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ENGINEERING-GEOLOGICAL ZONING AS A SCIENTIFIC-METHODICAL BASIS FOR SCHEME'S DEVELOPMENT OF ENGINEERING-CONSTRUCTION ASSESSMENT (ON THE EXAMPLE OF IRPIN TOWN KYIV REGION)

The article is aimed at conducting the engineering-construction assessment of Irpin town of Kyiv region. It is based on the engineering-geological zoning of the settlement, which provides the allocation of different-level taxonomic units with a set of natural and anthropogenic factors of construction conditions from the largest unit (engineering-geological region) to the smallest (sites and subsites). Engineering and geological surveying and mapping became the main research methods. The main result of the study was a comprehensive comparison of data on the geomorphological, geological-genetic structure, hydrogeological conditions, soils' composition and properties of Irpin. It ultimately provided an opportunity to build a large-scale synthetic map of engineering-geological zoning and engineering-construction assessment of the town. The study identified eleven engineering-geological sites with appropriate characteristics of natural and anthropogenic factors of construction conditions factors, including have been identified, among which six sitesare unfavorable for construction. The scientific novelty of the above research lies in the application of engineering-geological zoning as a basis for engineering-construction assessment, which is not limited to the selection of planning restrictions of an engineering-geological nature. For the first time the novel method of engineering-geological subsites' selection is based on the principle of taking into account natural hazards and morphometric characteristics of the relief. They reflect the degree of erosion dissection, potential for the of modern relief-forming processes' manifestation and soil erosion. The practical aspect of the conducted research consists in creating a high-quality scheme of engineering-construction assessment, supplementing the scheme of existing planning restrictions, selecting optimal and economically justified measures for engineering preparation and territories' protection against dangerous geological processes. Engineering-geological zoning allows you to determine safe places for the accomodation of engineering structures, their structural features, choose rational types of foundations, reduce the cost of survey and construction work and generally improve the design's quality.

Key words: engineering-geological zoning; engineering construction assessment; taxonomy units; dangerous geological processes; morphometric characteristics; geological-lithological structure; Irpin.

Introduction

The scheme of engineering-construction assessment is desirable among additional graphic materials of projects of settlements' master plans as determined by the State Building Regulations [SBR B.1.1-14:2021, 2022]. It is created on the basis of engineering-geological zoning of the town territory, which involves the selection of multilevel taxonomic units that have a certain set of common engineering-geological conditions. They ultimately determine whether construction sites belong to a certain suitability category. As practice shows, the engineering-construction assessment scheme is far from the above standards in most cases. Designers are limited to the mandatory scheme of existing planning restrictions. Along with the allocation of sanitary and protective zones from enterprises, transport, engineering networks and infrastructure objects, they show restrictions of an engineering-geological nature. They include the delineation of areas and development of dangerous natural processes. Other natural and evaluation factors are neglected. This entails an inadequate assessment of the degree of construction sites' suitability, irrational and dangerous placement of structures from the point of view of their construction and operation, inappropriate or incomplete volume of measures for engineering preparation and protection of the territory [Simonov, Kruzhalin, 1993].

Engineering-geological maps with engineering geological conditions form the basis for engineering construction scheme's development. Geological structure of the territory, lithological composition, hydrogeological conditions and current natural and technogenic geological processes are the most important of these conditions. Engineering geological zoning maps have a particular significance among engineering geological maps for engineering-construction assessment. They are drawn up as a result of identification in the space on the basis of theoretical positions' combination and tutorial methods of objectively existing territorial elements that have common engineering geological features of their delineation from territories that haven't such features, their mapping and description [Trofimov, Krasilova, 2008].

Different order' territorial units are allocated during regional type of engineering geological zoning and each next unit is allocated from previous (larger) by dividing it into separate parts on the basis of specific classification features. Each allocated territorial unit is characterized by bright individuality and gets a unique characteristic and own name..

The principles of engineering-geological zoning were most fully developed by I. V. Popov, who proposed to distinguish engineering-geological regions, oblasts, districts and subdistricts of various orders as independent taxonomic units.

Engineering-geological regions are distinguished by structural and tectonic features. The engineering-geological region of the first order is the largest taxonomic unit. The second-order region, namely the engineering-geological province, is distinguished by its morphostructure and hydrogeological structure. The region of the third order (subprovince) is distinguished on the basis of the morphogenetic type of the territory of the first order [Popov, 1951].

I. V. Popov proposed to distinguish engineering-geological areas within one region based on geomorphological features. With this approach, the geomorphological features of the territory are a consequence of the history of its geological development, mainly in recent times. We can say that engineering-geological regions are territories distinguished by geostructural features as a result of the analysis of the history of the geological development of this territory for the entire time available to us. Engineering-geological oblasts are parts of regions that have had different development in recent times, which was reflected in their geomorphological features [Popov, 1951]. So, engineering-geological oblasts are distinguished on the basis of the II order's morphogenetic type.

Engineering-geological districts in the engineering-geological oblasts are distinguished on the territory of which the uniformity of the geological structure is noted. It is expressed in the same sequence of rocks' occurrence, their thickness and petrographic composition. Such relatively small territories can be formed under the conditions that they experienced tectonic movements of the same sign and intensity over their entire area. They wereand were in the same paleoclimatic conditions throughout their development history, which goes beyond the latest stage of the Earth's geological development [Popov, 1951]. Therefore, engineering-geological districts are distinguished on the basis of the common conditions of geological development.

Engineering-geological subdistricts can be allocated within one engineering-geological district according to different states of rocks, as well as manifestation of modern and ancient geological processes., if necessary [Popov, 1951]. For example, within one engineering-geological area there may be different strata of rocks located in a stratigraphic sequence and characterized by similarity or natural variability of engineering-geological characteristics. So, engineering-geological subdistricts are distinguished on the basis of engineering-geological rock complexes of rocks of a certain age of geological layers of a certain age.

Engineering-geological sites can beare allocated within subdistricts during a large-scale engineering-geological study of the territory, within which engineering-geological subsites can be allocated. As a rule, theseengineering-geological sites are distinguished according to the construction conditions of construction, i.e.that is, according to the assessment of a complex of natural and anthropogenic factors. There are different approaches to the selection of engineering-geological subsites within their boundaries of the sites. We proposed the selection of subsites according to the geodynamic processes' manifestation as well asand according to the relief's morphometric characteristics.

This approach to the definition of taxonomy units in engineering-geological zoning is shown in Fig. 1 [Popov, 1951; Trofimov, Krasylova, 2008].

Attempts at engineering-geological zoning have been made in Ukraine in such cities as Odesa [Shpakovsky, 1999], Dnipro [Sumatokhina, 2004], Kalush [Mykolaenko, et al., 2019], Reni district of Odesa region [Zhyrnov, 2015], basins of the Prut River [Marchak, 2012] territories along the Small Adzhalyk estuary [Chuiko, 2001], in the Carpathian region [Rudko, Guda, 2013]. Such a procedure was done in other regions of the world: in the Fortaleza region [Zuquette, et al., 2004], Japan [Wakamatsu & Matsuoka, 2013], Albania [Muceku, 2012], in cities Tunis [El May, et al., 2010], Taipei [Huang, et al., 1987], Athens [Koukis & Sabatakakis, 2000], Ostrava [Marschalko, et al., 2012], Mymensingh [Akter, et al., 2018], Almada [Paula da Silva & Rodrigues-Carvalho, 2006], Mecca [Al Solami, et al., 2006], Bendery [Grebenshchikova et al., 2021], Cagul [Bogdevych & Isichko, 2016].

