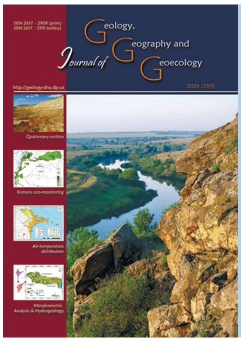

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Comprehensive assessment of the environmental impact of coastal development in the Dnipro River, exemplified by the city of Dnipro

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Abstract. The paper analyses the current state and ecological value of the natural and anthropogenic sections of the floodplain of the middle Dnipro. A comprehensive ecological assessment of the impact of development in the area of the confluence of the Dnipro and Samara rivers included an analysis of the lithological composition of soils in terms of construction suitability and modelling of possible geomorphological and hydrological risks (landslides, flooding). The degradation of the aquatic environment due to man-made pressures on coastal zones was also considered, with the main factors identified being urbanisation, wastewater discharge, transport pollution, and regional anthropogenic impact. The degradation of floodplain landscapes in the Dnipro agglomeration due to development was analysed, along with the risks posed by hazardous natural processes and the disruption of the territory's hydrogeological regime. It was established that the studied area is an unstable natural and anthropogenic formation composed of secondary washed sands, which are subjected to the pressure of turbulent currents of the Dnipro River and the Archierey Strait. This increases the risk of shoreline erosion and landslides. Based on field observations and satellite image analysis for the period from 1984 to 2024, the dynamics of residential landscape formation in the near-Dnipro part of the city of Dnipro were traced. It was established that since the 1990s, renaturalisation processes have intensified, resulting in the formation of a floodplain forest-meadow complex with a predominance of deciduous tree plantations. The territory is characterised by high biotic diversity and the mosaicity of microlandscapes, which create conditions for the existence of various species of fauna. It has been demonstrated that the most rational scenario for the development of the territory is the creation of a strict water protection zone, which will minimise technogenic risks and preserve the ecosystem services of floodplain landscapes. Analysis of satellite images and archival materials confirmed the long-term trend of the absorption of natural floodplains by urban development — from the transformations of the Dnipro Valley in the 1930s–1970s to the modern urbanisation phase.

Keywords: coastal landscapes, geological environment, floodplains, biodiversity, soils, engineering and geological activities

Комплексна оцінка впливу на довкілля забудови прибережних територій ріки Дніпра (на прикладі м. Дніпра)

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Анотація. У роботі проаналізовано сучасний стан та екологічну цінність природно-антропогенної ділянки заплави середнього Дніпра. Комплексна екологічна оцінка впливу забудови в районі злиття річок Дніпро та Самара включала аналіз літологічного складу ґрунтів щодо будівельної придатності та моделювання можливих геоморфологічних і гідрологічних ризиків (зсуви, підтоплення). Також розглянуто деградацію водного середовища внаслідок техногенного навантаження на прибережні зони, серед основних чинників якого визначено урбанізацію, скидання стічних вод, транспортне забруднення та регіональний антропогенний вплив. Проаналізовано деградацію заплавних ландшафтів Дніпровської агломерації, спричинену забудовою, а також ризики небезпечних природних процесів і порушення гідрогеологічного режиму території. Встановлено, що досліджувана ділянка є нестабільним природно-антропогенним утворенням, сформованим вторинними намитими пісками, які зазнають напірного впливу турбулентних течій р. Дніпро та Архієрейської протоки. Це зумовлює підвищений ризик руйнування берегової лінії та зсувів мас ґрунтів. За результатами польових спостережень і аналізу космічних знімків за період 1984–2024 рр. простежено динаміку формування селітебного ландшафту Придніпровської частини м. Дніпро. Встановлено, що з 1990-х рр. активізувалися процеси ренатуралізації, унаслідок чого сформувався заплавний лісо-лучний комплекс із переважанням листяних деревних насаджень. Територія характеризується високим біотопічним різноманіттям і мозаїчністю мікроландшафтів, що створює умови для існування різноманітних видів фауни. Доведено, що найбільш раціональним сценарієм розвитку території є створення суворої водоохоронної зони, що дозволить мінімізувати техногенні ризики та зберегти екосистемні послуги заплавних ландшафтів. Аналіз космічних знімків і архівних матеріалів підтвердив довготривалу тенденцію поглинання природних заплав міською забудовою — від трансформацій долини Дніпра у 1930–1970-х рр. до сучасної урбанізаційної фази.

Ключові слова: прибережні ландшафти, геологічне середовище, заплавні території, біорізноманіття, грунти, інженерно-геологічна діяльність.

