 times larger than aver-

Short scientific paper

age minimal flow (Halcrow Water and Water Management Institute, 2000). While large parts of the upper river section in Austria (315 km) were channelised for hydropower production, the middle and the lower sections (130 km) starting upstream of the Austrian border at Šentilj (Spieldfeld) are still largely intact. The river banks and bed of the river section along the Slovenian-Austrian border (33.28 km) is completely regulated with a 60 to 80 m wide river bed. Flood protection dikes (embankments) were constructed along the flood plain of the river section in Slovenia (the Inner Mura, 27 km) in the period 1972-1990 with a level of service against flooding of 1:100 years. The Mura River has a variety of typical plant and animal communities, ranging from pioneer to mature stages, including pannonian-dinaric and pontic-caspian elements, with large floodplain forests and side arm systems. Apart from natural landscapes, there is a highly value cultural landscape.

METHODS

Hydrology: Existing national monitoring data (HMZ, 1995a; HMZ 1995b; HMZ 1995-2004a; HMZ 1995-2004b; ARSO 2000) have been used to investigate whether there have been any long-term changes in rainfall or river flow which may have had adverse impacts on the River Mura wetlands. First the average values for annual precipitation for rain gauge stations at Gornja Radgona, Murska Sobota and Lendava for the period 1961 to 2000 are defined and linear trend estimated. Then the average discharge values at 95 %, 90 %, 80 %, 50 % and 1 % frequency for Petanjci station for six sequential periods (25 year period from 1926-2000) plotted against the average annual precipitation values for Murska Sobota and Gornja Radgona to find any significant trend for change in the relationship between rainfall and river flows. On the Mura River mainstream within Slovenia there are two gauging sites with virtually continuous records of mean daily discharge from 1926. The Petanjci gauge with available record period 1926 - 2000, is situated within the border section and upstream of that part of the Mura wetland complex that lies within the country. The Mursko Središče gauge with available record 1926 – 1990, is sited at the downstream boundary of the system. The only other river of any significance that could be considered as part of the wetland complex is the Ščavnica, which enters the Mura between the two gauging sites but which is ungauged.

For the purposes of consistency the contemporaneous records (from 1926 to 1990) at each site are emphasised and the later data at Petanjci considered independently. Linear trends have been analysed on the discharge data (annual, frequency distribution) to find any long term hydrological changes.

The contribution of the wetland system to the overall hydrology is referred to as the 'residual' hydrology that is the difference between the inflows (at Petanjci) and the outflows (at Mursko Središče). The storage or attenuation effect of the residual area (wetlands in Slovenia) is shown by the flow duration curve (FDC) of the daily flows from the residual area and was obtained by subtracting the quantiles of the FDC at Mursko Središče (downstream) from that at Petanjci (upstream).

Based upon what data appears to be available from hydrological studies from 1981 and 1990 and field inspection in 2001 the availability of transportable material is assessed and historic changes in river cross-sections and bed levels defined. The linear trends of groundwater level changes of the Mura river aquifer are studied for 18 locations for the period 1961-2000 and 1981-2000. Parameters investigated are average levels, maximum levels, minimum levels, average depth and amplitudes.

Draft vegetation history: The vegetation cover of the pilot area of 8.2 km^2 from 18th Century were interpreted from Austro-Hungarian military maps, made between 1763 and 1787, which were exclusively used for military purposes and formed a part of "Emperor Joseph II Land Survey" (Rajšp and Ficko, 1996). The maps were drawn at a scale of ca. 1:28 000. They are not sufficiently accurate to be processed directly by GIS (Čarni et al., 1998), but by positioning the settlements were possible to transfer categories, clearly visible from the maps into GIS, using Arc-View 3.2 computer program. The following categories were distinguished: forest (including scrub and wooded grasslands), grassland (pastures and meadows), fields, vineyards and orchards included and settlements. The first areal photographs available are 40 years old and the following categories are visible: forest (including scrub and wooded grasslands), grassland (pastures and meadows), fields, vineyards, orchards, settlements and river channel with larger gravel bars. The photographs (accurancy of 1: 17500) are not geo-oriented. With geo-referrencing to settlements we transferred categories, clearly visible on the photographs into GIS, using AUTODESK MAP computer program. The present-day land-cover were taken from the data base of agriculture land use, a GIS-supported database, owned by Ministry of agriculture, forestry and food of the Republic of Slovenia (Anon., 2002). It is based on digital aerial photographs. The categories were aggregated and simplified to make data comparable with the older maps.

Habitat evaluation: Habitats were mapped on a pilot area Veržej – Mota (Leskovar and Jakopič, 2000) and later adapted to the "PHYSIS" typology, based on Palearctic classification (Devillers et al., 1993; Devilliers and Devilliers-Terschuren, 1996), which was chosen as one of the most accurate one. Hierarchical classification is based on vegetation typology. This classification was adopted and modified for Slovenian conditions. (Jogan et al., 2004) Due to various transitional stages and mixed habitat types also "hybrids" (transitional forms, mixture or mosaic) between 2 or 3 habitat types were used.

Habitat evaluation was attributed due to species-richness, naturalness, species-rarity and rate of invasion of allien species.

Results

Hydrology: Linear trend for annual precipitation values at three locations, Gornja Radgona, Murska Sobota and Lendava for the period 1966-1990 are estimated to be slightly positive, whereas for the period 1966- 1995, precipitation values for Ledava have a slight negative trend. Regarding the average discharge values at 95 %, 90 %, 80 %, 50 % and 1 % frequency for Petanjci station for six sequential periods compared against the average annual precipitation values for Murska

Sobota and Gornja Radgona we conclude that there is no discernible or significant trend for change in the relationship between rainfall and river flows, and that any change in hydrology that may exist is apparently statistically independent of climate.

