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RESEARCH AND MAPPING OF LANDSLIDES WITHIN THE BOUNDARIES OF THE MIDDLE DNIPRO INDUSTRIAL–URBAN AGGLOMERATIONS

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Abstract. Research on and mapping of landslides of Dnipropetrovs'k–Dniprodzerzhins'k industrial-city agglomeration were carried out during the period of 1978–2002, on the basis of geological material obtained with the help of funds, space pictures and own research. The results were as follows: rules of spatial landslides development and its dynamics for almost 30 years period have been recognised, the main natural and technical factors of landslides activation have been discovered; passports of the most dangerous moving sites have been created; sites of the high risk of landslides appearance and its possible negative consequences for nature and population as well as for technical constructions have been determined.

Key words: landslides relief, landslide activation, mapping of landslides, landslides.

Abstrakt. Osuwiska występujące na obszarze aglomeracji Dniepropietrowska i Dnieprodzierżyńska były badane i kartowane w latach 1978–2002, dzięki materiałom geologicznym uzyskanym przy pomocy grantów, wykorzystaniu zdjęć satelitarnych oraz badaniom własnym. W wyniku badań poznano prawa rządzące powstawaniem i rozwojem osuwisk przez prawie 30 lat, opisano główne przyrodnicze i techniczne przyczyny aktywacji osuwisk, opracowano opisy miejsc najbardziej zagrożonych ruchami osuwiskowymi, określono też miejsca dużego ryzyka powstawania osuwisk oraz potencjalnych zagrożeń dla środowiska naturalnego, mieszkańców i budowli technicznych.

Słowa kluczowe: rzeźba terenów osuwiskowych, aktywacja osuwiska, kartowanie osuwisk, osuwiska.

INTRODUCTION

Research on development rules of the last decades natural disasters has reached important results in the estimation of ecological safety. In particular, it concerned industrial-cities agglomerations where technical pressure essentially strengthened the natural development of dangerous processes, and made threats of their activation which could lead to catastrophes.

The Dnipropetrovs'k–Dniprodzerzhins'k industrial-city agglomeration is one of the greatest in Ukraine. It is located within the boundaries of the Middle Dnipro valley complexes and watershed plateau. On the territory of Dnipropetrovs'k and Dniprodzerzhins'k cities live over 1.3 million people. More than 400 industrial enterprises are located there, including powerful metallurgical, machine-building and chemical ones. Besides, the agglomeration is placed between two hydroelectric power stations built above (Dniprodzerzhins'k) and below (Zaporizhya) the current Dnipro course. Within the limits of the agglomeration functions also a thermal station Pridniprovska. All the above mentioned enterprises apply "wet" technologies that essentially influence process of raising the subsoil water level, which increases danger of the landslides activation.

Activation of landslides can have catastrophic character and threatens the environment by loss of natural stability of the geosystems. It belongs, therefore, to the most dangerous processes characteristic for the studied region. The appearance of these processes not only influences the natural rocks positions. It also destroys and changes morphology of ravines and gullies slopes, forms specific moving relief, and threatens the safety of the people residing there. That is why further development of theoretic-methodological research bases of the mass movement processes within the territory of industrial-city agglomerations is still actual, with a special emphasize on the complex optimization of the economic use of territorial resource.

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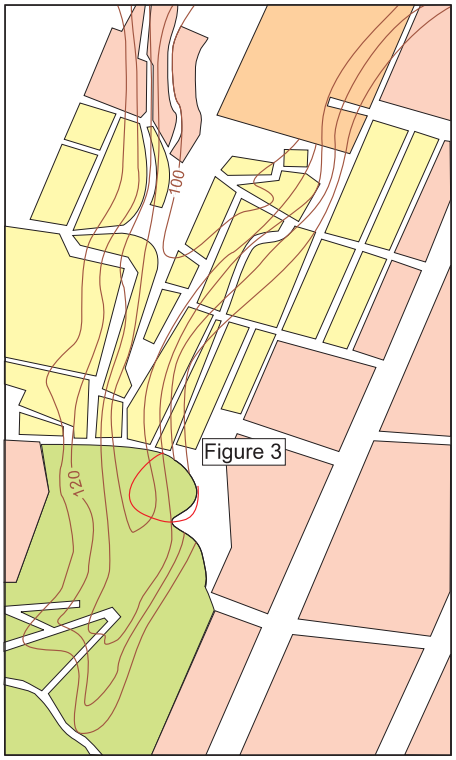

