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Methods of Geoecological Zoning Using Geotechnical Cartographic Base (through the Example of Karaganda Region of Kazakhstan)

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***Abstract* – Geoecological zoning of the eastern part of Nurinsky district of Karaganda region was performed for the first time to assess the conditions for construction of the motorway section within the framework of the One Belt, One Road idea. The paper analyzes current approaches to geoecological zoning of territorries and their use for the study area. The methodology included an integrated assessment of geo-ecological conditions with respect to geotechnical and geomorphological conditions using appropriate cartographic materials. The paper shows the role of geotechnical zoning in geo-ecological zoning of the territory. Based on the criteria selected in the ArcMap geo-information systems, maps of geo-ecological conditions and geo-ecological zoning of the eastern part of Nurinsky district, Karaganda region, were compiled. These maps can be used at pre-design stages of road or railway construction and other types of territorial development planning.**

Keywords – geoecological zoning; geotechnical maps; geomorphological conditions; methodological approaches; cartographic base.

I. INTRODUCTION

The study of regional geo-ecological potential is of great importance for economic development of the region. Further development of the economy of Kazakhstan should be based on intensive export-import exchange to involve a rich resource potential of the country. For 2017, the republic has 17 bln tons of forecast oil resources, 148 bln tons of iron, 4.7 bln tons of manganese and about 3 bln tons of chromite ores, and copper – 182 mln tons, lead – 108 mln tons and other and metal resources [1]. Due to small population density in the central part of Kazakhstan and its concentration mainly in certain areas in the south of the republic, where the population density reaches 40 people per 1 km^2, Kazakhstan does not have a well-developed network of communication highways, primarily railways [1]. The lack of a developed road transport network hinders the economic development of Kazakhstan, does not allow utilization of its resource potential and prevents labor migration.

This study was performed to select a possible area for implementation of the idea of a new Silk Road with the idea of One Belt, One Road as its part put forward at the 25th meeting of the Foreign Investors Council (May 22, 2012) by the President of the Republic of Kazakhstan N.A. Nazarbayev. The final version of the route for the new Silk Road is not currently fully developed. According to published data, the project is based on construction of three railway corridors (and associated highways): northern, central and southern ones. All of them will connect the eastern provinces of China with the countries of Western Europe.

The route of the northern corridor will pass through Kazakhstan and the Russian Federation to the Baltic Sea, and its western branch will pass through Belarus and Poland to Germany and Holland. According to the idea of One Belt, One Road, an option to create a transport corridor is construction of railway and associated highway routes through the territory of Karaganda region [2, 3], which is geographically justified. An effective and economical tool for solving the problem of choosing the route, environmental safety during the construction and operation of railways and highways at the first stage, is geo-ecological zoning based on existing cartographic and other data to identify the areas with varying degrees of suitability of geological and geographical conditions for construction. The study of the natural conditions and environmental characteristics of the territory showed that its landscape is significantly diverse. The soil cover of the region is predominantly light chestnut, brown and gray-brown soils, which are unproductive and can be used for pasture or hay only. The vegetation cover is represented by grass-wormwood communities with low bioproductivity. Under these conditions, geological and geographical conditions will be the limiting factors in transport construction. Therefore, geotechnical principles of zoning can be used as the base. the geological and geographical conditions of Karaganda region were studied to perform geoecological zoning of the eastern part of Nurinsky district of the Karaganda railway and highway.

II. Methods and materials

The most effective tool for studying, predicting and monitoring natural and anthropogenic phenomena is geo-ecological zoning [4]. At present, there is no single methodological approach to geoecological zoning of the territory, but there are many viewpoints on the problem [5]. It exhibits two trends: landscape-geomorphological [6–8], and indicator-ecological [9]. Geoecological zoning of the territory is the result of different manifestations of natural and anthropogenic processes and phenomena, or zoning factors, such as geological structure, history of geological development, landscape-climatic conditions, manifestations of endogenous and exogenous, and geological hazards [10, 11] , and an anthropogenic impact [4, 7]. As a result of geoecological zoning, maps of geoecological conditions can be compiled, including those used to solve specific problems, the risks of economic development and economic assessment of the consequences of anthropogenic impact, territory pollution, resistance to anthropogenic impact and other special maps, and primarily digital GIS based maps [12, 13].

