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ASSESSMENT OF HAZARDOUS ENGINEERING-GEOLOGICAL AND HYDROGEOLOGICAL PROCESSES ON THE ALMATY CITY TERRITORY

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The relevance *of the research is caused by the need to study hazardous engineering-geological and hydrogeological processes developing on Almaty city territory that pose a threat to the life of urban residents and to industrial and civil building. In addition, the relevance of the research is caused by the need to assess the human economic activity impact on the geological environment state.*

Purpose: *description and zoning of the Almaty city territory according to the type and modern state of development of hazardous geological processes and identification of the most hazardous areas potential, from the point of view of the development of hazardous geological processes for their detailed study; selection of an experimental site for assessing and prediction buildings underflooding development using a geofiltration models.*

Objects: *landslides, landfalls, mudflow phenomena developing in the foothill sites; the groundwater level rising in the central part of the city in the sites of existing water intakes facilities; underflooding of certain sites in the northern part of the city.*

Methods: *research and classification of hazardous geological processes developing in the Almaty city; systematization and analysis of the main factors of their occurrence and development on the territory, based on the results of earlier field investigations and published works; field research and mapping of the selected experimental site; creation of a database, including climatic, geological, hydrological, hydrogeological data; route survey of the experimental site, the groundwater level monitoring in observation wells; observations of the state of river flow and flood events.*

Results. *On the territory of Almaty city, there are three main groups of hazardous geological processes associated with certain areas: 1 – landslides, landfalls, mudflows developing in the foothill areas of the city; 2 – groundwater level rising in central part of the city, where existing water intakes, leading to increase in the seismicity level; 3 – underflooding resulting from the deterioration of the natural drainage of territory due to the filling and planning of the existing depressions in the relief and the «кarasu» rivers. The assessment of the potential underflooding of the territory allowed us to class it as the first degree in terms of potential underflooding. The estimated period of the territory underflooding will be from 4 to 5 years. Taking into account the dynamics of the process of the territory underflooding, it is concluded about the necessity to create a geofiltration model for predictive assessment of the process development of buildings flooding on this territory.*

Key words:
Hazardous geological processes, urban area, underflooding, groundwater, monitoring.

Introduction

Hazardous engineering-geological (HGP) and hydrogeological processes refer to geologic phenomena that are formed under the influence of natural or human factors and cause losses to human life and property, as well as damages to the environment [1]. Common types of geologic hazards in urban areas include earthquakes, ground subsidence, landslides, mudflows, ground fissures, soil erosion, underflooding and water pollution [2]. The research on geologic hazards mainly focuses on the establishment of disaster prediction models. To predict the landslide disaster, Liu and Wu [3] proposed a landslide recognition framework. Bovolenta, Bianchi [4] in their research uses three-dimensional numerical model to predict slope behavior in occurrence of water table fluctuations in Ville San Pietro. In addition, Nsengiymva and Valentino [5] uses GIS-based machine learning simulations to forecast landslides susceptibility and risks. Orozco, Caballero and Nader [6] studied the early warning system of the flood disaster, developed intelligent disaster prediction application program. Leng, Liu and Mei [7] established a geologic hazard prediction model, which could provide decision support for disaster prevention and mitigation, also accesses warning model services and realizes comprehensive information management, monitoring, and warnings of multiple types of geological disasters. Causes of some HGP on urban territories was described on the example of a representative part of Kiev city. It was found that violation of the safe habitation conditions in cities is related to the unsuccessful placement of objects in different functional zones that have different degrees of safety of the inhabitation. It happens in case of HGP, together with emergency situations. Changing the groundwater level and soil water content have the most dangerous influence among the considered effects [8].

Anker et al. assessed the effect of rapid urbanization on Mediterranean karstic mountainous drainage basins in Israel. In order to prevent flooding, the urban areas should be planned with runoff infiltration zones in a way that will prevent their hydrological effect on the adjacent natural drainage systems. In addition to flood mitigation and groundwater recharge, the vacant land used as runoff absorbing strata provides social benefits for the surrounding community [9].

Almaty city is situated on the Ile Alatau foothill zone. Currently, in Almaty agglomeration is place more than 1,5 million people with high density. The territory is characterized by a high concentration of industrial facilities, residential buildings, summer cottages, engineering communications. Begining from the 90s of the last century, here the intensive housing development was began in the foothills of the Ile Alatau range, which is most susceptible to HGP [10]. The building was carried out without installation of a drainage canals network for intensive surface runoff. Irrigation of sites located on landslide slopes was uncontrolled. As a result, in recent years there was an activation of slope gravitational processes, which, unfortunately, led to human losses [11]. Since HGP in the foothill zone is extended in time, its intensification is expected in the near future. Considering that the foothill zone of Ile Alatau locate in the zone of 9–10 magnitude earthquakes [12], even an earthquake with an intensity of 5–6 magnitudes may provoke here numerous gravitational displacements. The map of engineering-geological zoning of the territory of Almaty city and its suburbs according to the conditions of development and intensity of HGP at a scale of 1:50,000 was composed by Mustafayev et al. [10]. On this map the points for organizing monitoring of HGP in the area of Almaty city were recommended.

