Prospects for the use of new technologies in assessing the impact of geological and technological risks

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Abstract. Nowadays, operator companies pay much attention to the introduction and development of technologies for development of oil fields using horizontal wells. This situation is due on the one hand to relatively greater efficiency of operation on horizontal wells, as compared with vertical, and problems typical for horizontal wells (low share of 10-30% of the “working” part of the horizontal well, specificity of the influence of heterogeneity of the reservoir during stimulations, difficulty and water source control on the other hand. In addition, it is necessary to take into account a number of factors causing the exclusive use of horizontal wells: a restriction on the location of the wellhead relative to the target areas of the reservoir, a restriction on the number of wells, the development of fields with highly viscous and super-viscous oils, and the operation of unconventional (dense) reservoirs. The main objective of this work is to determine the prospects for the application of new technologies to increase the efficiency of operation of horizontal wells. It is impossible to describe the full picture without reflecting the results of the analysis of the performance of horizontal wells in field development, the problems of planning investments for drilling horizontal wells, as well as considering aspects of the economic evaluation of the use of technologies designed to improve the efficiency of horizontal wells. Much attention is paid to identifying the causes of declining oil production due to premature irrigation of horizontal wells. Various options for the occurrence of flow heterogeneity and their influence on the development of reservoirs using horizontal wells are considered.

1. Introduction
The initial data for the formation of investment projects for drilling wells are the magnitude of capital and operating costs, the size of tax rates and the planned level of oil production - derived from the initial level of oil production and its rate of decline [1].

Based on the initial data, the discounted profitability index (DPI), net present value (NPV) and the project payback period are calculated. Currently, these indicators in PJSC TATNEFT are the only criteria for assessing the attractiveness of an investment project (influencing decision making).

However, it should be noted that the success of investment projects related to geological uncertainty,
including projects on drilling wells, is subject to the influence of geological and technological risks:

- non-confirmation of geological information about the object of development (lack of reserves, low filtration and capacitive properties);
- complications in the process of well construction (deviation of the wellbore profile from the project, installation of the shank (filters) outside target intervals);
- identification of problems during well operation.

The occurrence of these risks leads to a decrease in the effectiveness of investment projects for drilling horizontal wells. Thus, the probability of occurrence of geological and technological risks must be considered as one of the main criteria for assessing the attractiveness of investment projects.

On the other hand, a quantitative assessment of geological and technological risks makes it possible to economically justify the use of various drilling and injection technologies.

2. Materials and methods

This work included a detailed study of investment planning projects for drilling horizontal wells (HS), the effectiveness of horizontal wells and assessing the impact of geological and technological risks on the implementation of planned production figures. The results obtained in the article are based on a statistical analysis of the implementation of planned production of investment projects, a quantitative assessment of geological and technological risks of non-fulfillment of planned indicators of investment projects, an analysis of the main causes of geological and technological risks [2-9]. In data processing, the methods of statistical data analysis, factor analysis of the influence of geological and technological risks and mathematical modeling were used.

3. Results and Discussion

Analysis of the implementation of the planned production of investment projects

Statistical analysis showed (Figure 1) that the distribution of horizontal wells in terms of accumulated oil production over 10 years of operation for the main development objects is close to normal, obey the distribution law and can be described using probability characteristics [10-15]:

- Wells that develop carbonate reservoirs of the Protvinskii horizon (green line). The distribution center corresponds to cumulative oil production of 12.5 thousand tons, taking into account the confidence interval of 8-21 thousand tons. The probability of a well getting into the zone of non-fulfillment of the planned indicators for the 10 year of operation is 68%.
- Wells confined to terrigenous deposits of the Bobrikovian horizon (gray line). The distribution has an asymmetrical shape, curved to the right (the largest cumulative production), which is reflected in the size of the confidence interval of 6-31 thousand tons. The probability of hitting a well in the zone of non-compliance with planned targets is 59%.
- Wells confined to carbonate reservoirs of the Tournaisian horizon (red line). The distribution center corresponds to the cumulative oil production of 21.5 thousand tons, the confidence interval of 16-29 thousand tons. The probability of hitting a well in the zone of non-compliance with planned targets is 27%.
Figure 1. Distribution of horizontal wells by the cumulative oil production for 10 years of operation by development objects.