Introduction. *The relevance of the topic* stems from the intensive development of the Dnipro River floodplain within the Dnipro agglomeration, which disrupts ecosystems, increases flood risks, and degrades water quality. The article presents a modern approach to developing recommendations for environmentally oriented planning of urbanised territories located in the coastal zones of rivers or reservoirs. The Land and Water Codes of Ukraine strictly limit the development of river floodplains and refer them to coastal protective strips (Zemelnyi kodeks, 2026, p. 61; Vodnyi kodeks Ukrainy, 2026, p. 88-89). The construction of any structures, except for special engineering and hydraulic structures, is prohibited. Floodplains are important ecosystems; their ploughing and development degrade rivers. There is a gap between the requirements of Ukraine's codes regarding coastal protective strips and real urban development plans. From a socio-ecological perspective, it is necessary to recognise that floodplains are important recreational areas and biodiversity centres. Their chaotic development limits citizens' access to water bodies and destroys natural landscapes, which reduces the quality of life in the agglomeration.

In order to carry out a comprehensive assessment of the environmental risks of development of floodplain areas in the area of the confluence of the Dnipro and Samara rivers, the study focused on the following key tasks: to analyse the engineering and geological properties of the geological environment and soils of the Dnipro floodplain; to determine the risks of dangerous natural processes, in particular, the intensification of landslides, changes in the groundwater level, and hydrological flooding, which may lead to the disruption of the stability of floodplain ecosystems; to assess the anthropogenic impact of the use of natural coastal zones on the quality indicators of surface and groundwater.

Materials and methods

To conduct ecological and geological studies, various analytical methods were employed. To characterise the current state of the environment and identify influencing factors, the following data were analysed: 1) field observations of the studied area and adjacent areas; 2) geological reports and maps of the Dnipro River basin and its tributaries near the city of Dnipro regarding the geological and geomorphological structure of sedimentary rocks and the nature of the surface relief; 3) data on the hydrogeological conditions of the area and aquifers of engineering and geological significance; 4) satellite images of the geomorphology of floodplain areas; 5) long-term observations of the species composition of flora and fauna and the dynamics of biocenoses of the studied area and adjacent territories.

General characteristics of the geological environment and soils

Holocene deposits within the studied area, as shown in (Derzhavna heolohichna…, 2006), are characterised by a variety of genetic types, among which are eluvium of modern soils, aeolian sands, alluvium of floodplains of river valleys, alluvial-diluvial deposits, lacustrine facies of old and artificial reservoirs, lake-marsh deposits, and technogenic formations (Manyuk, 2021a,b). Eluvial deposits are represented by modern and fossil soils; lacustrine-marsh deposits make up the bottoms of floodplain and oxbow lakes and are characterised by clay-silt formations of dark grey and black colour, often with an admixture of finegrained sandy fractions, with frequent alternation of clay and sandy layers. The thickness of the sediments ranges from 0.3 to 1.5 m. Alluvial sediments occupy the bottoms of the largest rivers within the system of erosional forms (the Dnipro and Samara rivers), where they are represented by light yellowish-grey quartz sands 3–6 m thick, rarely up to 10 m. The sands are poorly sorted, medium- to coarse-grained, with gravel and pebble inclusions, silted in places, clayey, and washed in some areas. Technogenic formations are common in areas of anthropogenic pressure in the coastal zone. These include alluvial sand spits, embankments, and artificial areas of the right bank of the Dnipro for development, large structures and highways, quarry dumps, dams, embankments, etc.

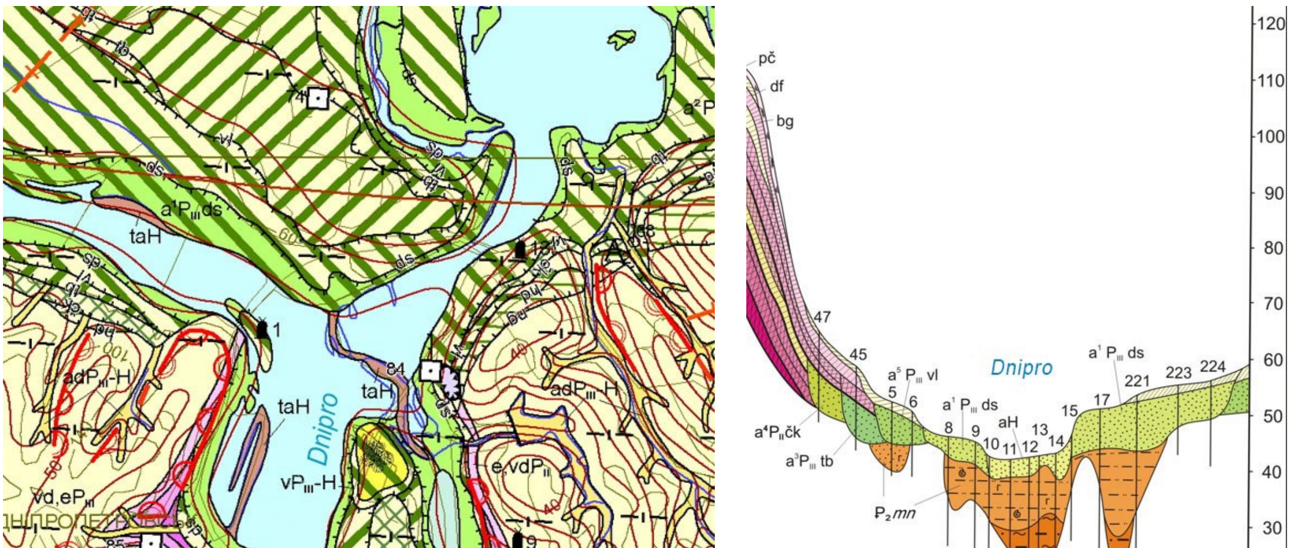
The sedimentary rocks of the floodplain area within the city of Dnipro comprise a complex of Quaternary deposits with a thickness of 10 to 20 m. The basis of the section is made up of modern alluvial deposits, alluvium of the first floodplain terrace, as well as buried Paleogene deposits in the valleys of the Dnipro and Samara rivers, which lie at a depth of 6 to 20 m (Fig. 1).

