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Analysis of anthropogenic transformation of the hydrographic network in the northern part of Lviv according to cartographic sources

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Abstract. The emergence of new and densification of existing urban spaces in Lviv leads to anthropogenic transformation of the hydrographic network. The purpose of the study was to analyse the degree of transformation of water objects in the northern part of the city based on cartographic sources. The study covered the northern part of Lviv, the town of Dublyany, the villages of Malekhiv, Velyki Hrybovychi, Zbyranka and Murovane. The study of water bodies was carried out with topographic maps of the scale range from 1:25,000 to 1:100,000, which made it possible to cover a time period of more than 240 years. Clear trends to decrease the length of open channels, the number of tributaries and the water content of the Holoskivskyy, Zboivskyy and Malekhivskyy streams, which is due to both natural and anthropogenic factors had been marked. The length of the natural channel of the Holoskivskyy stream decreased from 4.7 to 0.9 km, the Zboivskyy stream – from 5.2 to 3.2 km, and the Malekhivskyy stream – from 7.9 to 5.3 km. The largest number of ponds (15 units; 10.3 hectares) on streams was found in the second half of the 18th century. Subsequently, a decrease in both the number and area of ponds was observed. The lowest figures fall on the interwar Polish period, when only four ponds with a total area of 2.5 hectares were recorded. During the Soviet period, the number and area of ponds increased slightly (9 units; 4.6 hectares) and reached the level that existed in the second half of the 19th century. There were 14 water mills operating on most of the ponds of that time located in the villages of Holosko Velyke, Zamarstyniv, Zboyishcha and Malekhiv. After that, the number of mills steadily decreased: at the beginning of the 19th century – nine; in the second half of the 19th century – seven; in the interwar period – five. After the World War II, the operation of all water mills was stopped. The conducted analysis of the degree of transformation of the hydrographic network is aimed at correcting the development plan of the northern part of the city and implementing the environmental management system

Keywords: hydrographic network; stream; river bed; pond; topographic map

Introduction

The issue of protecting and preserving watercourses and reservoirs in Lviv and its agglomeration is crucial for environmental, social, and economic reasons and involves maintaining biodiversity and landscape diversity, providing water to the population and economy, regulating the microclimate, creating recreational opportunities, etc. Water bodies in regions where there is a shortage of surface water are becoming important. Taking into account global

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climate changes, terrain features and watershed locations, Lviv belongs to such a region itself. In fact, the entire hydrographic network of the city is hidden in collectors, and there are no large water bodies within its boundaries, which is why the watercourses and reservoirs that remain in the city or are located within the Lviv agglomeration are of particular value to residents. In view of this, any measures and steps related to the restoration, preservation and protection of water bodies within Lviv and its agglomeration are of great importance.

The issue of anthropogenic transformation of the hydrographic network has been considered in many publications, in particular, the problems of economic impact on water bodies are discussed in the paper by V. Andreev *et al.* (2021). Geoecological studies of river basins are described in the works of L. Tsaryk *et al.* (2020) and I. Khomiak *et al.* (2022). In this study, the main aspect of the description of the study area is focused on the Holoskivskyy, Zboivskyy, and Malekhivskyy streams, which belong to the basin of the main river of the city, the Poltva. These streams operate under specific conditions, as the Main European Watershed, which divides the Baltic and Black Sea basins, runs through the upper reaches of their basins. The analysed streams have similar conditions for the formation and development of their valleys and floodplains, but differ in the level of their anthropogenic transformation. The studied streams are located in the basin of the transboundary Western Bug River, which is heavily transformed and polluted in the study area (Khilchevskyi *et al.*, 2018), in particular due to the Poltva tributary, which is the main collector of Lviv (Kurhanevych & Shipka, 2020). The features of the construction and operation of this collector are described in the monographic work of O. Karelin (2021). As of 2024, most of the water bodies in the study area are in unsatisfactory hydroecological condition, are heavily polluted, and require channel cleaning and a number of optimisation measures aimed at complying with the Water Code of Ukraine (1995) and establishing the boundaries of coastal protection strips of 25 m in width.

Cartographic materials serve as the basis for studying the conditions of formation of natural landscapes and the degree of their anthropogenic transformation. To recreate a retrospective of the dynamics, development, and consequences of natural and anthropogenic processes in the studied area, cartographic sources from different historical periods are important. They should be used to analyse the location, current state, and development of natural and economic systems, and to study the place names of geographical objects of the time. Researcher E. Ivanov (2018; 2019) has accumulated experience in retrospective geographical research using topographic (cadastral) maps of different time periods on a scale from 1:25,000 to 1:100,000. The use of cartographic information involves solving various technical issues related to the determination of the scale of topographic maps for the values of hydrological parameters of the river network, as in A. Selehieiev *et al.* (2023), and the analysis of morphometric parameters and the design of thematic maps using a raster geoprocessing tool, as in H.S. Çadraku (2022). The historical cartographic sources of Lviv and their interpretation should also be focused on. Among the reviews, attention should be paid to publications that analyse topographic maps and plans of Lviv in various historical sections – from Austrian to Soviet (Sossa, 2020). However, most historical maps and plans of the city do not cover the study area, so the purpose of this work was to conduct a comparative analysis of the degree of anthropogenic transformation of water bodies and to outline their hydroecological status.

