FACULTY OF SCIENCE AND TECHNOLOGY

MASTER THESIS

Study programme / specialisation:
Marine and Offshore Technology

The spring semester, 2022

Open / ~~Confidential~~

Author:
Vadim Oganov

....
(signature author)

Course coordinator: Professor Yihan Xing
Supervisor(s): Associate professor Charlotte Obhrai, University of Stavanger

Thesis title:
Technical and Technological Solutions For the Development of Gas Fields in the Waters of the Ob Bay

Credits (ECTS): 30

Keywords:

Development
Deposits
Ob Bay
Taz Bay
Geological characteristics
Technological characteristics
Multi-lateral well

Pages: 92

+ appendix: 8

Stavanger, 15th of June 2022
date/year

Acknowledgements

This thesis concludes my master's studies in the University of Stavanger's Marine and Offshore Technology program. I would like to thank everyone who has assisted and supported me during this thesis project.

I would like to express my gratitude to Gazprom Neft Shelf LLC for the opportunity to use technical and technological materials for the development of Arctic oil and gas fields. In addition, thanks for the possibility of using materials provided by LLC VNIIGAZ-Gazprom.

Abstract

The master's thesis contains materials on conceptual schemes for the integrated development of deposits in the Barents, Pechora and Kara Seas; the results of the analysis of geological, technical and technological indicators of the development of deposits in the Ob Bay.

The main technological indicators for the development of deposits are presented. Options for the integrated development of the deposits of the Ob Bay are determined, considering the proposed designs and profiles of multi-lateral wells and the results of calculations of the main pipeline. The expediency of the joint arrangement of the Obskoye field with the Kamennomysskoye-more field with the transportation of products to the GTU at cape Paursnyi is shown.

Table of Contents

List of Figures

List of Tables

Chapter 1 - Introduction

The development of the fuel and energy complex of the Russian Federation in the near future is based on the development of oil and gas resources of the continental shelf.

A number of gigantic and unique deposits have been discovered on the shelf of the Arctic and Far Eastern seas. These are, first of all, the Shtokman gas condensate field in the Barents Sea and Rusanovskoye and Leningradskoye on the Priyamal shelf of the Kara Sea. Industrial gas reserves have been discovered in the waters of the Ob-Taz Bay, such as the Kamennomysskoye More and the Severo-Kamennomysskoye.

Promising in the group of deposits of the Ob and Taz bays are Chugoryakhinskoye, Obskoye, Parusovoye, Antipayutinskoye, Tota-Yakhinskoye. The total level of production at these deposits is planned to reach 60 billion. m^3 per year in the future.

The Kamennomysskoye-More deposit is the most prepared for development today. In the Ob Bay, the Obskoye and Chugoryakhinskoye deposits are unprofitable with autonomous development. Therefore, for the successful development of these deposits in difficult climatic and geological and technical conditions, the use of new technical, technological and organizational solutions, the creation and application of fundamentally new high-tech technologies and technical means, including floating and stationary drilling and drilling ice-resistant platforms, underwater production complexes, systems of preparation for the transport of technical means in combination with modern approaches to the integrated development of oil and gas fields for specific water areas is required..

Chapter 2 - Analysis of climatic and geological conditions of the Ob Bay water area

In hydrometeorological terms, the Ob Bay belongs to the Ob-Yenisei region of the Kara Sea and is characterized by complex hydrometeorological conditions. It is known that the Ob Bay is a bay of the Kara Sea, located between the Yamal and Gydan peninsulas. The territory of the Ob Bay is a continuation of the Ob River, having an area formed with a width of 30-75 km, stretched for 750 km with a total water surface of 55500 km^2 (Rokos et al., 2020). The average depth of the Ob Bay is 9.0 m, and ranges from 5.4 m to 18 m. The region of the Ob Bay can be considered Arctic, since the entire territory of the bay is located beyond the polar circle. The climate of the Ob Bay can be considered for the northern part of the water area as a zone of polar marine climate, and for the southern part as a subarctic climate area. The average annual average temperature is minus 9-10 ℃, while in the coldest month (February) at Cape Kamenny the average temperature is minus 27 ℃. The polar night lasts 40 days.

The formation of the ice cover of the Ob Bay begins in early October, and the complete freezing of the southern part of the bay occurs by mid-December. The thickness of the ice cover in the middle part of the bay reaches 170-185 cm. According to the available long–term data, the opening of ice occurs depending on the zone of the Ob Bay, for example, in the middle part it is opened in the first half of July, and the full one may be in mid-August. On average, the Ob Bay is covered with ice for 8 months a year, and the duration of the navigation period ranges from 90 to 120 days.

In general, climatic and hydrological conditions can be characterized by the following:

- low air temperatures and seasonal variability; storm conditions; spray icing of engineering structures, which can seriously affect the operation of such structures;
- tidal changes in sea level; the presence of large ice formations; the existence of soldered ridges of hummocks-stamukh; plowing the bottom with keels of drifting hummocks, etc.

There are also complex engineering and geological conditions of the seabed due to the presence of weak clay soils with a thickness of 9.0 to 18.0 m in the upper bottom part. The bottom soil is blue viscous silt, and the coastal shoals are mostly sandy. According to the results of the study of the upper part of the sedimentary layer up to 70 m from the bottom of the sea, it is possible to divide the sedimentary layer into stratigraphic-genetic complexes and subcomplexes. The marine Lower Pleistocene and Middle Pleistocene sediments are represented by heavy loams and light clays with rare inclusions of plant residues, coarse-grained material and sandy interlayers. The alluvial Upper Pleistocene deposits of the Kazantsev formation are composed mainly of gray with a greenish tinge, small and medium-sized sands, with characteristic inclusions of shell and coarse-grained material. Knowledge of this information is necessary at the design stage of well construction with both underwater and above-water well heads, field development, offshore stationary structures, laying of communications and underwater pipelines.

When analyzing the natural-climatic and engineering-geological conditions of the waters of the Ob bay, it is necessary to take into account the complex and prolonged ice situation, which results in:

- high values of ice loads on hydraulic structures;
- the threat of destruction of unprotected underwater facilities due to the plowing of the bottom of the water area by ice formations;
- minimum duration of the navigation period for drilling and construction and installation works.

Also unfavorable for the purposes of construction engineering-geological and hydrological conditions characterized by:

- the all-round presence of silty and fluid-plastic soils in the surface layer;
- the presence of permafrost rock mass under the bottom of the Ob bay, mainly in the coastal zone (Rokos et al., 2020);
- high activity of lithodynamic processes that pose a threat of soil erosion at the base of marine facilities;
- small water depths in the water area that prevent the use of the necessary floating technical means;
- complex geocryological conditions in the areas of construction of onshore facilities and gas transportation, characterized by high dynamism and reactivity of cryogenic processes: thermal erosion, thermokarst, etc..

Chapter 3 - Conceptual approaches to the arrangement of the waters of the Barents, Pechora, and Kara seas

A large number of oil and gas fields are located on the shelf of the Arctic seas of the Russian Federation, 21 offshore and 14 transit fields have been discovered. According to various estimates, the gas potential of the Arctic sector can reach 100 trillion m^3, which, for example, is concentrated in the Kara Sea – in the sediments of the Lower Cretaceous, Cenomanian and upper horizons of the Middle Jurassic; in the Barents Sea, resources are confined to the sediments of the Lower-Middle Jurassic and Triassic; in the waters of the Ob and Taz Bay of the Kara Sea in the sediments of the Cenomanian and alb-apt. Productive horizons are located at various depths and in complex geological and technical conditions.

It should be especially noted that the giant Shtokman gas condensate field has been discovered in the Barents Sea. The shelf of the Pechora Sea contains industrial resources in the Prirazlomnoye, Dolginsky, Medinsky, Varandey Sea; large gas condensate fields - Leningradskoye and Rusanovskoye are noted on the shelf of the Kara Sea; Kharasaveyskoye and Kruzenshternskoye, Skuratovskoye and Nyarmeyskoye are also promising offshore structures. The Kamennomysskoye-more, Severo-Kamennomysskoye, Chugoryakhinskoye and Obskoyoe gas fields have been discovered on the shelf of the Ob Bay. However, for the successful and speedy development of the deferred oil and gas fields on the Arctic shelf of the Russian Federation, the development and application of unique technical and technological solutions for the arrangement and operation of offshore drilling and production facilities will be required.

When developing Arctic oil and gas fields, one must face the unique climatic and hydromorphological conditions of the work areas in terms of complexity and severity.

When considering the problems of field development considering the level of risks on the shelf, such as geological, technical, technological, commercial, organizational and others, it is important to take into account that under the existing tax legislation most offshore fields have a low level of efficiency. Therefore, in modern realities, when developing offshore Arctic deposits, attention should be paid to the problem of complex development of a number of fields in one water area, i.e. the creation of oil and gas production clusters, taking into account information on a more accurate assessment of the potential or recoverable reserves of deposits, the optimal choice of capacity and location of field facilities, efficient production technologies, collection and preparation for transport, when assessing remoteness from coastal communications and infrastructures.

A number of organizations are engaged in the problems of complex development of oil and gas fields, while it should be noted the important role of LLC VNIIGAZ-Gazprom in the development of basic technical and technological solutions for the development of deposits of the Arctic shelf of Russia (Mirzoev, 2008). Let us consider the conceptual solutions proposed for the integrated development of Arctic oil and gas fields.

Decree of the President of the Russian Federation No. 645 "On the strategy for the development of the Arctic Zone of the Russian Federation and ensuring national security for the period up to 2035" states that the oil and gas sector of the economy and in particular the commissioning of Arctic oil and gas fields, will play an important role in the development of the northern territories. Involvement in the development of the Kara Sea deposits may be the most potentially promising in the medium term.

Resource-forming in the waters of the Kara Sea is the Leningrad gas condensate field, which belongs to the unique hydrocarbon deposits in terms of reserves, second only to the Shtokman gas condensate filed on the shelf of the Barents Sea. The Leningrad gas condensate field with an estimated gas reserves of about 3 trillion m^3 of gas with four satellite fields (Rusanovskaya, Skuratovskoye, Nyarmeyskoye, Severo-Leningradskoye), which total reserves of about 1 trillion m^3 and about a dozen structural hydrocarbon traps with reserves of more than 1 trillion m^3, in total reserves amount to about 5.1 trillion. m^3. It should also be noted that the existing onshore deposits – Yamal-Tambey group and onshore-offshore - Kruzenshternskoye and Kharasaveyskoye, together with the marine ones noted earlier with the additional exploration of all fields, can fully assess the possibility of integrated industrial development (**Figure 3.1**). The Leningradskoye field, as a well-studied field with unique reserves located within the Priyamal zone, can be taken as an object of approbation of gas production and transportation technologies. An acceptable solution for the arrangement of the Leningrad gas condensate filed and a number of others may be the use of deep-sea and underwater production complexes. For these fields, at the stage of design and further development, an integrated approach should be used to create a system of offshore gas production of a group of fields, ensuring the most efficient development of gas reserves for the entire period of the project. And a scientifically based solution to determine the number and location of well pads and production wells, with the creation of a remote system for monitoring and controlling gas production, with year-round and reliable gas supply from offshore wells to the gas field system and further delivery to the main gas pipelines with environmental safety can become an important system advantage in the development of gas and gas condensate fields of the Priyamal shelf (Mirzoev, 2008).

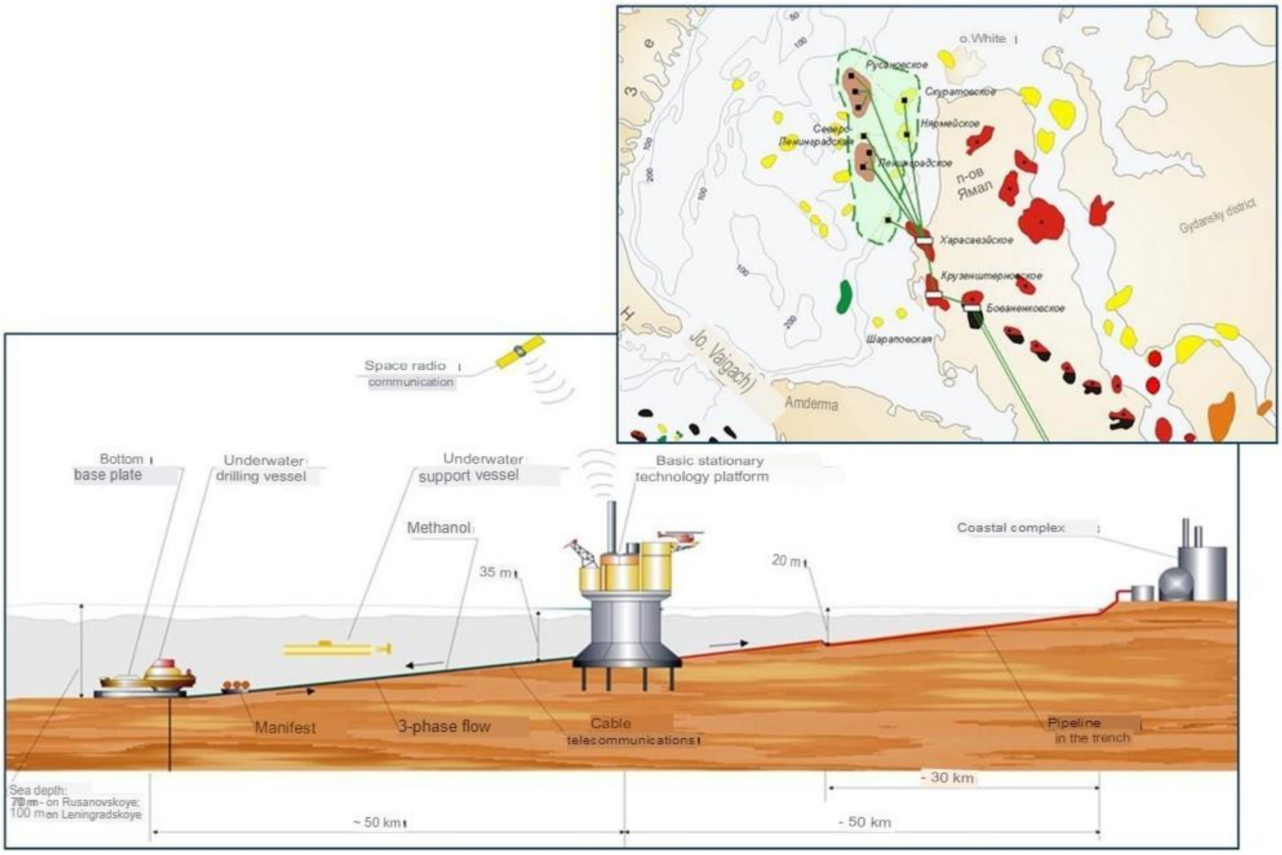

Figure 3.1 The scheme of the complex method of arrangement of deposits of the Kara Sea (Geonedra, 2018).

In order to ensure the necessary level of efficiency of the development of offshore fields, it is necessary to use the method of complex arrangement, which allows:

- to create unified onshore support bases for groups of deposits
- to create a unified transportation capacity for the transportation of hydrocarbons for groups of fields;
- to create a unified technological complex for the preparation of extracted products for transportation;
- to create a unified system of management, control and safety of work in the fields of groups of fields;
- to reduce the number of facilities for the development of groups of deposits.

The advantage of "complex methods" of arrangement is as follows:

- the joint use of the GTU and auxiliary infrastructure, also designed to receive gas from other fields, ensures a reduction in capital costs and operating costs for the development of each field;
- the possibilities of preparing fields of different gas composition are expanding;
- ensures the design load of pipelines for a longer period of time;

Let us consider approaches to the integrated development of the Pechora Sea deposits, taking into account potential and already discovered ones. First of all, this is the existing Prirazlomnoye oil field, equipped with the help of the Prirazlomnoye MLSP with the possibility of year-round operation. It is known, that current production is already more than 10 million tons of oil (VD-TV, 2019).

The following deposits have been discovered in the waters of the Pechora Sea – Varandey more, Dolginskoye, Medynskoye with adjacent promising structures Severo-Gulyayevskaya, Polyarnaya, Vostochno-Gulyayevskaya, Alekseevskaya and Pakhanchevskaya. At the same time, it should be noted that since the potential reserves of structures are relatively small, it is unprofitable to develop them separately. However, the identity of the geological, geographical, climatic and technical and technological conditions of the exploitation of deposits, the creation of systems for the field preparation of hydrocarbons and its transport provides stable prerequisites for the formation of a unified system for the development of these deposits. At the same time, decisions on the construction of dynamics and production levels for deposits are based on estimates of recoverable reserves.

The scenarios being developed for the integrated development of fields and their corresponding forecast levels of oil production over the years will differ in the order of field commissioning and the rate of oil extraction. Taking into account the difficult climatic conditions, graphs of forecast production levels can be constructed with an assessment of productivity and the progress of the phased development of the transport system, eventually aimed at export by the tanker fleet. Serious problems in the complex development of fields may be the difference in the composition of the oil of individual fields from the oil of the Prirazlomnoye field. For example, in order to organize advanced oil production at the Varandey-More field, it will be necessary to use an ice-resistant platform with its own oil storage to create an oil transportation system. Consequently, when choosing schemes for the integrated development of the fields of the Pechora Sea, several schemes for the organization of oil transport can be evaluated, taking into account the capabilities of underwater oil pipelines of various lengths and tanker fleets.

Considering the high cost of developing offshore hydrocarbon resources, field development should be carried out using combined arrangement schemes with combinations of a small number of platforms and wells with large horizontal waste and underwater completion, as well as with the minimum necessary complex of technological processes on platforms.

Special attention should be paid to the unique Shtokman gas condensate field (SGCF) located in the central part of the Russian sector of the Barents Sea shelf. SGCF is located 650 km away from Murmansk. The nearest land is 300 km away from the western coast of the Novaya Zemlya archipelago. The reserves of the Shtokman field in category C1 amount to 3.94 trillion m^3 and about 56 million tons of gas condensate. As noted earlier, the discovery of large deposits of the Barents Sea region, such as the Ludlovskoye gas and gas condensate Ledovoe and a number of small ones, including the Murmanskoe, Severo-Kildinskoye, Zapadno-Ludlovskoye, Terskoye and others, can potentially be considered when assessing the integrated development of this oil and gas region (**Figure 3.2**).

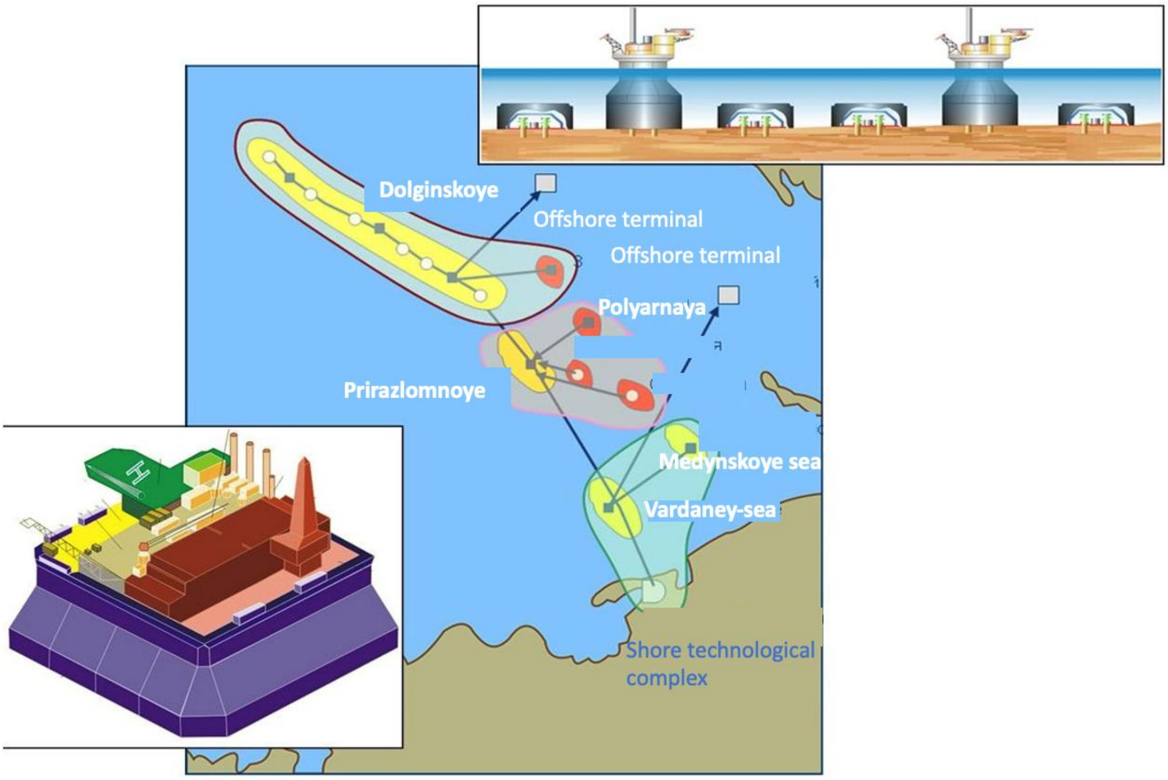

Figure 3.2 The scheme of development of oil fields development on the shelf of the Pechora Sea.

It should be noted that the Shtokman field itself is a multi-layer deposit with a depth of productive layers from 1800 to 2480 m. The water thickness in the field zone reaches from 280 to 380 m. The average temperature (with fluctuations from -8 ℃ to +8 ℃) of the environment is about +0.8 ℃, the water temperature in the bottom layer, including in the area of the proposed pipeline routes, is about -0.6 ℃. The estimated annual production is 90 billion m^3. When producing with an output of up to minimum wellhead pressures of about 1.5 MPa, depending on the initial operating debits of wells, a decline in production at the field may begin in 25 years. The fund of production wells during the construction of SGCF can range from 125 to 150 wells.

The development of the Shtokman gas condensate field includes a number of approaches (**Figure 3.3**), in which up to now not one of the options have priority. However, let us try to analyze the most interesting solutions (Neftegaz, 2021). According to one of the schemes for arranging the location of the wellheads, it can be designed with underwater and above-water location of the wellheads and collection of products on stationary platforms to prepare for transportation to shore facilities. This version of the schematic diagram of the SGCF arrangement is based on the use of three ice-resistant stationary platforms. According to this scheme, gas is collected from underwater production complexes and sent to platforms, where it is combined in a prefabricated manifold with gas from wells located on the platform and then distributed along technological lines. The diameters of the discharge lines and gas pipelines are determined in accordance with the results of hydraulic calculations for the actual flow rates of wells, which reach from 1 to 2 million m^3 / day, and pipeline diameters from 400 mm to 600 mm. For known conditions, the flowchart of gas preparation for transportation is based on the method of low-temperature separation with a turbodetander unit. For SGCF, such a gas treatment scheme is the most preferable.

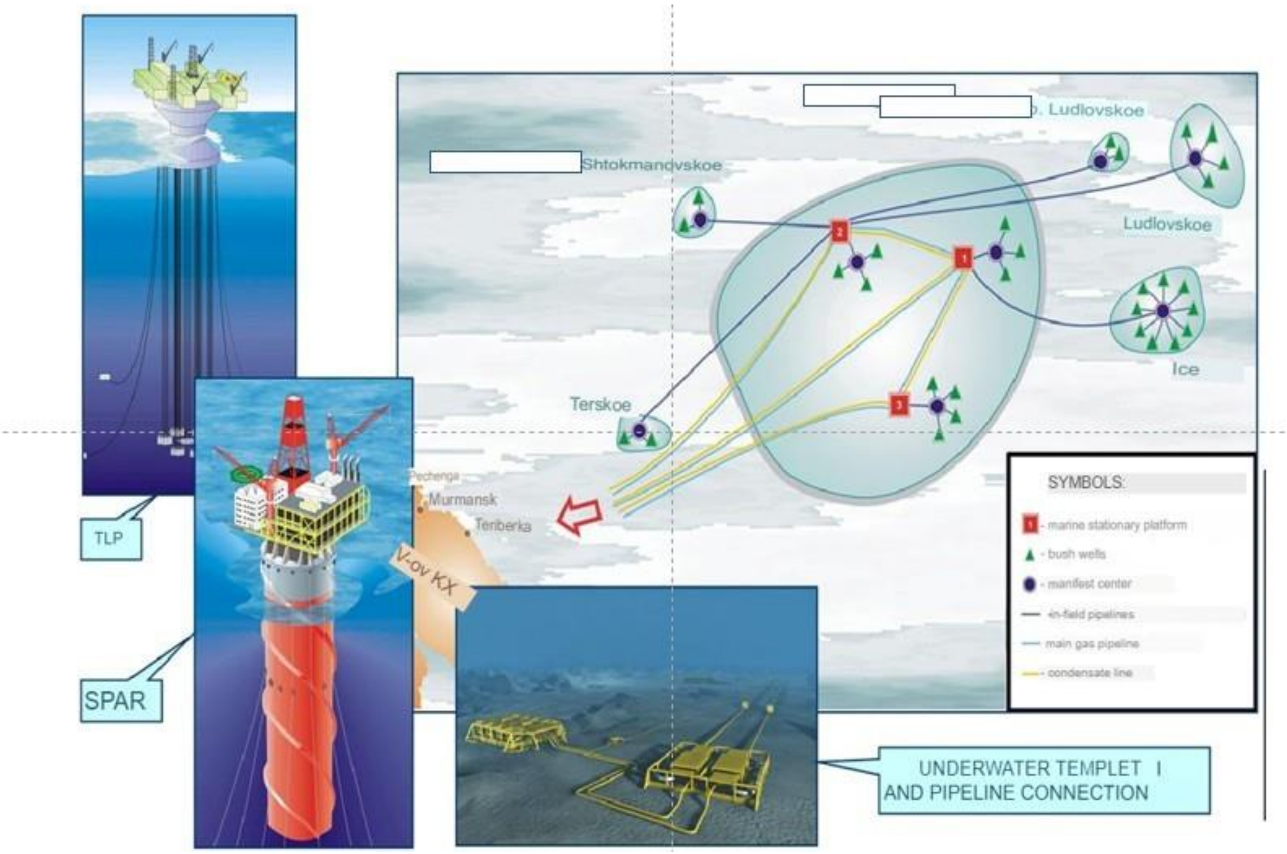

Figure 3.3 The scheme for the development of the Shtokman gas station and its satellites (Neftegaz, 2021).

Thus, two concepts become important in the development of SGCF: the installation of an LNG floating plant at the field itself or the placement of a floating hydrogen production plant at the field, while the entire field will be covered by the estimated amount of underwater production units. Both of these concepts envisage moving away from the use of trunk pipelines and switching to the transportation of products by gas carriers, as opposed to the approach of using FPU (Floating Production Unit) with the preservation of pipelines to LNG plants.

Modern concepts of arrangement will provide for the use of floating plants FPSO (**Figure 3.4**), which are floating systems for the extraction, storage, and shipment of well products. Due to sufficient mobility, it is possible to solve the problems of possible iceberg danger, i.e., leaving the point of work with safe undocking from production facilities.

Figure 3.4 FPSO- floating systems with the ability to produce, store and unload oil.

The most important advantage of FPSO systems is that it is possible to provide for the use of FLNG (Floating Liquified Natural Gas), a plant for the production of liquefied natural gas, for SGCF. In this case, it is possible to completely abandon the expensive main pipeline system and use only in-field pipeline laying or pipeline from nearby gas fields.

