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# Predicting the Development of a Low Gas-Saturated Zone of the Medvezhye Field Based on Geological and Hydrodynamic Modeling

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**Abstract**
Given the rising water cut and reduced gas flow rate at large fields in Western Siberia, the issue of further development of productive formations of such fields is urgent. The factor of efficient use of natural resources also needs to be considered for extraction to be the most productive. The study is devoted to the construction of a 3D geological model of the PK1 layer of the Medvezhye field and a 3D hydrodynamic model created on its basis. Four project variants for the development of the transition zone of the PK1 formation of the Medvezhye field are proposed. The forecast period spans from 2023 to 2060.

**Keywords**: 3D geological modeling, field development, gas, cenomanian deposits

## 1. Introduction

According to the energy strategy of the Russian Federation until 2030 approved by order of the Government of the Russian Federation of November 13, 2009, N 1715-r, the goal of the country's energy policy is to maximize the efficient use of natural energy resources. One of the priority areas of the gas industry is to create equipment, technologies, and materials to improve the reliability of wells and to open reservoirs, including deposits of low-pressure natural gas. The definition of low-pressure gas is given, for example, by Sarancha et al. (2015). At the final stage of production, the issue of rational use of reservoir energy is important due to the increase in water cuts (Omelchenko & Griaznova, 2009). Water cuts occur because most of the natural gas fields are developed by water pressure mode (Sizova, 2017). Russia has enormous gas reserves (Kolokolova, 2018) and remains the largest exporter of natural gas (Stepanenko, 2021). The largest number of reserves is concentrated in the fields of the Nadym-Pur-Taz region (Bugrii et al., 2013; Davydova et al., 2014).

Geological modeling as a method of studying oil and gas deposits is widely employed. Currently, according to methodological guidelines, all design documents for the development of oil and gas fields should be based on 3D geotechnological models (Zakrevskii & Popov, 2021). Geological models are almost always built with a limited set of input data, obtained mainly using indirect methods of research (Fadeev, 2022; Ladeishchikov et al., 2022; Vakhitova et al., 2011). In our case, there was enough data available to build models reflecting all properties of the PK1 formation of the Medvezhye field.

The purpose of the study was to build a 3D geological model under conditions of insufficient geological and geophysical information to predict the development of the low gas-saturated zone of the Medvezhye field.

## 2. Methods

### Input Data and Construction of the Model

### Building the basis of the 3D geological model

Drawing on the works of Russian theorists and practitioners, as well as our personal experience in geological modeling, preliminary conclusions were made about the possibility of creating the model under conditions of limited geological and geophysical information. Based on the analysis of the information available, it was decided to create the database for modeling based on data from the calculation of reserves, which certainly does entail some limitations in terms of the completeness of the scope of data for research and processing.

Based on estimations of reserves in the Cenomanian gas deposit of the Medvezhye field, lithological, structural, and other geological features of the Cenomanian deposits were identified.

The productive stratum is represented by alternating predominantly sandy and silty-clay layers and formations of different thicknesses, often lenticular in shape, which do not correlate even within the same area. In modeling the probability cube, this fact was considered as an indirect sign of high dissection and lithological variability of the Cenomanian productive complex along the section. Based on these data, it was decided not to distinguish strata within the Cenomanian productive complex when building the 3D geological model, and to take the roof of Cenomanian sediments as a basis for modeling the structural framework without considering the position of the bottom of the Cenomanian sediments stratigraphy, since it is located much lower than the position of the gas-water contact by absolute elevation. In addition, data on the opening marks at the bottom of the Cenomanian stratigraphy are available for a much smaller number of wells than had been drilled at the time of compiling the materials for the reserve's estimation. Thus, considering the needs of subsequent hydrodynamic modeling, the base of the structural framework is built conformally to the Cenomanian sediments roof so that the thickness of the water-saturated reservoir is no less than 20 m. In the process of analyzing geological and geophysical information on the Medvezhye field, reviewing Russian and international experience in creating 3D geological models of Cenomanian deposits and general ideas about the structure of the Cenomanian gas-bearing complex, it was concluded that the position of the bottom of the considered horizon stratigraphy does not affect the amount of reserves estimated.

Gas saturation modeling in the 3D geological model of the Medvezhye field is based on data from the results of the interpretation of geophysical well surveys and core studies. The need to build a low gas-saturated zone is driven by scientific exploration in the area of unconventional distribution of reservoir rocks of the Cenomanian productive complex. It is important to note that the Cenomanian Stage in the Nadym-Purov oil and gas bearing area is recognized as a single object of search for gas deposits, so the materials of neighboring fields were used to establish the low gas-saturated zone.

As a result, a model with a grid of 200*200*0.4m was built. The result is presented in the section of the gas saturation cube (Figure 1). This dimensionality of cells allows both optimizing the process of building the 3D geological model of the Cenomanian productive complex of the field, which is unique in terms of reserves, and passing such models on for further filtration modeling.