Note: The analysis involved averaged oil production indicators embedded in investment projects for drilling the HS, and average statistics based on actual data from the operation of horizontal wells drilled over a ten-year period.

The greatest manifestation of their risks of non-compliance with the planned indicators for oil production identified during the development of terrigenous deposits of Bobrikovian and carbonate sediments of the Protvinskii horizons indicates the existence of a fairly narrow framework for the effective use of horizontal wells in these geological conditions.

Quantitative assessment of geological and technological risks of non-fulfillment of planned indicators of investment projects

Quantitative assessment of geological and technological risks that lead to non-fulfillment of planned production figures was carried out according to the deterministic method. This method allows to take into account the probability of occurrence of events and to evaluate the possible consequences of the occurrence of these events.

Further, two possible scenarios are considered - with the manifestation of geological and technological risks and without their manifestation for the main development objects (Protvinskii and Bobrikovian Horizons, Tournaisian stage) by the 10th year of operation (table). The probabilities of non-compliance with the planned indicators of oil production defined in the previous chapter were taken as the probability of geological and technological risks:

- for Protvinskii horizon – 68 %;
- for the Bobrikovian horizon – 59 %;
- for the Tournaisian stage – 27 %.

Each option has three possible scenarios - optimistic (P90), most likely (P50) and pessimistic (P10).

For each of the options (taking into account the likelihood of its occurrence and implementation scenarios), the expected results of drilling a single horizontal well were calculated.

So, for the Protvinskii horizon, as a result of geological and technological risks, in an optimistic...
scenario of non-fulfillment of planned oil production, losses will amount to (negative NPV) 6.5 USD, in the most likely scenario - 28 USD, in the case of a pessimistic scenario - 45.7 USD. If the geological risks do not manifest themselves, then we can expect a profit of $ 18.8. according to the optimistic scenario, 10.2 USD - in the case of developments in the most likely scenario, and 6 cu - under the pessimistic scenario.

The final result, taking into account the probability of occurrence of geological and technological risks (non-fulfillment of planned production) equal to 68 % and the probability of their non-manifestation, constituting 32 % according to an optimistic scenario, provides for a profit of 12.3 cu. (DPI = 1.10). Under the most likely scenario, investments in horizontal well drilling in the Protvinskii horizon will result in losses of $ 17.9. (DPI = 0.84) for 1 well or 39.7 cu (DPI = 0.62) according to the pessimistic scenario. Under such conditions, investing in horizontal well drilling projects on the Protvinskii horizon is impractical.

Table 1. Efficiency of investment projects for drilling horizontal wells, taking into account the likelihood of geological and technological risks

| Risk occurrence variant | The object of development | possible shortages, thousand mt | expected NPV of a variant per one well, cu | probability of occurrence of risks, u.fr. | expected NPV of a variant considering probability for one well, cu |
|--------------------------|---------------------------|----------------------------------|------------------------------------------|------------------------------------------|--------------------------------------------------------|
|                          |                           | P20 | P50 | P10 | P20 | P50 | P10 | P20 | P50 | P10 | P20 | P50 | P10 |
| Protvinskii horizon       | 12.5                      | 7.0 | 3.0 |     | 9.5 | 41.3 | 67.2 | 0.68 | -6.5 | -28.1 | -45.7 |
| Bobrikovian horizon       | 14.0                      | 10.0 | 6.0 | -1.8 | -23.7 | -47.6 | 0.59 | -1.1 | -14.0 | -28.1 |
| Tournaisian stage         | 17.9                      | 14.5 | 9.0 | 18.2 | 0.9 | -29.4 | 0.27 | 4.9 | 0.2 | -7.9 |