Materials and Methods

An area covering the northern part of Lviv was selected for the hydrological and hydroecological study, as well as the settlements of the Lviv City Territorial Community bordering it from the northeast – the town of Dubliany, the villages of Malekhiv, Velyki Hrybovychi, Zbyranka, and Murovane. In June 2024, a field survey of the study area was conducted to determine the current state and degree of anthropogenic transformation of the hydrographic network in the northern part of Lviv. The survey included an inspection of the state of water bodies, determination of their hydrological parameters, water sampling and photographic recording. At the same time, local residents were interviewed, and their assistance was provided in finding the remains of some watercourses and reservoirs. This made it possible to clarify map information that has not been updated for more than 30 years.

The scale of the study was chosen for analysing various cartographic geodata. The study of the conditions of emergence and formation of modern landscapes in the northern part of Lviv was carried out on the basis of topographic maps of the scale of 1:25,000-1:50,000. The historical and cartographic collections of the Cabinet of Cartography of the Vasyl Stefanyk Lviv National Scientific Library, the Central State Historical Archives of Ukraine in Lviv, and various online cartographic sources (Lomnicki, 1899; Arcanium maps, n.d.; Military Geographical Institute..., n.d.; Topographic maps..., n.d.) were studied. The topographic maps of the appropriate scale for five retrospective geographical periods (individual topographic surveys, metrics) were selected, which allowed to cover a chronological period of more than 200 years (from the second half of the 18th to the second half of the 20th and early 21st centuries), in particular: Austrian maps of the First Topographic Survey (1779-1783), scale 1:28,800; Austrian maps of the Second Topographic Survey (1819-1820), scale 1:28,800; Austrian maps of the Third Topographic Survey (1869-1887), scale 1:25,000; Polish maps of the Military Geographic Institute (1929-1939), scale 1:25,000; Soviet maps of the General Staff of the USSR (1968-1989), scale 1:50,000. According to the regulation on the use of cartographic data, which was exacerbated during the Russo-Ukrainian War, there is a ban on publishing a more detailed scale.

The choice of cartographic materials has led to the need for relatively equal time intervals between topographic surveys, which in this case is 40-60 years. The first topographic surveys occurred during the period of the Austrian Empire, which accompanied the cadastral metrics (land surveys) of the studied territory. Based on these metrics, the first maps suitable for retrospective geographical analysis were compiled. Interwar Polish and postwar Soviet maps were also relevant for this analysis, as they were similar in scale and in the way they depicted the topographic situation. To enhance the interpretation of the cartographic materials, sheets of other topographic maps were used: Austrian, scale 1:75,000 (1890s); interwar Polish, scale 1:100,000 (1920s-1930s); Soviet, scale 1:100,000 (1990s).

At the same time, cartographic works on the studied territory from other countries and time periods were analysed, which turned out to be unsuitable for retrospective geographical analysis of the anthropogenic transformation of the hydrographic network in the northern part of Lviv. Topographic maps for different historical periods compiled by the military topographic departments of the Russian Empire, Germany, and the United States were used. The selected maps are compilation maps, built using the topographic foundations and cartographic information of the above-mentioned Austrian and Polish maps of previous time periods. Materials from the period of World War II at a scale of 1:100,000 were used, namely German (1939) and American (1944) topographic maps. The Google Maps (n.d.) and Geoportal of Lviv (n.d.) mapping web services were used to clarify the current information on water bodies. However, these mapping resources lack a unified understanding of the location of water bodies in the city.

Results and Discussion

The Austrian maps of the First Topographic Survey, which are more than 240 years old, show an extensive network of watercourses that originate near the Main European Watershed and drain their own water into the Poltva (Western Bug River Basin). The study area is sloping from west to east, namely from the Roztochia uplands to the complex structure of the Pasmove (Hriadove) Pobuzhzhia, which is characterised by raised ridges and wide valleys. This slope determined the general direction of flow of all the studied watercourses, which have a clear northwest-southeast direction, mainly towards the wide Poltva River valley. The Malekhivskyy stream is mapped as a third-order watercourse, while the Holoskivskyy and Zboivskyy streams are mapped as second-order. It is possible that these streams were also classified as third-order watercourses, but this is not reflected on the topographic map (Fig. 1).

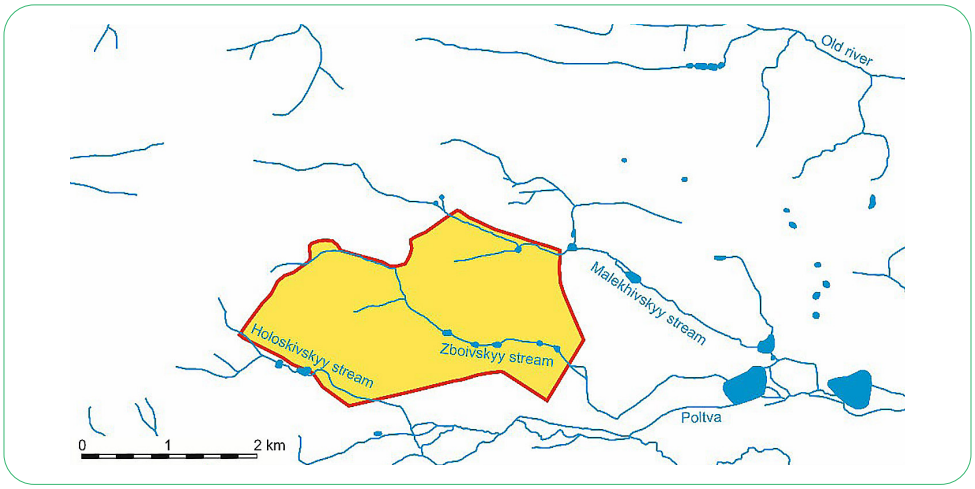

Figure 1. Anthropogenic transformation of water networks in the study area based on the analysis of the Austrian map of the First Topographic Survey (1779-1783)

