Vol. 4, No. 1, 2022

https://doi.org/10.23939/jtbp2022.01.086

Roman Hnativ[1], Oleg Yakhno[2] and Ihor Hnativ[3]

ANALYSIS OF FACTORS INFLUENCING THE FORMATION OF THE CHANNEL FLOW OF THE RIVERS OF PRYKARPATTIA

Lviv Polytechnic National University,
[1] Department of Hydrotechnics and Water Engineering;
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute",
[2] Department of Applied Hydroaeromechanics and Mechanotronics;,
Lviv National University of Nature Management,
[3] Department of Ecology
gnativ.roman.m@gmail.com

© Hnativ R., Yakhno O., Hnativ I., 2022

Channel processes are the most dynamic exogenous geomorphological processes. This scientific field of research has many complex scientific problems and has long been developed in Ukraine and around the world in various fields of science, namely geomorphology, hydrology and technical sciences. The channel process is in constant and close connection with the geological, geomorphological, climatic and soil conditions of the territory. The composition of the weathering products and the yield on the surface of the bedrock determines, together with the above factors, the amount of solid material carried away by water, and at the same time the changing shape of the channel of these flows. A study of changes in channel processes in the Prykarpattia region, which confirmed the development of active exogenous processes in mountain river basins, especially in sloping areas.

Key words: channel processes; riverbed networks; sediment movement; watersheds; exogenous processes; mountain rivers; flow of rivers.

Introduction

The movement of liquids and solid particles, caused by the influence of liquids on them, form a phenomenon that occurs in nature on rivers and flowing bodies of water, and such currents are called channel streams. A feature of the channel flow is the interaction between the velocity field, which is formed under the influence of boundary surfaces and the channel, the shape of which is formed in turn under the influence of the velocity field.

This interaction leads to the formation on the earth's surface of channel forms, extremely elongated in the direction of water runoff and very limited in width. Channel shapes change continuously, under some conditions quickly, and in others slowly, usually under the influence of climatic factors, namely the annual cycle of precipitation and temperature and partly tectonic factors. The whole complex of phenomena as the primary formation of channel forms and their subsequent changes is called the channel process (Baryshnikov, 2016).

The channel process is in constant and close connection with the geological, geomorphological, climatic and soil conditions of the territory. Climate, in particular precipitation and temperature, determines the amount and distribution over time of water masses from the atmosphere of the area. The paths and flow rates of these water masses are determined by the terrain, which in turn changes under the influence of tectonic processes. The composition of the weathering products and the yield on the surface of the bedrock determines, together with the above factors, the amount of solid material carried away by water, and at the same time change the shape of the channel of these flows. Vegetation, which increases the connectivity of the fertile soil layer with its root system, affects the course of the channel process, sometimes slowing down and complicating lateral erosion, thus increasing the intensity of deep erosion.

The foothills of the Stryi River and other right tributaries of the Dniester, mainly belong to the type of semi-mountain rivers. It is characterized by very active transformations of the channel with the formation of various forms of channel relief, so it is an important area of hydroecological research. The purpose of this article is to analyze the horizontal deformations of the Stryi riverbed for the period 2002–2017 and to study the influence of major factors on the transformation of the riverbed, erosion and landslides in the Prykarpattia.

Channel processes are the most dynamic exogenous geomorphological processes. This scientific field of research has many complex scientific problems and has long been developed in Ukraine and around the world in various fields of science, namely geomorphology, hydrology and technical sciences. Such research is conducted at Kyiv, Lviv, Chernivtsi universities, Lviv Polytechnic National University and other scientific institutions. The river valleys of the Carpathian region are well studied, in particular, classifications of riverbeds according to various criteria have been created, vertical and horizontal deformations of individual river valleys have been studied. Studies of channel changes were also conducted in the valley of the Stryi River, channel changes at different time intervals were analyzed, and types of channels and meanders were identified (Horishnyy, 2014; Obodovsky, 1998).

When studying the mechanism of river flow, it is first necessary to take into account its peculiarity and the sharp difference between natural and artificial flows. This feature is the interaction between the stream and the channel. During the flow of artificial flows in pipes and channels, design, calculation and construction of the channel shape are carried out so as to pass the required flow rate for the specified hydraulic characteristics, namely slope, speed, etc. This channel is designed so that it is constant and not affected by the flow. Under natural conditions, river flows themselves create a channel of the appropriate shape, in turn, and the channel in its form affects the velocity field of the flow, ie the channel and the flow are in a certain interaction.