Fig. 2. Technical load on the Voycekhovich ravine slopes

Fig. 3. Abandon 14-storeyed dwelling house, deformed as result of landslide activation

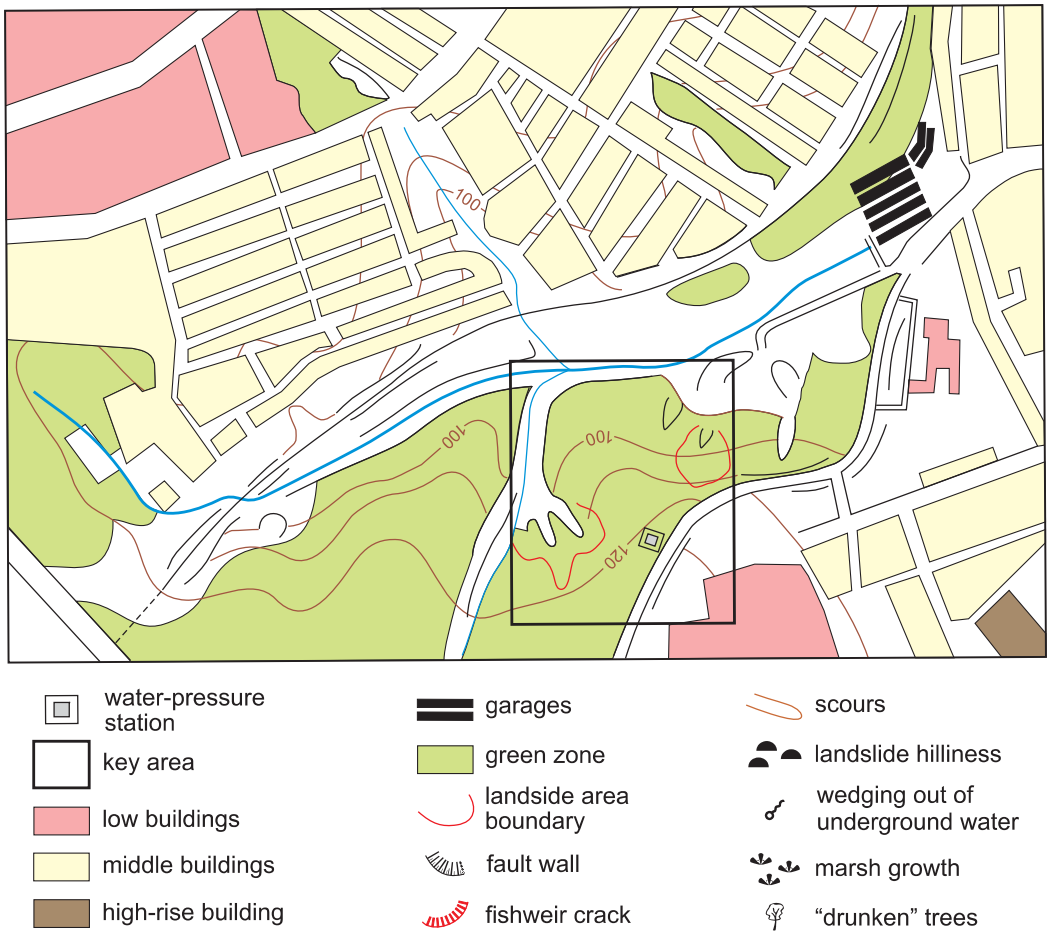

Fig. 4. Technical load on the Tonelnaya ravine slopes

Presently, capacity of this water horizon is not sustained and closely connected with the depth of water appearance: in areas where the red-brown waterproof basement is elevated, the capacity of the horizon is minimal, being 0.5–1.0 m thick, and in the basement depressions is maximal, with the horizon thickness of 6–9 m. The average depth of the subsoil water level varies from 0.5 up to 10.0 m, but within the boundaries of the high right-bank terraces it increases to 14–25 m. On flood--lands and low terraces, the subsoil water appears on surface in places, forming boggy sites. Water in the water horizon is replenished by the infiltration of atmospheric precipitation, by water inflowing from the lower water horizons, and also by water seeping from water pipelines. Behaviour of the anthropogenic water horizon is changeable, closely connected with quantity of water which it carries.

The great importance for the development of relief and sliding processes has also Neogene water horizon contained in the sediments of the Poltava series, lying at the depth of 4–6 m in ravines, and at the depth of 26–55 m on the watershed plateau and the left-bank of accumulative plain (absolute marks 65–75). The Neogene sand is a host for this water horizon. The water replenishment of the horizon in watershed is supplied by vertical infiltration from the anthropogenic water horizon, in places where waterproof bed is lacking, and in the ravines — by infiltration of the atmospheric precipitation and flowing surface water. The Neogene water horizon is unloading into the Dnipro River.

The main types of technical operations which change the hydrogeological conditions of the city territory are: formations of depressive cones in water complexes, use of "wet" technologies by enterprises, faulty operations of water pipelines, water drainage from underground tunnels, etc.

Technical factors. The main technical causes of landslides activation within the agglomeration boundaries are as follows:

— regulation of the Dnipro River and rise of its level by 4.4 m in average as a result of the construction of a water basin in 1932 as well as of the destruction of many natural drains by infilling;
