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FORECASTING ORF BY THE MARTOS METHOD AND THE STATISTICAL METHOD USING THE EXAMPLE OF DEPOSIT X



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The article discusses the effectiveness of the Martos method and the statistical method for predicting oil recovery factor using the example of the X field. Today's values of oil recovery factors (ORF) for Triassic horizons were determined taking into account the active water pressure regime with artificial maintenance of reservoir pressure (RPM) and the drilling of 16 new production wells. This approach required a revision of ORF values due to the transition to natural reservoir development and the cessation of maintaining reservoir pressure by water injection. The failure to drill new wells has also had a significant impact on ORF.

At current production, when 44.7% of the field's reserves have been extracted, and taking into account the remaining reserves, the development period of the field will not exceed 42 years.

It is also planned to increase the number of hydraulic engineering measures to expand drainage zones and involve additional reserves in development.

Having compared the two methods for calculating ORF, we can conclude that although V.N. Martos' method is based on reservoir parameters, and the statistical method uses historical data, the results of their calculations differ slightly.

KEY WORDS: *deposit, deposit, water pressure regime, reservoir pressure maintenance, water injection.*

X КЕН ОРНЫНЫҢ МЫСАЛЫНДА МАРТОС ӘДІСІМЕН ЖӘНЕ СТАТИСТИКАЛЫҚ ӘДІСПЕН КИН БОЛЖАУ

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Мақалада Мартос әдісінің тиімділігі және X кен орнының мысалында КИН-ны болжаудың статистикалық әдісі қарастырылған.триас горизонттары үшін мұнай өндіру коэффициенттерінің (КИН) бүгінгі мәндері қабаттық қысымды (PPD) жасанды қолдайтын белсенді су қысымы режимін және 16 жаңа өндіруші ұңғымаларды бұрғылауды ескере отырып анықталды. Бұл тәсіл табиғи режимде кен орындарын игеруге көшуге және су айдау арқылы қабат қысымын ұстап тұруды тоқтатуға байланысты КИН мәндерін қайта қарауды талап етті. Жаңа ұңғымаларды бұрғылаудан бас тарту Кинге де айтарлықтай әсер етті.

Ағымдағы өндіру кезінде, кен орны қорларының 44,7% -ы алынған кезде және қалдық қорларды ескере отырып, кен орнын игеру кезеңі 42 жылдан аспайды.

Сондай-ақ дренаж аймақтарын кеңейту және игеруге қосымша қорларды тарту үшін гидротехникалық іс-шаралар санын ұлғайту көзделеді.

Кин есептеудің екі әдісін салыстыра отырып, В.Н. Мартос әдістемесі коллектордың параметрлеріне негізделгенімен және статистикалық әдіс тарихи деректерді қолданғанымен, олардың есептеу нәтижелері аздап өзгереді деген қорытынды жасауға болады.

***ТҮЙІН СӨЗДЕР:** кен орны, кен орны, су қысымы режимі, қабат қысымын ұстап тұру, су айдау.*

ПРОГНОЗИРОВАНИЕ КИН МЕТОДОМ МАРТОСА И СТАТИСТИЧЕСКИМ МЕТОДОМ НА ПРИМЕРЕ МЕСТОРОЖДЕНИЯ Х

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Рассматривается эффективность метода Мартоса и статистический метод для Прогназирование КИН на примере месторождения Х. Сегодняшние значения коэффициентов нефтеизвлечения (КИН) для триасовых горизонтов были определены с учетом активного водонапорного режима с искусственным поддержанием пластового давления (ППД) и бурения 16 новых добывающих скважин. Этот подход требовал пересмотра значений КИН из-за перехода на разработку залежей на естественном режиме и прекращения поддержания пластового давления закачкой воды. Отказ от бурения новых скважин также существенно повлиял на КИН.

При текущей добыче, когда извлечено 44,7% запасов месторождения, и с учетом остаточных запасов, период разработки месторождения не превысит 42 лет.

Предусматривается также увеличение количества гидротехнических мероприятий для расширения зон дренирования и вовлечения дополнительных запасов в разработку.

Сравнив два метода расчета КИН, можно сделать вывод, что хотя методика В. Н. Мартоса основана на параметрах коллектора, а статистический метод использует исторические данные, результаты их расчетов незначительно различаются.

***КЛЮЧЕВЫЕ СЛОВА:** месторождение, залежь, водонапорный режим, поддержание пластового давления, закачка воды.*

Introduction. The increase in the efficiency of oil extraction from actively developed fields is comparable to the discovery of new fields, so this problem is important for all oil-producing countries in the world.