From 2004 to 2006, «Almatyhydrogeology» LTD carried out the work for monitoring dangerous geological processes at Kaskelen-Talgar test site. The work was carried out according to the VSEGINGEO methodical guide [13–15]. Regular observations were carried out to study the dynamics of development of hazardous geological processes at 27 stationary observation posts in Almaty region on the area of Kaskelen-Talgar test site. The observation results were submitted in report [16]. For a proper feasibility study the engineering works for preventing HGP development it is necessary to comprehensively investigate the engineering-geological situation of HGP manifestation areas, to analyze their intensity, to research the physical and mechanical properties of soils and rocks, and also to reasonably predict the dynamics of these processes' development in time.

The main types of the hazardous engineering-geological and hydrogeological processes on Almaty city territory

Overview map and layouts of the studied sites on the Almaty city territory shown on Fig. 1.

Based on the results of studying HGP development on the territory of Almaty city, the following types of HGP have been identified (Fig. 2): type 1 – associated with the movement of the mass of soil and water under the influence of gravity and the energy of the water flow; type 2 – associated with the urban area underflooding.

On the territory of the city of Almaty and the areas of prospective development adjacent to it, there are two main zones for development of hazardous geological and engineering-geological processes. The first zone includes a group of HGP associated with the movement of the mass of soil and water under the influence of gravity and the energy of the water flow. This group includes: landslides, collapses, land subsidences, mudflows, land runoff and solifluction processes. Geographically, this zone is located in the southernmost foothill areas of the city and along the built-up river valleys. The second group of HGP is associated with the underflooding of the urban area and we referred it to the second zone of the development of these processes. Plots belonging to this zone are located in the northern plain part of the city to the north of Ryskulov Avenue.

Landslides, landfalls and mudflow phenomena

Significant development of these processes in the basins of the rivers Kaskelen, Aksay, Bolshaya and Malaya Almatinka. Along the streams Akzhar, Kokshukyr, Malyutinsky, Kyzylzhar, which are the centers of mudflows due to intensive precipitation, it led to significant changes in the structure of the valleys of these streams, with the activation of landslides, collapse, lateral and bottom erosion. Along the mudflow channel the overlapping debris roads, river beds, destroyed engineering communications were recorded. Areas exposed to HGP are also associated with the slope trimming during road construction, terracing slopes under large-scale construction on slopes located near Butakovka, Krasny Vostok, Mechet, Priroda, Alga, Arai, 1,5 km south-west of the village Kamenka and others. The location of the recorded landslide areas and the damage caused by them to buildings and engineering structures are shown in Table 1.

As an example for describing the development of landslide processes, we selected an experimental site located on northwestern slope of Kok-Tobe Mount, as the most dangerous, on which complete information was collected and work was carried out aimed at slope-strengthening this landslide (slope-strengthening work was carried out by JSC «Gidrospetsstroy»).

Landslide on the northwestern slope of Kok-Tobe Mount. The studied site is located in a low-mountainous part on the right bank of Malaya Almatinka River at elevations of 1054, 1102 m. Geomorphologically, the site is confined to the area of denudation of tectonic low-mountain relief. The shape of mountain structures is represented by smoothed watersheds and convex, steep slopes covered with dense herbaceous vegetation (Fig. 3).

Landslide is related to the domestic and storm water drainage problems, immediately after construction of the cable car and «Aul» restaurant on Kok-Tobe Mount. By the middle of 1980s, a landslide was formed here due to water leakage from pipes. The landslide descended into Solonovka river valley without causing any harm, except for a small flood. In 1998, due to a water leakage from the main water conduit laid along the northwestern slope of the mountain, a landslide-stream descended, consisting of waterlogged masses of soil with a volume of 700–900 m^3. The soil natural state was disturbed by the road and construction sites planning. In the second half of the 1990s, due to the increase in soil moisture, a breakaway crack began to form and the soils of the northwestern slope began to slide slowly. Slope-strengthening work using bored piles was carried out in the period from 2002 to 2005 and stopped landslide formation (Fig. 4).