— significant age of water carrying networks (30–60 years) and the resulted considerable water loss (15–35%);
— presence of the "wet" technologies enterprises (metallurgical, electropower, chemical and others);
— increased loading of the slopes by the too dense construction of multi-storey houses;
— undercutting slopes during roads and/or pipelines construction;
— influence of vehicles vibrations.

The potentially movable areas are recently actively utilised for recreational purposes. For instance, constructions of a sports complex, such as skating rink and artificial ski line (Fig. 2, 3) are carried out on moving terrace in a Tunnel ravine. Construction of this complex negatively influences stability of the potentially sliding site because of large scale works and the increase of static load.

REGIONAL CONDITIONS FOR THE APPEARANCE OF SLIDING PROCESS

Within Dnipropetrovs'k–Dniprodzerzhins'k agglomeration boundaries, there are 202 landslide sites, including 23 active sites (Fig. 9). The total area covers 2,663 km^2. Almost 50% of it is located within the inhabited and industrial areas (Fig. 10).

Landslides developed on the gullies-ravines slopes on the right-banks of both bridges are made mainly of loess identical to loams of late anthropogenic age, and are characterised by high sensitivity to various technical influences. Having a weak hardness and significant susceptibility to deformations, the loams under certain conditions (high humidity, increase of upload) undergo plastic deformations which can lead to catastrophic infringement of stability and the landslide deformation of slopes. The majority of landslides activate on the over wetted slopes.

The greatest deformations caused by landslides are observed on territories with high changeability of surface relief, characterised by quick level changes, from 8–12 m up to 25–35 m, and steepness of more than 5–10°. Every landslide makes a moving site which sizes define scale of the phenomenon. They can be different. Areas of some landslide sites change from 90 square m up to 5,000–6,000 m^2, and even up to 45,000 m^2. Landslides in the city territory are also very variable in morphological features. The most widely spread are circus type and face-to-face landslides. Sliding occurs on red-brown clays or kaolins.

