On development of technology for protecting the potential of oil fields in the Far North

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Abstract. The Far North is the major oil and gas region in the Russian Federation. Large oil and gas fields occupy a special place. The economic attractiveness of fields and corresponding land plots contradicts the requirements for environmental protection, which raises the problem of rational and efficient land use. The analysis of literary sources and available techniques and technologies allows preserving the potential of the Far North deposits. In the study, the level of land disturbance and the corresponding environmental risks are analyzed. The most effective technology for reducing the adverse effect on the soil is described. Criteria for minimizing damage to the environment of the Far North are developed with due regard to regional features. The enhanced techniques and technological solutions, which increase the efficiency of the use of field areas with minimum environmental risks, are proposed and described in detail.

1. Introduction

In the Far North, where the construction, operation and abandonment of oil and gas wells are taking place, the Nenets, indigenous smaller-numbered peoples of the north, are engaged in traditional economic activities, reindeer husbandry, fishing, hunting, and gathering wild plants.

The Nenets need vast territories with no intensive development of oil and gas production. Unlike the Khanty-Mansiysk Autonomous Okrug, Yugra, there are no communities and ancestral lands of the indigenous peoples of the North, the ancestral lands of reindeer breeders and fishermen registered in accordance with the legislation of the Russian Federation [1]. The climatic conditions of the fields in the Far North and the vulnerable flora and fauna have a significant impact on the organization of production at the oil and gas complex.

All this requires constant monitoring of the environmental protection and the protection of hardly renewable land resources, as well as the use of technical solutions for the rational use and minimization of environmental damage, which are implemented in the environmental projects on the construction, operation and abandonment of wells. Compliance with the basic requirements for the rational use of land resources ensures the preservation of natural resources for future generations, therefore, a scientifically based approach to the development of measures for rational use of natural resources [2–3]. To minimize the loss of land resources as a result of pollution by oil and gas products and to decrease the area of the developed field, a number of technological solutions are proposed:
2. Methods and materials
The study aims to develop the technology for protecting land occupied by oil and gas facilities in order to improve land efficiency, minimize the development area and eliminate environmental damage with regard to the regional characteristics of the Far North. To achieve the above aim, it is necessary to:

- Analyze the level of land disturbance in the the Far North and environmental risks;
- Classify disturbances in soil and vegetation cover of land plots during the development of oil and gas fields;
- Develop criteria for minimizing damage to the territories occupied by oil and gas fields with regard to the regional features of the Far North;
- Develop and improve existing methodological and technological solutions to reduce the area of land plots occupied by oil and gas facilities for further land restoration and its use by small-numbered and indigenous peoples living in the Far North.

3. Results
One of the ways to minimize damage to the environment is a technological solution for cluster well drilling, that is, placing several wells on one cluster site (cluster of wells). In this case, the wells occupy the minimum territory of the tundra limited by the boundaries of the well cluster, and the drainage zone occupies the maximum possible area of the productive formation due to drilling of directional multilateral wells. In addition, to reduce the overall dimensions of the well cluster, it is recommended to place X-trees perpendicular to the well axis or place wells in pairs. To increase the drainage zone, it is proposed to construct multihole and multilateral wells. The first ones are used for penetrating several productive layers, the second ones are used for penetrating one layer in its different vertical parts. However, both types of wells have a common drawback – the drainage zone is limited in width and the wellbore and its radius. These wells, in our opinion, should be equipped according to the packer scheme with sealing of the annular space with a packer and filling this space with the above packer sealing fluid.

