ORIGINAL RESEARCH ARTICLE

**DOI**: https://doi.org/10.18599/grs.2019.3.55-61

# Optimization of reserve production from water oil zones of D3ps horizon of Shkapovsky oil field by means of horizontal wells

*R.F. Yakupov[1], V.Sh. Mukhametshin[2], I.N. Khakimzyanov[3]*, V.E. Trofimov[4]*

[1]*Bashneft-Dobycha LLC, Ufa, Russian Federation*
[2]*Oktyabrsky Branch of the Ufa State Petroleum Technological University, Oktyabrsky, Russian Federation*
[3]*Institute TatNIPIneft Tatneft PJSC, Almetyevsk, Russian Federation*
[4]*BashNIPIneft LLC, Ufa, Russian Federation*

An analysis was made of the development of sections of the D3ps formation of the Devonian terrigenous sequence of the Shkapovsky field, with a share of contact zones of more than 78 %, which showed that the exploitation of deposits by vertical and deviated wells is unprofitable. Studies show that the development of reserves at the facility occurs along highly permeable interlayers located in the plantar. The construction of sectoral geological and hydrodynamic models showed a detailed distribution of residual oil reserves by area and section in areas with low production values.

When analyzing the parameters of the operation of wells with horizontal completion, it was found that the selection of mobile oil reserves localized in a volume limited by the plane of the initial oil-water contact and the surface formed by the rise of the oil-water contact when pulling the water cone to the wells with horizontal completion is comparable with the period of reaching a water cut of 95 %. The volumetric method was used to calculate the moving oil reserves in the area of water cone formation. It is recommended to drill wells with horizontal completion as an effective method of additional production of residual oil reserves in fields with similar geological and physical conditions.

**Keywords**: well, oil-water contact, reserves recovery, coning, water saturation

**Recommended citation**: Yakupov R.F., Mukhametshin V.Sh., Khakimzyanov I.N., Trofimov V.E. (2019). Optimization of reserve production from water oil zones of D3ps horizon of Shkapovsky oil field by means of horizontal wells. *Georesursy = Georesources,* 21(3), pp. 55-61. DOI: https://doi.org/10.18599/grs.2019.3.55-61

A review of the literature related to the analysis of oil fields development in Russia (Baymukhametov et al., 2005; Mukhametshin, 2017, 2018; Mukhametshin et al., 2018) shows that most of the oil deposits concentrated in terrigenous reservoirs are at a late stage. Terrigenous Devonian sediments confined to the South Tatar Arch are among them. A striking representative of this group of objects is the Shkapovsky oil field. The objects of development of the Devonian strata are characterized by high values of the oil recovery factor (ORF) – more than 0.5, and high water cut – more than 97.5 %. Analysis of oil reserves by section and area, allocation and localization of residual oil reserves at a late stage of development will allow replicating this experience in other large and unique oil fields. The priority task of research in this area is the justification of technological solutions to increase the degree of development of mobile oil reserves in the current economic conditions.

Eight development facilities have been identified at the Shkapovsky field. The main objects of the Devonian terrigenous strata are D3ps and D2vor-ard layer. They account for 97.5 % (reservoir D3ps – 61.7 %, reservoir D2vor-ard – 35.8 %) of the initial recoverable oil reserves of the field.

The D3ps layer is characterized by high reservoir properties: porosity – 20 %, permeability – up to 0.4 μm$^2$. The reservoir is saturated with low viscosity oil, with high gas content and saturation pressure of oil with gas. The design value of the recovery factor is 0.554. The geological structure of objects, the facies features of development, the physicochemical properties of the fluids saturating them are described in sufficient detail in the scientific literature (Baymukhametov et al., 2005; Lozin, 1971; Andreev et al., 1996; Lozin et al., 2017). The selection from the initial recoverable reserves for Devonian terrigenous objects is more than 95 % with the current water cut of more than 97.7 %, which indicates a high degree of oil reserves development. Under the conditions of the Shkapovsky field, the main reason for the decrease in the current profitability of the

*Corresponding author: Ilgizar N. Khakimzyanov
*E-mail: khakimzyanov@tatnipi.ru*

development is the high current oil-water factor. The selection of a large volume of water requires the cost of transportation, preparation and injection of associated produced water.

The aim of the study is to search for technological solutions that will ensure the achievement of the approved oil recovery factor, taking into account the main conditions – the selection of residual oil reserves and the profitability of oil production.