Methodically, we believe that the principles of geotechnical zoning should be the base of geoecological zoning for economic development of the territory, in particular the construction of roads for various purposes. These principles are currently most developed and suitable. Differentiation of territories into geotechnical areas is based on data sufficient to assess the state of ecosystems since the soils within the areas have specific composition, properties, wetting conditions and temperature regime, including frost penetration. This data can be used to estimate the response of the geological environment to the technogenic impact, the development of dangerous exogenous processes and horizontal and vertical migration of pollutants. For regional geoecological zoning of the territory of Karaganda region, the use of geotechnical maps is justified among other options for construction of highways due to its geological structure.

Geotechnical zoning is one of the types of territory typification using the predetermined features. geotechnical zoning is carried out according to certain principles to compare and evaluate the whole variety of geotechnical conditions of different territories. The fundamental principles of geotechnical zoning were developed by I.V. Popov (1961) [14], who proposed to select geotechnical regions, districts and subdistricts of different order as independent taxonomic units.

Geotechnical regions are distinguished by a structural-tectonic feature. Geotechnical areas within one region are distinguished by geomorphological features. That is, geotechnical regions are areas identified by geostructural features.

In geotechnical zoning, the territory with similar geological structure, geomorphology are referred to as geotechnical areas. Within a single geotechnical region, if necessary, geotechnical subdistricts can be distinguished by different state of rocks, manifestation of modern and ancient geological processes, etc.

In a broader sense, territory typification takes into account not only geological, structural and geomorphological features, but also zonal, primarily climatic factors. On a global scale, this principle was implemented by S.B. Ershova in 1979 [15]. We use the approach to geotechnical zoning, which is based on simultaneous consideration of regional and zonal factors, which makes it possible to distinguish geo-ecological units, since the zonal factor takes into account natural and climatic conditions, and the regional factor considers geological-geomorphological factors of the territory.

This approach was first used by E.S. Melnikov for zoning of the cryolithozone of Western Siberia (Melnikov et al., 1969) [16]. Later on, this approach was theoretically developed and used in the works of S.V. Viktorov (1976), L.V. Bakhireva (1980), G.A. Golodkovskaya (1989), D.G. Ziling, V.T. Trofimov (1995), V.T. Trofimov (2007) et al. [17–20].

The method of geoecological zoning of the eastern part of Nurinsky district is primarily based on various geological and geographical factors and includes several steps:

1. Choosing a cartographic base. The unified cartographic base for geoecological zoning of the site was a map of geotechnical zoning of Karaganda region of 1967 at a scale of 1: 1 000 000) [21]. Geotechnical maps can serve as the most informative starting point at various stages of the development of a territory for the purpose of building roads, including geoecological zoning.

Geotechnical maps are specialized maps that show only the features of the natural environment essential for the design of roads and linear structures. In this case, the map presents geotechnical conditions for the depth required for the design. The legends show the lithological composition of rocks, hydrogeological conditions, modern physico-geological processes, engineering properties of soils [21]. Geotechnical maps, along with topographic maps, are always one of the main documents for the road construction.

The geotechnical map of Karaganda region shows: 1. Composition, thickness and contours of surface deposits. 2. Depth to groundwater. 3. Modern geotechnical processes and the stability of rocks.

2. At the second stage, the features of geoecological zoning were chosen. The choice of features for zoning was based on the study of cartographic and stock material on the territory of the site. Based on the map of the geomorphological structure of the Republic of Kazakhstan (Fig. 1) [22], the conditions (criteria) for geoecological zoning that affect the construction of railways and roads were identified.