To effectively extract hard-to-reach oil reserves, it is necessary to have a reliable physical and geological knowledge base that will allow you to assess the production capabilities of productive formations. This will also allow for informed selection and systematic improvement of development methods, enhanced oil recovery technologies and enhanced oil recovery (EOR) methods that are most suitable for specific types of fields.

The choice of the X deposit as the main objects of research in this work is not accidental. Firstly, the site is characterized by a complex geological structure and high heterogeneity, being a multi-block field. Secondly, the field is at the third stage of development. Thirdly, the reservoir pressure maintenance system was canceled at the site due to geological problems. Fourthly, the experience of many years of developing oil deposits and reservoirs using intensification technologies and increasing development efficiency is valuable.

Hard-to-recover reserves (HTR) of oil and gas - reserves of fields, deposits or individual parts thereof, characterized by geological conditions of oil occurrence and (or) its physical properties that are relatively unfavorable for extraction (concentrated in deposits with low-permeability reservoirs and viscous oil).

In general, the production of hard-to-recover oils is one of the main tasks of the modern oil industry, in which scientific, analytical and engineering approaches are used to identify the most effective and cost-effective method for increasing oil recovery for a specific well. Of all the variety of problems in the extraction of hard-to-recover oils, in my dissertation I will analyze the problem of a geological nature. Low porosity and low permeability of rocks in burial conditions.

At the X deposit, exploratory drilling began in 1985 and was discovered in 1986. The first information about the geological structure of the structure was obtained as a result of seismic CDP studies in combination with structural drilling. The discoverer of the field is well №1, in which the oil and gas potential of Triassic deposits was established. The oil flow rate during testing of the T-I horizon was 25 m^3/day. Exploratory drilling in the Triassic section identified six productive horizons.

Current reserve production is 44.7% of the initial recoverable reserves, while the approved design oil recovery factor (ORF) of Triassic horizons was calculated for a development system in active water-pressure mode with artificial RPM and drilling of 16 new production wells. As a result, the current transition to the development of deposits in a natural mode requires a revision of the approved oil recovery factors, based on recalculated recoverable reserves. In my dissertation, I will calculate the oil recovery coefficient using the statistical method and the method of the scientist V. Martos, and at the end I will conduct a comparison analysis [1-3].

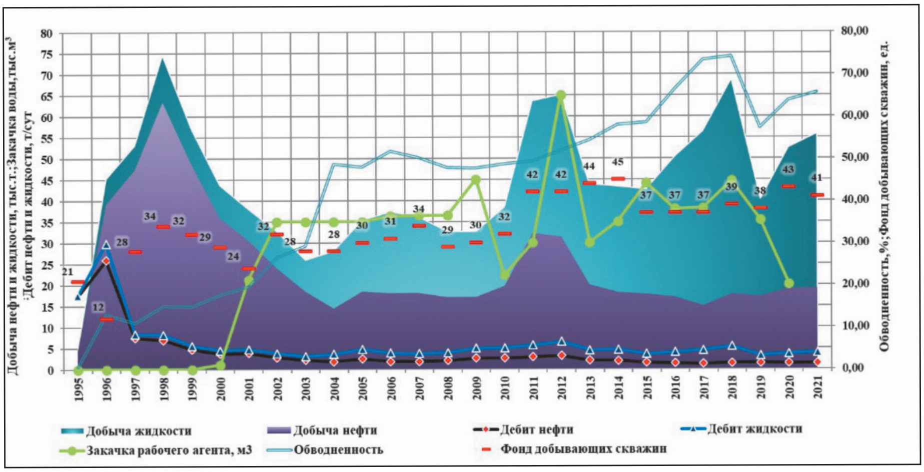

Figure 1 – **Dynamics of key development indicators for the site as a whole**

The salt dome in the study area is characterized by an isometric structure and is complicated by two cornices (*Fig. 1*). In the southeast of the area, in the area of the North Kotyrtas field, the presence of a cornice was confirmed by drilling [4]. Wells №№14 and 29, after opening the salt strata with a thickness of 874 m and 1042 m, respectively, passed about 1000 m through Permian-Triassic terrigenous deposits. According to well logging data [5-7], sandstones are almost completely absent in the sub-canopy part of the interval and the prospects for discovering deposits here are very low.