In nature, there are no rivers with a calm flow with a rocky bed or, conversely, turbulent rivers with a bed that is easily washed away. They do not exist because the river could wash away all the small materials of its bed and expose the rocky bottom only at very high speeds, and fine sandy or muddy bottoms cannot be maintained at high speeds. In natural channel flows, as a result of long-term interaction of flow and channel, a special relationship is formed between the slope, flow rate, channel shape and particle size (Baryshnikov, 2016).

Such conditions can occur not only on the plain, but also in the foothills adjacent to the plain, where mountain-type rivers carry enough crushed solid material and deposit it along the course. There is no reason to assume that in these conditions morphometric dependences will have a significantly different appearance from the plane conditions. On mountain rivers flowing in narrow gorges along a bed of practically indelible rocks, only partially covered with movable material due to falling from lateral debris, the issue of morphometry is fundamentally different and very little studied.

Materials and Methods

Thanks to the long-standing system of hydrological monitoring, the hydrological parameters of the river network of the Stryi River are among the most fully studied in the Dniester River basin. In different periods, a total of 15 hydrological posts and observation points for the hydrological regime of the rivers of this basin operated here. Today there are 11 posts and one hydrological station “Stryi”. System hydrological observations allow us to identify the most important features of the Stryi river basin, namely the patterns of changes in the state of the hydro system over time, which depend mainly on climatic conditions (Horishnyy, 2014). We conducted a study of changes in riverbed processes in the Carpathian region by comparing satellite images 2002–2017 with topographic plans in 1992 and 2008, which showed that changes in the bed of the Stryi River run along its entire length.

Results and discussion

Streams, rivers and flows of groundwater are the system of water supply of territories. The water formed in the catchment areas flows down through surface channels and underground paths, depending on the nature of precipitation and the dynamic shape of river basins. The catchment landscapes are shaped by the region's long geological and biological history, as well as current events such as floods, fires and man-made environmental impacts, including deforestation, dam construction and anthropogenic pollution.

Within the catchment area, flow channels usually increase in size and complexity in the direction of flow (Fig. 1). The smallest or first-order flows in the network often start as runoff from snow areas or other sources. Two first-order streams combine to form a second-order channel, and so on, to form a network (Hauer and Lamberti, 2007). A large river, such as the Dniester, often has several large tributaries, and each can feed from several to many smaller streams (Fig. 1). Thus, each large watershed has many sub-basins. Erosion capacity usually increases with the size of the flow. Boulders, gravel, sand and silt are transferred from one section of the channel network to another depending on the runoff and geomorphometry of the valley. Sedimentary zones, called floodplains, form between steep valleys (Ward, 1989; Stanford et al., 2005).