Source: created by the authors

The oldest cadastral map is informative, showing geographical objects that reveal the water management activities of the time. The Holoskivskyy stream has two large (1.0 hectares each) and one small pond with water mills, as well as three dams with drained reservoirs. In Zamarstyniv, there are two flow-through mills on the stream. There are five small ponds on the Zboyishchia stream in the Zboyishchia Village, all with water mills. Four different-sized ponds with water mills and two more dams on drained reservoirs were found on the Malekhivskyy stream. The largest of them was the one with an area of more than 3.0 hectares. Thus, watercourses and reservoirs played an important role in the economy of the villages of Holosko Velykyi, Zamarstyniv, Zboyishcha, and Malekhiv.

The analysis of the Austrian maps of the Second Topographic Survey reflects the situation in the first half of the 19th century. This topographical map shows the network of watercourses in better detail and shows its branching down to the source. In this case, the studied streams are mapped as third-order watercourses (Fig. 2). As for the

number of ponds, it has increased to six ponds at both Holoskivskyy and Zboivskyy streams. Most of them housed water mills. No ponds were recorded on the Malekhivskyy stream during this period. The stream channels continue to be open along their entire length, are natural in nature and travel moderately through the valleys, and the presence of a significant number of ponds indicates that they are full of water. Stream valleys determine the structure of settlement in suburban villages. The extent of anthropogenic transformation of water bodies in the second half of the 19th century is shown on Austrian maps of the Third Topographic Survey. Based on this topographic map, it can be argued that the order of the Holoskivskyy and Zboivskyy streams has been reduced to the second order, while the Malekhivskyy stream remains a third-order watercourse (Fig. 3).

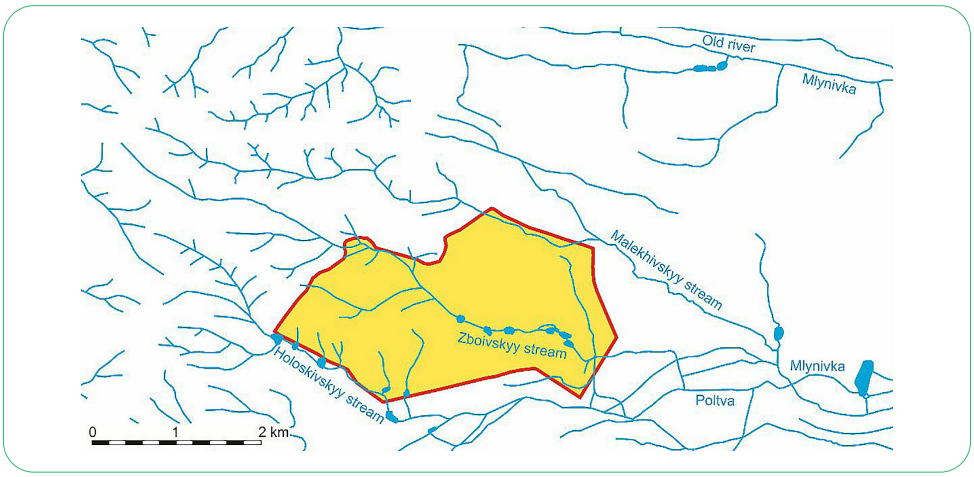

Figure 2. Anthropogenic transformation of water networks in the study area based on the analysis of the Austrian map of the Second Topographic Survey (1819-1820)

Source: created by the authors

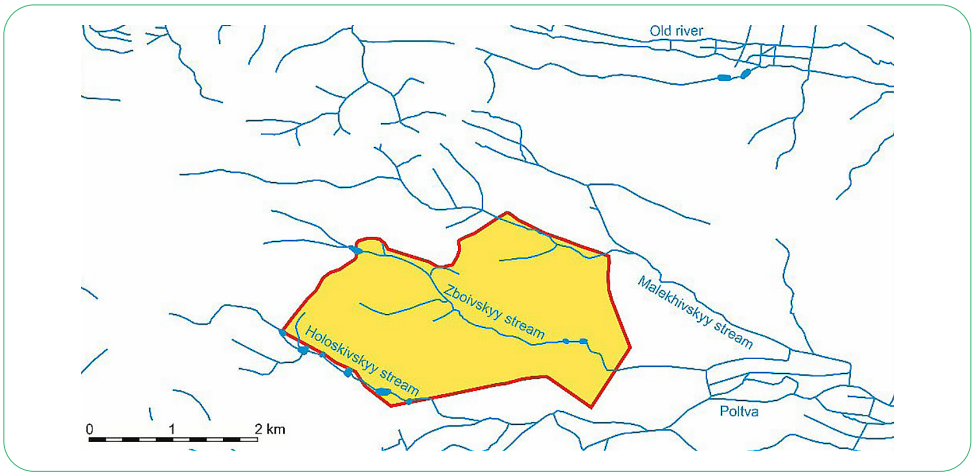

Figure 3. Anthropogenic transformation of water networks in the study area based on the analysis of the Austrian map of the Third Topographic Survey (1869-1887)