It is necessary to solve a number of problems to achieve the goal of justification of measures to gain project ORF subject to profitability:

- analysis of technological indicators of oil reserves in water-oil zones and areas of the terrigenous sequence of the Devonian sediments, geological and field analysis for the localization of concentration areas of residual oil reserves;

- review of the technologies used and the justification of the method of increasing the degree of development of the water-oil zones;

- evaluation of the effective introduction of technology based on the parameters of the wells, calculation of technical and economic indicators of developing deposits using the proposed technology.

Methods for solving the tasks are defined in accordance with the field of research. Hydrodynamic, field and geophysical studies were carried out using standard equipment. The objects of research were production and injection wells of the Shkapovsky oil field.

The indicators of oil reserves in the field indicate the high technological efficiency of the field development system. Development has been ongoing since 1955. The first well to start operating the D3ps facility is well No. 3ShKA with an initial production rate of anhydrous oil of 52.7 tons/day. Subsequently, the D3ps reservoir was drilled along a 400 × 400 m grid, 730 wells were in oil operation and 216 wells were in production. Since 1956, artificial flooding was implemented at the facility. The experience of more than 60 years of development has proven the high efficiency of the waterflooding system. The increase in fluid withdrawals, the gradual phased intensification of technological parameters, combined with the strengthening of the water flooding system, allowed from 1955 to 1970 maintaining annual oil production at more than 5 million tons. During this period, 118.1 million tons were selected, which is more than 75 % of the current accumulated production in the field.

The dynamics of oil production can be considered classical, in which all four stages of development are clearly distinguished. For deposits of such sizes and reserves, maintaining a high level of oil production for a long time was correct, reasonable and indicates the effectiveness of development technology. The strongest evidence of the validity of the conclusion about the effectiveness of implemented development system is high oil recovery; the current ORF for the D3ps object is 0.536 (Baymukhametov et al., 2005; Lozin, 1971; Andreev et al., 1996; Lozin et al., 2017; Borisov et al., 1964; Chekushin et al., 2015). Fundamental decisions were made such as the drilling of water-oil zones and their separation from the main deposits by rows of injection wells.

In the process of strengthening the waterflooding system with rows of injection wells, seven blocks were allocated for the D3ps object (Fig. 1). The blocks were characterized by different sizes of oil-saturated

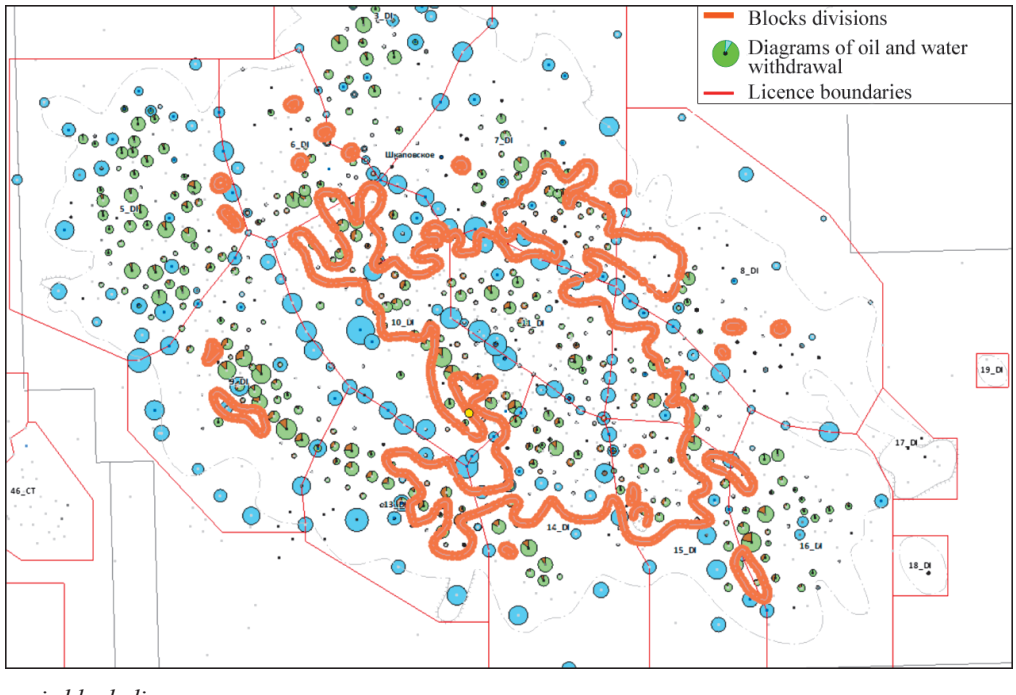


*Fig. 1. D3ps reservoir block diagram*

thicknesses, the presence of water-oil zones, pure oil zones (ChNZ). High values of current recovery factor (0.603-0.646) were achieved for blocks in the central part of the D3ps reservoir, which is due to overflow between blocks. Their formation by cutting rows of injection wells was completed only in 1978, i.e. 23 years after the start of development.