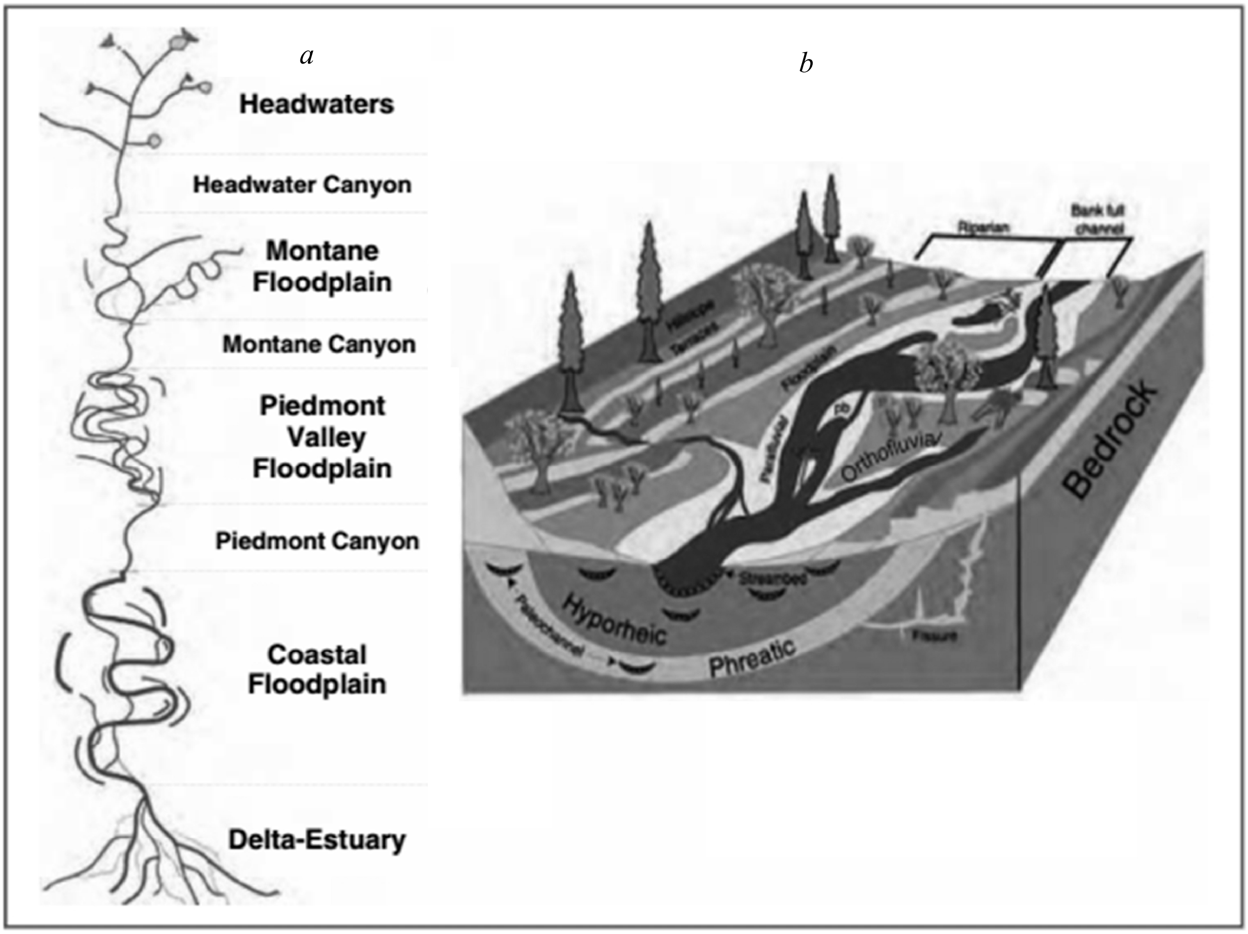

Fig. 1. General view of the formation of the river network (a) and the longitudinal distribution of floodplains and valleys within the river with a three-dimensional structure of alluvial floodplains (b) (Hauer and Lamberti, 2007)

Fluid dynamics have been studied in detail over the last two centuries, but the complexity of hydraulic phenomena in running water has not been fully analyzed. The traditional methods used by engineers to design open channels are empirical. They are usually solved by neglecting the boundary layers, turbulent vortices and the distribution of parts of the flow that move in the natural channel in different directions. This complexity of the flow is related to the actual conditions of its movement.

In the extensive network of riverbeds there are tributaries of different orders, which flow into the main river (Fig. 2). On the scale of the catchment (Fig. 2, *a*), the hydraulic state of the flow is generalized as uniform or gradually variable from top to bottom in the longitudinal profile of the flow. Uniform flow conditions occur when the slope of the water surface and the channel are approximately parallel with a slight change in the cross-sectional area of the flow. In many natural flows, especially downstream, uniform flow equations with correction factors are used to take into account the main flow obstacles and turbulent energy losses created by local flow inhomogeneities (Millar, 1999). Conventional flow assumptions with correction factors for natural channels and floodplains are an integral part of runoff and flow models used to model riverbeds and floods. Reducing the complexity of the flow, which is necessary to solve these problems, is a shortcoming in forecasting real flows and the formation of channels (Kondolf et al., 2000; Hauer and Lamberti, 2007).