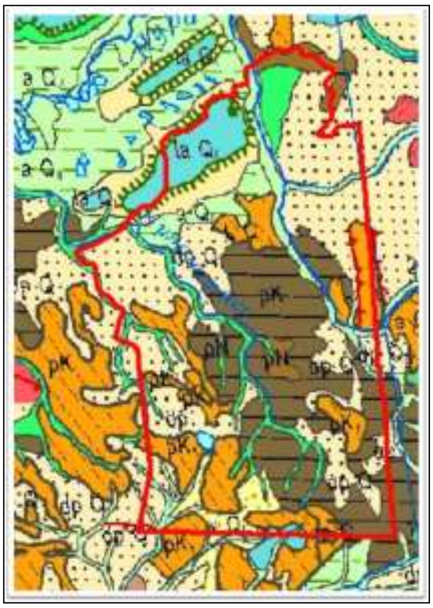

Fig. 1. Map of the geomorphological structure of Nurinsky district of Karaganda region [22].

In total, 10 geomorphological parameters and 11 geotechnical groups of rock complexes, 3 variants of depth to groundwater, 3 variants of seasonal freezing of soils, and 4 variants of modern exogenous processes were considered as conditions for relief formation and as the reasons for their possible negative impact on the surface during intensification in the road construction (Table 1).

3. The third stage. The criteria chosen based on the cartographic materials were used to compile a map of geoecological conditions of the eastern part of Nurinsk district of Karaganda region using ArcMap geographic information systems (Fig. 3).

4. At the next stage, the constructed map of the geoecological conditions of the eastern part of Nurinsky district of Karaganda region was taken as a basis, and 24 geoecological areas were identified based on the complex of conditions:

- denudation slope with flexible rocks and freezing depth of 1.5–2.5 m;
- denudation slope with coherent rocks and freezing depth of 1.5–2.5 m;
- terraces floodplain and above the floodplain with sandy, sandy compacted and pebbly ductile, and coherent rocks with groundwater depth of up to 10 m and freezing depth of 1.5–2.5 m;
- floodplains with sandy coherent and coherent rocks with groundwater depth of 5–10 m and freezing depth of 1.5–2.5 m;
- plain accumulative alluvial with ductile rocks and freezing depth of 1.5–2.5 m;
- plain accumulative alluvial with coherent rocks and freezing depth of 1.5–2.5 m;
- plain accumulative deluvial-proluvial with ductile rocks with developed linear erosion and freezing depth of 1.5–2.5 m;
- plain accumulative deluvial-proluvial with coherent rocks and coherent with sandy and gravel-detrital rocks and freezing depth of 1.5–2.5 m;
- plain accumulative deluvial-proluvial with rocks, with developed karst and linear erosion with groundwater depth of 5–10 m and freezing depth of 0.7–1.5 m;
- plain accumulative deluvial-proluvial with rocks with groundwater depth of 5–10 m and freezing depth of 1.5–2.5 m;
- plain accumulative deluvial-proluvial with saliniferous rocks with freezing depth of 1.5–2.5 m;
- plain accumulative deluvial-proluvial with rocks and freezing depth of 1.5–2.5 m;
- plain accumulative deluvial-proluvial with rocks and freezing depth of 2.5–3.5 m;
- plain accumulative lacustrine-alluvial with coherent rocks and groundwater depth up to 10 m and freezing depth of 1.5–2.5 m;
- plain accumulative lacustrine-alluvial with ductile rocks and freezing depth of 1.5–2.5 m;
- 16 - plain accumulative eolian with sandy and coherent with sandy and gravel-detrital rocks and freezing depth of 0.7–1.5 m;
- plain denudation - wavy peneplain with ductile rocks with developed linear erosion and freezing depth of 1.5–2.5 m;
- plain denudation - wavy peneplain with semi-rocks and rocks and freezing depth of 1.5–2.5 m;
- plain denudation - wavy peneplain with semi-rocks and rocks with groundwater depth of 5–10 m and freezing depth of 1.5–2.5 m;
- plain denudation - slightly wavy peneplain with semi-rocks with freezing depth of 1.5–2.5 m;
- denudation steep hills with rocks and groundwater depth of up to 5 m with freezing depth of 1.5–2.5 m;
- denudation steep hills with rocks and groundwater depth of 5–10 m with freezing depth of 1.5–2.5 m;
- denudation steep hills with rocks and subsidence and groundwater depth of 5–10 m with freezing depth of 2.5–3.5 m;
- denudation steep hills with rocks with freezing depth of 1.5–2.5 m.