To solve the problem of localization of residual oil reserves concentration zones, the analysis of geological and field information was carried out, mapping was completed, and the development of oil reserves from geographically isolated areas of the reservoir was assessed (Fig. 1). When selecting the sites, the stages of drilling, formation of a system for maintaining reservoir pressure, the current state of development, and also the features of the geological structure were taken into account. However, such a division did not allow the correct localization of pure oil zones due to possible oil flows between the blocks during the formation of the facility development system.

For this reason, a transition was made to larger cells for analysis – for water-oil zone and pure oil zone. Pure oil zones are localized in the central part of the object and are characterized by the highest geological and physical characteristics. The total oil-saturated area is 183,297 thousand m$^2$, while the share of pure oil zones is 22 % of the area, and the share of pure oil zone is 78 %. The well grid is most densely drilled in pure oil zones – 11.3 ha/well, while specific oil production reached 162 thousand tons/well. The density of the grid of wells in pure oil zone is 24.5 ha/well, the specific oil production is 120.0 thousand tons/well. The cumulative oil production of the object as of 01.01.2017 is 99924 thousand tons, of which 50619 thousand tons (50.6 %) at the water-oil zones.

The evaluation of production coverage along the section is carried out. An oil saturated reservoir of the D3ps facility was identified in 1,076 wells, of which 725 were in production. The degree of opening of oil-saturated thickness by perforation is not high; the average for the facility is 0.6 units, which is associated with significant water-oil zones.

To control the production in the wells of the facility, 62 studies were carried out to determine the inflow profile and 769 studies to determine the injectivity profile. Coverage of the mining fund by research amounted to 10 %, and injection – 87.4 %.

For producing and injection wells, the results of field geophysical studies were analyzed, for example, the coefficient of operating layers, defined as the ratio of operating layers to the perforation interval, averaged 84 % (Fig. 2). The leading production of the middle and lower parts of the reservoir has been identified, which is associated with higher reservoir properties. Studies

