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ИЗВЕСТИЯ

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ZONING OF KARAGANDA CITY TERRITORY ACCORDING TO THE STABILITY DEGREE OF THE GEOLOGICAL ENVIRONMENT

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Abstract. Continuing planet's population growth requires more intelligent use of the territorial, resource, and agricultural components. Complex relationships between technical objects and natural environments manifest itself as fundamental changes in the geological environment and the development of exogenous geological processes. The high anthropogenic load on the environment requires the application of geotechnical investigations modern methods. In this regard, the geological processes study and the city territory zoning according to the geological environment stability is relevant.

The research purpose is a comprehensive study of the territory natural conditions of Karaganda city to assess the stability of its geological environment.

While investigating the territory of Karaganda city, 200 wells were drilled up to 20 m deep; core samples collection were taken; a geological description of core samples collection was made; the groundwater level was measured; the physical and mechanical properties of soils were determined in the laboratory. After analyzing the available data, the stability of the geological environment estimation criterion was developed and the city territory zoning was made, which were displayed on a series of maps created using the AutoCAD software. The zoning of the territory was carried out according to the principle of vertical and areal heterogeneity.

Based on the results of the current state geoenvironment assessment in Karaganda city territory, criteria were established and ranged whereby a general stability of the geological environment assessment to construction development was carried out.

After summing up all the criteria of engineering-geological environment assessment a special map was obtained for assessing the stability of Karaganda city geological environment on a scale of 1: 100000.

The use of Karaganda city geological environment stability map will make it possible to assess the territory at the geotechnics' survey preliminary stage, saving time and money.

Key words: geological environment stability, stability criteria, swelling, subsoil waterlogging, man-made environmental impact

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ГЕОЛОГИЯЛЫҚ ОРТАНЫҢ ТҰРАҚТЫЛЫҚ ДӘРЕЖЕСІ БОЙЫНША ҚАРАҒАНДЫ ҚАЛАСЫНЫҢ АУМАҒЫН АУДАНДАСТЫРУ

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Аннотация. Әлем халқының үздіксіз өсуі аумақтық, ресурстық, диқаншылық құрамдастарын ұтымды пайдалануды талап етеді. Техникалық объектілер мен табиғи жағдайлар арасындағы күрделі қатынастар геологиялық ортадағы түбегейлі өзгерістер және экзогендік геологиялық процестердің дамуы түрінде көрінеді. Қоршаған ортаға жоғары антропогендік жүктеме инженерлік-геологиялық зерттеулердің заманауи әдістерін қолдануды қажет етеді. Осыған байланысты геологиялық процестерді зерттеу және геологиялық ортаның тұрақтылығы бойынша қала аумағын аудандастыру аса өзекті.

Зерттеудің мақсаты – геологиялық ортаның тұрақтылығын бағалау үшін Қарағанды қаласы аумағының табиғи жағдайларын жан-жақты зерттеу. Қарағанды қаласының аумағын зерттеу кезінде тереңдігі 20 м дейін 200 ұңғыма бұрғыланды; тау жыныстарының үлгілері алынды; алынған керн геологиялық сипаттамасы жүргізілді; жер асты суларының деңгейі өлшенді; зертханадағы топырақтың физикалық-механикалық көрсеткіштері анықталды.

Алынған деректерді талдағаннан кейін геологиялық ортаның тұрақтылығын бағалау үшін критерийлер әзірленді және қала аумағын аудандастыру жүргізілді, олар AutoCAD бағдарламалық жасақтамасының көмегімен жасалған карталар сериясында көрсетілді. Аумақты аудандастыру тік және аудандық әртектілік қағидаты бойынша жүргізілді. Қарағанды қаласының аумағында гео ортаның қазіргі жай-күйін бағалау нәтижелері бойынша геологиялық ортаның құрылыстық игеруге тұрақтылығын жалпы бағалау жүргізілген критерийлер анықталды және сараланды. Инженерлік-геологиялық ортаны бағалаудың барлық критерийлерін жинақтағаннан кейін 1:100 000 масштабтағы Қарағанды қаласы аумағының геологиялық ортасының тұрақтылығын бағалаудың арнайы картасы алынды.