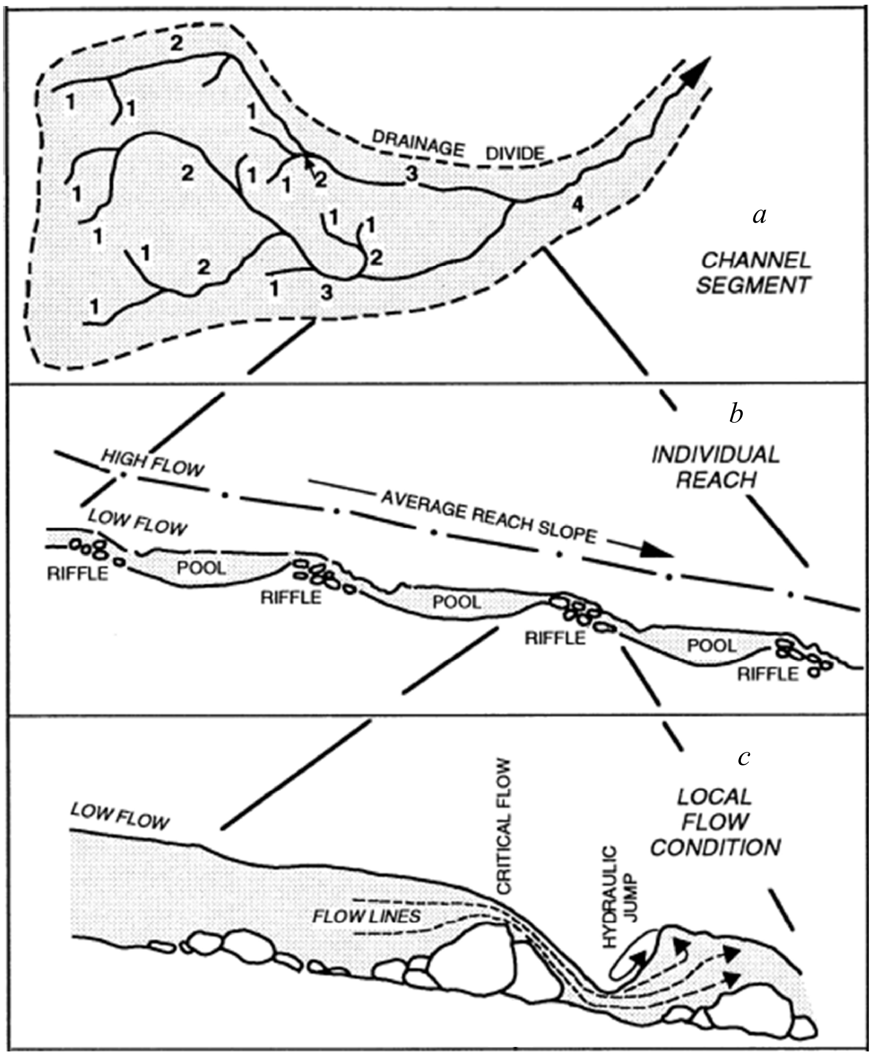

Fig. 2. Hydraulic conditions in the flow, considered from different scales (Hauer and Lamberti, 2007)

In the scale of the flow length (Fig. 2, *b*) can be identified areas of inhomogeneous flows. On moving channels, the natural sinusoid, accompanied by flood flows, forms pools and shoals located at a distance of 2 to 6 times the width of the channel. On the scale of the river section (Fig. 2, *c*), individual flow lines and flow states can be delineated and partially analyzed using equations for rapidly changing, inhomogeneous flows. The local velocity and depth of the flow is dominated by its momentum and gravity, rather than ultimate friction (Gregory et al., 1994; Hauer and Lamberti, 2007).

Solid runoff in our river basin differs significantly, as differences in the values of solid runoff in mountainous and flat parts of the basin indicate the influence of the hydrodynamic regime of different sections of the flow. During periods of floods and flooding, debris and its fractional redistribution are deposited. If we take into account the processes of landslides and linear erosion, the value of total denudation is about 1.5–3.0 mm/year, which corresponds to the intensity of tectonic movements in the Skibovy Carpathians and Precarpathians. Hydromorphological studies have shown that, depending on the type of river, in 50–100 years it can shift by much more than its width, forming new channels, branches and changing the configuration of the channel. This should be taken into account when designing and constructing hydraulic structures, when crossing power lines across rivers, laying gas and oil transportation networks and other work related to channel processes. Displacement of the channel has a significant impact on environmental processes, especially to determine the areas of flooding and the extent of destruction after occurrence floods or flooding (Burshtynska et al., 2019; Hajdukiewicz et al., 2016).