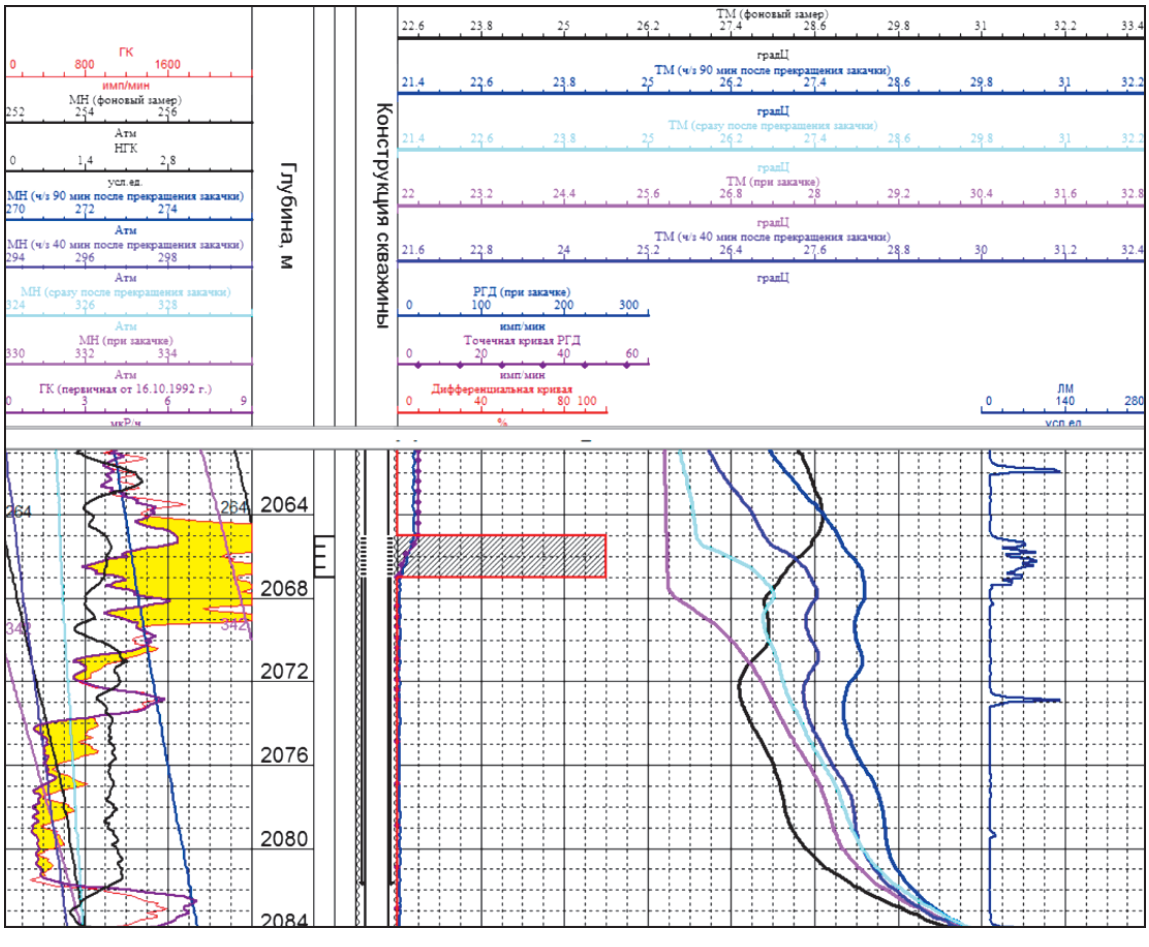


*Fig. 2. The injectivity profile in the D3ps formation*

conducted to determine the residual oil saturation and inflow intervals indicate the development of reserves in highly permeable interlayers located in the bottom.

Fundamental decisions on the rational additional development of deposits of a large oil field by horizontal sidetrack wells are presented in (Lozin et al., 2017; Chekushin et al., 2015; Rogachev et al., 2018; Khakimzyanov et al., 2011; Bin Liu et al., 2013 ; Chen Huabin et al., 2016; Hector Ngozi Akangbou et al., 2017; Márton L. Szanyi et al., 2018; Moudi Al-Ajmi et al., 2017).

To solve the problems posed, we constructed sectoral geological and hydrodynamic models that allow us to detail the distribution of oil reserves over the area with low production values and to evaluate localization by section taking into account the accumulated volume of geological and field information (Fig. 3).

According to the results of the calculations, a number of advantages were identified from the use of horizontal sidetrack wells with respect to the previously implemented development system with the drilling of directional wells:

- the productivity of horizontal sidetrack wells is 5 times higher compared to the directional wells; in conditions of active inflow of bottom water, a multiple decrease in depression is possible in order to prevent cone formation and watering of wells;

- drainage of a 3 times larger area entails a multiple large cumulative production over the forecast period;

- installation in the upper parts, relatively low permeability zone allows effectively developing non-draining reserves during the development of the object by horizontal sidetrack wells.

Together, these factors lead to an increase in cumulative well production at comparable drilling costs, which increases the cost-effectiveness of drilling and operating wells with horizontal completion.

The statement about the localization of oil in the bedside zone and upper low-permeability interlayers was confirmed by the results of the drilling of pilot conventionally horizontal sidetracks for the horizontal sidetrack wells (Fig. 4).

The technical implementation of the conventionally horizontal sidetracks installation in the corridor, limited by a thickness of up to 3 m, became possible with the help of modern navigation equipment.

In total for the period 2012-2018 three horizontal sidetrack wells were drilled into the water-oil zones of the D3ps layer. All wells are characterized by significant initial oil production rates (28-82.6 t/day). The performance indicators of the wells are presented in table 1.

The current oil production rate per well is on average 8.2 tons/day, with a water cut of 98.3 %. The main factor in the reduction of oil production during operation for all horizontal sidetrack wells is the increase in water cut. Monitoring the profitability of exploited drilled open-cast mining shows a positive value, which confirms the initial calculations of the effectiveness of the enterprise's investment in drilling open-cut deposits in the Shkapovsky field.

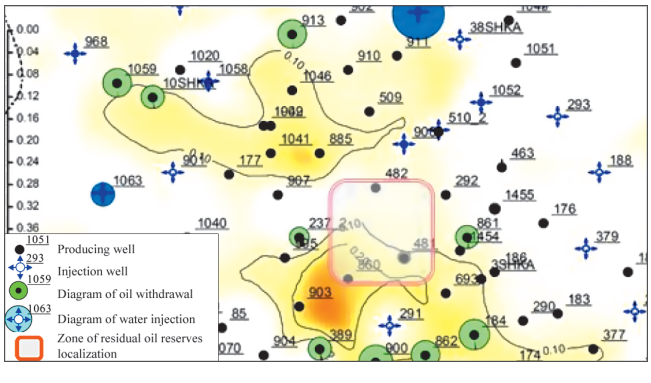


*Fig. 3. The calculation results of localization of pure oil zones in the reservoir D3ps (01/01/2013)*