Based on the results of the analysis of the well-known conceptual schemes for the integrated development of the shelf field of the Russian Federation, it can be noted that the integrated method can significantly improve the efficiency of design solutions by reducing the number of facilities for the development of groups of fields; creating a unified technological complex for collecting and preparing extracted products for transportation; creating a unified transport system for groups of fields; creation of a unified management system, control over the provision of work in the fields, as well as the use of unified coastal complexes for groups of fields.

Chapter 4 - Analysis of geological and technical conditions and technological indicators of the development of the Kamennomysskoye-More, Severo-Kamennomysskoye and Obskoye deposits

4.1 Overview of the Kamennomysskoye-more deposit

The Kamennomysskoye-More deposit is located in the waters of the Ob bay, near the Yamburgskoye field being developed on land. The depth of the bottom of the Gulf in the area of the deposit is 4-11 m. The deposit was discovered in 2000. The maximum exposed depth of sedimentary deposits is 2840 m . The most ancient uncovered deposits are the Goteriv-Valanginsky.

In the context of the deposit in the terrigenous sediments of the Cenomanian, a massive gas deposit has been identified. The deposits of Alba and Apta are watered. Reservoir layers are represented by sand-siltstone rocks with high porosity. According to the size of reserves, the deposit belongs to large ones. Cenomanian gas deposit completed exploration (**Figure 4.1** Overview of the work area.)

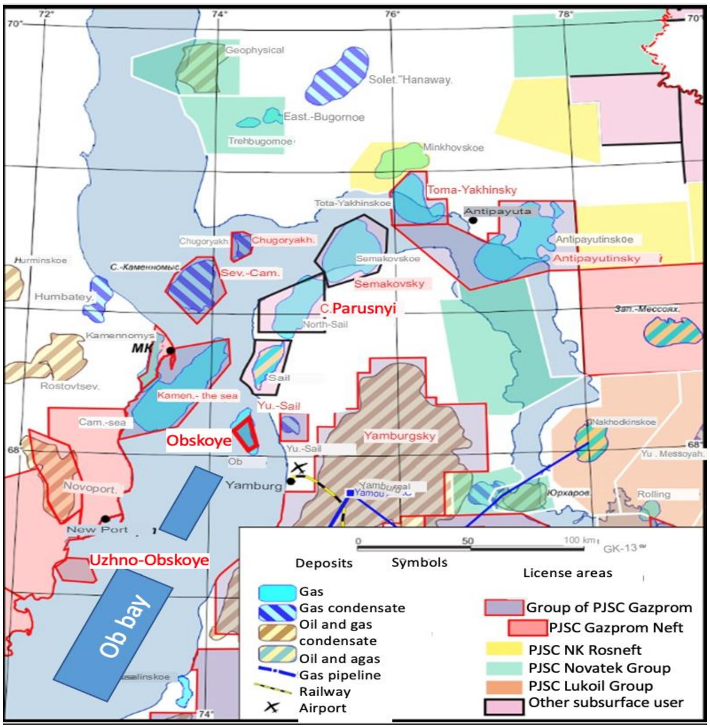

Figure 4.1 Overview of the work area.

The dimensions of the Kamennomysskoye-more deposit are 14-20 x 60 km, the height is 95.6 m. The gas deposits are massive, underlain by reservoir water. The position of the gas-water contact is assumed at minus 1027 m. The effective gas-saturated thicknesses at the Kamennomysskoye-Sea deposits are up to 75 m. The average coefficients of porosity, gas saturation and permeability for the deposit of the Kamennomysskoye-More deposit are 31.8%, 72.1% and 519 mD. When testing Cenomanian deposits of the Kamennomysskoye-more field, the resulting gas inflows amounted to 423 thousand m^3/day. The formation gas is mainly methane in composition, the methane content is 98.72 – 99.16%.

Drilling of exploration wells at the Kamennomysskoye - more field was carried out from jack-up drilling rig "Amazon" (**Figure 4.2** Jack-up drilling rig «Amazon».), (**Table 4.1**) and jack-up drilling rig "Murmanskaya" (**Figure 4.3** Jack-up drilling rig «Murmanskaya».).

Figure 4.2 Jack-up drilling rig «Amazon».

Table 4.1 Main technical characteristics of jack-up drilling rig «Amazon».

Parameter	Value
Overall dimensions (length x width x side height), m	50×37×5,8
Draft along the waterline (deepest), m:	
without removable spudcan	3,7
with removable spudcan	8,26
Operating conditions:	
wave height (maximum), m	8,7
wind speed (maximum), m/s	27,8
Crew, people	68
Lifting capacity of deck cranes, T:	
Starboard	34
port side	20
Lifting capacity of the drilling rig, T	350
Power of the main power plant, kW	2550
Weight of the drilling rig, t	6500
Year of construction	1982 (Norway)

Figure 4.3 Jack-up drilling rig «Murmanskaya».

Exploration wells № 2, 3 and 4 were drilled with the help of jack-up drilling rig "Amazon" with four support columns. Jack-up drilling rig "Amazon" is designed for drilling exploration wells up to 3000 m deep, at sea depths from 4 m to 51 m.

Well № 1 was drilled from the Murmanskaya jack-up drilling rig with three support columns. The Murmanskaya jack-up drilling rig is designed for drilling exploration wells up to 6500 m deep, at sea depths from 10 m to 100 m.

Well № 5 was drilled from the floating drilling complex Obsky-1. Exploration wells No. 1-6 were drilled to depths of 1275 m, 1200 m, 2235 m, 1205 m, 1101 m and 2840 m.

The development of the field for Gazprom is comparable in importance to the Prirazlomnoye field located on the shelf of the Pechora Sea.

At the same time, the production level of the Kamennomysskoye-More field will amount to 15 billion m^3/year for 13 years of continuous production.

4.1.1 Geological and technological characteristics of the Kamennomysskoye-more deposit

The Kamennomysskoye-More field belongs to the Kamennomysskaya oil and gas accumulation Zone. It is dated to the Kamennomyssky arch, located in the South Yamal-Messoyakhinskaya saddle. The arch has a submeridional strike, which was revealed by prospecting and profile seismic surveys. Cenomanian and Lower Cretaceous deposits are promising for gas and condensate searches in this structure (Gazprom-VNIIGAZ LLC, 2006).

Sand-clay deposits of the Mesozoic-Cenozoic sedimentary cover, effusive-sedimentary and sedimentary complexes of the Triassic, as well as metamorphosed sedimentary-volcanogenic formations of the Paleozoic basement take part in the geological structure of the Kamennomysskoye-more deposit. At the Kamennomysskoye-more deposit, a section to the greatest depth (2840 m) was opened in the well № 6. Quaternary, Paleogene and Cretaceous deposits have been characterized by drilling.

According to the results of exploratory work at the Kamennomysskoye-more filed, two deposits were identified.

A gas condensate deposit was detected in the deposits of the goteriv during testing of the search well 6, located in the northeastern part of the area. During field studies of the productive reservoir in this well, a relatively small gas flow rate of 12-16 thousand m^3/ day was obtained.

Considering this circumstance, as well as the low degree of exploration, this deposit is not considered as an object of development in the submitted project technological document.

Industrial gas content in the context of the Kamennomysskoye-more field is established in Cenomanian sediments. This deposit is confined to a productive reservoir isolated in the roofing part of the sediments.

Productive deposits are represented by light gray fine- and fine-grained quartz sandstones with layers of siltstones and clays. The type of collector is pore. The cover of the deposit is a pack of clays.

The deposit belongs to the type of massively stratified. The position of the gas-water contact based on the materials of geophysical studies of wells is justified at minus 1027 m.

The structural trap controlling the Cenomanian gas deposit is a brachianticlinal fold elongated in a northwesterly direction. The northwest wing of the fold is complicated by two discontinuous faults forming a graben with an amplitude of up to 60 m. The dimensions of the structural trap are 10-20 x 60 km, the height is 95.6 m. The trap is completely filled with gas.

The structure of the Cenomanian gas deposit is illustrated by longitudinal and transverse geological sections.

The gas is methane in composition (methane content 98.75-99.21% vol.). In addition to methane, the gas contains ethane 0.03-0.08% vol., carbon dioxide 0.02-0.04% vol., nitrogen 0.68-1.14% vol., argon 0.06%.

According to the results of gas composition analyses, there is no condensate in the deposit, the ethane content is substandard. Helium was not detected in the composition of the gas. The gas density at 20 C is 0.672 g/cm^3.

Taking into account the sufficient degree of deep drilling of the entire area of the deposit, the reserves of the Cenomanian deposit are classified as C1 and amounted to 534,743 million m^3 (Gazprom Dobycha Yamburg LLC, 2018).

Field studies of the properties of the Cenomanian deposit were carried out in four exploration wells (KM-1, 2, 3, 4).

The summary results of these studies are presented in the **Table 4.2**.

Table 4.2 Results of well and reservoir studies.

Name	Number of		Change interval	The average value for the formation
	Well	Measurements		
Initial reservoir pressure, MPa	4	4	9,99-10,18	10,08
Pressure at the wellhead, MPa	4	26	5,24-8,73	7,32
Depression on the formation, MPa	4	26	0,04-1,71	0,66
Gas flow rate, 1000 m³/day	4	26	150-423	267
Filtration resistance coefficients:				
A, MPa2/(1000 m³/day)	4	4	0,0042-0,0676	0,0264
B, MPa2/(1000 m³/day)2	4	4	0,000005-0,000019	0,000013
Reservoir temperature, C	4	4	27,2-28,4	27,9
Hydroconductivity, mDm/sDr:				
according to the stationary research	4	4	44156-716024	305284
By non stationary research	4	4	76012-1368325	442454
Piezo-conductivity, m^2/s	4	4	0,146-4,584	1,401
Reservoir permeability, mD:				
according to core research	2	66	0,76-2948,23	519
according to GIS	4	4	419-1032	708
on GIS by stationary research	4	4	45-835	331
on non stationary research	4	4	78–1596	494

It should be noted that according to the results of determining the coefficients A, B, S and D of exploration vertical wells and estimating their flow rates, it follows that the average gas flow rate in the southwestern part of the deposit (wells KM-2-4) with a depression equal to 5% of the initial reservoir pressure is 640 1000 m^3/day, which is significantly higher than the same indicator for the northeastern part of the deposit (139 thousand m^3/day). Considering this, as well as the fact that the south-western part is characterized by high permeability of the reservoir and is located within the water area with a small water thickness, namely, about 7 m, it can be concluded that the south-western part of the deposit is more promising and should be considered as a priority object of exploitation. The north-eastern part of the deposit with worse properties of the productive reservoir should be considered as an object of exploitation of the second phase of the development of the deposit.

The development of the Cenomanian deposit of the Kamennomysskoye-More field is proposed to be carried out by the project fund of producing wells in the amount of 42 units. The reserve wells fund in the amount of 5 units is subject to construction at the end of the construction period of producing wells if the producing wells do not provide the design level of gas production in the amount of 15.1 billion m^3 per year. To control the development of the deposit, it is recommended to drill one vertical control well after drilling production wells. Thus, the total fund of project wells in accordance with the recommended option is 64 units. This project fund of wells is distributed among the well pads as follows.

The main well pad is connected to a stationary ice-resistant structure and includes 26 wells, including 20 project production wells, 5 reserve wells and 1 control well.

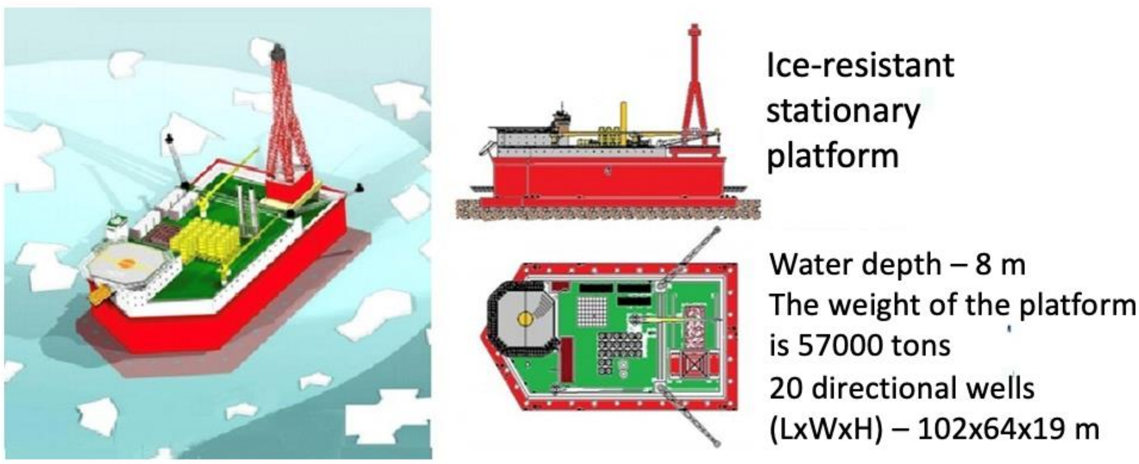

Figure 4.4 Offshore Ice-resistant fixed platform (OIRFP) project for the field.

The fixation of the OIRFP on the muddy bottom of the Ob Bay will be provided by gravity-pile fastening.

OIRFP (**Figure 4.4**) will be placed on the ground, its underwater part is filled with seawater, and then the platform is fixed with 56 piles with a diameter of more than 2 m, submerged in the ground at 47 m.

The center of this well pad is located between exploration wells 4 and 5 (**Figure 4.5**). The hole bottoms of producing wells in the bush are located along circular batteries with radii of 2000 m (8 well), 2500 m (8 well) and 3500 m (4 well). The first priority for drilling are wells with a battery radius of 2000 m; then wells with a battery radius of 2500 m and, in the third turn, wells with a battery radius of 3500 m. Reserve wells are planned for drilling with a battery radius of 1500 m. The horizontal borehole of the main well pad has a length of 500 m and is located in the zone of the greatest productivity of the formation. Part of the wells of this well pad should open a gas deposit in the area of well № 4 (exploration), in which high reservoir productivity is recorded. Another part of the producing wells will open a reservoir in an area with gas-saturated thicknesses of 60-70 m, which should ensure high gas flow rates.

The forecast of gas volumes produced is made on the condition that by the beginning of the first year of development, 8 wells of the producing fund will be drilled and equipped on the main well pad. Subsequently, in the first and second year of development, it is necessary to drill and equip the remaining wells of this well pad.

The proposed scheme of putting wells into operation will allow in the third year of development to reach the design level of production of 15.1 billion m^3 of gas per year.

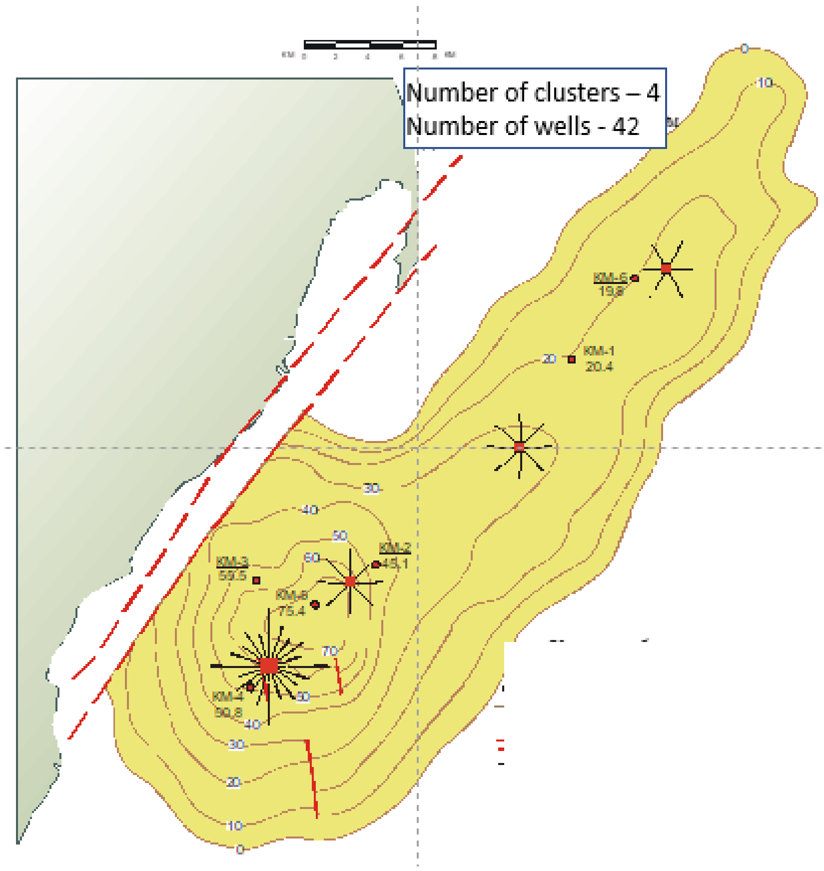

Figure 4.5 The layout of the well pad and wells of the recommended option.

The second well pad is located between exploration wells 5 and 2 at a distance of 7 km from the first well pad. The arrangement of the wellheads of this pad can be carried out both by the surface method using ice-resistant block conductors, and by the underwater method using underwater production complexes and ice-resistant drilling rigs. It is advisable to carry out the justification of the method of arrangement at the stage of justification of investments in the development of the field (DOAO CCBN of Gazprom OJSC Podolsk, 2013).

This (second) well pad, including 8 wells, is projected to be put into operation in the seventh year of development in order to extend the period of gas production in the amount of 15.1 billion m^3. The bottom hole in this pad are removed from the center of the pad by 1500-2000 m and are located in the arched part of the deposit with gas-saturated reservoir thicknesses of 50-70 m. This will contribute to achieving high gas flow rates of wells.

The third is a pad that is 13 km away from the second one in a north-easterly direction. This pad, which includes eight producing wells, is projected to be put into operation in the 10th year of development. The bottom holes in the third pad are removed from its center by 1500-2000 m.

The third well cluster is located in the formation zone with a gas-saturated thickness of ~ 30 m, which implies lower productivity of wells compared to the previous clusters.

The arrangement of the wellheads of this well pad can be performed both above-water and underwater.

The fourth well cluster, consisting of 6 wells, is projected to be put into operation in the 14th year of the deposit development. The bottom holes of the wells of the fourth pad are removed from its center by 1500-2000 m.

For the main well cluster, a scheme of placement of producing wells along three circular batteries with radii of 2000 m, 2500 m and 3500 m is proposed. In accordance with this, three types of well profiles are recommended.

The profile of wells located within a circle with a radius of 2000 m (profile 10) is three-interval and includes vertical (281 m), set (842 m) and zenith angle stabilization (1492 m) intervals. The total length of the borehole for the tool in this profile is 2615 m, including 500 m in the interval of the productive formation.

The profiles of wells located in circles with a radius of 2500 m and 3500 m are also three-interval and are characterized by the length of the barrel according to the tool, respectively, 3067 m and 3972 m (profiles 3 and 4). The most difficult to implement are wells with a profile of 4. It is recommended to drill these wells after drilling wells with a waste of 2000 m and 2500 m on a stationary structure. The profiles of wells located in the northeastern section of the deposit (profiles 11 and 12) are also three-interval and are similar in their parameters to profile 10.

The depths of the casing string with their justification for wells with a horizontal departure from the projection of the well head to the formation of 3500 m are shown in **Table 4.3** Landed depths and casing diameters for wells with a waste of 3500 m.. The direction with a diameter of 508 mm (20") is recommended to a landed depth of 130 m in order to overlap unstable quaternary deposits. Similar landed depth and conductor diameters are recommended for other wells of the producing fund.

Table 4.3 Landed depths and casing diameters for wells with a waste of 3500 m.

№	Casing name	Nominal column diameter, mm(")	Landing interval		Bit diameter while drilling under the column mm (")	Justification of the casing string landing
			Vertically (from – to)	Along hole (from – to)		
1	Conductor	508 (20)	0 – 130	0 – 130	660,4 (26)	Covering unstable Quaternary deposits, preventing wellhead from destruction
2	Collar	340 (13 3/8)	0 - 630	0 - 737,7	445,5 (17 1/2)	Overlapping of unstable deposits prone to screes, collapses, losses. Prevention of hydraulic fracturing of rocks in the spudcan zone. BOP installation.
3	Production	245 (9 5/8)	0 - 1000	0 - 3972	311,1 (12 1/4)	Gas production from Cenomanian deposits

The design profiles of wells of the recommended development option are characterized by large amounts of horizontal waste exceeding the vertical depth by 2.0-3.5 times. Drilling of such wells is a difficult task due to the need to create a sufficient load on the bit when drilling and lowering the production column into an elongated and shallow borehole (Khoshtaria V.N., 2021).

The calculated load on the hook during the landing of a column with a diameter of 245 mm in wells with a waste of 3500 m with a wall thickness of 12 mm (850 m) in the upper part and 8.9

mm in the lower part is equal to 6.5 t with a resistance coefficient when the column moves in an open trunk of 0.3. However, if this coefficient is equal to 0.35, additional effort will be required to an operational column of more than 0.6 tons to ensure its landing.

Thus, when lowering the casing string when cementing wells with a waste of 3500 m, it is necessary to provide special lubricating components when preparing drilling mud in order to ensure a friction coefficient of no more than 0.3.

The development of the deposit in accordance with the recommended option is characterized by the following feature.

Taking into account the significant difference in productivity in individual areas of the deposit, it is proposed to put them into development in a certain sequence.

At the initial stage, a more productive south-western part of the deposit is being introduced into development. It is proposed to develop the deposit on the resource base of this part of the deposit (340 billion m^3) in the first period. The rate of gas extraction from the initial gas reserves of this part of the deposit will be about 4.5%. The project level of gas production at this rate of extraction will remain for seven years and by the tenth year it is projected to take 120.7 billion m^3 from the deposit, which will amount to 35.5% of the initial gas reserves of the southwestern part of the deposit.

At the second stage of development, it is proposed to put into operation the north-eastern part of the deposit by drilling and arranging two clusters of wells on its area with a time gap of four years.

Thus, the third cluster (**Figure 4.6**) of wells is supposed to be put into operation in the tenth year of development, and the fourth – in the fourteenth.

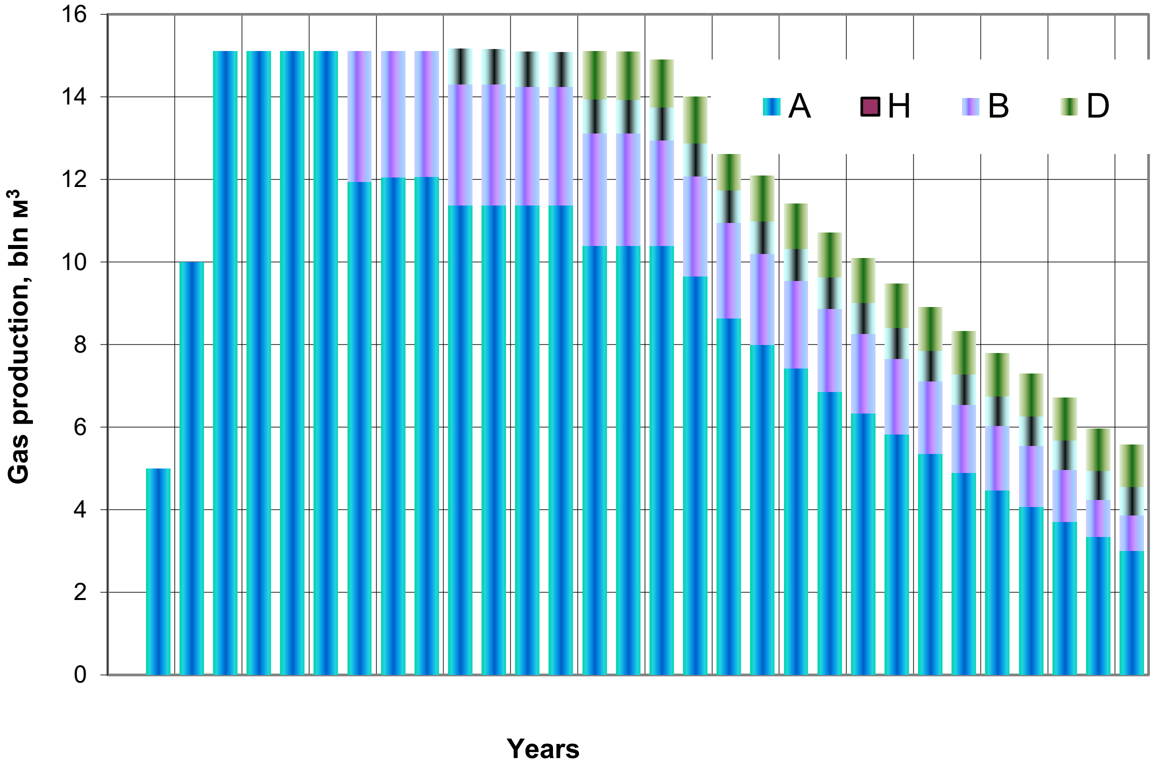

Figure 4.6 Dynamics of gas production.

The proposed sequence of development of individual well clusters will allow the project level of gas production to be maintained for thirteen years. By the end of the period of continuous production (the fifteenth year of development), 211 billion m³ of gas is projected to be extracted from the deposit, which will be about 40% of the initial reserves.

It should be noted that the rate of gas extraction during the period of constant production is 2.8% of the initial gas reserves of the entire deposit, which, taking into account the specifics of its geological and operational characteristics, is an acceptable value.

A long period of constant gas production at the above-mentioned extraction rate is a factor conducive to improving the economic efficiency of field development.

Total gas production during the development period under review (thirty years) it is 357.5 billion m³, which corresponds to 66.9% of the initial reserves. The relatively low degree of gas extraction from the deposit during this period is a consequence of two factors, the relatively short service life and the rate of gas extraction from the northeastern part of the deposit.

Gas extraction by two well clusters located in the southwestern part over thirty years of operation is estimated at 322.9 billion m^3, which corresponds to 95% of the reserves of this part. It is obvious that these pads will to some extent drain the north-eastern part of the deposit.

Over the forty-year period of development of the Cenomanian deposit, the total volume of gas production is estimated to be 400 billion m^3 or 74.7% of its initial reserves.

If the economic conditions of the field development change, it is possible to increase the rate of gas production and, on this basis, achieve a higher recovery coefficient over the thirty-year period of operation.

The average gas flow rate of the main well cluster according to the results of calculations on the filtration model presented in the second part of the report is 1.8-2.1 million m^3/day. The high gas flow rates corresponding to the first cluster A are due to the good filtration properties of the formation in the area of the location of the well faces, as well as the elongated borehole in the interval of the productive formation. With the introduction of other pads located in the worst productivity zones of the formation, the average gas flow rate is significantly reduced.

The stock of operating wells during the development period under review is reduced from 42 units to 37 units, which corresponds to its decrease by ~ 12 %.

The reason for the disposal of wells is the flooding of their products during the intrusion of reservoir waters into the gas-saturated zone of the formation. The intrusion of reservoir waters into the gas reservoir will cause some effect on the drop in reservoir pressure, contributes to its less intensive reduction compared to the gas regime of the reservoir.

The share of the pad associated with a stationary ice-resistant structure and including 20 producing wells (Cluster A) for a thirty-year period accounts for 269.8 billion m^3 of total gas production, which corresponds to 75% of total gas production from the deposit.

The Kamennomysskoye - More deposit is the largest and systemically important in the region of the Ob and Taz. It is planned to use its production and transport infrastructure in the complex development of other deposits in the region. The field development facilities on the right bank of the Ob Bay ensure the effectiveness of the integrated development of the entire region.

