APPLIED LANDSCAPE ECOLOGY

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SPATIAL INTERACTION OF ELEMENTS OF GAS PIPELINES GEOTECHNICAL SYSTEMS IN WESTERN SIBERIA CRYOLITHIC ZONE

SUMMARY. The article contains an assessment of graded landscape ecological environment of the gas transportation corridors. The assessment is the result of the map-based analysis of spatial interaction between elements of geotechnical systems.

The authors compiled a set of 1:5000 maps of the key GTS sections: they are landscape ecological maps of landscape facies groups showing elements of geotechnical systems and different soil moisture environments. The map units are defined on the basis of aerospace images photostructural integration.

The map also has marginal notes for areas with different soil moisture conditions: dry, semi-dry, moist, damp and frozen peat environments are outlined; they are described as regards their spatial interaction with and effects on the operational status of the gas transportation system.

The article identifies the reasons and describes characteristics of water erosion, thermokarst processes and earthworks washaways, which contribute to the deterioration of gas transportation systems and add to their costs. The article includes recommendations on monitoring and design of gas pipeline geotechnical systems in the utility line areas which accounts for mutual interaction of engineering projects via ecosystems.

KEY WORDS. Pipeline, geotechnical system, thermal erosion, hydro erosion, stability.

Over many years of monitoring the pipeline networks in the Nadym–Pur–Taz interfluve the experts from Tyumen Research Institute of Gas Pipeline Design OOO (limited liability company) [1–2], Tyumen State University [3–5] and other research centres have defined the shortcomings associated with the engineering support for the pipeline design. Namely, though there is an understanding that the geotechnical systems (GTS) and environmental technical systems (ETS) do exist and function, there are no requirements to design and account for them as separate entities in the design documentation required by the RF State Expert Evaluation Department.

This article contains the analysis of changes in the spatial structure of the geotechnical systems of transport gas pipelines based on the mapping of spatial interaction geosystems (SIG).

Subject-matter and Methods. Today the transport part of the gas trunklines (GTL) *Zapolyarnoye–Urengoy* has three operated trunkline strings with a diameter of 1.420 millimetres, 190 km each, and two looping pipelines. These pipelines are constructed in a single utility line area which includes a network of service roadways. The first three strings of the pipeline utilise the technology of permafrost foundation use, type I, which retains the permafrost. To make a better choice of the most effective technology to prevent the thawing of the permafrost soils, they used 11 methods of laying GTL. The new looping pipelines currently under construction are laid underground.

The utility line area includes the roadway *Korotchaevo–Zapolyarnoye*, the methanol pipeline *Korotchaevo–Zapolyarnoye*, the condensate pipeline *Zapolyarnoye–Urengoy* complete with a network of service roadways intersecting with the system of the gas trunklines. The aggregate width of the utility area reaches 10 to 15 km.

According to the landscape zoning of Yamal–Nenets Autonomous Area [13–14] the pipeline network *Zapolyarnoye–Urengoy* is located in the following landscape zones: northern Pur–Taz, Varga–Salki, Middle Pur valley and Hadutte–Pur zones. The sporadic permafrost zone is characterized mostly by high-temperature permafrost soil.

This gas transport geotechnical system includes hierarchically organized typological units: type (subtype), class and sort of the pipeline sections.

Type of the GTS section is defined on the basis of group specifications of their location that are differentiated according to the degree of drainage, the hydro- and cryostructures which determine pipeline construction method (underground, semiunderground, ground, aerial crossing, underwater crossing, watercourse crossing).

Subtype of the GTS section are classified according to the engineering solutions employed in the framework of the pipeline laying technique in operation (thermal insulation, strengthening, weighting, soil replacement, etc.); they reflect the permafrost soil peculiarities of the ground patch under the pipeline that were taken into account at the design stage of the construction project.

Class of the GTS section is limited by the structural components and a set of meso- and microrelief forms that are created to construct a section of the gas pipeline system.

Sort of the GTS section is the aggregate of the environmental reactions, resulting in a natural set of facies, varying for different types of location and aimed at stabilizing (harmonising) the new geosystems. It is recognized as a set of spatial and anthropogenic structural elements that affect biocenotic and hydromorphic types.