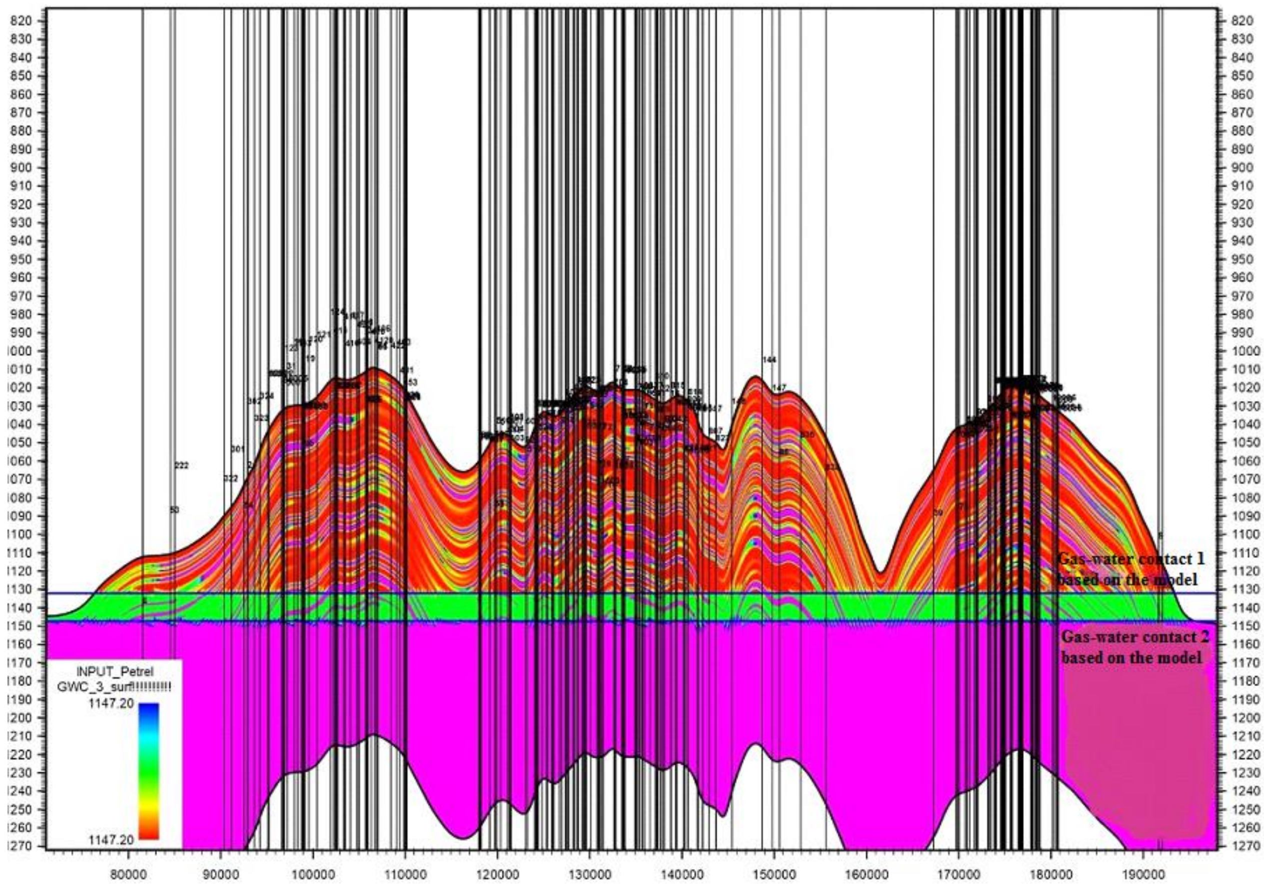


Figure 1. Cross-section of the gas saturation cube with cell dimensions 200*200*0.4m

**Building the Geotechnical Model**

The use of digital constantly operating geotechnological models of fields is one of the primary directions of improving the quality of design, control, and management of the development of hydrocarbon fields (Silich et al., 2013). The prototype constantly operating geotechnological model of the Cenomanian productive complex is a combination of a 3D geological model of the deposit and a filtration (hydrodynamic) model of its development processes. Based on the constructed digital geological model of the Cenomanian deposit of the Medvezhye field, using the certified tNavigator v21.2 software package by Rock Flow Dynamics per relevant regulations (Ministry of Energy of the Russian Federation, 2000), a numerical hydrodynamic model of the gas field was created. Analysis of information about the type of deposit and the fluids saturating it indicates that numerical modeling of the development process should employ the extended two-phase black oil filtration model (gas and water phases present).

Figure 2 shows a general view of the hydrodynamic model of the Cenomanian productive complex on the example of the Medvezhye field, considering the zonal structure.

