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EXPLORING APPROACHES TO THE RESTORATION OF THE USTIA RIVER WITHIN THE RIVNE CITY

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ABSTRACT

Aim of the work

The paper describes the current condition of the Ustia River. The river suffers from pollution and shows signs of degradation. Lack of the survey data is the critical constraint for the studies with the intention of enhancing the design of its riverbed. The assessment of the hydraulic feasibility of possible riverbed arrangements, as an approach to the development of the revitalization plan, is presented in this paper.

Materials and methods

Historic maps of the neighbouring Rivne terrain were studied to track changes of the river route. Data of available water quality studies, field hydrological measurements, were used in the study. Modelling with HEC-RAS 1D was performed to examine the assumption of low velocities and assessment of the hydraulic feasibility of the proposed concept of the river bed modifications.

Results and conclusions

The study revealed that the drastic drop in water quality can be attributed to the last riverbed transformations and the development of Rivne. Along a significant part of its urban section, the river channel has low fill levels during periods of low flow. The average velocities can be considered as extremely low for the river to maintain its ability to self-purify. From a river hydraulics perspective, and given the constraints of the urban setting, in-channel enhancements can be considered as a restoration method. Developing a numerical model of the riverbed was demonstrated to be a useful tool on the stage of preparing a revitalization plan, serving as a means of assessing the hydraulic feasibility of various arrangements options even under limited input data.

Keywords: urban river, restoration, river degradation, river hydraulics, hydraulic feasibility

INTRODUCTION

Motivation for the study

River ecosystems are an integral part of the human habitat. Therefore, river health is critical for human well-being. Nowadays, however, the majority of rivers suffer from degradation, primarily due to human activity, including the discharge of pollutants, urban development and land use. In the long term, this can inhibit river's ability to self-purify. Small rivers are particularly susceptible to degradation.

River revitalization work has become an urgent need to improve the condition of river ecosystems and restore ecological balance. However, urban landscapes often present a limited potential for river restoration due to their spatial constraints or flood protection considerations. The Ustia River, the subject of this study, is a small river in western Ukraine. It has undergone significant engineering transformations, including damming, straightening and channelization along almost its entire length. Yet short segments outside settlements remain in a close to their natural state.

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A large part of the river runs through the city of Rivne. There are numerous signs of river degradation, including algal blooms, muddy water, reduced water velocity, lentic water in some areas and an unnatural colour. The water also has foam and surface sheen, as well as floating waste and debris accumulation. During warm periods, a pungent odour is noticeable. Nevertheless, there is evidence of aquatic life, including plants, fish and frogs. Water quality is particularly poor at the edges of the city. It is crucial to define efficient ways to improve the river's condition in order to comply with ecological and social standards.

It is quite common for small rivers in Ukraine to have no consistent and aggregated data, such as representative daily or monthly hydrological, rainfall data, high-resolution topographical surveys and bathymetric data. The lack of survey data, including that relating to hydrology and riverbed morphology, is a critical limitation when it comes to detailed hydraulic modelling for the design of riverbed enhancements. Survey management and collecting sufficient data takes a lot of time, which significantly restricts developing revitalization plans.

This paper describes the current river course arrangements at the edges of the city, focusing on river hydraulics as a key aspect of river dynamics in the context of riverbed enhancement planning. The assessment of the hydraulic feasibility of riverbed arrangements under condition of limited survey data is presented as an approach to progress revitalization studies of the urban sections of the river.

Background of the study

Human activities that typically impact rivers include the discharge of pollutants, and alterations to floodplains and river courses that include the construction of dams and the straightening of waterways. These activities affect the rivers' ability to maintain themselves (Kiraga and Remer, 2023).

In urban settings, concrete riverbeds, culverts and bridges are also common. These hard engineering techniques often result in rivers exceeding their assimilation and regeneration capacity. River restoration approaches involves modifying river channels to improve the hydrological, geomorphic and ecological processes within a degraded riverbed and watershed, and replacing lost elements of the natural system (Wohl et al., 2015), in order to provide favourable conditions for river self-purification.

River restoration is a complex process that can involve catchment management, reconnecting floodplains, removing barriers, restoring meanders, stabilizing riverbanks using bioengineering methods, reconfiguring channels and restoring riparian areas, as well as controlling species. However, the effect of each method can be ambiguous, as restoration activities do not always facilitate the required ecosystem processes, and other unknown circumstances can hinder the ecological response (Wohl et al., 2015). Defining an appropriate river restoration plan for urban river sections is still more complicated due to dense urban development. Therefore, restoration should be innovative and adapted to specific urban conditions as it is usually aimed to mimic the natural river course as closely as possible but without compromising the functioning of riverbed arrangements, for instance, without contributing to increased risk of flooding. Urban rivers should be considered a hybrid of culture and nature, which has significant implications for the river restoration projects (Wohl et al., 2015).

For the river under study, slow flow are observed in most of the year, which is a typical factor that can hamper water quality (Langbein and Durum, 1967; Macura et al., 2016; Ugbebor et al., 2012). Presumably, low velocities facilitate the built-up of sediment resulting in shallower water and reduced habitat area for aquatic life. With low velocities dissolved oxygen levels can drop, triggering anaerobic processes, which is particularly problematic in warm weather. Furthermore, longer residence time of water results in nutrients and pollutants concentrate leading to algae blooms. For lowland rivers, sediment transport and deposition are the most influential factors in river dynamics (Wojak et al., 2023). River hydraulics is a vital aspect in the study of river dynamics, as it focuses on the interactions between hydrological flow, sediment transport, and channel morphology. This paper addresses river hydraulic improvements as one of the approaches to enhancement of river conditions.