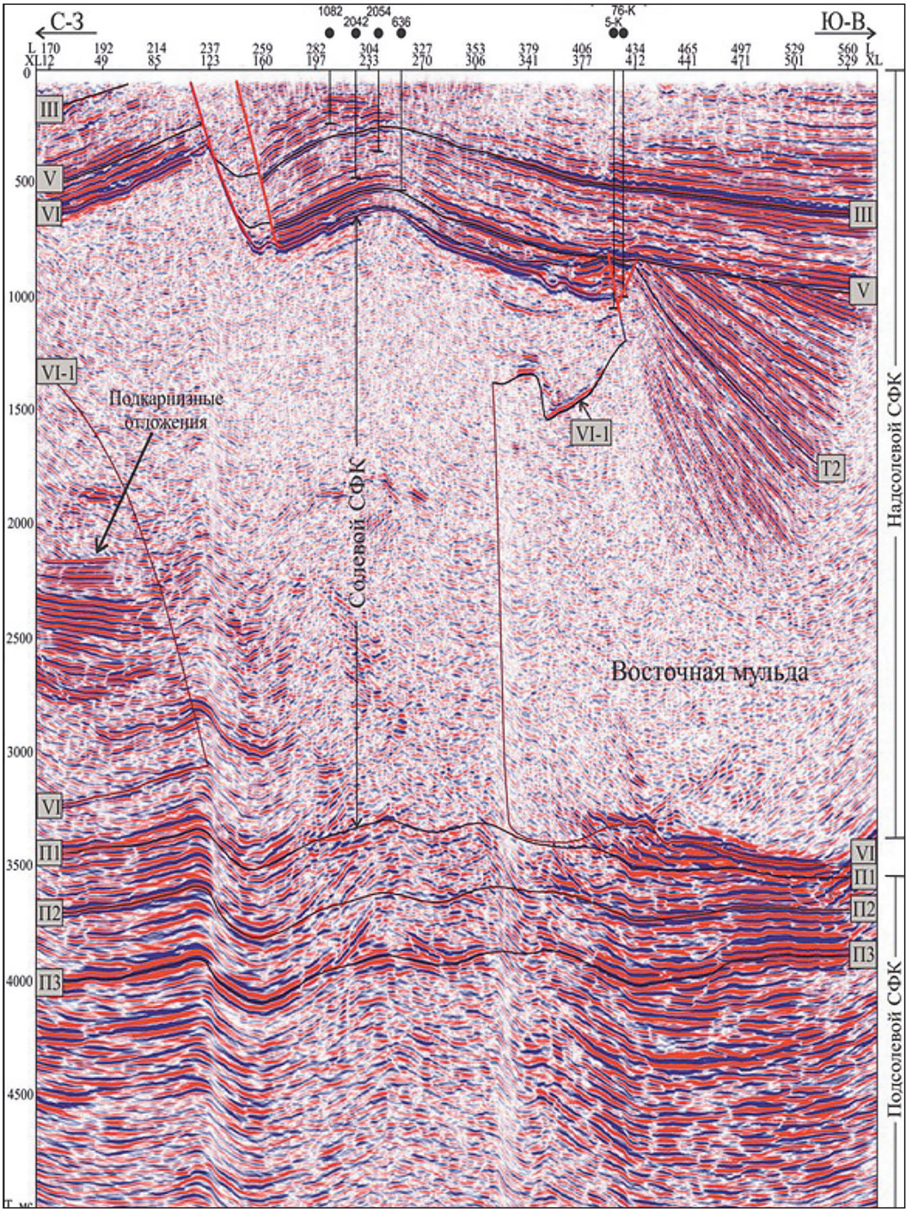

Figure 2 – **Characteristics of the wave field on the work area**

Based on seismic data from 2010, structural constructions were carried out on the reflecting horizon T2 (the top of the Middle Triassic deposits) and on the top of the Triassic productive horizons (T-I, T-II, T-III, T-IV, T-V). As a result, the location and number of disjunctive faults have changed significantly, and in some formations the oil and gas bearing area has increased compared to data from previous years, which is due to changes in the geometry of the deposits.

To the east, the uplift is complicated by two extended faults F_3 and F_4 with a southeastern strike, limiting the horst; in this part of the structure, the "T-IV" surface plunges steeply from an absolute elevation of -1080 m to an absolute elevation of -2250 m over a distance of 2.5 km (*Fig. 2, 3*). In the south the structure is complicated by a structural nose.

The structural plans of the productive horizons T-V, T-III, T-II, T-I in plan repeat the structure of the T-IV horizon, the length, direction and number of faults remain the same, but the structure takes on a more regular shape, and the extent of tectonic faults in the western part of the area changes upward (faults F_1 and F_2). In the eastern part, faults (F_3 and F_4) retain their configuration.

According to drilling data, the position of tectonic disturbances was clarified, low-amplitude, about 5-10 m faults f5 with a fall to the west and f_6 and f_7 with a dip to the south were identified, which were carried out based on the difference in the OWC elevations.