In the alluvial and lacustrine-alluvial deposits of the Dnipro floodplain, there are sands, often with gravel and pebbles, as well as pebbles, and in places alternating layers of sands, loams, clays, sandy loams, gravel-pebble material, and less often loams, sandy loams, silts. The first suprafloodplain terrace (a1P III ds) was partially flooded after the creation of the Dnipro Hydroelectric Power Plant; its alluvium lies within the studied territory on marine sediments of the Mandrykivka layers of the late Eocene, and in places where they are absent, on rocks of the Precambrian crystalline basement (Fig. 1) (Manyuk, 2013, 2014; Stetsyuk, Manyuk, Ivanik, 2025).

In the watershed areas adjacent to the floodplain, a fairly complete section of subaerial and subaquatic sediments is characteristic, with a rhythmic alternation of loess and loess-like loams with fossil soils, which, within the Dnipro valley and its tributaries, are replaced by various subfacies of alluvial terraces (Fig. 2) (Manyuk, 2017).

The soil cover of the studied area is represented in the watersheds adjacent to the Dnipro by ordinary medium-humus chernozems on loess of the Black Sea climatic type or by older horizons of the Upper Pleistocene (Fig. 3).

In the floodplain areas of the Dnipro River, a genetic series of meadow-chernozem and meadow soils is found, which develop on diluvial loess-like loams, alluvial deposits, lacustrine-glacial sediments, and



aH - channel alluvium and alluvium of river floodplains
taH - technogenic deposits, alluvial type
vP$_{III}$-H - Holocene aeolian deposits
adP$_{III}$-H - alluvial-diluvial deposits of the bottoms of ravines and gullies
a^{1}P$_{III}$ds - alluvium of the first (Desna) floodplain terrace
vd,eP$_{III}$ - undissected aeolian-diluvial and eluvial deposits of the upper part of the Quaternary system: loams, loess-like, and fossil soils