River description

The Ustia is a small 68-km-long river with a catchment area of less than 1,000 km². The city of Rivne is the largest population cluster along the river. The

urban river segment is around 12 km long. It is the city's main waterway.

As it is typical for most of the cities, the riverbed within the city has been altered (see Figure 1) for urban planning purposes, such as preventing land waterlogging and flooding, as well as for recreational use. The main modifications include the construction of dams and the straightening of the riverbed. The earth dam that retains the reservoir is located upstream of the city. Figure 1c depicts the spillway appurtenant to the main dam, while Figure 1d–g shows the current condition of the river at specific locations.

Design documentation for the dam is unavailable. However, references of the relocation of the riverbed in the 1930s were found (see Figure 2). Then, in the 1950s and 1980s, the next stage of the riverbed channelization was carried out, involving the slabbing of the banks (Figure 2) within 3 km long river section. Several more weirs were then constructed. Outside the city, the river was also mostly straightened. However, in the naturally occurring segments, the river exhibits a slightly meandering route pattern (see Figure 1a) with a sinuosity index (Horacio, 2014) of around 1.23. To provide insight into the current situation of the urban river and its arrangements, Figure 3 presents the river profile.

Figure 4 shows a map representing an integrated assessment of river water quality according to the ecological and water quality investigations (Rivne City Council, 2020). Water quality studies were performed in 2018. River water sampling was provided in 14 measurement locations during the dry weather period. Water quality was assessed using 18 typical indicators (pH, BOD, nutrients, suspended solids, dissolved oxygen, etc.). Water quality was categorized as good, satisfactory, poor or very poor based on the analysis

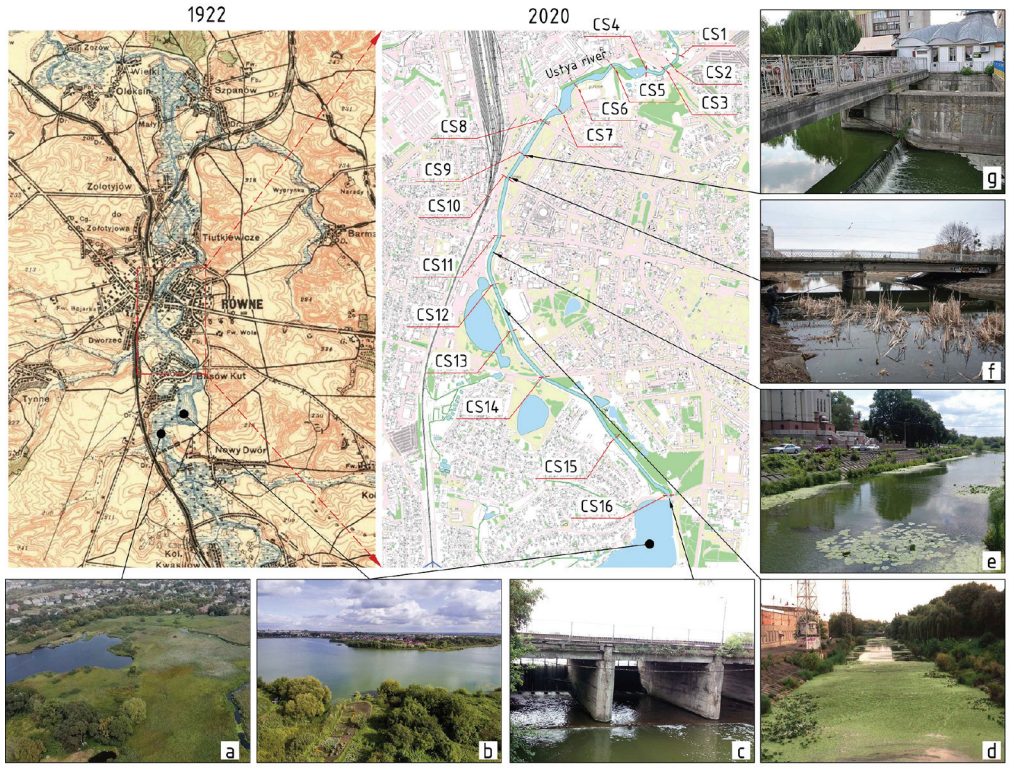

Fig. 1. Historical maps of the Rivne city area with photos of the following locations: a) Basiv Kut reservoir; b) upstream area in near-natural river state; c) Basiv Kut spillway; d) channelized river section near the stadium; e) channelized river section near the pedestrian bridge; f) channelized river section near the bridge on Sagaydachnoho Street; g) downstream weir (Source: Historic maps of the Rivne oblast (n.d.), Suspilne Rivne (2023); OGO.ua. (2015); Maksymchuk (2018); Photo by the authors)