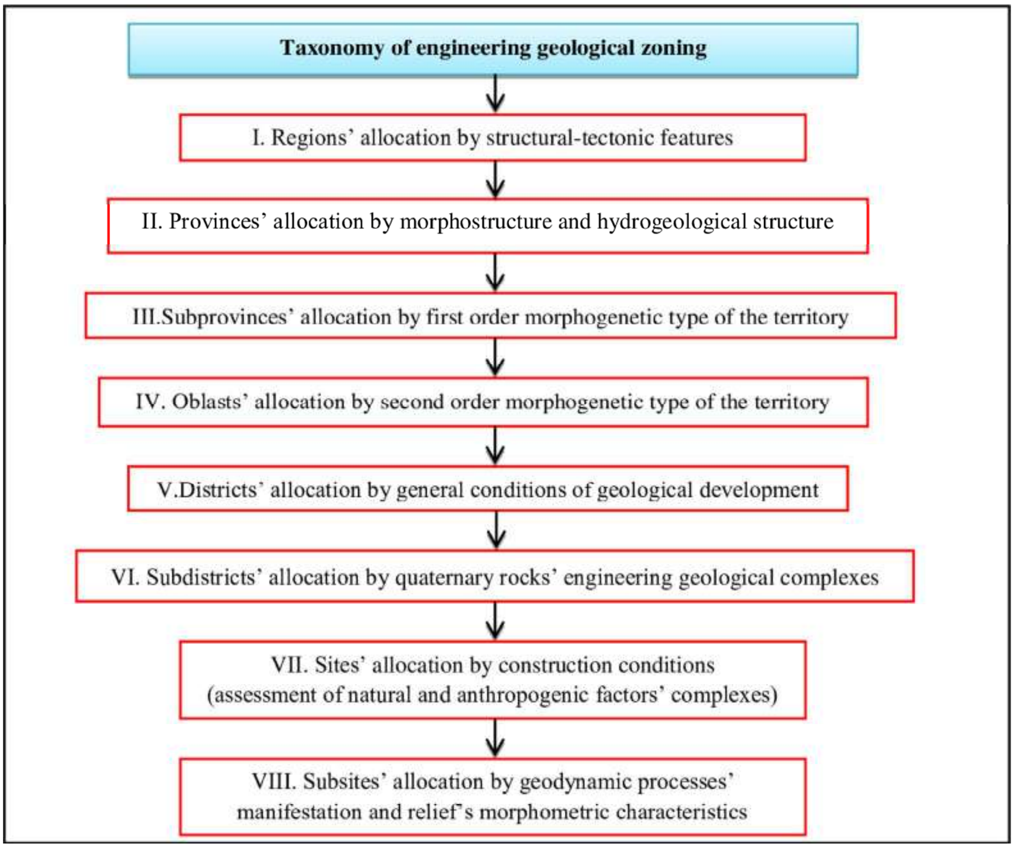


Fig. 1. Taxonomy of engineering-geological zoning

Purpose

The purpose of this article is to carry out the engineering-geological zoning of the territory of Irpin town, Kyiv region, for the qualitative and justified allocation of the town areas with different degrees of favorability for construction development. The geomorphological, geological-lithological structures, hydrogeological conditions of the city were investigated for this purpose. The study researched the composition and properties of the soil, conducted a morphometric analysis of the territory and managed to identify dangerous natural and anthropogenic processes. This allowed us to create appropriate maps and distinguish different-level taxonomic units of engineering-geological zoning. The final result includes the allocation of engineering-geological sites and subsites based on the construction assessment of the complex of natural and anthropogenic conditions, the course of geodynamic processes and morphometric features of the city. The engineering-construction characteristics are provided for each site and subsite. This helped to form the basis for the creation of a qualitative scheme of engineering-construction assessment of Irpin town.

Materials and methods

The initial data for engineering-geological zoning consist in a topographic survey on Irpin town in scale 1:5000, as well as materials of engineering and geological investigations conducted between 1990 and 2020 for the construction of residential and public buildings by different design organizations and companies. 154 geotechnical reports were analyzed. Those materials were collected and systematized at SE "Ukrainian Institute of Engineering Technical Exploration for Construction" (UKRIINTR) [Tsybko, 2020]. We also studied a Geological map in scale of 1:50000 on sheets of Kyiv region [Solovytsky, Vozgryn, 1990) and used a project of the master plan for Irpin town [Master plan of Irpin town, 2017].

Field studies and geological surveys of Quaternary deposits were carried out by departments of UKRIINTR. The results of the studies included the following: selection of genetic types of the surface relief of Irpin town, its morphological and age features; the studying of the geological-lithological structure; the creation of geological-lithological sections, as well as the physical-mechanical properties of the soils (engineering-geological elements); research of hydrogeological conditions of Irpin town; recording manifestation of dangerous natural processes .

Specified materials allowed us to create the geomorphological map (1:5000), geological-lithological map (1:5000), hydrogeological map, map of the underground water depth and chemistry of Irpin town (1:5000).

Engineering-geological surveying and mapping became the main research methods. Finally, the complex comparison of the above-mentioned data was transformed into a synthetic large-scale map of engineering-geological zoning and engineering-construction assessment of Irpin town (1:5000) (Fig. 2).).

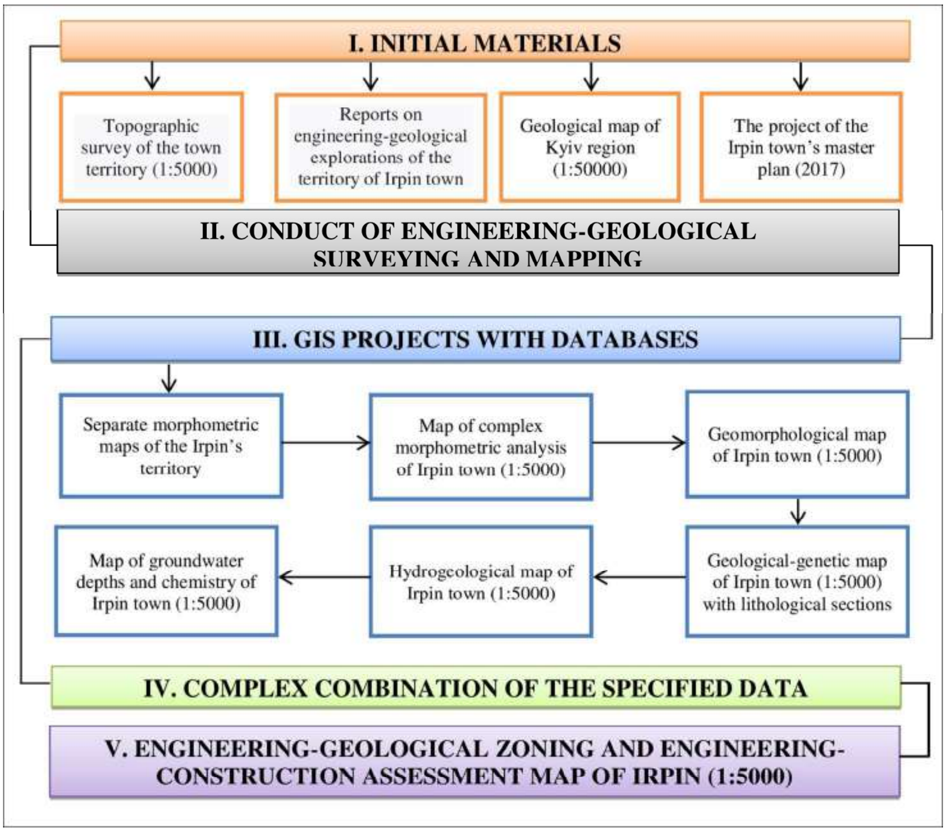


Fig. 2. Data and methodology of the research

Results

Irpin town administratively is situated in the central part of Kyiv region at the distance of 7 km North West from Kyiv, which is the capital of Ukraine.

Geographically, Irpin town is situated in the south-eastern part of the East European Plain, on the north-western slope of the Ukrainian crystalline Shield, within Kyiv Polissia as a part of the Polissia Lowland. According to the map of general geomorphological zoning of Ukraine, the investigated territory corresponds to Makariv moraine water-glacial gentle undulating slightly separated plain between the Irpin, Buchanka, Teteriv and Zdvyzh River valleys [Palienko et al., 2004].

Physical geographic and administrative town location helps to establish the location of Irpin according to the principles of engineering and geological taxonomy. Irpin is situated within the East European platform, the province of the northeastern slope of the Ukrainian crystalline Shield, Kyiv Polissia subprovince, engineering and geological region of the Makariv moraine water-glacial gently undulating, dissected plain [Tsybko, 2020]. Engineering geological districts are provided by general conditions of geological development and by relief morphogenetic types.

Engineering-geological survey of Irpin identified floodplains with swamp massifs and peat depressions of the Holocene age. It also determined the floodplain terrace of the Irpin and Buchanka rivers, the plateau and the elevated part of the moraine-water-glacial plain of the Dnipro period with absolute elevations above 135–160 m. The study established the lowland part of the moraine-aqueous-glacial plain of the Dnipro period with absolute elevations of 120–135 m, bottoms of beams and drift cones of the Holocene age, and areas with artificially modified relief. [Barshchevskyi et al., 1989].

Dangerous natural processes in Irpin town include flooding within the floodplain of the Buchanka and Irpin rivers, inundation within the flood terrace and the first floodplain terrace of the Buchanka and Irpin rivers. It is connected with naturally high levels of groundwater, floodplain flooding processes during spring tide and also unloading of aquifers into permanent and temporary watercourses.

Eutrophication occurs within the floodplain of the Buchanka and Irpin Rivers. It is associated with spring floods and unloading of aquifers confined to Middle-Quaternary water-glacial deposits of watershed.

River erosion is relatively underdeveloped along the Irpin and Buchanka Rivers. However, it is distinct in some areas, where the floodplain deposits are eroded during spring floods.

Sand deflation is connected with eolian activity. It is observed in some areas of flood and first floodplain terraces of the Irpin and Buchanka Rivers (north east and north west town outskirts) [Tsybko, 2020].

Significant hydration of Quaternary deposits, high groundwater level, which provokes flooding, waterlogging and eutrophication are the main obstacles for urban development [Rudenko et al., 1971].

A complex morphometric analysis of the territory of the Irpin town was carried out. It established the indicators of slope steepness, horizontal and vertical dissection and exposure of slopes. This index can characterize the degree of erosion dissection, manifestation of current relief-forming processes, and soil erosion in any territory. The final result included ranking the complex morphometric index into 3 categories according to the complexity of the building development [Kravchuk, 1991].