Source: created by the authors

This may indicate a certain decrease in the water content of the studied streams and the loss of some small tributaries. Six ponds with water mills continue to operate on the Holoskivskyy stream, in the villages of Holosko Velykyi and Zamarstyniv. The area of the largest ponds does not exceed 0.8-1.0 hectares. Another mill is located at the confluence of the stream with a separate branch of the Poltva River, which is labeled Mlynivka. The area in this neighborhood is called Stavky. In the Zboyishcha Village, the ponds are disappearing, and the only pond (0.8 hectares) in the valley of the Zboivskyy Stream is located in its upper reaches, in an area similarly named Stavky. In the valley of the Malekhivskyy stream, upstream from the Malekhiv Village, there is a water mill that operates at the speed of the stream's tributary.

In the early 20th century, Austrian topographic maps were updated to a scale of 1:75,000. Despite its smaller scale, they are highly informative. The number of water mills on the Holoskivskyy stream has been preserved, and one mill and several small ponds on the Zboivskyy

stream have been restored. On the other hand, no ponds or mills are registered on the Malekhivskyy stream. The natural and geographical patterns of the emergence and development of modern landscapes in the northern part of Lviv are associated with the formation of watercourse floodplains, which is well reflected on the map of quaternary sediments (Lomnicki, 1899). This map was created on the basis of the previously discussed topographic base. The valleys of watercourses are composed of alluvial deposits (sands, sandy loams), their width is not significant (up to 100 m), and in the lower part they widen slightly (up to 200-250 m). The lower part of the streams ends in the wide valley of the Poltva River.

It is worth considering the interwar period on the basis of Polish topographic maps of the Military Geographic Institute. The analysis of these maps allowed to identify a significant reduction in the number and shallowing of watercourses, which is associated with the intensification of agricultural development of the suburban areas of Lviv. The Malekhivskyy stream has become a second-order watercourse, while the Holoskivskyy and Zboivskyy streams are first-order streams that do not receive any tributaries (Fig. 4).

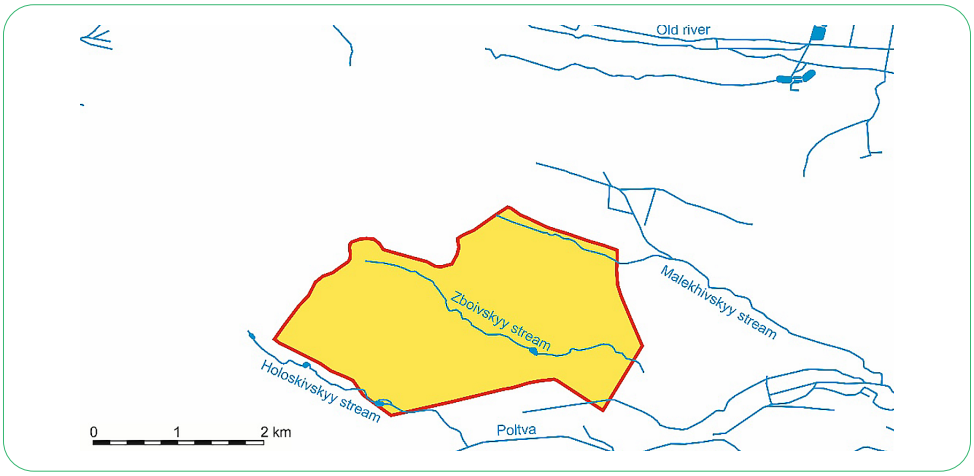

Figure 4. Anthropogenic transformation of water networks in the study area based on the analysis of the Polish topographic map of the Military Geographical Institute (1929-1939)
Source: created by the authors

At the same time, the Zboivskyy stream is lost just beyond the Zboyishchia Village, in the swampy Poltva valley. It is likely that the stream could not be investigated and flows into the Poltva downstream. At the same time, there is a significant reduction in the length of watercourses and a decrease in the number and area of ponds. Only three small ponds remain in the valley of the Holoskivskyy stream and one on the Zboivskyy stream. The only operating water mills (5 units) remained on the Holoskivskyy stream. At this stage of changes to the water supply network in the northern part of Lviv, the riverbeds in some areas were turned into underground or reclamation channels, and most of the ponds disappeared. In the early 20th century, the level of urbanisation increased and the water content of the city's rivers decreased. They were no longer able to transport suburban wastewater and began to turn into dirty ditches.

Polish topographic maps at a scale of 1:100,000 largely do not confirm the information from detailed topographic maps of the same period. There was an error in the mapping of the Holoskivskyy stream – it is not shown in the upper reaches, although water mills along the valley are marked. The Zboivskyy stream is classified as a second-order watercourse. The number of registered ponds also differs: two on the Holoskivskyy stream; five on the Zboivskyy stream; and one on the Malekhivskyy stream. The map also shows one water mill each on the Zboivskyy and Malekhivskyy streams. These inconsistencies may also be due to the borrowing of data from a previous Austrian topographic survey. During the World War II, two separate cartographic documents were created in Germany and the United States on the basis of Polish topographic works. Although these topographic bases are composite, hastily made, the way they are presented makes it possible to analyse the features of the valleys of the studied streams and to clarify the features of the hydrographic network during this period.