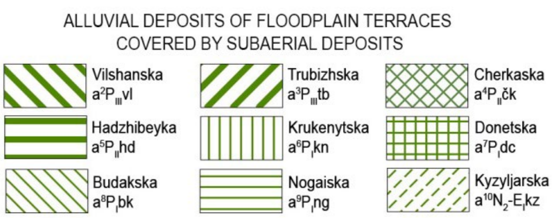


Fig. 1. Geological map of Quaternary deposits, section to it and legend

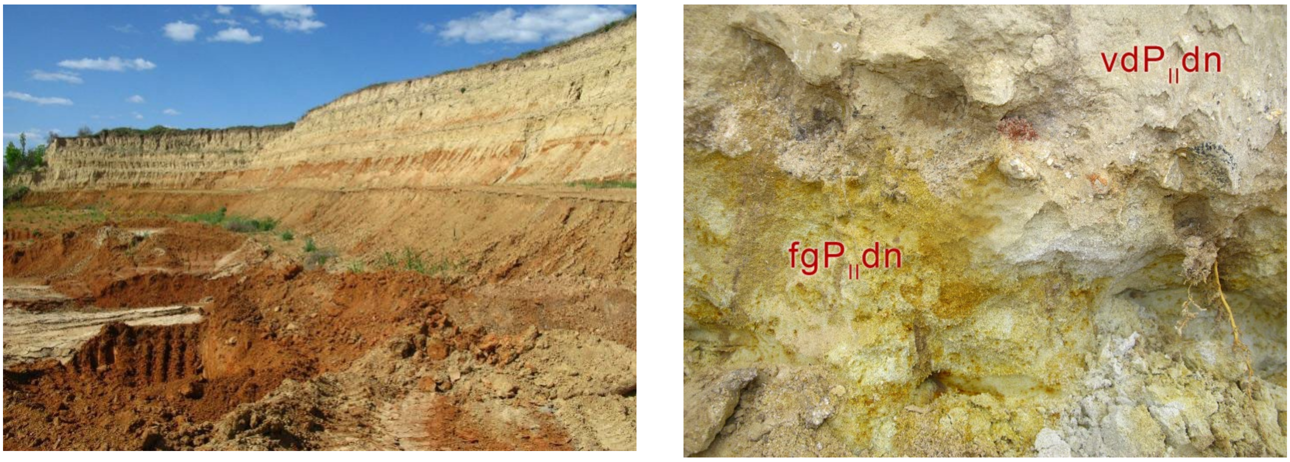


Fig. 2. Section of Quaternary sediments (left) and contact of fluvioglacial sediments with alluvium of the Dnipro climatolite (right) in the Rybalsk quarry

fluvioglacial sands (Derzhavna heolohichna…, 2006; Manyuk, 2001). Meadow-chernozem soils occupy a transitional position, being classified as semi-hydromorphic. They are characterised by the relatively close occurrence of groundwater levels, typically between 3 and 5 m deep. These soils have a loamy texture, a well-defined granular structure, and a high humus content, which can reach 6–8% (Ekolohichnyi pasport m. Dnipro., 2016). A key diagnostic feature of these soils is gleying in the subhumus horizon, found at depths of 120 to 150 cm, which occurs due to periodic capillary moistening. The soils generally have a neutral reaction and exhibit high saturation with bases, such as calcium (Ca^{2+}) and magnesium (Mg^{2+}). Meadow soils, on the other hand, develop under conditions of constant hydromorphism, with groundwater levels between 1 and 3 m. They are significantly influenced by groundwater and alluvial waters. The process of overwetting leads to intense gleying of the parent material and the lower parts of the soil profile, which is indicated by a blue-grey colour due to iron reduction and a reduction in aeration. At the confluence of the Dnipro and Samara rivers, floodplain soils consist of deposits often formed on light fluvioglacial sands. Although these soils tend to have a lower humus content, they can achieve higher potential fertility under certain water regimes.

The research area is situated within a first-order hydrogeological basin: the Donetsk basin of stratified-block waters (Derzhavna heolohichna…, 2006). This basin contains groundwater found in the sedimentary strata of the Cenozoic, Mesozoic, and Palaeozoic eras. The aquifer consists of modern alluvial and alluvial-diluvial deposits, which are prevalent in the floodplains of rivers and the bottoms of large gullies. The water-bearing rocks include clayey sands, sandy loams, and loams, which rest upon Pleistocene, Neogene, and Paleogene deposits, or directly on crystalline basement rocks. This aquifer is unconfined and is typically the first water horizon encountered from the surface. Its thickness does not exceed 5.0 m, with water levels ranging from 0.2 m to 5.0 m deep. Water availability can vary significantly, and water quality differs, being predominantly classified as hydrocarbonate-sulfate, chloride-sulfate, chloride-hydrocarbonate, and calcium-magnesium-sodium types. The water regime is influenced by climatic factors, and the primary source of water supply is infiltration, supplemented by underflow from adjacent horizons, which is then discharged into riverbeds. Unfortunately, this horizon is not protected from surface pollution (Mokritska et al., 2019) (Fig. 5).

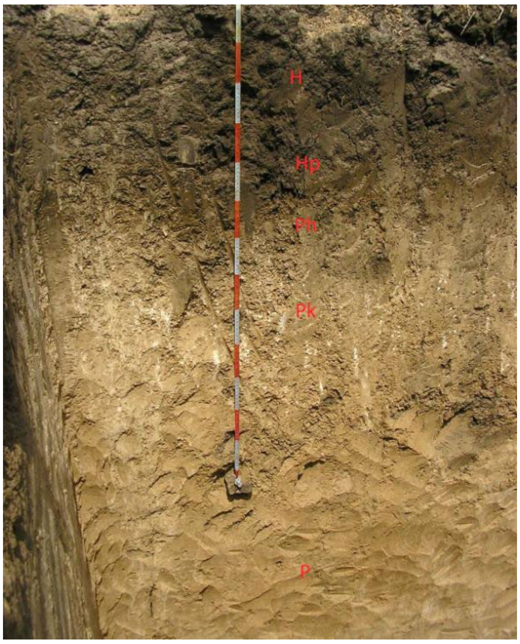


Fig. 3. Ordinary low-humus chernozem on loess (Atlas pochv Ukrainskoi SSR, 1979).