Data comparison of the morphogenetic structure of the territory, aerials of development of dangerous natural processes and complex morphometrical analysis enabled the creation of a geomorphological map of Irpin town (Fig. 3)

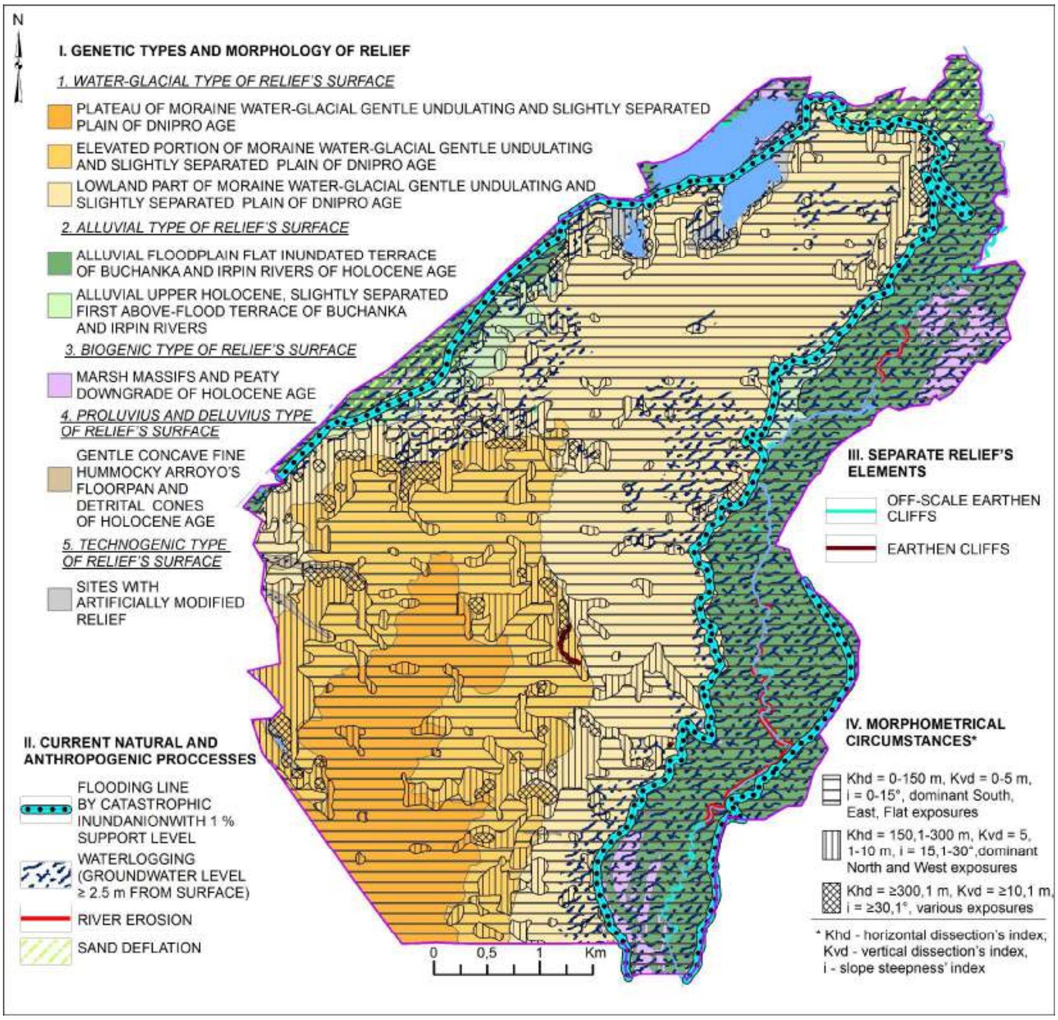


Fig. 3. Geomorphological map of Irpin town

The morphogenetic and morphological structure of the relief lays the foundations for the selection of engineering-geological districts and subdistricts. However, it is necessary to distinguish corresponding geological-genetic complexes of Quaternary sediments within the erosion-accumulative alluvial plain and the denudation-accumulative watershed moraine water-glacial plain. In addition, determination of the lithological composition of the mentioned Quaternary deposits allows identifying relief morphological elements.

Therefore, the analysis of the territory geomorphological features and their geological structure made it possible to distinguish four geological-genetic rock complexes on the territory of Irpin town:

1. A complex of modern alluvial sandy-clay deposits (alIV) with a thickness of 10–16 m represented by fine-grained quartz sands of light yellow and gray-yellow color with lenses and interlayers of sandy loams and loams with a thickness of 0.3–0.9 m.

2. A complex of Upper Quaternary alluvial sandy-clay deposits (alIII) with a thickness of 8–2 m, represented by quartz medium-grained sands of light gray and yellow-gray color with lenses and layers of sand with a thickness of 0.2–0.5 m.

3. A complex of Upper Quaternary water-glacial sand-clay deposits (fIIdn) with a thickness of 5–20 m represented by granular quartz sands of a light gray color with lenses and interlayers of sands, loams and clays with a thickness of 0.2–2.7 m with the inclusion of gravel and weakly rolled pebbles of crystalline rocks.

4. A complex of Upper Quaternary moraine deposits (gIIdn) with a thickness of 8–13 m, represented by boulder loams and clays, in places with layers of sand [Tsybko, 2020].

The analysis of the geotechnical properties of the soils made it possible to divide the selected complexes into 12 engineering-geological elements (EGE). The names of engineering-geological elements are shown in Fig. 4, geological-lithological sections are presented in Fig. 5, physical-mechanical properties of engineering-geological elements are described in Fig. 8.