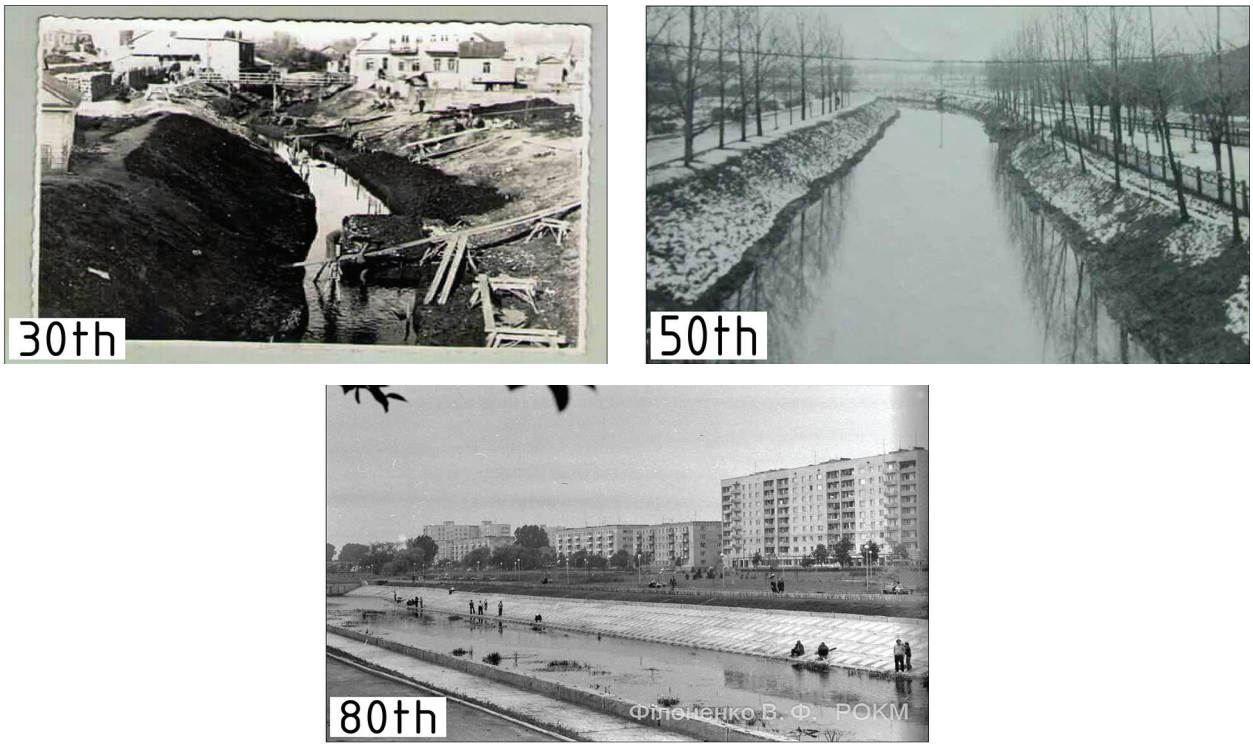

Fig. 2. Archive photos of riverbed arrangements within the city of Rivne (Source: Suspilne Rivne, 2023)

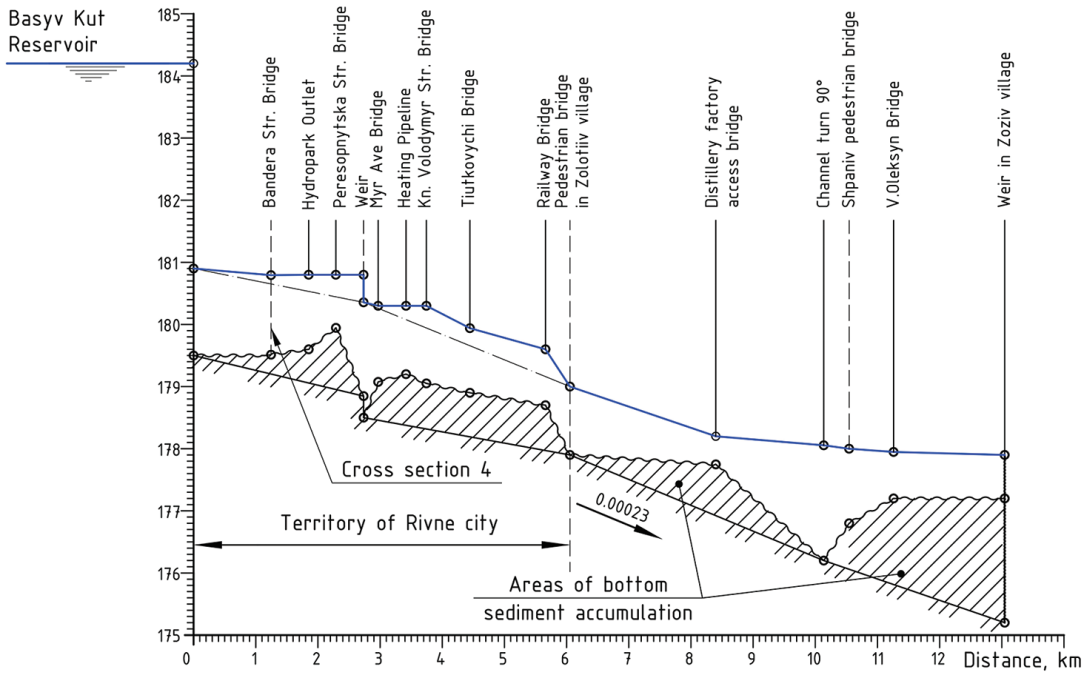

Fig. 3. Riverbed profile in the contemporary arrangements of the riverbed according to field measurements performed by authors in 2011 (Source: Authors' own elaboration)