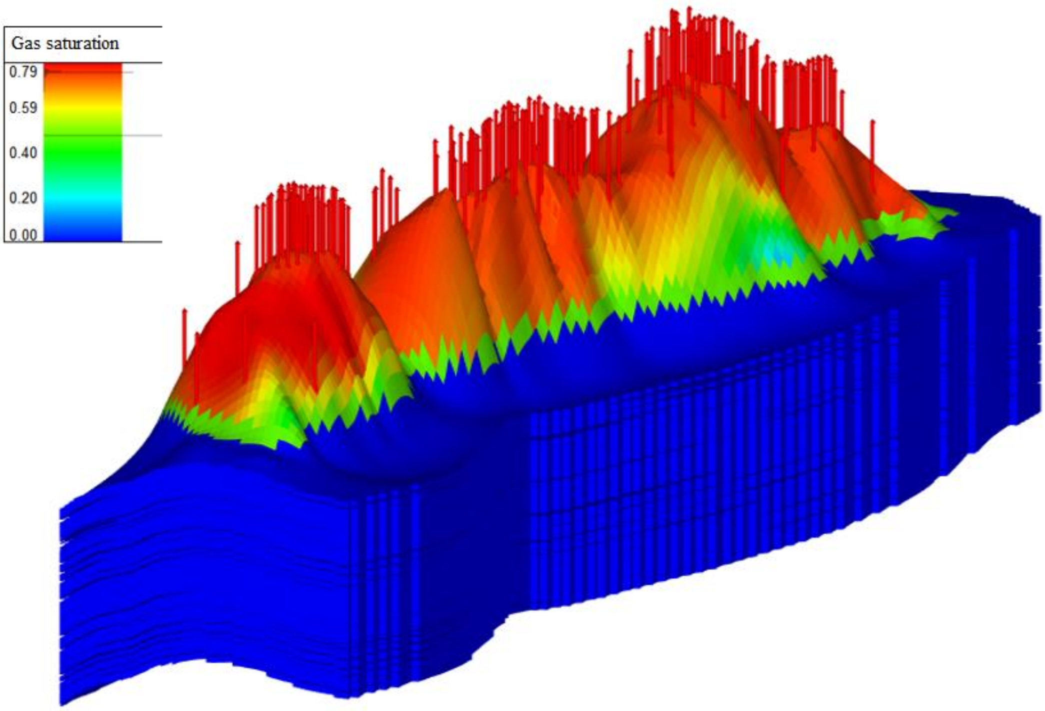


Figure 2. General view of the model of the Cenomanian productive complex on the examples of the Medvezhye field

**3. Results and Proposals on the Development of the Low Gas-Saturated Zone**

Hydrodynamic modeling is one of the most crucial stages of field development design (Zakirov, 2009). It is an effective tool that allows defining the main points of gas production: the structure of residual and recoverable reserves and the determination of development potential.

Our hydrodynamic model was built based on the developed geological model of the Medvezhye field of the Cenomanian complex. The modeling involved a total of 320 exploration and production wells.

The purpose of creating a model of the selected gas deposit was to confirm the possibility of gas production from the transition zone of the Cenomanian productive complex and to justify geological and technical measures in the medium- and long-term development prospects with the help of multi-variant calculations.

As of today, the Cenomanian gas deposit is known to be over 80% depleted, the gas composition is mostly methane (methane content of 98%) (Kolmakov, 2012).

**Description of Projected Options for the Development of the Transition Zone**

Proceeding from the available information, several project variants of the development of the transition zone were calculated for the constructed 3D hydrodynamic model of the Medvezhye field. As of October 1, 2012, the total number of wells in the field amounted to 488, of which: 259 were active, 83 were inactive, 89 were observation wells, 18 were liquidated, 11 were awaiting liquidation, and 28 were in conservation.

All variants assume the completion and transfer of the most promising wells that are in good technical condition. If the observation and abandoned wells are removed from the total fund of 488, there are 370 potential wells for transfer, and if the edge wells are taken out of consideration, 360 wells remain, which is the maximum number of wells.

It is planned to start gas production through isolation of the overlying horizon and reperforation in the low gas-saturated zone of the Cenomanian complex. The rate of commissioning of the main well fund is set at 60 wells per year. Wells in additional options are commissioned at a rate of approximately 12 wells per year and are distributed by year. The forecast period starts in 2023 and ends in 2060.

**Variant 1:** proposes to transfer wells that have been exhausted in the overlying zone to gas production from the low gas saturated horizon. There are 210 wells involved in production, located in the dome areas of the reservoir. Figure 3 shows the location of the wells.

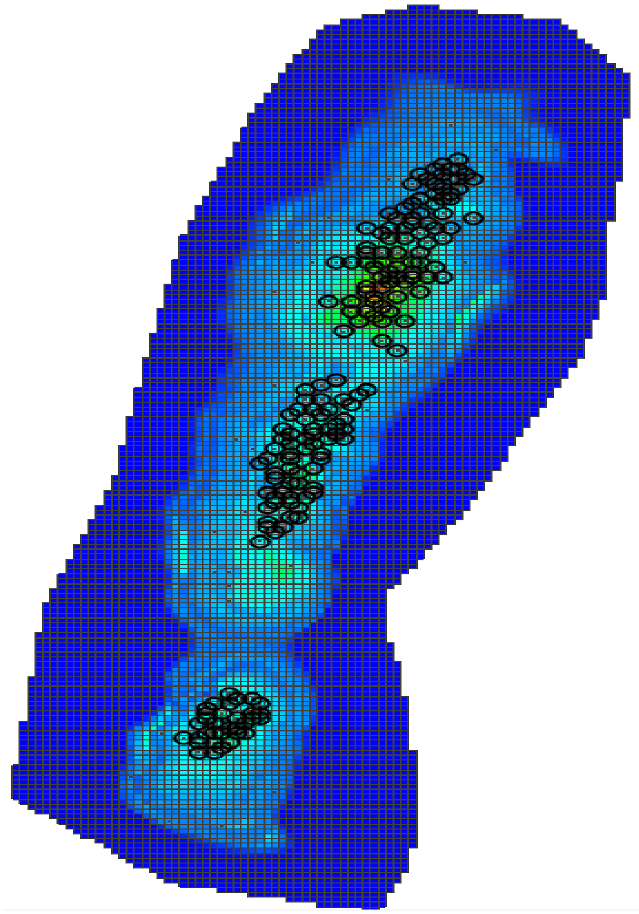

Figure 3. Distribution of the well pool in variant 1 across the field area

Figures 4 and 5 show the results of modeling of variant 1.