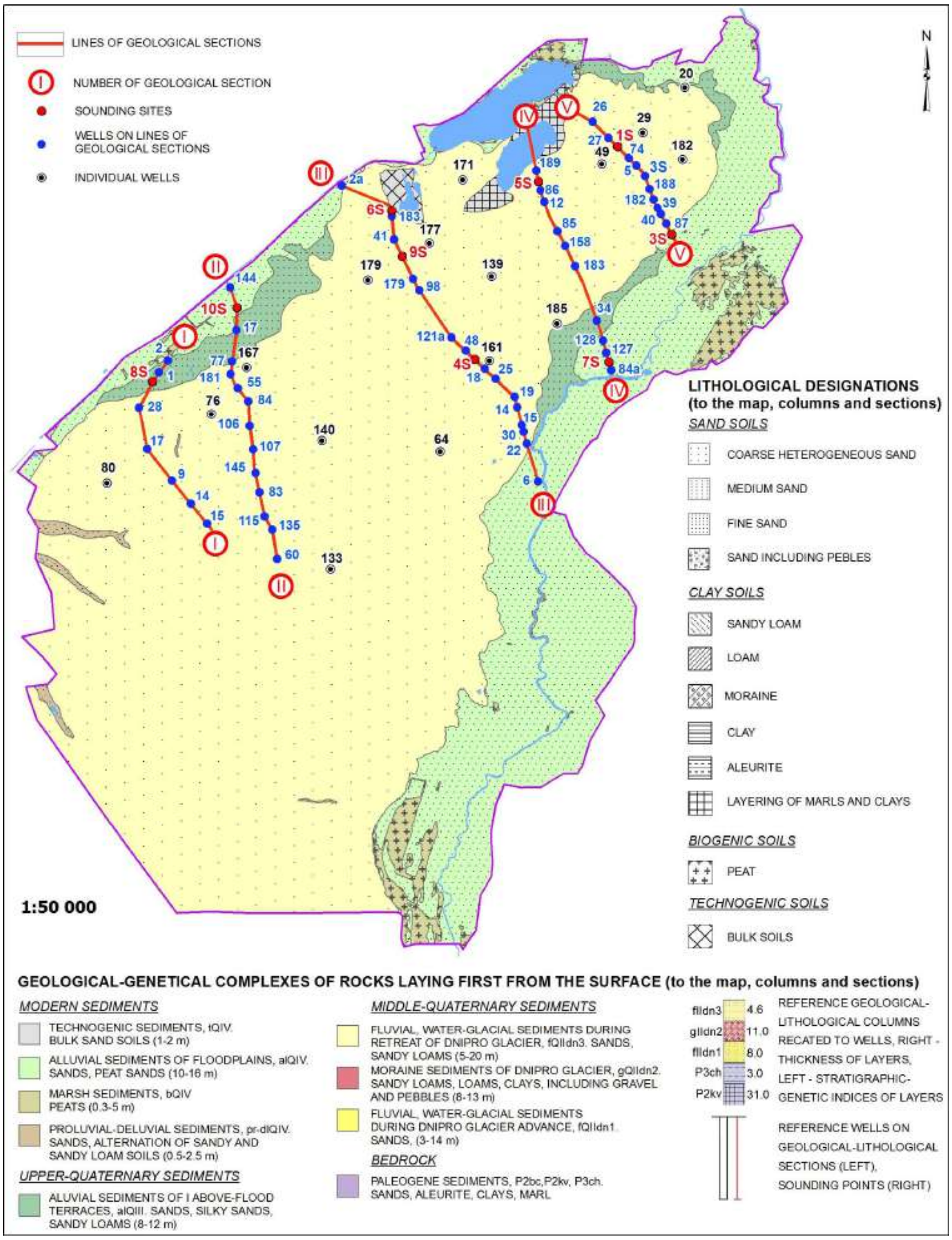


Fig. 4. Geological-genetic map of Irpin town

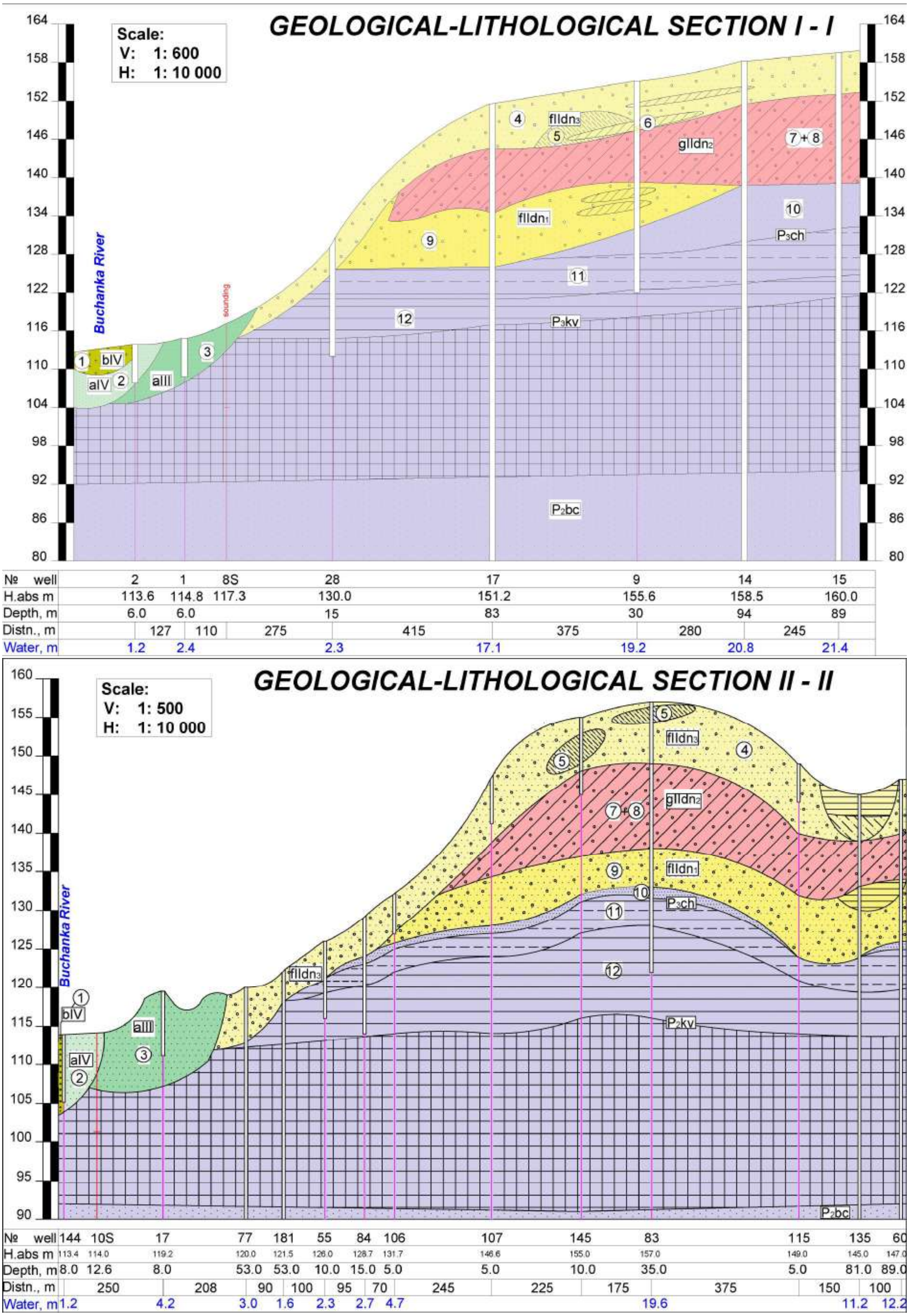


Fig. 5. Geological-lithological sections I-V on Irpin town's territory along conditional lines

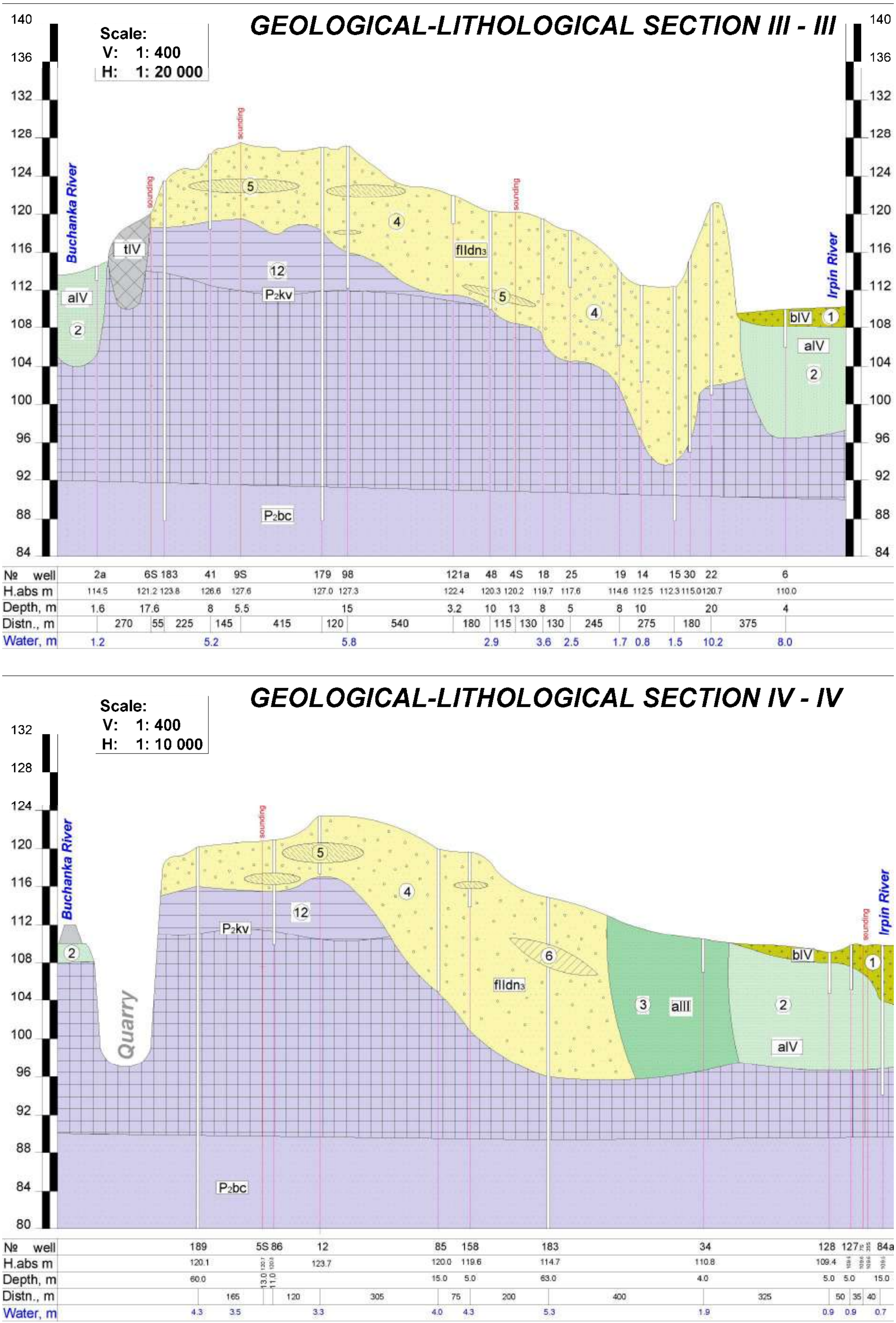


Fig. 5. (Continuation). Geological-lithological sections I-V on Irpin town's territory along conditional lines

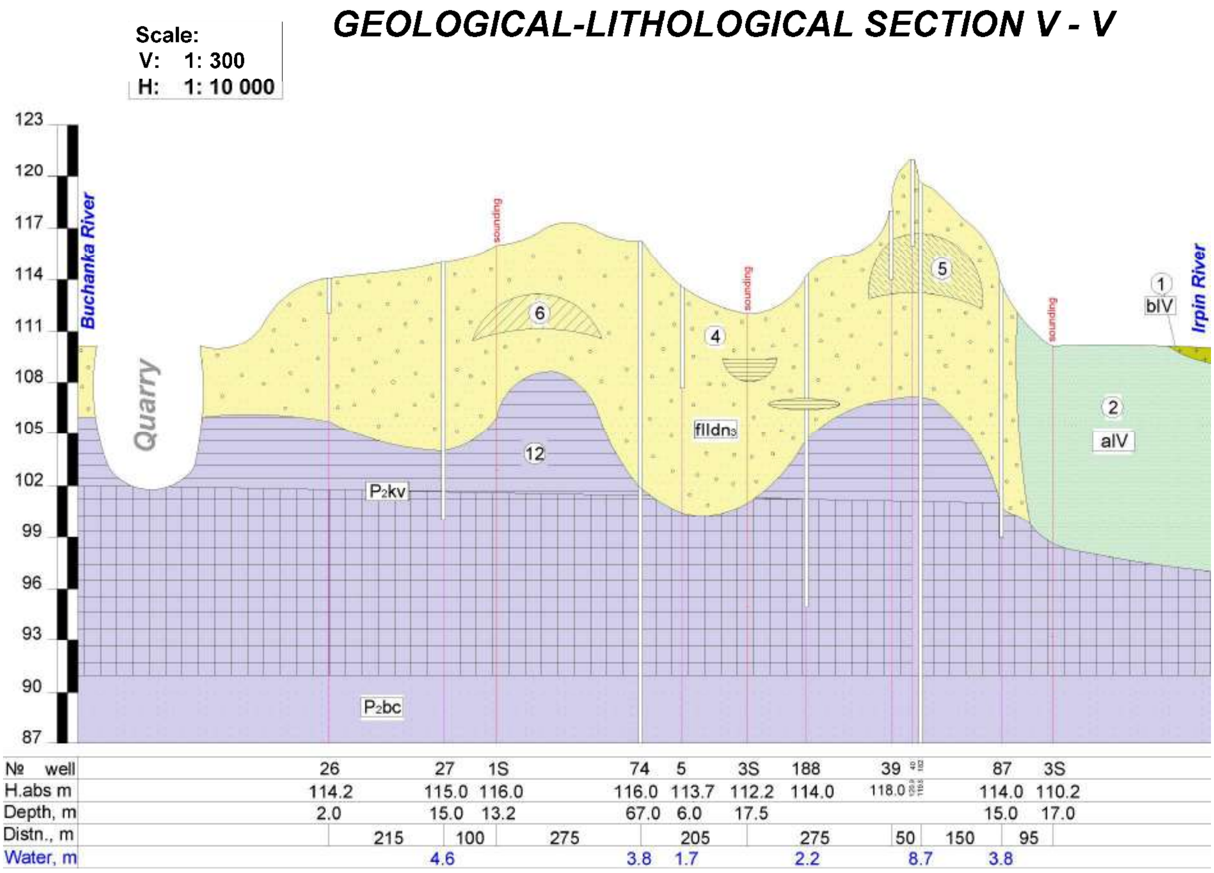


Fig. 5. (End). Geological-lithological sections I-V on Irpin town's territory along conditional lines

Engineering-geological districts and subdistricts can be distinguished based on the comparison of geomorphological and geological-lithological maps in accordance with the taxonomy scheme of engineering-geological zoning. Physical-mechanical properties of engineering-geological elements are the basis for the selection of engineering-geological sites. However, hydrogeological data are needed for this, so the selection of engineering-geological sites is currently impossible [Sedin et al., 2015].