The retrospective geographical review of cartographic information was concluded by analysing topographic maps of the Soviet period, which reflect the situation as of the 1980s and 1990s. On topographic maps at a scale of 1:50,000, all watercourses are divided into natural and artificial (canals) streams. In particular, the open channel of the Poltva River then started from I. Mykolaichuk Str. During the development of the northern part of Lviv, the higher sections of the Poltva were sewered into the city's main collector. Intensive development also necessitated the sewerisation of the lower part of Holoskivskyy stream, which was caught in the dense urban development. There are two ponds in the open stream area, the largest of which is Stosyk Pond (0.9 hectares). In the lower part of the Holoskivskyy stream valley, two artificial reservoirs are depicted, which are practically connected with river activity. The open channel of

the Zboivskyy stream begins at the beginning of the quarter along Shchurat Str. and continues to flow along the Zboishchy District and under the bridge near the modern Halytskyi crossroads, and flows into the Poltva drainage canal system. A pond (0.6 hectares) is shown at the head of the stream, which was already diverting water to the collector. There was also a small pond on the stream not far from the Emergency Hospital. The Malekhivskyy stream underwent the least changes, its channel to the E372 (M-09) Lviv-Rava-Ruska Hwy. remained virtually unchanged with three small ponds. Due to the loss of water content in the upper reaches, the flow is shown as intermittent (seasonal). Below the road, the channel is partially canalised and receives a tributary with an extensive system of drainage channels, which closely fits and continues to drain infiltrates from the liquidated Hrybovychi landfill as of 2024. In general, the order of the studied watercourses has not changed compared to the previous mapping (Fig. 5).

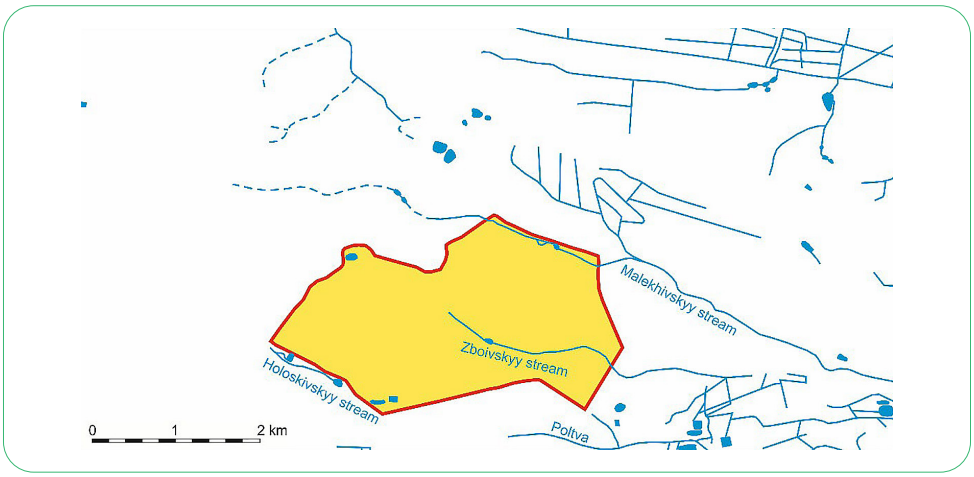

Figure 5. Anthropogenic transformation of water networks in the study area based on the analysis of the Soviet topographic map of the USSR General Staff (1968-1989)

Source: created by the authors

The Soviet period played a crucial role in the transformation of Lviv's waterways. During this period, the city's territory expanded significantly. Changes were particularly intense in the new neighbourhoods, where new residential and industrial districts were built. Large-scale work to block open streams in the northern part of Lviv was carried out in the 1970s and 1980s. Accesses to the middle and lower reaches, as well as to new construction sites, have been closed. Some springs, small ponds, and remnants of natural streams in park areas up to 1.0-1.5 km long remain. The beds of most watercourses were then filled up or hidden underground in collectors. According to G. the Poltva tributaries are piped over longer stretches: Holoskivskyy stream – 3.2 km, Zboivskyy stream – 0.6 km. Underground channels are also used for wastewater disposal.

Information from Soviet topographic maps at a scale of 1:100,000 is very generalised and duplicates data from more detailed topographic maps. The only difference is the presence of a pond on the Zboivskyy stream, in a downstream location. It is worth noting the increase in the length of watercourses in the Poltva and Yarychivka valleys (Yarychivka Canal), which is due to their drainage and canalisation. And the emergence of a large number of sedimentation ponds in the area of active operation of the Lviv sewage treatment plant and infiltration ponds at the Hrybovychi landfill.

Based on the review of the mapping information, the main hydrological parameters of the hydrographic network of the study area were measured, which are shown in Table 1. The analysed parameters include the length of the open part of watercourses. In the absence of their image on the topographic map, it was understood that the stream was in a collector or that there was no information. The number and area of ponds and the number of water mills were recorded, which gives an indirect idea of the water content of watercourses and their water use.