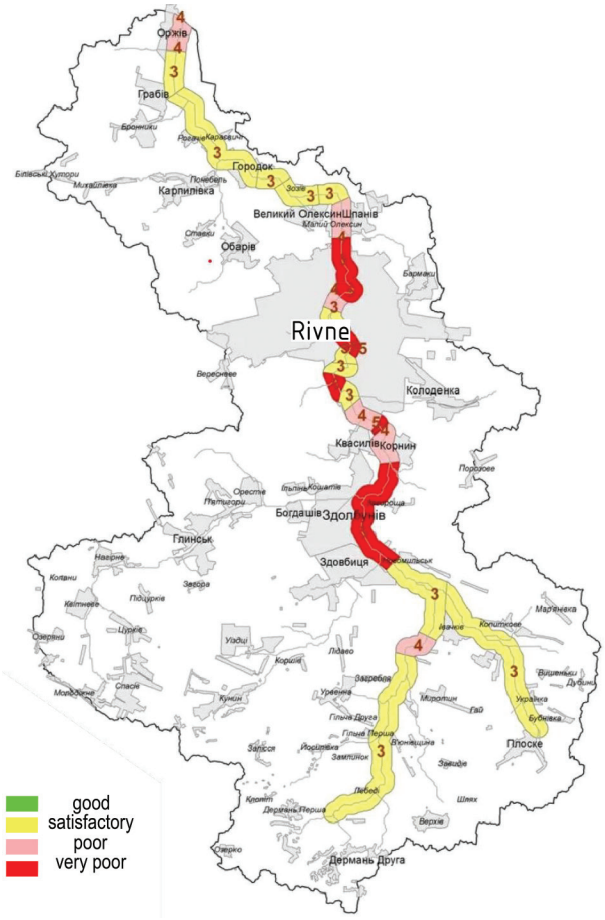

Fig. 4. Water quality map (Source: Rivne City Council, 2020)

within three blocks of indicators: saline water quality, tropho-saprobiological and specific).

Most of the actions planned by the municipality today consider the upstream reservoir. However, interventions are also necessary for the downstream river channel. Although few local surface aeration installations have been implemented along the channel, they have had little effect on the river water quality.

So far, most of the field studies conducted for river restoration planning focused on ecological aspects and water quality. In addition to studying biodiversity and pollution levels, assessing the hydraulic conditions would help to ensure the efficiency of the planned interventions in the channelized river corridor.

In its near-natural sections, both upstream and downstream of the city, the riverbed is 6 to 10 m wide with a maximum width of 16 m. Within the channelized section, it is approximately 22 m wide. The average riverbed slope is 0.0002. The low velocities in the channelized section are assumed to be unsatisfactory, that can facilitate creating unfavourable hydraulic conditions for river health.

Although the large-scale restoration seems impossible in constrained urban areas, in-channel enhancements can effectively introduce modifications that increase flow velocities and create diverse flow patterns within the channel. This approach combines natural and engineering methods to alter the riverbed, such as placing boulder clusters to create localized scour and velocity variation, thalweg realignment, riffle–pool sequences, and a two-stage bed arrangement. A concept of the two-stage bed is further considered in this study as a technique of riverbed enhancement.

MATERIALS AND METHODS

Historic maps of the terrain around Rivne (Historic maps of the Rivne oblast) were studied to track changes to the river route, identify the period when the major engineering changes occurred and the possible purpose of damming the river. Two maps, from 1922, and from 2020, are presented in Figure 1 for comparison.

In order to examine the assumption that unsatisfactory low river flow velocities could potentially facilitate sediment build-up and nutrient accumulation throughout most of the year, a hydraulic simulation of river channel flow was performed. Key hydraulic parameters of the flow, such as flow velocity and depth, were considered. Sediment characteristics, nutrient levels, oxygenation were not considered in this study.

The river flow estimations used to set the flow range in numerical modelling (see Table 1) were obtained based on the equation recommended by Ukrainian regulations for maximum river flow during rain flood (see Strelets (ed.), 1987; Gopchenko et al., 2017) for a catchment area of 519 km².

As presented in the report (Rivne City Council, 2020), estimations of the maximum and average long-term flow of the river were provided based on the values indicated in the reservoir passport, as well as on long-term data on the regime and resources of surface waters, prepared by the Central Geophysical Observatory of the State Hydrometeorological Service of Ukraine.

In the absence of a consistent series of hydrological data for the Ustia River, minimum flow estimates were obtained using the reduction formula (SNiP 2.01.14-83, 1983) and the genetic formula of A.M. Befani (Strelets (ed.), 1987).

The first method (SNiP 2.01.14-83, 1985), which is recommended for the catchments ranging from 20 to 1200 km^2, determines flow using the reduction equation based on the river catchment area and parameters specific to the catchment geography.

The Befani equation defines minimum flow based on normal soil recharge rate into groundwater as well as the reduction factor that accounts for reduced infiltration in small areas. It also considers the impact of forest cover, lakes and karst soils on groundwater recharge within the catchment. Specific estimates of flow with the given probability that characterize river water capacity and flood flow are listed in Table 1.

Table 1. Flow estimations for the Basiv Kut reservoir

#	Flow probability	River flow, $m^3 \cdot s^{-1}$
1.	1%	92.68
2.	5%	55.61
3.	10%	38.93
4.	25%	22.24

The minimum 30-day flow module is computed based on an empirical groundwater runoff module and a specific regional conversion factor. The 30-day minimum discharge with 75% probability of exceedance for the summer–autumn low-flow period was estimated at 0.51 $m^3 \cdot s^{-1}$. This was adopted as a representative low-flow metric for the river behaviour modelling. This value was computed as an average of the values obtained using two abovementioned methods.