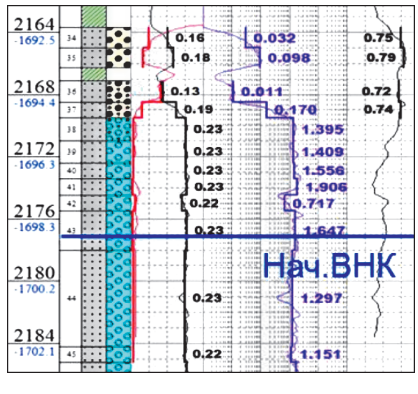


*Fig. 4. The estimation results of oil saturation from the section of the D3ps formation in the pilot conventionally horizontal sidetrack well No. 1611l1*

| Number of well | Year of input | Oil production rate, t/day | | Water production rate, t/day | | Water cut, % | | Cumulative production, thous. t | |
|---|---|---|---|---|---|---|---|---|---|
| | | Initial | Current | Initial | Current | Initial | Current | of oil | of water |
| 1611G | 2014 | 82,6 | 7,5 | 441 | 540 | 78,4 | 98,6 | 15,7 | 641,5 |
| 1530G | 2015 | 28,5 | 7,4 | 889 | 472 | 96,3 | 98,0 | 10,6 | 681,9 |
| 1514G | 2015 | 36,8 | 9,8 | 551 | 613 | 92,3 | 98,4 | 14,7 | 550,9 |
| The average for one well | | 49,3 | 8,2 | 627,0 | 541,7 | 89,0 | 98,3 | 13,7 | 624,8 |

*Table 1. Performance indicators of new horizontal wells*

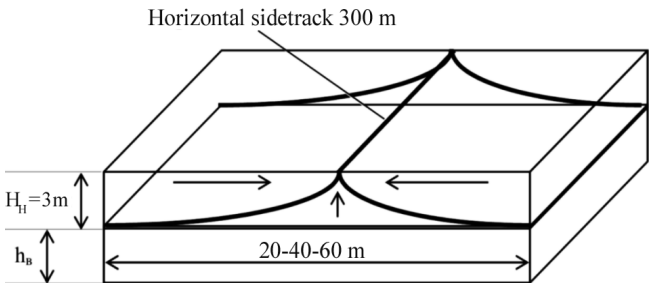


*Fig. 5. Scheme of raising the surface of the oil and gas complex in the drainage zone of the horizontal sidetrack wells*

It is obvious that a depression funnel is formed in the first days of operation in the drainage zone of the horizontal sidetrack wells drilled in the oil-water zone of the formation (Fig. 5).

The time to reach the maximum water cut is determined by the period necessary for the selection of oil reserves localized in a volume limited by the plane of the initial oil-water contact and the surface formed by the rise of the oil-water contact during the formation of the water cone. The volumetric method was used to calculate the moving oil reserves taken during the distribution of a water cone with a base of 20, 40, 60 m. The geometric volume of the water cone was calculated, and mobile oil reserves in the volume of the cone were obtained. The table 2 shows the calculation results for horizontal sidetrack well No. 1611G of the Shkapovsky field 300 m long drilled in the roof of the oil-saturated part of the reservoir with a thickness of 3 m.

It can be assumed that when the water cone is raised, the water cut of the well production from conventionally horizontal sidetracks will be more than 95 %. This is confirmed by field data for horizontal sidetrack well No. 1611G. The accumulated oil withdrawal when reaching a water cut of 95 % amounted to 2.2 thousand tons. Thus, we can assume that the size of the cone base is 60 m.

The calculations performed on sectoral hydrodynamic models of Devonian formations made it possible to evaluate the effectiveness of horizontal sidetrack wells and conventionally horizontal sidetracks on the Devonian waterfields of the Shkapovsky field.

Figure 6 shows the distribution of oil saturation in the near-wellbore area as a result of the formation of a water cone with an oil-saturated capacity of 12 m for a horizontal and vertical method of well completion when oil production reaches 10 thousand tons.

Thus, it can be concluded that drilling in the geological conditions of the Devonian sediments of the Shkapovsky field reduces the rate of cone formation, which positively affects the accumulated well production.

As calculations performed on sectoral geological and technological models have shown, the value of the predicted cumulative oil production should be 50 thousand tons. Thus, the expected indicators of cumulative oil production are at the minimum level to ensure profitability under current macroeconomic conditions.