Within the agglomeration territory, there are two types of the most widespread landslides as far as the depth of their basement deformations is concerned: deep and superficial. Deep landslides develop on slopes with steepness higher then 15°. They have complex structure and mainly circusidentical and face-to-face forms. They are widely spread in homogeneous and isotropic loess, identical with loams. They activate under influence of natural and technical factors. These landslides are responsible for greater erosive systems of the right-bank part of the city. They slowly move down the slope on a distance of 120 to 520 m. The maximal depth of their deformations reaches 20–30 m.

Superficial landslides within the cities territory have small sizes (up to 100 m^2), and developed in aeolian-diluvial loams of the late anthropogenic age. They are characterised by incorporating a part of slope into the deformed basic horizon, not reaching the slope's bottom part, though. The landslides develop on slopes with steepness of 5–15°. The depth of slopes deformation does not exceed 1–3 m. As far as their form is concerned, the superficial landslides have circus, angular outlines, similar to typical glaciers. There are also old, already stabilised, landslides within the cities territory. These landslides reveal traces of two-three former displacements complicated by small landslides and ravines which still continue to grow.

The studies on the rules governing the activation of the sliding processes and on their factors within the industrial agglomeration boundaries allowed to develop the following main models of the preventive (precautionary) protective actions:

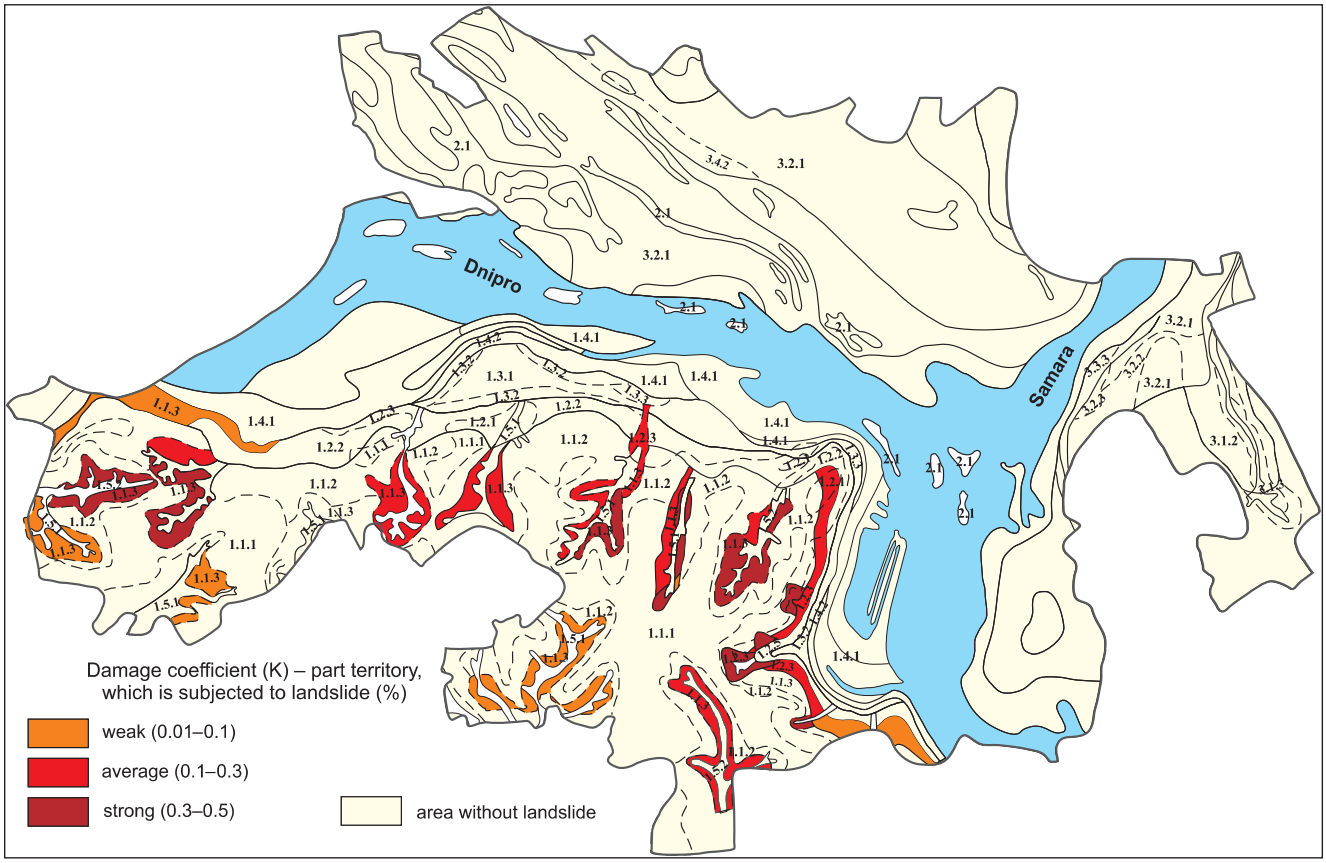

Fig. 9. Development of landslide processes in Dnipropetrovs'k