On the basis of photostructural integration of aerospace images [4–5] a number of key sections were mapped with 1:5000 scale to show facies groups of the natural ETS and types of GTS sections, their location in the GTS, as well as locations with different moistening conditions [15–16]. This work results in a landscape ecological map of the gas pipeline transportation geotechnical system that illustrates the distribution of the spatial interaction geosystems [5].

The subject-matter of the research is a key section of the GTS located in the wooded tundra environment. The area is dominated by easy ridges and slightly bogged lacustrine-alluvial terrace, type IV, loamy soil covered with lichen coenosis and thin larch forest.

The main surface is parcelled by runoff ravines. The major erosion factor is a no-name creek (Figure 1, southwest part). Other runoff ravines are small and do not form watercourses. Permafrost soils are found in moist ground and under the peat floors.

This territory has several types of GTS sections, laid as follows: underground (elevated drained areas); semiunderground (runoff ravines, permafrost areas); aerial and watercourse crossings (lower parts of runoff ravines). These were classed into nine sybtypes of the GTS sections.

Classes and sorts of the GTS sections were taken into account at landscape ecological mapping.

The nonstandard conditions of the gas transportation system elements are caused by the following processes: water erosion, thermal erosion and permafrost soil slaking.

Figure 1: WorldView-2 aerospace image of the key site

Results and Discussion. From the engineering viewpoint greater importance is attributed to the evaluative (interpretative) soil moisture maps based on the inventory landscape ecological map. The soil moisture maps show areas that differ in the amount of soil moisture: dry—semi-dry—moist—damp, permafrost peat-bogged.

Most areas of the well-drained lands of the type IV lacustrine-alluvial terrace are dry, which is signalled by the consistent lichen cover easily registered at the aerospace images. Dry soil moisture regime is also typical for the elevated areas of the pipeline earthworks that are the grass-covered bases of the GTS, its edge areas and access roadways. These areas bear underground waters below the annual frost depth and have no permafrost soils.

The semi-dry areas are located in lower parts of the terrain in runoff ravines that do not accumulate water over the daytime. They are the moist hollows in the drained lands with dwarf shrubs and mosses and their lower slope parts. The underground waters here are 0.5–1 m deep. In some winters they form permanent snow patches. If these areas accumulate peat they develop high-temperature permafrost soils.

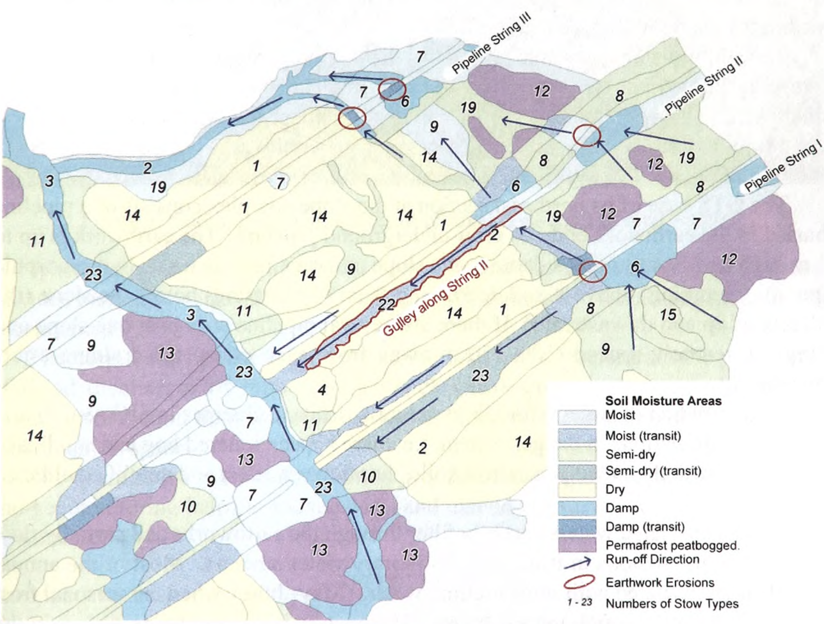

Figure 2: Soil moisture map for a site of the GTS

Moist conditions are typical for the water-rich runoff patches covered with shrubs, grass and mosses, and for unwatered parts of the frozen peat bogs, i.e. areas of blocked runoff without open water patches. The underground water level is close to the surface, and the permafrost soils are morphed as permanent snow patches here. If the geosystem “stabilizes” these disturbed mostly peat-bogged areas recover permafrost soils.