| Risk nonoccurrence variant | The object of development | possible shortages, thousand mt | expected NPV of a variant per one well, cu | probability of occurrence of risks, u.fr. | expected NPV of a variant considering probability for one well, cu |
|----------------------------|---------------------------|----------------------------------|------------------------------------------|------------------------------------------|--------------------------------------------------------|
|                            |                           | P20 | P50 | P10 | P20 | P50 | P10 | P20 | P50 | P10 | P20 | P50 | P10 |
| Protvinskii horizon       | 28.5                      | 21.0 | 18.0 | 58.6 | 31.8 | 18.7 | 0.32 | 18.9 | 10.2 | 6.0 |
| Bobrikovian horizon       | 44.0                      | 32.0 | 21.5 | 96.2 | 68.9 | 34.6 | 0.41 | 39.4 | 28.2 | 14.2 |
| Tournaisian stage         | 28.0                      | 22.5 | 18.5 | 56.8 | 39.2 | 21.2 | 0.73 | 41.5 | 28.6 | 15.5 |

| Total                     | The object of development | expected DPI of the investment portfolio for one well | expected NPV of the investment portfolio for one well |
|---------------------------|---------------------------|--------------------------------------------------------|--------------------------------------------------------|
|                           |                           | P20 | P50 | P10 | P20 | P50 | P10 | P20 | P50 | P10 | P20 | P50 | P10 |
| Protvinskii horizon       | 1.10                      | 0.84 | 0.62 | 12.3 | -17.9 | -39.7 |
| Bobrikovian horizon       | 1.29                      | 1.12 | 0.88 | 38.4 | 14.3 | -13.9 |
| Tournaisian stage         | 1.35                      | 1.23 | 1.06 | 40.4 | 28.9 | 7.5 |

The high probability of the risk of non-compliance with planned targets (59 %) affects the final results of investments in drilling on the Bobrikovian horizon. Investments involve making a profit in the amount of 38.4 USD in an optimistic scenario and 14.3 USD according to the most likely scenario. In the case of a pessimistic scenario, we should expect $ 13.9. damages. A positive investment result with a significant probability of risk is due to the high level of production and NPV for successful wells covering losses from inefficient projects. Nevertheless, the DPI of investment projects for drilling wells on the Bobrikovian horizon, taking into account the risks of non-fulfillment of planned targets under the most likely scenario (DPI = 1.12), is at a level unacceptable for making a positive decision on their implementation.

Due to the low probability of occurrence of geological and technological risks, investment projects for drilling horizontal wells for deposits of the Tournaisian stage seem to be the most attractive. In the case of a pessimistic scenario, the profit from the project will be 7.5 cu. per well (NPV = 1.06).
According to the most likely scenario, the profit will be equal to 28.9 USD ($I = 1.23$) and 46.4 USD ($NPV = 1.35$) in the event of an optimistic scenario.

For the Protvinskii horizon, the problem of the manifestation of geological and technological risks according to the results of calculations is estimated at 49.7 cu. per well, for the Bobrikovian horizon, this value is 54.6 cu per well, for the Tournaisian stage – 10.3 cu

Thus, a quantitative risk assessment allows us to assess the effectiveness of horizontal wells in various geological conditions. The results obtained during the risk assessment indicate the need for a risk management system and the development of tools (technologies) aimed at reducing the likelihood of geological and technological risks.

For the successful implementation of technologies designed to increase the effectiveness of horizontal wells and effective risk management, it is necessary to identify factors affecting the magnitude of the likelihood of risk occurrence.

Analysis of the main causes of geological and technological risks

Figure 2 shows the dynamics of the values of annual oil production relative to the initial level, as well as the rate of decline in annual production.

As can be seen from the presented dynamics, the main reason for non-fulfillment of planned indicators of investment projects for drilling horizontal wells is a significant excess of the actual rate of decline in oil production (15-25%) over the design figures set at 5% per year.

So, by the year 10 of operation, the actual level of oil production is only 15% of the initial one. The planned level of oil production by the 10th year of operation is set at 73% of the initial value. Thus, in fact, over 10 years of operation, 92% of the possible production is produced during the effect period. This indicates that the period of effect of 15 years, laid down in investment projects, is overestimated and in fact does not exceed 10 years.