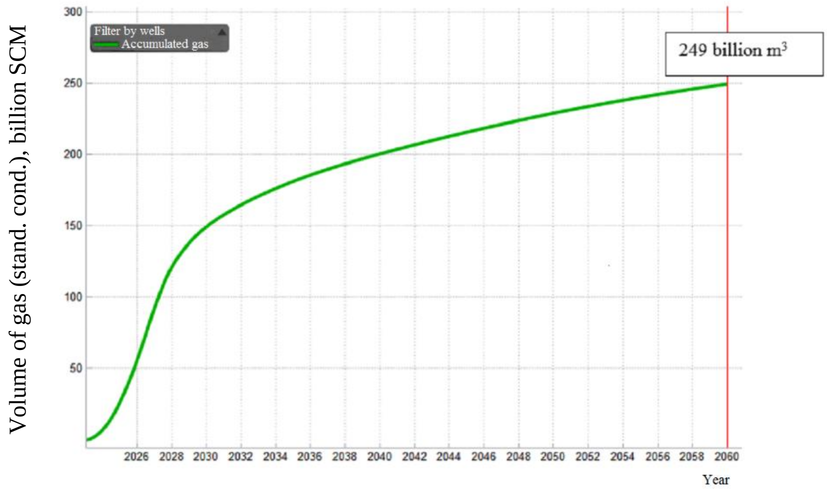


Figure 4. Cumulative gas production in variant 1 of the development of the Medvezhye deposit in the period from 2023 to 2060

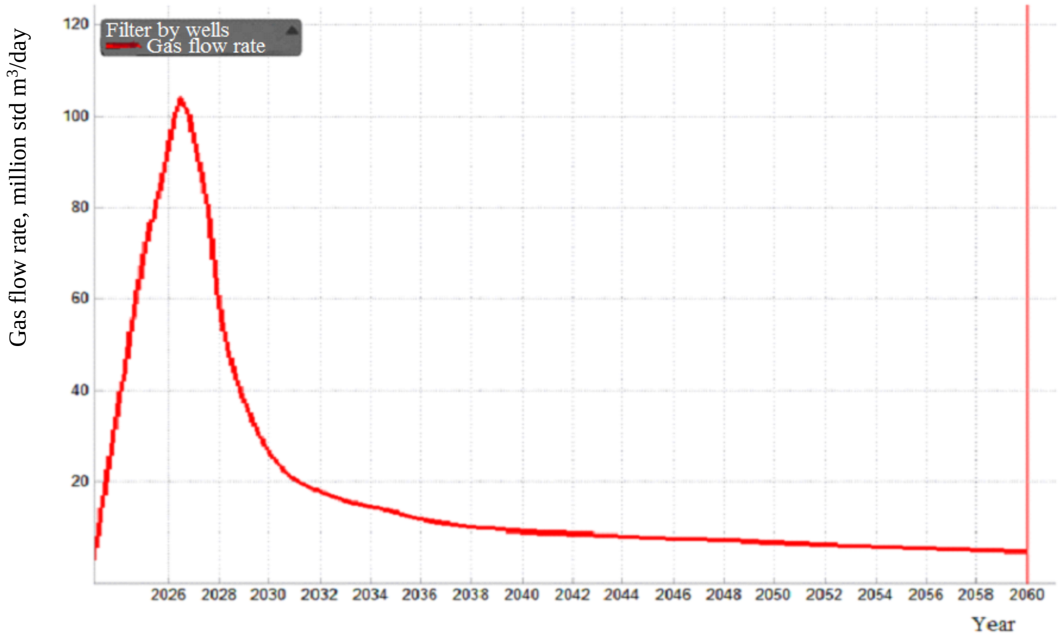


Figure 5. Average gas flow rate in variant 1 of the development of the Medvezhye deposit in the period from 2023 to 2060

Table 1. Comparison of Gas Reserves and Production

| Geological reserves, billion $m^3$ | Estimated gas production, billion $m^3$ | Gas recovery factor |
|---|---|---|
| 550 | 249 | 0,45 |

Forecast variant 1 has a peak gas flow rate in 2026 equal to 103 million $m^3$ of gas per day and is characterized by the possibility of recovering up to 45% of the initial geological reserves in a short period of 37 years. The commissioning of wells is gradual (60 wells per year).

**Variant 2:** consists in the additional transfer of wells in the overlying zone that have been exhausted to gas production from the low gas-saturated horizon. In addition to the 210 wells already in production in variant 1, an additional 30 wells are added in the prospective zone. Figure 6 shows the location of the wells, with the additional wells highlighted in red.

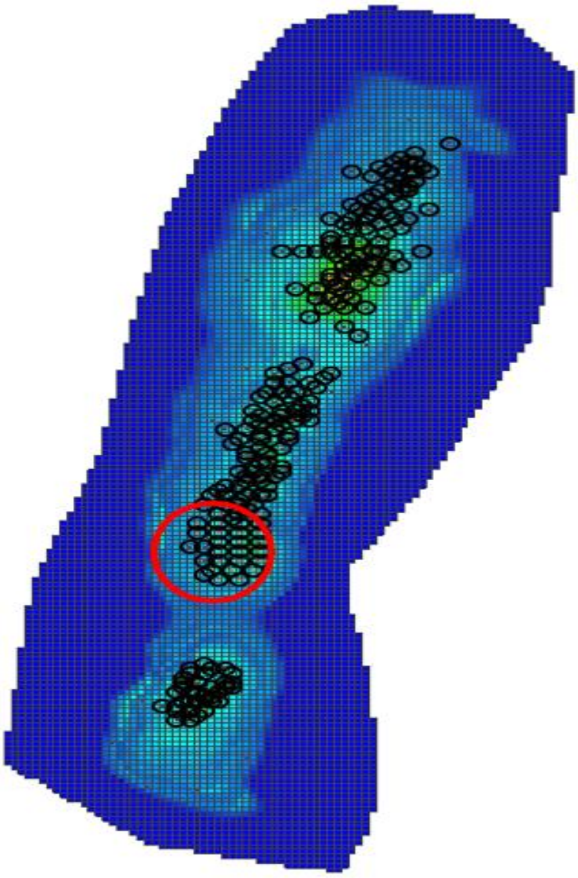

Figure 6. Distribution of the well pool in variant 2 across the field area

Figures 7 and 8 show the results of modeling of variant 2.