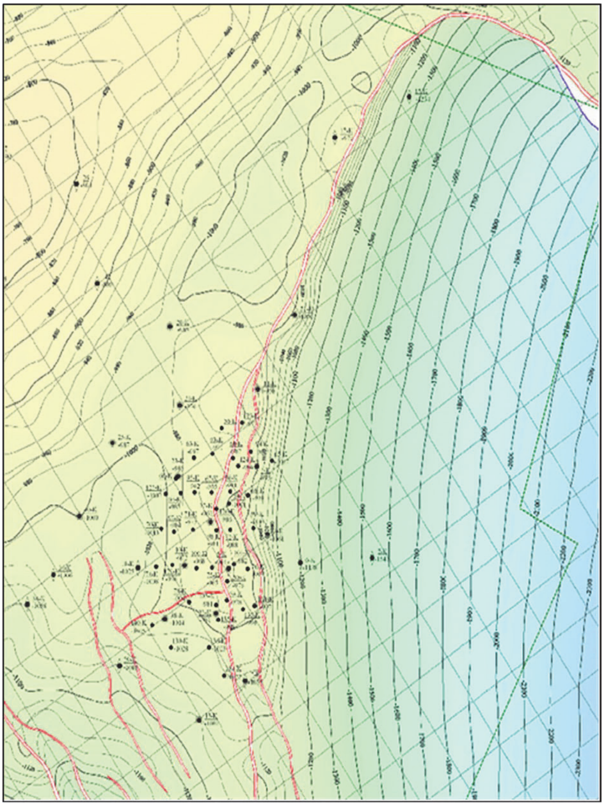

Figure 3 – **Structural map for OG-T2 (top of Middle Triassic deposits)**

In this work, the average values of filtration and reservoir properties and initial oil saturation were substantiated by core, well logging and well hydrodynamic testing data [8-10].

The initial oil saturation of sand reservoirs was determined by geophysical methods. The largest number of determinations (241) was made for the T-IV horizon, and the smallest (5) for the T-VI horizon. The average oil saturation value obtained from well logging varies from 0.56 to 0.661 units.

The average gas saturation value obtained from well logging varies from 0.55 to 0.674 units.

Analysis of core studies. Basic information about the nature of illumination from core material and laboratory analyzes of the productive strata was obtained during exploratory drilling in 21 wells (№№1, 2, 3, 5, 6, 7, 10, 11, 13, 14, 19, 20, 21, 22, 23, 24, 25, 36, 37, 38, 40).

In general, 1,502.9 m of core sampling was completed in the field, with linear removal being 474.05 m or 31.54% of the penetration. Drilling in the productive part is 621.4 m with core removal of 226.89 m or 36.51% of drilling. A total of 296 core samples were analyzed for the field, of which 174 samples came from well №22. The productive horizons [11-15] account for 134 analyzed core samples. Effective capacities are covered by 76 core analyses, of which 63 analyzes are accepted as standard.

Core sampling characteristics are given in *Table 1*.

Table 1 – **Core sampling characteristics**

Well number	General drilling with core sampling			Core sampling in the productive part			Total samples analyzed	Samples collected in the productive part	Standard samples
	Drilling	Removal of core from drilling		Drilling	Removal of core from drilling				
	m	m	%	m	m	%			
1	85	12,5	14,71	14	1,6	11,43	14	-	-
2	75	22,85	30,47	1	0,6	60	6	-	-
3	92	25,17	27,36	17	5,2	30,59	6	1	-
5	84,9	34	40,05	60	28,4	47,33	6	5	-
6	94	30,65	32,61	17	9,1	53,53	6	-	-
7	60	11,25	18,75	29,3	6,95	23,72	17	-	3
10	42	12,8	30,48	15	7,45	49,67	3	-	-
11	70	28,7	41	15	3,8	25,33	9	-	-
13	49	14,25	29,08	14	5,7	40,71	2	1	-
14	53	11,03	20,81	-	-	-	2	-	-
19	46	15,15	32,93	26	8,45	32,50	2	-	-
20	40	7,6	19	13	3,3	25,38	3	1	-
21	55	9,6	17,45	20	3,25	16,25	4	-	-
22	262	137,84	52,61	164,4	83,4	50,73	174	107	53
23	55	15,01	27,29	30	7,26	24,20	2	2	-
24	45	26,7	59,33	30,5	17,9	58,69	5	1	4
25	48	7,07	14,73	15,6	2,9	18,59	6	-	-
36	50	7,025	14,05	30	4,775	15,92	4	1	-
37	91	19,05	20,93	60	11,35	18,92	16	3	3
38	46	9,8	21,30	22,6	5,6	24,78	3	2	-
40	60	16	26,67	27	9,9	36,67	6	2	-
Total:	1502,9	474,05	31,54	621,4	226,89	36,51	296	134	63

The complex of studies includes the determination of a standard set of parameters: mineralogical and volumetric density, open and total porosity, permeability, carbonate and particle size distribution, oil and water content. In addition, electrical and acoustic parameters and capillary characteristics of reservoir rocks were determined.