Fig. 4. Ordinary medium-humus chernozem on loess-like loams of the Black Sea climatic type (Sazhavka basin) and meadow-chernozem soil of the floodplain (right, https://uk.wikipedia.org/wiki/Лучно-чорноземні_грунти)

The next aquifer, of Lower–Upper Quaternary alluvial deposits, is confined to the floodplain terraces of the Quaternary age of the Dnipro, Samara, Kilchen, Vovcha, and others. The aquifers are composed of mixed-grained sands with layers of loam, sandy loam, and clay. The depth of the static level, as indicated by terrace surface marks, varies from 0.5 to 15 m. The aquifer thickness reaches 21 m. The chemical composition of the waters varies; the main types are hydrocarbonate-sulfate, sulfate-hydrocarbonate, or sulfate-hydrocarbonate-chloride. The cationic composition is sodium and calcium, often mixed. Mineralisation varies from 0.2 to 3.2 g/dm^3, rarely up to 5.0 g/dm^3 (in the Samara River valley within the Novomoskovsk district). The waters are soft; in areas with increased mineralisation, they are hard, characterised by higher nitrate levels. The horizon is fed by the infiltration of atmospheric precipitation and by the underflow of water from lower aquifers; it is drained into river channels. It is important to note that this aquifer is not protected from surface pollution (Derzhavna heolohichna…, 2006).

Based on our comprehensive assessment, we have selected surface waters as the focus for the next stage of our research. Our primary objective is to analyse the impact of long-term coastal infrastructure operation on the hydrochemical indicators of the Dnipro River. A retrospective analysis of environmental monitoring

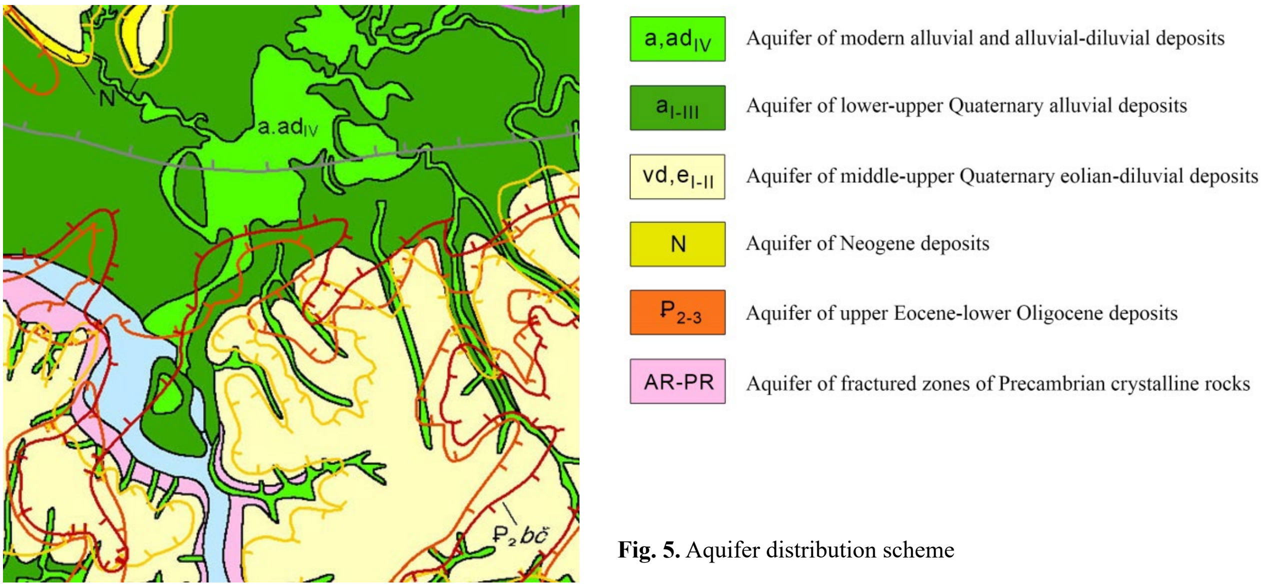


Fig. 5. Aquifer distribution scheme

data and materials from the Central Geophysical Observatory of Ukraine for 2025 has revealed that the water quality in the Dnipro area does not meet regulatory requirements for chemical and microbiological indicators (Tsentralna heofizychna observatorii …, 2026). It has been established that the water quality in the river near the city of Dnipro does not meet the standards for chemical and microbiological indicators. This condition manifests as follows. Firstly, there is a massive bloom of cyanobacteria (blue-green colour of water) due to the growth of algae. Low redox potential values confirm the suppression of natural self-purification processes, creating favourable conditions for the development of pathogenic microflora. Secondly, organic pollution is recorded. In the autumn of 2025, an excess of biochemical oxygen demand (BOD_5) was recorded, which may indicate organic pollution of the reservoir. Thirdly, the instability of individual indicators of the chemical state of water is observed. The water's acidity level, as indicated by pH indicators, at some points approached critical levels, likely due to a complex mix of anthropogenic and natural factors. Fourthly, there is an excess of lactose-positive E. coli on some beaches in the urbanised area. The critical level of microbiological pollution led to a complete ban on beach operations in 2025. According to (Komykh, 2018), in the right-bank part of the city in 2018, 78 storm sewer outlets into the Dnipro River were not equipped with treatment facilities, of which 69 outlets were for surface and industrial runoff, and 9 outlets were for emergency and washing waters (Ekolohichnyi pasport m. Dnipro., 2016; Komykh, 2018). Under such conditions, the implementation of coastal development plans poses a potential threat to water quality, as untreated wastewater is likely to be directly discharged through the existing network into the river ecosystem.