So, the first district is represented by Upper- and Holocene Quaternary QIII–QIV erosion and accumulation alluvial plain with absolute marks of 107–118 m. Alluvial deposits with a thickness of 8–16 m lie on the Kyiv suite marls, which include a water-resistant layer for this area. Two engineering-geological subdistricts are allocated in the first district: 1) Alluvial floodplain inundated flat terrace with marsh massifs and peaty downgrade of Holocene age that composed modern alluvial deposits alQIV with capacity of 10–16 m, covered by modern organogenic formations (silt, peat) bQIV with capacity of 0.3–5.0 m. Alluvial deposits are represented by quartz fine-grained sands of light yellow and gray yellow colors with a layer of sandy loams and loams with capacity of 0.3–0.9 m. The alluvial complex lies on the washed-out surface of the Kyiv suite marls P2kv; 2) Alluvial Upper Holocene slightly separated first floodplain terrace that composed by alluvial sandy and clayey deposits alQIII with capacity of 8–12 m, that represented by alluvial quartz fine-grained sands of light gray and yellow-gray colors with lens and layers of sandy loams with capacity of 0.2–0.5 m. The alluvial complex lies on the washed-out surface of the Kyiv suite marls P2kv.

The second district is represented by Middle Quaternary QII denudation and accumulative watershed moraine water-glacial plain with absolute marks of 120–160 m. Water-glacial and glacial deposits with a thickness of 5 to 23 m lie on the marls of the Kyiv suite, which is a regional water-resistance layer for this area. Four engineering-geological subdistricts are allocated in the II district: 1) the lowland part of the moraine-water-glacial plain of the Dnipro period with absolute elevations of 120–135 m. Subdistrict is composed of a complex of middle Quaternary fluvial-glacial sandy-clayey deposits (flQIIdn3) with capacity of 5–20 m at 10 m medium capacity. The complex is represented by medium-grained light gray quartz sands with lenses and interlayers of sands, loams and clays with a thickness of 0.5–2.7 m with the inclusion of gravel and weakly rolled pebbles of crystalline rocks. Sometimes the gravel-pebble material is collected in the form of lenses and layers; 2) the elevated part and plateau of the moraine-water-glacial plain of the Dnipro period has absolute elevations of 135–160 m. Subdistrict is composed of moraine complexes (glQIIdn2) with a thickness of 8–13 m. They are covered and underlain by fluvioglacial sand-clay deposits of the advance and retreat of the Dnipro glacier (flQIIdn1 and flQIIdn3). Moraine deposits are represented by loams and clays with the inclusion of pebbles and boulders. Fluvial-glacial deposits are represented by average-grained quartz sands with layers of sandy loams and loams including gravel and pebbles; 3) the bottoms of the beams and cones of Holocene age are composed of modern proluvial-deluvial deposits of QIVpr-dl, which are represented by medium-grained quartz sands, interlayering of sandy and loamy soils with a thickness of 0.5–2.5 m; 4) Sites with artificially modified relief presented by recent technogenic deposits tQIV are mounds with structural sorted medium-grained light gray, gray-yellow sands and interlayering of marls and clay with a thickness of 1–2 m [Tsybko, 2020].

Five aquifer complexes are distinguished within the Irpin town territory in accordance with the geological structure and geostructural features of the district:

1) aquifer complex confined to Modern and Upper Quaternary alluvial deposits;

2) an aquifer complex confined to Mid-Quaternary water-glacial and glacial deposits;

3) aquifer complex in Bucha-Kaniv sediments;

4) aquifer complex in Cenomanian sediments;

5) aquifer complex of the fractured zone of Precambrian crystalline rocks [Alekseev, 2005].

The depth of the groundwater table varies widely: from 0–2 m in river valleys to 20–25 m in the watershed. According to the composition, water is mainly sulfate-hydrocarbonate, sulfate-chloride calcium-sodium-magnesium, and fresh. There are three types and degrees of groundwater aggressiveness: weak total acid aggressiveness (type I), medium alkaline aggressiveness (type II) and strong sulfate aggressiveness (type III) (Fig. 6) [Tsybko, 2020].

Engineering-geological sites within the subdistricts can be distinguished by assessing the complex of natural and anthropogenic conditions, analyzing the geomorphological, geological-lithological structure, hydrogeological conditions, composition and properties of the soils of Irpin town. It is necessary to provide them with the appropriate engineering-construction characteristics, which will finally compose the engineering-construction assessment of the Irpin territory.

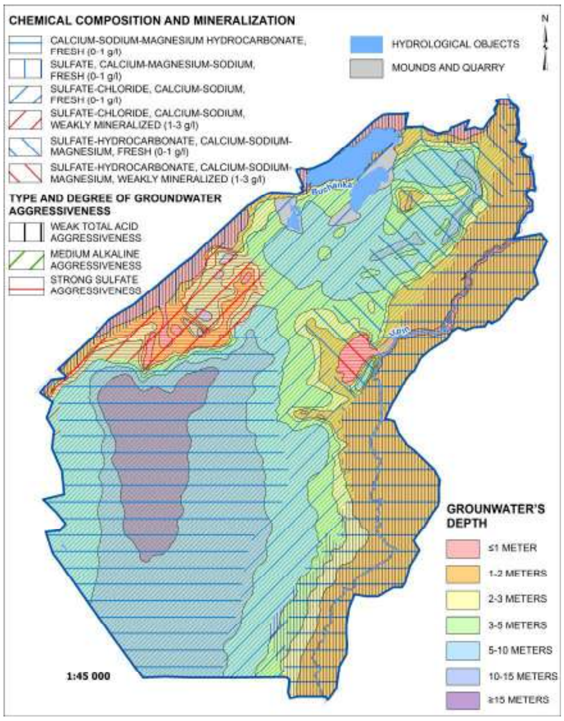


Fig. 6. Groundwater's depth and chemistry of Irpin town

We selected eleven engineering-geological sites with the corresponding characteristics of natural and anthropogenic factors of construction conditions according to the principles of engineering-geological zoning (Fig. 7, 8).

I-1-a. The site is represented by floodplains of the Buchanka and Irpin rivers. The site is unfavorable for construction development according to hydrogeological and lithological conditions. The maximum marks of the groundwater level are higher than the marks of the foundations. There are weak soils (mud, peat) in the geological section at various depths. Flooding and waterlogging are widespread here. Development of the site contradicts the articles 80, 81, 88 of the Ukrainian Water Code. Conditions for construction are unfavorable. Currently, the floodplains are drained, reclaimed and widely used for agricultural land.

I-2-a. The site is unfavorable for construction according to hydrogeological conditions: the maximum groundwater levels are higher than the foundations. Groundwater has weak and medium aggressiveness to concrete. The soil is sandy, impermeable. The conditions for construction are unfavorable. The close proximity of groundwater levels (0–2) m) which have weak alkaline (type I) and strong sulfate (type III corrosion) aggressiveness, requires waterproofing and lowering the level of groundwater, as well as the implementation of anti-erosion measures. The soils have a high bearing capacity, so the construction on a natural basis is possible.

I-2-b. The site is considered favorable for construction according to the hydrogeological conditions. The maximum levels of groundwater are at the depth of foundation lying or at a depth of 1–2 m. The soils are sandy, impermeable. There are no geological processes that negatively affect construction. The territory is conditionally favorable for construction. Groundwater lies at depths of 2–5 m and has a weak alkaline (I type) of corrosion and strong sulfate (III type of corrosion) aggressiveness. Measures to reduce groundwater, waterproofing are needed. The soils are characterized by high bearing capacity. Therefore, the construction on a natural basis is possible.