Қарағанды қаласының геологиялық ортасының орнықтылық картасын қолдану уақыт және ақша ресурстарын үнемдей отырып, инженерлік-геологиялық ізденістердің алғашқы кезеңінде аумақты бағалай алуға мүмкіндік береді.

Түйін сөздер: геологиялық ортаның тұрақтылығы, тұрақтылық өлшемдері, ісіну, су деңгейінің көтерлуі, техногендік әсер ету.

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РАЙОНИРОВАНИЕ ТЕРРИТОРИИ ГОРОДА КАРАГАНДЫ ПО СТЕПЕНИ УСТОЙЧИВОСТИ ГЕОЛОГИЧЕСКОЙ СРЕДЫ

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Аннотация. Непрерывный рост населения планеты требует более рациональное использование территориальной, ресурсной, земледельческой составляющих. Сложные взаимосвязи между техническими объектами и природными условиями проявляются в виде коренных изменений геологической среды и развития экзогенных геологических процессов. Высокая антропогенная нагрузка на окружающую среду требует применения современных методов инженерно-геологических исследований. В связи с этим актуальным является изучение геологических процессов и районирование территории города по устойчивости геологической среды.

Целью исследования является всестороннее изучение природных условий территории города Караганды для оценки устойчивости ее геологической среды.

При исследовании территории города Караганды было пробурено 200 скважин глубиной до 20 м; отобраны образцы горных пород; произведено геологическое описание извлеченного керна; замерен уровень подземных вод; определены физико-механические показатели грунтов в лаборатории. Проанализировав полученные данные были разработаны критерии для оценки устойчивости геологической среды и произведено районирование территории города, которые были отображены на серии карт, созданных при помощи программном обеспечения AutoCAD. Районирование территории проводилось по принципу вертикальной и площадной неоднородности.

По результатам оценки современного состояния геосреды на территории города Караганды установлены и ранжированы критерии, по которым проводилась общая оценка устойчивости геологической среды к строительному освоению. После суммирования всех критериев оценки инженерно-геологической среды была получена специальная карта оценки устойчивости геологической среды территории города Караганды масштаба 1:100 000.

Применение карты устойчивости геологической среды города Караганды позволит проводить оценку территории на предварительной стадии инженерно-геологических изысканий, экономя временные и денежные ресурсы.

Ключевые слова: устойчивость геологической среды, критерии устойчивости, набухание, подтопление, техногенное воздействие.

Introduction. In recent years, there has been an active economic growth in the construction industry in the Republic of Kazakhstan. The volume of construction work performed throughout Kazakhstan from 2016 to 2020 increased from 3.3 to 4.9 trillion tenge. The volume of construction work in the Karaganda region increased from 1.5 to 4.7 trillion tenge over the period from 2016 to 2020. Every year the building structures and structures of civil and industrial facilities become more complicated (Bureau of National statistics, 2019).

The development and use of new technologies and engineering structures is a certain disturbance of the course of nature. Complex relationships between human-induced objects and natural environments are manifested in the form of fundamental changes in the geological environment and the character of the development of exogenic geological processes. Due to the fact that the population of the planet is constantly growing, the use of the territorial, resource, agricultural component should become more rational. The territory geological conditions must be taken into account not only when developing mineral deposits, but also when expanding into new territories for the construction of buildings and structures in reclaimed areas or disturbed by technogenic processes (Rukavitsyn, 2018).

To assess the future construction area, it is necessary to conduct geological engineering survey. The purpose of engineering-geological studies is a comprehensive survey of the future construction site, specifically the determination of the territory geological structure, groundwater monitoring, determination of the physical and mechanical characteristics of soils. Special attention should be paid to predicting hazardous natural and man-made processes (Xu P., et al, 2020).