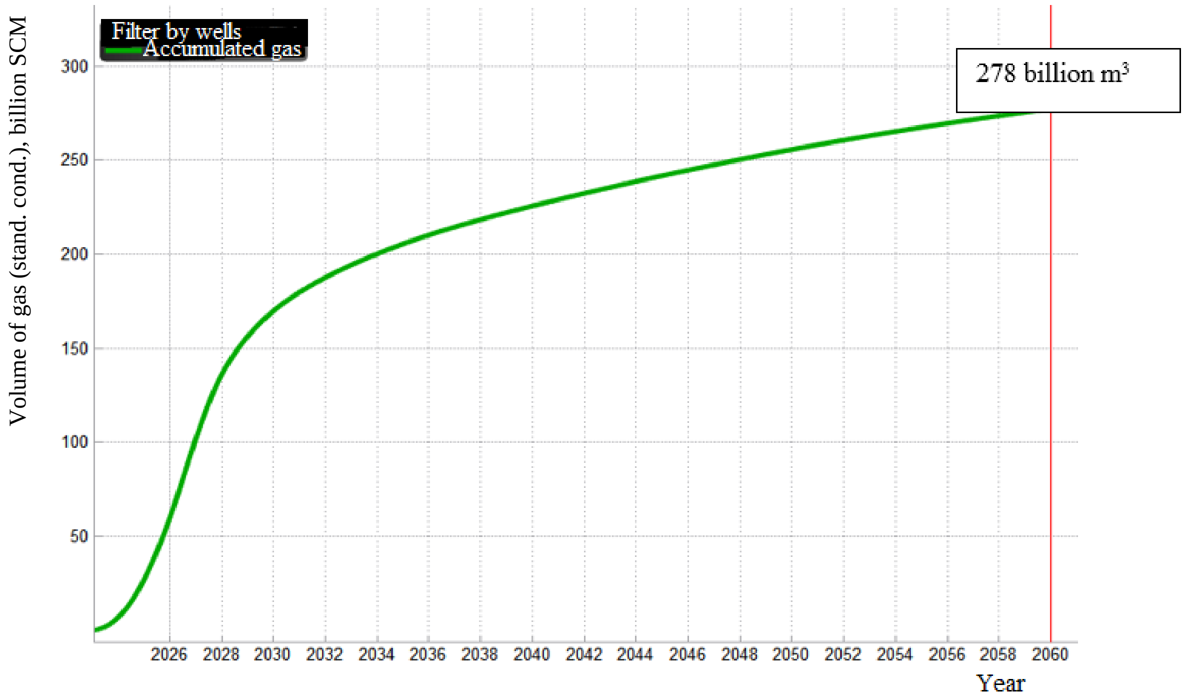


Figure 7. Cumulative gas production in variant 2 of the development of the Medvezhye deposit in the period from 2023 to 2060.

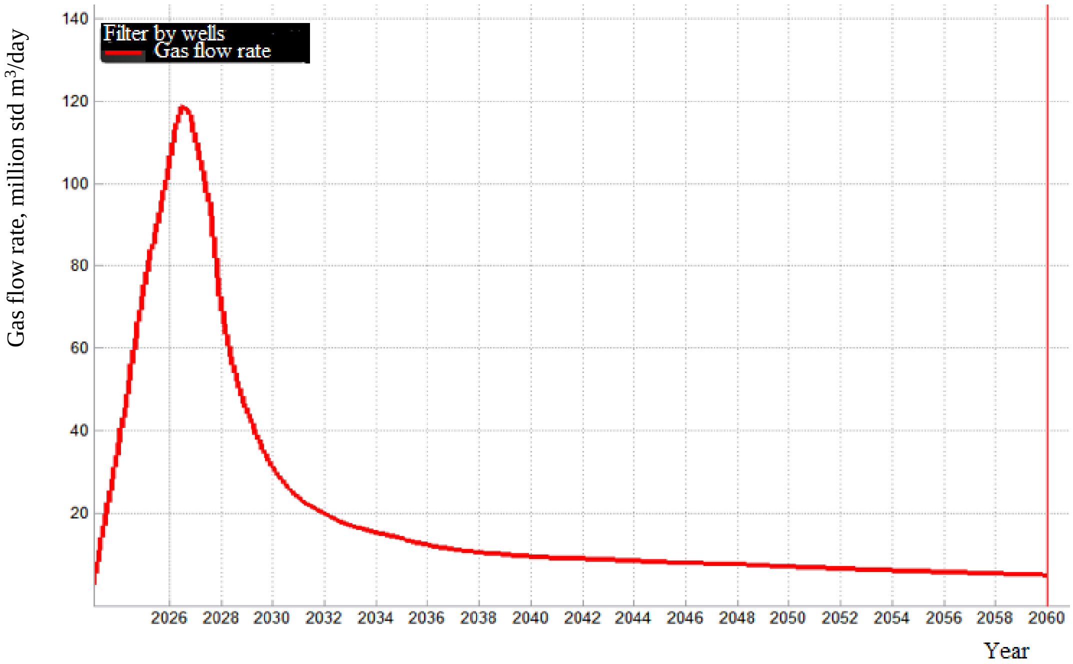


Figure 8. Average gas flow rate in variant 2 of the development of the Medvezhye deposit in the period from 2023 to 2060

Table 2. Comparison of Gas Reserves and Production

| Geological reserves, billion $m^3$ | Estimated gas production, billion $m^3$ | Gas recovery factor |
|---|---|---|
| 550 | 278 | 0,50 |

Forecast variant 2 has a peak gas flow rate of 118 million $m^3$ of gas per day in 2026 and the potential to recover up to 50% of the initial geological reserves in a short period of 37 years. The additional 30 wells help to bring previously undrained areas into development.