Therefore, to increase the drainage zone, a well design with hydraulic fracturing is more preferable. The resulting fractures contribute to a more extended drainage zone of the productive formation. However, the drawback of this multilateral well is the insufficient drainage zone limited by the radius of the hydraulic fracture. To increase the drainage zone of the productive formation, it is proposed to use a branched well (patent of the Russian Federation No. 101082), in which lateral branches should be laid from the main horizontal wellbore, and multistage hydraulic fracturing of the formation should be performed in the branches and in the horizontal wellbore. This leads to the maximum drainage zone both in width (along the length of the side branches) and in radius (along the length of all fractures). As a result, a reliable and most importantly effective and environmentally friendly design of a branched well was developed for the exploitation of hydrocarbon deposits in the severe conditions of the Far North with the maximum possible protection of land resources and environment. This was achieved by drilling the main horizontal wellbore in the productive formation and laying several lateral bores parallel to the plane of the gas-water contact. With this, hydraulic fracturing of the formation was performed in each lateral bore with the formation of fractures that do not reach the plane of the gas-water contact by 2–5 m, while the lateral bores can be located both in the upper boundary of the productive formation and in the productive formation itself.
At present, an increase in gas production in Russia is due to the development of fields in the Far North, which requires protection of land resources in the tundra zone in order to minimize damage to the environment when drilling wells. The branched well for the exploitation of watered hydrocarbon deposits makes it possible to solve the problem of protecting lands and environment while ensuring the required volumes of hydrocarbon production.

This technological solution provides the maximum possible protection of land resources and environment from pollution and transformation of landscapes. Traditional development of oil and gas deposits requires a number of wells necessary to in drill the entire drainable area of the productive formation. In this case, a large area is occupied by oil and gas facilities, which inevitably leads to its technological pollution. The pollution consequences can be avoided or reduced by using the method of cluster drilling of wells. For greater effect, it is proposed to use a multihole well instead of traditional horizontal wells. The advantage of this well is that the well head is located on one cluster site with small overall dimensions, and the drainage zone occupies the area required for production due to the horizontal main and lateral bores and available branches, therefore, the pollution of the area is minimized.

The proposed technological solution is as follows. A multi-layered multi-hole well penetrates the hydrocarbon deposit. The well includes the main and lateral bores with horizontal sections of the main and lateral bores located in one productive formation and directed in diametrically opposite directions. Each horizontal section includes horizontal lateral branches, which are also directed in diametrically opposite directions relative to the horizontal sections of the main and lateral bores. In the horizontal sections of the main and lateral bores, hydraulic fractures were made before and after the lateral branches with the formation of fractures directed perpendicularly to the gas-water contact and the upper boundary of the productive formation, and the fracture length does not attain the plane of the gas-water contact.

The proposed technological solution for multi-layered wells ensures the minimum size of the cluster site for reliable and efficient exploitation of hydrocarbon deposits in conditions of the limited area, for example, when drilling wells in a lacustrine-swampy area of the Far North in the Arctic zone or in the zone of marine and offshore fields, including watered deposits, with a simultaneous increase in oil and gas production rates due to the increased drainage area of the bottom-hole zone with minimization of soil pollution in the area occupied by oil and gas facilities.

During implementation of technological solutions, the area of development will be reduced one and a half to three fold, depending on the norms for the land plot provided for by the project on the field development.

The increasing oil and gas consumption, which annual production volume in the country is more than 300 million tons, leads to the need to intensify the processes of its production. The performance criteria are:

- Reduction of the well cluster area;
- Drilling of one multilateral well;
- Increase in the drainage area;
- Minimization of damage;
- Reduction of the area occupied by wells.

An increase in oil and gas production, the resulting failures of mechanisms, disruptions of the technological process, as well as natural disasters lead to severe accidents, which can be accompanied by large fires, large material losses, deterioration of the ecological situation in the fire zone and adjacent areas, and human casualties. To ensure environmental protection, all well abandonment works are carried out in compliance with safety regulations in the oil and gas industry and regional instructions and guidelines (RD 51-1-96 Guideline on environmental protection during well construction on land and on hydrocarbon fields of polycomponent composition, including hydrogen sulfide-containing ones; RF patent No. 2074308). Moreover, duration of works to abandon wells is of a non-stationary nature, therefore, when assessing the impact of pollution sources on the environment, the work can be divided into two stages: preparatory and final works, which make up about 40% of the
total duration of work, and the actual work to abandon the well, which is more than 60%. As mentioned earlier, the following groups of pollution sources are distinguished during well abandoning: a power generation facility, including a mobile diesel power plant (DPP) involved in all stages of the technological process, and an emergency DPP of lower power that operates only in case of emergency; a steam production facility for technological needs, including a permanently operating mobile and emergency steam heating unit; accompanying production facilities, including a permanently operating section of mobile lifting unit and a periodically operating section for refueling equipment, a parking area for special equipment, a storage facility for chemical reagents, a section for welding. The most dangerous is emergency well flowing, which is a stationary process characterized by high flow rates and long duration until the fountain is sealed, and it often leads to the destruction of the rock structure and watering of the formation [4, 5].