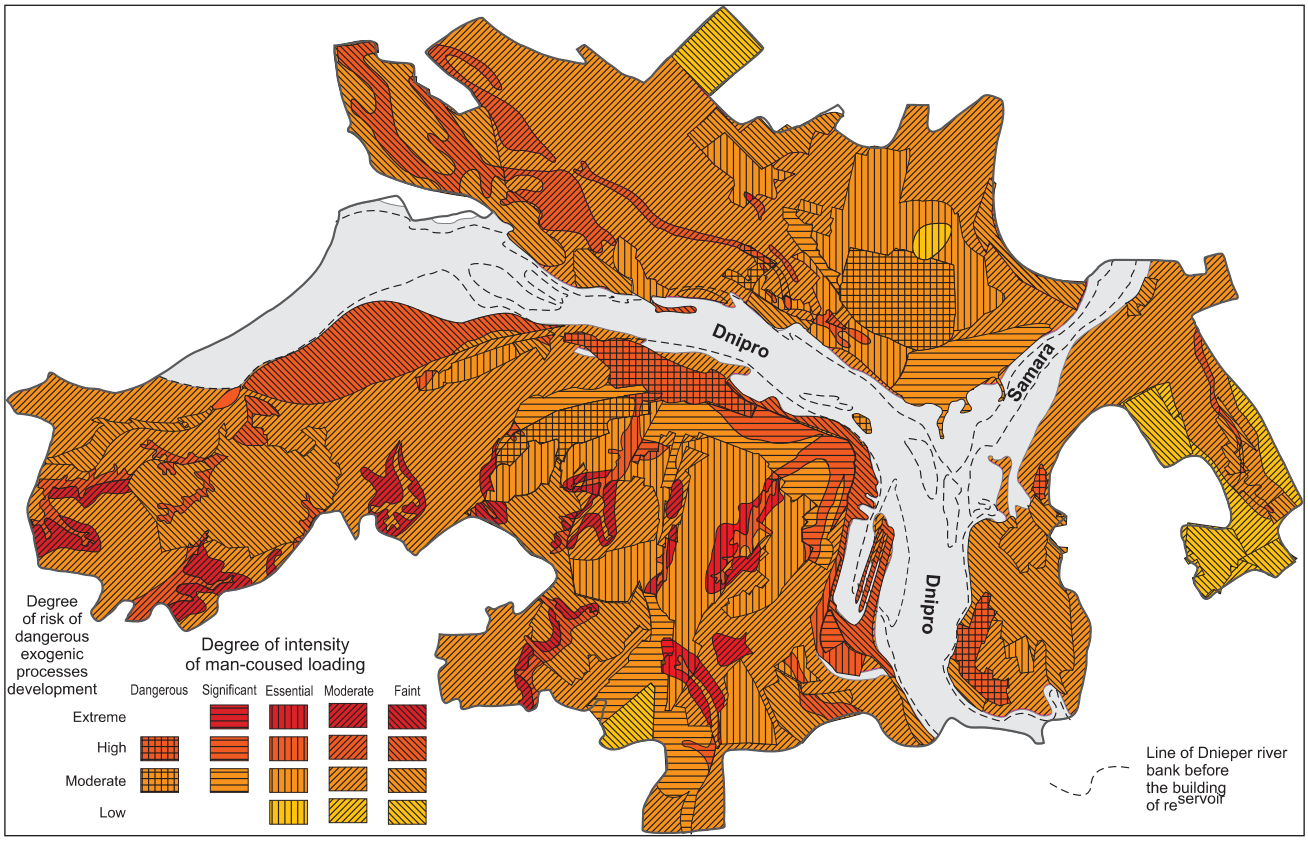

Fig. 10. Ratio of risk degree of dangerous exogenetic processes development and intensity of man-caused uploading

1. As the soils slopes stability depends on the balance conditions between a landslide and stabilising forces, the designing of a slope uploading should take into consideration the preservation of an appropriate amount of stabilisation forces which will prevent displacement of the ground. Landslide activation forces have mainly gravitational character and depend on the combined weight of ground and water. There could be the following ways of the reduction of landslide activation forces and the increase of stabilising forces: changing the landslide direction and structure, strengthening slopes by buttresses, keeping prisms, retaining walls etc., and forming constructions for tapping superficial and groundwater.
2. As an alternative, a decision could be made on changing the site of housing and linear engineering constructions.
3. In cases, when transferring of the objects planned or constructed within the dangerous landslide site limits is impossible, a variant of unstable ground removal should be considered. This can be economically advantageous only then, when the small volumes removal of weak soils, lying at insignificant depth, would be at stake.

Unfortunately, very little is applied from the above suggested actions in the most dangerous sites of Dnipropetrovs'k–Dniprodzerzhins'k agglomeration (Fig. 5).

CONCLUSIONS

Within the studied region boundaries, activation of landslides caused by technical reasons became a very serious problem, especially in the situation of a very intensive industrial and housing engagement of that territory.