To compare the effect of drilling horizontal sidetrack wells at the Shkapovsky field, we analyzed the operation of analogous wells drilled under similar geological conditions at the Troitsky, Belebeyevsky and Znamensky fields at the D3ps and D2vor-ard strata. The performance indicators of oil production at the considered wells are presented in Fig. 7.

| Number of well | Size of the cone base, m | Geometric volume of the water cone thous. $m^3$ | Porosity un. fr. | $K_{нн}$, un. fr. | $K_{пер}$, un. fr. | Density of oil, $t/m^3$ | Geological reserves, thous. t | Moving oil reserves thous. t |
|---|---|---|---|---|---|---|---|---|
| 1611G | 20 | 7,7 | 0,20 | 0,88 | 0,901 | 0,863 | 1,1 | 0,7 |
| | 40 | 15,5 | | | | | 2,1 | 1,4 |
| | 60 | 23,2 | | | | | 3,2 | 2,2 |

*Table 2. The calculation results of mobile oil reserves in the volume of cone formation of well No. 1611G of the Shkapovsky field*

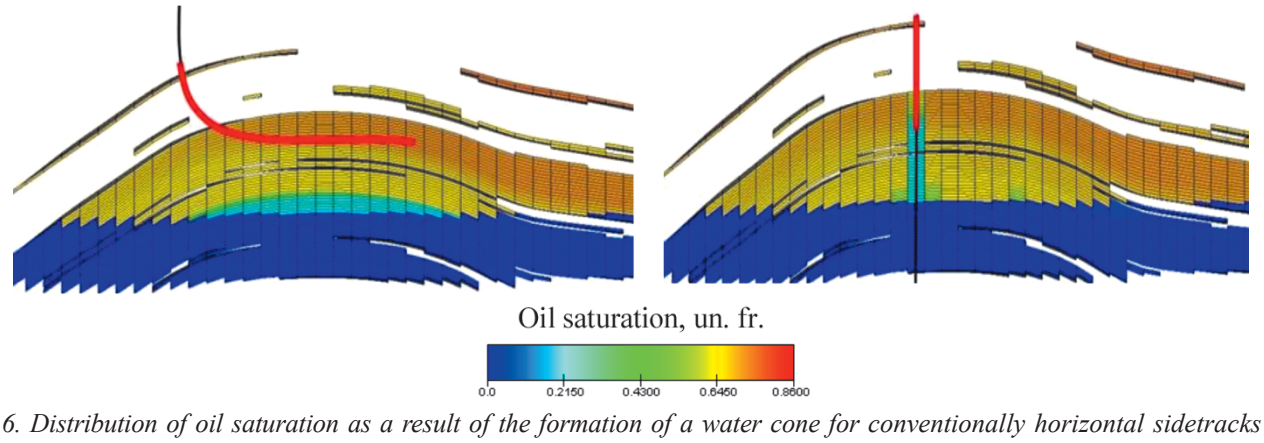


*Fig. 6. Distribution of oil saturation as a result of the formation of a water cone for conventionally horizontal sidetracks and horizontal sidetrack wells*

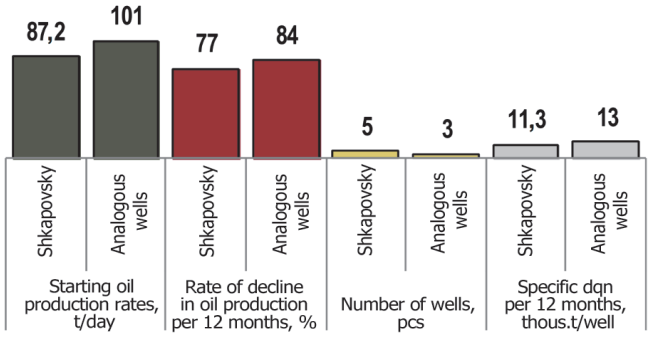


*Fig. 7. Comparison of performance indicators for drilling horizontal wells at the D3ps layer of the Shkapovsky field and analogous fields*

The dynamics of the wells of the Shkapovsky field and analogous wells are identical and are characterized by high starting oil production rates of 87 and 101 tons/day, respectively, as well as a further sharp decrease due to the pulling of bottom water. The rate of decline in oil production in the first year is 77 and 84 %, respectively.

Evaluation of the technological effectiveness of the proposed solutions was performed on the D3ps development site of the Shkapovsky field as a whole using a hydrodynamic model. The calculations show significant unprofitable values of profitability in the full implementation of the drilling project well stock of the Devonian objects of the Shkapovsky field for residual oil reserves.