Table 1. Hydrological parameters of the hydrographic network of the study area

Parameters of watercourses and reservoirs / Topographic maps	Length of the open part of watercourses, km			Total number of ponds, units	Total area of ponds, hectares	Total number of watermills, units
	Holoskivskyy stream	Zboivskyy stream	Malekhivskyy stream			
Austrian map of the First Topographic Survey (1779-1783)	4.7	5.2	7.9	15	10.3	14
Austrian map of the Second Topographic Survey (1819-1820)	5.2	7.5[1]	9.9[1]	12	7.7	9

Table 1, Continued

Parameters of watercourses and reservoirs / Topographic maps	Length of the open part of watercourses, km			Total number of ponds, units	Total area of ponds, hectares	Total number of watermills, units
	Holoskivskyy stream	Zboivskyy stream	Malekhivskyy stream			
Austrian map of the Third Topographic Survey (1869-1887)	5.1	5.4	7.6	8	4.7	7
Polish map of the Military Geographical Institute (1929-1939)	3.4	4.2[2]	5.3	4(8)[3]	2.5	5(7)[3]
Soviet map of the USSR General Staff (1968-1989)	0.9	3.2	5.3	9	4.6	0

Notes: [1] – length of watercourses with a gully and beam network; [2] – it is possible that the length is longer; [3] – data based on a Polish topographic map of the Military Geographic Institute at a scale of 1:100,000

Source: created by the authors

The cartographic works of different years differed in the way they were constructed; nevertheless, there is ample evidence to outline the trends of anthropogenic transformation of the hydrographic network over the past 240-250 years, so it is worth summarising them in accordance with Table 1. The main parameter of the negative processes that have occurred with watercourses in the northern part of Lviv is the reduction in the length of their open part. The length of the open part of the Holoskivskyy stream decreased from 4.7 to 0.9 km (5.2 times), the Zboivskyy stream from 5.2 to 3.2 km (1.6 times), and the Malekhivskyy stream from 7.9 to 5.3 km (1.5 times) (Fig. 6).

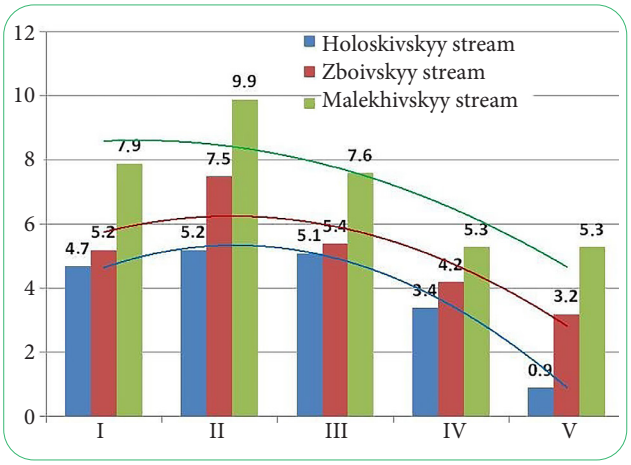

Figure 6. Length of the open part of watercourses in the study area in different retrospective geographical periods, km

Note: I – 1779-1783; II – 1819-1820; III – 1869-1887; IV – 1929-1939; V – 1968-1989

Source: created by the authors

If the maximum fixed flow lengths are taken, the ratios are changed to 5.8, 2.3, and 1.9 times, respectively. The intensity of hydrological processes also varied over time, so in the Austrian period it was balanced, and in the Polish and Soviet periods it was noticeable and accelerated. Already in the second half of the 19th century, there were trends of reducing the length of watercourses, which intensified significantly with the beginning of the development of the northern part of Lviv and the increased anthropogenic pressure on the natural environment in the basins of the studied streams. The process of water reduction in the streams of the study area differed and led to different consequences for the management of the inhabitants. The number and area of ponds are self-sufficient indicators that illustrate the use of water resources in the study area. During the study period, these indicators changed significantly (Fig. 7).

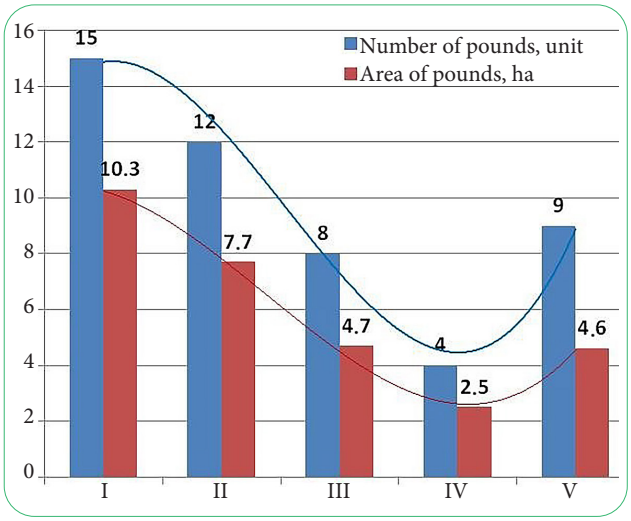

Figure 7. Number and area of ponds on the studied streams in different retrospective geographical periods

Note: I – 1779-1783; II – 1819-1820; III – 1869-1887; IV – 1929-1939; V – 1968-1989

Source: created by the authors

The largest number of ponds (15 units) on the studied streams was recorded in the second half of the 18th century. During this period, the largest area of water bodies was also observed – 10.3 hectares. In the following years, there was a gradual reduction in both the number of ponds and their area. The lowest figures are from the period of interwar Poland, when only four ponds with a total area of 2.5 hectares were registered. In Soviet times, the situation

improved somewhat, with the number of ponds increasing to 9 and their area to 4.6 hectares, which was close to the figures of the second half of the 19th century. The excessive and unjustified growth of water use in the Soviet period, in order to counteract the general trend of decreasing river water content and the rapid sprawl of the northern districts of the city, led to the depletion of the studied streams.