Research Results

The studied area was historically (until 1932) the upper part ("head") of the large river island of Stanovyi (also known as Vorontsovsk or Kinsk). The island was separated from the main channel of the Dnipro by the old riverbank (Fig. 6), which ran approximately along the current Naberezhna Peremohy Street (Collection of detailed maps…, 2026). With the completion of the construction of the Dnipro Hydroelectric Power Plant dam, the island was almost completely flooded by the waters of the Zaporizhzhia reservoir. In 1941, after the demolition of the Dnipro Hydroelectric Power Plant dam, the water level in the reservoir dropped significantly (but did not reach the original levels of the Dnipro riverbed before the flooding). The flooded island resurfaced several times over the years, but was finally submerged by 1947. In the shallow waters that formed on the site of the flooded island, large-scale sand dredging began in the early 1970s (to support the construction of the embankment and new residential areas). As a result, a secondary dredged area was formed, an artificial peninsula with a total area of about 30 hectares. In the southwestern part of the peninsula, a cape-like protrusion measuring up to 5 hectares was formed, on which a boat station with a network of internal canals and berths was later built in the second half of the 1970s. In the 1990s, the base gradually fell into disrepair, and the canals were partially silted up and partially filled in by new land users. The area is at an altitude of 51.5–58 m above sea level. An old axial road passes through the peninsula, built on an alluvial dam in the late 1930s.

It is important to note that in this area, secondary deposits have formed from masses of washed sands located on the surface of the flooded island and partially on the ancient Dnipro riverbed. Additionally, the coastline of the site is influenced by the flows

Fig. 6. The upper part of Stanovyi Island on the topographic map of 1853 (left), and on the aerial photograph of 1941 (Collection of detailed maps…, 2026)

of the Dnipro riverbed, which approach the present peninsula from the northeast in two currents: the first flows from the Archiereyskaya Strait, located between Monastyrsky Island and the rugged right bank of the Dnipro, while the second branches off westward from the main flow of the Dnipro fairway. As a result, variable turbulent flows develop near the coast, leading us to view this area, given its artificial alluvial origin, as unstable and potentially vulnerable to coastal erosion and the displacement of washed soil masses during floods of the Dnipro River. Therefore, the most viable scenario for this territory is to designate it as a water protection zone for the Dnipro, which can provide a range of ecosystem services typical of floodplain island ecosystems.

From a biodiversity perspective, this area holds considerable interest. Over the past 50 years, since the completion of alluvial works in 1970, a microlandscape has formed that resembles the natural floodplain complex characteristic of the Dnipro valley in the steppe zone.

Based on field observations and satellite image analysis for the period from 1984 to 2024 (Tsentralna heofizychna observatoria …, 2026), the dynamics of residential landscape development in the near-Dnipro part of the city of Dnipro were determined. The most intensive renaturalisation processes developed after the decline of the boat station, and it was during this time (from the 1990s to the present) that a floodplain forest-meadow complex spontaneously formed here, with deciduous tree plantations predominating. More than 150 tree species are represented, mainly by native species – Populus nigra L., P. alba L., Salix alba L., S. acutifolia Willd., S. fragilis L., Ulmus minor Mill., etc. The trees range in height from 8 to 18 m, and their ages range from 15 to 50 years. On a significant portion of the site, trees form a closed canopy. However, many semi-open and open glades with mainly meadow and meadow-ruderal herbaceous vegetation have also been preserved. The unevenness of the microrelief, trees of different ages, and the alternation of closed stands and glades create a mosaic microlandscape with various ecological niches, which are favourable for maintaining high natural diversity and generally correspond to the natural forest ecosystems of the middle floodplain type (Maniuk et al., 2018). On drained alluvial substrates with a sandy-silty or sandy-silty granulometric composition, a fertile soil layer is dynamically formed, which can be defined as young technogenic fluvisols in the depressions of the relief with signs of gleying. The edaphotopes of the peninsula, depending on the position in the relief, are characterised by a variable moisture regime - from seasonally dry (mesoxerophilic) to constantly fresh mesophilic and hygromesophilic. Trees form the main, upper tier of pioneer vegetation, the crown closure of which varies from complete closure to a completeness of 0.5–0.6. Wide clearings between trees create favourable conditions for the settlement of biotopes by various species of birds, insects, and animals, typical of the Dnipro floodplains and islands. The permanent or seasonal, temporary stay of more than 60 species of birds was recorded on the studied site, including such species as *Phasianus colchicus L., Phalacrocorax carbo L., Rallus aquaticus L., Fulica atra L., Columba palumbus L., Picus canus Gmelin, etc.* Among mammals, the following are characteristic: Erinaceus roumanicus *Barrett-Hamilton, Ondatra zibethicus L*., and *Apodemus flavicollis* Melchior.