Fig. 1. Overview map and layouts of the studied sites on the Almaty city territory: 1 – underflooding; 2 – landslide

Рис. 1. *Обзорная карта и карта экспериментальных участков на территории г. Алматы: 1 – процесс подтопления; 2 – оползневой процесс*

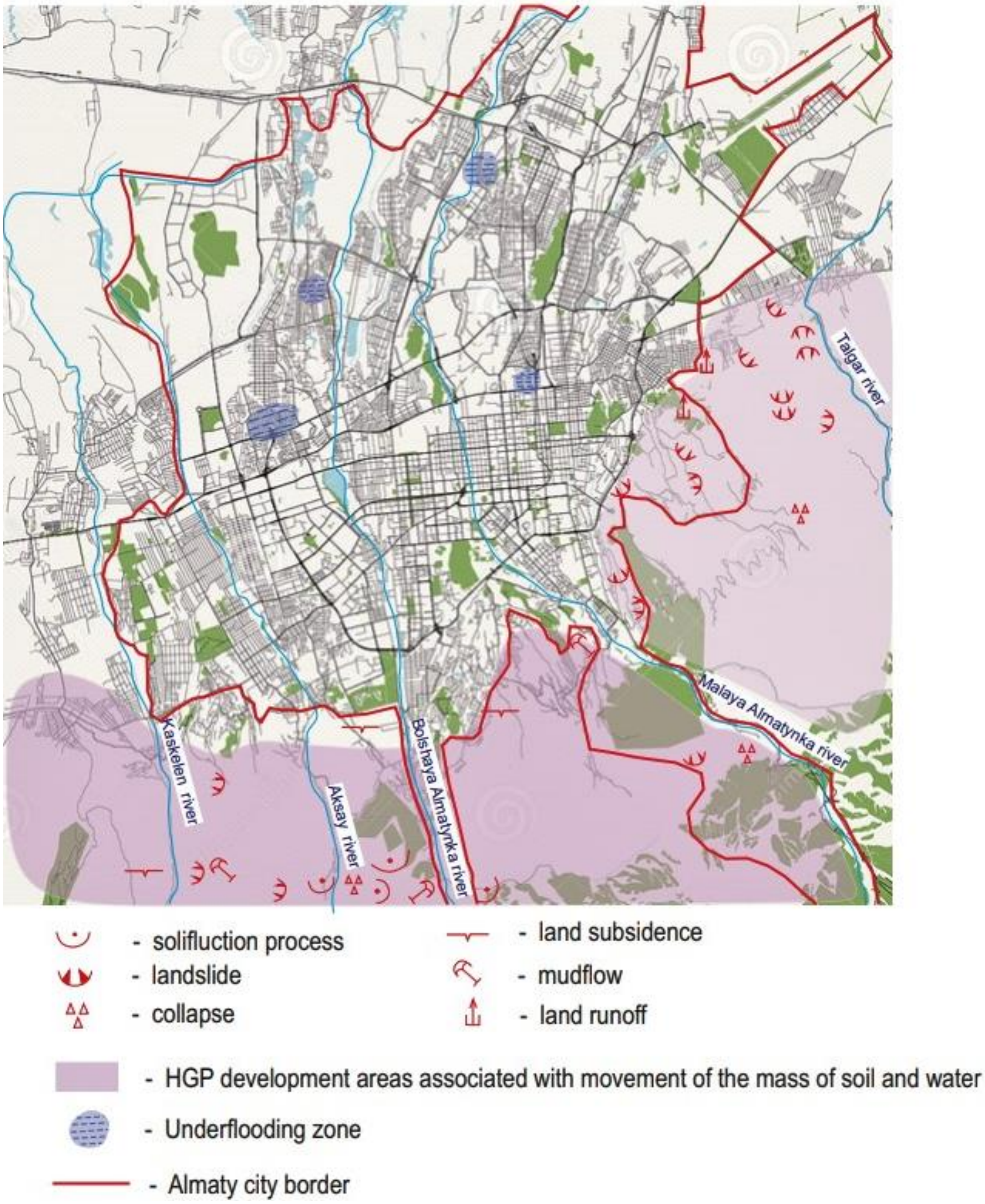

Fig. 2. *Zoning map of Almaty city according development of HGP*

Рис. 2. *Карта районирования г. Алматы по развитию опасных геологических процессов*

Soils composing the landslide slope, leveled watershed and near-watershed surfaces are lithologically represented by a two-layers stratum: upper layer represented by loess-like loam, macroporous, dense, slightly moist. And the underlay part of the soil profile is boulder-pebble with sandy-loamy filler. The physical and mechanical properties of the upper layer have the following values:

- Natural moisture 16,6–22,9 %
- Dry unit weight 1,19–1,33 g/cm^3
- Porosity 50,9–55,4 %
- Plasticity index 8,9–11,9
- Subsidence capacity 0,01–0,034
- Natural cohesion 0,018–0,22 MPA
- Underwater cohesion 0,004–0,018 MPA
- Natural internal friction angle 25–29°
- Underwater internal friction angle 24–28°

Thus, along with geological, geomorphological, climatic conditions, the technogenic factors, such as overloading the slope, artificial waterlogging of soils, undercutting of slopes, are of great importance for HGP activation. All this reduces the slope stability and may lead to collapse of the cable car station, observation platforms, as well as houses located at the foot of Kok-Tobe Mount (Fig. 4).

The necessary parameters characterizing the landslide-prone area, which will be used in the further calculation of the slope stability, were entered into the documentary database of the landslide area.

Table 1. *Location of the recorded landslide areas*
Таблица 1. *Расположение зафиксированных оползневых участков*

HGP type Вид ОГП	Location Местоположение	HGP damage to buildings and engineering structures Повреждение объектов народного хозяйства за счет ОГП
Landslides Оползни	Kyrgauyldinka river basin, middle reaches, road on the dacha «Gornyi sadovod» Бассейн р. Кыргаульдинка, среднее течение, дорога на даче «Горный садовод»	Road blockage/Завал дороги
	Kyrgauyldinka river basin, Koklai sai tract Бассейн р. Кыргаульдинка, урочище Коклай сай	Road blockage/Завал дороги
Landslide and erosion Оползневые и эрозионные процессы	Electric substation site 131a Gorny Gigant, on the crest of trampolines mountain Участок электроподстанции 131 а Горный гигант, на гребне горы трамплинов	Collapse of power transmission line supports, equipments Обрушение опор ЛЭП, оборудования
Landslide Оползень	Besagash township, AKNM micro-district, no 3 and 5 houses Посёлок Бесагаш, микрорайон АКНМ, дома № 3 и 5	Deformation and destruction of homes Деформация и разрушение домов
	Right side of Aksay river at the exit from mountains, in the area of 4 built cottages Правый борт р. Аксай на выходе из гор, в районе 4 построенных коттеджей	Homes destruction on the top and at the foot of the slope Разрушение домов на вершине и у подножья склона
	Remizovka river basin, Kotyrbulak dachas Бассейн р. Ремизовка, дачи Котурбулак	Homes destruction Разрушение дачных домов
	Kaskelen river, 1 km southern of the landslide dam, on the slope of northern exposure Река Каскелен, 1 км южнее селевой плотины, на склоне северной экспозиции	Destruction of houses, buildings Разрушение домов, строений
	Kaskelen river, 1 km western of the landslide dam, on the slope of southwestern exposure Река Каскелен, 1 км западнее селевой плотины, на склоне юго-западной экспозиции	Destruction of houses and country sites Разрушение дач, дачных участков

Fig. 3. *Landslide on the northwestern slope of Kok-Tobe Mount. Photo is from «Monitoring of hazardous geological processes at Kaskelen-Talgar test site in 2017–2018»*

Рис. 3. *Оползень на г. Кок-Тобе. Фото взято из отчета «Ведение мониторинга опасных геологических процессов на Каскелен-Талгарском полигоне за 2017–2018 гг.»*

Underflooding of certain sites in the northern part of Almaty city

Underflooding of the urban territory takes place on the foothill plain of Zailiyskiy Alatau [3]. The filling and planning of existing topographic lows and «karasu» rivers [17], that decrease in natural drainage, leads to underflooding of buildings and other engineering structures. «Karasu» rivers are formed on the foothill plain in the groundwater discharge zones and have spring feeding, to which snow and rain precipitations are added [17, 18].