4.2 Overview of the Severo-Kamennomysskoye deposit

The Severo-Kamennomysskoye gas condensate field was discovered on August 22, 2000 and is located in the water area of the Ob Bay. The nearest settlements are villages Yamburg (100 km to the southeast on the right bank of the Ob River) and the village Mys Kamenny (30 km south on the left bank of the Ob River). The Yamburgskoye gas condensate field is under development and located 100-120 km southeast of the Severo-Kamennomysskoye field on the Taz Peninsula, in the interfluve of the Ob and Taz rivers. The Yamburg-Center gas pipeline and the Yamburg-Urengoy condensate pipeline are operating 150 km to the southeast. There is the base of material and technical supply of Gazprom enterprises (LLC Gazpromflot, LLC Gazprom Dobycha Yamburg) in the village Yamburg. An overview map of the work area is shown in the **Figure 4.7** (DOAO CCBN of Gazprom Podolsk, 2012).

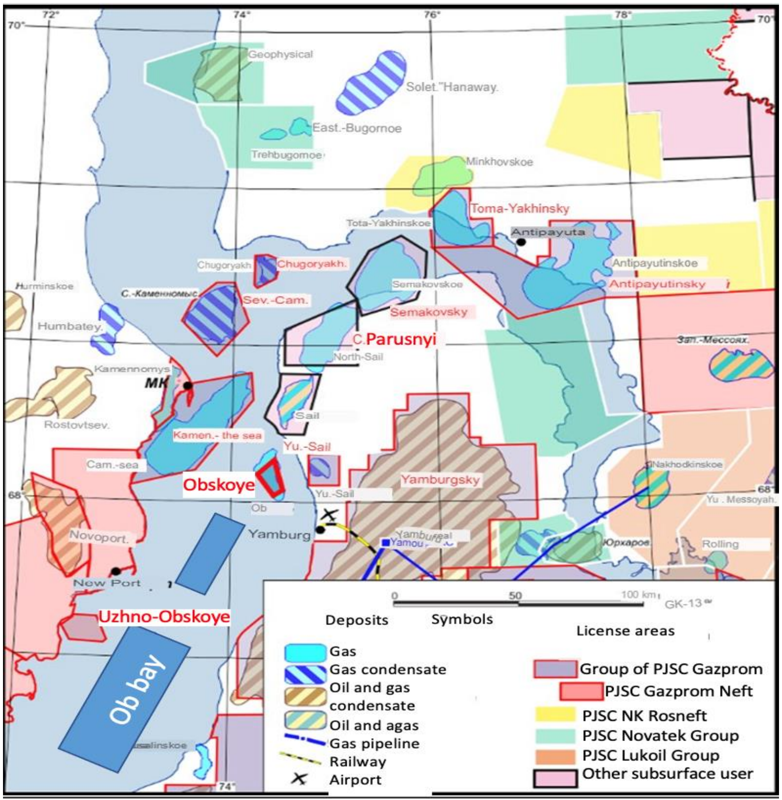

Figure 4.7 Overview of the work area.

The average annual temperature is well below 0 °C. Atmospheric circulation is generally variable. In summer, northern and north-easterly winds prevail in the area. On average, 2 to 5 days with a storm and a wind force of more than 7 points are observed per month in the summer period.

4.2.1 Geological and technological characteristics of the Severo-Kamennomysskoye deposit

The bottom relief is a flat, hollow-sloping surface. The bottom of the Ob Bay is composed of modern alluvial-marine, lagoon-marine and buried ancient alluvial sediments. The tides in the Ob Bay have a shallow semi-daily character. The navigation period falls on August – the first decade of October. The duration of the interglacial period is 60 – 80 days (DOAO CCBN of Gazprom Podolsk, 2012).

In accordance with the recommended option for the development of the deposit, the project fund of wells in the amount of 37 units is planned to be put into operation within six years.

First of all, one vertical well is planned for drilling in the center of the pad. Despite the fact that this production well is intended for the production of reservoir gas, its main functions include the functions of an observation well. The construction of a vertical well is planned to be carried out within half a month.

Secondly, 6 hollow-directional production wells are drilled with a discharge of 1000 m horizontally from the center of the cluster. The construction of these wells will take 6 months.

In the third stage, it is planned to drill 12 hollow-directional production wells with a 2000 m departure from the center of the pad. The drilling time of wells of this design will be 18 months.

The last 18 hollow-directional production wells with a bottom-hole outlet from the center of the bush 4000 m are drilled for 36 months.

Thus, by the end of drilling of the operational fund of wells, the number of wells will be 37. Part of the wells from the general fund (4 units) is planned to be used as operational and observational.

Table 4.4 shows the dynamics of putting the project fund of wells into operation

The layout of the well faces relative to the center of the cluster according to the option of the development of the deposit of the Severo-Kamennomysskoye field is shown in **Figure 4.8**.

Table 4.4 Dynamics of well commissioning according to the recommended option.

Parameter	Year					
	1	**2**	**3**	**4**	**5**	**6**
Drilled wells	10	8	6	6	6	1
Depth:						
- 0 m	1					
- 1000 m	6					
- 2000 m	3	8	1			
- 3000 m			5	6	6	1
Fund of operating wells	10	18	24	30	36	37

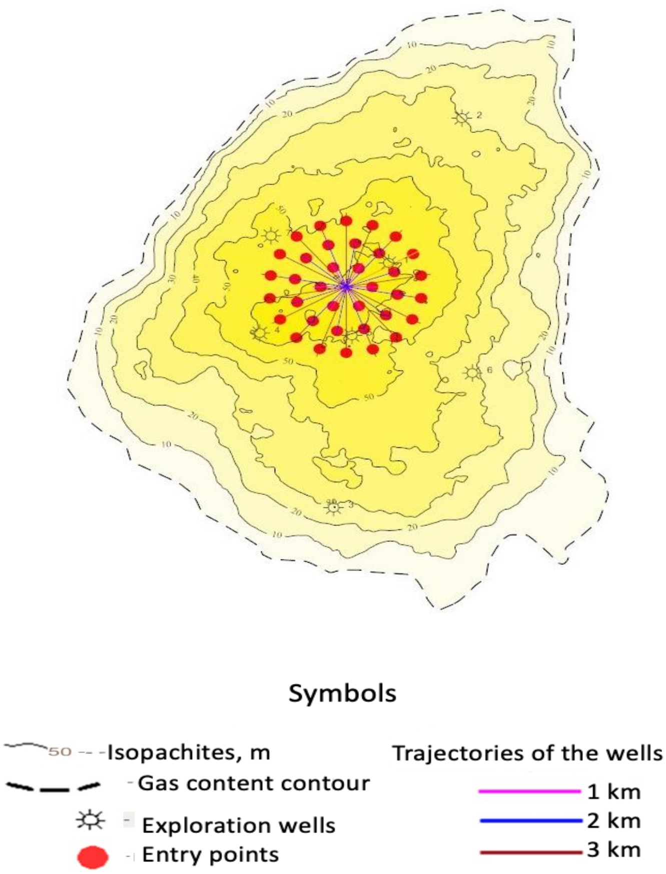

Figure 4.8 The layout of the hole bottoms of the wells of the deposits of the Severo-Kamennomysskoye field.

In accordance with the recommended option for the development of the Cenomanian deposit of the Severo-Kamennomyssk gas condensate field, the location of producing wells is planned to be carried out in one pad with the placement of bottom holes in three circular batteries with a waste of 1000 m, 2000 m, 3000 m. The total fund of wells is 37. It is planned to drill one vertical well in the center of the pad, 6 wells with a waste of 1000 m, 12 wells with a waste of 2000 m and 18 wells with a waste of 4000 m. This arrangement of wells contributes to a significant coverage of the deposit during its drainage and the location of the faces inside the fifty-meter isopachite.

The recommended option of the procedure for putting wells into operation allows the most efficient allocation of capital costs necessary for drilling the operational fund of wells, without reducing technological indicators.

The equipment of the wellheads is supposed to be carried out by the surface method. The expediency of placing wellhead equipment on the platform is due to the sufficient reliability of this technological solution in conditions of heavy ice conditions and a short navigation period.

For the arrangement of the field, one ice-resistant hydraulic structure is provided with the placement of the necessary production infrastructure to ensure the drilling and operation of producing wells, as well as the preparation of recoverable products for transportation to shore. One offshore gas pipeline passing along the bottom of the Ob Bay is provided for the supply of products to the shore as part of the transport system of the offshore production complex. The coastal facilities of the arrangement, taking into account the joint development of the North-Kamennomysskoye and Kamennomysskoye-Sea deposits, are supposed to be located at cape Sailing. Further, the prepared gas is planned to be delivered to the head compressor station of the Yamburgsky oil and gas condensate field.

The project maximum annual level of gas production provided by the implementation of the recommended options for the development of the Severo-Kamennomysskoye field, for the recommended option is projected to provide in the amount of 14.52 billion m^3. At the same time, gas extraction within 15 billion m^3 per year is maintained for 9 years. Exploiting the deposit for 25 years, the accumulated production will amount to 276.80 billion m^3 (78.85% of the initial reserves), and by the end of development 308.92 billion m^3 (88.00% of the initial reserves).

The construction of vertical and horizontal wells is envisaged for the development of the Cenomanian gas condensate deposit of the Severo-Kamennomysskoye field. Among the vertical wells, the first one is planned to be used as a producing one, the rest as observation wells.

For producing horizontal wells, the design of wells in a single-bore design is provided. At the same time, taking into account the optimization of production, the following requirements are established for the profiles of wells:

- the deviation from the vertical along the bottom of the borehole should be 1000, 2000 and 3000 m;
- the length of the uncovered part of the formation should be 250 m;
- the distance between the points of entry into the formation of boreholes should be at least 500 m;
- bottom holes should be located above the boundary of the gas-water contact at least 15 m.

The results of the calculation of horizontal well profiles are given in **Table 4.5 - Table 4.6** Parameters of the well profile (Severo-Kamennomysskoye field) with a deviation from the vertical of 2000 m. and in **Figure 4.9 - Figure 4.10**.

The profile parameters are calculated based on the specified deviations from the vertical and the length of the horizontal section. Well profiles have the following features:

- deviation from the vertical of the borehole is made below the collar rig;
- the intensity of the change in the zenith angle and azimuth is from 1.0^{o} to 1.3^{o} per 10 m of penetration;
- the maximum intensity of up to 4 per 10 m of penetration is set during the formation of a window in the casing and is characterized by the parameters of the baffling slip;
- the length of the boreholes along the productive layer is 250 m.

When developing projects for the construction of wells, the profiles of wells can be adjusted taking into account the peculiarities of changing the geological characteristics of the field section (the location of wells on the structure, the marks of the roof of the formation, its thickness and the required length of the borehole along the formation).

Table 4.5 Parameters of the well profile (Severo-Kamennomysskoye field) with a deviation from the vertical of 1000 m.

Depth along the borehole, m	**Zenith angle**	**Azimuth**	**Vertical depth, m**	**Offset to the north,m**	**Deviation from the wellhead ,m**	**Spatial intensity of trunk curvature by 10 m of penetration**	**Intensity of curvature of zenith angle by 10 m of penetration**
The main hole							
0	0,00°	0,00°	0	0	0	0,000°	0,000°
525,7	0,00°	0,00°	525,7	0	0	0,000°	0,000°
1207,44	85,22°	0,00°	982,46	420,16	420,16	1,250°	1,250°
1287,67	85,22°	0,00°	989,14	500,11	500,11	0,000°	0,000°
1338,52	85,22°	0,00°	993,38	550,78	550,78	0,000°	0,000°
1789,96	85,22°	0,00°	1031	1000,65	1000,65	0,000°	0,000°
0,00°	1056	1299,62			1299,62	0,000°	0,000°

Table 4.6 Parameters of the well profile (Severo-Kamennomysskoye field) with a deviation from the vertical of 2000 m.

Depth along the borehole, m	**Zenith angle**	**Azimuth**	**Vertical depth, m**	**Offset to the north,m**	**Deviation from the wellhead, m**	**Spatial intensity of trunk curvature by 10 m of penetration**	**Intensity of curvature of zenith angle by 10 m of penetration**
The main hole							
0	0,00º	0,00º	0	0	0	0,000º	0,000º
450	0,00º	0,00º	450	0	0	0,000º	0,000º
483,1	0,00º	0,00º	483,1	0	0	0,000º	0,000º
1138,59	85,22º	0,00º	922,27	403,98	403,95	1,300º	1,300º
1470,59	85,22º	0,00º	949,94	734,83	734,79	0,000º	0,000º
1736,67	85,22º	0,00º	972,11	999,98	999,94	0,000º	0,000º
1837,35	85,22º	0,00º	980,5	1100,31	1100,27	0,000º	0,000º
2393,48	85,22º	0,00º	1026,84	1654,51	1654,46	0,000º	0,000º
2443,39	85,22º	0,00º	1031	1704,24	1701,19	0,000º	0,000º
2743,4	85,22º	0,00º	1056	2003,21	1999,54	0,000º	0,000º

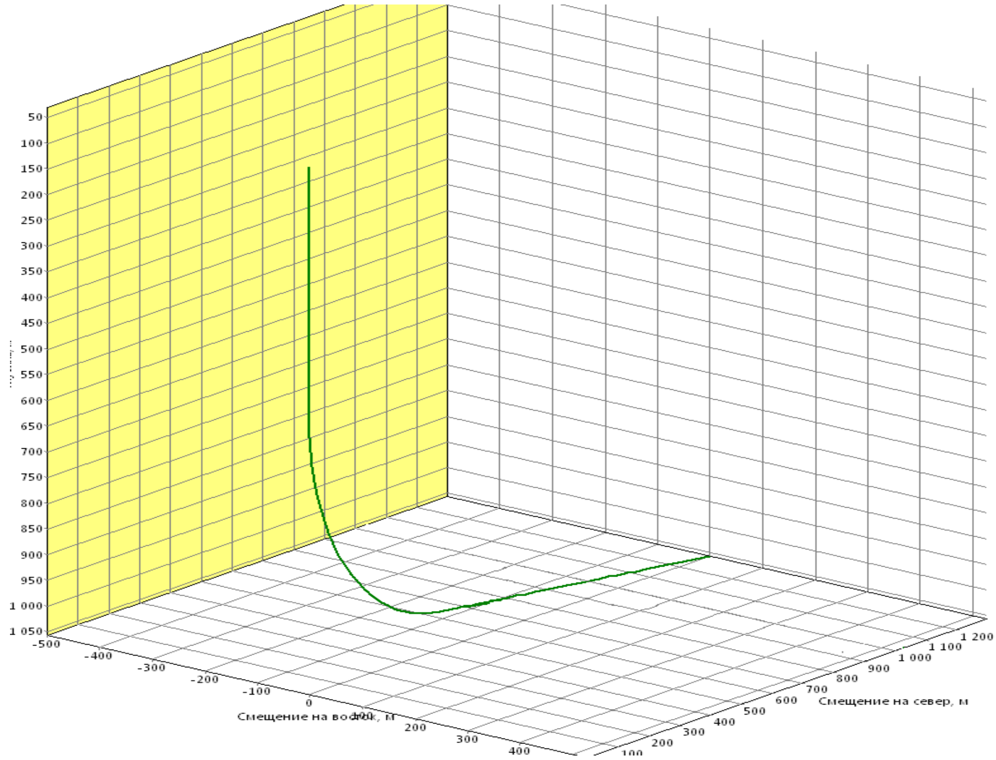

Figure 4.9 The profile of the well at the Severo-Kamennomysskoye field with a deviation from the vertical of 1000 m.

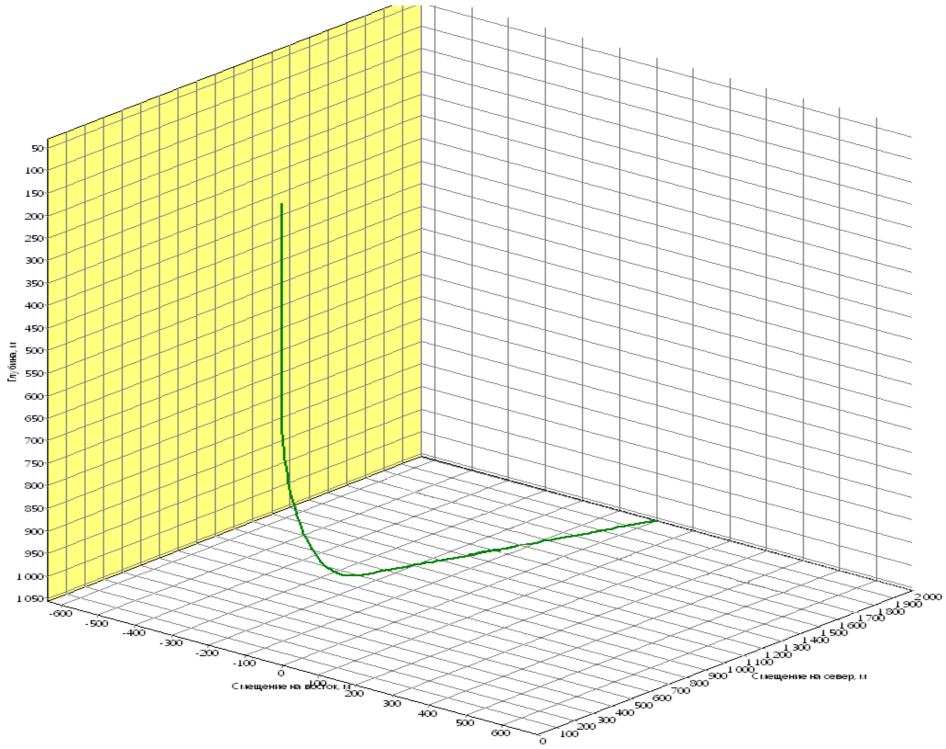

Figure 4.10 The profile of the well at the Severo-Kamennomysskoye field with a deviation from the vertical of 2000 m.

Well designs are determined by a combination of technical and geological factors, according to which the diameters of the casing strings and the setting depth are determined (Aliyev et al., 1978).

In producing wells, lift columns with a diameter of 178 mm are provided, which can be placed in a 245 mm casing. One of the main elements of the safe operation of the well is a tubing mounted safety valve installed in the wellhead of the production string, having a diameter of 233.6 mm, and casing pipes with a diameter of 340 mm are required for its placement in the well. Borehole joint systems are selected from the conditions of the possibility of access to the main and side holes through a production string without killing of the well. In this regard, the design of wells will include:

- drainage column with a diameter of 820 mm with a setting depth of 20 m;
- the conductor with a diameter of 630 mm with a setting depth of 165 m for the organization of closed circulation of drilling mud and overlap of unstable rocks;
- a collar rig with a diameter of 508 mm with a setting depth of 450 m to prevent hydraulic fracturing of rocks in case of gas occurrences and overlap of possible water-manifesting horizons or gas hydrate deposits;
- an intermediate string with a diameter of 340 mm with a setting depth that provides overlap of the extended interval of the zenith angle set;
- a productional liner with a diameter of 245 (273) mm with a setting depth of the casing shoe to the roof of the formation and a liner hanger 200 m above the shoe of the intermediate string;
- a slotted liner with a diameter of 168 mm in the productive reservoir;

For the landing and cementing of the productional liner, a 245/340 mm cemented liner hanger is used. The slotted liner of the main hole is landed and hanged using a 168/245 mm non-cemented liner hanger.

Cementing of the conductor, the collar rig, the intermediate rig and the productional liner is carried out to the entire setting depth.

For the liner hanger of the boreholes, it is allowed to use an imported device ("TIW TOP" of the company "Cortex Services", FLEX-LOCK of the company "BEKER") or domestic devices such as PHC and PHN of JSC "Tyazhpressmash". If possible, using hanger devices 273/340, the use of a productional liner with a diameter of 273 mm is allowed.

The selection and justification of the design of wells and their construction technologies at the development stage of this work are carried out taking into account the requirements of PB 08-624-03 (Khoshtaria V.N., 2021) and other regulatory documents.

In the recommended option, the well stock is 37. The commissioning of the full fund of wells will take place in the sixth year of field development. The maximum annual gas production reaches about 14.5 billion m^3, the design level of the maximum annual extraction falls on the 6th year of development and is maintained for 9 years. Over the forty-one-year period of field development, the accumulated selection is 308.92 billion m^3 (88.00% of the initial reserves). At the same time, over a twenty-five-year period, in the recommended version, the total gas production will amount to 276.80 billion. m^3 of gas, which is 78.85% of the initial reserves. The amount of water introduced at the end of the field operation will amount to 903.26 million m^3. The drop in wellhead pressure lasts up to 33 years of development, after which it reaches the limit stipulated by the technological mode of operation of wells. The average flow rate at the beginning of development is 1041.98 thousand m^3 / day, with a depression on the reservoir of about 0.15 MPa. With gas extraction of about 50% of the initial reserves, the average flow rate will be 1075.08 thousand m^3/day with a depression of 0.45 MPa.

4.3 Overview of the Obskoye deposit

The Obskoye deposit is located in the southern part of the water area of the Ob Bay on the territory of the Yamalo-Nenets Autonomous Okrug of the Tyumen Region of the Russian Federation with the district center in Salekhard (**Figure 4.11**). 35-40 km northwest of the Ob deposit are the port and airport in the village Yamburg, and 90 km southwest of the deposit is a port in the village Noviy Port. The most convenient anchorage is the port of Yamburg. The deposit was discovered in 2003. The nearest field under development is Yamburgskoye (Gazprom Dobycha Yamburg LLC, 2018).

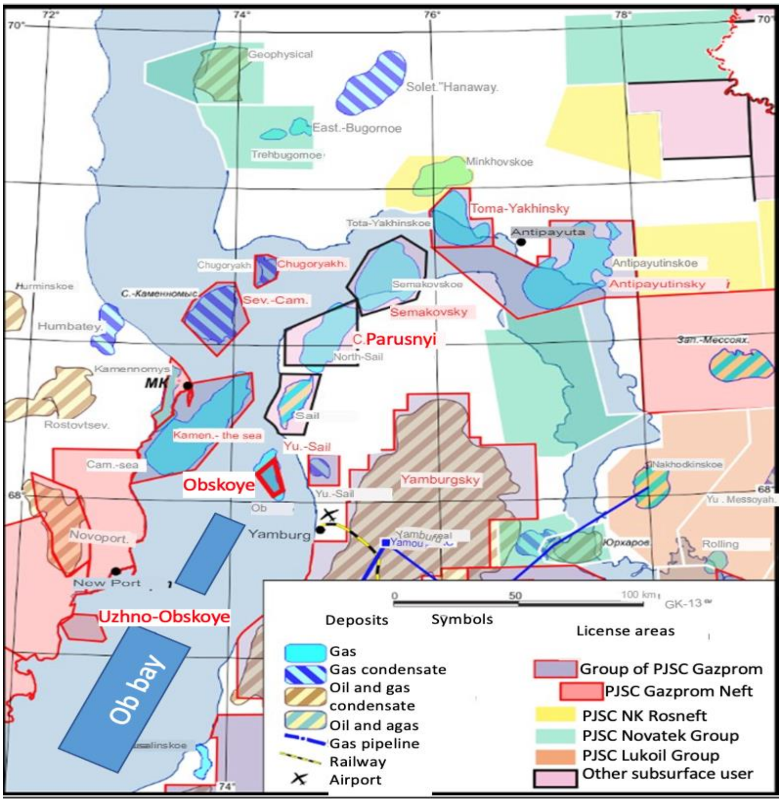

Figure 4.11 Overview of the work area.

The area of work in hydrometeorological terms belongs to the Ob-Yenisei region of the Kara Sea and is characterized by complex hydrometeorological conditions.

The license for exploration and production of minerals SHKM 16074 NE dated 27.05.2016 was issued by Gazprom Dobycha Yamburg LLC.

The Ob deposit is average in terms of the size of its geological reserves, and it belongs to the simple ones in terms of its geological structure. A gas deposit in the Cenomanian, PK1 formation K2s, dated to the Cenomanian deposits of the Upper Cretaceous, has been identified at the field.

One exploration and evaluation well № 1-Obskaya - has been drilled at the field. The well was stopped at the bottom of 2230 m in the Aptian sediments. Core sampling was carried out in the well, a GIS complex was performed and Cenomanian sediments were tested in the range of 1066 - 1076 m. When testing the well, a gas inflow was obtained. The gas flow rate at the 22.2 mm fitting was 425 thousand m^3/day. The filtration-capacitance properties of the core formation were studied on 83 samples. According to GIS, porosity and permeability were determined in the prospecting and evaluation well № 1-Obskaya. One hydrodynamic study was performed.

4.3.1 Geological and technological characteristics of the Obskoye field

As it is known, a project document "Technological scheme for the development of the Ob gas field in the waters of the Ob Bay of the Kara Sea" was drawn up for the development of the Ob gas field in 2014, based on earlier data from seismic exploration and testing of an exploratory well. The gas reserves of the Ob field were approved in 2003. Basic information included, a massive type of deposit, underlain by plantar water. The position of the gas water contact is set at the mark – 1056.8 m. The size of the deposit is 13x25-5km, the height is 13.9 m. The total gas–saturated thickness in the arched part of the deposit is 10.9 m, the average is 4.5 m (**Table 4.7** Geological and physical characteristics of productive layers of the deposit.).

In 2022, Gazprom VNIIGAZ LLC and Gazpromdobycha Yamburg LLC in the prepared Supplement to the technological scheme for the development of the Ob gas field in the waters of the Ob Bay of the Kara Sea, all modern existing geological and technical information is reinterpreted. So, it is noted that the deposit is a massive dissected non–penetrable interlayers with dimensions of 8x18km, a height of 14 m, and an average effective gas-saturated thickness of 6.5 m. The Vcenomanian deposit in the K2S Cenomanian formation, PK1 is accepted as a single object with uniform characteristics and a gas-water contact, **Figure 4.12** (Rokos et al., 2020).