**Variant 3:** involves the additional transfer of exhausted wells in the overlying zone to gas extraction from the low gas-saturated horizon. In addition to the 240 wells previously in production from variant 2, 50 more wells are added in the prospective zone. Figure 9 provides the location of the wells, with the additional wells highlighted in red.

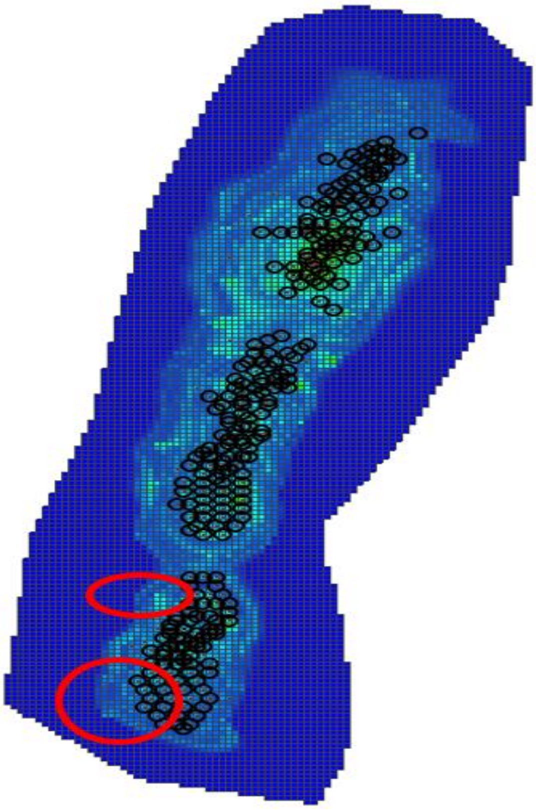

Figure 9. Distribution of the well pool in variant 3 across the field area

Figures 10 and 11 show the results of modeling of variant 3.

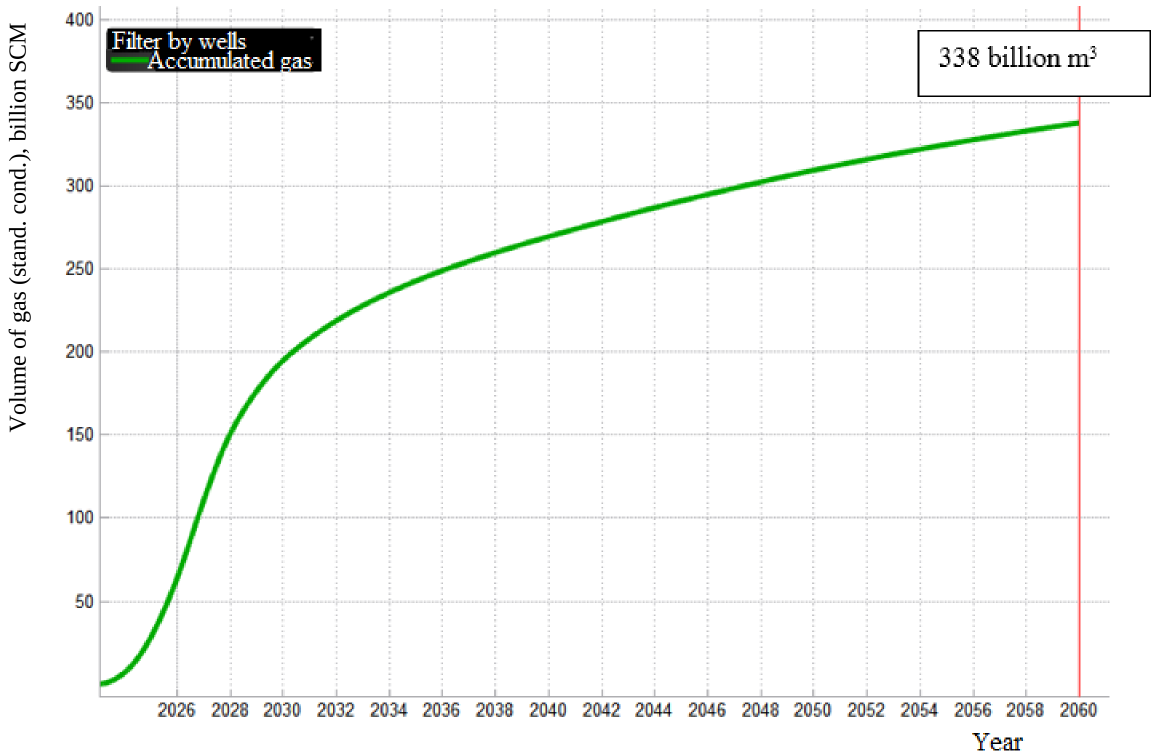


Figure 10 – Cumulative gas production in variant 3 of the development of the Medvezhye deposit in the period from 2023 to 2060