The fields of Western Siberia, especially at the final stage of field development, exhibit a large number of exploration wells with leaking production strings. Every year these wells lose their technical resource and reliability due to corrosion, which can lead to gas manifestations and open gas fountains with the ignition of a gas flow. A large number of leakage intervals entails the need for isolating work at all leakage intervals, which increases its cost. In these conditions, it is impossible to reliably abandon a well with many leakage intervals using traditional methods. There are several methods for abandoning a well with numerous leakage intervals of production string, for example:

- the installation of a cement bridge over the productive formation, filling the wellbore with technological solution, dismantling the X-tree, and installing a concrete block with a benchmark at the well head;
- the installation of cement bridges at the perforation intervals and at all leakage intervals, filling the wellbore with technological solution, installing a cement bridge in the casing shoe, filling the wellbore with non-freezing fluid at the permafrost interval, dismantling the X-tree, installing a concrete bollard with a benchmark at the well head [6–8].

The drawback of these methods for eliminating wells with multiple leakage intervals of the production string, which are located in the hard-to-reach area of the permafrost zone, is insufficient reliability. The methods do not take into account the presence of permafrost in the well head, periodic thawing and freezing of the well support, which causes leakage in the production string. In addition, they do not take into account numerous leakage intervals in the production string, which increases the cost of works on isolation of all leakage intervals. Moreover, the methods do not take into account the difficulties of transportation of the equipment previously used in the well from the well head of the abandoned well.

This technological solution enables:

- Development of a set of measures to prevent accidents;
- Compliance with safety regulations in the oil and gas industry;
- Compliance with standards and instructions Use in permafrost conditions;
- Minimization of the likelihood of emergency well flowing;
- Calculation of the probability of accidents;
- Minimization of the risk of well depressurization;
- Minimization of the risk of accidents at abandoned wells.

The efficiency criterion implies the installation of a monolithic cement bridge, covering all the leakage intervals of the production string, in particular, the entire permafrost zone and the perforation interval. This provides a higher degree of reliability for abandoning a well as a hazardous facility and increases the environmental safety of the territory where the well existed. In addition, the need to remove equipment from the well head, except for the X-tree, is eliminated.

Projects for the development of fields in the Far North were developed in the early 90s and 2000s, while the works started only in 2012. With this regard, it became necessary to make adjustments to the project, since the technologies used by subsoil users for hydrocarbon production showed low land use efficiency and ceased to be relevant due to increased requirements for the environmental safety of oil
and gas production. The anthropogenic impact on land resources can be minimized through the use of environmentally friendly technologies for the construction and operation of oil and gas facilities, as well as through timely technological inspection, land and environmental control in relation to subsoil users. In terms of environmental protection, rational use of land resources and their protection should be considered as an optimization between traditional and industrial use of natural resources, ensuring optimal and balanced areas in land and subsoil use.

Rational subsoil use is implemented as follows:

- Allocation of a licensed plot for development;
- Consideration of regional features of the land;
- Development of a project for the development of an oil and gas field;
- Development (specification) of criteria for minimizing damage to land use during industrial development;
- Development of legal and regulatory requirements and recommendations for land protection;
- Development of environmentally friendly technological solutions for land use in the territories occupied by the objects of the oil and gas complex;
- Compliance with the norms of land and environmental legislation, land monitoring;
- Reclamation and restoration of anthropogenic disturbances of land [9–12].