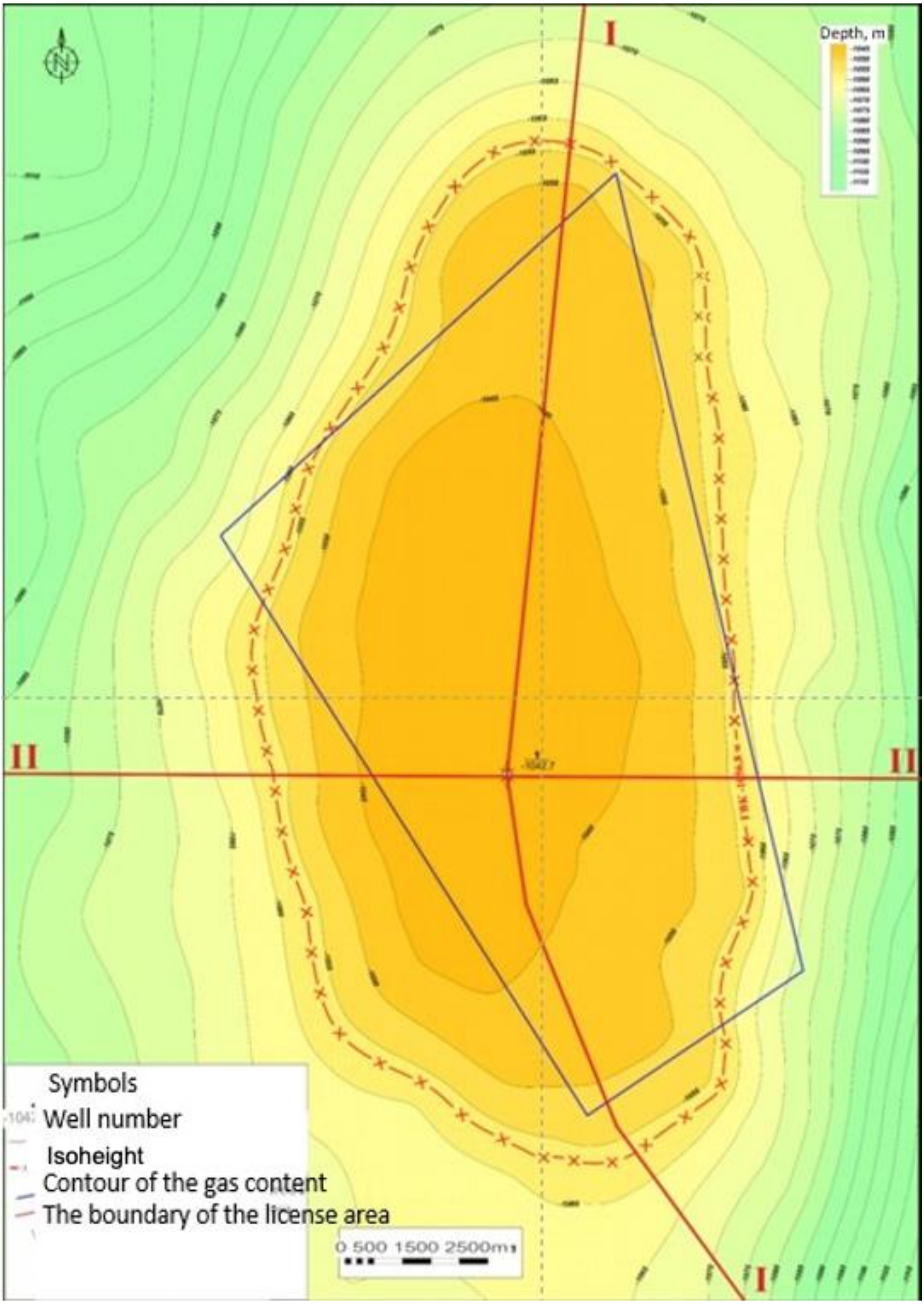

Figure 4.12 Structural map on the roof of the reservoir PK_1.

Table 4.7 Geological and physical characteristics of productive layers of the deposit.

№	Parameter	Unit	Productive layers K2s Cenomanian, PK1
1	Average depth of the roof	M	1049,8
2	The absolute mark of the oil-water contact	M	-
3	The absolute mark of the oil-gas contact	M	-
4	Absolute mark of gas-water contact	M	−1056,8
5	Type of deposit		Massive
6	Type of collector		Porous
7	Oil/gas bearing area	1000. m^2	118444
8	Average overall thickness	M	85,6
9	Average effective oil-saturated thickness	M	-
10	Average effective gas saturated thickness	M	7,2
11	Average effective water saturated thickness	M	-
12	Porosity coefficient		0,33
13	Oil saturation coefficient		-
14	The coefficient of oil saturation		-
15	Oil saturation coefficient of the reservoir		-
16	The coefficient of gas saturation of the reservoir		0,71
17	Permeability (by core)	$micrometer^2$	
18	Coefficient of sandiness		0,81
19	Dismemberment	.	21
20	Initial reservoir temperature	ºC	28,1
21	Initial reservoir pressure	mPa	10,3
22	Oil viscosity in reservoir conditions	mPa*c	-
23	Oil density in reservoir conditions	g/cm^3	-
24	Oil density in surface conditions	g/cm^3	-
25	Volume coefficient of oil		-
26	Sulfur content in oil	%	-
27	Paraffin content in oil	%	-
28	Oil saturation pressure with gas	mPa	-
29	Gas content	m^3/t	-
30	Condensation start pressure	mPa	-
31	Condensate density under standard conditions	g/am^3	-
32	Condensate viscosity under standard conditions	mPa*c	-
33	Potential content of stable condensate in gas (C5+)	g/m^3	-
34	Hydrogen sulfide content	%	отс.
35	Gas viscosity in reservoir conditions	mPa*c	
36	Gas density in reservoir conditions	kg/m^3	0,672
37	Gas super-compressibility coefficient		0,840
38	Water viscosity in reservoir conditions	mPa*c	
39	Water density in surface conditions	g/cm^3	
40	Compressibility		
41	of oil	$1/mPa \times 10^{-4}$	-
42	water	$1/mPa \times 10^{-4}$	
43	rocks	$1/mPa \times 10^{-4}$	
44	Displacement coefficient (by water)		
45	Displacement coefficient (by gas)	.	
46	Productivity coefficient	m^3/day * mPa	
47	Filtration resistance coefficients:		
48	A	$MPa^2/(1000.m^3/day)$	0,018
49	B	$MPa^2/(1000.m^3/day)^2$	$9,68 \times 10^{-6}$

Rocks of the Paleozoic folded basement, transitional Permo-Triassic complex and terrigenous sand-clay formations of the platform Mesozoic-Cenozoic sedimentary cover take part in the geological structure of the Ob deposit.

The Ob local uplift in tectonic terms is confined to the southwestern pericline of the Srednetazovsky arch, which is separated from the Napalkovsky megaswell by depressions of the Antipayutinsky mega bend. From the south-east of Srednyi-Tazovsky arch is bounded by a Parusnyi mega bend (Gazprom Dobycha Yamburg LLC, 2018).

In total, one gas deposit has been identified at the field in Cenomanian sediments (K2s Cenomanian, PK1). The study of the Ob deposit by seismic exploration and drilling is shown in

Figure 4.13. Longitudinal and transverse geological sections of the Cenomanian deposit of the Ob deposit are shown in **Figure 4.14**.

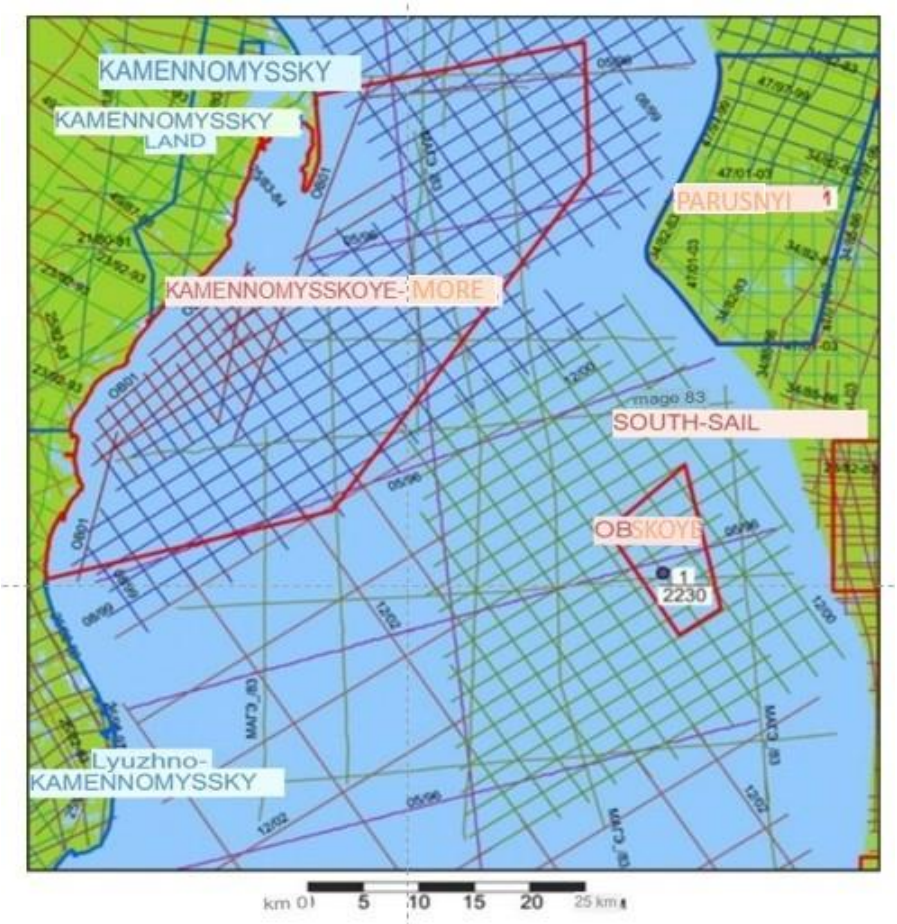

Figure 4.13 Scheme of study of the area of work (Gazprom Dobycha Yamburg LLC, 2018).

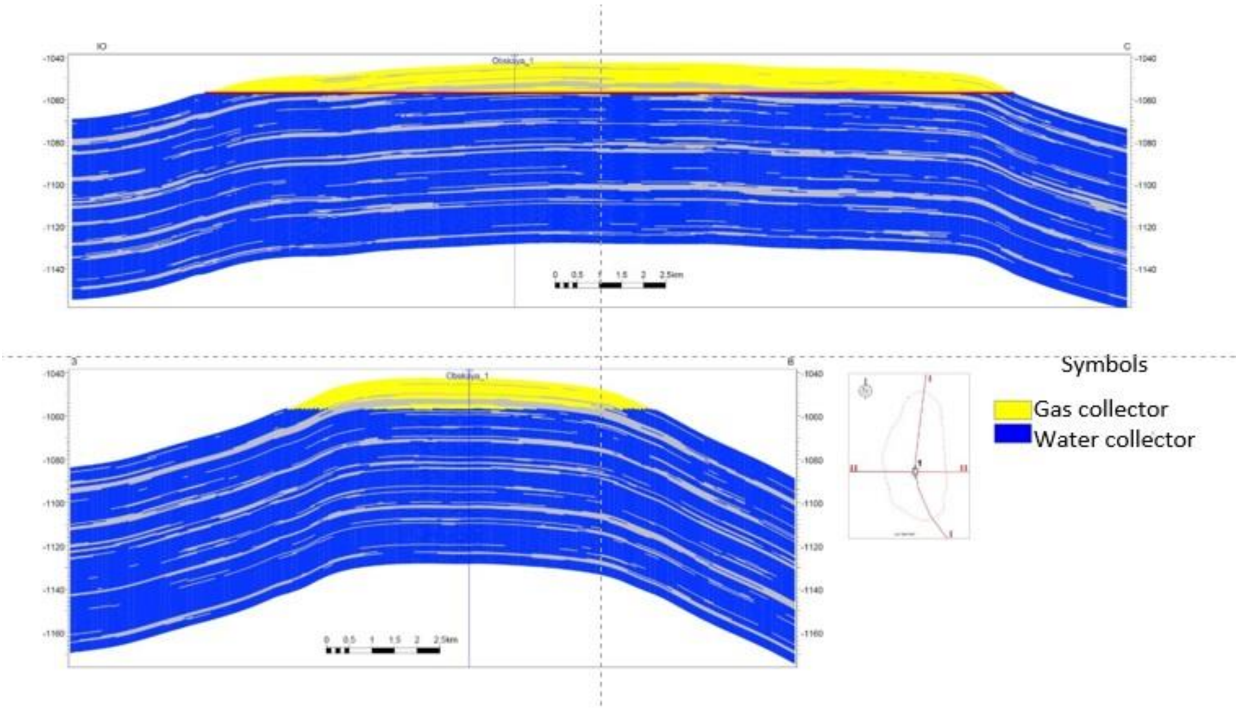

Figure 4.14 Geological sections of the Ob deposit.

The gas reserves of the Ob deposit were approved once in 2003 (Protocol No. 518 (m) - 2003 dated 28.11.2003).

The reserves assessment was carried out in accordance with the new classification of hydrocarbon reserves, which came into effect on 01.01.2016. The total reserves of free gas in the K2s Cenomanian, PK1 formation within the Ob licensed area amounted to 20,402 million m^3, the reserves were fully estimated by category B1. Within the unallocated fund, the gas reserves of the Cenomanian deposit amounted to 3,463 million m^3, the reserves are fully estimated by category B1. In general, gas reserves in the field amounted to 23,865 million m^3.

Compared with the reserves listed on the State Balance Sheet within the Ob field, the initial geological reserves of gas in category C1/B1 increased by 19,098 million m^3 (401%), including 15,635 million m^3 (328%) within the boundaries of the license area of SHKM 16074 NE. These increases are due to a significant change in the structural surface of the roof of the deposit due to the performed re-processing and reinterpretation of seismic data. Free gas reserves will be reflected on the state balance sheet as of 01.01.2023.

A comparison of the reserves submitted for design with those listed on the State Balance Sheet is given in **Table 4.8**.

Table 4.8 State of free gas reserves of the Obskoyoe field.

Productive deposits (formations), objects, the deposit as a whole	Initial reserves of free gas, mln m³						Current reserves of free gas (excluding production in 2022), mln m ³		
	Approved by Rosnedra*			On the state balance 01.01.2022					
	Geological	Recoverable	Recoverable coefficient	Geological	Recoverable	Recoverable coefficient	Geological	Recoverable	Recoverable coefficient
	B_1	B_1	B_1	C_1	C_1	C_1	B_1	B_1	B_1
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Licensed area									
K2s Cenomanian, PK1	20 402	15 106	0,74	4 767	4 767	1	20 402	15 106	0,74
Total by licensed area (SHKM 16074 NE dated 27.05.2016)	20 402	15 106	0,74	4 767	4 767	1	20 402	15 106	0,74
Field									
Total by field	23 865	17 666	0,74	4 767	4 767	1	23 865	17 666	0,74
Licensed area (SHKM 16074 NE)	20 402	15 106	0,74	4 767	4 767	1	20 402	15 106	0,74
Unallocated fund	3 463	2 560	0,739	-	-	-	3 463	2 560	0,739

4.3.2 The main technological indicators for the options for the development of the Obskoye field

The three-dimensional geological model was created in accordance with the requirements of the main regulatory documents on the calculation of reserves and the design of the development of offshore hydrocarbon deposits.

When constructing a geological model of the Cenomanian deposit of the Ob deposit , the following methods were used: structural map of the roof of Cenomanian sediments, established marks of plasto-intersections of the roof of Cenomanian sediments according to the drilling of a search well, the accepted level of gas-water contact. Technological indicators of the development of the Obskoye field as a whole are presented in the **Table A.1**. During the transition from the geological model to the filtration model, the grid was not enlarged.

The filtration model of the Cenomanian gas deposit of the Ob deposit is characterized by the following parameters:

- number of cells – 6 292 800;
- dimension – 160×230×171 cells;
- average cell size – 100×100×0,5 m.

The discrepancy of reserves in the geological model compared to the filtration model was 1.5%, which is acceptable.

Cenomanian gas deposit in the Cenomanian formation K2s, PK1 is accepted as a single operational facility (hereinafter referred to as PK1) of development with uniform thermobaric characteristics and gas-water contact.

The characteristics of the main technological indicators of gas production development of the Obskoye deposit are given in **Table 4.9**.

Table 4.9 Characteristics of the main technological indicators of gas production development.

Years and periods	Gas production, mln,m³		Gas extraction coefficient	Active wells fund	Average gas flow m³/day	Average pressure among wells, MPa			
	Annual	Total				Formation	Bottomhole	Wellhead	At the GTU entry
1	2	3	4	5	6	7	8	9	10
1	279	279	0,012	1	804	9,83	9,59	5,5	5,31
2	544	823	0,034	2	784	9,67	9,31	5,33	4,63
3	765	1588	0,067	3	735	9,4	9,06	4,93	2,83
4	953	2541	0,106	4	687	9,06	8,74	4,83	1,73
5	888	3429	0,144	4	640	8,74	8,41	5,05	1,73
6	802	4231	0,177	4	578	8,45	8,14	4,99	1,73
7	747	4978	0,209	4	538	8,18	7,88	4,86	1,73
8	704	5682	0,238	4	507	7,92	7,63	4,72	1,73
9	671	6353	0,266	4	483	7,68	7,4	4,58	1,73
10	639	6992	0,293	4	461	7,44	7,17	4,46	1,73
11	611	7603	0,319	4	440	7,21	6,95	4,33	1,73
12	584	8187	0,343	4	421	7	6,74	4,2	1,73
13	561	8749	0,367	4	404	6,79	6,53	4,05	1,73
14	532	9281	0,389	3	511	6,52	6,2	3,35	1,73
15	494	9775	0,41	3	475	6,33	6,02	3,23	1,73
16	478	10254	0,43	3	460	6,15	5,84	3,14	1,73
17	464	10718	0,449	3	446	5,97	5,66	3,04	1,73

18	448	11166	0,468	3	430	5,8	5,5	3	1,73
19	432	11598	0,486	3	415	5,64	5,34	2,92	1,73
20	418	12016	0,503	3	401	5,48	5,18	2,83	1,73
21	404	12420	0,52	3	388	5,32	5,02	2,71	1,73
22	389	12808	0,537	3	374	5,17	4,87	2,65	1,73
23	375	13184	0,552	3	360	5,02	4,72	2,57	1,73
24	362	13545	0,568	3	347	4,88	4,58	2,51	1,73
25	349	13894	0,582	3	335	4,74	4,45	2,45	1,73
26	334	14228	0,596	3	321	4,6	4,32	2,4	1,73
27	321	14549	0,61	3	308	4,47	4,19	2,36	1,73
28	308	14857	0,623	3	296	4,35	4,07	2,32	1,73
29	296	15153	0,635	3	284	4,23	3,96	2,28	1,73
30	282	15435	0,647	3	271	4,12	3,85	2,25	1,73
31	270	15705	0,658	3	259	4,01	3,75	2,21	1,73
32	258	15964	0,669	3	248	3,9	3,65	2,18	1,73
33	248	16212	0,679	3	238	3,8	3,55	2,15	1,73
34	237	16449	0,689	3	228	3,71	3,46	2,11	1,73
35	227	16676	0,699	3	218	3,61	3,37	2,08	1,73
36	217	16893	0,708	3	208	3,52	3,29	2,06	1,73
37	208	17100	0,717	3	200	3,44	3,21	2,03	1,73
38	198	17298	0,725	3	190	3,36	3,13	2	1,73
39	189	17487	0,733	3	181	3,28	3,06	1,97	1,73
40	179	17666	0,74	3	172	3,21	2,99	1,95	1,73

The development of the Ob deposit is supposed to be carried out in the depletion of the deposit, the maintenance of reservoir pressure in the deposit is not provided.

This information, due to the increase in the area of the deposit, allows us to reconsider the decision on the number of producing wells. For the development of the Ob gas field, it is possible to use two solutions – underwater arrangement, with the use of underwater production unit and surface - the construction of an ice-resistant block conductor, as well as an increase to two well clusters. The rationale for choosing the underwater production unit approach is based on the construction of wells in the interglacial period using a jack-up drilling platform with further arrangement of underwater production equipment on the seabed (Mirzoev, 2008). With a sufficiently large number of advantages, such a solution, even with a significant reduction in costs, given the difficult climatic conditions and technical and technological tasks, the lack of practical implementation experience is currently quite promising. The solution to the problems of optimal development of oil and gas fields is based on determining the potential and maximum allowable flow rate of producing wells. Knowledge of the flow rates is important for determining the rational consumption of reservoir energy and the most complete recovery of reserves. As it is known, on the basis of geological – hydrodynamic and numerical modeling, decisions are made on the number of wells, the placement of their bottomholes, the trajectory of the boreholes in the zone of the productive formation (**Appendix A**). In order to ensure optimal production of reserves at the Ob gas field, in our opinion, it may be necessary to justify the choice of new solutions that allow to correctly influence the increase in their productivity (Aliyev et al., 1978).
According to the existing design solutions for the use of underwater production unit, it can be noted that the use of shallow and horizontal wells with borehole deviations from the vertical of 770 m, 1070 m, 10380 m, 1700 m, 2390 m, 2840 m was considered the most preferable. The expediency of using horizontal wells is associated with their clustering at one point and the placement of cluster equipment at one underwater production unit. Such a decision should help to increase the design level of gas production during the period of constant sampling, and the amount of projected production can be achieved in a shorter period of operation of the Ob field. For the effective development of the Ob gas field, there are a number of options for arrangement.

As a result, 10 options for the development of the Ob deposit were formed, of which the last 2 options include the construction of multi-lateral wells. The estimated development period for the options is 40 years. From the point of view of development, the options differ in annual sampling levels (0.54–1.11 billion m³ per year), the fund of producing wells from 3 to 9 with downhole waste from the wellhead to 3000 m and the number of clusters - 1 or 2. Development options 2-10 involve the construction of an ice-resistant block conductor. At the same time, the implementation of option 5 will require the construction of two ice-resistant block-conductors (**Figure 4.15**).

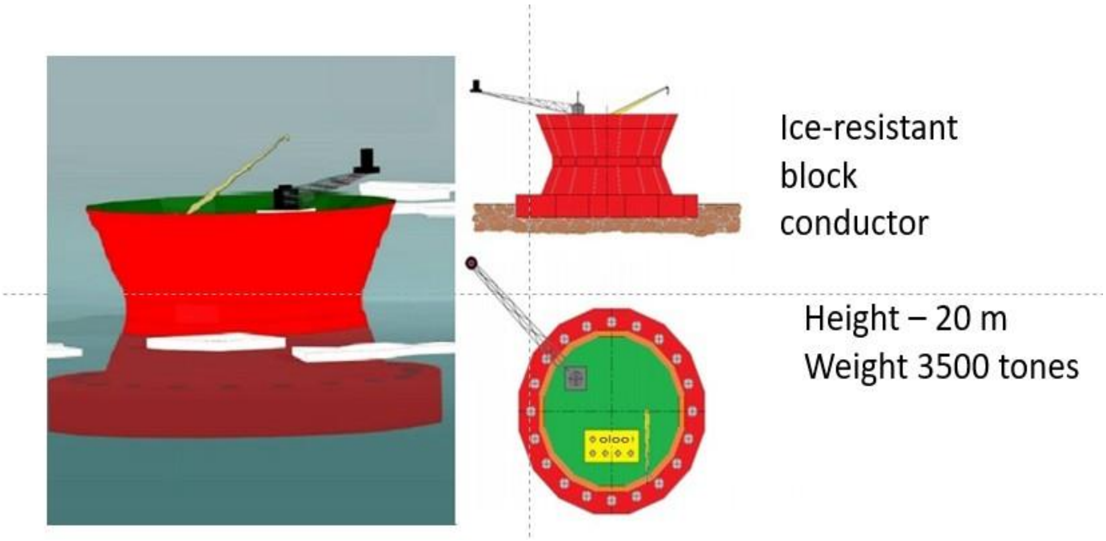

Figure 4.15 Block - conductor project for the field.

The length of the borehole of producing horizontal wells in the productive interval is 100 m, however, due to the development of technology and technology for the construction of multi-lateral wells, taking into account information on the geomechanics of the productive horizon and the ability to control the flow rates of individual branches of multi-lateral wells, the length of the horizontal section can be increased to 250 meters. Typical profile of horizontal, two-hole and three-hole wells are shown in **Figure 4.16**-- **Figure 4.20** The layout of the project wells. Option 5..

<u>Option 1</u>

According to option 1, in accordance with the "Rules for the preparation of technical projects for the development of hydrocarbon deposits", it is assumed that the main technical solutions adopted in the current project document will be evaluated on an updated geological basis. The fund of producing wells under this option is 3, including 1 well with a bottom hole from the wellhead of 770 m, 1 – 2390 m and 1 – 2840 m.

Option 1 is characterized by the following indicators:

- the total fund of wells – 3 horizontal producing gas wells;
- well fund for drilling – 3 horizontal producing gas wells;
- the maximum annual production of free gas is 542 million m^3;
- the duration of the permanent production period is 7 years;
- accumulated gas production (reserve category B1) – 15,767 million m^3;
- free gas extraction coefficient (reserve category B1) – 0.661.

Option 2

Option 2 is based on option 1 and provides for the expansion of the production fund of wells to 4 (1 cluster), including 2 wells with a waste of 2000 m and 2 wells with a waste of 3000 m. In comparison with option 1, in this option, the placement of faces, profiles and structures of producing wells was optimized, taking into account changes in the geological basis.

Option 2 is characterized by the following indicators:

- the total fund of wells – 4 horizontal producing gas wells;
- well fund for drilling – 4 horizontal producing gas wells;
- the maximum annual production of free gas is 659 million m^3;
- the duration of the permanent production period is 8 years;
- accumulated gas production (reserve category B1) – 17,091 million m^3;
- free gas extraction coefficient (reserve category B1) – 0.716.

Option 3

In accordance with option 3, compared with option 2, it is planned to increase the fund of producing wells without increasing the number of clusters to 5 (3 wells with a waste of 2000 m and 2 wells with a waste of 3000 m).

Option 3 is characterized by the following indicators:

- total fund of wells – 5 horizontal producing gas wells;
- well fund for drilling – 5 horizontal producing gas wells;
- the maximum annual production of free gas is 824 million m^3;
- the duration of the permanent production period is 6 years;
- accumulated gas production (reserve category B1) – 18,011 million m^3;
- free gas extraction coefficient (reserve category B1) – 0,755.

Option 4

Option 4 provides for drilling 6 wells (1 cluster). At the same time, it is planned to drill 4 wells with a waste of 2000 m and 2 wells with a waste of 3000 m.

Option 4 is characterized by the following indicators:

- the total fund of wells – 6 horizontal producing gas wells;
- fund of wells for drilling – 6 horizontal producing gas wells;
- the maximum annual production of free gas is 985 million m^3;
- the duration of the permanent production period is 2 years;
- accumulated gas production (reserve category B1) – 18,830 million m^3;
- free gas extraction coefficient (reserve category B1) – 0.789.

Option 5

Option 5 assumes an increase in the drainage zone by drilling two well pads, 6 wells in cluster 1 (4 wells with 2000 m waste and 2 wells with 3000 m waste) and 3 wells in cluster 2 (1 well with 1000 m waste and 2 wells with 2000 m waste).

Option 5 is characterized by the following indicators:

- the total fund of wells – 9 horizontal producing gas wells;
- fund of wells for drilling – 9 horizontal producing gas wells;
- the maximum annual production of free gas is 989 million m^3;
- the duration of the permanent production period is 4 years;
- accumulated gas production (reserve category B1) – 19,226 million m^3;
- free gas extraction coefficient (reserve category B1) – 0,806.

In order to assess the provision of reservoir gas volumes for the additional loading of the capacities of the GTE of cape Parusnyi deposits Kamennomysskoye-more on the basis of development options 2-4, development options 6-8 have been additionally formed, assuming peak dynamics of production of reservoir products..

Option 6

Option 6 is characterized by the following indicators:

- the total fund of wells – 4 horizontal producing gas wells;
- well fund for drilling – 4 horizontal producing gas wells;
- the maximum annual production of free gas is 953 million m^3;
- accumulated gas production (reserve category B1) – 17,666 million m^3;
- free gas extraction coefficient (reserve category B1) – 0,740.

Option 7

Option 7 is characterized by the following indicators:

- total fund of wells – 5 horizontal producing gas wells;
- well fund for drilling – 5 horizontal producing gas wells;
- the maximum annual production of free gas is 1,064 million m^3;
- accumulated gas production (reserve category B1) – 18,279 million m^3;
- free gas extraction coefficient (reserve category B1) – 0,766.

Option 8

Option 8 it is characterized by the following indicators:

- the total fund of wells – 6 horizontal producing gas wells;
- fund of wells for drilling – 6 horizontal producing gas wells;
- the maximum annual production of free gas is ,109 million m^3;
- accumulated gas production (reserve category B1) – 18,994 million m^3;
- The free gas extraction coefficient (reserve category B1) is 0,796.