The geological environment of the agglomeration is suppressed by various influences, especially connected with industrial infrastructure, especially with enterprises functioning on "wet" technologies, with water pipelines losing significant amounts of water, and because of the insufficient development of the drainage constructions.

The non-uniformity of the geological environment increases the danger of the cumulative actions of all kinds of technical causes impact, raising the degree of landslides development risk. Thorough investigations of the landslides activation behaviours will greatly assist in making the right decisions on different types of constructions location as well as on the recommendations for stabilisation of the endangered landslides sites.

REFERENCES

GOSHOVSKY S.V., RUDKO G.I., BLINOV P.V., 2004 — Engineer-geological analysis, monitoring and defence of the landslides territory. ZUKC, Lviv.

GOSHOVSKY S.V., RUDKO G.I., PRESNER B.M., 2002 — Ecological safety of the techno-natural geosystems in connections with catastrophic development of geological processes. Nechlava, Kiev.

INFORMATIONAL BULLETIN on the state of the geological environment of Ukraine in 1997. 2000. Issue 16.

POLISHUK S.Z., KUSHINOV N.V., SERDYUK Y.Y. *et al*., 2003 — Forecasting of dangerous geological processes (on example of Dnipropetrovs'k region). *In*: Countries and regions on the way of balanced development: 111–114. Academperiodika. Kiev.

SUMATOKHINA I.M., 2004 — Estimation of damaging of the large city territory by exogenic processes. *In*: Ukraine: geographical problems of constant developing. Collection of scientific articles. In four volumes. VGO Obrii, **3**: 173–174.

SUMATOKHINA I., DUK N., 2004 — Risk of dangerous exogeodynamical processes development on the territory of large cities. *Polish Geol. Inst. Sp. Papers*, **15**: 85–90.