Most of the ponds of that time, located in and around the villages of Holosko Velykyi, Zamarstyniv, Zboishcha, and Malekhiv, had water mills. The existence of the mills testifies to the sufficient water availability of watercourses at that time, which were able to regularly fill the ponds and supply water flow energy for their operation. The proximity to Lviv necessitated a large number of water mills, so at the end of the 18th century their number was the highest (14 units). From this retrospective and geographical period, the number of mills steadily decreased: at the beginning of the 19th century – nine; in the second half of the 19th century – seven; in the interwar period – five (Fig. 8). After the World War II, all water mills were finally shut down due to the loss of water in the streams and the economic inexpediency of further operations.

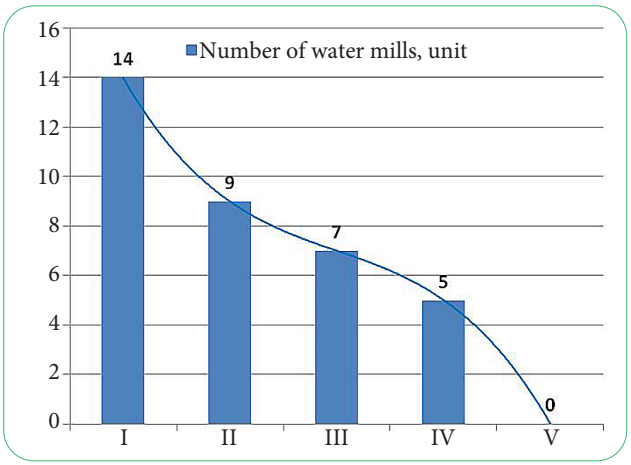

Figure 8. The number of water mills on the studied streams in different retrospective geographical periods

Note: I – 1779-1783; II – 1819-1820; III – 1869-1887; IV – 1929-1939; V – 1968-1989

Source: created by the authors

The Holoskivskyy stream remains the most abundant tributary of the Poltva in the northern part of Lviv. The natural channel has been conditionally preserved for a length of about 1.0 km. The watercourse was filled with springs; five springs were examined at its beginning and along the channel (100-150 m lower). The Zboivskyy stream is drying up, and the pond where it started has turned into a swampy area. This indicates the loss of power sources in the upper part of the stream. In its middle part, the largest anthropogenic transformational changes and sewerage were found. The Malekhivskyy stream is characterised by a similar situation with the current transformation of water bodies within the neighbouring Zboivskyy stream. Potentially, this stream had a longer valley and higher water content, which it lost due to various natural and economic reasons. According to topographic maps of the late 20th and early 21st centuries, the length of the open part of the stream is 3.8 km.

As of 2024, almost the entire hydrographic network of the northern part of Lviv is hidden in collectors, and there are no large water bodies within the city, which is why the watercourses and reservoirs that remain in the city or are located within the Lviv agglomeration are of particular value to residents. In view of this, any measures and steps related to the restoration, preservation and protection of water bodies in Lviv and its agglomeration are of great importance for the formation of a new environmentally safe urban environment and the implementation of an environmental management system.

The evolution of river systems in the context of human activity has been a hot topic of research, discussion, and debate among geographers and hydrologists. The study of spatial and temporal changes in river systems was primarily related to the study of their structural transformation. The basis for the study of river systems was laid by R. Horton (1945). The researcher proposed a system of ordinal classification of flows and established a number of quantitative statistical regularities of their structure, which later became known as Horton's Laws. Many works have been devoted to the study of the ordinal classification of rivers. For example, S. Sarnavskyi *et al.* (2020) conducted a retrospective analysis by comparing the hydrographic network of these rivers in certain time frames to determine the nature and directions of changes in the river network of the Khorol and Govtva river basins (Dnipro River basin). Also, in the works of I. Kovalchuk *et al.* (2020) many questions in the study of river basins are devoted to the structural transformation of river networks. An interesting analysis is presented in the work of L. Carraro *et al.* (2020). The authors studied how geomorphology shapes the structure of river networks and, in turn, controls the variability of physical habitats and affects spatial patterns of biota. However, such studies have a significant margin of error because they cover large areas and usually use maps of different scales, which affects the accuracy of the research. Structural methods mainly focus on the static characteristics of river networks. They did not take into account changes in the river network, such as erosion, channel changes, seasonal fluctuations in water levels, etc.

Many studies of river systems are related to the study of their hydrochemical and geoecological state, these are the works of V. Khilchevskyi *et al.* (2018), O. Pylypovych & Kh. Ternovetska (2023). Human activity has a significant impact on water systems (pollution, water flow regulation, urbanisation). Hydroecological assessments are often limited to local impacts or specific parameters, but do not always take into account the complex and long-term effects of anthropogenic pressures that may affect river or water systems at a broader regional or global level.

An important method of studying river systems is the method of comparing topographic maps of different

times. Comparing large-scale maps of the same scale allows to track how human activities have affected the river network, such as infrastructure construction, marsh drainage, land reclamation, or urbanisation. Changes in river channels are often the result of impacts on the hydrological regime (creation of reservoirs, changes in the runoff system, changes in vegetation, etc.). For example, a detailed analysis of changes not only in the hydrological network, but also in the development of dangerous exogenous processes in the Blahnit River Valley, Romania, was carried out by comparing large-scale maps by C. Răducă *et al*. (2021). This method of research is possible for a limited time period, because accurate topographic maps of the 1:25,000 scale are available only from the first half of the 20th century. Austrian topographic maps of the 18th century were used by K. Witkowski & M. Witkowski (2018) to study the impact of water mills on the hydrological network of the Polish city of Wadowice and other areas within the Carpathian Region of the Lesser Poland Voivodeship. According to scientists, the functioning of mills is an important factor that led to the transformation of the river network.