Study of historic maps revealed that the reservoir was created back in the 19th century, and the riverbed within the city was straightened in the 1930s–1950s of the 20th century. The last riverbed alterations were made in the 1970s and included gated damming, paving the slopes and likely damming with an overflowing dyke, which was probably constructed for recreation purposes.

Field data (see Figure 3) were used for model calibration. Field measurements were performed by one of the authors. Currently, the referenced data is the only available that represent the entire urban segment of the river, and the measurements were carried out at a time. The session of measurements of water levels and flow depths were performed along the river segment within the city and suburbs. Measurements were provided in 2011 during a warm period. During the session, water levels were gauged using a total station, and manual water depth measurements were made along the centre line of the riverbed. A total of 19 measurement locations were involved, including 12 within the city limits. These field measurements confirmed the build-up of concrete prisms, possibly intended to create a backwater effect on the river flow in one of the locations near the bridge. The field study covered the entire river segment under consideration, therefore, enabling the general pattern of the hydraulic profile to be identified.

Throughout the data provided by the field study, the water levels were assumed to be the most suitable and plausible piece of information, given that water levels are constant within the cross section and were delivered with appropriate accuracy. Based on these considerations, data of the field study were used to calibrate the model.

HEC-RAS simulations were performed for the river section within the city. River cross-sections were outlined based on the 1:2,000 scale city topographic base map, with a 1 m contour interval. The following main assumptions were made in developing the model. The cross-sections are comparatively uniformly-shaped trapezoidal. The slope ratio (1:3) was estimated using geodetic levelling. As bottom invert elevations along the riverbed are unavailable, assumed values were used in the model. Sediment deposits were assumed to be uniformly distributed. The elevation of the downstream damming dyke of the section under study is also unknown.

The developed model is limited to the urban river section, where the simple riverbed shape resulting from the 1970s chanellization activities enables modelling with limited data. This part of the river also displays numerous signs of degradation.

The HEC-RAS model includes 16 cross-sections (see Table 2), starting from downstream of the reservoir and ending at the point where the riverbed ceases to be channelized (See Figure 1). The total length of the modelled section is around 3.5 km, covering the

Table 2. Description of the HEC RAS model cross-sections

CS label	Location	Distance, m
16	Downstream of the reservoir weir	406
15	Intermediate; pedestrian bridge	558
14	Bridge, Str. Bandery	340
13	Intermediate	247
12	Intermediate	316
11	Bridge, Str. Soborna; intermediate pier	327
10	Bridge, Str. Sahaydachnoho; intermediate pier	150
9	Canal gate regulator	224
8	Bridge, Str. Myru	116
7	Intermediate	196
6	Intermediate	244
5	Intermediate	219
4	Intermediate	116
3	Bridge, Kn. Volodymyra	41
2	Intermediate	93
1	Str. Kiury	
	Σ	3593

channelized urban segment. Bridges along the urban segment are supposed to have little effect on the river flow since the bridge abutments are placed outside the bounds of the channelized bed's top edge. The exceptions are two bridges (cross-sections (CS) #10 and #11), which are supported by the pier in the middle of the river cross-section, were accounted for in the model. The regulator (CS #9) was modelled using the overflow gate in-line structure component. The overflow dyke was introduced to the model as a locally elevated bottom level.

Manning's coefficient of 0.04 was assigned to the riverbed, taking into account the poor condition of the concrete slabs and the presence of grit deposits (HEC-RAS Hydraulic Reference Manual). Modelling was provided for steady flow within the range of flows 0.1…90 $m^3 \cdot s^{-1}$, with normal depth set as the upstream and downstream boundary conditions.

One advantage of developing a numerical model of a river in an urban setting is that the riverbed is often uniform in shape. Consequently, the number of tuning parameters can be reduced, enabling modelling with limited survey data.

Water surface elevations in the 12 cross-sections from the 2011 field study were used as the target values for model calibration, as this data was considered to be the most reliable available. Water depths obtained in field measurements at the upstream boundary cross-section, and upstream and downstream of the gated weir, were set as model parameters. Water depth was used as a reference data for the 1 $m^3 \cdot s^{-1}$ flow profile.

The calibration metrics the Root Mean Squared Error (RMSE), which evaluates the average size of the residuals, and the Nash-Sutcliff (NSE), which indicates the relative difference between the magnitude of the residual variance and the measured data (Kuhn and Johnson, 2013), were employed to assess the goodness of fit of simulated data to the observed data.

The hydraulic feasibility of the concept of the two-stage cross-section as an approach to the riverbed enhancement was assessed using the calibrated HEC-RAS model. The potential for increasing flow velocities for low flows was examined.

In assessing the hydraulic feasibility of riverbed alterations, the efficiency criterion was defined as achieving velocities observed in the current state of the river within the cross-sections demonstrating better performance (e.g. as for sections with close to the natural state) or under conditions that facilitate river self-healing (e.g. as during high-flow periods). For the Ustia River, velocities for flows over 5 $m^3 \cdot s^{-1}$ can be used as the target value for riverbed modifications.