The development option for the D3ps layer with drilling of 12 horizontal sidetrack well and production of 50 thousand tons per well, compared with the option to implement 21 directional wells and production of 20 thousand tons per well, ensures that the maximum oil recovery factor of 0.55 days is achieved at the objects and an increase in accumulated net present value by 871 million rubles for the design period of development.

As a prospect, it is proposed to introduce a method of additional production of residual oil reserves at the development sites of the Devonian terrigenous strata of deposits associated with the South Tatar Arch, such as Serafimovsky, Tuimazinsky, and Abdulovsky. According to preliminary estimates, the volume of implementation of the method in deposits with underlying water is more than 100 wells.

Summarizing the results of the study allowed us to make the following conclusions:

1. Analysis of oil reserves in the D3ps formation by area and section based on the data of geological field analysis revealed faster production in the middle and lower parts of the formation, which is associated with higher reservoir properties, and the localization of pure oil contact in the upper part of the formation.

2. The construction of sectoral geological and hydrodynamic models showed a detailed distribution of residual oil reserves by area and section in areas with low production values. Well drilling confirmed the initial findings.

3. It was revealed that the selection of mobile oil reserves localized in a volume limited by the plane of the initial water-oil contact and the surface formed by raising the water-oil contact when the water cone is pulled up to the horizontal sidetrack wells is comparable with the period of reaching the water cut of 95 %. The volumetric method was used to calculate the moving oil reserves in the area of water cone formation.

4. The performance indicators of the horizontal sidetrack wells of the Shkapovsky field are comparable to the horizontal sidetrack wells drilled at the objects of the analogous deposits, and are characterized by high (up to 82 t/day) starting oil production rates. A negative factor is a sharp decrease in oil production due to pulling the bottom water. The rate of decline in oil production in the first year is more than 70 %.

5. The calculations of the development options for the D3ps formation show that the maximum oil recovery factor is achieved by drilling 21 horizontal sidetrack wells and specific oil production of 50 thousand tons against 12 directional wells with specific oil production of 20 thousand tons. The use of horizontal sidetrack wells increases the accumulated net present value by 871 million rubles for the design period of development.

6. It has been proposed at fields similar in geological and field characteristics that drilling of the horizontal sidetrack wells as an effective method of additional production of contact oil reserves.

An important task is the scientific substantiation of the rational pace of additional development of water-oil zones by means of horizontal sidetrack wells by optimizing the technological modes of operating these wells and their placement, allowing to ensure the profitability of the extraction of pure oil zones.

## References

Andreev V.E., Kotenev Yu.A., Davydov V.P. (1996). Perspektivy primeneniya gorizontal'nykh skvazhin na mestorozhdeniyakh NGDU «Ishimbayneft'» [Prospects for the horizontal wells employment at the oilfields of Oil and Gas Producing department "Ishimbayneft"]. *Neftepromyslovoe delo = Oilfield engineering*, 2, pp. 12-14. (In Russ.)

Baymukhametov K.S., Lozin E.V., Popov A.M. (2005). Proyektirovaniye i osnovnyye rezul'taty razrabotki Shkapovskogo neftyanogo mestorozhdeniya [Designing and the basic results of Shkapovskoye petroleum deposit development]. *Neftyanoe khozyaystvo = Oil industry*, 4, pp. 59-63. (In Russ.)

Bin Liu, Shiqing Cheng, Xiangrong Nie, Yongjie Zhao. (2013). Evaluation of damage to horizontal wells through equivalent horizontal well length. *Petroleum Exploration and Development*, 40(3), pp. 378-382. DOI: 10.1016/S1876-3804(13)60046-4

Borisov Yu.P., Pilatovskiy V.P., Tabakov V.P. (1964). Razrabotka neftyanykh mestorozhdeniy gorizontal'nymi i mnogozaboynymi skvazhinami [Oil fields development by horizontal and multi-branch wells]. Moscow: Izd. Nedra, 154 p. (In Russ.)

Chen Huabin, Tang Kai, Chen Feng, Chen Jianbo, Li Benchi, Ren Gouhui. (2016). Oriented cluster perforating technology and its application in horizontal wells. *Natural Gas Industry B*, 3(5), pp. 439-444. DOI: 10.1016/j.ngib.2016.09.001

Chekushin V.F., Ganeev A.I., Lozin E.V. (2015). Dorazrabotka zalezhey krupnogo neftyanogo mestorozhdeniya s pomoshch'yu gorizontal'nykh skvazhin [Last stage development of giant oil field by horizontal well systems]. *Neftyanoe khozyaystvo = Oil industry*, 10, pp. 82-85. (In Russ.)