Deformations of the channel are a consequence of the development of denudation processes in the basin, increasing the volume of solid runoff and sedimentation of debris, as well as its fractional redistribution in the channels, which increase especially during floods and flooding. They cause changes in the hydrological regime and structure of the river system, the destruction of residential and commercial buildings, as well as floodplain infrastructure (Kovalchuk et al., 2013; Mykhnovych and Pylypovych, 2017). Neglecting the planned and high-altitude displacements of riverbeds often leads to unpredictable consequences. Erosion of the shore can lead to the rupture of a gas or oil pipeline, leading to a strong explosion and fire, as well as pollution of the river with petroleum products and environmental damage. Channel processes are associated with the washing of bridge piers, power lines, significant material losses and even casualties during floods and inundations. (Watson and Basher, 2005; Hu et al., 2017).

The analysis showed that the riverbeds of the Carpathians are very unstable and are characterized by intense erosion of the shores and bottom. The average value of bottom erosion is in the range from 1 to 60 mm/year for the last 20–30 years. Coastal erosion ranges from a few centimeters to 1.5–3.7 meters per year. The changes revealed as a result of the analysis of longitudinal profiles have shown that they are caused by natural and anthropogenic factors. This is a man-made activity, which includes the development of gravel quarries in floodplains and riverbeds and their straightening, regulation of runoff, changes in forestry and land use. Natural factors, such as climate change and water runoff, etc., are also affected (Allan and Castillo, 2007; Richards et al., 2002).

The main reasons for the intensification of erosion processes in the Stryi river basin and its tributaries are gravel extraction from the riverbed near city of Stryi and increased water runoff during floods, which is noticeable on the longitudinal profiles of the analyzed rivers. This is also confirmed by the nature of the spread and development of vertical deformations in other river systems of the Ukrainian Carpathians (Kovalchuk et al., 2013). Selection of gravel and pebble material and straightening of riverbeds are characteristic of almost all river systems of the upper Dniester basin. The presence of sand-gravel mixtures on the channel territory encourages their extraction, which is often unauthorized, which causes deformation processes of the riverbed and its banks (Snitynskyi et al., 2019; Snitynskyi et al., 2020).

In scientific works (Burshtynska et al., 2017; Burshtynska et al., 2018) the Stryi River was monitored for a 128-year period from the village of Dovhe to the town of Zhydachiv, Stryi district, Lviv region. The riverbed is conventionally divided into mountainous, foothill and plain parts. The length of the foothills of the river is 50 km, it is located between the village of V. Sinyovidne and the town of Gnizdychiv, Stryi district, Lviv region and is characterized by significant multi-sleeve river. In 1886, the maximum width of the multi-sleeve was up to 1.5 km, the river was divided into 3–4 sleeve. After almost 100 years (1989), the width between the extreme sleeve decreased to 500 m, but in the satellite image of 2000 there is a significant intertwining of the channel, and in the image (2014) the riverbed of Stryi River in this area is one-sleeved, indicating reducing the water content of the river. In the foothills, the channel is shifting in the north-western direction and poses a threat of flooding of the Kyiv – Chop highway of international importance. It is indicated that the reason for the change in the nature of the channels is the significant influence of anthropogenic factors, namely the selection of gravel-sand materials (Burshtynska et al., 2018; Rudko and Petryshyn, 2014).

We conducted a study of changes in the channel processes of rivers in the Prykarpattia region, which confirmed the development of active exogenous processes in mountain river basins, especially in sloping areas (Fig. 3, 4).

Fig. 3. Removal of sand and gravel deposits in the Stryi riverbed

Fig. 4. Destruction of the shoreline and floodplains in the Stryi riverbed

Conclusions

During the research period, significant changes took place in different parts of the Stryi riverbed. In the area near the village of Pokrivtsi, the multi-sleeve of the riverbed has decreased compared to 1978. The number of islands decreased, but a long island was formed near the village of Strygantsi, and the channel shifted to the north.