Integral curves of porosity distribution by class with permeability Kper<1mD and Kper>1mD were constructed. The intersection of the integral curves determined the boundary value of porosity equal to 9.8%.

Thus, porosity for deposits was determined by two methods: according to well logging data and according to the results of core analyses.

Core porosity [16-18] was studied in 1-4 wells on 1-35 samples, permeability was also studied in 1-4 wells on 2-23 samples. According to well logging, the number of porosity determinations is 5-251 values. The average values of the porosity coefficient based on core and well logging data range from 0.20 to 0.28 units. Average porosity coefficient values for gas-saturated reservoirs range from 0.23-0.285.

Average permeability values determined from core are 17.5-232.5 $\mu m^2 * 10^{-3}$, and according to the results of hydrodynamic studies they vary within 0.5-200 10-3*μm^2.

The properties of oil in surface conditions were studied by 142 surface samples taken from productive horizons: T – 1 sample, T-I – 7 samples, T-II – 22 samples, T-III – 36 samples, T-IV – 68 samples, T-V – 6 samples, 2 samples from jointly selected horizons.

The bulk of the samples characterize the properties of oil from the T-II, T-III and T-IV horizons. When analyzing the available data on previously collected samples, a difference is observed in the density values of surface oil within one block in the roof and printer parts of the structure. Thus, in blocks IV, V, in the roof part of the structure, relatively lower densities were measured compared to the marginal parts, where the oil density reaches 0.950 g/cm^3. Significant fluctuations in oil properties are associated with the complex geological structure of deposits, disturbed by faults and in individual wells in contact with water. To clarify such changes in the fluid system of the field, oil densities were additionally measured in wells №№38, 60, 64, 71, 75, 78, 79, 93, 123, 125, 129, 132, 134, 140. As a result of the measurements, the previously obtained values for the blocks were confirmed [19-20]. Based on this, the density of separated oil is taken based on the average values of all samples separately for blocks.

After rejecting incorrect values, surface oils of Triassic horizons are classified in the following order:

Oil class. According to the average values of sulfur content, oils from all productive horizons are low-sulfur and belong to class 1 (variation range from 0.29 to 0.60 wt.%).

Type of oil. Along the horizons, the density of oil varies from particularly light (density less than 830 kg/m^3) to bituminous (density more than 895.0 kg/m^3).

Oil group. The content of chloride salts in all samples has not been determined, and therefore it is not possible to classify them.

The paraffin content in oils across all horizons is found in the range of 0.24-0.89 wt%.

According to ST RK 1347-2005 oil, the above oils are classified as low-paraffin and paraffinic, low-resin and resinous oils. The yield of fractions boiling up to 300ºC for Triassic oils is 47.1 – 69.5% vol., including up to 200ºC the yield of distillates is 24.9 – 40.6% vol.

The maximum level of oil production of 63.4 thousand tons was reached in 1998. Already next year there is a sharp decline in production by 23%. By 2003, oil production had decreased to about 18 thousand tons/year and continues to this day. It is worth noting that in the period from 2010 to 2012 there was an increase in oil production, which is associated with the commissioning of 17 new production wells. However, starting from 2013 to 2017, oil production decreased to 15.0 thousand tons. Afterwards, from 2018 to 2021, there is an increase in annual oil production figures. In 2020, 19.0 thousand tons were produced, which is mainly due to the commissioning of well №38 in May 2020 from abandonment at the I+Returnable facilities; over 8 months of operation, production was 1.7 thousand tons, which is almost 10% of total annual production for 2020. Also, at the end of 2020, hydraulic fracturing was carried out on two production wells, as a result of which water was brought up in well №109, and oil production in well №125 increased by 2-3 times, and additional oil production in three months amounted to 264 tons. In 2021, oil production remained at the level of the previous year.

The main technological development indicators for objects and for the field are presented in *Figures 4-7*.