RESULTS AND DISCUSSIONS

A study of historical maps revealed that the river's course has changed drastically over the last century. Notably, the entire neighbouring area is prone to land waterlogging. It was found that the main reservoir could have been impounded in the 19th century, apparently for controlling land waterlogging. The drastic drop in water quality is likely associated with the last riverbed transformations at the end of the 20th century and the subsequent development of the city, which in all probability led to an increase in pollutant loads as well. This can imply that the root causes of the degradation are within the reach scale (Beechie et al., 2010).

The developed HEC-RAS model of the river within the urban section enables simulation of the river flow hydraulics throughout the flow range from minimum to flood flows.

Calibrating the model against field data on water surface elevations enabled the production of model-supported estimates of the channelized bed invert elevations, which were unavailable from other sources. Furthermore, calibrating the model facilitated the identification of the main drivers of the current hydraulic profile configuration and enabled the assessment of the backwater effects provided by the gated weir and the downstream pile-up.

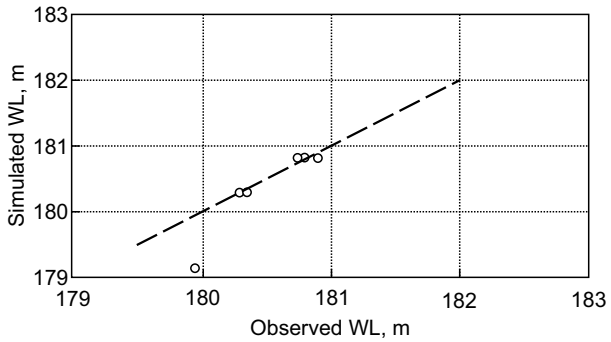

Fig. 5. Simulated versus observed values calibration plot (Source: Authors' own elaboration)

During model calibration, the key factors to which the given model was the most sensitive were identified: bottom slopes within the individual sections and the elevation of the damming dyke. Therefore, the weir crest level (CS #9), the coping of the pile-up (CS #3), the bottom inverts and bottom slopes were selected as the tuning parameters. Flow depth was identified as having no significant impact on the simulated water surface profile in this case study, as the dammed river reach is modelled. For the next sections of the river without damming structures, more field data would be required for model calibration.

The performance of the model is illustrated by a calibration plot of simulated versus observed values (Figure 5). The values of calibration metrics are presented in Table 3. Based on these metrics, model represents well the dammed section of the modelled area, however more detailed data is necessary to calibrate the downstream sections.

Table 3. Calibration metrics

Calibration metrics	For all cross-sections involved in calibration	Excluding the cross-section located beyond the dammed river reach
RMSE	0.29	0.05
NSE	0.14	0.91

The average depth and flow velocities were obtained using HEC-RAS simulations for the river in its current configuration, as well as for the configuration with the proposed modifications. The depth and flow velocities for two representative cross-sections in both simulated scenarios are presented in the Table 4.

Throughout the simulated urban section in its current configuration, the river channel has low fill levels at low flows, including the minimum flow. Flow velocities under 0.05–0.10 m · s^{-1} are typically considered too low on river flows, as they can cause stress to the river, resulting in an ecological imbalance (Davis et al., 2025). The aver-

Table 4. Flow parameters for the selected cross-sections of the HEC-RAS model

CS label	Flow parameter	For current state riverbed for flows, m^3 · s^{-1}				For enhanced riverbed for flows, m^3 · s^{-1}			
		0.5	1.0	2.0	5.0	0.5	1.0	2.0	5.0
15	Velocity, m · s^{-1}	0.02	0.03	0.06	0.13	0.18	0.24	0.26	0.29
	Water depth, m	1.76	1.79	1.86	2.03	0.5	0.72	1.09	1.58
10	Velocity, m · s^{-1}	0.02	0.03	0.06	0.13	0.36	0.41	0.44	0.48
	Water depth, m	1.860	1.900	1.960	2.100	0.270	0.450	0.790	1.260

age velocities obtained through modelling are extremely low and seem to be insufficient to facilitate neither oxygenation, nor removal of pollutants and nutrients. Changes in the bed microrelief due to sediment retention can be expected at low velocities as well.

In terms of the significant backwater effect, it is not realistic to expect a noticeable increase in velocity without removing the structures impeding the flow. Alongside this, the two-stage cross-section arrangement is meant to ensure reduce the cross-section area. The proposed geometry of the two-stage cross-section is 5 m wide and 1 m deep at the bottom. An example of the river bed cross-section modifications is presented in Figure 6. However, in the view of the river urban settings, the riverbed at the bridge location should undergo minor alterations.

Hydraulic profiles for the current and modified riverbed conditions are presented in Figure 7 and Figure 8, respectively.