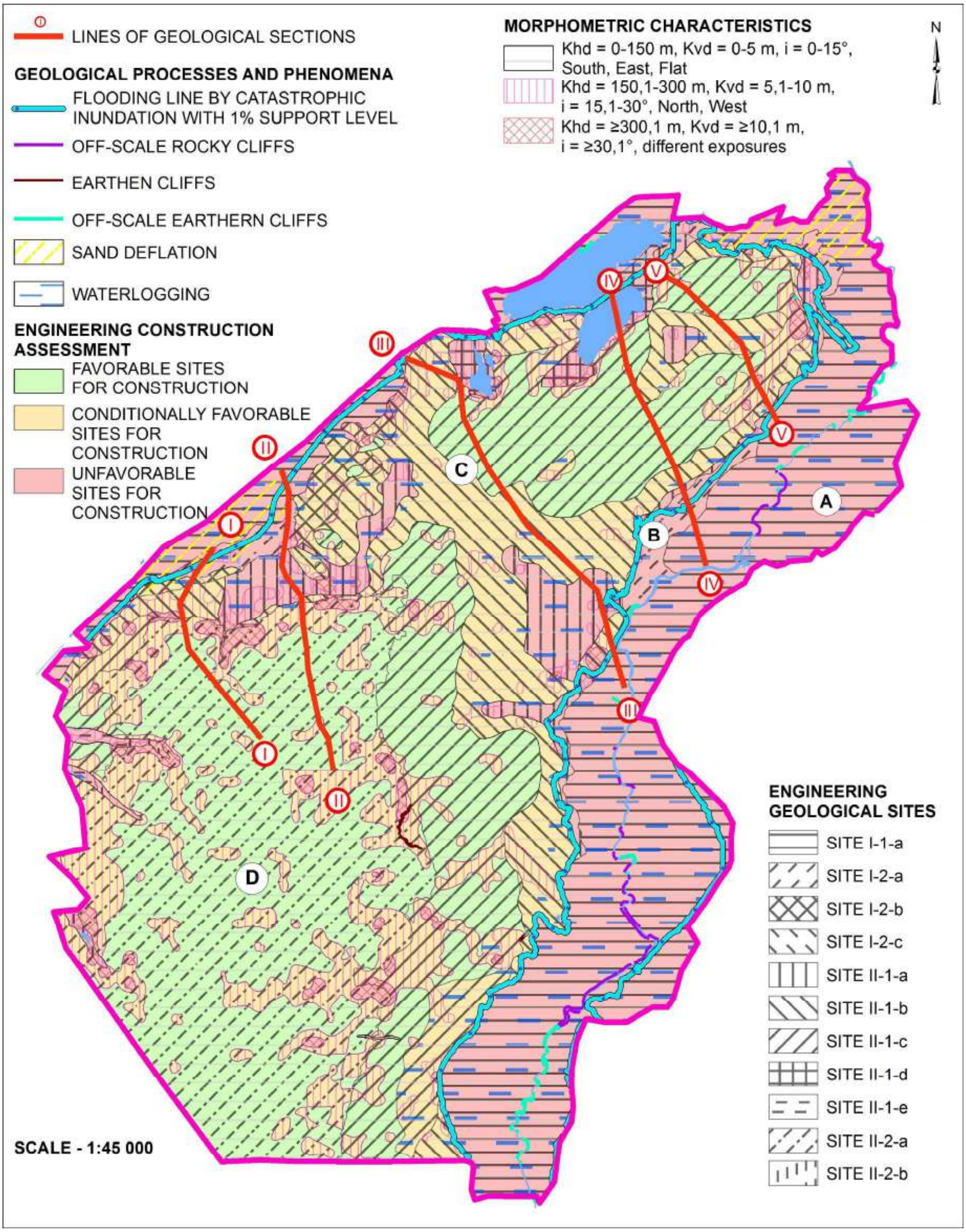


Fig. 7. Engineering-geological zoning and engineering-construction assessment of Irpin town

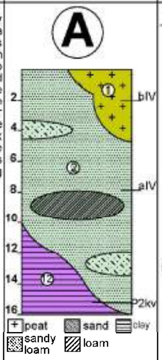
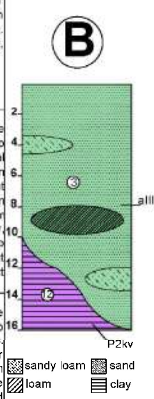
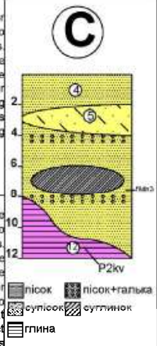
PROVINCE (MORPHOSTRUCTURE HYDROGEOLOGICAL STRUCTURE)	**SUBPROVINCE** (I ORDER MORPHO-GENETIC TYPE)	**OBLAST** (II ORDER MORPHO GENETIC TYPE)	**DISTRICT** (GENERAL CONDITIONS OF GEOLOGICAL DEVELOPMENT)	**SUBDISTRICT** (QUATERNARY ROCKS' ENGINEERING-GEOLOGICAL COMPLEXES)	**SITE** (CONSTRUCTION CONDITIONS – ASSESSMENT OF NATURAL AND ANTHROPOGENIC FACTORS' COMPLEXES)	**TYPICAL GEOLOGIC-LITHOLOGIC COLUMN**	**SOILS' GEOTECHNICAL PROPERTIES**	**SITES' ENGINEERING GEOLOGICAL ASSESSMENT**
NORTHERN SLOPE OF UKRAINIAN CRYSTALLINE SHIELD Composed of a layer of Paleozoic, Mesozoic and Cenozoic sedimentary rocks, the section of the sedimentary layer ends with deposits of glacial and extraglacial formations with a thickness of 400-600 m, represented by fluvioglacial, alluvial, glacial, lake-swamp and loess-loam lithological-genetic complexes. Precambrian rocks, Cretaceous system (K2), Paleogene system (P2kn, P2bc, P2kv, P2ch) and deposits of the Quaternary system (Q) take part in the geological structure of the studied area. The upper hydrogeological layer is composed of Quaternary and Paleogene sediments.	**KYIV POLESIA ON THE BLURRED PALEOGENE-NEOGENE BASIS** It represents glacial, moraine and moraine-sandr lowland plains dissected by wide, shallowly incised terrigenous (floodplain and two suprafloodplain terraces) river valleys. The moraine plains are characterized by hilly relief and unconsolidated areas of terraced and sandr massifs are characterized by eolian forms. Significant areas in river valleys are swamped. A moraine complex of Quaternary sediments is widespread in the western part of Kyiv Polesia. There is a small area of peat complex in the north-eastern part, on the rest of the area – alluvial, fluvioglacial sandy complex.	**MAKARIV GENTLE UNDULITING SLIGHTLY SEPARATED MORAINE-SANDR PLAIN.** A weakly hilly lowland plain with absolute marks on the surface from 100 to 190 m. The roof deposits are represented by the following lithological-genetic rock complexes: water-glacial (various-grained sands), alluvial, (fine-grained sands), glacial (clays, loams, sandy loams) and biogenic (peats). The sediment capacity of the most widespread water-glacier complex varies from 70 to 200 m. Groundwater lies at a depth of 0-25 m and confines to fluvioglacial, alluvial and moraine deposits. Mainly fresh water, hydrocarbonate, sulfate and mixed types, possessing I, II, III types of aggressiveness towards concrete. There are such geological processes: waterlogging, flooding and sand deflation.	**I. EROSIVE-ACCUMULATIVE PLAIN (QIII-QIV)** with absolute surface marks of 107-118 m. Alluvial deposits with a thickness of 8-16 m lie on the marls of the Kyiv suite, which is a water barrier for this area. Groundwater in Quaternary deposits is pressureless, fresh (up to 1 g/l). There is practically no connection between pressure (P2bc) and underground waters in this area. The main aquifer for centralized water supply is the Bucha aquifer lying at a depth of 20-30 m.	**I-1.** The subdistrict is represented by the floodplains of the Irpin and Buchanka rivers and is composed of a complex of alluvial sand-clay deposits (aIV) with a thickness of 10-16 m almost everywhere covered by modern organic formations (bIV) with a thickness of 0.3-5.0 m. The alluvial deposits are represented by quartz fine-grained sands of light yellow and gray-yellow color with a thickness of 0.3-0.7 m. This complex lies on the blurred surface of marls of the Kyiv suite (P2kv).	**I-1-a.** The site is represented by floodplains of the Buchanka and Irpin rivers. The site is unfavorable for construction development according to hydrogeological and lithological conditions. The maximum marks of the groundwater level are higher than the marks of the foundations. There are weak soils (mud, peat) in the geological section at various depths. Widespread flooding and waterlogging.	**A** 	**1. FINELY DECOMPOSED PEAT** W–22% γo–1,97 gf/cm³ γc–1,6 gf/cm³ e–19 τ–0,07 MPa Eo–2,6MPa **2. QUARTZ FINE-GRAINED SAND** Ch–1,7 Cc 7-15% γo–2,02gf/cm³ γc–1,60-1,75 gf/cm³ Natural slope's angle under water – 25° Angle of internal friction – 29-35° φ–34° C–0,03 kgf/cm² Eo–240 kgf/cm²	Development of the site contradicts articles 80, 81 of the Ukrainian Water Code. Conditions for construction are unfavorable. Currently, the floodplains are drained, reclaimed and widely used for agricultural land.
				I-2. Covers the first floodplain terraces of the Irpin and Buchanka rivers. Composed of a complex of Upper Quaternary alluvial sandy-clay deposits (aIII) with a thickness of 8-12 m. The alluvial deposits are represented by quartz fine-grained sands of light gray color with lenses and interlayers of sandy loam with a thickness of 0.2-0.5 m. The alluvial complex lies on the eroded surface of marls of the Kyiv suite (P2kv).	**I-2-a.** The site is unfavorable for construction according to hydrogeological conditions: the maximum groundwater levels are higher than the foundations. Groundwater has weak and medium aggressiveness to concrete. The soil is sandy, impermeable.		**3. QUARTZ MIDDLE FINE-GRAINE SAND** Ch–2,1 Cc–8-12% γo–2,00 gf/cm³ γc–1,70 gf/cm³ φ–37° C–0,01 kgf/cm² Eo–280 kgf/cm² Natural internal friction–32° Under water–25°	The conditions for construction are unfavorable, the close proximity of groundwater levels (0-2) m) which have weak alkaline (type I) and strong sulfate (type III corrosion) aggressiveness requires waterproofing and lowering the level of groundwater, as well as the implementation of anti-erosion measures. The soils have a high bearing capacity – construction on a natural basis is possible.
					I-2-b Site is considered favorable for construction according to the hydrogeological conditions. The maximum levels of groundwater are at the depth of foundation laying or at a depth of 1-2 m below. The soils are sandy, impermeable. There are no geological processes that negatively affect construction.	**B** 	**4. QUARTZ MULTI-GRAINED SAND** Ch–3,4 Cc–8-12% γo–2,00 gf/cm³ γc–1,72 gf/cm³ φ–27° C–0,02 kgf/cm² Eo–320 kgf/cm². Natural internal friction angle–33°, under water–29°.	The territory is conditionally favorable for construction. Groundwater lies at depths of 2-5 m and has a weak alkaline (I type of corrosion) and strong sulfate (III type of corrosion) aggressiveness. Measures to reduce groundwater waterproofing are needed. The soils are characterized by high bearing capacity - construction on a natural basis is possible.
					I-2-c The site is quite favorable for construction according to the complex of conditions. The maximum groundwater levels are more than 30 m below the foundations. The soils are sandy and impermeable. There are no geological processes that negatively affect construction.		**5. SANDY LOAM** W–16% Wl–22% Jp– 1-7(4) γo–1,92 gf/cm³ γc–1,69 gf/cm³ e–0,58 φ–27° C–0,160 kgf/cm² Eo–300 kgf/cm².	Conditions for construction are quite favorable. Groundwater has a strong sulfate aggressiveness, (III type of corrosion) lies at depths of more than 5 m. Soils have a high bearing capacity. Measures for engineering preparation of the territory are not required.
			II. DENUDATION-ACCUMULATIVE WATERSHED MORAINE-SANDR PLAIN mid-Quaternary age with absolute marks of 120-160 m. Quaternary deposits with a thickness of 50 to 230 m lie on the marls of the Kyiv suite which is a regional water barrier for this area. Groundwater in Quaternary deposits is pressureless, mostly fresh, (up to 1 g/l) and weakly mineralized (up to 2.5 g/l) in places. There is practically no connection between pressure (P2bc) and underground waters. The main aquifer for centralized water supply is the Bucha aquifer, lying at depths of 30-60 m.	**II-1.** Covers the lower part of the watershed plain between the Irpin and Buchanka rivers with absolute surface elevations of 120-135 m. The subdistrict is composed of a complex of middle quarters of fluvioglacial sand-clay deposits (fIIdn3) with a thickness of 5.0 to 20.0 m with an average thickness of 10.0 m. The complex is represented by light-gray multi-grained, mainly medium-grained quartz sands with lenses and layers of sands, loams and clays with a thickness of 0.2-2.7 m. Inclusions of gravel and weakly rolled pebbles of crystalline rocks are observed. Fluvioglacial sediments lie on the washed-out surface of marls of the Kyiv suite (P2kv).	**II-1-a** The site is unfavorable for construction according to hydrogeological conditions. The maximum marks of the groundwater level above the foundations. Groundwater has medium and strong aggressiveness towards concrete. There is a flooding of the territory.	**C** 	**6. LIGHT LOAM** Jp–10 W–13% Wl–26% γo–2,14 gf/cm³ γc–1,89 gf/cm³ e–0,43 φ–23° C–0,265 kgf/cm² Eo–460 kgf/cm²	The conditions for construction are unfavorable, the closeness of groundwater levels (0-2 m) with average overall acid aggressiveness (II type of corrosion) requires waterproofing and lowering of the groundwater level, as well as the implementation of anti-corrosion measures. It is necessary to arrange artificial bases and foundations.
					II-1-b. Site is conditionally favorable for construction according to hydrogeological conditions. The maximum marks of the groundwater level are at the depth of the foundations or 1-2 m below. There are no geological processes that negatively affect construction. Groundwater is moderately aggressive towards concrete. Soils are sandy-clay, impermeable.		**7. CLAY** Jp–22 Wl–44% W–22% γo–1,99 gf/cm³ γc–1,63 gf/cm³ e–0,67 φ–18° C–0,500 kgf/cm² Eo–350 kgf/cm²	The territory is conditionally favorable for construction. Groundwater lies at a depth of 2-5 m and has average overall acid aggressiveness (II type of corrosion). The soils have a high bearing capacity - construction on a natural basis is possible. A small amount of planning work is required.

