Studying Hydrogeological Conditions for the Purpose of Developing Methods of Drying the Walls of Zhairem Deposit Dalnezapadny Site

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Abstract. The mining and geological characteristics of the Zhairem deposit that consists of the Zapadny and Dalnezapadny pits, are considered. The hydrogeological surveys carried out at the site are described. The site for hydrogeological testing includes the area around the Zapadny and Dalnezapadny pits, as well as test pumping and testing with the use of a downhole flowmeter. In the course of studies, theoretical and empirical methods were used; there were studied and applied archival historical data. Conducting geotechnical surveys made it possible to compose a conceptual characterization of the hydrogeological system around the mine and to obtain high-quality initial data for predicting the flow of groundwater. The final stage was the development of recommendations in order to prepare for the pumping of water from the Dalnezapadny 1-2 pit and future expected inflows, in order to carry out high-quality drainage of the Dalnezapadny 1-2 site walls.

Keywords: deposit, pit, hydrogeological conditions, groundwater, drainage, inflow, pumping, drainage wells, level decrease, wall stability.

Introduction
The Zhairem deposit consisting of the Zapadny and Dalnezapadny pits is located in the Devonian volcanic belt in the Karaganda region, Figure 1.

The relevance of the work is determined by the fact that standard open-cast mining methods are used at the Zhairem mine. The Zhairem mine consists of three pits: the Zapadny pit, the Dalnezapadny 2 pit, and the Dalnezapadny 1 pit. The Zapadny pit is an active quarry, today its depth is about 140 m, the planned final mark is 209 m in 2024. There is no work in the Dalnezapadny 2 pit, the water depth in it reaches approximately 95 m. The start of production in this open pit is scheduled for 2024. There is no work in the Dalnezapadny 1 pit, the water depth in it reaches approximately 65 m. The start of production in this open pit is scheduled for 2032. Water disposal from both pits is needed for the purpose of preparing the Dalnezapadny site for mining, after the full completion of mineral extraction in the existing Zapadny pit by 2024, therefore, studying hydrogeological conditions and developing methods of draining the walls of the site is an urgent task [1].

The objective is studying hydrogeological conditions and developing methods of draining the walls of the Dalnezapadny site of the Zhairem deposit in order to ensure the development of the flooded section of the polymetallic ore deposit in an open cast way.

The research tasks include determining hydrogeological conditions of the site, current groundwater levels and direction of flows, developing methods and scenarios of draining open pits and forecasting groundwater inflows.

The object of the study is two connected large pits, the flooding of which has not been regulated since 1993, when the extraction of polymetallic ores was stopped (the Dalnezapadny site pits).

Hydrogeological conditions. The Zhairem field, according to the modern scheme of hydrogeological zoning, is located in the northern part of the West-Balkhash hydrogeological basin of the second order that belongs to the Balkhash basin of the first order of the Central Kazakhstan region.

There are two hydrogeological floors in the area of the deposit. The upper floor is formed
by pore groundwater occurring from the surface of loose clastic sedimentary deposits of the Quaternary system. The lower floor is formed by fissure and fissure-karst waters of the rocky Middle Paleozoic massif and pore waters of the Upper Oligocene deposits [1].

In accordance with the hydrogeological stratification of groundwater, in the area of the deposit there are distinguished the following main hydrogeological units (from top to bottom). The upper hydrogeological floor includes:

- the permeable anthropogenic modern horizon of bulk dumps;
- the locally weak water-bearing lacustrine modern horizon;
- the aquifer alluvial upper Quaternary horizon;
- the modern horizon;
- the locally aquifer eolian-alluvial mid-Quaternary-modern horizon;
- the locally weak water-bearing deluvial-proluvial Lower-Upper Quaternary horizon;
- the impermeable Neogene horizon.

The lower hydrogeological stage includes:

- the Upper Oligocene aquifer;
- the weak water-bearing zone of Lower Carboniferous sedimentary and intrusive rocks;
The permeable anthropogenic modern horizon of heap dumps is confined to the existing overburden dumps located to the northwest and south of the Dalnezapadny 1 and 2 pits (Northern and Southern dumps) and to the dump located to the southwest of the Zapadny pit of the Zhайrem deposit. The bulk grus-crushed stone-block deposits with the inclusion of clay lenses are permeable. Water that enters the dumps due to atmospheric precipitation and water that forms in them as a result of condensation, infiltrate through the deposits of the dumps to their bottom that lies on low-permeable Quaternary deposits. The groundwater dumps serve as a source of additional power for the downstream aquifer hydrogeological units. In the process of infiltration of atmospheric precipitation through the body of the dump, there can occur leaching the rocks and ore mineralization contained in it. As a result, the formed groundwater can be saturated with components in concentrations exceeding their background value in natural groundwater [2].