For clarity, the layout schemes of the project wells on the map of the gas–saturated thicknesses of the Cenomanian deposit of the Ob field are presented in Figures 3.17 - 3.21 according to the variants.

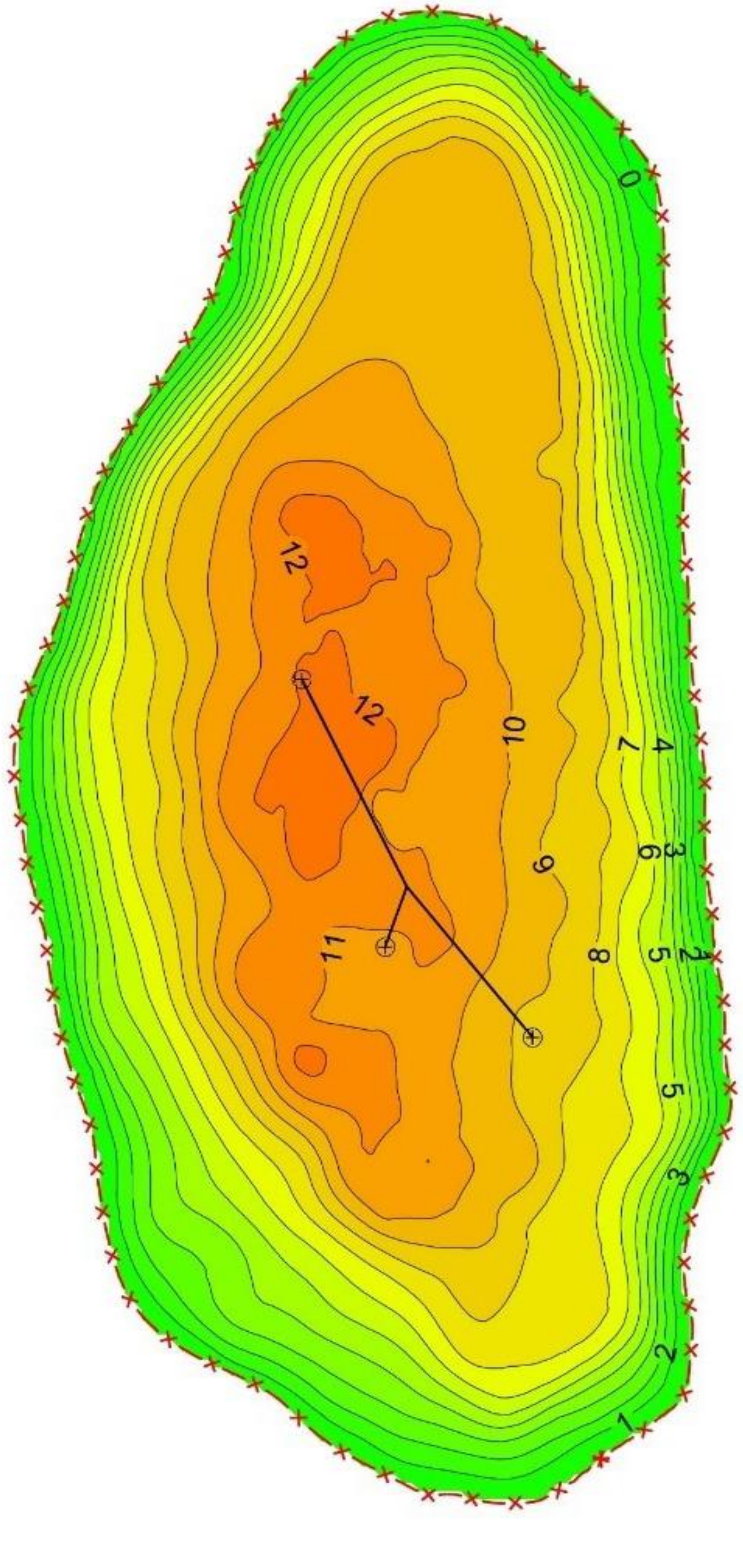

Figure 4.16 The layout of the project wells. Option 1.

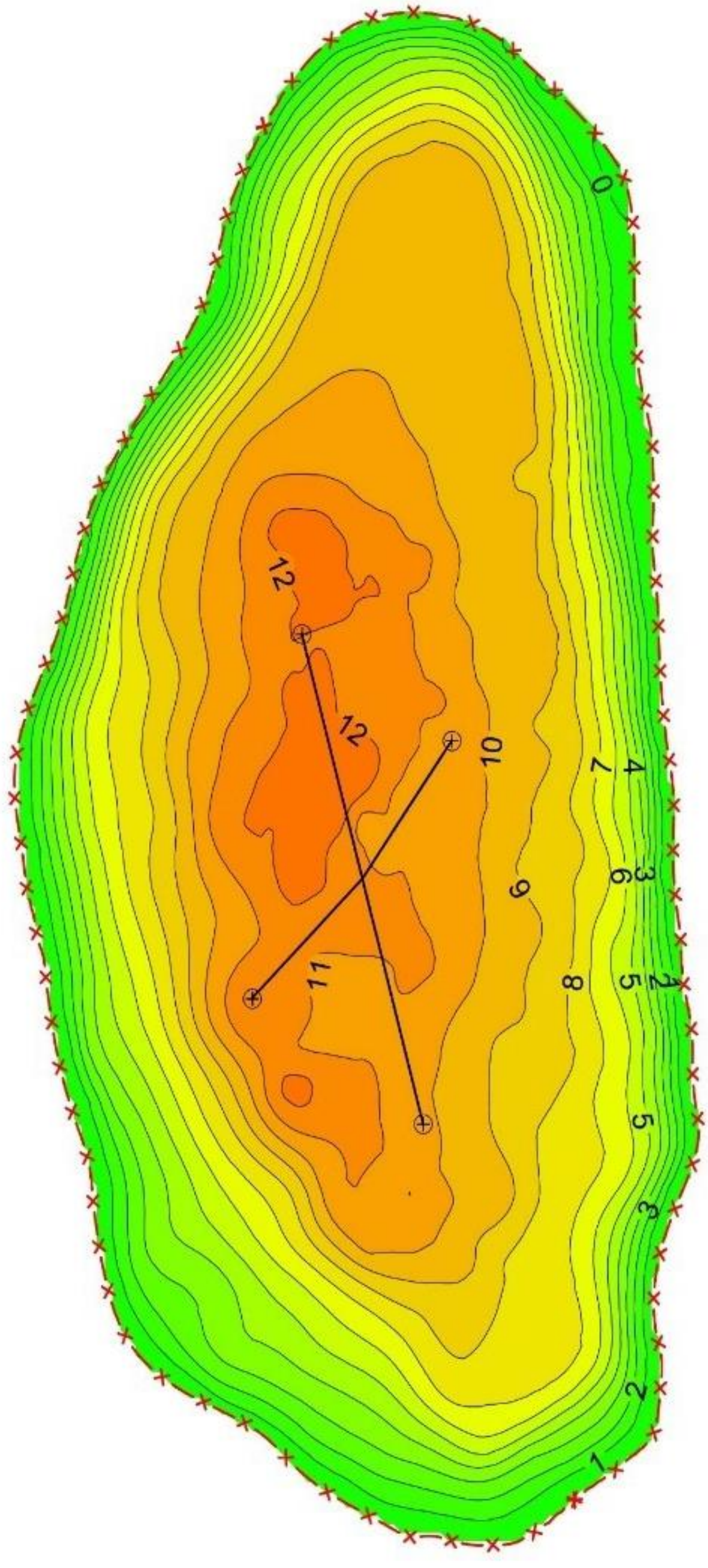

Figure 4.17 The layout of the project wells. Option 2 and 6.

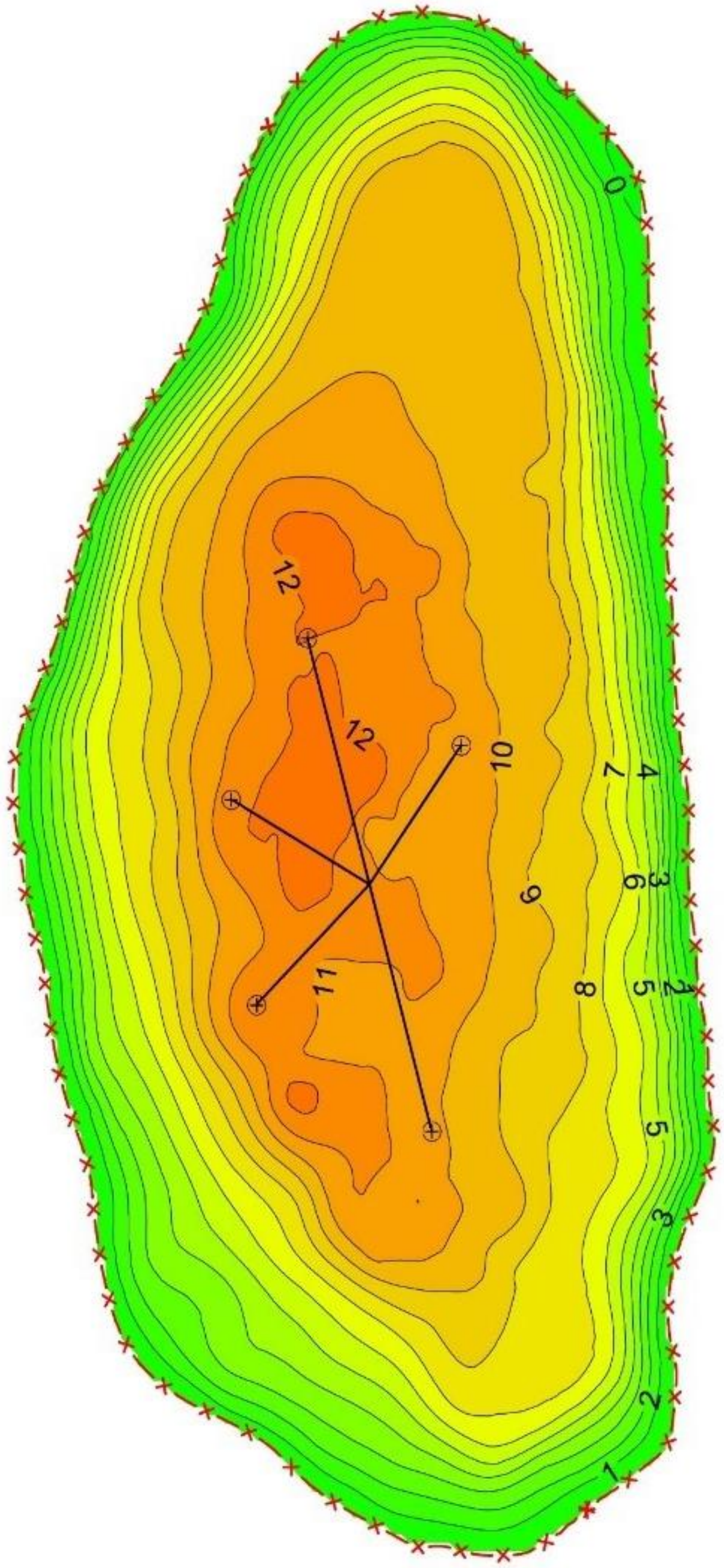

Figure 4.18 The layout of the project wells. Option 3 and 7.

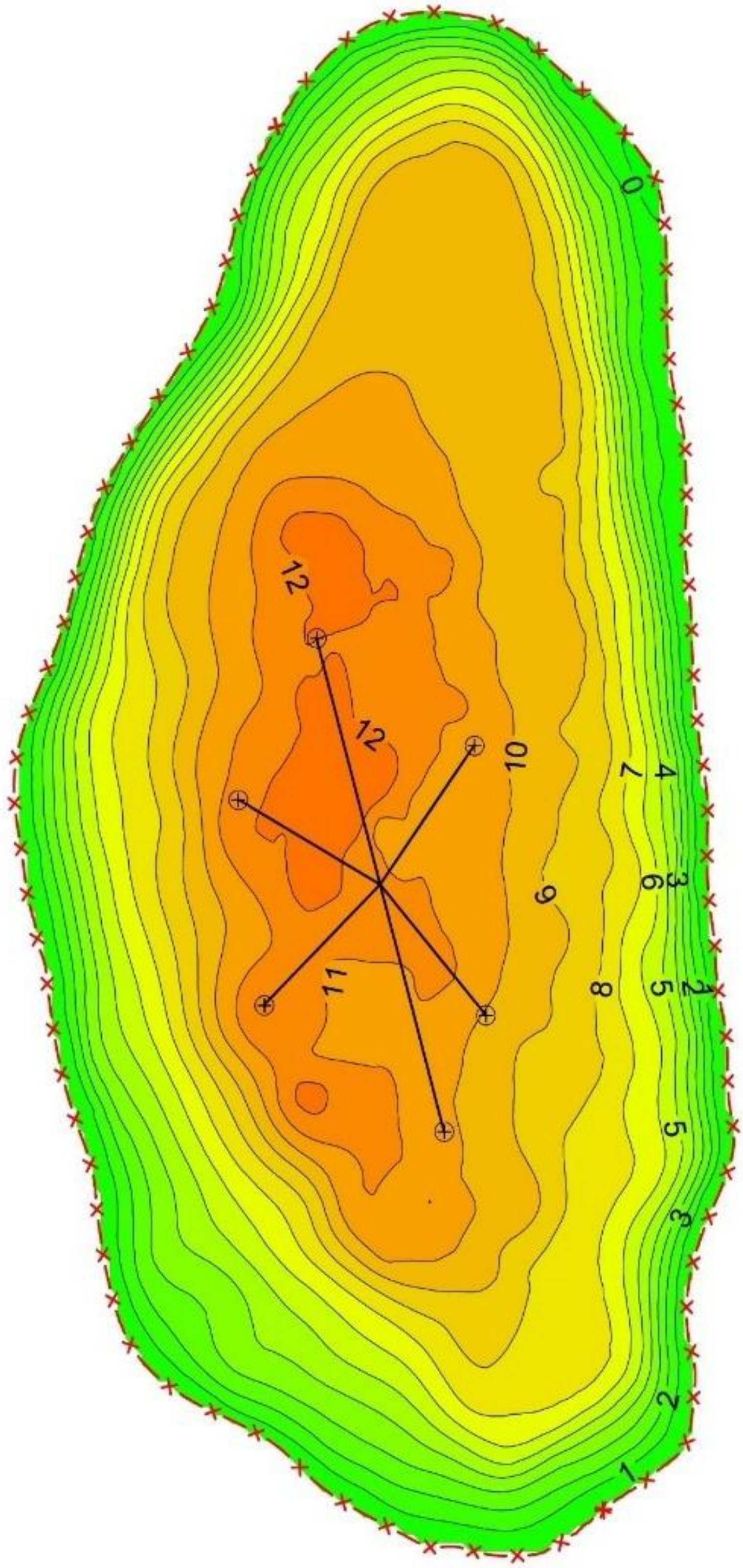

Figure 4.19 The layout of the project wells. Option 4 and 8.

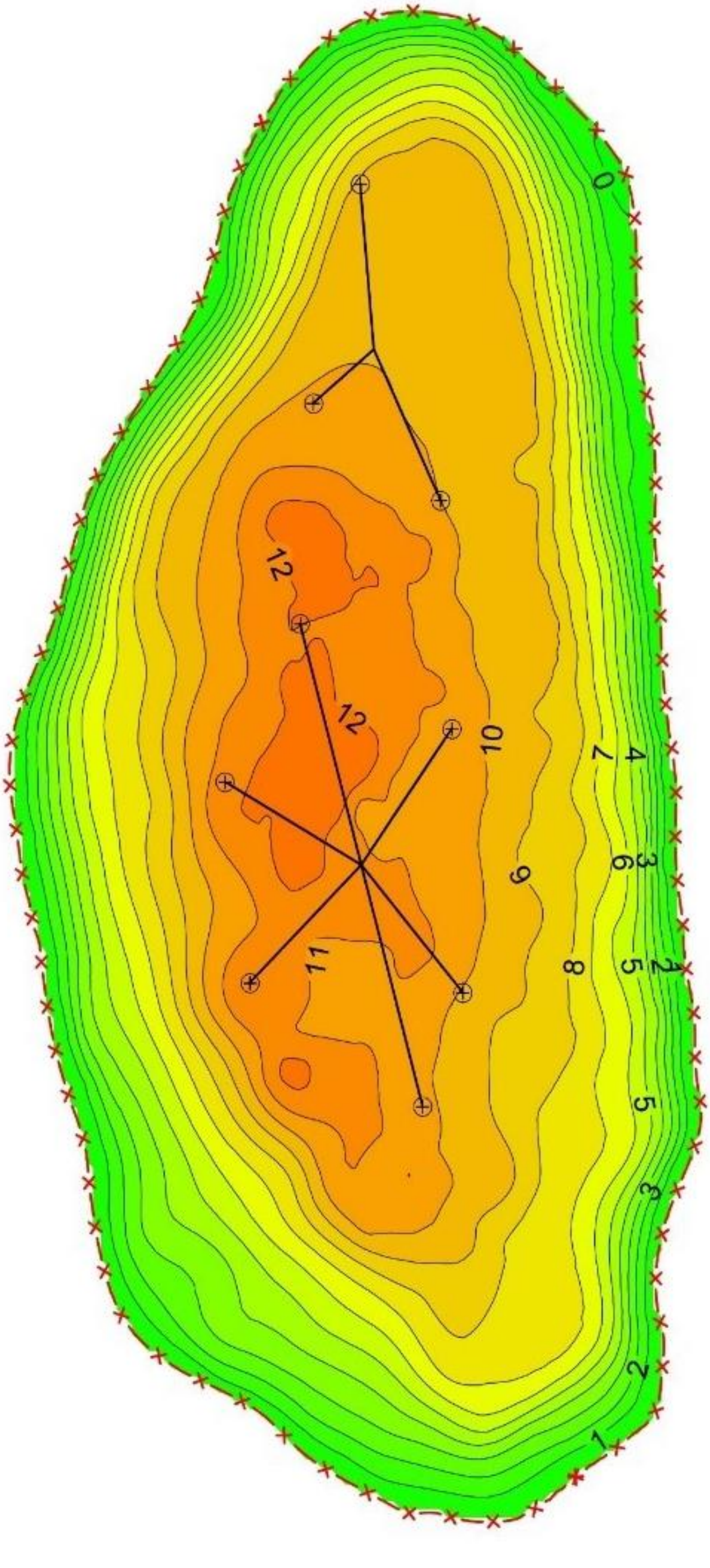

Figure 4.20 The layout of the project wells. Option 5.

A comparison of the main technological indicators for the options for the development of the Cenomanian gas deposit of the Ob field is shown in **Figure 4.21 - Figure 4.23**.

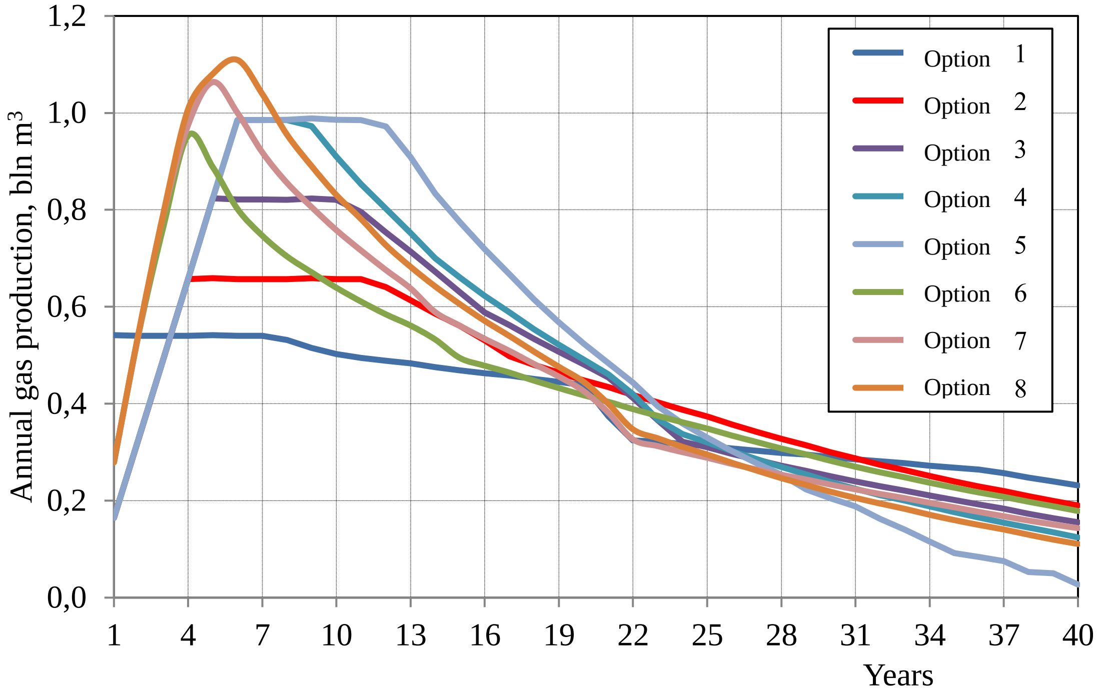

Figure 4.21 Dynamics of annual gas production for the forecast period by options.

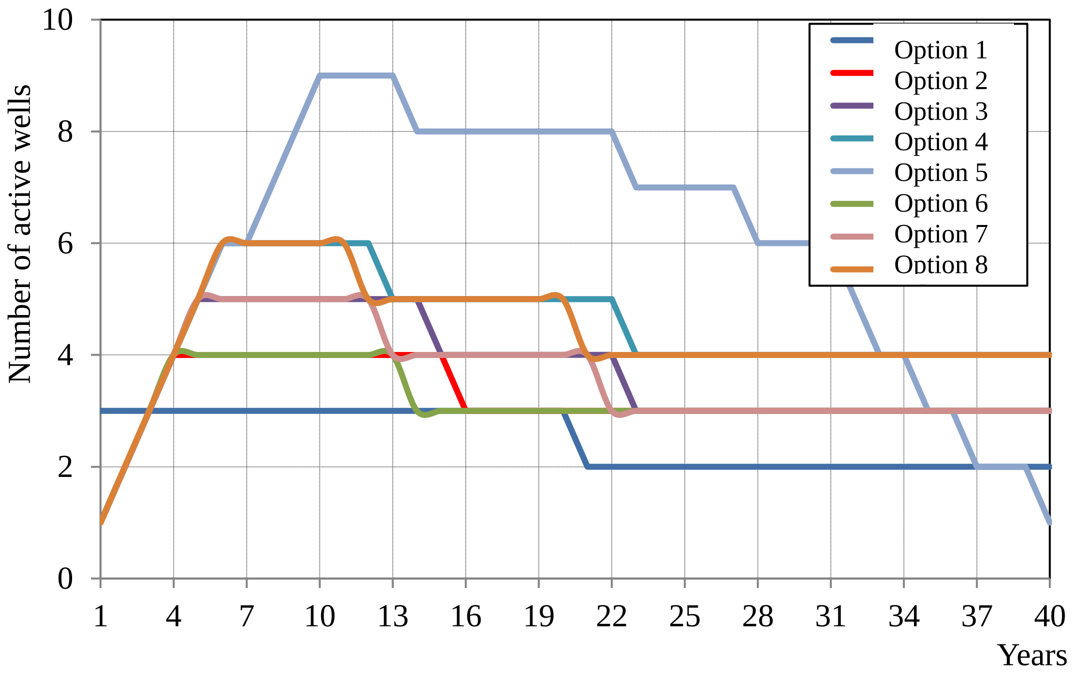

Figure 4.22 Dynamics of the fund of producing wells by options.

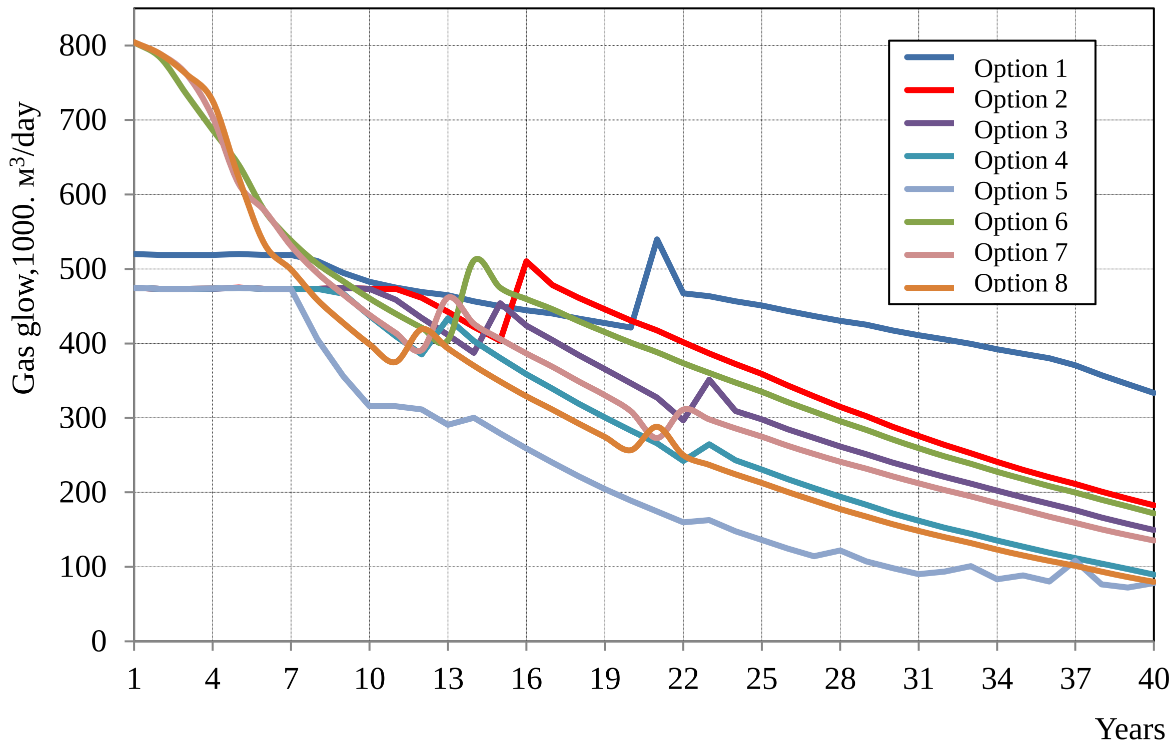

Figure 4.23 Dynamics of gas flow rates of project wells by options.

To date, the main option, according to the results of the analysis of technological indicators of the Ob deposit, is the development of the deposit by three horizontal producing wells. This approach will allow one to reach the maximum level of gas extraction per year – 0.55 billion m³, while 3.6 billion m³ of accumulated production can be achieved over 14 years of operation of the Ob gas field. If one provides for the construction of four horizontal production wells, the maximum level of product selection will be 0.62 billion m³ per year, with a field life of 13 years, the volume of accumulated production will reach 3.69 billion m³.

The use of multi-lateral wells is proposed to increase the flow rate of wells. The use of multi-lateral wells will increase the total flow rate of wells with fewer wells on the bush.

<u>Option 9</u>

Option 9 (**Figure 4.24**) is characterized by the following indicators:

- the total fund of wells – 3 two-hole producing gas;
- fund of wells for drilling – 3 two-hole producing gas;
- the maximum annual production of free gas is 1,008 million m ^{3};

- accumulated gas production (reserve category B1) – 17,972 million m^3;
- free gas extraction coefficient (reserve category B1) – 0,753.