Thus, one of the urgent problems of the development of the oil and gas industry in the Far North can be solved to significantly increase the volume of hydrocarbon production not increasing the area of land included in industrial production. The proposed and described technological solutions of the environmentally oriented land use system are used at all stages of construction, operation and abandonment of wells. At the same time, a certain optimization effect is achieved through reducing the size of the well cluster site, increasing the drainage zone, minimizing environmental pollution, increasing hydrocarbon production, reducing the likelihood of accidents, reducing capital investments and operating costs, and reducing the time for well abandonment.

All land plots allotted for the construction and operation of oil and gas facilities must be reclaimed and be suitable for traditional use of natural resources. Reclamation of disturbed lands must be carried out strictly within the agreement duration period. With regard to the regional features of the Far North, the period allotted to the subsoil user for restoration of the land plot to a suitable state can be extended in case of consent of the right holder of this land plot (Decree of the Government of the Russian Federation dated 02.23.94 No. 140 On land reclamation, removal, conservation and rational use of the fertile soil layer). Land reclamation should be carried out in accordance with the reclamation project, which is carried out in two stages. The first stage of reclamation is technological. At this stage, the area is cleaned from garbage, industrial waste and is prepared for covering with a fertile layer. During technological reclamation, it is proposed to ‘clean-up’ the territory after dismantling of equipment and facilities, to remove garbage and unused materials, as well as to treat the places of fuel spills with biological reclamation preparations, such as Canadian Phagnum Peatmoss and Bioros.

To accelerate the process of natural restoration of vegetation, it is recommended to create a ridged relief by cutting and turning the top layer of the soil. On the inverted soil substrate, on the ridges, plants will grow faster and the original plant communities will recover. Salts, along with sediments, will accumulate in depressions between ridges. After that, they will be carried out from the places of saline waters accumulation. After the technological stage, the biological stage is started. Biological reclamation is carried out by reseeding of perennial grasses. For reclamation in the northern regions, forest grasses are most suitable (alnigenic bluegrass, Haupt's salt grass, Lapland reed grass, northern lime grass, etc.), which are drought and temperature resistant. In the absence of commercial production of seeds of local herbs, the use of the following types of herbs is allowed: boneless fire, red and sheep fescue, meadow bluegrass, wheatgrass. For biological reclamation, humic-mineral concentrates (HMC) can be used [8].

At present, the problem of reclamation of drilling waste disposal sites – sludge pits – is of high relevance. One of the possible solutions is the use or processing of drilling sludge into building soil. Another solution is to process drilling sludge to obtain ‘soil’ suitable for use as a fertile substrate. Soil
is obtained by mixing drilling sludge with mineral soils. The proportions are calculated individually based on the properties of the sludge. Additional substances are mineral and organic fertilizers necessary for plant growth. Concentrations depend on the types of herbal mixtures or tree species for planting. The soil is used for biological reclamation. It is applied as a fertile layer on leveled and prepared surfaces. After that, plant seeds are sown or tree seedlings are planted. For successful reclamation of disturbed and contaminated lands, the industrial environmental control service must identify the causes and nature of the environmental problems, and the spatio-temporal patterns of their negative consequences, and choose methods and means for ceasing, mitigating and eliminating these consequences.

Funding for restoration works should be carried out at the expense of the main activities of enterprises that committed violations, that is at the expense of a special reserve of capital investments [9]. The regulatory authorities conduct an inventory of damaged and disturbed lands and determine the main ways of reclamation. First of all, uplands, as most productive, should be subject to restoration, as well as sandy and sandy loam waving hills with signs of gully formation, mineral mounds of heaving ridge, and man-made landscapes represented by embankments. Upon completion of drilling, reclamation of these areas should be aimed at creating more valuable natural landscapes. To carry out timely and high-quality reclamation, it is necessary to involve organizations that have experience and material and technical and scientific resources, because land users often do not cope with the volumes or do not have experience in performing these works. A reclamation program for disturbed lands can be developed based on the following options:

- implementation of measures for restoration of disturbed lands to their initial state and for further use in the national economy;
- partial implementation of measures, implementation of the technological stage of reclamation and use of the territory for the construction of social and engineering and transport facilities;
- refusal of reclamation.