The linear trends of annual average discharges and minimal discharges for Petanjci and Mursko Središče are negative. The same is true for 1 %, 50 % and 80 % frequency distribution values, but positive for 95 % and 90% frequencies. The FDC of the flows in the Mura mainstream indicates a continuous distribution, but the flows from the wetland fall into three distinct component parts, representing floods and low flows and a definitive and virtually constant outflow discharge of 7 cumecs which typifies flows for virtually 40 % of the year.

The availability of transportable material in mid 70' has been much lower than the river transporting capacity, which was estimated to be from 20,000 to 70,000 cubic metres per year. Typical d50 sizes quoted from the 1970's were of the order of 5-10 cm at Mursko Središče, and estimated transport has been of the order of 30,000 tonnes or 17,000 cubic metres for an average year.

The results of the surveys in the period between 1971-89 indicate that the average lowering of the river bed at Austria- Slovenia border is 33 cm. The maximum values extend to 88 cm and were observed below the Cmurek bridge, while in the profile of the Radenci bridge the elevation of the river bed in the range of 11 cm was recorded. Surveys of the ground water levels in the wells closer to the river indicate the average level of lowering of groundwater tables for 30 cm and the same is true for the river bed, while surveys in areas further away from the river show that the groundwater tables have decreased more. The river bed of the Mura at Petanjci lowered for 27 cm during the period 1970-80. Further lowering of the bed profile was apparently controlled with technical measures, the effects of which were shown in lowering of the river bed profile by 16 cm in the following ten years. The amount of bed degradation decreases downstream in the Inner Reach.

Draft vegetation history and habitat evaluation: A decline of both water surfaces and riparian forests was percieved. Water surface has declined for 9% in 200 years, the biggest change happend in tha last 40years. Area of riparian forest has declined for 30%. Today 4 % of the area is covered by running water surface, the main stream of the Mura river. At this part a great proportion is still forested (65%), but among forest 10% is degraded by allien *Robinia pseudoacacia.* Only 35% of are is completely natural or nature-close stage.

DISCUSSION AND CONCLUSIONS

Changes in water and sediment flow dynamics have been influenced by the construction of hydropower plants in the upper parts of the Mura River in Austria. Coupled with extrensive water abstrations and controlled drainage of water in tributary stream network have stimulated extensive lowering of the river bed, groundwater level and increased rate of bed erosion. It is estimated that the level of river bed in the border section of the Mura River (Slovenia/Austria) has decreased by of the order of 1.0 m, and decreased river

bed levels can be observed well into the Inner Mura Section. A substantial (and significant) difference is evident for the residual flows which reflect the hydrology of the wetland (residual area between Petanjci and Mursko Središče) complex itself. Flood outflows have almost doubled there in the latter period while the median and low flow regime has fallen to less than a half of the discharges that typified the pre 1965 hydrology. This pattern points to a very large reduction to the natural storage available within the wetland complex.

The situation is especially visible during the periods of low and average water levels. Dynamics of channel and flooding patterns are, together with soil moisture and human impacts, the main factors influencing riparian zones. In these areas the direction of flow is from the soil water and groundwater into the channel. Nowadays water from the main channel of the Mura fills the soil only when a flood pulse raises the level of the river above the hydraulic base level. Hence, the level of groundwater and water in the channel are mutually dependent. Numerous backwaters and oxbows, once typical for the floodplain areas along the Mura River, now have very weak or no connection at all with the river waters.

References

Anonymus (2002): Kmetijska raba tal Slovenije. - Ministrstvo za kmetijstvo, gozdarstvo in prehrano RS, Ljubljana.

ARSO (Agency for environment of the republic of Slovenia) (1999): Hydrological data 1926 – 1990. Archive.

Devillers, P., Devillers-Terschuren, J. (1996): A classification of Palaearctic habitats. - Council of Europe.

Devillers, P., Devillers-Terschuren, J., Vander Linden, C. (1993): Palaearctic Habitats: a DatabaseProvisional draft (PHYSIS Database). - Institute Royal des Sciences Naturelles de Belgique.

Čarni, A., Jarnjak, M., Ostir-Sedej, K. (1998): Past and present forest vegetation in NE Slovenia derived from old maps. *Applied Vegetation Scienc*e 1, 253-258.

Halcrow Water and Water management Institute (2000): Transboundary Co-operation in Nature Conservation and Wetland Management for the Danube River Basin. Component 1: Sustainable River Basin Development and Wetland Management in the Lower Mura River. Final Report, London.

HMZ (Ministry for Environment and Physical Planning - National Hydrometeorological Institute). (1995a): Klimatografija Slovenije-Padavine 1951-1980. Ljubljana.

HMZ (Ministry for Environment and Physical Planning - National Hydrometeorological Institute). (1995b): Klimatografija Slovenije - Padavine 1961-1990. Ljubljana.

HMZ (Ministry for Environment and Physical Planning - National Hydrometeorological Institute). (1995_2004a): Meteorološki letopisi Slovenije 1991-2000. Ljubljana.

HMZ (Ministry for Environment and Physical Planning - National Hydrometeorological Institute). (1995 -2004b): Hidrološki letopisi Slovenije 1991-2000. Ljubljana.

Jogan, N., Kaligarič, M., Leskovar, I., Seliškar, A., Dobravec, J. (2004): Habitatni tipi Slovenije HTS 2004. Ministrstvo za okolje, prostor in energijo, Ljubljana. 63

Rajšp, V., Ficko, M. (1996): Slovenija na vojaškem zemljevidu (Josephinische Landesaufnahme 1763-1787 fuer das Gebiet der Republik Slowenien). - ZRC SAZU and Arhiv Republike Slovenije, Ljubljana.