It is advisable to use multi-scale maps to analyse changes in the hydrological network over a longer period of time. For the city of Lviv, this methodology was applied by G. Bayrak (2016), and described in detail the changes in the river network over a period of more than 200 years, but her research was limited to the year 2000 and did not include all the rivers in the northern outskirts of Lviv. That is why a detailed analysis of changes in the river network of the northern outskirts of Lviv was carried out using topographic maps of a scale range from 1:25,000 to 1:100,000. Studying old topographic maps allowed to understand what river systems and surrounding areas were like in the past. This is especially important for the development of projects to restore rivers and natural ecosystems, as the initial state can be determined and compared with the changes that have occurred over time. Historical data obtained by comparing topographic maps can be used to model future changes in river systems. This is useful for predicting the impact of climate change, urbanisation, or other factors on river systems. Therefore, comparing topographic maps of different time periods is a valuable method for multidimensional analysis of river systems, providing information about their evolution, the impact of human activities, environmental changes, and planning for future water management.

Conclusions

Based on the analysis of anthropogenic transformation of the water network of the northern part of Lviv, the authors concluded that within the northern part of Lviv there was a decrease in the length of open channels, as well as the water content of all watercourses. This is due to both natural (changing climatic conditions) and anthropogenic (excessive development, destruction of slopes, creation of new highways, etc.) factors. Since the second half of the 18th century, the length of the natural channel of the Holoskivskyy stream has decreased by 3.8 km, the Zboivskyy stream by 2.0 km, and the Malekhivskyy stream by 2.6 km. A decrease in ponds and watermills was recorded. The largest number of ponds (15 units; 10.3 hectares) on streams was found in the second half of the 18th century. In the future, the number and area of ponds decreased. The lowest figures fall on the interwar Polish period, when only four ponds with a total area of 2.5 hectares were recorded. During the Soviet period, the number and area of ponds increased (9 units totalling 4.6 hectares) and reached the level that existed in the second half of the 19th century. There are two ponds left in the area of the open stream of Holoskivskyy stream, the largest of which is Stosyk Pond (0.9 hectares). As for the water mills, they were located on ponds in villages: Holosko Velyke, Zamarstyniv, Zboyishcha, and Malekhiv, there were 14 water mills. After that, the number of mills steadily decreased: at the beginning of the 19th century – nine; in the second half of the 19th century – seven; in the interwar period – five. After the World War II, the operation of all water mills was stopped. A significant decrease in the water content of streams, which is due to the intensive transformation and development of urban space, led to their sewerage. The best water availability situation is observed in the upper part of the Holoskivskyy stream, where many springs have been preserved, while in the upper parts of the Zboivskyy and Malekhivskyy streams, most springs have dried up. The prospect of further research is to measure the water content of watercourses with open channels, create a GIS model of their catchments, identify coastal protection strips and sanitary zones of the springs feeding these watercourses in order to implement environmental protection measures to preserve them.

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Conflict of Interest

None.

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Аналіз антропогенної трансформації гідрографічної мережі в північній частині Львова на основі картографічних джерел

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Анотація. Поява нових та ущільнення існуючих міських просторів у Львові призводить до антропогенної трансформації гідрографічної мережі. Метою дослідження був аналіз ступеня перетворення водних об'єктів у північній частині міста на основі картографічних джерел. Дослідження охоплювало північну частину Львова, смт. Дубляни, села: Малехів, Великі Грибовичі, Збиранка і Муроване. Вивчення водних об'єктів проведено за допомогою топографічних карт масштабного ряду від 1:25 000 до 1:100 000, що дали змогу охопити часовий період у понад 240 років. Відзначено чіткі тенденції до зменшення довжини відкритих русел, кількості приток і водності Голосківського, Збоївського і Малехівського потоків, що зумовлено природними та антропогенними чинниками. Довжина природного русла Голосківського потоку зменшилася з 4,7 до 0,9 км, Збоївського потоку – з 5,2 до 3,2 км, а Малехівського потоку – з 7,9 до 5,3 км. Найбільше ставів (15 одиниць; 10,3 га) на потоках зафіксовано в другій половині XVIII ст. У подальшому спостерігалося зменшення як кількості, так і площ ставів. Найнижчі показники припадають на міжвоєнний польський період, коли обліковано лише 4 стави загальною площею 2,5 га. У радянський період кількість і площа ставів дещо зросла (9 одиниць; 4,6 га) та досягла рівня, що існував у другій половині XIX ст. На ставах у селах Голоско Велике, Замарстинів, Збоїща і Малехів діяло 14 водяних млинів. Відтоді чисельність млинів зменшувалася: на початку XIX ст. – 9; у другій половині XIX ст. – 7; у міжвоєнний період – 5. Після Другої світової війни функціонування водяних млинів припинено. Проведений аналіз ступені трансформації гідрографічної мережі спрямований на корекцію плану розвитку північної частини міста та впровадження системи екологічного менеджменту

Ключові слова: потік; русло; став; млин; топографічна карта