Changes in tectonic hydrogeological processes, as well as the influence of building structures on soil strata can cause the development of dangerous geological processes. Negative man-made impacts are not an inevitable consequence of human development. This is the result of an insufficient level of technical development, poor knowledge of the anthropogenic impact consequences, and underestimation of the environment's characteristics. The development of such processes can cause invaluable damage to the state of engineering structures, the environment and humans (Koshliakov, et al, 2021).

In this regard, such an integral assessment as the stability of the geological environment becomes relevant. The lack of engineering-geological zoning maps significantly slows down the design construction work and does not allow for a preliminary assessment of the territory. Authors from Saudi Arabia carried out work on the creation of an engineering-geological map of the future economic city territory. The study area was divided into 6 zones according to their physical and mechanical properties; rock outcrops are mapped; geological hazards which have a negative impact on the territory were identified (Al-Sehly, et al, 2018).

Drawing up a town planning from an engineering and geological standpoint is a multi-level and multi-factorial process. The tasks of reducing the probability of geological hazard occurrence in the urban development of Xiamen city were solved by a comprehensive assessment of the geological environment using an intuitionistic fuzzy weighted average set (Cai, et al, 2016).

Scientists from Hungary analyzed the development of subsidence dolines and found that their development is determined by the secondary porosity of bedrock, the inclination of the bearing surface, the characteristics of the cover (thickness, grain size, calciferous content), bedrock hydrology (rock boundary, water collecting surface features, rainfalls), water level changes, thaw permafrost and anthropogenic activity. Based on the results of the work, it became possible to predict the development of subsidence dolines according to the factors and environments of their development (Veress, 2021).

Determining the stability of the geoenvironment requires an assessment of the current conditions and trends in its development. Researchers in Canada have developed geo-indicators that can detect both rapid, catastrophic geological processes and the more pervasive, slow-onset changes that are generally evident within a human lifespan. The developed set of geoindicators constitute a kind of landscape metric. For example, droughtiness, dust transport and land use will affect the magnitude, duration and frequency of dust storms (Berger, 2021).

After the introduction of pile foundations and mass construction of nine-story buildings in Tomsk city, a significant increase in the groundwater level associated with anthropogenic activities was noticed. To establish the causes of the changes, studies were carried out to determine the engineering and geological conditions of the city. On the engineering-geological and hydrogeological maps, the dynamics of changes in the groundwater level was reflected, the zones of groundwater flooding and change soil properties were outlined, and a reasonable forecast was given for the further development of flooding processes (Leonova, et al, 2021). An engineering-geological typification of the area was also carried out as the basis for a regional forecast of changes in the geological environment in connection with human engineering activities (Emeljanova, et al, 2010).

Engineering-geological zoning works covered other regions of Russia. The territory zoning of the middle reaches of the Kuban River was carried out and 8 regions were identified according to the geomorphological feature (Shulyakov, et al, 2014).

When zoning Moscow city, the territory was subdivided into geological bodies that are similar in their geological history, structure and composition. Based on the results of the work, a map was built that reflects the assessment of the identified taxonomic units according to the complexity degree of their natural conditions (Osipov, et al, 2016). Maps of Moscow city geologic hazard and the danger of the geological processes impact on construction projects were also compiled.

When making an assessment of the risk and danger of impact, not only the geological stability of the territory was estimated, but also the types of buildings, their foundations and other design features of the objects (Golodkovskaya, et al, 1981).

For Siberian Federal District (Russia), a map of engineering-geological zoning was made according to the conditions for the development of exogenous processes. The map reflects the spatial distribution of geological environment types with varying degrees of resistance to both natural evolution processes and technogenic impacts (Abaturova, et al, 2009).