The damp conditions develop at undisturbed areas of open water and at anthropogenic runoff zones and lowlands (termokarst areas) with the blocked runoff. Summer temperatures increase the annual temperatures, cause degradation of the permafrost soils and greater termokarst effect.

Frozen peat areas occur in the valleys of small watercourses as well as in flat small-layer peat bogs (up to 0.8 m) along the scattered runoff valleys. Once a frozen peat area is used as a construction site it develops moist conditions if the water is drained or damp conditions if the water runoff is blocked.

In cases when it is devoid of permafrost soils the hydromorphology degree of the area is dependent on the runoff conditions. When the pipelines are constructed at permafrost soils, soil deterioration is determined by ground sagging. The drainage system contributes to turning the area into a moist one, followed by thermo stabilisation, but if the melt waters are blocked they accumulate in the hollows and develop the thermokarst lakes which lead to permafrost soil deterioration.

When evaluating the gas transportation GTS, special attention should be paid to the areas with transit inflow moistening conditions. The transit areas are the areas within the spatial influence of the GTS.

The soil moisture map analysis shows that the construction of the GTS disturbs hydromorphological types of areas because underground and surface waters get dislocated. The construction brings about new landscape and geomorphological conditions determined by replacement of soils and earthworks leading to changes in meso- and microrelief forms and types of soil and flora associations.

The GTS base of its northeast section at the slope complex consists of a pipeline buried in the earthwork body of semi-underground pipeline. The earthwork is up to 1 m high and functions as a dam for the slope complex increasing its hydromorphic quality (damming) above it and decreasing them (dewatering) below the slope (the effects of up and downstream). If there are several pipeline strings at one slope and they are scarcely spaced (100–150 m away from each other) the draining effect increases.

Accumulation of waters (flooding) naturally leads to changes in SIG resulting in structural alternations in the geosystem, i.e. there appear watered bog and small lake complexes with degraded permafrost soils, thermokarst effect and amplified effected area.

The accumulated waters partially filter through the earthworks and partially flow down through erosions in it forming temporary water streams. Most of the annual runoffs are associated with snow melting waters (May–June), when the seasonal frost prevents filtering through the earthwork. This results in accumulating waters in the damp lowlands and dump-like floods which restructure the territory below.

So, accumulation of melt waters by the first pipeline string leads to flood-like discharges through eroded parts of the earthwork and creates a series of transit hydromorphic SIG (Figure 2). Then the second string blocks these waters and there appears a gulley along the second string, 270 m long and up to 3 m deep (Figure 3).

Conclusion. The way natural component of the GTS develops is determined by the degree of technogeneous component influence, and the latter can be described in terms of the features of the new environments as SIG.

The negative frost-erosion processes are a sort of the feedback in *the natural environment— technical construction* system and they come about as a result of incomprehensive account of possible environmental reactions.

Damming the surface waters runoff causes a number of transformations in the SIG, and their negative effects of gullying and thermo erosion depend on the amount of liquid waters, which is a major environment-changing factor.

The areas with dammed surface waters are important for geotechnical monitoring in cryolithic zone conditions because they help to evaluate the intensity and direction of the processes affecting the stability of the GTS.

Figure 3: Gullying erosion as a result of flood discharges of melt waters

When designing utility line areas it is important to account for interrelations between the components of the GTS through SIG, especially when cascade damming is concerned.

The design and operation projects should take into consideration the possibility of flood discharges of melt waters which cause gullying erosion. In natural environmental conditions this erosion does not happen because of insufficient water accumulation space.

The quantitative assessment of these processes effected through remote sensing and geomonitoring helps to reduce costs and extend the survey to the whole of the pipeline network.

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