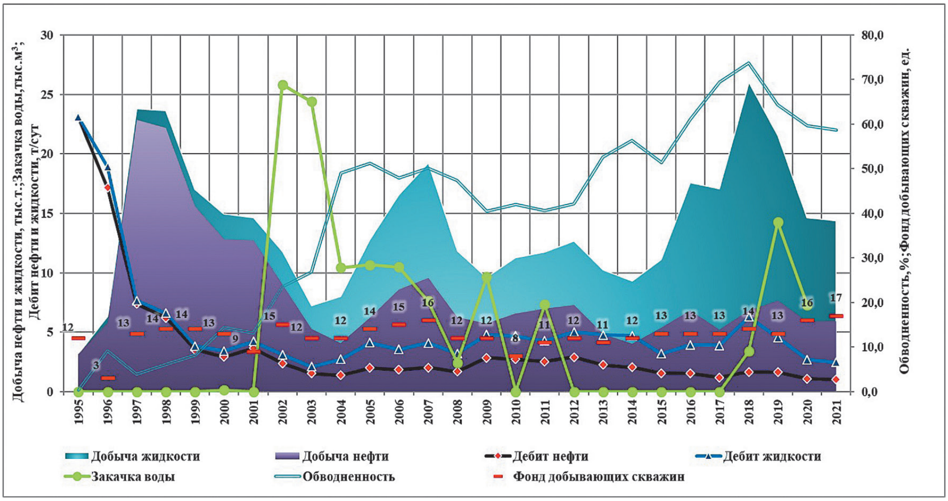

Figure 4 – **Dynamics of main indicators of development of object I**

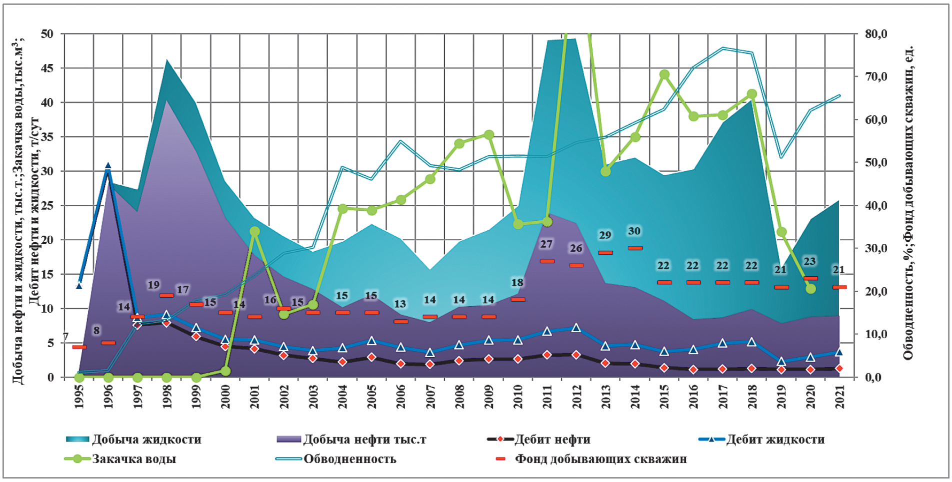

Figure 5 – **Dynamics of the main technological indicators of the development of object II**

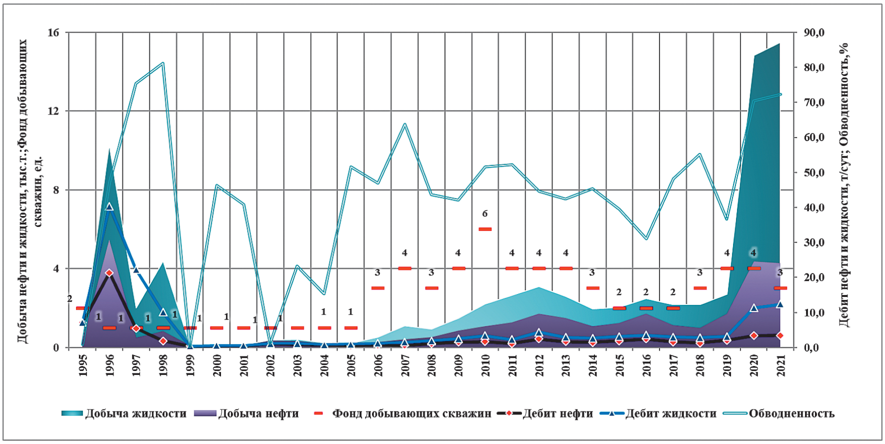

Figure 6 – **Dynamics of the main technological indicators of the development of the Returnable object**