The locally weak water-bearing lacustrine modern horizon in the area of the deposit is confined to local drainless basins located on the gentle slopes of the Bair River valley and among the dunes of the hilly plain adjacent to the Bair River valley from the northwest. In the modern relief, these basins form saline fields (sors) and takyrs. The area of the basins is from 0.5 to 3.4 km², the depth does not exceed 0.4-1.0 m. The horizon of lake sediments is mainly fed by precipitation during the snowmelt period. In addition, the horizon confined to shallow basins, which are located between the dunes, can be fed from the surrounding aquifer eolian-alluvial Middle Quaternary-modern horizon.

The hydrogeological system of Zhайrem can be divided into two main aquifers: Quaternary deposits and karst limestone formations. However, much of the groundwater flow is expected to be associated with geological structures in weathered and fractured rock formations, in particular along individual faults such as near the Dalnezapadny pit [2].

Groundwater continues to flow into the pits of the Dalnezapadny site as groundwater discharge after the cessation of mining in 1993 continues with a gentle hydraulic slope around the pits due to the still existing drawdown funnel. Today the surface level of both pit lakes today is about 85 m below the earth's surface. This corresponds to the water level drop of about 75 m below the natural water level before mining.

The static water level (without pumping) in well 7025 near the Zapadny pit is 50 m below the ground level. The depth of groundwater at points more distant from the pits is only 10-20 m below the ground level, which is considered to be almost the same as the static level before the start of mining at Zhайrem.

**Hydrogeological surveys at the site.** Carrying out engineering-geological surveys allowed making a conceptual characteristic of the hydrogeological system around the mine and obtaining the quality data for introducing the groundwater flow into the digital model. Historical data were also used in this study.

The site for hydrogeological testing included the area around the Zapadny and the Dalnezapadny pits, as well as test pumping and testing using a downhole flowmeter. The purpose of the tests was as follows (Table):
- obtaining the information of the variability of hydraulic characteristics along strike;
- studying the variability of hydraulic characteristics with depth;
- defining and characterizing the hydraulic behavior of individual geological objects, such as faults, fault zones and cracks.

After completion of the staged tests, all the pumping wells (except for well 7025) were tested for pumping at a constant rate within 72 hours, followed by the minimum 24-hour recovery [2].

A total of 17 boreholes were tested at Zhайrem using flowmeters to determine groundwater flow horizons in the depth of occurrence. Five wells were pre-existing dewatering wells and 12 ones were new monitoring wells. A detailed analysis of the flowmeter data

### Brief review of hydraulic properties defined as a result of testing for pumping at a constant rate

<table>
<thead>
<tr>
<th>Well</th>
<th>Average coefficient of transparency (T) [m²/day]</th>
<th>Hydraulic conductivity (K) [m/day]</th>
<th>Coefficient of storage (S) [-]</th>
<th>Dewatering coefficient (Sy) [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well 57</td>
<td>85.57</td>
<td>0.38</td>
<td>3.54E-03</td>
<td></td>
</tr>
<tr>
<td>Well 60</td>
<td>24.58</td>
<td>0.10</td>
<td>2.48E-05</td>
<td>0.11</td>
</tr>
<tr>
<td>Well 66</td>
<td>170.85</td>
<td>0.91</td>
<td>1.47E-03</td>
<td>No data</td>
</tr>
<tr>
<td>Well 70</td>
<td>656.47</td>
<td>3.20</td>
<td>1.84E-03</td>
<td>0.02</td>
</tr>
<tr>
<td>Well 114</td>
<td>48.11</td>
<td>0.25</td>
<td>1.74E-03</td>
<td>No data</td>
</tr>
<tr>
<td>Well 7025</td>
<td>129.98</td>
<td>1.30</td>
<td>2.74E-04</td>
<td>No data</td>
</tr>
</tbody>
</table>
made it possible to determine the change in hydraulic conductivity with depth. As a result, two broad water inflow zones were identified, one at the depth of 80 to 100 m and the other at the depth of 160 to 210 m below ground level (Figure 2).