<u>Option 10</u>

Option 10 (**Figure 4.25**) is characterized by the following indicators:

- total well stock – 2 two-hole producing gas wells, 1 three-hole producing gas well;
- fund of wells for drilling – 3 multi-lateral producing gas;
- the maximum annual production of free gas is 1,060 million m^3;
- accumulated gas production (reserve category B1) – 18,220 million m^3;
- The free gas extraction coefficient (reserve category B1) – 0,766.

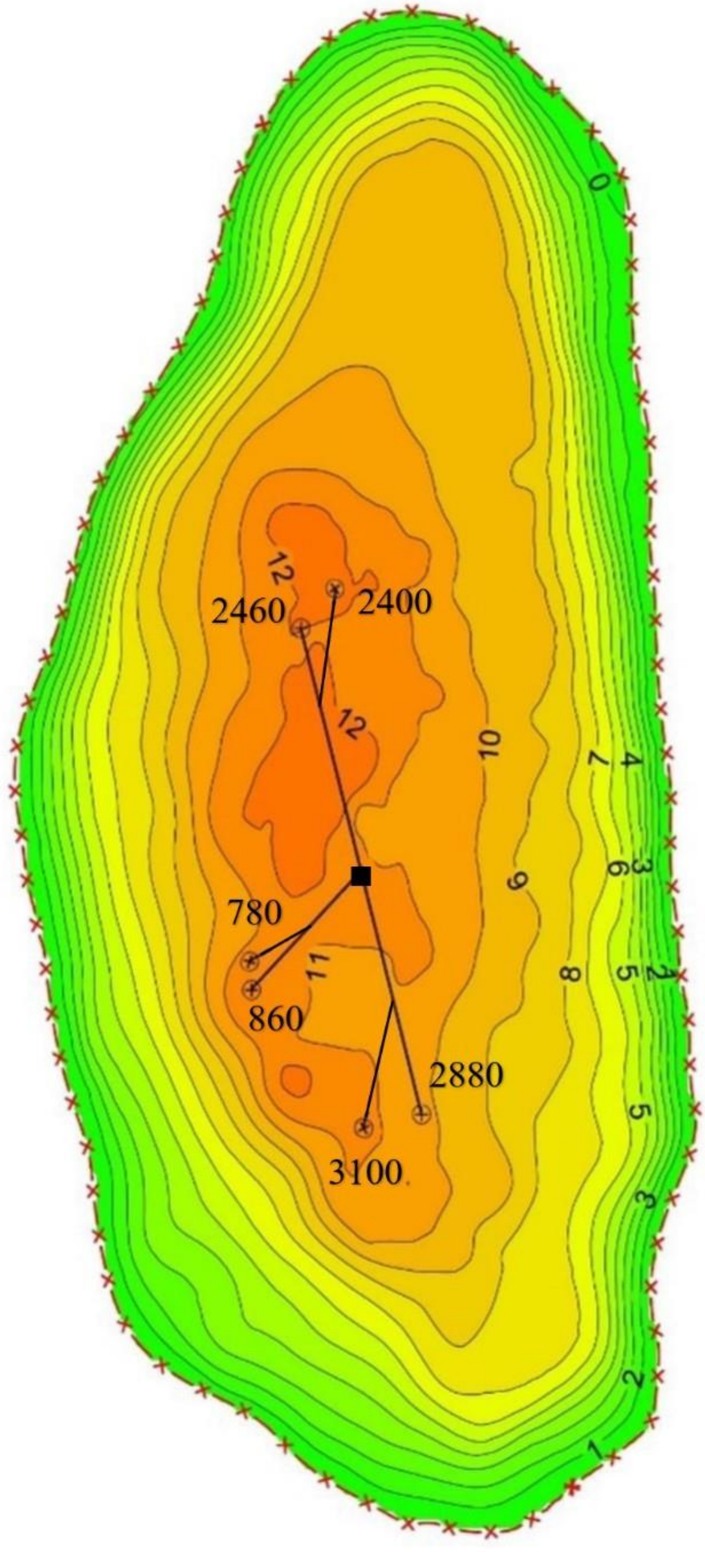

Figure 4.24 The layout of the project wells. Option 9.

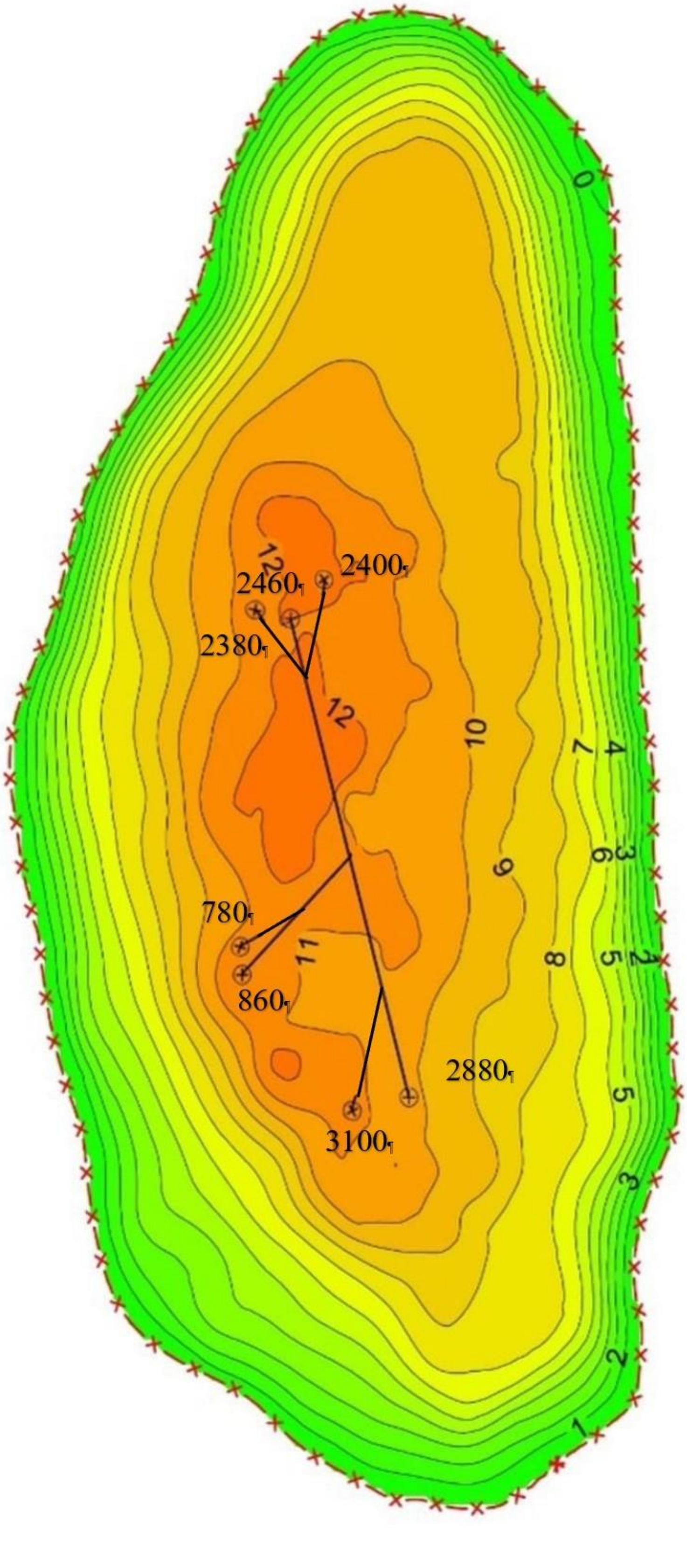

Figure 4.25 The layout of the project wells. Option 10.

The accumulated production for all 10 options for the forecast period is shown in the diagram:

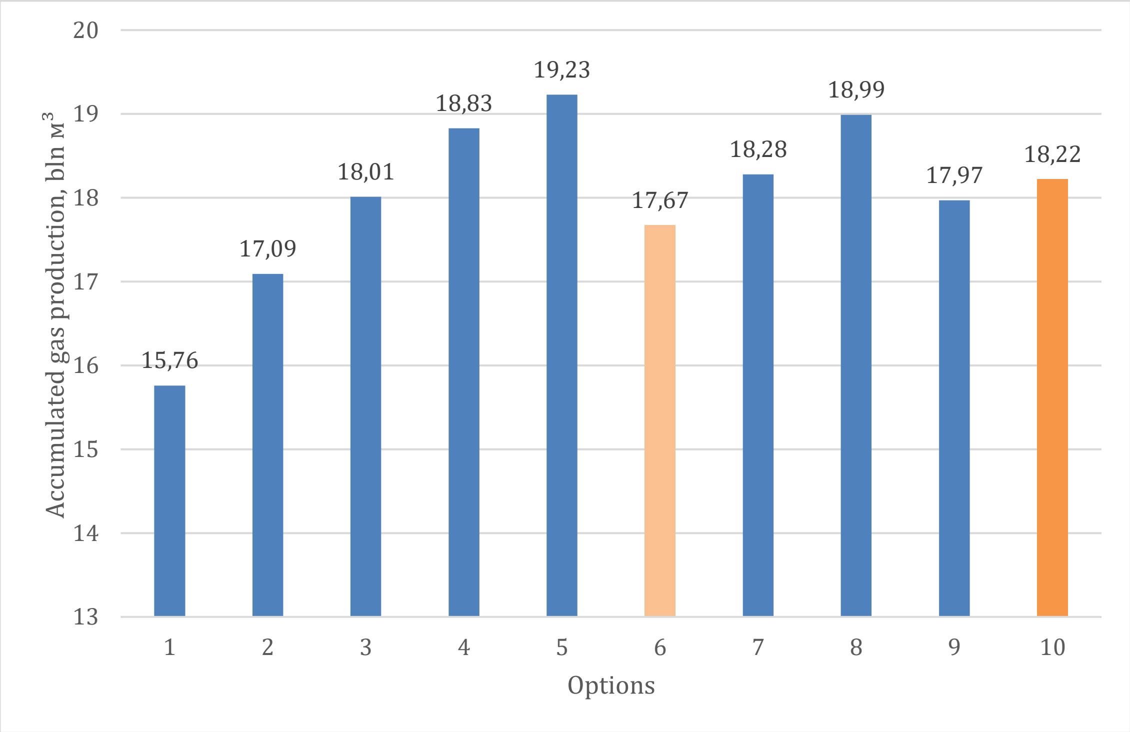

Figure 4.26 Accumulated gas production for the forecast period by options.

The development of the field by horizontal and multi-lateral wells is an urgent direction in the oil and gas industry today. Operational reliability and efficiency of the marked wells depends on reasonable consideration of geological, technical and hydrodynamic conditions of construction and operation of wells, and this is primarily the design of wells, the features of the device of the faces, depending on the type of completion, etc.

It is also important to note that the choice of multi-lateral wells is influenced not only by the filtration and reservoir properties of the reservoir and the properties of the extracted products, but also by the interference of boreholes and branches with each other at their close location, but also by hydraulic processes caused by the confluence of flows in the junction zone of the lateral branch with the main borehole of the production column. The main advantage of such wells over horizontal wells is considered to be the reduction of filtration resistances due to the presence of branches from the main horizontal borehole. At the same time, it should be noted that multi-lateral and wells provide an increase in flow rate, productivity coefficient, oil and gas recovery, etc. The use of such wells with the ability to solve problems in geonavigation and geomechanics, can allow the passage of the borehole inside the productive reservoir in the zone with the best reservoir properties. Consequently, it is possible to achieve a multiple increase in productive characteristics and maximum production efficiency. It is important to note that according to the modern classification, the difference between a multilateral well and a multi-lateral is in the location of the borehole branching zone. For example, a multilateral well is characterized by the placement of a branching zone above the productive horizon, and in this case the branches may intersect the productive layers at several points.

In a multi-lateral well, the branching zone is located between the roof and the sole of the productive reservoir and, accordingly, such a well crosses the horizon at one point. At the same time, it should be noted that quite a large number of studies by domestic and foreign authors, such as S.K. Sokhoshko, S. D. Joshi, G. I. Renard, J. M. Dupuy, M. J. Economaides, C.I. Grachev, Yu.P.Borisov, V.A.Iktisanov, are devoted to the issues of assessing the productivity of horizontal oil wells. However, with questions of determining the flow rate of a horizontal well, one can refer to the works of Z.S.Aliyev, V.V.Sheremet, S.To.Sokhoshko , in which it is noted that, unlike oil horizontal and multilateral wells, where the resulting hydraulic losses have a negligible effect on the prediction of productivity, in gas wells, the importance of taking into account hydraulic resistances when gas moves along the borehole is shown. The authors note that this provision is associated with a higher speed of gas movement, travel pressure losses and mixing of gas flows, including in the area of the junction of the main borehole and branches, and in general has a significant impact on the final flow rate of the well. It should be noted that the flow rate of a multi-lateral well can be several times higher than the flow rate of a vertical or inclined well, and at least 1.5-1.75 times higher than the flow rate of a horizontal well. Based on this provision, in order to achieve the required value of the design flow rate from a bunch of wells, from one underwater production unit, the following composition of the bush can be proposed - one horizontal well and two multi-lateral wells instead of three horizontal wells for one underwater production unit (Vovk V.S., 2008).

Let us take a closer look at the technical and technological solutions for the construction of horizontal and multi-lateral wells. The most important proposals for the construction of such wells are the justification of the choice of the well design, the profile of wells, the trajectory of boreholes and branches, the solution of a set of tasks for the completion of wells, taking into account the hydrodynamic and geological technical conditions of drilling and operation of wells. Based on the results of plotting the combined pressures, the basic design of a horizontal well can be selected. The design of a horizontal well should consist of - a water separation column with a diameter of 630 mm, lowered to a depth of 20 m, - a conductor with a diameter of 508 mm with a setting depth of 165m, for overlapping unstable rocks, - a collar rig with a diameter of 340 mm with a setting depth of 450 m to prevent hydraulic fracturing of rocks, in case of gas occurrences and overlap of possible water-manifesting horizons-taliks or gas hydrate deposits, - an intermediate column with a diameter of 245 mm with a depth of setting determined to overlap the interval of the zenith angle, an operational column = a liner with a diameter of 168 mm with a setting depth into the roof of the productive layer and liner hanger 200 m above the shoe of the intermediate column, - a slotted liner with a diameter of 114 mm in the productive layer. A packer hanger of 168x245 mm will be used to lower and mount the production liner. The slotted liner is hanged using a non-cemented lifter hanger of 114x168 mm. Cementing of casing columns should be carried out for the entire length. The design of a multi-lateral well is justified and selected considering the existing system of trunk joints and branches according to the international classification TAML.

As it is known today, according to the classification, there are 6 levels of complexity of the joints of the main trunk with a branch (**Figure 4.27**). To ensure reliable and long–term operation of the object of operation - wells, with the ability to control the process of selecting products to obtain the necessary downhole information, it is proposed to build multi-lateral wells according to TAML according to 5 levels of complexity. Modern technical and technological approaches provide for the use of special technical means to ensure proper tightness of the joint of the main trunk and the additional branch.

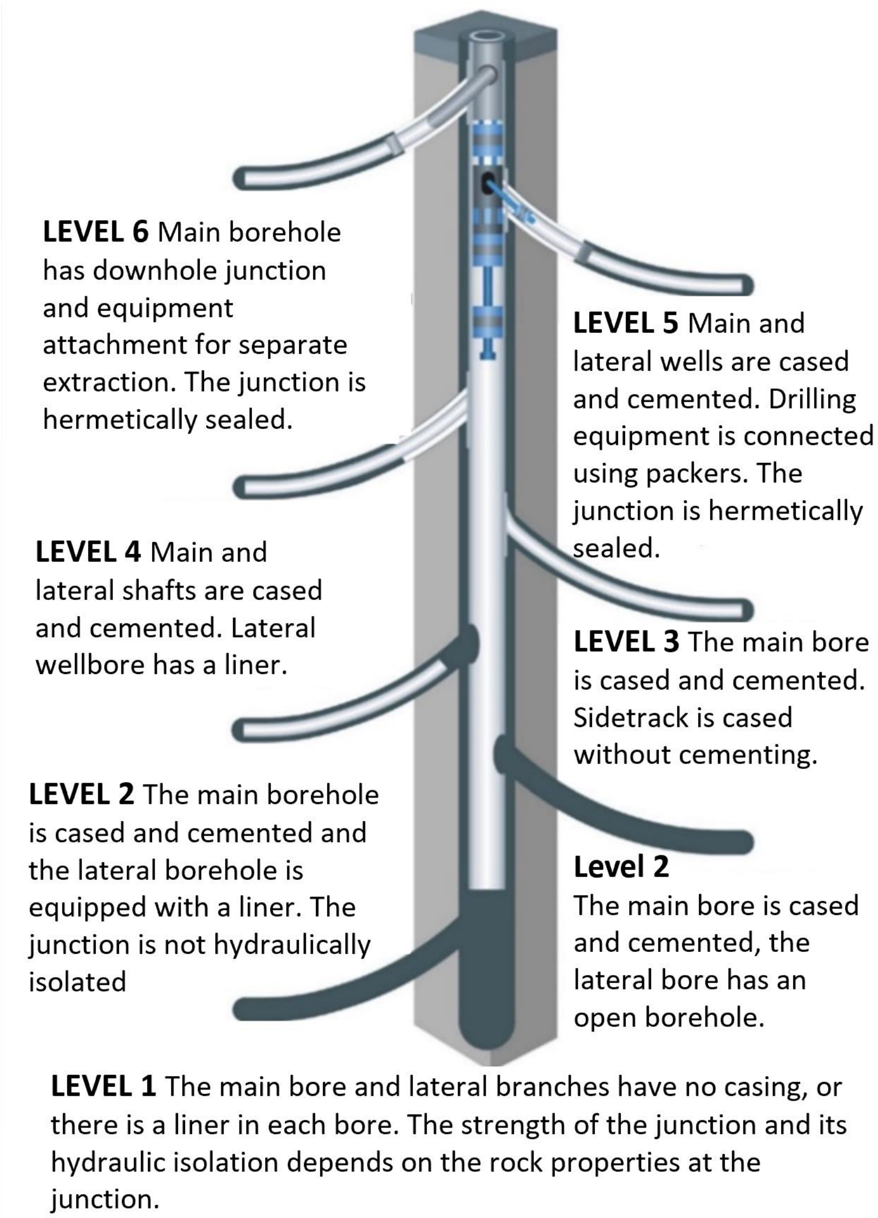

Figure 4.27 Classification of TAML

Thus, taking into account the geological, technical and geomechanical conditions of construction, it is necessary to determine the following parameters of horizontal and multi-lateral wells. Horizontal well № 1, as located in the dome part of the deposit with a discharge of 860 m projected in an approximate azimuth of 190 degrees, multi-lateral well No. 2 with a discharge of the main borehole of 2460 m and an additional branch with a discharge of 2400 m respectively with orienting azimuths of 145 and 130 degrees, multi-lateral № 3 with a discharge of the main borehole of 3100m and an additional branch of 2880 m and, respectively, the approximate azimuths of 330 and 350 degrees. The profile parameters of horizontal and multi-lateral wells are shown in **Figure 4.28** - **Figure 4.30** (Khoshtaria V.N., 2021).

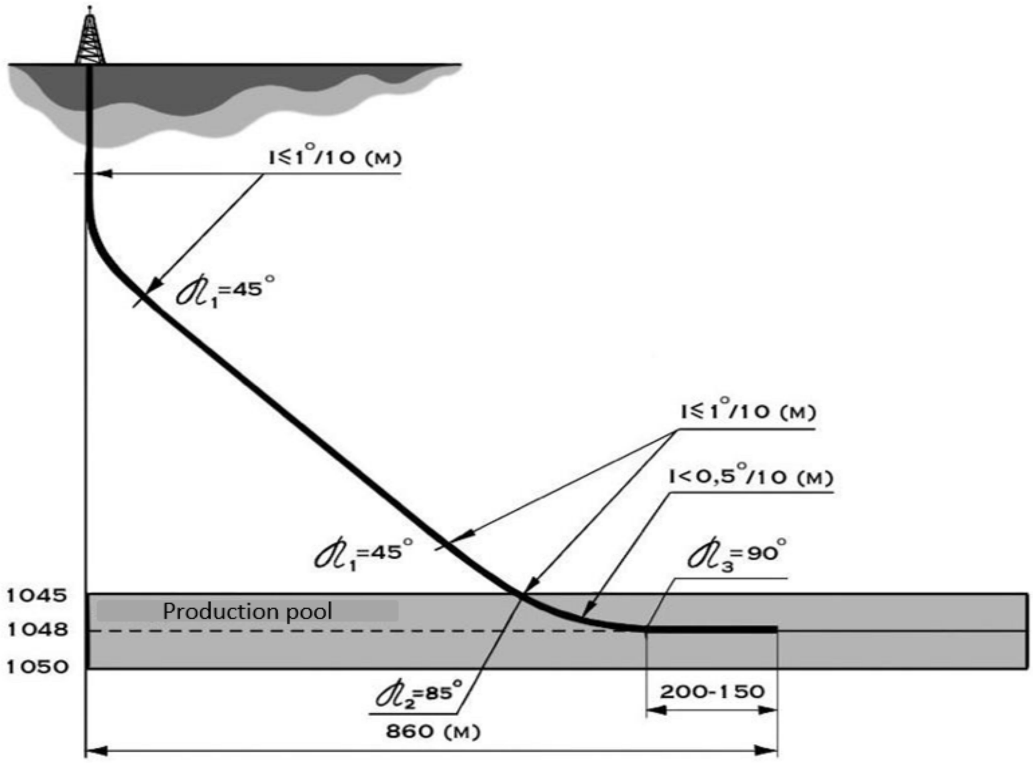

Figure 4.28 Profile of Horizontal well.

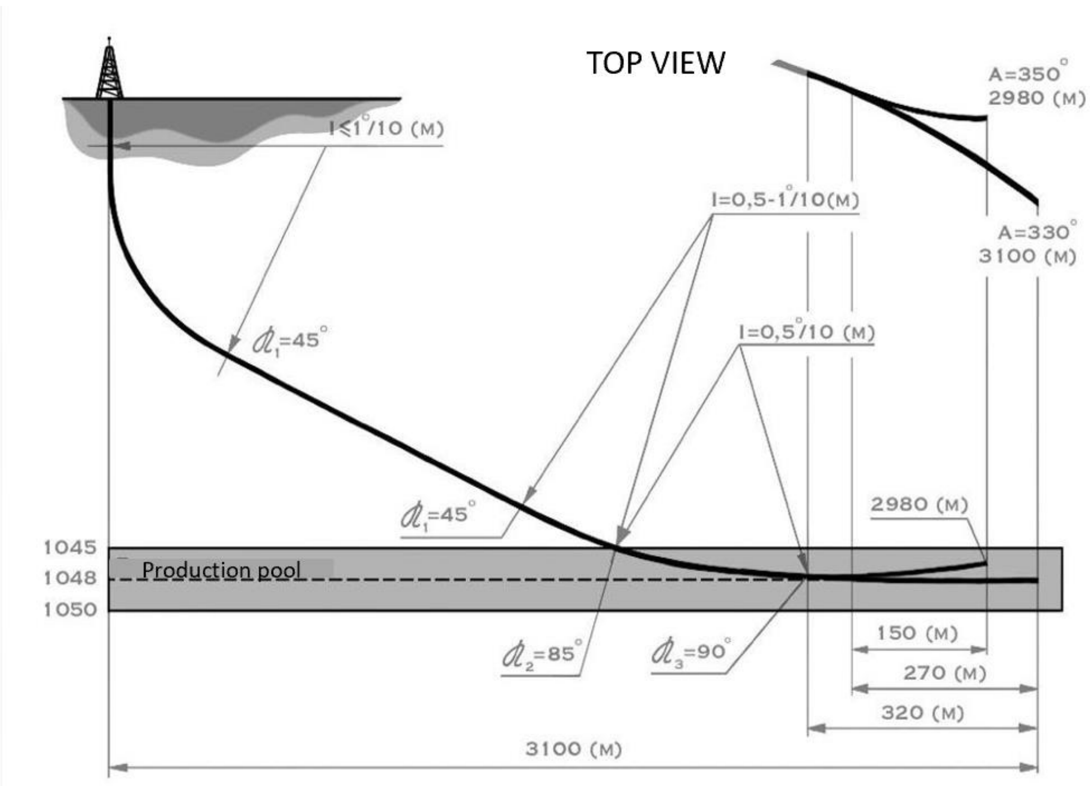

Figure 4.29 Profile of a multi-lateral well.

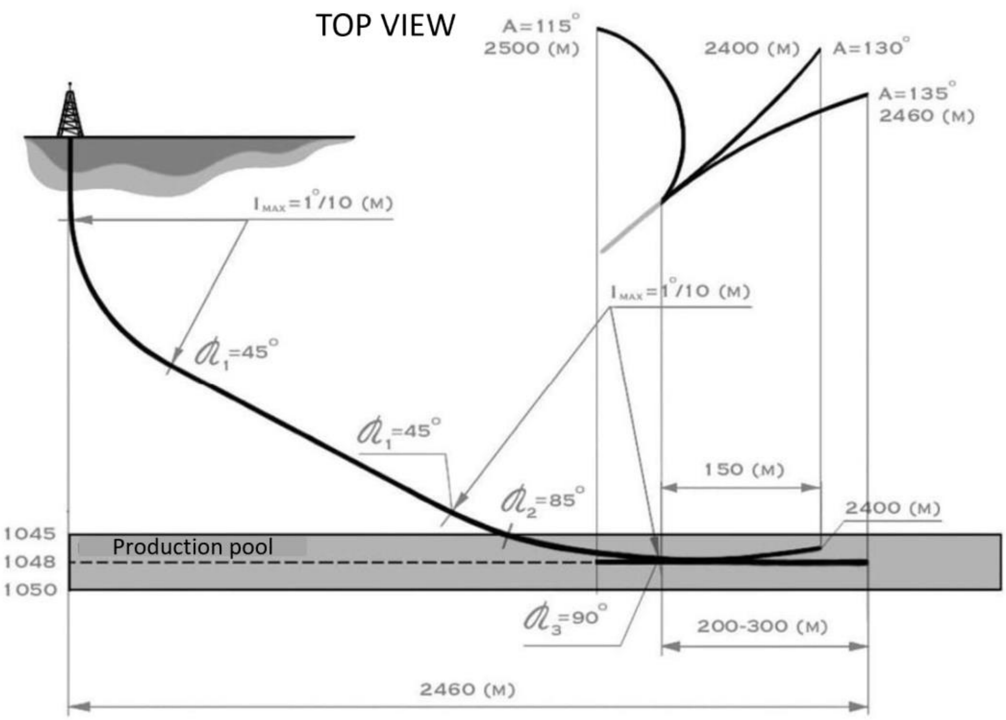

Figure 4.30 Profile of a multi-lateral well.

The main objects of the development of the Obskoye field are an ice-resistant platform of the block-conductor type and a pipeline from the field to the Parusnyi GTU.

Ice-resistant block-conductor – is used as a conductor for drilling production wells, placing wellheads and fountain equipment of wells and carrying out maintenance and maintenance work. Ice-resistant block-conductor, as well as other types of platforms under consideration, have a well-developed foundation plate, the main purpose of which is to reduce the risk of erosion of the soil base from the action of currents and waves.