Over the past 10 years, observations of Lepus europaeus Pallas and Vulpes vulpes L. have been recorded in this studied area. The studied area is also periodically visited by the beaver Castor fiber L. The examples given can be considered «umbrella species» for this studied area. Their presence indicates the significant conservation value of this studied area as a centre with a high concentration of species typical of floodplain islands and the banks of the Dnipro.

Between 2001 and 2012, gradual reconstruction and alterations in the hydrographic network of the Dnipro River floodplain in Samara were observed. During this period, preparations for further development of the peninsula began. Any additional construction is likely to result in the destruction of populations of many species and cause irreversible habitat loss. In particular, natural biodiversity was already significantly damaged in the areas developed between 2013 and 2016. Since April 2017, two high-rise buildings have been erected along the coastal zone. In 2020, developers fenced off an area for the future construction of a dozen high-rise buildings. This blocked access to the water and created conditions for the development of a local landfill.

Construction activities near the Dnipro River and in areas with unfavorable development conditions will result in increased soil depletion and erosion. Additionally, these activities will lead to silting of the riverbed and pollution of the channel and floodplain areas from sewage, fuel, and lubricants. Any construction project requires substantial amounts of fuel and lubricants for machinery, including cranes (both tower and truck-mounted), excavators, bulldozers, concrete mixer trucks, dump trucks, and other vehicles. The removal and transportation of construction materials, soil, and waste further contribute to environmental pollution, including groundwater contamination. Furthermore, these areas are located in a zone prone to dust storms and wind-induced soil erosion (Karty Ukrainy, 2026).

The open soil surfaces of pits, dumps, and landfills, formed as a result of construction (lasting at least 1.5 years) near the Dnipro River, will contribute to dusting, environmental pollution , and siltation of the aquatic environment. All of these have serious consequences for both the ecosystem and human economic activity. Environmental consequences include: 1) Reduction of oxygen levels in water. Suspended solid particles and oil products reduce sunlight penetration, leading to decreased photosynthesis in aquatic plants and algae. This results in lower dissolved oxygen levels, which are critically important for aquatic fauna and flora. 2) Destruction of habitats of aquatic fauna, fish spawning grounds, and disruption of the food chain, ultimately decreasing biodiversity. 3) Sedimentary deposits and artificial waste alter the chemical composition of water. They can increase nutrient concentrations (e.g., phosphorus), leading to eutrophication, rapid algae growth, and waterlogging. 4) Toxic effects on aquatic organisms. Silt can clog fish gills, causing death. Pollution also accumulates in food chains, affecting fish and, ultimately, humans. 5) Reservoir pollution negatively affects drinking water quality, potentially deteriorating public health.

In the future, river water volume will decrease due to sediment accumulation and shallowing. A decrease in riverbed depth reduces the river's capacity to convey water. This increases the risk of seasonal flooding, especially during sudden or heavy rainfall. Flooding may occur in harbours and along the fairway, hindering navigation and making it difficult or impossible to move ships.

We have also identified the following unfavourable engineering and geological characteristics of the coastal zone within the city of Dnipro for construction: 1) High humidity and flood risk. Meadow floodplains are located in low-lying areas. The proximity of groundwater and periodic flooding make these areas unsuitable for constructing major structures. 2) Low bearing capacity. Floodplain soils contain high organic matter and moisture, resulting in low strength. They are prone to compaction under load, which can lead to foundation subsidence and building deformation. 3) Looseness and heterogeneity. Floodplain soils are composed of alternating layers of peat, loess, loam, clay , and sand. Such heterogeneity causes uneven foundation subsidence. 4) High groundwater activity. Groundwater lying close to the surface (1–3 m) can corrode foundations and building materials. Groundwater from the first aquifer is sulfate-aggressive towards concrete.

During construction, effective drainage is essential to lower groundwater levels. Changes in groundwater are likely, as the first aquifer is located in the modern alluvial and lacustrine-alluvial deposits of the Dnipro River floodplain, typically at depths of 0–3 meters. The construction of foundations and underground structures disrupts the natural flow of groundwater. This creates additional discharge zones, reducing groundwater levels and causing waterlogging in surrounding areas. Heavy construction equipment compacts soil, altering permeability and reducing surface water infiltration, which negatively impacts aquifer replenishment. Moreover, materials such as asphalt and concrete cover large areas, blocking water from seeping into the soil. Over time, this can decrease groundwater levels, reduce flow rates, alter water quality and chemical composition, and, ultimately, affect plant diversity.