In the lower reaches of the Stryi River, two sections with different morphodynamic type of channel can be distinguished. Slightly winding and branched into sleeves in the section Strygantsi – Zhydachiv and with mostly free meandering from the town of Zhydachiv to the village of Zaliski. Analyzing topographic maps of different years, periodic general increase or decrease of meandering of the channel was revealed. The process of natural dynamics of the channel has anthropogenic factors, which consist in its artificial straightening and its change in some areas.

References

Baryshnikov N. B. (2016). Dynamics of channel flows. Textbook. Ed. 2nd, revised and additional. St. Petersburg: RSGM. 342 p. (in Russian). https://www.twirpx.com/file/3530351/

Horishnyy P. (2014). Horizontal deformations of the lower reaches of the Stryi riverbed in 1896–2006. *Problems of geomorphology and paleogeography of the Ukrainian Carpathians and adjacent territoriesm,* 68–74 (in Ukrainian). https://geography.lnu.edu.ua/wp-content/uploads/2017/05/Horishnyy-Horyz-deform.pdf

Obodovsky O. G. (1998). Channel processes: textbook manual. Kyiv: RVC Kyiv. un-ty. 134 p. https://www.twirpx.com/file/1552674/

Hauer F. Richard and Lamberti Gary A. (2007). Methods in Stream Ecology (Second Edition), *Academic Press Academic,* 896. https://doi.org/10.1016/B978-0-12-332908-0.X5001-3.

Ward, J. V. (1989). The four-dimensional nature of lotic ecosystems. *Journal of the North American Benthological Society,* 8:2–8. https://doi.org/10.2307/1467397.

Stanford, J. A., Lorang M. S. and Hauer F. R. (2005). The shifting habitat mosaic of river ecosystems. *Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie* 29:123–136. https://doi.org/10.1080/03680770.2005.11901979.

Millar R. (1999). Grain and form resistance in gravel-bed rivers. *Journal of Hydraulic Research.* 37:303–312. https://doi.org/10.1080/00221686.1999.9628249.

Kondolf G. M., Larsen E. W., and Williams J. G. (2000). Measuring and modeling the hydraulic environment for assessing instream flows. *North American Journal of Fisheries Management,* 20:1016–1028. https://doi.org/10.1577/1548-8675(2000)020<1016:MAMTHE>2.0.CO;2.

Gregory K. J., Gurnell A. M., Hill C. T., and Tooth S. (1994). Stability of the pool-riffle sequence in changing river channels. *Regulated Rivers: Research and Management,* 9:35–43. https://doi.org/10.1002/RRR.3450090104.

Burshtynska H. V., Babushka A. V., Bubnyak I. M., Babiy L. V., Tretyak S. K. (2019). Influence of geological structures on the nature of riverbed displacements in the upper part of the Dniester basin. *Geodynamics,* Vol. 2 (27). 26–40 (in Ukrainian). https://ena.lpnu.ua/handle/ntb/52220.

Hajdukiewicz H., Wyżga B., Mikuś P., Zawiejska J., Radecki-Pawlik A. (2016). Impact of a large flood on mountain river habitats, channel morphology, and valley infrastructure. *Geomorphology,* Vol. 272, 55–67. https://doi.org/10.1016/j.geomorph.2015.09.003.

Kovalchuk I., Mykhnovych A., Pylypovych O. and Rud'ko G. (2013). Extreme Exogenous Processes in Ukrainian Carpathians. Book chapter in: Geomorphological impact of extreme weather: Case studies from central and eastern Europe. *Loczy Denes. Series: Springer Geography,* Part 1, 53–67. https://www.researchgate.net/ publication/ 323965793_ Extreme_ Exogenous_Processes_in_Ukrainian_Carpathians_Book_chapter_in_Geomorphological_ impact_of_extreme_weather_Case_studies_from_central_and_eastern_Europe.

Mykhnovych A. V., Pylypovych O. V. (2017). Riverbed deformations in the upper Dnister catchment under gravel-pits exploitation. *Problems of geomorphology and paleogeography of the Ukrainian Carpathians and adjacent territories,* 1, 112–122. http://nbuv.gov.ua/UJRN/prgeomorpal_2017_1_11.