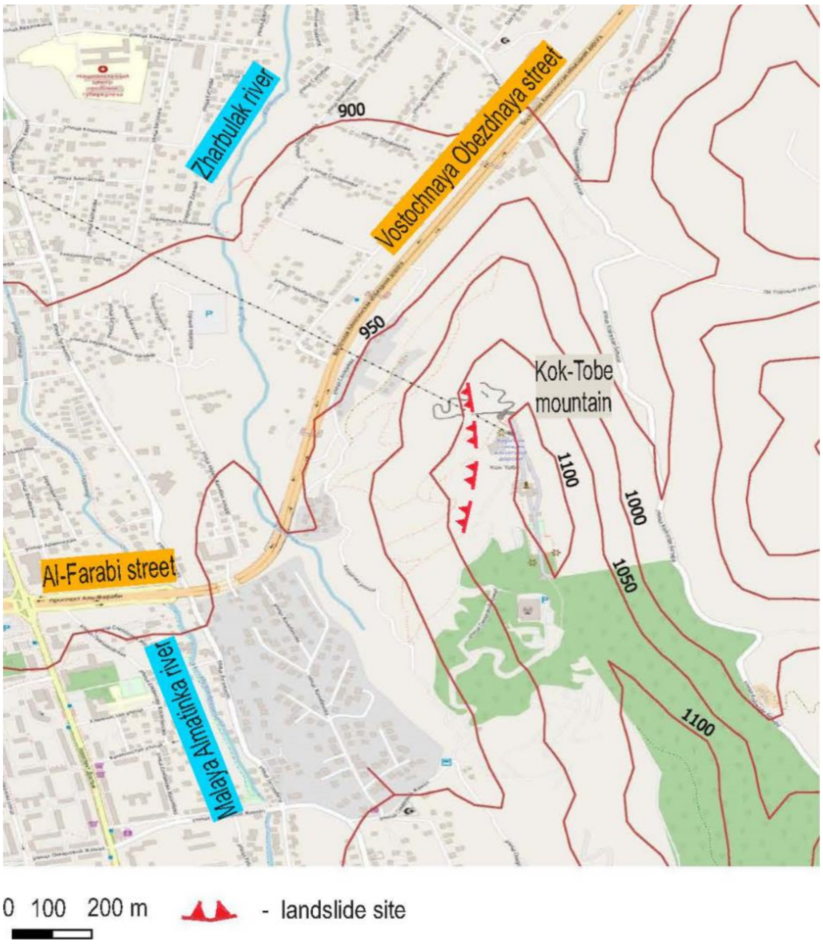

Fig. 4. *Layout of the experimental site 2 on the slope of Kok-Tobe Mount*
Рис. 4. *Карта экспериментального участка 2 на г. Кок-Тобе*

Fig. 5. *One of the «karasu» rivers in winter. Photo of A. Zhakyp, 2020*
Fig. 5. *Одна из рек карасу в зимнее время года. Фото сделано Жакып А., 2020*

Currently, these natural rainwater and groundwater drains in the north part of Almaty city are mostly filled up and planned and this process continues (Fig. 2).When the ravines are filling, a local increase in the level of groundwater is observed due to the decrease of their drainage conditions. Partial backfilling of ravines during construction of roads crossing them is accompanied by water dampening and formation of swampiness and underflooding (Fig. 5). The process of underflooding of the territory of the northern part of Almaty city was studying at the experimental site located north of Ryskulov Street (Fig. 1). The phenomenon of underflooding was most clearly developed on the territory of the Akbulak micro-district in 2016, when groundwater level rose to ground surface, and basements in nearby houses were flooded. This was the reason for choosing this area as an experimental site for a detailed description and assessment of the potential flooding of the territory of Almaty.

Description of «underflooding» experimental site and investigation methods

«Northern part of Almaty city» – the experimental site is located in the northwestern part of Almaty city, north of Ryskulov Street, in Akbulak micro-district, along Yessenin and Armavirskaya streets (Fig. 6). Geomorphologically, the township is located on an alluvial-proluvial foothill plain. In lithological terms, the experimental site is confined to the Upper Quaternary alluvial-proluvial deposits (apQ_{III}).

Water-bearing rocks in this area are represented by gravel-pebble and gravelly sands. Granulometric composition of gravel and pebbles: content of clay particles – 1,3 %; silty – 2,9 %; sandy – 39 %; gravel – 57,8 %. Soil density – 1,65 g/cm^3; at maximum compaction – 1,8 g/cm^3, natural angle of repose – 32°, underwater – 25°. The aggregate is medium-grained sand with the following particle size distribution: clay particles – 0,8 %; silty – 4,3 %; sandy – 59,1 %; gravel – 35,8 %; natural angle of repose of dry soil – 31°, underwater – 24°.

During the construction of the settlement, planning of the territory and backfilling of «karasu» rivers were carried out, which is the basis for drainage of groundwater and rainwater, especially in a high-water year.