Fig. 8. Legend to the engineering-geological zoning map of Irpin town

I-2-c. The site is quite favorable for construction according to the complex of conditions. The maximum groundwater levels are more than 30 m below the foundations. The soils are sandy and impermeable. There are no geological processes that negatively affect construction. Conditions for construction are quite favorable. Groundwater has strong sulfate aggressiveness, (III type of corrosion) lies at depths of more than 5 m. Soils have a high bearing capacity. Measures for engineering preparation of the territory are not required.

II-1-a. The site is unfavorable for construction according to hydrogeological conditions. The maximum marks of the groundwater level above the foundations. Groundwater has medium and strong aggressiveness towards concrete. There is flooding of the territory. The conditions for construction are unfavorable, the closeness of groundwater levels (0–2 m) with average overall acid aggressiveness (II type of corrosion) requires waterproofing and lowering of the groundwater level, as well as the implementation of anti-corrosion measures. It is necessary to arrange artificial bases and foundations.

II-1-b. The site is conditionally favorable for construction according to hydrogeological conditions. The maximum marks of the groundwater level are at the depth of the foundations or 1–2 m below them. There are no geological processes that negatively affect construction. Groundwater is moderately aggressive towards concrete. Soils are sandy-clay, impermeable. The territory is conditionally favorable for construction. Groundwater lies at a depth of 2–5 m and has average overall acid aggressiveness (II type of corrosion). The soils have a high bearing capacity, so the construction on a natural basis is possible. A small amount of planning work is required.

II-1-c. The site is quite favorable for construction according to the set of natural conditions. The maximum groundwater level is more than 3.0 m below the level of the foundations. Groundwater is moderately aggressive towards concrete. Soils are sandy-clay, impermeable. There are no geological processes that negatively affect construction. Conditions for construction are quite favorable. Groundwater lies at depths of more than 5 m. The soils have a high bearing capacity, so the construction on a natural basis is possible. A small amount of planning work is required. Special measures for engineering preparation are not required.

II-1-d. The site is represented by technogenic landforms: sand embankments and a clay quarry. This area is unfavorable for construction. The site is not planned for construction. Involvement of undermined territories in construction is impossible.

II-1-e. The site is represented by a gully network with a manifestation of gully erosion and flooding processes. The site is unfavorable for construction due to the complexity of the geomorphological conditions and the presence of dangerous natural processes. The site is unfavorable for construction. The site is characterized by inundation and intensive manifestation of gully erosion. The site serves as a place for discharging groundwater, which makes construction impractical.

II-2-a. The site is quite favorable for construction according to the complex of natural conditions. The maximum groundwater level is more than 3.0 m below the level of foundations. Groundwater is moderately aggressive towards concrete. The soils are sandy and clayey, impermeable. There are no geological processes that negatively affect construction. Conditions for construction are quite favorable. Groundwater lies at depths of more than 5 m. The soils have a high bearing capacity. It is possible to build on a natural basis. A small amount of planning work is required. Special measures for engineering training are unnecessary.

II-2-b. The site is represented by a gully network with a manifestation of gully erosion and flooding processes and by engineering-construction characteristics it is similar to site II-1-e (Figs. 7, 8) [Tsybko, 2020].

We present the engineering-construction characteristics of the engineering-geological subsites of Irpin town according to the geodynamic process manifestation and relief morphometric characteristics (see table, Fig. 7).

Engineering-geological subsites of Irpin town

Engineering-geological subsites	Engineering-construction assessment
1	2
Subsites with manifestation of flooding line by catastrophic inundation with 1 % support level	The subsites are unfavorable for construction, as the process is typical for the floodplains of the Buchanka and Irpin Rivers (violation of the requirements of Articles 80, 81, 88 of the Ukrainian Water Code) with unsatisfactory engineering and construction characteristics. The installation of embankment dams or raising the banks to non-flooding levels with gabion structures is necessary to eliminate flooding [BC B.1.1-25-2009, 2010]
Subsites with rocky and earthen cliffs	Subsites are unfavorable for construction, since construction is impossible on cliffs. Cliff subsites require complex engineering planning and protection: it is necessary to carry out earth planning works, arrange drainage systems, build retaining walls and as much as possible greening of steep slopes [BC B.1.1-24:2009, 2010]
Subsites with sand deflation	The subsites are unfavorable for construction, as the process is typical for the floodplains of the Buchanka and Irpin Rivers with unsatisfactory engineering-construction characteristics. The installation of artificial obstacles or the anchoring of sand massifs with vegetation with a branched root system is necessary to eliminate sand deflation

Continuation of Table

1	2
Subsites with underflooding	Underflooding subsites refer to both unfavorable and conditionally favorable areas for construction depending on their location within specific areas and the expressiveness of the process. The floodplains of the Irpin and Buchanka Rivers belong to underflooding areas. Underflooding also covers local subsites and above-flood terraces and bottoms of gully network. Local subsites of the lowered part of the moraine water-glacial plain with groundwater levels up to 3.0 m from the day surface belong to underflooded areas. Shore fortification with gabions using waterproof geomembranes up to non-flooded marks, backfilling with mineral soil is recommended to eliminate underflooding. Installation of horizontal closed drainage is proposed for local areas of underflooding. Clearing water areas and flooding of reservoirs, rivers, canals and ditches is an important measure to reduce the area of under flooded subsites. It is necessary to organize a network of closed storm sewers and establish coastal protective strips of the Irpin and Buchanka Rivers. Carrying out phytomelioration measures, organization of beaches and construction of anti-erosion hydrotechnical structures is desirable within coastal protective strips. Elimination of cesspools and water-absorbing wells within the town is necessary, as they contribute to the process of underflooding [SSU-Н Б В.1.1-XX:201X, 201X]
Subsites with morphometrical characteristics: K_{hd} – 0–150 m/ha; K_{vd} – 0–5 m/ha; i – 0–15°; dominant South, East exposures, Flat	The subsites belong to favorable areas for construction. There is no need for special engineering training and protection measures. Installation of networks of closed storm sewers is necessary
Subsites with morphometrical characteristics: K_{hd} – 150.1–300 m/ha; K_{vd} – 5.1–10 m/ha; i – 15.1–30°; dominant North, West exposures	The subsites belong to conditionally favorable territories for construction. Certain measures of engineering preparation are necessary: carrying out land works for vertical and horizontal planning, in certain subsites it is necessary to install anti-erosion hydrotechnical structures. The terrace location of buildings and structures, the arrangement of drainage systems or storm sewer networks and the maximum possible greening of the territory with the planting of moisture-loving tree species with a branched root system is necessary on subsites with a relief slope of 20 to 30°. Improvement of microclimatic characteristics through the use of appropriate climatic equipment, light protection devices is necessary for living rooms
Subsites with morphometrical characteristics: $K_{hd} \geq 300{,}1$ m/ha; $K_{vd} \geq 10{,}1$ m/ha; $i \geq 30{,}1°$; different exposures	The subsites belong to unfavorable areas for construction. Significant materially costly measures for vertical and horizontal planning of the territory are necessary. Mandatory installation of closed horizontal drains and closed storm sewers. Terracing and fastening with retaining walls is necessary when developing slopes. The development of gravitational geological processes is possible. These subsites are not recommended to be involved in construction, the organization of green zones and afforestation of the territory is considered the optimal option

Discussion

The conducted research allows determining two topics for discussion:

- disadvantages of engineering-geological zoning of Irpin town;
- practical significance of engineering-geological zoning of Irpin town;.