Inside the support part are also placed: fountain fittings, switch lines, manifolds and access ladders. **Figure 4.31** and **Figure 4.32** show a view of the Ice-resistant block-conductor. After completion of the drilling work on the roof (deck) Ice-resistant block-conductor will install a crane for lifting small loads.

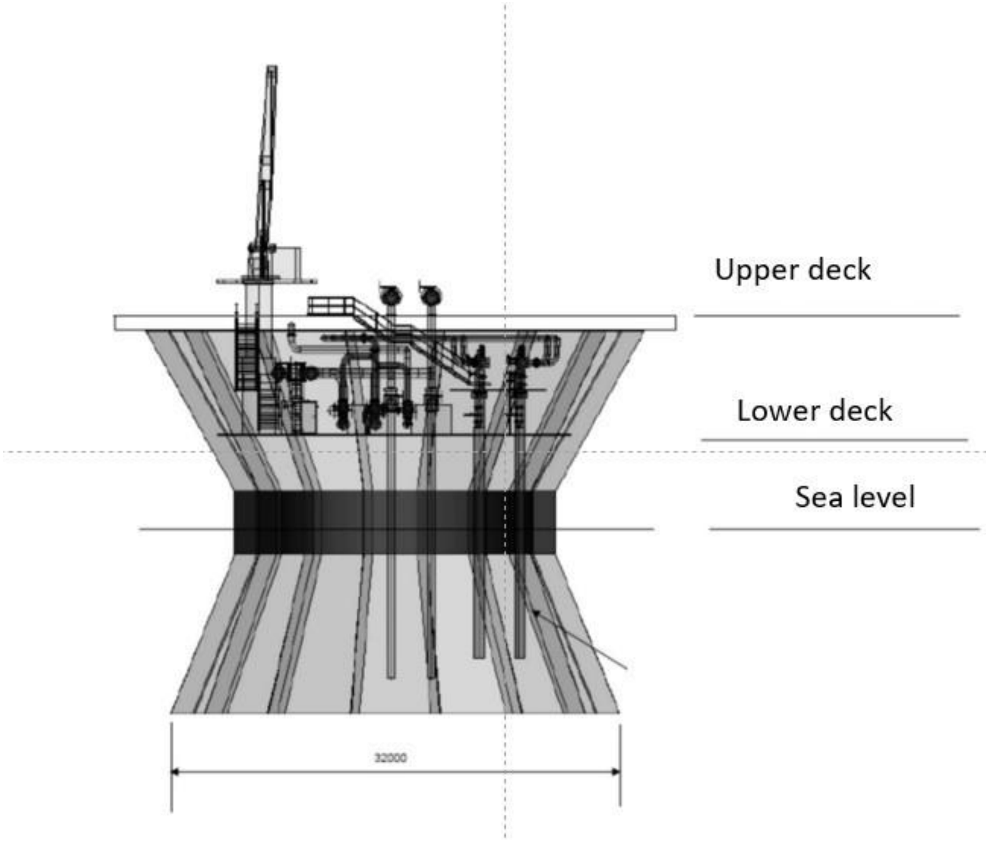

Figure 4.31 General scheme of Ice-resistant block-conductor (side view).

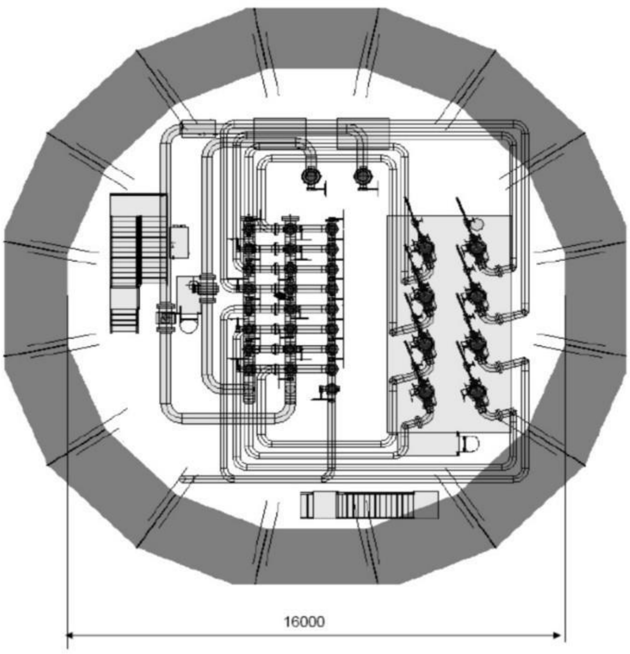

Figure 4.32 General scheme of Ice-resistant block-conductor (top view).

It is planned to use a small–sized ice-resistant platform, designed for operation in an automatic unpopulated mode, which will reduce the cost and construction time, expand the possibilities of its manufacture. The possibility of using the platform is associated with the construction of offshore ice-resistant drilling rig, with the help of which year-round drilling of wells through platform is provided. Inside the platform housing there are 3 water separation columns for drilling wells, two pipeline risers for gas transportation with a diameter of 200 mm.

The structures under consideration must meet the following basic requirements:

- to ensure safe year-round operation in the natural conditions of the Ob Bay;
- to ensure the performance of technological functions provided for by technological schemes of field development.

Mobile ice-resistant drilling rig is necessary for drilling production wells in a year-round continuous mode when using Ice-resistant block-conductor or underwater production unit for field development.

In non-freezing waters, in which there are no problems associated with ice, for similar purposes, conventional jack-up drilling rigs with an overboard console are used.

Drilling of wells in the Ob Bay using jack-up drilling rig and Ice-resistant block-conductor is possible, but only during the navigation period. With this approach, the drilling of a cluster of 3 wells will last 3 years at the rate of one well per season.

With the use of mobile ice-resistant drilling rig, a cluster of 3 wells with underwater or above-water wellheads is supposed to be drilled within 1 year. There are no operating mobile ice-resistant drilling rigs in the world.

There are still unrealized plans to create such a facility to work in shallow areas of the Northern Caspian Sea, where the possibility of using underwater production complexes is also being considered.

The proposed mobile ice-resistant drilling rig design combines the properties and advantages of a submersible type platform when it is in operation, and a jack-up type platform when crushing and removing support columns from the ground is performed. In this sense, the proposed design is combined. The mobile ice-resistant drilling rig is designed for use at water depths up to 15 m. The lower limit will depend on the size of the rig.

Structurally, the mobile ice-resistant drilling rig contains a floating hull with ballast compartments, guide shafts in which support columns are located, freely passing through them, and mechanisms for vertical movement of support columns.

Adjustable sealing devices with remote control are installed at the exit points of the support columns from the housing, ensuring the pinching of the support columns in the housing.

On the bottom of the hull there are "skirt" structures with a height of 1.5 m. The platform body is made in ice-resistant design, has double sides and a bottom. The shape of the case meets the requirements of joint work with the mobile ice-resistant drilling rig, as a result of which the Ice-resistant block-conductor can be installed at a minimum distance from it.

To install the tower-winch unit above the wellheads located on the Ice-resistant block-conductor, the platform has a retractable console.

During drilling, the console can be supported by a block conductor. Cylindrical support columns with a diameter of 6 m.

The walls of the support columns have a variable value – the maximum thickness is assumed to be 80 mm. The performed calculations of stability on the ground under the influence of global ice load showed that this design of the mobile ice-resistant drilling rig meets the operating safety conditions in the Ob Bay.

The characteristics of the upper structure of the mobile ice-resistant drilling rig, except for lifting mechanisms, are approximately adopted by analogy with the upper structure of the Ice-resistant block-conductor for drilling wells.

Mobile ice-resistant drilling rig with an installed complex of drilling and auxiliary equipment, with support columns raised to the maximum upper position, are towed to the installation site afloat due to the hull's own buoyancy. At the drilling point, with the help of lifting mechanisms, the support columns are lowered down and crushed into the bottom soil, also using the own weight of the platform body with installed equipment. By receiving water into the ballast compartments, the platform body is immersed to the bottom of the water area.

The ascent mobile ice-resistant drilling is provided in the reverse sequence: using remote control, the sealing devices are unclenched and the support columns are released from the clamps.

The ballast compartments of the hull are blown through, using the buoyancy force, and the hull is torn off from the bottom of the water area. If necessary, in order to overcome the forces of adhesion of the hull to the bottom, the bottom washout system is activated.

Having a positive buoyancy, the platform body moves along the support columns and floats to the surface of the water. With the help of lifting mechanisms and using the lifting force of the housing, the support columns are removed from the ground.

The general and top view of the mobile ice-resistant drilling r is shown in **Figure 4.33**. The sequence of work on installing the mobile ice-resistant drilling rig at the drilling point is shown in **Figure 4.34**.

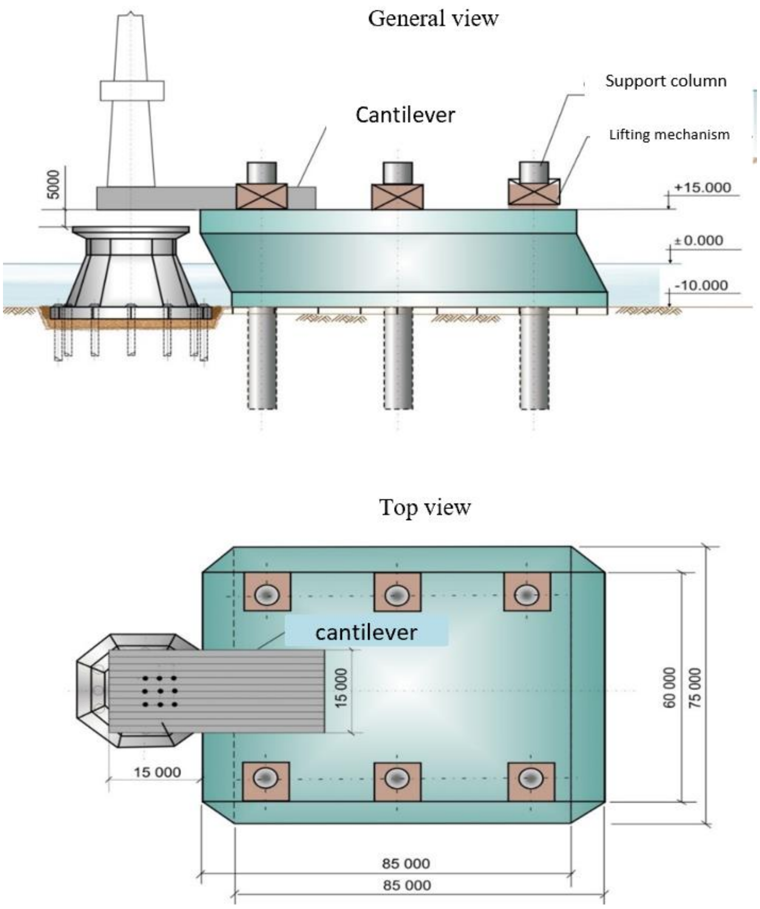

Figure 4.33 General view and top view of Mobile ice-resistant drilling rig.

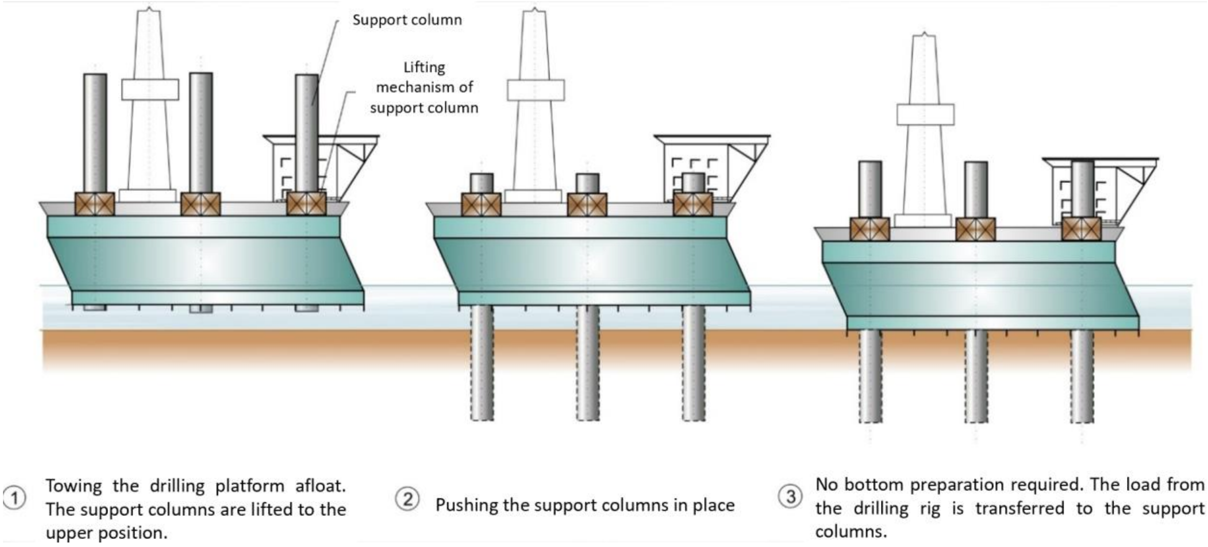

Figure 4.34 The sequence of installation of the Mobile ice-resistant drilling rig.

4.3.3 Recommendations for further exploration of the Obskoye field

Detailed areal works of the OGT MOU have been carried out at the Ob deposit (12/00), which made it possible to prepare the uplift for deep exploratory drilling by Cenomanian and Albaptian deposits (1999). The reservoir K2s Cenomanian, PK1 was studied by a uniform network of seismic profiles (2x3 km). Based on these geological and geophysical data, considering the results of the construction of the well № 1-Obskaya geological model was built. At the moment, the stage of geological exploration of the subsurface is over. There are no plans to carry out additional seismic surveys at the Ob deposit.

The Ob deposit currently has 100% confirmed reserves of category B1 in the Cenomanian, PK1 K2 formation. Exploration and evaluation well № 1-Obskaya was stopped at the bottom of 2230 m in the Aptian sediments. Core sampling was carried out in the well, a GIS complex was performed, and Cenomanian sediments were tested in the range of 1066 1076 m. When testing the well, a gas inflow was obtained. The gas flow rate at the 22.2 mm fitting was 425 thousand m^3/day.

Further additional exploration activities will be carried out at the stage of production drilling. At the stages of drilling and operation of the field, the refinement of the object under development takes place. Based on the results of the clarification, if necessary, the gas reserves are clarified and an addendum to the project document for the development of the field is drawn up. In preparation for the development of the Cenomanian deposit, cluster production drilling of four wells will be carried out. During the construction of production wells, a complex of geophysical studies will be carried out.

To improve the geological and hydrodynamic models of the Cenomanian deposit of the Obskoye gas condensate firld being developed, it is recommended to perform additional studies (GIS) in production wells. Based on the results of these studies, it is necessary to carry out thematic and research works: "Comprehensive studies of core and reservoir fluids in order to clarify the permeability and porosity of the Cenomanian deposit of the Ob deposit" and further - research on the construction of updated geological and hydrodynamic models of the Cenomanian deposit of the Ob field as part of the preparation of a new project document for development.

To prevent risks during drilling, it is necessary to provide an appropriate temperature regime of the drilling fluid and appropriate technical solutions during the construction of the well.

Chapter 5 - The main options for the complex arrangement of the Ob-Taz Bay

The concept of the development of the fields of the Ob and Taz Bays suggests starting gas production from the Kamennomyssky-more. Severo-Kamennomysskoye will be put into operation next. The expected combined production volume at the two fields is 30 billion cubic meters. m per year. After that, the fields of the Parusovaya group and Semakovskoye will be involved in the development, and then — Tota-Yakhinskoye and Antipayutinskoye, located near the northern shore of the Taz Bay. Previously, the Obskoye field was not even shown on the initial charts of options for the integrated development of the Ob-Taz Bay, due to small hydrocarbon reserves. After the assessment of reserves carried out in accordance with the new classification of hydrocarbon reserves, which came into effect on 01.01.2016, gas reserves amounted to 23,865 million m³.

Gas production in the Ob-Taz Bay according to the variants are shown in **Figure 5.1** - **Figure 5.3**.

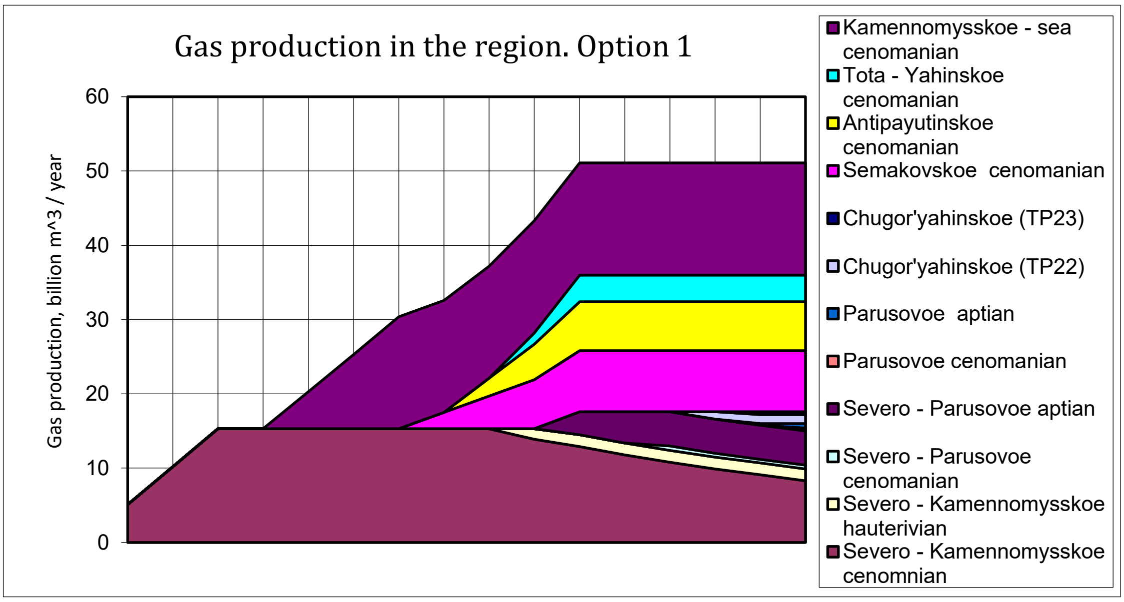

Figure 5.1 Gas production in the region. Option 1.

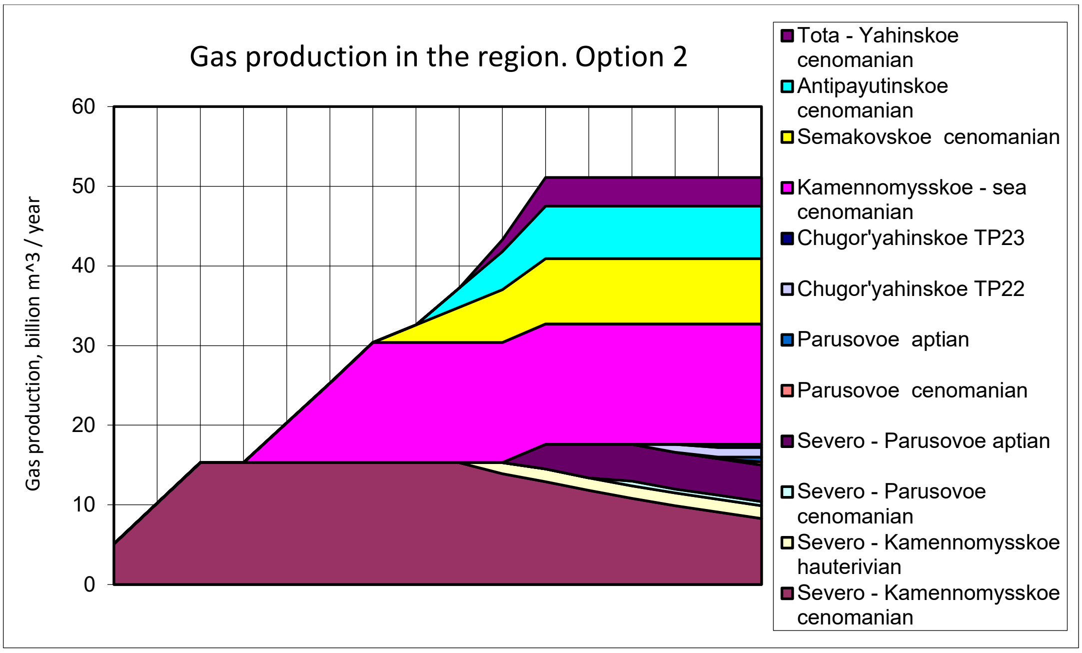

Figure 5.2 Gas production in the region. Option 2.

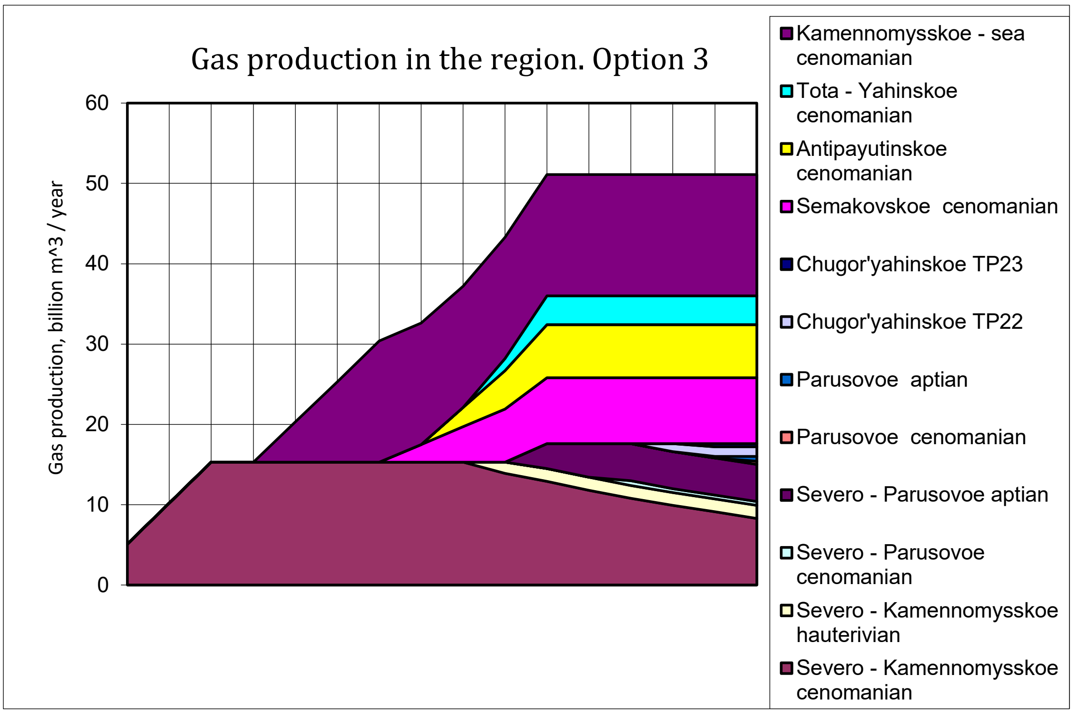

Figure 5.3 Gas production in the region. Option 3.

The commissioning of the Ob deposit into development is planned to be carried out during the period of falling production volumes and unloading of the production capacities of the onshore GTU.

Chapter 6 - Options for transporting gas from the Obskoye field

To determine the rational diameter of the main pipeline, calculations were carried out using the PIPEPHASE software product. 2 pipeline diameters of 254mm and 200mm were considered. The recommended internal diameter of the pipeline is 200 mm. During the calculations, the pipeline was divided into 3 sections: 15 km, 15 km, 11.5 km. The total length from the Ob deposit to the GTU at Cape Parusnyi is 41.5 km. Installation of a compressor station is not required. The results of the initial pressure calculation are presented in the **Table 6.1**.

Table 6.1 Initial pressure calculation results.

Years and periods	gas flow rate, 1000 m 3/day	Initial pressure, MPa	Wellhead pressure, MPa	Pressure at the entrance to the GTU, MPa
1 year	804	4,94	5,5	2,83
5 years	640	3,81	5,05	1,73
10 years	461	3	4,46	1,73
15 years	475	3,06	3,23	1,73
20 years	401	2,74	2,83	1,73
25 years	335	2,6	2,45	1,73
30 years	271	2,31	2,25	1,73
35 years	218	2,12	2,08	1,73
40 years	172	1,85	1,95	1,73

In accordance with the provided technological schemes of arrangement, the assessment of the economic efficiency of the development of the Ob deposit was carried out for the case of joint development with the Kamennomysskoye-More and Severo-

Kamennomysskoye fields with the connection of a gas pipeline to the GTU of cape Parusnyi. Gas transportation options:

- At GTU of cape Parusnyi; (**Figure 6.1**)
- At GTU - 2 Yamburg oil-gas-condensate field;
- At the village Yamburg for the use of gas for their own needs and as fuel for a power plant;
- At GTU of Ugno-Parusnyi field;
- Gas supply to the Ice-resistant block-conductor A platform of the Kamennomysskoye-more field;

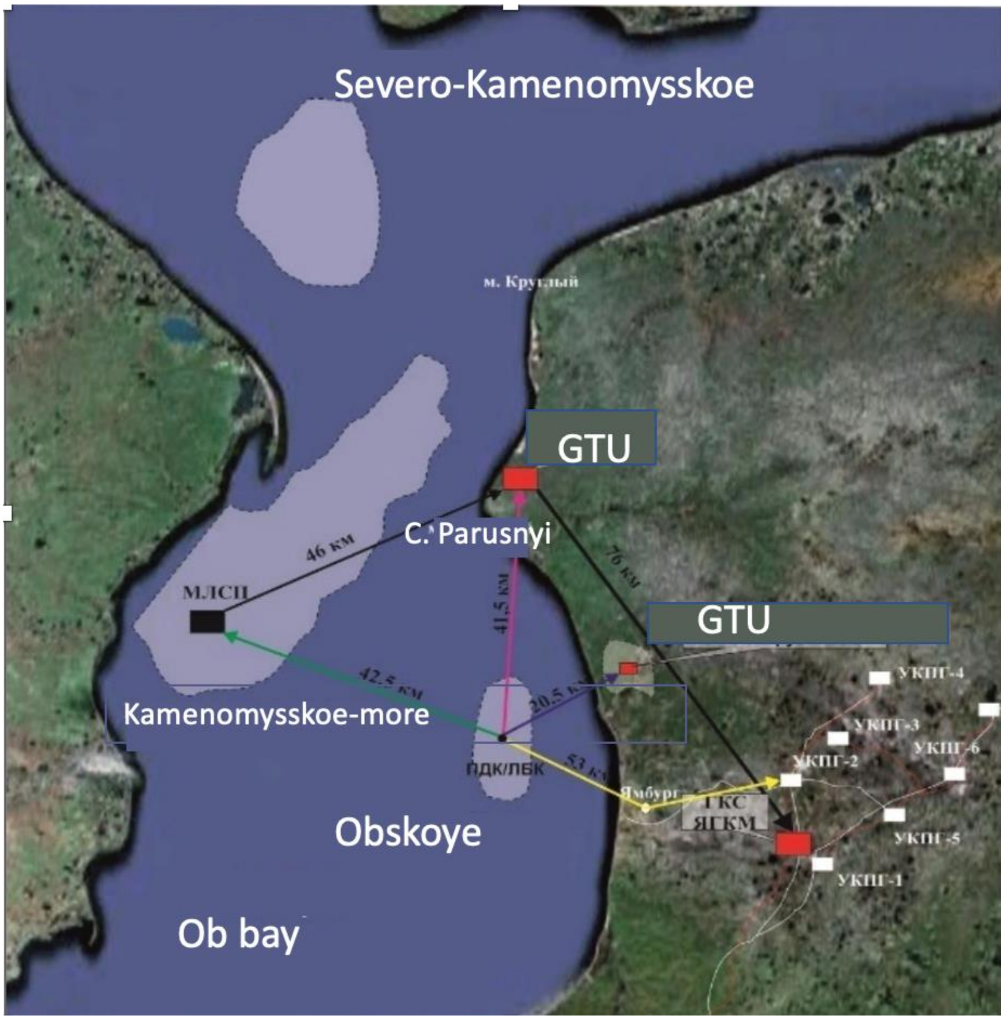

Figure 6.1 Gas transportation options.