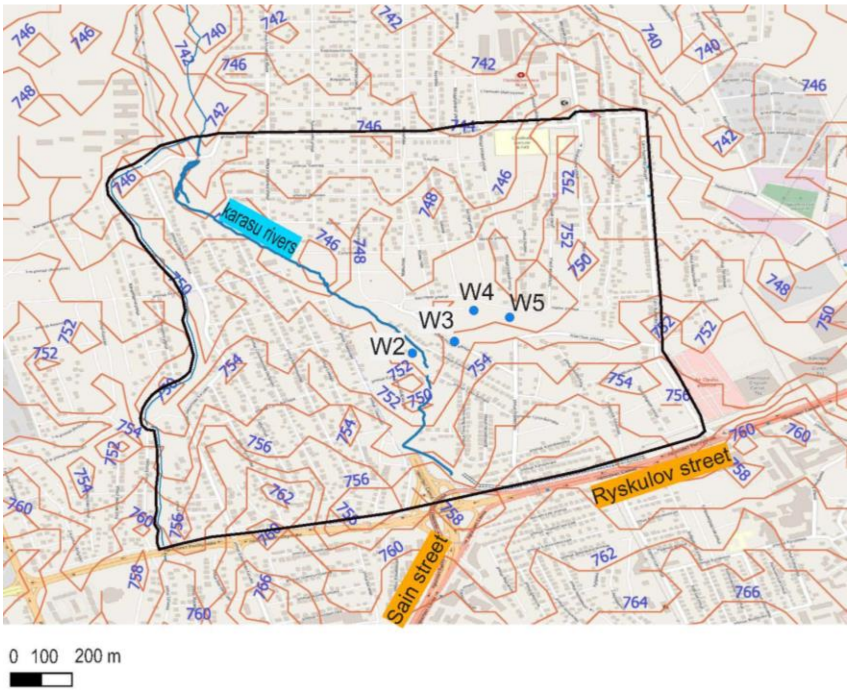

Fig. 6. *Layout of the factual material of the Northern part of Almaty city experimental site, Akbulak micro-district: W2 – monitoring wells*

Рис. 6. *Карта фактического материала экспериментального участка в северной части г. Алматы, мкрн. Акбулак: W2 – наблюдательные скважины*

This caused a rise in groundwater levels, and, as a result, underflooding of urban utility services communications and industrial and residential buildings. The processes of underflooding especially manifested in a high-water year, when, during the period of heavy rains, the monthly norm of precipitation fell per one day. A negative role in this process was also played by a large area of asphalted territories located hypsometrically south of Ryskulov Street, as well as the absence of storm sewers necessary for the collection and outflow of rain and melt water. These wells are used for systematic monitoring of the influence of the groundwater level on the development of waterlogging and soil salinization.

Monitoring of underflooding process development was based on the data received from the observation post at the experimental site. One of the criteria for choosing these observation posts for monitoring was the degree of their impact on the vital population activity, buildings and communications. At the same time, special attention was paid to the seasonal periods of groundwater fluctuations and periodic underflooding of the territory by groundwater. Monitoring of underflooding development included the following: observation of groundwater levels; condition of the river runoff; atmospheric precipitation; flood phenomena. The observation results compiled a documentary database of the experimental site for the study of the underflooding. In addition, this database includes: temporally data on the «karasu» river flow, set maps of the «karasu» rivers location from 1967 to present time; topographic plans of the Almaty city in 1967, 1995 and 2017; maps of the groundwater depth and hydrodynamic pressure of the upper soil layers. The condition of the river runoff and flood phenomena were monitored by means of visual observations after the occurrence of floods and heavy rainfalls. The groundwater levels depth was recorded according to the data of regular measurements in observation wells. The observation wells layout is shown in Fig. 6. Five wells, up to 15 m depth, were drilled on the site. The frequency of measurements was three times a month. At the same time, operational changes in the hydrogeological and hydrodynamic conditions of the territory, which determine the activity of flooding, were also monitored.

Assessment of potential underflooding of the territory was carried out based on the use of the potential underflooding criterion P [19]:

$$P = (h_e - \Delta h)/H_c, \qquad (1)$$

where h_e is the groundwater level before flooding, determined according to engineering survey data, m; $\Delta h = f(x, y, t, w_0)$ is the value of the possible (predicted) rise of groundwater for the estimated period of time, m (determined on the basis of filtration calculations in accordance with the «Recommendations for the forecast of underflooding of industrial sites with groundwater» (VNII VODGEO, 1976) [20]; H_c is the critical level of underflooding with groundwater, from the ground surface, m. While $P \le 1$ and $t_c \le T_p$ (t_c is the period of time during which $H_c = h_e - \Delta h$ occurs), the territory is potentially underflooded.

Results and discussion

A significant rise in the groundwater level in April–May was found which is associated with periods of heavy rains and melting snow. In 2016, the (rainiest) high groundwater level remained until August. In wells no. 3, 4, groundwater was at ground level (Fig. 7). Cellars in nearby houses were flooded. It should be noted that 2016 was the most water-abundant year for the last 10-year observation period.