Results discussion

The assessment of the impact of construction on coastal and floodplain landscapes reveals that any construction or alteration of the geological environment leads to changes in the landscape, biodiversity, and topography, ultimately transforming it into an anthropogenic landscape. These changes result from engineering and geological activities aimed at creating suitable conditions for the placement of buildings, structures, sites, roads, and both surface and underground infrastructure.

In the study by Arjola Pilua (Arjola Pilua et al., 2025), buffer zones are recommended at varying distances from the coastline, following established methods in landscape ecology and urban planning. This method considers multiple buffer distances simultaneously, allowing for a comprehensive analysis of the landscape's longitudinal and transverse composition. By utilizing modern GIS technologies, the study assesses the effects of these buffer zones on various environmental components. The results are then compared to develop practical conclusions and recommendations.

The extensive development of the floodplain poses significant risks of man-made accidents by disrupting the natural hydrological balance and increasing vulnerability to natural disasters. One of the primary dangers is flooding, which can trigger artificial disasters. After the Dnipro Hydroelectric Power Plant was launched, floods caused by the overflow of the Dnipro River have become less threatening to the city. Currently, the main concern is issues related to the capacity of the existing stormwater sewage system, which struggles to handle intense rainfall effectively.

The ongoing war since February 2022 and the continuous attacks on energy facilities in Ukraine have demonstrated that risks associated with hydraulic structures can lead to catastrophic consequences. The primary threats may include the following:

Firstly, there is the threat of flooding. As mentioned earlier, the development of the floodplain decreases the soil's ability to absorb surface water. This results in higher water levels, accelerated surface runoff, and an increased risk of seasonal flooding in both developed areas and nearby regions. Consequently, the soil becomes excessively waterlogged, potentially causing damage to or destruction of buildings and underground utilities.

Secondly, there is a significant threat to infrastructure. River currents and flooding can damage bridges, roads, and other facilities located on the floodplain. This damage may result in large-scale man-made disasters, particularly if it affects gas pipelines, sewage systems, or power grids already located within the coastal zone. For instance, if a gas pipeline is compromised, highly flammable natural gas may leak, potentially causing explosions and widespread fires. This situation poses a direct threat to human life and health while also destroying buildings and infrastructure. Additionally, damage to sewage systems can result in soil and water contamination, which may lead to outbreaks of infectious diseases.

Thirdly, the increasing population density in floodplain areas raises the number of individuals who may require evacuation during floods or other emergencies. However, dense development and limited access roads can complicate or block evacuation routes, leading to unforeseen challenges.

Conclusions

A comprehensive assessment of the environmental impact of the development of the coastal areas of the Dnipro River near the confluence of the city of Samara allows us to draw the following conclusions.

The specified location is known for its high biodiversity, attributed to the mosaic landscape and the combination of forest and meadow ecosystems. The dynamic soil development and variability in moisture levels create various ecological niches. This area represents the natural floodplain landscapes of the middle Dnipro, supporting a wide range of animal species. These features highlight the importance of preserving this ecosystem in urban planning.

The studied area is an unstable natural and anthropogenic formation, composed of secondary washed sands subjected to the pressure of turbulent currents of the Dnipro River and the Archierey channel. Due to the high risk of shoreline destruction and soil mass displacement, the only rational scenario for the territory's functioning is the establishment of a strict water protection zone to preserve the ecosystem services of floodplain landscapes.

Based on an analysis of satellite images and archival data from a selected landfill, four key phases of anthropogenic impact on the natural floodplain landscape have been identified: 1) the phase of early changes in the Dnipro River valley (1930–1970), caused by the construction of a reservoir and alluvial works during the construction of the city embankment; 2) the transition phase (2001–2012), characterized by the beginning of systemic deformation of the floodplain hydrographic network; 3) the active-transformational phase (2013–2016), a stage of intensive replacement of the natural landscape with a man-made one (development of the peninsula); 4) the urbanization phase (from 2017 to the present), the final stage, accompanied by the complete elimination of natural ecosystems on the peninsula and their replacement by capital development.

These phases confirm a steady trend toward the horizontal absorption of natural territories at the expense of valuable floodplain lands. Overall, they illustrate the consistent expansion of urban areas into floodplain landscapes.

Thus, coastal development is a critical factor in ecosystem degradation. Anthropogenic transformation leads to the irreversible loss of hydromorphic soils, which, according to the Water Code of Ukraine, constitutes a direct violation of environmental legislation. Therefore, the preservation of floodplain landscapes is possible only if the development of coastal protective strips is halted.

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