Watson A. J., Basher L. R. (2005). Stream bank erosion: a review of processes of bank failure, measurement and assessment techniques, and modelling approaches. Integrated Catchment Management Programme. *Report Series: Bank erosion review. Landcare ICM Report,* No. 2005–2006/01, 32. https://icm.landcareresearch.co.nz/ knowledgebase/ publications/public/ICM_report_bank_erosion.pdf.

Hu Z., Wang L., Tang H., Qi X. (2017). Prediction of the future flood severity in plain river network region based on numerical model: A case study. *Journal of Hydrology,* Vol. 29 (4), 586–595. https://doi.org/10.1016/S1001-6058(16)60771-0.

Allan David J., Castillo María M. (2007). Stream Ecology. Structure and function of running waters (Second Edition). *Springer*, 436. https://doi.org/10.1007/978-1-4020-5583-6.

Richards K., Brasington J., Hughes F. (2002). Geomorphic dynamics of floodplains: ecological implications and a potential modelling strategy. *Freshwater Biology,* Vol. 47, 559–579. https://doi.org/10.1046/j.1365-2427.2002.00920.x.

Snitynskyi V., Khirivskyi P., Hnativ I., Yakhno O., Hnativ R. (2019). Changing aquatic ecological systems of the foothills of the Dniester river basin under anthropogenic loading. *INTERNATIONAL SCIENTIFIC CONFERENCE 15 – 16 November 2019, GABROVO*, 279–283. https://unitech.tugab.bg/

Snitynskyi Volodymyr, Khirivskyi Petro, Hnativ Ihor, Hnativ Roman (2020). Landslides and erosion phenomena in the foothills of the Carpathian region rivers. *Theory and building practice.* Lviv: LPNU, Vol. 2, No. 1, 9–15. https://doi.org/10.23939/jtbp2020.01.009.

Р. М. Гнатів[1], О.М. Яхно[2], І.Р. Гнатів[3]

[1] Національний університет “Львівська політехніка”,
кафедра гідротехніки та водної інженерії;

[2] НТУУ “Київський політехнічний інститут імені Ігоря Сікорського”,
кафедра прикладної гідроаеромеханіки і механотроніки;

[3] Львівський національний університет природокористування,
кафедра екології

АНАЛІЗ ФАКТОРІВ ВПЛИВУ НА ФОРМУВАННЯ РУСЛОВОГО ПОТОКУ РІЧОК ПРИКАРПАТТЯ

© Гнатів Р. М., Яхно О. М., Гнатів І. Р., 2022

Руслові процеси є найдинамічнішими екзогенними геоморфологічними процесами. Цей науковий напрям досліджень вирішує багато складних наукових проблем та давно розробляється в Україні та у світі в різних галузях науки, а саме геоморфології, гідрології та технічних науках. Русловий процес постійно та тісно зв’язаний із геологічними, геоморфологічними, кліматичними та ґрунтовими умовами цієї території. Склад продуктів вивітрювання і вихід на поверхню корінних порід визначає спільно із вищевказаними факторами кількість твердого матеріалу, що зноситься водою, а разом із тим і зміну форми русла цих потоків. Досліджено зміни руслових процесів річок Прикарпатського регіону, які підтвердили розвиток активних екзогенних процесів у басейнах річок гірських річок, особливо на схилових територіях.

Основними причинами активізації ерозійних процесів у басейні р. Стрий та її приток є забір гравію із русла річки біля м. Стрий та збільшення стоку води під час повеней, що відображається на поздовжніх профілях аналізованих річок. Цей висновок підтверджується також поширенням та розвитком вертикальних деформацій в інших річкових системах Українських Карпат.

Відбір гравійно-галькового матеріалу та випрямлення русел річок характерні майже для всіх річкових систем верхньої частини басейну Дністра. Наявність на русловій території піщано-гравійних сумішей спонукає до їх видобування, яке часто є несанкціонованим, що спричиняє деформаційні процеси русла річки та її берегів. Легкі за механічним складом ґрунти розмиваються, особливо під час паводків. Це спричиняє розвиток ерозійних процесів у руслах та на прилеглих територіях.

Ключові слова: руслові процеси; мережі річкових русел; переміщення наносів; водозбірні басейни; екзогенні процеси; гірські річки; річкові течії.