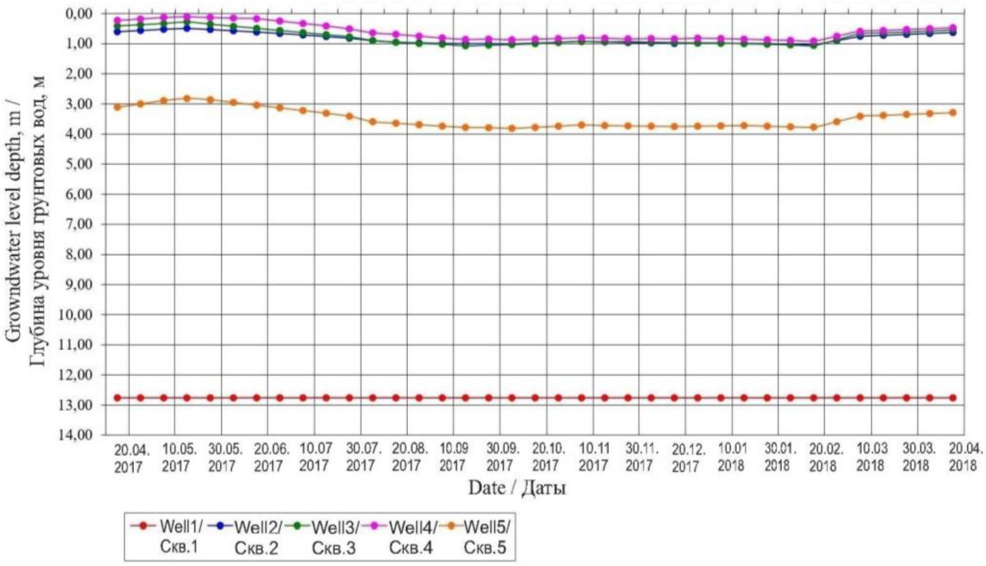

Fig. 7. *Fluctuations in the groundwater level in 2017–2018. Monitoring post in Akbulak micro-district*
Рис. 7. *Колебания уровня грунтовых вод за 2017–2018 гг. Пост мониторинга в мкрн. Акбулак*

From April 2017 to April 2018, the minimum values of the groundwater level were typical for the end of August – the beginning of September (Table 2). The observation results show that spring snowmelt and abnormal rains are the decisive factors for underflooding of this territory. The minimum depths of groundwater levels are recorded in wells 2–4.

Assessment of potential underflooding of the territory is shown in Table 3.

Based on the assessment performed, this territory belongs to the first degree in terms of potential underflooding.

Table 2. *Groundwater level fluctuation*
Таблица 2. *Колебание уровня грунтовых вод*

Well number Номер сква-жины	Groundwater rises levels (depth from ground surface) Уровни подъема грунтовых вод (глубина от поверхности земли)		Amplitude of groundwater level fluctuations Амплитуда ко-лебания уровня грунтовых вод
	Maximum Максимальные	Minimum Минимальные	
	m/м		
2	0,49	1,04	0,55
3	0,28	1,04	0,76
4	0,11	0,91	0,80
5	2,82	3,81	0,99

Table 3. *Assessment of potential underflooding of the territory*
Таблица 3. *Оценка потенциальной подтопляемости территории*

Value names Наименование показателя		Symbol, unit of measure Условное обозначение, единица измерения	min миним.	average средн.	max макс.
Natural groundwater level Естественный уровень подземных вод		he, m/м	0,29	0,64	0,99
Critical underflooding level Критический уровень подтопления		Hc, m/м	1,50		
Natural conditions of the territory Природные условия территории		from 1 to 6, scheme от 1 до 6, схема	4		
Water consumption category Категория по водопотреблению		from A to D, group от А до Г, группа	D/Г		
Specific water consumption Удельный расход воды		m^3/day per 1 ha $м^3$/сут на 1 га	50–500		
Type of underflooding Тип подтопляемости		from I to IV, type от I до IV, тип	III		
Probable rate of level rise Вероятная скорость подъема уровня	in the first 10 years за первые 10 лет 10–15 years/лет 15–20 years/лет 20–25 years/лет	V, m/year/м/год	0,10 0,03 0,03 0,02	0,20 0,07 0,05 0,04	0,30 0,10 0,08 0,06
Estimated rise in groundwater level Расчетное повышение уровня подземных вод	in the first 10 years за первые 10 лет 10–15 years/лет 15–20 years/лет 20–25 years/лет	h=Vt, m/м	1,00 1,15 1,27 1,38	2,00 2,33 2,59 2,79	3,00 3,50 3,90 4,20
Underflooding criterion Критерий подтопляемости	in the first 10 years за первые 10 лет 10–15 years/лет 15–20 years/лет 20–25 years/лет	P=(he–Δh)/Hc	0,90		
Assessment of the territory for underflooding Оценка территории по подтопляемости		if P≤1, potentially underflooded при P≤1, потенциально подтопляемая	potentially underflooded потенциально подтопляемая		
Estimated period of underflooding of the territory Расчетный срок подтопления территории		tc=(he–Hc)/V, years/лет	4,3		
Degree of potential underflooding of the territory by the time of process development Степень потенциальной подтопляемости территории по времени проявления процесса 1 degree – up to 5 years/1 степень – до 5 лет 2 degree – up to 10 years/2 степень – до 10 лет 3 degree – up to 15 years/3 степень – до 15 лет 4 degree – up to 20 years/4 степень – до 20 лет 5 degree – up to 25 years/5 степень – до 25 лет		up to 5 years, degree до 5 лет, степень	1		
Classification criteria (P) for underflooding Критерий типизации (P) по подтопляемости		1st degree, potentially underflooded territory 1-я степень, потенциально подтопляемая территория			