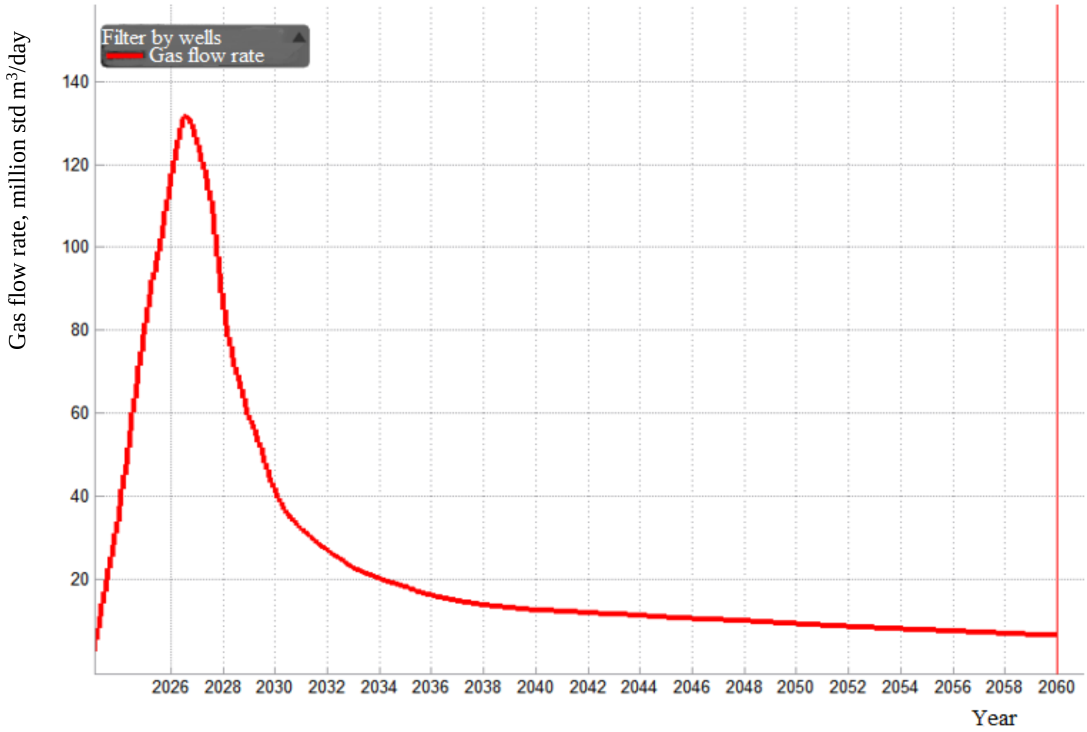


Figure 11. Average gas flow rate in variant 3 of the development of the Medvezhye deposit in the period from 2023 to 2060

Table 3. Comparison of Gas Reserves and Production

| Geological reserves, billion $m^3$ | Estimated gas production, billion $m^3$ | Gas recovery factor |
|---|---|---|
| 550 | 338 | 0,61 |

Forecast variant 3 has a peak gas flow rate of 131 million $m^3$ of gas per day in 2026 and the potential to recover up to 61% of the initial geological reserves in a short period of 37 years. The additional 50 wells help to bring previously undrained areas into development, and compaction of the well network allows for a higher gas recovery factor to be achieved.

**Variant 4:** consists in compacting the central part of the formation with additional wells to develop previously uncovered zones of the low gas-saturated horizon. This option is distinguished by the maximum possible transfer of wells in the overlying zone that have been exhausted. In addition to the 290 wells from variant 3, another 50 wells are added in the prospective zone. Figure 12 shows the location of the wells, with additional wells highlighted in red.

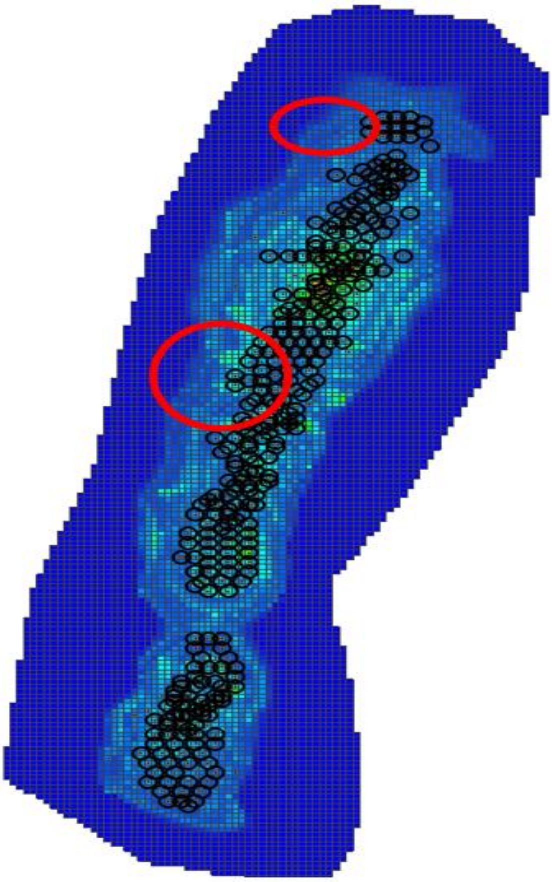

Figure 12. Distribution of the well pool in variant 4 across the field area

Figures 13 and 14 present the results of modeling of variant 4.