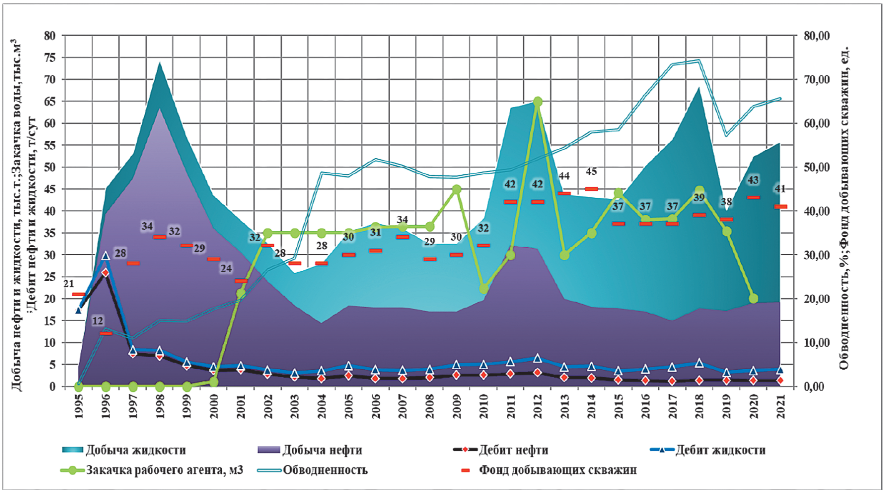

Figure 7 – **Dynamics of key development indicators for the site as a whole**

Development of the X deposit is carried out in accordance with the approved development analysis. The effectiveness of the implemented development system was assessed based on an analysis of the current state.

From the analysis it follows that, in general, during the reporting period, the design and actual indicators are at the same level, the development of the site is carried out in accordance with the approved project document.

ORF was approved in the “Recalculation of reserves...” as of 07/01/2013. ORF was approved taking into account the drilling of new production wells and maintaining the RPM system, however, in mid-2020, injection was stopped, injection wells were put on hold due to a lack of injectivity due to poor reservoir properties of the Triassic horizons, which in turn led to a significant decrease in reservoir pressure relative to the initial one (large reservoir compartmentalization and low sand content), as a result of which achieving the approved ORF is impossible.

Methods for calculation of ORF using the Martos method and the statistical method. It has been proven that the drainage area of each well, depending on the relative position of neighboring wells and their operating mode, can be replaced in hydrodynamic calculations by a circle of equal area.

Changes in development indicators: flow rate, pressure, at the bottom and on the contour of the drainage area, gas factor - can be determined using the method proposed by M.M. Glagovsky and L.A. Zinovyva [21].

The relationship between flow rate q_n and pressure drop at a point in time is equal to

$$q_n = \frac{2\pi kh(H_k - H_c)}{ln\frac{r_k}{r_c} - \frac{1}{2}}$$

Where q_n is the well flow rate, m^3/s, k is the formation permeability, m^2, h is the formation thickness, m, r_r is the drainage contour radius, m, r_r is the well radius, $(H_k - H_r)$ is the difference between the generalized Khristianovich function in Pa, at values of pressure on the contour of the drainage area p_k and pressure at the bottom of the well p_r in Pa.

$$H_k - H_c = \int_{p_c}^{p_k} \frac{F_H(s)}{\mu_H(p)\beta(p)} dp$$

Here $F_H(s) = \frac{k_H}{k}$ is the ratio of the phase permeability for oil to the permeability of the formation, which is a function of the oil saturation of the vapor space; μ_H - dynamic viscosity of oil, depending on pressure, in Pa*s; β – volumetric coefficient, depending on pressure.

$$H_k - H_c = \frac{a}{2}(p_k^2 - p_c^2) + b(p_k - p_c)$$

$$a = \frac{\frac{F_H(s_k)}{\beta(p_k)\mu_H(p_k)} - \frac{F_H(s_c)}{\beta(p_c)\mu_H(p_c)}}{p_k - p_c}$$

$$b = \frac{F_H(s_k)}{\beta(p_k)\mu_H(p_k)} - \frac{\frac{F_H(s_k)}{\beta(p_k)\mu_H(p_k)} - \frac{F_H(s_c)}{\beta(p_c)\mu_H(p_c)}}{p_k - p_c} p_k$$

where $s_k s_r$ –are, respectively, the oil saturation of the pores on the contour of the drainage area and in the well.

Considering that the development of the field is envisaged in a natural mode with an elastically closed and dissolved gas mode, the method of V.N. Martos was used to substantiate the oil recovery factor. The V.N. Martos technique is used for fields developed in an elastic mode with a predominance of dissolved gas. The technological ORF was calculated using a formula that in turn combines two formulas: ORF in the elastic mode and ORF in the dissolved gas-dominated mode. The method is based on geological and physical characteristics and takes into account such indicators as rock compressibility coefficient, porosity, initial oil saturation, formation oil compressibility coefficient, saturation coefficient of bound water in rocks, formation water compressibility coefficient, initial formation pressure, saturation pressure, volumetric coefficient and viscosity of formation oil at saturation pressure.

The calculation results are presented in *Table 2*.

1. Elastic mode formula=ORF 1.

$$\eta = \frac{\beta_n + m * (S_н * \beta_н + S_в * \beta_в) * (P_0 - P_н)}{m * S_н}$$

Where

η - ORF in elastic mode, fractions of units.