Conclusions and recommendations

1. On the territory of Almaty urban agglomeration, the following main groups of HGP associated with certain areas were studied: 1 – landslides, landfalls, mudflow phenomena developing in the foothill regions; 2 – underflooding in the northern part of the town. Underflooding is related to the decrease in the natural drainage of the territory due to filling and planning of existing topographic lows and «karasu» rivers. Spring snowmelt and abnormal rains are also the important factors for underflooding of this territory.
2. Analysis of monitoring observations at the «underflooding» experimental site and assessment of potential underflooding of the territory carried out based on them, made it possible to classify this territory as the first degree in terms of potential underflooding. At the same time, underflooding estimated period of the territory will be from 4 to 5 years.
3. Taking into account the dynamics of underflooding in the northern part of the city, it is necessary to create a geo-filtration model for predictive assessment of development of underflooding of buildings and structures on this territory.

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ОЦЕНКА ОПАСНЫХ ИНЖЕНЕРНО-ГЕОЛОГИЧЕСКИХ И ГИДРОГЕОЛОГИЧЕСКИХ ПРОЦЕССОВ НА ТЕРРИТОРИИ ГОРОДА АЛМАТЫ

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Актуальность *исследования обусловлена необходимостью изучения опасных инженерно-геологических и гидрогеологических процессов, развивающихся на территории г. Алматы, представляющих угрозу жизнедеятельности населения, промышленному и гражданскому строительству, а также необходимостью оценки влияния хозяйственной деятельности человека на компоненты геологической среды.*

Цель: *описание и районирование территории алматинской агломерации по опасным геологическим процессам для выбора наиболее характерных участков для их детального изучения; обоснование выбора экспериментального участка для создания геофильтрационной модели, оценки развития процесса подтопления зданий и сооружений данной территории.*

Объекты: *оползни, обвалы, селевые явления, развивающиеся в предгорных районах; подъем уровня подземных вод в центральной части города на участках действующих водозаборов и подтопление отдельных районов в северной части города.*

Методы: *исследование и классификация развивающихся опасных геологических процессов в г. Алматы, систематизация и анализ основных факторов их возникновения и развития на территории по результатам ранее проведенных полевых исследований и опубликованных работ; полевые исследования и картографирование выбранного экспериментального участка; создание базы данных, включающей климатические, геологические, гидрологические, гидрогеологические данные; маршрутное обследование площадки, контроль уровня грунтовых вод в наблюдательных скважинах; наблюдение за состоянием речного стока и паводковыми явлениями.*

Результаты. *На территории алматинской городской агломерации выделено три основные группы опасных геологических процессов, приуроченных к определенным районам: 1 – оползни, обвалы, селевые явления, развивающиеся в предгорных районах города; 2 – подъем уровня подземных вод в центральной части города на участках действующих водозаборов; 3 – подтопление отдельных районов в северной части города. Подтопление участков в северной части города Алматы происходит вследствие уменьшения естественной дренированности территории за счет засыпки и планировки существующих понижений в рельефе и речек «карасу». Оценка потенциальной подтопляемости территории позволила отнести данную территорию к первой степени по потенциальной подтопляемости. При этом расчетный срок подтопления территории составит от 4 до 5 лет. Учитывая динамику процесса подтопления территории в северной части города, возникает необходимость создания геофильтрационной модели для прогнозной оценки развития процесса подтопления зданий и сооружений данной территории.*

Ключевые слова:
Опасные геологические процессы, городская территория, подтопление территории, подземные воды, мониторинг.

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