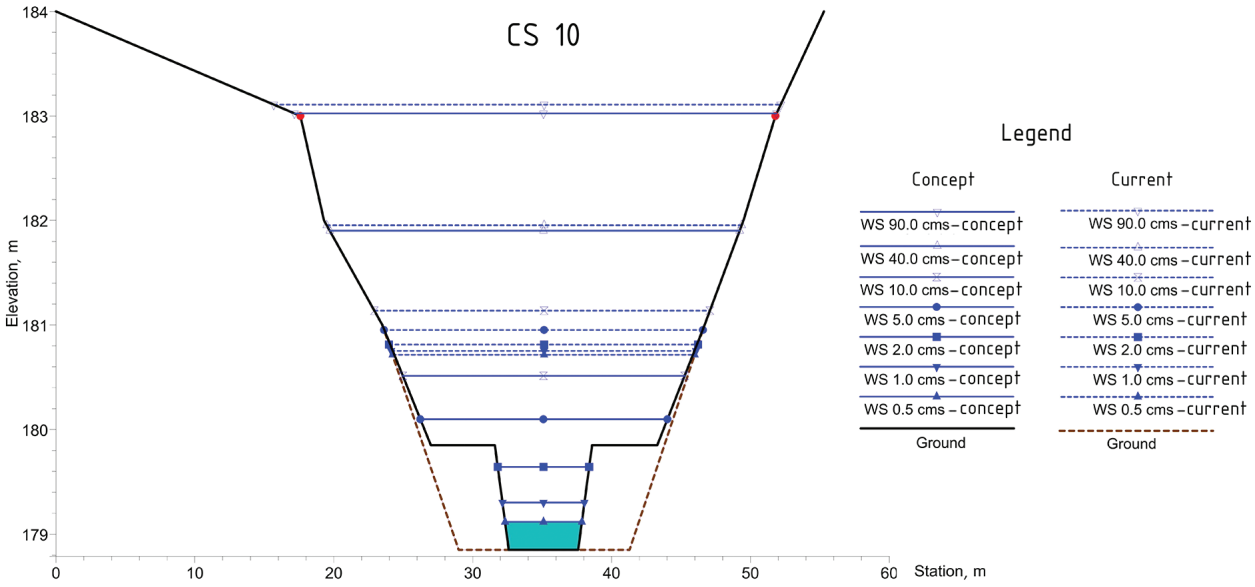

Fig. 6. Example of the riverbed cross-section modifications (Source: HEC-RAS modelling results)

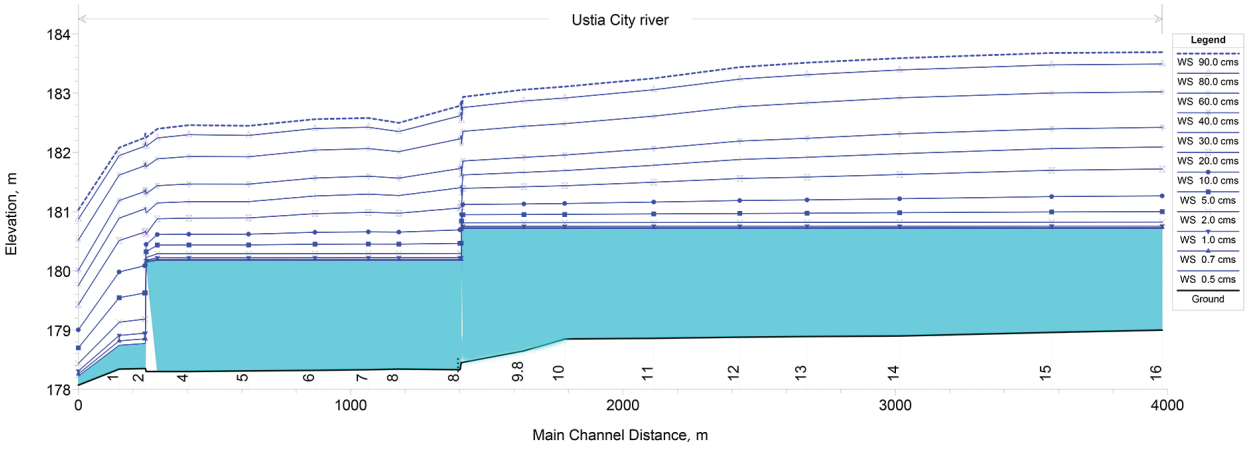

Fig. 7. Hydraulic profile for the current condition of the riverbed (Source: HEC-RAS modelling results)

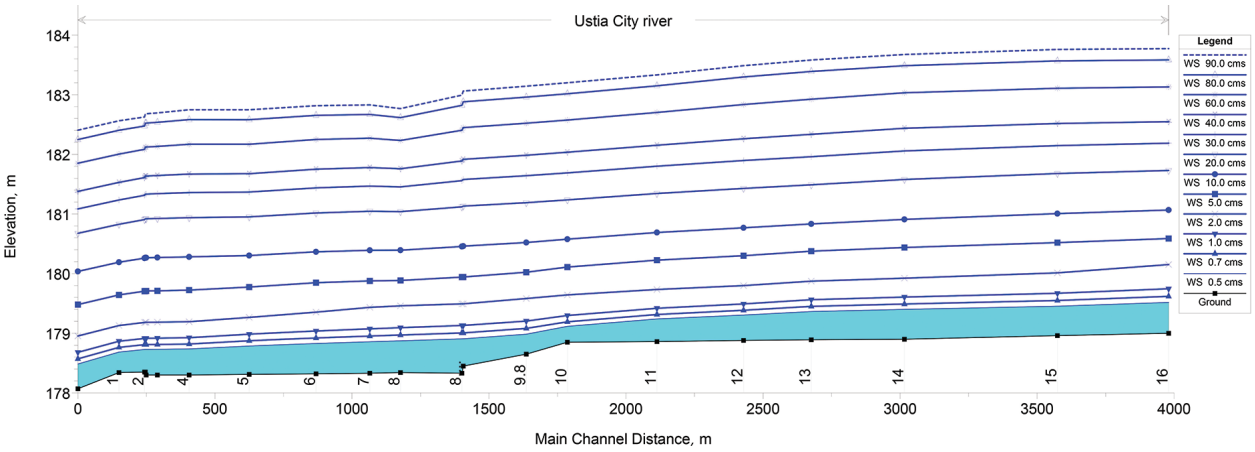

Fig. 8. Hydraulic profile for the modified riverbed (Source: HEC-RAS modelling results)