A comprehensive analysis and assessment of natural and technogenic components that determine the stability of the geological environment were carried out for the territory of Olkhon Island (Russia). To assess the geological environment stability of the island, the comprehensive analysis principle of its geological and geomorphological components was used: the distribution of thickness and the soil occurrence mode with different physical, chemical and deformation properties; geomorphological aspects of the island's territory (slope gradient, type of relief); area affected by exogenous geological processes (density spread of processes) (Pellinen, et al, 2012).

Assessment and forecasting of the geological environment stability to natural and man-made impacts was carried out on Ulaanbaatar city territory (Mongolia). The geological environment state was displayed in a set of special maps showing its structure, thickness, hydrogeological conditions, geodynamic conditions and relief features. A set of such maps made it possible to create a generalized integral model of the engineering-geological situation of the territory, to assess the conditions of engineering-geological processes, the current state of the environment and the possibility of its evolution under the influence of technogenic factors (Bat, et al, 1995).

The choice of criteria by which the assessment of the geological environment stability is carried out depends on the geomorphology, tectonics, geological and hydrogeological conditions of the study area. The main purpose of the research is to assess the stability of the geological environment for the Karaganda city territory.

Materials and basic methods.

As a result, geological engineering survey in the city of Karaganda, the following was done: 200 engineering and geological wells were drilled up to 20 m deep; core samples collection were taken; a geological description of core samples collection was made; the groundwater level was measured; the physical and mechanical properties of soils were determined in the laboratory. Karaganda city is located on the territory of a denudation-erosion relief form, represented by pediment plains. The denudation-erosion relief, represented by water-divided, rarely sloped hillocks and elevated pediment plains, was formed in areas that experienced less intense neotectonic uplifts. Pediment plains with areas of preserved Paleogene clayey mantle of waste are the most widely developed in the city. The surface of the plains is often covered with eluvial formations 0.2–0.4 m thick and complicated by ridges and hills with very gentle slopes (3-6˚). The predominance of clay formations in the soil covering prevents the replenishment and active water exchange of groundwater, contributing to formation of marshes and salinity of soils in the leveled relief areas and an increase in the total mineralization of groundwater. A hydrography characteristic feature of Karaganda city territory is a dense river synodic, which is represented by a relatively large number of temporary streams that have a flow only during the spring snowmelt. The hydrographic system of Karaganda city is represented by the rivers Nura, Malaya and Bolshaya Bukpa, Sokur, Kokpekty. The largest waterway is the Nura River. The Kokpekty and Sokur rivers are confluents of the Sherubainur river, which is a Nura river confluent. The Malaya and Bolshaya Bukpa rivers are part of the Sokur river basin. The rivers are fed mainly by snow and partly by groundwater.

The relief of Karaganda city territory is undergoing significant changes associated with the industrial activity of coal mines. The city was divided into two parts - Old and New. The old city territory in terms of relief is a sloping plain with small hills separated by wide flat-bottomed coombes and gulches, through which atmospheric and mine waters drain. The territory of the New City is located on flattened ridges that slope towards the river. Technogenic landforms, which were formed as a result of the overburden waste storage from quarries and mines, are influenced by slope exogenous processes, which increases water-erosion activity, smooths down and destroys irregularities. The emergence of positive and negative landforms creates new conditions for the microclimate formation. Technogenic impact activates the processes of linear erosion, deflation, suffusion, formation of gully and water gall. In the city geological structure, deposits of the Quaternary and Neogene periods are of the greatest interest.

Quaternary deposits cover the entire territory with a thin cover, except for the tops of the hills. However, they differ in a significant variety of genetic types. On the vast smoothed areas, as well as within the watershed small hills, a stratum of cover yellow-brown loams, loamy-sandy and loamy-rubble deposits of eluvial, deluvial, deluvial-proluvial and mixed subaerial genesis is developed. Alluvial Upper Pleistocene - Holocene deposits are common in all valleys of the modern hydrographic system, and are represented by loams and sandy loams, enriched at the base with sand and pebble formations, and within mountain areas - with poorly rounded landwaste. Their thickness varies within 5-20 m, rarely reaches 30 m.