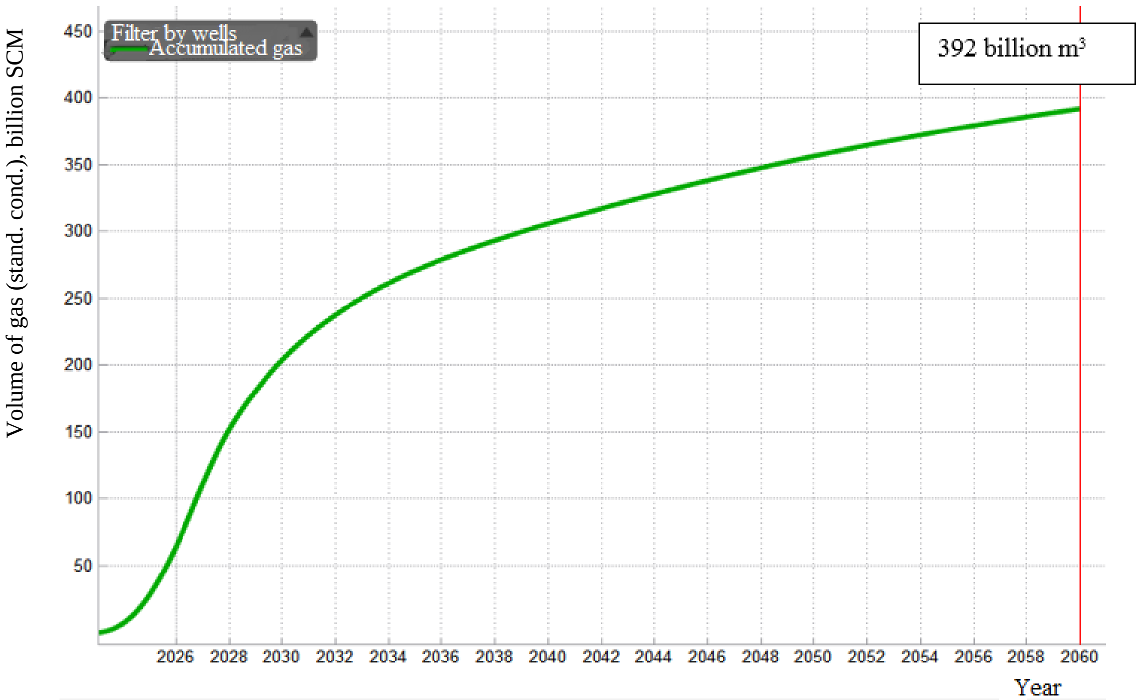


Figure 13. Cumulative gas production in variant 4 of the development of the Medvezhye deposit in the period from 2023 to 2060

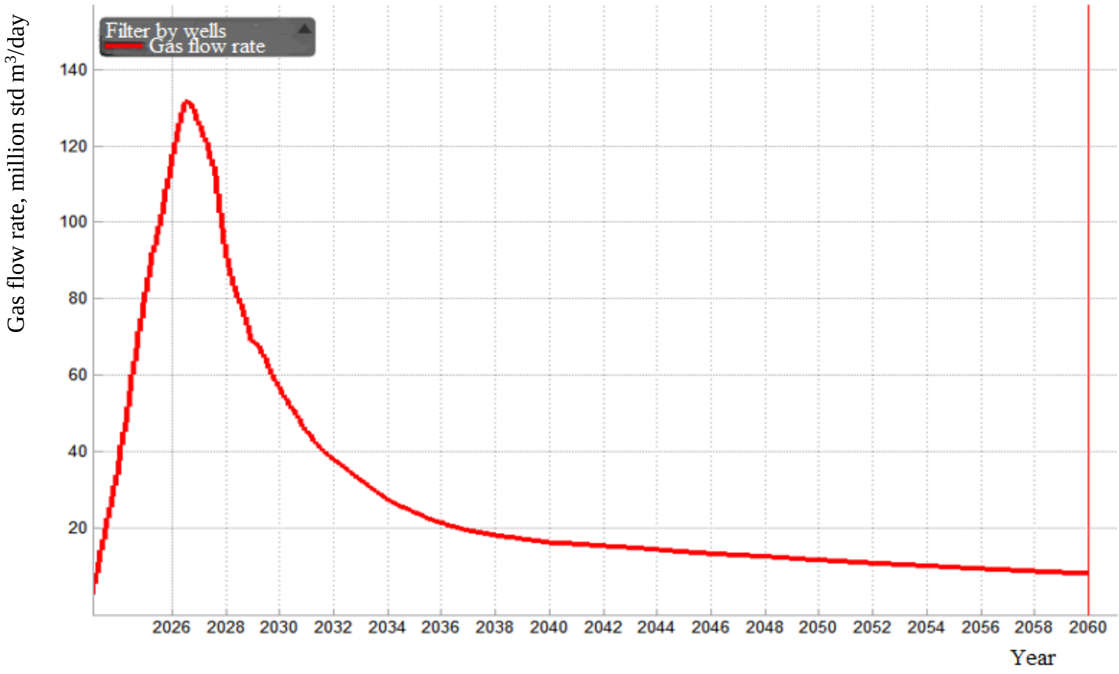


Figure 14. Average gas flow rate in variant 4 of the development of the Medvezhye deposit in the period from 2023 to 2060

Table 4. Comparison of Gas Reserves and Production

| Geological reserves, billion m$^3$ | Estimated gas production, billion m$^3$ | Gas recovery factor |
|---|---|---|
| 550 | 392 | 0,71 |

Forecast variant 4 has a peak gas flow rate of 131 million m$^3$ of gas per day in 2026 and the ability to recover up to 70% of the initial geological reserves in a short period of 37 years. An additional 50 wells help to bring previously undrained areas into development, and by compacting the well network, a higher gas recovery factor can be achieved.

## 4. Conclusions

The 3D geological model built with a lack of geological and geophysical information reflects the basic laws of distribution of filtration-capacity properties of the Cenomanian productive complex of the Medvezhye field. The created hydrodynamic model can precisely reproduce all the processes taking place in the deposit during formation development and proves the possibility and expediency of extraction from the low gas-saturated zone.

Based on the information obtained by hydrodynamic calculations, several versions for developing the transition zone of the Cenomanian productive complex of the Medvezhye field are proposed. Gas extraction from the low-pressure horizon can cover the needs of the population of nearby settlements for sufficiently cheap electricity. Extraction from this zone is also necessary, as rational subsoil use is one of the obligatory aspects of extraction in the Russian Federation (Supreme Council of the Russian Federation, 1992, Article 23).

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