TABLE I. GEOECOLOGICAL CRITERIA FOR ZONING

Morphostructures (genesis, subclass, type)	Geotechnical groups of rock complexes	Others
1. Denudation and steep hills	1. Ductile with sandy and sandy-pebble	**Depth to groundwater**
2. Floodplains	2. Flexible	Up to 5 m
3. Denudation slope	3. Sandy	Up to 10 m
4. denudation plain– wavy peneplain of 20-50 m	4. Sandy coherent	Absent
5. Denudation plain– slightly wavy peneplain of up to 20 m	5. Saliniferous	**Freezing depth**
6. Accumulative eolian plain	6. Sandy compacted, sandy pebble with ductile	2,5-3,5
7. Terraces flood plain and above the flood plain	7. Sandy compacted	1,5-2,5
8. Accumulative alluvial plain	8. Cohrsive with sandy and partially pebble-detrital	0,7-1,5
9. Accumulative lacustrine-alluvial plain	9. Coherent	**Modern exogenous processes**
10. Accumulative deluvial-proluvial plain	10. Semi-rocky	Karst
	11. Rocky	Linear erosion
		Subsidence
		Absent

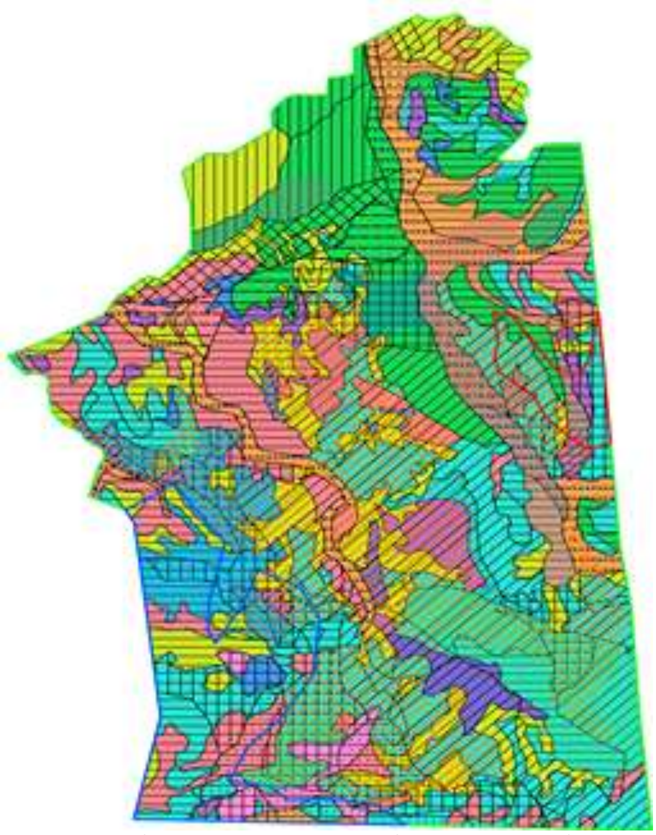

Fig. 2. Map of geoecological conditions of the eastern part of Nurinsky district of Karaganda region.

In accordance with the selected areas, a map of geoecological zoning of the eastern part of Nurinsky district of Karaganda region was created using geographic information systems ArcMap (Fig. 3).

Fig. 3. Map of geoecological zoning of the eastern part of Nurinsky district in Karaganda region. Numbers of the districts on the map correspond to those in the text.

III. CONCLUSION

For initial assessment of the possibility of railways and roads construction within the framework of the idea One Belt, One Road, geoecological zoning was carried out and a map of geoenvironmental zoning of the eastern part of Nurinsky district in Karaganda region of Kazakhstan was created. Systmatic approaches were based on principles of geotechnical zoning. Maps of geotechnical zoning, geomorphological conditions, literature data and GIS technologies were employed. A geoecological map of the territory was created as an intermediate stage. It provides geomorphological parameters, geotechnical groups of rock complexes, groundwater depth, seasonal freezing of soils, and modern exogenous processes. According to the conditions, 24 geoecological regions were identified. Geoecological zoning of this territory was carried out for the first time and can be used for pre-design surveys in implementation of the idea One Belt, One Road.

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