Neogene poorly consolidated sediments are developed almost everywhere. The lower stratum of the Neogene period has a clay composition and is divided into two formations: Aral - Lower-Middle Miocene, represented by lacustrine dense gypsum clays, and Pavlodar - Upper Miocene - Lower Pliocene, also composed of clays with gypsum inclusions and carbonate nodules; sand lenses are occasionally observed in some areas. Pliocene formations have a variegated composition and an inconsistent ratio of clayey, sandy, gravelly and pebbly rock varieties. The thickness of these sediments, which have a lacustrine-alluvial genesis, does not exceed 20 m. The hydrogeological conditions of Karaganda city territory from the point of construction development view are represented by aquifers of alluvial Lower Quaternary-modern deposits and lacustrine-alluvial Lower-Middle Quaternary deposits, which have a depth from 3 to 5 m. Engineering-geological zoning is the identification of a territorial elements system in a complex and multifaceted geological environment based on a set of theoretical understandings and methodological techniques that have some common engineering-geological features, limiting them from territories that do not have these features, systematics, mapping, description (Trofimov, 2008).

The zoning of Karaganda city territory was carried out according to the principle of vertical and areal heterogeneity, due to the successive change in area of the geological environment types, which differ in composition, structure, properties, and consequently, in different responses to technogenic impact. The geological environment stability was assessed by developing a series of maps reflecting the engineering and geological characteristics of the territory, consisting of component-by-component assessments set. When they are combined, all the details of each component impact are determined, these impacts are summed up, and a certain integral assessment is obtained, which is reflected on the corresponding map (Shirokova, et al, 2017).

Maps were constructed in the AutoCAD program, in which Karaganda city topographic map of on a scale 1:100 000 was used as a base map. Drilled wells were applied to the topographic base, reflecting the geological data of the territory. Territories with the same conditions of the considered criteria were combined into one district. Taking into account the physical-geographical and engineering-geological conditions of Karaganda city, as well as theoretical provisions for assessing the stability of the geological environment, the following criteria are proposed:

1 Soil design strength. This is one of the most important parameters in the construction of buildings and structures, as it allows to determine the maximum possible values of the overlying mass structure that the underlying surface can withstand. Fluid sandy loams, loams, clays, silt sands, as well as soaked subsiding sandy loams and loams have the lowest design strength (less than 300 kPa). High

design strength (>500 kPa) is typical for coarse, medium-grained sand and coarse-grained soil. Intermediate values of design strength (300 - 500 kPa) have hard sandy loam, loam, clay, fine-grained sand and coarse-grained soil with clay filler. Depending on the value of the design strength of the territory composed of the above soils, this factor will be evaluated as follows:

- territories composed of soils with a design strength of less than 300 kPa (low resistance - 1 point);
- territories composed of soils with design strength from 300 to 500 kPa (average degree of stability - 2 points)
-territories composed of soils with a design strength of more than 500 kPa (high degree of stability - 3 points).

2 Depth of groundwater. The close occurrence of groundwater can lead to flooding of the territory and, as a result, bring certain difficulties during construction – a change in the conditions of surface discharge during the vertical planning of the territory, a long gap between the earthwork operations and construction works; during operation - infiltration of leaks, reduction of evaporation under buildings and coatings. In urban areas, often a high level of groundwater can be explained by leakage from sewer and water-bearing communications. Deterioration of soil properties when moistened is an important aspect. During the soil flooding, large and uneven deformations of subsoils occur, called subsidence. In some cases, subsidence reaches 0.5 - 1.0 m or more. In such case, buildings and constructions experience excessive deformation, with the consequence that structures are destroyed and become unsuitable for further operation. According to the nature of flooding, it is necessary to distinguish naturally or man-made flooded areas (with groundwater level depths of less than 3 m) and non-flooded ones. Thus, the ranking of the territory depending on the level of groundwater occurrence was carried out as follows:

- the depth of the groundwater level below 3 meters from the surface – 3 points,
- the depth of the groundwater level above 3 meters – 2 points.