![Figure 2. Dynamics of planned and average (actual) levels of oil production and the rate of decline in oil production](image)

**Figure 2.** Dynamics of planned and average (actual) levels of oil production and the rate of decline in oil production

From the analysis of the curves (Figure 2) it can be concluded that in the period from 4 to 8 years of operation there is a significant increase in the rate of decline in production and a decrease in the level of oil production and, as a result, a decrease in the efficiency of using horizontal wells.
Further analysis of the reasons for the decline in the level of oil production showed that one of the reasons for the decrease in the efficiency of horizontal wells is their premature watering. Thus, the percentage of wells with a water cut of more than 80% in 10 years of operation increases from 8 to 51%, while the percentage of wells with a water cut of less than 20% decreases from 72 to 29% (Figure 3).

![Figure 3](distribution_of_horizontal_wells_by_water_cut_groups_less_than_20_and_more_than_80.png)

**Figure 3.** Distribution of horizontal wells by water cut groups (less than 20% and more than 80%) by year of operation after drilling

The effect of premature flooding on the likelihood of risk of non-compliance with planned targets differs depending on the object of development (Figure 4). So, for the Protvinskii horizon, the proportion of wells that fail to meet production targets due to premature watering is the largest and is equal to 81%. For wells of the Tournaisian stage, the problem of premature watering is not so urgent, the proportion of wells that do not meet the planned targets for this reason does not exceed 28%.

![Figure 4](distribution_of_reasons_for_non_fulfillment_of_production_targets.png)

**Figure 4.** Distribution of the percentage of reasons for non-fulfillment of production targets
Thus, in continuation of the quantitative risk assessment, it can be noted that with a decrease in the probability of premature irrigation of horizontal wells, the likelihood of non-compliance with production targets for various development sites will decrease by a multiple of its effect. For the Protvinskii horizon, the solution to the problem of premature watering (zero probability) is estimated at 40.2 cu according to the results of calculations, per well, for the Bobrikovian horizon, this value is 36 cu per well, for the Tournaisian stage – 2.8 cu on the well.

4. Conclusion
To determine the prospects for the use of new technologies, it is necessary to introduce a more sophisticated mechanism for the comparative assessment of the attractiveness of an investment project. The scenario approach to investment planning can be the most acceptable.

Analysis of investment projects planning showed an optimistic approach to assessing the attractiveness of investment projects and planning production indicators. So, by the year 10 of operation, the actual level of oil production averages only 15 % of the initial one. The planned level of oil production by the 10th year of operation is laid in projects at 73 % of the initial value.

The experience of using the HS has shown that horizontal technologies have a fairly narrow geological and technological framework for effective use and a high probability of the risk of non-compliance with the planned indicators of oil production.

The statistical probabilities of non-compliance with the planned oil production targets (failure to reach DPI = 1.15 by the 10th year of operation) for the main target drilling horizons of the SGA are:

- for Protvinskii horizon – 68 %. The results of the projects with this probability in the most likely scenario (R50) per well: DPI = 0.84; NPV = -17.9 cu;
- for the Bobrikovian horizon – 59 %. The results of project implementation with such a probability for P50 per one well: DPI = 1.12; NPV = 14.3 cu;
- for the Tournaisian stage – 27 %. Results of project implementation with such a probability for P50 per one well: DPI = 1.23; NPV = 28.9 USD

The reason for the decrease in the level of oil production in wells with horizontal termination is their premature watering and low reservoir properties of the layers. The impact of the risk of premature well flooding on the overall risk of non-compliance with the planned oil production figures differs for various development sites (for the Protvinskii horizon — 81 %; for Bobrikovian — 66 %; for the Tournaisian stage — 27 %).

The cause of premature watering is the advance selection of reserves at the most permeable intervals due to the uneven inflow of fluid through the wellbore (geological risks – 41 %), high specific rates of selection with incomplete formation involvement in the development (technological risks – 36 %), as well as wiring the trunk wells in the water-saturated zone of the reservoir (technical risks – 23 %).

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