When choosing a reclamation option, the following factors should be considered:

- regional features;
- planned use of land resources in the national economy;
- level or degree of land disturbance;
- terms of implementation of reclamation measures;
- cost of works.

4. Conclusion
The necessity of applying the technology for protecting lands of the oil and gas production industry was substantiated in order to preserve the natural resource potential of the territory and the traditional way of life of indigenous peoples. New and improved technologies for the rational use and protection of land resources of oil and gas facilities in the Far North in the presence of permafrost were described. The technology for abandonment of a hazardous production facility reduces the likelihood of open fountains in the field, minimizes the duration of works and ensures the protection of land resources. The embankment of the well head site of the abandoned well in winter is due to creation of a tamped snow working site and ice embankment preventing the penetration of contaminated substances and technological solutions into the land resources of the tundra with minimum capital and operating costs, and with subsequent biological reclamation in summer. The technology for reclamation of disturbed lands occupied by oil and gas facilities in the Far North was described.

References
[1] Kustysheva I N 2014 From land management to construction and liquidation of an object with ensuring environmental safety of technological processes Problems and methods of ensuring reliability and safety of oil, oil products and gas transport systems: materials of the International Scientific and Practical Conference (23 Apr. 2014, Ufa) pp 515
[2] Bocharova A A 2008 The problem of rational use of forest fund lands Collection of scientific papers of postgraduates and young scientists: 120 years of the Siberian State Geodetic Academy (Novosibirsk) vol 5 pp 58–62.

[3] Bocharova A A, Zharnikov V B 2012 Basic conditions of rational use of forest fund lands Vestnik SGGA 3(19) 69–77.

[4] Shangareev R R 2018 Role of employee motivation in an industrial occupational risk management system IOP Conference Series: Earth and Environmental Science 194(2) 022033. DOI: 10.1088/1755-1315/194/2/022033.

[5] Shangareev R R 2020 Assessment of professional risks in the operation of mud pumps IOP Conference Series: Materials Science and Engineering 905 012087. DOI: 10.1088/1755-1315/905/1/012087.

[6] Akhmetov R T, Mukhametshin V V, Kuleshova L S, Grezina O A, Malyshev P M 2020 The generalized correlating function of capillary curves and the relationship of the filtration-capacitive parameters of reservoirs in Western Siberia with the size distribution of pore channels Journal of Physics: Conference Series 1661(1) 012016. DOI: 10.1088/1742-6596/1661/1/012016.

[7] Zeigman Yu V, Mukhametshin V V, Kuleshova L S 2020 Management of flooding of low-production deposits according to geological and field data IOP Conference Series: Earth and Environmental Science 579 012019. DOI: 10.1088/1755-1315/579/1/012019.

[8] Mukhametshin V Sh 2020 Justification for increasing the performance of hydrochloric acid treatment in wells of fields with carbonate reservoir IOP Conference Series: Materials Science and Engineering 905(1) 012083. DOI: 10.1088/1755-899X/905/1/012083.

[9] Gumerov A K, Khasanova A R, Gumerov A G, Shamazzov A M 2019 Applicability of energy flow vector in the mechanics of destruction Oil and Gas Business 17(5) 89–92. DOI: 10.17122/ngdelo-2019-5-89-92.

[10] Gumerov A K, Khasanova A R 2020 Stress corrosion cracking in pipelines IOP Conf. Ser.: Mater. Sci. Eng. 952 012046. DOI:10.1088/1757-899X/952/1/012046.

[11] Igtsamova G R, Nosirov D Sh 2018 Peculiarities of problem solving at studying well drilling with the use of linear differential equations with constant coefficients Advances in Engineering Research 157 211–214. DOI: 10.2991/aime-18.2018.41.

[12] Igtsamova G R, Yangirova Z Z, Nosirov D Sh 2020 Ecological Consequences of Reservoir Water and Drill Cuttings Discharging in the Sea Continental Shelf Advances in Economics, Business and Management Research 113 479–483. DOI: 10.2991/fred-19.2020.97.