3 Specific soils occurrence. Swelling soils are widespread in the area under consideration. During engineering-geological surveys subsiding soils were encountered in individual cases; therefore, they were not considered during engineering-geological zoning. Subsoils composed by swelling soil should be designed to take into account the ability of these soils to swell out when wet and shrink when dry. During swelling, the porosity of the rock and its water content increase due to the increase in the hydrate shells thickness on the surface of the clay particles. Extraction of unfree water in clay leads to modification of its internal structure. Swelling depends on the mineralogical and granulometric composition of rocks. The minerals of the montmorillonite group are characterized by the greatest swelling, and the minerals of the kaolinite group are characterized by the least. Underestimation of swelling soils causes damage to many industrial and civil structures. Thus, the reason for the collapse of four 5-storey sections of the eight-section apartment complex «Besoba» in Karaganda city in 2012 is the

underestimation of the swelling properties of clay soils and the lack of appropriate engineering solutions.

Ranking by this factor was performed as follows:

- absence of specific (swelling) soils – 3 points;
- areas of distribution of weakly swelling soils – 2 points;
- areas of distribution of medium, strongly swelling soils – 1 point.

4 Man-made impact. There are 7 mines on the territory of Karaganda: Kostenko mine, Severnaya mine, Kirovskaya mine, Gorbachev mine, A. Baizhanov mine, Stakhanovskaya mine, Kuzembaev mine. Large areas of uncovering coal seam by driftage and a sharp increase in their permeability due to technogenic fracturing determined the active influence of mines on the hydrogeological conditions of the adjacent territories. Changes in the geological structure of the bowels and the earth's surface are associated with the deformation of rocks in the coal-overlaying unit. Disturbance of the soil structure accelerates the development of erosion processes in the territories adjacent to the coal strip mine, causing disturbances of the earth's surface far from their contours. As a result, numerous zones of water-conducting cavities are formed in the rock mass in the subsided area, dips, deflections, flooded and marshy areas appear on the surface.

In the zone of geological faults, watercourses can change, water pressure decreases, and waters of different horizons mix. The formation of kettle holes as a result of soil subsidence often leads to their flooding with groundwater. Within Karaganda city territory, due to the production of coal in the nearest mines, a large plot of land gives rise to subsidence. In some places, the ground sank almost two meters. Newly formed kettle holes were filled with ground and thawing water. Waterlogging of the territories adjacent to the formed reservoirs was also noted. Such kettle holes were formed: in the area of Tereshkova Street, in the direction of the Maykuduk area (Figure 1); on both sides of the road, Novgorodskaya St., flooding of the electrical transmission tower was also noted here; at the intersection of the main street - Bukhar - Zhyrau and Saranskoe highway (Figure 2).

Figure 1 – Kettle holes on Tereshkova street

Figure 2 – Kettle holes at the intersection of St. Bukhar-Zhyrau and Saranskoye Highway

The classification of the territory adjacent to the mining zones was carried out as follows:

- territories located within plants and factories (mines, quarries) – 1 point;
- territories outside the zone of plants and factories – 3 points.

Results and discussions. The qualitative and quantitative characteristics of the listed leading factors were divided into three groups, which, depending on the stability degree were assigned 1, 2, 3 points.

On the Karaganda city territory, according to the actual combination of leading factors and the total points corresponding to this combination, three types of geological environment were distinguished with a high (total points - more than 10), medium (8-10 points) and low (less than 8 points) stability degree of the geological environment. A map of a special typological engineering-geological zoning was compiled according to the stability degree of the geoenvironment to technogenic impacts on a scale of 1:100 000 (Figure 3). Summary on the criteria for assessing the geological environment is presented in Table 1.