Hector Ngozi Akangbou, Martin Burby, Ghasem Nasr. (2017). Effectively optimizing production of horizontal wells in homogeneous oil reservoirs. *Journal of Petroleum Science and Engineering*, 150, pp. 128-136.

Lozin E.V. (1971). O produktivnosti skvazhin Shkapovskogo mestorozhdeniya na pozdney stadii razrabotki [On the Shkapovsk oil field wells productivity at the late stage of development]. *Neftyanoe khozyaystvo = Oil industry*, 9, pp. 44-49. (In Russ.)

Lozin E.V., Akhmerov R.Z. (2017). Uroki razrabotki Shkapovskogo neftyanogo mestorozhdeniya [Lessons learned from the Shkapovsk oil field development]. Ufa: BashNIPIneft', 371 p. (In Russ.)

Márton L. Szanyi, Casper S. Hemmingsen, Wei Yan, Jens H. Walther, Stefan L. Glimberg. (2018). Near-wellbore modeling of a horizontal well with Computational Fluid Dynamics. *Journal of Petroleum Science and Engineering*, 160, pp. 119-128.

Moudi Al-Ajmi, Bader Al-Azmi, Roberto Peña, Drew Hembling. (2017). Improvement in Horizontal Well Drilling Efficiency Increases Oil Production in North Kuwait. *SPE Kuwait Oil & Gas Show and Conference, 15-18 October 2017*. Kuwait City, Kuwait, 23 p. DOI: 10.2118/187568-MS

Mukhametshin V.V. (2018). Obosnovaniye trendov povysheniya stepeni vyrabotki zapasov nefti nizhnemelovykh otlozheniy Zapadnoy Sibiri na osnove identifikatsii ob"yektov [Rationale for trends in increasing oil reserves depletion in Western Siberia cretaceous deposits based on targets identification]. *Izvestiya Tomskogo politekhnicheskogo universiteta. Inzhiniring georesursov = Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering*, 329(5), pp. 117-124. (In Russ.)

Mukhametshin V.V., Andreev V.E. (2018). Povysheniye effektivnosti otsenki rezul'tativnosti tekhnologiy, napravlennykh na rasshireniye ispol'zovaniya resursnoy bazy mestorozhdeniy s trudnoizvlekayemymi zapasami [Increasing the efficiency of assessing the performance of techniques aimed at expanding the use of resource potential of oilfields with hard-to-recover reserves]. *Izvestiya Tomskogo politekhnicheskogo universiteta. Inzhiniring georesursov = Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering*, 329(8), pp. 30-36. (In Russ.)

Mukhametshin V.V. (2017). Ustraneniye neopredelennostey pri reshenii zadach vozdeystviya na prizaboynuyu zonu skvazhin [Eliminating uncertainties in solving bottom hole zone stimulation tasks]. *Izvestiya Tomskogo politekhnicheskogo universiteta. Inzhiniring georesursov = Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering*, 328(7), pp. 40-50. (In Russ.)

Rogachev M.K., Mukhametshin V.V. (2018). Kontrol' i regulirovaniye protsessa solyanokislotnogo vozdeystviya na prizaboynuyu zonu skvazhin po geologo-promyslovym dannym [Control and regulation of the hydrochloric acid treatment of the bottomhole zone based on field-geological data]. *Zapiski Gornogo instituta = Journal of Mining Institute*, 231, pp. 275-280. DOI: 10.25515/PMI.2018.3.275. (In Russ.)

## About the Authors

*Rustem F. Yakupov* – Deputy Head of the Field Development Department, Bashneft-Dobycha LLC
30/1 Karl Marks st., Ufa, 450077, Russian Federation

*Vyacheslav Sh. Mukhametshin* – DCs (Geology and Mineralogy), Professor of the Department of Oil and Gas Fields Exploration and Development, Director, Oktyabrsky Branch of the Ufa State Petroleum Technological University
54a Devonsky st., Oktyabrsky, 452607, Russian Federation

*Ilgizar N. Khakimzyanov* – DCs (Engineering), Head of the Laboratory, Oil Fields Development Department, Institute TatNIPIneft Tatneft PJSC, Professor of the Oktyabrsky Branch of the Ufa State Petroleum Technological University
40 M.Djalil st., Bugulma, 423326, Russian Federation
E-mail: khakimzyanov@tatnipi.ru
Tel: +7(85594)78-741

*Viktor E. Trofimov* – Researcher, BashNIPIneft LLC
86/1 Lenin st., Ufa, 450006, Russian Federation

*Manuscript received 19 September 2018;*
*Accepted 14 February 2019; Published 1 September 2019*