1. Disadvantages of engineering-geological zoning of Irpin town.

The major disadvantage of engineering-geological zoning is absence of information about neotectonic movements, structural forms, whose activity is displayed in relief and Quaternary deposits' structure. The information about a number of factors is of engineering significance. Such factors include summary amplitude of neotectonic movements, neotectonic active discontinuous disturbances, recent violations, selection of neotectonic structures, faults of different orders. As those factors can affect the stability of structures and their trouble-free operation, this information is valuable for the definition of suitability of building sites. There is no information about selection of morphostructures of the first, second and third orders and tectonic lineaments [Barshchevsky et al., 1989].

Irpin has a favorable seismic profile according to the general seismic zoning map [BC V.1.1-12:2014, 2014]. However, if the microseismic zoning of the town were carried out, increased seismic activity would be possible within the areas with the development of dangerous natural processes, increased morphometric indicators, and neotectonic movements. This requires special measures for laying foundations and construction of building frames.

The development of dangerous natural processes has been studied; however, there is no data on anthropogenic morphogenesis within the town. This is primarily manifested in changes in the relief, soil cover, vegetation, and hydrogeological conditions. Taking into account the close location of Irpin town to Kyiv, the capital city, and the pace of construction development for residential and public development, it is worth considering first of all the general equation of the relief, the erosion of geomorphological faces on the surface, the gradual disappearance of the natural microrelief, the appearance of anthropogenic microrelief (quarries, earthworks embankments, dams, berms, road ditches) [Shnyukov et al., 1993].

The main disadvantages in determination of geotechnical properties of soils (engineering-geological elements) within the town of Irpin are the absence of the following studies: a) determination of chemical properties of soils, in particular, missing data on solubility, acid-base properties and soils' chemical aggressiveness; b) determination of physical properties of soils, in particular, missing information on thermophysical (thermal capacity, frost resistance of soils) and electrical properties (electrical conductivity, corrosive activity of soils); c) determination of biotic properties of soils (biological activity, bioaggressiveness and biocorrosion in soils); d) determination of certain physical-mechanical properties of soils (rheological properties: creep, relaxation of stresses in soils, soils' long-term strength; dynamic properties: soils' behavior under vibration and impulsive effects, soils' liquefaction) [Trofimov et al., 2005].

It is worth noting that the construction of geological-lithological sections and the determination of geotechnical properties of soils took place only in the high-density area and most developed northern, northeastern and northwestern parts of the town, while the rest of the Irpin territory has not been explored. This is a significant disadvantage for the urban development in the distant future.

2. Practical significance of engineering-geological zoning of Irpin town.

The practical aspect of the conducted engineering-geological zoning consists in the creation of a high-quality scheme of engineering-construction assessment, which is desirable among the graphic materials of the master plan of the settlement [BC B.1.1-14:2021, 2022]. The allocation of areas unfavorable for construction is of special importance for design engineers and architects. Such areas should be excluded for urban development. In addition, the conducted research helps to highlight planning restrictions of an engineering-geological nature. The engineering-geological zoning map will serve as the basis for the mandatory scheme of engineering preparation and protection of the city. The given engineering-construction characteristics of engineering-geological sites and subsites will help determine the necessary volume of earth planning works (vertical and horizontal planning of the territory) and choose appropriate measures on engineering protection of the town territory. Engineering-geological zoning provides accurate information about the development of dangerous natural processes and helps to accurately allocate an economically justified volume of planning and protective measures. Engineering-geological zoning allows us to correctly choose the location of buildings, their construction, to determine excavation works, rational types of foundations [Trofimov, Krasylova, 2008]. The obtained materials make it possible to reduce the scope and terms of search works, cut cost of civil and industrial construction and improve the quality of project solutions.

Conclusions

1. Qualitative engineering-construction evaluation as part of the project of the town master plan should be based on the engineering-geological zoning of the territory with the allocation of taxonomic units of different order.

2. The allocation principles of taxonomic units of different levels were established by I.V. Popov. They provide for the distinguishing engineering-geological regions, as the largest taxonomic unit of engineering-geological zoning according to structural-tectonic features. Engineering-geological provinces are allocated according to morphostructure and hydrogeological structure, subprovinces – according to the first order morphogenetic type of the territory, oblasts – according to the second order morphogenetic type of the territory, districts – according to the common conditions of geological development, subdistricts – according to the engineering-geological complexes of rocks of the Quaternary stratum, sites – according to construction conditions. It is recommended to allocate subsites according to the manifestation of geodynamic processes and morphometric characteristics of the relief.

3. Geomorphological, geological and lithological structures, hydrogeological conditions were investigated, the composition and properties of soils were analyzed, a morphometric analysis of the territory was made, dangerous natural and anthropogenic processes were identified for the justified selection of

town sites with different degrees of suitability for construction.

4. Eleven engineering-geological sites are allocated with appropriate characteristics of natural and anthropogenic factors of construction conditions in accordance with the principles of engineering-geological zoning, among which six sites are unfavorable for construction.

5. Subsites with the manifestation of flooding by catastrophic floods of 1 % security level, with the manifestation of rocky and earthen cliffs and with the manifestation of sand deflation are considered unfavorable for construction. In addition, subsites with the manifestation of underflooding refer to both unfavorable and relatively favorable territories for construction. Subsites with high indicators of horizontal and vertical dissection and slope steepness are unfavorable for construction, as there is a high probability of erosion and gravity processes development.

6. The practical aspect of the conducted engineering-geological zoning consists in the creation of a high-quality scheme of engineering-construction assessment, supplementing the scheme of existing planning restrictions. The map of engineering-geological zoning is the basis for the mandatory scheme of engineering preparation and protection of the town. Engineering-geological zoning allows correct choice of the locations of buildings and their structures. It helps to determine excavation works, rational types of foundations, reduce the volume and cost of prospecting works and construction and improve the quality of project solutions.

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ІНЖЕНЕРНО-ГЕОЛОГІЧНЕ РАЙОНУВАННЯ ЯК НАУКОВО-МЕТОДИЧНА ОСНОВА ДЛЯ СКЛАДАННЯ СХЕМИ ІНЖЕНЕРНО-БУДІВЕЛЬНОЇ ОЦІНКИ (НА ПРИКЛАДІ МІСТА ІРПІНЬ КИЇВСЬКОЇ ОБЛАСТІ)

Мета статті – здійснення інженерно-будівельної оцінки міста Ірпінь Київської області на основі виконання інженерно-геологічного районування населеного пункту, яке передбачає виділення різнорівневих таксономічних одиниць із набором природних та антропогенних факторів умов будівництва від найбільшої одиниці (інженерно-геологічного регіону) до найменших (ділянок та підділянок). Основні методи дослідження – інженерно-геологічне знімання та інженерно-геологічне картографування. Результат дослідження – комплексне зіставлення даних про геоморфологічну, геолого-генетичну будову, гідрогеологічні умови, склад та властивості ґрунтів м. Ірпінь, що у кінцевому випадку надало можливість побудувати великомасштабну синтетичну карту інженерно-геологічного районування та інженерно-будівельної оцінки населеного пункту. Виділено одинадцять інженерно-геологічних ділянок із відповідними характеристиками природних та антропогенних факторів умов будівництва, серед яких шість несприятливі для будівництва. Наукова новизна дослідження полягає у застосуванні інженерно-геологічного районування як основи для виконання інженерно-будівельної оцінки, що не обмежується лише виділенням планувальних інженерно-геологічних обмежень. Вперше запропоновано методику виділення інженерно-геологічних підділянок за проявом небезпечних геологічних процесів та морфометричними характеристиками рельєфу, що відображають ступінь ерозійної розчленованості, потенціал прояву сучасних рельєфоутворювальних процесів та ерозії ґрунтів. Практичний аспект здійсненого дослідження полягає у створенні якісної схеми інженерно-будівельної оцінки, доповненні схеми наявних планувальних обмежень, підборі оптимальних та економічно обґрунтованих заходів з інженерної підготовки та захисту територій проти небезпечних геологічних процесів. Інженерно-геологічне районування дає змогу визначити безпечні місця для розміщення інженерних споруд, їх конструкційні особливості, вибрати раціональні типи фундаментів, зменшити вартість вишукувальних та будівельних робіт та загалом поліпшити якість проєктування.

Ключові слова: інженерно-геологічне районування; інженерно-будівельна оцінка; таксономічні одиниці; небезпечні геологічні процеси; морфометричні характеристики; геолого-літологічна будова; Ірпінь.

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