Assessment of the leading factors of the geo-environment type in terms of the stability degree

Table 1

Factors determining the category of the geological environment stability	**The stability degree of the geological environment type**		
	High- 3 points	**Medium - 2 points**	**Low- 1 point**
Soil design strength	territories composed of soils with a design resistance of more than 500 kPa	territories composed of soils with design resistance from 300 to 500 kPa	territories composed of soils with a design resistance of less than 300 kPa
Depth of groundwater, m	the depth of the groundwater level below 3 meters from the surface		depth of groundwater level above 3 meters
Specific soils occurrence	absence of specific (swelling) soils	areas of distribution of weakly swelling soils	areas of distribution of medium, strongly swelling soils

Man-made impact	territories outside the zone of plants and factories		territories located within plants and factories (mines, quarries)
Results	**More than 10**	**8-10**	**Less than 8**

The assessment of the territory was carried out as a result of ranking and summing up the selected factors.

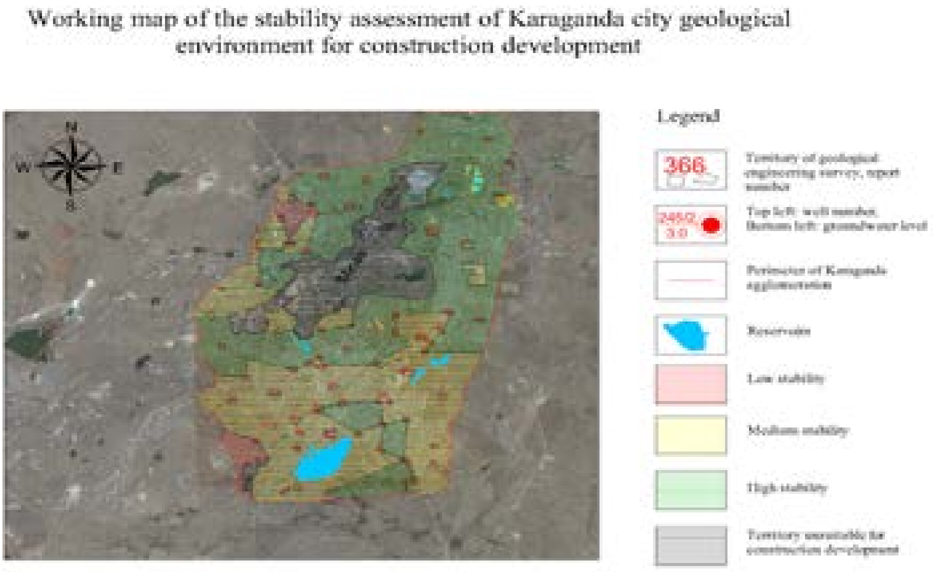

Figure 3 - Working map of the stability assessment of Karaganda city geological environment for construction development

On a working map of the stability assessment of Karaganda city geological environment, areas with low stability are identified, which are shaded with red dashed lines, areas with medium stability - with yellow dashed lines, areas with high stability - with green dashed lines. It should be noted that the land in the area of dead pits and productive mines due to the formed technogenic relief and methane gas explosion hazard in the vugs of the mines can't be used for construction. In this regard, this territory was not taken into account, and was marked as a territory unsuitable for construction development and painted over with black dashed lines. Also, the territories of the and waste stabilization ponds are painted over with black dashed lines.

Conclusion. Analyzing the working map of the geological environment stability of Karaganda city territory the following conclusions can be drawn:

- territories with low stability are not widespread and are located in the southwestern and northwestern parts of the city;
- territories with medium stability prevail in the southern and northwestern parts of the city, and only small islands are located in the northeastern part;

- high stability of the geological environment is represented in most of the city and is concentrated in its north-eastern part.

Thus, it can be concluded that the north-eastern part of Karaganda city is a promising area for construction development. A working map of the geological environment stability of Karaganda city will allow for an engineering and geological assessment of the territory at the pre-project stage of construction work, saving time and money resources. Also, the use of the geological environment stability map can be used in the development of the urban planning scheme of the city.

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