The option of transporting gas to the projected gas storage facility in the area of Cape Parusnyi is recommended, since in comparison with other options it seems rational, meets the recommendations for the integrated development of deposits in the region.

The field is not supposed to install additional facilities for compressing or preparing well products.

The collection system is represented by a manifold in the underwater well module. further production of wells without preliminary preparation is sent to onshore facilities via a pipeline with a nominal diameter of 200 mm and a length of 41.5 km, of which 38.5 km is offshore and 3 km in the coastal part. Further, the production of wells is combined with the flow from the fields of Severo-Kamennomysskoye and Kamennomysskoye - more.
Hydraulic and thermal calculations of well production flow modes were carried out using Pipesim software.

Pipeline diameters were determined based on two main requirements:

- minimization of hydraulic losses in pipelines and ensuring maximum use of reservoir energy;
- ensuring stable and uniform removal of gas condensate products from underwater pipelines.

It is known that when promoting reservoir products to the well faces, it also contains free water. The thermohydraulic calculations carried out were made under the assumption that free water is brought to the surface in a volume equal to the volume of condensation water under reservoir conditions. The analysis of the thermobaric operating conditions of the pipelines of the gas collection system indicates the possibility of hydrate formation in the pipelines and to ensure their reliable operation at the design capacity, it will be necessary to use anti-hydrate measures. As the main antihydrate agent, it is recommended to feed an aqueous solution of methanol of 70% concentration into the flow of reservoir products.

The hydrate formation inhibitor is intended to be introduced into the flow of reservoir products at the wellhead. According to the estimates, in order to prevent hydrate formation in the pipelines of the gas collection system, a methanol consumption of 6-8 g/m^3 will be required. Hydraulic and thermal calculations of the flow modes of multiphase flows in gas pipelines were also carried out using the licensed PipeSim software product. The Peng-Robinson equation was used as the thermal equation of state, which makes it possible to adequately calculate the gas-liquid equilibrium of gas condensate systems, as well as their thermodynamic and thermophysical properties. When carrying out hydraulic calculations, data on design (by year) gas withdrawals from wells and wellhead pressure values were used.

The following values of the temperature of reservoir products at the wellhead and bottom layers of seawater and the temperature of the base soils on the onshore section of the gas pipeline collector were used to assess the thermal operating conditions of the pipelines of the gas collection system:

- The temperature of reservoir production at the wellhead (up to the fitting) is assumed to be equal to 15 °C at maximum well debits.
- The temperature of the bottom layers of seawater was assumed to be equal to 2 °C;
- The ambient temperature for the onshore section of the pipeline was assumed to be equal to 5 °C (Gazprom Dobycha Yamburg LLC, 2018).

Information about the route profile is taken from a digital model of geological heights and a bathymetry map using the satellite information system Kara Sea software package. Ob and Taz bays. The profile of the route is shown in the **Figure 6.2**

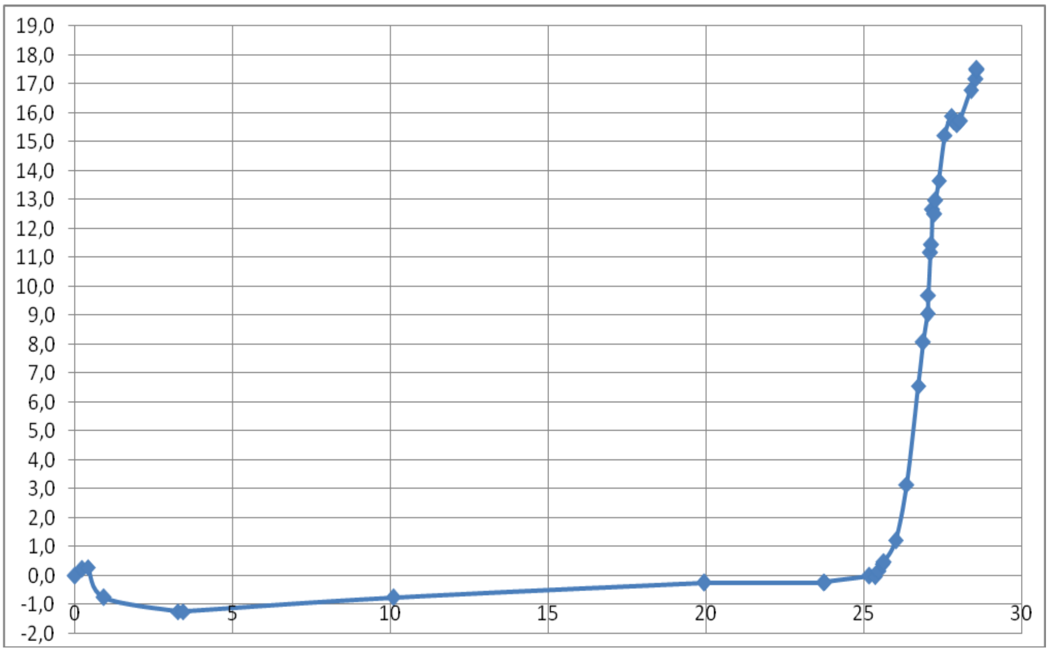

Figure 6.2 The profile of the route for the option of transporting gas to Cape Parusnyi.

According to the calculations, the minimum wall thickness will be less than 4 mm. According to the requirements of the regulatory document, the wall thickness is assumed to be 4 mm. According to the recommendation for anticorrosion measures, a 3-millimeter allowance for general corrosion is accepted. As a result, the wall thickness is assumed to be 7 mm. Passive and active means of protection are provided to prevent corrosion of the outer surface of the pipes.

As a passive means of protection, it is recommended to use an external epoxy-polyethylene coating, which is a multi-layer system.

The ice situation in the area of deposits and construction sites is characterized by the presence of drifting ice, ice hummocks and stamukhs. Consequently, there is a risk of damage to offshore pipelines by dams in the coastal zone, which is eliminated by compliance with the criteria of sinking. By analogy with pipeline solutions, in the development projects of the Severo-Kammenomysskoye field and the Kammenomysskoye-Sea field, the pipeline is laid in a trench at a depth of 3 meters from the upper forming pipeline along its entire length. Additional protection in the form of a concrete coating is not provided.

6.1 Evaluation of the economic efficiency indicators of the proposed option

In accordance with the technological schemes provided for the arrangement, an assessment of the economic efficiency of the Ob deposit was carried out.

The assessment was carried out for cases of joint development of the fields of Severo-Kamennomysskoye and the place of birth of Kammenomysskoye-more with connection to the GTU of cape Parusnyi and for autonomous development of the Obskoye field.

Table 6.2 presents the summary indicators of the recommended option for the development of the Ob gas field, based on the results of technical and economic calculations, taking into account their joint arrangement (DOAO CCBN of Gazprom OJSC Podolsk, 2013).

Table 6.2 Indicators of economic efficiency of the recommended option.

	Indicators	**Autonomous development of the Ob deposit**	**Joint development of Kamenomysskoe-more, Severo-Kamennomysskoe and Ob fields**
1	Commodity volume of gas billion, m^3	3,51	572,5
2	Revenue from gas sales, million rubles	11923	1943039
3	Capital investments, million rubles	9424	339233
4	Operating costs, million rubles	13580	1016281
5	Payback period, years	16	9,8

For the development of the field with connection to the GTU at cape Parusnyi. the total volume of capital investments is 9424 million rubles. Revenue from the sale of gas during the development of the Ob field with the connection of the gas pipeline to the GTU at cape Parusnyi reaches 11923 million rubles.

Chapter 7 - Conclusions

1. The well-known conceptual solutions for the complex development and operation of deposits and structures of the regions of the Barents, Pechora, Kara Seas, Ob and Taz bays are considered, allowing to increase the economic indicators of the development of deposits in the region as a whole or groups of deposits.

2. Currently, the gas reserves of the Obskoye field have been reapproved and amounted to 23.865 billion m^3, which was the basis for the development of a new project in the system of integrated development of the Kamennomysskoye-More and Severo-Kamennomysskoye fields.

3. The technical and technological indicators of the field are considered, taking into account new gas reserves (23.865 billion m^3):

    - fund of production wells (3);
    - number of well clusters (1);
    - volume of cumulative production - 18,220 million cubic meters.

4. Options of technological schemes of arrangement of both underwater and surface location of wellheads are considered.

5. Based on the analysis and comparison of the terms of commissioning of the production wells fund, a solution for the construction of multi-lateral wells with an above-water location of the mouths on a platform of the ice-resistant block-conductor type is proposed as the main variant of the arrangement scheme.

6. For the effective development of the production wells fund, the use of mobile ice-resistant drilling rig is proposed, which provides year-round construction of wells. Based on the fact that drilling of the entire fund of wells can be carried out within one year with the help of mobile ice-resistant drilling rig, preference is given to this option.

7. The estimated calculations of gas transportation to the gas storage facility at Cape Parusnyi by a pipeline with a length of 41.5 km and a diameter of 200 mm

8. The results of the evaluation of the effectiveness of the implementation of the Obskoye field development project show that in the conditions of the current tax legislation, with the necessary amounts of capital investments, operating costs, all options are characterized by negative values of NPV. However, at complex development of Obskoye field with the Kamennomysskoye Sea and Severo-Kamennomysskoye fields, the proceeds from the sale of the extracted gas may amount to 1 943 039 million rubles for the field.

References

Aliyev, Z. S., Andreev, S. A., Vlasenko, A. P., & Korotaev, Y. P. (1978). Technological mode of operation of gas wells.

DOAO CCBN of Gazprom OJSC Podolsk. (2013). Justification of investments in the development of the Kamennomysskoye-More gas field. The main technical and technological solutions for the development of the field. Arrangement schemes.

DOAO CCBN of Gazprom Podolsk. (2012). *The development project of the Severo-Kamennomysskoye gas condensate field*.

Gazprom-VNIIGAZ LLC. (2006). *Project technological document for the development of the Severo-Kamennomysskoye gas field of Gazprom-VNIIGAZ LLC*.

Gazprom Dobycha Yamburg LLC. (2018). *Supplement to the technological scheme for the development of the Ob gas field in the waters of the Ob Bay of the Kara Sea by Gazprom VNIIGAZ LLC*.

Geonedra. (2018). Leningradskoye gas condensate feild is a unique resource-forming field in a promising gas-forming cluster of the Kara Sea shelf. (History, available results and development prospects). https://geonedra.ru/2018/leningradskoe-mestorozhdenie-shelf/

Khoshtaria V.N., K. V. A., Rybnikov A.N. et al. (2021). Bulletin of the Association of Drilling Contractors №4.

Mirzoev, D. (2008). Fundamentals of offshore oil and gas fields: state, problems and prospects: Collection of scientific papers.

Neftegaz. (2021). *Evolution of technical solutions for the Shtokman gas condensate field and a modern view of its arrangement*. https://magazine.neftegaz.ru/articles/shelf/677243-evolyutsiya-tekhnicheskikh-resheniy-dlya-shtokmanovskogo-gkm-i-sovremennyy-vzglyad-na-ego-obustroyst/

Rokos, S. I., Kulikov, S. N., Skurikhin, V. N., & Sokolov, V. P. (2020). Offshore stratigraphy and litology of Ob and Taz Bays of the Kara Sea. *Relief and quaternary formations of the Arctic, Subarctic and Northwestern Russia*(7), 164-167. https://doi.org/doi:10.24411/2687-1092-2020-10725

VD-TV. (2019). *Prirazlomnoye field – efficient production*. https://vd-tv.ru/content/prirazlomnoe-mestorojdenie-effektivnaia-dobycha-nefti

Vovk V.S., S. R. O., Mirzoev D.A. (2008). State and prospects of development of offshore oil and gas fields. *Scientific research of Gazprom-VNIIGAZ LLC Development of offshore oil and gas fields: state, problems and prospects of VNIIGAZ LLC*.

Appendix A - Technological indicators of the development of the Obskoye field

Table A.1 Technological indicators of the development of the Obskoye field (as a whole)

№	Parameter	Unit	Years									
			1	2	3	4	5	6	7	8	9	10
1	Residual reserves of free gas	Mln m³	17386	16843	16078	15124	14236	13435	12688	11984	11313	10673
2	Free gas production since the beginning of development	Mln m ³	279	823	1588	2541	3429	4231	4978	5682	6353	6992
3	Gas extraction coefficient		0,012	0,034	0,067	0,106	0,144	0,177	0,209	0,238	0,266	0,293
4	Production of free gas total	Mln m ³	279	544	765	953	888	802	747	704	671	639
5	Gas consumption for own needs,	Mln m ³	7,3	12,7	21,1	19,5	22,2	20,3	19,2	17,2	16,6	16,0
6	including technological needs,	Mln m ³	2,5	2,5	2,4	0,3	0,3	0,3	0,3	0,2	0,2	0,2
7	Commissioning of new production and injection wells from drilling	Well	1	1	1	1						
8	– including from production drilling	Well	1	1	1	1						
9	– including from exploratory drilling	Well										
10	Transfer of wells from other categories	Well										
11	Transfer of wells from other facilities	Well										
12	Average depth of a new well	M	1048	1048	1048	1048						
13	Production drilling of all	1000 m	2,8	2,8	3,8	3,8						
14	Fund of producing gas wells at the end of the year	Well	1	2	3	4	4	4	4	4	4	4
15	The current fund of producing gas wells at the end of the year	Well	1	2	3	4	4	4	4	4	4	4
16	Disposal of producing wells	Well										
17	Injection wells commissioning	Well										
18	Disposal of injection wells	Well										
19	Injection wells fund at the end of the year	Well										
20	The current fund of injection wells at the end of the year	Well										
21	Gas production from new wells	Mln m ³	279	272	255	238						
22	Average flow rate of a new gas well	1000m³/day	804	784	735	687						
23	Average number of days of operation of a new well	days	347	347	347	347						

24	Estimated gas production from new wells of the previous year in this year	Mln m ³		272	255	238	222					
25	Expected estimated gas production from transferred wells of this year	Mln m ³		272	510	715	888	802	747	704	671	639
26	Gas production from transferred wells	Mln m ³		272	510	715	888	802	747	704	671	639
27	Change in gas production from transferred wells	Mln m ³	0	0	238,0	205,0	173,1	-86,3	-54,9	-42,9	-32,9	-31,8
28	Coefficient of change in gas production from transferred wells		0,00	0,00	0,47	0,29	0,19	-0,11	-0,07	-0,06	-0,05	-0,05
29	Average operating fund of transferred wells	well		2	3	4	4	4	4	4	4	4
30	Average flow rate of transferred gas wells	1000m³/day		784	735	687	640	578	538	507	483	461
31	Average intake rate of injection wells for gas	1000m³/day										
32	Average number of days of operation of the transferred well	Days		347	347	347	347	347	347	347	347	347
33	Gas injection	Mln m ³										
34	Gas injection since the beginning of development	Mln m ³										
35	Selection compensation current	%										
36	Compensation of selection from the beginning of development	%										
37	Average reservoir pressure at the end of the year	MPa	10,2	10,0	9,7	9,4	9,0	8,7	8,5	8,2	7,9	7,7
38	Average wellhead (working) pressure at the end of the year	MPa	5,5	5,3	4,9	4,8	5,0	5,0	4,9	4,7	4,6	4,5
39	The rate of gas extraction from the initial approved reserves	%	1,2	2,3	3,2	4,0	3,7	3,4	3,1	2,9	2,8	2,7
40	Rate of gas extraction from current approved reserves	%	1,2	2,3	3,3	4,3	4,2	3,9	3,8	3,7	3,7	3,7
41	Stable condensate content	g/m³										
42	Condensate extraction	1000 t										
43	Condensate extraction since the beginning of development	1000 t										
44	Technological losses of condensate	%										
45	Condensate extraction coefficient											

Table A.2 Technological indicators of the development of the Obskoye field (as a whole)

№ п/п	Parameter	Unit	Years									
			11	12	13	14	15	16	17	18	19	20
1	Residual reserves of free gas	Mln m³	10063	9478	8917	8384	7890	7412	6947	6500	6068	5650
2	Free gas production since the beginning of development	Mln m ³	7603	8187	8749	9281	9775	10254	10718	11166	11598	12016
3	Gas extraction coefficient		0,319	0,343	0,367	0,389	0,410	0,430	0,449	0,468	0,486	0,503
4	Production of free gas total	Mln m ³	611	584	561	532	494	478	464	448	432	418
5	Gas consumption for own needs,	Mln m ³	15,5	15,1	14,7	13,1	12,3	12,0	11,9	11,7	11,5	11,3
6	including technological needs,	Mln m ³	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,1
7	Commissioning of new production and injection wells from drilling	Well										
8	– including from production drilling	Well										
9	– including from exploratory drilling	Well										
10	Transfer of wells from other categories	Well										
11	Transfer of wells from other facilities	Well										
12	Average depth of a new well	M										
13	Production drilling of all	1000 m										
14	Fund of producing gas wells at the end of the year	Well	4	4	4	3	3	3	3	3	3	3
15	The current fund of producing gas wells at the end of the year	Well	4	4	4	3	3	3	3	3	3	3
16	Disposal of producing wells	Well				1						
17	Injection wells commissioning	Well										
18	Disposal of injection wells	Well										
19	Injection wells fund at the end of the year	Well										
20	The current fund of injection wells at the end of the year	Well										
21	Gas production from new wells	Mln m ³										
22	Average flow rate of a new gas well	1000m³/day										
23	Average number of days of operation of a new well	days										
24	Estimated gas production from new wells of the previous year in this year	Mln m ³										
25	Expected estimated gas production from transferred wells of this year	Mln m ³	611	584	561	532	494	478	464	448	432	418

26	Gas production from transferred wells	Mln m ³	611	584	561	532	494	478	464	448	432	418
27	Change in gas production from transferred wells	Mln m ³	-28,6	-26,2	-23,2	-28,8	-38,1	-15,8	-14,3	-16,7	-15,2	-14,8
28	Coefficient of change in gas production from transferred wells		-0,05	-0,04	-0,04	-0,05	-0,08	-0,03	-0,03	-0,04	-0,04	-0,04
29	Average operating fund of transferred wells	well	4	4	4	3	3	3	3	3	3	3
30	Average flow rate of transferred gas wells	1000m³/day	440	421	404	384	475	460	446	430	415	401
31	Average intake rate of injection wells for gas	1000m³/day										
32	Average number of days of operation of the transferred well	Days	347	347	347	347	347	347	347	347	347	347
33	Gas injection	Mln m ³										
34	Gas injection since the beginning of development	Mln m ³										
35	Selection compensation current	%										
36	Compensation of selection from the beginning of development	%										
37	Average reservoir pressure at the end of the year	MPa	7,5	7,3	7,0	6,8	6,7	6,5	6,3	6,1	6,0	5,8
38	Average wellhead (working) pressure at the end of the year	MPa	4,3	4,2	4,1	3,3	3,2	3,1	3,0	3,0	2,9	2,8
39	The rate of gas extraction from the initial approved reserves	%	2,6	2,4	2,4	2,2	2,1	2,0	1,9	1,9	1,8	1,7
40	Rate of gas extraction from current approved reserves	%	3,6	3,6	3,6	3,5	3,4	3,4	3,4	3,4	3,4	3,4
41	Stable condensate content	g/m³										
42	Condensate extraction	1000 t										
43	Condensate extraction since the beginning of development	1000 t										
44	Technological losses of condensate	%										
45	Condensate extraction coefficient											

Table A.3 Technological indicators of the development of the Obskoye field (as a whole)

№ п/п	Parameter	Unit	Years									
			21	22	23	24	25	26	27	28	29	30
1	Residual reserves of free gas	Mln m³	5246	4857	4482	4120	3772	3437	3116	2808	2513	2231
2	Free gas production since the beginning of development	Mln m ³	12420	12808	13184	13545	13894	14228	14549	14857	15153	15435
3	Gas extraction coefficient		0,520	0,537	0,552	0,568	0,582	0,596	0,610	0,623	0,635	0,647
4	Production of free gas total	Mln m ³	404	389	375	362	349	334	321	308	296	282
5	Gas consumption for own needs,	Mln m ³	9,8	9,6	9,5	9,3	9,1	8,5	8,1	7,8	7,5	7,2
6	including technological needs,	Mln m ³	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
7	Commissioning of new production and injection wells from drilling	Well										
8	– including from production drilling	Well										
9	– including from exploratory drilling	Well										
10	Transfer of wells from other categories	Well										
11	Transfer of wells from other facilities	Well										
12	Average depth of a new well	M										
13	Production drilling of all	1000 m										
14	Fund of producing gas wells at the end of the year	Well	3	3	3	3	3	3	3	3	3	3
15	The current fund of producing gas wells at the end of the year	Well	3	3	3	3	3	3	3	3	3	3
16	Disposal of producing wells	Well										
17	Injection wells commissioning	Well										
18	Disposal of injection wells	Well										
19	Injection wells fund at the end of the year	Well										
20	The current fund of injection wells at the end of the year	Well										
21	Gas production from new wells	Mln m ³										
22	Average flow rate of a new gas well	1000m³/day										
23	Average number of days of operation of a new well	days										
24	Estimated gas production from new wells of the previous year in this year	Mln m ³										
25	Expected estimated gas production from transferred wells of this year	Mln m ³	404	389	375	362	349	334	321	308	296	282

26	Gas production from transferred wells	Mln m ³	404	389	375	362	349	334	321	308	296	282
27	Change in gas production from transferred wells	Mln m ³	-13,4	-15,2	-13,7	-13,4	-12,9	-14,5	-13,3	-13,3	-12,2	-13,3
28	Coefficient of change in gas production from transferred wells		-0,03	-0,04	-0,04	-0,04	-0,04	-0,04	-0,04	-0,04	-0,04	-0,05
29	Average operating fund of transferred wells	well	3	3	3	3	3	3	3	3	3	3
30	Average flow rate of transferred gas wells	1000m³/day	388	374	360	347	335	321	308	296	284	271
31	Average intake rate of injection wells for gas	1000m³/day										
32	Average number of days of operation of the transferred well	Days	347	347	347	347	347	347	347	347	347	347
33	Gas injection	Mln m ³										
34	Gas injection since the beginning of development	Mln m ³										
35	Selection compensation current	%										
36	Compensation of selection from the beginning of development	%										
37	Average reservoir pressure at the end of the year	MPa	5,6	5,5	5,3	5,2	5,1	4,9	4,8	4,7	4,6	4,4
38	Average wellhead (working) pressure at the end of the year	MPa	2,7	2,7	2,6	2,5	2,5	2,4	2,4	2,3	2,3	2,2
39	The rate of gas extraction from the initial approved reserves	%	1,7	1,6	1,6	1,5	1,5	1,4	1,3	1,3	1,2	1,2
40	Rate of gas extraction from current approved reserves	%	3,4	3,4	3,4	3,4	3,4	3,4	3,3	3,3	3,3	3,2
41	Stable condensate content	g/m³										
42	Condensate extraction	1000 t										
43	Condensate extraction since the beginning of development	1000 t										
44	Technological losses of condensate	%										
45	Condensate extraction coefficient											

Table A.4 Technological indicators of the development of the Obskoye field (as a whole)

№ п/п	Parameter	Unit	Years									
			31	32	33	34	35	36	37	38	39	40
1	Residual reserves of free gas	Mln m³	1961	1702	1454	1217	990	773	565	367	179	0
2	Free gas production since the beginning of development	Mln m ³	15705	15964	16212	16449	16676	16893	17100	17298	17487	17666
3	Gas extraction coefficient		0,658	0,669	0,679	0,689	0,699	0,708	0,717	0,725	0,733	0,740
4	Production of free gas total	Mln m ³	270	258	248	237	227	217	208	198	189	179
5	Gas consumption for own needs,	Mln m ³	6,8	6,6	6,3	6,0	5,8	5,5	5,3	5,0	4,8	4,5
6	including technological needs,	Mln m ³	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
7	Commissioning of new production and injection wells from drilling	Well										
8	– including from production drilling	Well										
9	– including from exploratory drilling	Well										
10	Transfer of wells from other categories	Well										
11	Transfer of wells from other facilities	Well										
12	Average depth of a new well	M										
13	Production drilling of all	1000 m										
14	Fund of producing gas wells at the end of the year	Well	3	3	3	3	3	3	3	3	3	3
15	The current fund of producing gas wells at the end of the year	Well	3	3	3	3	3	3	3	3	3	3
16	Disposal of producing wells	Well										
17	Injection wells commissioning	Well										
18	Disposal of injection wells	Well										
19	Injection wells fund at the end of the year	Well										
20	The current fund of injection wells at the end of the year	Well										
21	Gas production from new wells	Mln m ³										
22	Average flow rate of a new gas well	1000m³/day										
23	Average number of days of operation of a new well	days										
24	Estimated gas production from new wells of the previous year in this year	Mln m ³										
25	Expected estimated gas production from transferred wells of this year	Mln m ³	270	258	248	237	227	217	208	198	189	179

26	Gas production from transferred wells	Mln m ³	270	258	248	237	227	217	208	198	189	179
27	Change in gas production from transferred wells	Mln m ³	-12,2	-11,6	-10,3	-11,1	-10,1	-10,0	-9,0	-10,1	-9,3	-9,7
28	Coefficient of change in gas production from transferred wells		-0,05	-0,04	-0,04	-0,05	-0,04	-0,05	-0,04	-0,05	-0,05	-0,05
29	Average operating fund of transferred wells	well	3	3	3	3	3	3	3	3	3	3
30	Average flow rate of transferred gas wells	1000m³/day	259	248	238	228	218	208	200	190	181	172
31	Average intake rate of injection wells for gas	1000m³/day										
32	Average number of days of operation of the transferred well	Days	347	347	347	347	347	347	347	347	347	347
33	Gas injection	Mln m ³										
34	Gas injection since the beginning of development	Mln m ³										
35	Selection compensation current	%										
36	Compensation of selection from the beginning of development	%										
37	Average reservoir pressure at the end of the year	MPa	4,3	4,2	4,1	4,0	3,9	3,8	3,8	3,7	3,6	3,5
38	Average wellhead (working) pressure at the end of the year	MPa	2,2	2,2	2,1	2,1	2,1	2,1	2,0	2,0	2,0	2,0
39	The rate of gas extraction from the initial approved reserves	%	1,1	1,1	1,0	1,0	1,0	0,9	0,9	0,8	0,8	0,7
40	Rate of gas extraction from current approved reserves	%	3,2	3,2	3,1	3,1	3,1	3,0	3,0	2,9	2,9	2,8
41	Stable condensate content	g/m³										
42	Condensate extraction	1000 t										
43	Condensate extraction since the beginning of development	1000 t										
44	Technological losses of condensate	%										
45	Condensate extraction coefficient											