Gullies and dry-valley systems of Kazan as a territorial reserve for the development of the city

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Abstract. The article considers possibilities of the use of gully systems of Kazan as a possible resource for territorial development. The city has extensively formed gully and dry valley networks located in different parts of the city. Multi-temporal analysis of cartographic material showed that currently there is an active development of gully systems especially in the central historical part of the city due to the technical capabilities and investment attractiveness. The nature of interaction of gully-dry valley systems and the city is of an overwhelming type.

1. Introduction
High levels of urbanization, urban population growth, inefficiencies and congestion in infrastructure and an increase in the number of vehicles are responsible for the shortage and scarcity of territories in urban systems. At present stage of many cities development, there is a need to revise and adjust some principles of urban planning in terms of more rational economic use of land resources and environmental safety [1].

There are several approaches to solve the problem of scarcity of land within city limits [2, 3]:
- Increasing the area of the city (new territory development);
- Seal buildings;
- Demolition (sanitation) with the subsequent construction on the site of more extensive and high-quality housing;
- Transfer of industrial enterprises out of city boundaries and development of the liberated territories;
- High-rise construction;
- Creation of artificial territories;
- Underground construction;
- Development of urban badlands.

According to the Explanatory Dictionary of the Russian language, the term "badlands" is defined as a terrain, inconvenient for ploughing and mechanized tillage [4]. In urban practice, unsuitable or inconvenient for development areas include land on which construction is complicated by adverse geological-engineering, hydrological, orographic, sanitation and hygiene [5, 6].

The urgency of the problem is due to the urban development situation when from the end of the twentieth century, the territories that were considered inconvenient by engineering reasons began to be developed again. In the past, limited technical capabilities excluded this kind of territories from urban-planning practice, and individual cases of their development were unique. Currently, the costs of their
development and their urban-planning value equalize the inconvenient territories with other areas of the city. The inconveniences in the zone of historical center increase their investment attractiveness.

One of the criteria underlying the allocation of uncomfortable territories is the presence of gully network [7]. Gully erosion is one of the most important processes of the modern topography development. Exercising direct influence on morphology of the topography and morphometric characteristics of its forms the formation of gullies is a dangerous natural-anthropogenic process.

The functioning of gully systems within settlements plays a special role. Knowledge of geocological regularities of interaction of natural objects with settlements within their limits consists of the study of individual development of gully systems and their interaction with the infrastructure of the city in direct contact with natural objects.

This paper is focused on problems of gully and dry-valley networks territories (badlands) development in Kazan.

2. Material and methods

The original data was a multi-temporal cartographic material (plans of the city of Kazan) [8]. A great number of plans and maps were compiled for the city of Kazan over a thousand-year history, but not all material is suitable for work purposes since cartographic works have different loads, degree of detail of the image, etc.

The plans and maps selected for the job had to meet the following criteria: to have different ages (the map of 1936 and the google satellite images of 2014 were analyzed), to provide visual observation and comparison of gully and dry-valley systems. The changes in the morphological and morphometric characteristics of the gully systems were defined using the program MapInfo. Determination of the types of interaction between the gully and dry-valley system and the city was done according to the classification proposed by Kovalev S.N. [9]:

a) dependent on relief (all types of buildings are located, depending on the type and landform of relief);

b) subordinated to relief (most of the buildings in the settlements are inserted in relief);

c) subordinating to relief (localities where during construction partial conversion of relief throughout the site or in its substantial part happens);

d) suppressing to relief (settlements or their parts, big industrial enterprises, where in the process of growth or on design stage features of relief are not taken into account and construction is carried out with complete conversion of the territory depending on the needs).

3. Results and discussion

Gullies in the city of Kazan have mainly two negative side effects: on the one hand – the gullies "eat" usable area; on the other hand – they lead to deformation and destruction of structures of different purpose [10, 11].

At present, gully erosion has much more difficult engineering-geological conditions in Vahitovsky, Sovietsky, Privilzhsky, Moscovsky and Aviastroitelnaya parts of the city. Under a threat there are the objects of civil and industrial purpose. Gully formation in Kazan is mainly due to geomorphological and geological conditions. The territory of the town located within the complex alluvial terraces of the Volga and Kazanka Rivers is deeply dissected not only by the valley of Kazanka River. However, in the low order rivers, the relief is characterized by great ruggedness and rock formation, represented by sandy-loam, sometimes sandy loess and differences between the Pleistocene and have high smearing.

In addition, rainy summer and autumn and, as a rule, abundantly snowy winters also contribute to the development of gully erosion.

Within the present territory of Kazan there are the following areas of gullies and dry valley systems: development Gorsko-Ometevskaya, Moscovskaya, Derbishinskaya, Tsaritsynskaya, Karavaevskaya, Zaretsenskaya, Sukhoretsenskaya, Krutushkinskaya. In general, the territory of Kazan is characterized by a moderate obrigatoriamente – an averaged coefficient gully dissection is 0.44 km/km². The density of gully network is shown in figure 1 [12].
Figure 1. The density of gully network in Kazan.

The longest gully-dry valley system in the city of Kazan is the Gorsko-Ometevskaya which is easy to read on the map of 1936. It is seen that this gully system being sufficiently developed consists of three independent branches: "Nesterovsky", "Ometievsky" (in place of the modern settlement Ometevo) and "Zaometevsky". It should be noted that in 1936 the area was practically the outskirts of the city and the natural development of gullies is not obstructed.

The Gorsko-Ometevskaya system, well observed in 1936, has now significantly changed. The "Nesterovsky" gully, especially its upper reaches on the map are practically not recognized. Currently, most of the gullies are completely covered and are used for residential development. This is one of the most built-up areas. There is an intensive construction of the sides of the gully from the side of Vishnevskogo street and its surroundings.

The "Zaometievsky" gully also has almost disappeared. In its place there is the Ometevskaya highway, which is laid along the bottom of the gully. The fact that this is a former gully is reminiscent of even redesigned but rather steep slopes.

It should be noted that in Kazan gullies and dry valleys are being used for highways not for the first time. Some practical examples include: the transport artery of Pushkin Street which was formed at the bottom of a crooked ravine that ran from Lake Kaban. Likewise, the transport highway was formed at the bottom of the ravine along Tankovaya and Tolstoy streets.

The "Ometevsky" gully located in the area of the former settlement. Ometevo is the only gully that has changed a little. Preservation of this gully was facilitated, evidently, by the fact that up to the present time private low-rise buildings have occupied this territory. Steep layers of gullies are used for garden plots. In the same vein, the presence of some gullies are reflected in the names of the streets. For example, Vyatsky Val Street, Podgornaya Street are among others.

Analyzing the development of the entire Gorsko-Ometevsky gully stretch it can be noted that this gully system underwent significant changes during the observation period (figure 2). Determining the nature of the interaction between the gully system and the city we can state that:

- the type of interaction refers to the dependence on relief (gullies of "Nesterovsky" and "Zaometevsky");
- dry-valley systems of Ometevsky illustrate the type subordinate to relief.

The shortage of land within the city limits can be solved through various approaches. One of them is the use of badlands which include gullies and dry valley system. Extensive gully systems in the city of Kazan are of considerable territorial reserves for development.
Figure 2. Gorsko-Ometevsky gully on the map of 1936 and on a satellite image of 2014 (Google).

Multi-temporal analysis of cartographic material showed that currently there is an active development of gully systems, especially in the central historical part of the city due to the technical capabilities and investment attractiveness. The nature of the interaction of gully systems and the city is overwhelming.

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