**Research results, developing drying methods.** In order to prepare the pumping of water from the Dalnezapadny 1-2 pits and future inflows, the following recommendations have been offered:

- it is necessary to test the pumps of all the rehabilitated dewatering wells to assess the pumping rate that can be achieved from each well. This information will be used to select suitable long life pumps, save money and avoid regular pump failures;

- accordingly, it is recommended to test the pumps at least one day with a step change in loads in each dewatering well, followed by the restoration of the water level within 12 hours. During the test, the pumping speed shall be increased every 100 minutes. The minimum of four test steps should be completed, resulting in a total pump test time of 400 minutes;

- during pump tests, the well water level data should be recorded according to the following time scale: 1 minute, 2 minutes, 3 minutes, 4 minutes, 4 minutes, 5 minutes, 7 minutes, 10 minutes, 15 minutes, 20, 25, 30, 40, 50, 60, 80, 100, 120, 150, 180, 240 minutes and every hour until the water level in the well is completely (or 90%) restored;

- for long-term dewatering of wells, a frequency converter (or a variable speed drive) should be used in each well to ensure the injection rate be controlled so that the well does not run dry, and the optimum rate is achieved throughout the entire dewatering time (Figure 3);

- more drainage wells need to be made around the Dalnezapadny 2 pit to pump out water and to reduce pore pressure in the sides of the pit, which can cause instability of the pit.
- to ensure the best groundwater draw-down, new dewatering wells at the Dalnezapadny 1-2 quarry should be located inside the quarry and in the areas that will not be developed later. New wells should be targeted to aquifers or high permeability zones to keep the total number of wells to the minimum;
- the locations of the new dewatering wells shown in Figure 3 were selected solely on the basis of mining areas and the geological map. In order to select the most suitable positions for new dewatering wells around the Dalnezapadny 2 pit, it is recommended to conduct a ground geophysical survey of the adjacent 100-meter zone around the Dalnezapadny pit. The study should be aimed at identifying geological structures and assessing the thickness of the weathered rocks that are expected to be the main source/or route of groundwater inflow into the quarry;
- core drilling is recommended from new wells and geotechnical core characterization alongside with acoustic scanning (ATV) to determine the direction of rock layers and fracture frequency. This geotechnical information will be important for analyzing the slope stability and updating the pit slope configuration to reflect changes in dewatering strategy;
- it is necessary to keep a record of the dynamics of the flowmeters readings in the wells (during pumping out) to assess the productivity of the wells and to determine the zones with a vertical flow. This type of work will allow placing well filters in the most efficient way;
- expanding the diameter of each new well for use as a dewatering well if the well has shown sufficient productivity. After completion of drilling and mounting equipment, it is necessary to clean the well, and the pump should be tested to assess the achievable pumping speed and to select a suitable pump.

Figure 3 – Location of new dewatering wells

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Исследование гидрогеологических условий с целью разработки способов осушения бортов участка Дальнезападный месторождения Жайрем

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Аннотация. Рассматриваются горно-геологические характеристики месторождения Жайрем, состоящего из карьеров Западный и Дальнезападный. Описываются гидрогеологические изыскания, произведенные на площадке. Место проведения гидрогеологических испытаний включало участок вокруг Западного и Дальнезападного карьеров, а также пробную откачку и испытания с использованием скважинного расходомера. При проведении исследований были использованы теоретические и эмпирические методы; изучены и применены архивные исторические данные. Проведение инженерно-геологических изысканий позволило составить концептуальную характеристику гидрогеологической системы вокруг рудника и получить качественные исходные данные для прогноза потока грунтовых вод. Заключительным этапом являлась разработка рекомендаций для того, чтобы подготовиться к откачке воды из карьера «Дальнезападный 1-2» и будущих ожидающих притоков, с целью осуществления качественного осушения бортов участка «Дальнезападный 1-2».

Ключевые слова: месторождение, карьер, гидрогеологические условия, грунтовые воды, осушение, приток, откачка, водоотливные скважины, понижение уровня, устойчивость бортов.

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