The proposed two-stage cross-section concept allows similar velocity values of around 0.2 m · s^{-1} to be reached for the range of low flows from 0.5 to 2 m^3 · s^{-1} (see Table 4), which are comparable to the velocities occurring in the riverbed under current conditions at a flow rate of 5 m^3 · s^{-1}. This can be considered appropriate. At the same time, flows ranging from 5 to 90 m^3 · s^{-1} can pass through the modified riverbed without causing a noticeable increase in the water level along the entire modelled segment. This could be an additional indicator of the hydraulic feasibility of the proposed concept.

The purpose of developing the model is to simulate the main specifics of the urbanized river section profile and to demonstrate the possible positive effect of riverbed modifications on the river hydraulics, rather than to obtain a model suitable for studying the impact of river dynamics on riverbed morphology. For such kind reliable model, more wide measurement sessions are necessary. In this study velocity is one of the major hydraulic parameters that has a significant influence on biological processes, therefore examining velocity changes in relation to riverbed geometry alterations can serve as an additional criterion for the assessment of the revitalization measures.

It is important to note, that, even if a riverbed modification is hydraulically feasible, it cannot ensure a proper revitalization effect unless supported by a study of the impact on water quality indicators. Research on river hydraulics aimed at establishing favourable hydraulic conditions for biological processes tend to be a key in defining efficient river restoration methods (Langbein and Durum, 1967; Macura et al., 2016; Ugbebor et al., 2012). To have a sustainable effect on river health, process-based restoration (Beechie et al., 2010), which is a complex, long-term, multistage iterative endeavour, can be considered a more efficient approach. However, examination of the physical (hydraulic) parameters is an indispensable stage of this approach.

CONCLUSIONS

In urban areas, the potential for river restoration is limited by urban development, making it challenging to define an effective restoration plan. In the view of limited available survey data, which is quite common for small rivers, developing of a numerical model that reproduces the general features of the key hydraulic parameters can serve to the assessment of the hydraulic feasibility of proposed riverbed modifications. Alongside this, individual criteria for the hydraulic performance of riverbed modifications should be used to assess the efficiency of river restoration planning. The outlined approach to hydraulic feasibility assessment was applied to explore revitalisation methods for the Ustia River.

Calibrating the model made it possible to obtain estimates of the channelized bed invert elevations, which were unavailable from other sources. That can be considered one of the main practical outcomes of the model development.

With the riverbed slopes identified in different sections, the effect of removing damming structures as a part of the revitalization actions, alongside alterations to the riverbed geometry, was demonstrated.

The approach used for model calibration, based on the water surface elevations, can be appropriate for small channelized urban river sections with simple geometry. It can represent the main specifics of a river's hydraulic profile and can be implemented in cases where survey data is lacking.

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ANALIZA METOD ODBUDOWY RZEKI USTIA NA TERENIE MIASTA RÓWNE

Streszczenie

Cel badania
W artykule opisano aktualny stan rzeki Ustia. Rzeka ta zmaga się z zanieczyszczeniem i wykazuje oznaki degradacji. Brak danych pomiarowych stanowi kluczowe ograniczenie dla badań mających na celu udoskonalenie kształtu koryta rzeki. W niniejszym artykule przedstawiono ocenę możliwości realizacji różnych wariantów ukształtowania koryta rzeki z punktu widzenia hydrauliki, co stanowi punkt wyjścia do opracowania planu jej rewitalizacji.

Materiały i metody
Przeanalizowano historyczne mapy obszaru w pobliżu Równego, aby ustalić zmiany przebiegu rzeki. W opracowaniu wykorzystano dane z dostępnych badań jakości wody oraz terenowych pomiarów hydrologicznych. Przeprowadzono modelowanie za pomocą programu HEC-RAS 1D w celu zweryfikowania założenia dotyczącego niskich prędkości przepływu oraz oceny wykonalności hydraulicznej proponowanej koncepcji modyfikacji koryta rzeki.

Wyniki i wnioski
W badaniu wykazano, że drastyczny spadek jakości wody można przypisać najnowszym przeobrażeniom koryta rzeki oraz rozwojowi miasta Równe. Na znacznej części odcinka przebiegającego przez obszar miejski koryto rzeki osiąga niskie poziomy wypełnienia w okresach niżówki. Aby rzeka zachowała zdolność do samooczyszczenia, średnie prędkości przepływu muszą być wyjątkowo niskie. Z punktu widzenia hydrauliki rzecznej oraz biorąc pod uwagę ograniczenia związane z otoczeniem miejskim, jako metodę odbudowy ekosystemu można rozważyć działania mające na celu poprawę warunków w korycie rzeki. Opracowanie modelu numerycznego koryta rzeki mogłoby zapewnić użyteczne narzędzie do wykonania planu rewitalizacji, służące do oceny wykonalności hydraulicznej różnych wariantów rozwiązań.

Słowa kluczowe: rzeka miejska, odbudowa, degradacja rzeki, hydraulika rzeczna, wykonalność hydrauliczna