β_n - rock compressibility coefficient, 10^{-4}, MPa^{-1}

m - porosity, fractions of units

S_o - initial oil saturation, fractions of units,

β_H - reservoir oil compressibility coefficient, 10^{-4}, MPa^{-1}

S_w - coefficient of saturation with bound water in rocks, fractions of units.

β_B - formation water compressibility coefficient, 10^{-4}, MPa^{-1}

P_0 - initial reservoir pressure, MPa

P_s - saturation pressure, MPa

2. Formula for the regime with a predominance of dissolved gas=ORF 2.

$$\eta = 0.41815[\frac{m * (1 - S_в)}{b_н}]^{0.1611} * \left(\frac{k}{\mu_н}\right)^{0.0979} * \left(\frac{P_н}{P_з}\right)^{0,1741} * S_в^{0.3722}$$

η - ORF in dissolved gas mode, fractions of units.

m - porosity, fractions of units

S_w - coefficient of saturation with bound water in rocks, fractions of units.

$b_н$ - volumetric coefficient, fractions of units.

k - permeability, μm2

μ_H - viscosity of reservoir oil at saturation pressure, mPa·s

P_s - saturation pressure, MPa

P_i - injection pressure, MPa

3. ORF 1+ORF 2=ORF

Calculation of ORF I object.

1. ORF in elastic mode, fractions of units.

η	**0,0140**	ORF in elastic mode, fractions of units.
β_n	5,1	rock compressibility coefficient, 10^{-4}, MPa^{-1}
m	0,25	porosity, fractions of units
So	0,66	initial oil saturation, fractions of units,
β_H	19,0	reservoir oil compressibility coefficient, 10^{-4}, MPa^{-1}
Sw	0,34	coefficient of saturation with bound water in rocks, fractions of units.
β_B	4,35	formation water compressibility coefficient, 10^{-4}, MPa^{-1}
P_0	10,8	initial reservoir pressure, MPa
Ps	5,7	saturation pressure, MPa

2. ORF in dissolved gas mode, fractions of units.

η	**0,1043**	ORF in dissolved gas mode, fractions of units.
m	0,25	porosity, fractions of units
S_w	0,34	coefficient of saturation with bound water in rocks, fractions of units.
$b_н$	1,14	volumetric coefficient, fractions of units.
k	0,007	permeability, μm²
μ_H	6,65	viscosity of reservoir oil at saturation pressure, mPa·s
P_s	5,7	saturation pressure, MPa
P_i	5,8	injection pressure, MPa

3. Final ORF. 0.0140+0.1043=0.118 fraction of units.

Calculation of ORF II object.
1. ORF in elastic mode, fractions of units.

?	0,0160	-	ORF in elastic mode, fractions of units.
?	4,4	-	rock compressibility coefficient, 10^{-4}, MPa^{-1}
m	0,24	-	porosity, fractions of units
Sн	0,62	-	initial oil saturation, fractions of units,
?	20,2	-	reservoir oil compressibility coefficient, 10^{-4}, MPa^{-1}
Sw	0,37	-	coefficient of saturation with bound water in rocks, fractions of units.
?	4,35	-	formation water compressibility coefficient, 10^{-4}, MPa^{-1}
P_0	12,0	-	initial reservoir pressure, MPa
Ps	6,3	-	saturation pressure, MPa

2. ORF in elastic mode, fractions of units.

?	0,1386	-	ORF in dissolved gas mode, fractions of units.
m	0,24	-	porosity, fractions of units
S_w	0,37	-	coefficient of saturation with bound water in rocks, fractions of units.
$b_н$	1,25	-	volumetric coefficient, fractions of units.
k	0,03	-	permeability, μm²
?	1,40	-	viscosity of reservoir oil at saturation pressure, mPa·s
P_s	6,3	-	saturation pressure, MPa
P_i	6,4	-	injection pressure, MPa

3. Final ORF. 0,0160+0,1386=0,155

The final indicators of the ORF calculations are presented in the following table 2. The oil recovery factor for the entire area was determined by a weighted average calculation through geological reserves.

Table 2 Estimated values of technological ORF

Object	ORF value
I	0,118
II	0,155
Overall for the area	0,135

ORF calculations using the statistical method and its results.

The second method for calculating ORF is the statistical method. A statistical approach to the study of oil recovery in order to predict the technological indicators of the development of fields at different stages of development is widely used in the CIS countries and abroad. Statistical methods are an effective tool for collecting and analyzing information. The use of these methods does not require large expenses and allows one to judge with a given degree of accuracy and reliability the state of the field under study (objects, horizons, layers), predict and regulate problems at all stages of their life cycle, and based on this, develop optimal solutions to achieve a particular task. This method of predicting technological indicators differs from hydrodynamic ones in its simplicity and constructiveness, which makes it possible to quickly evaluate objects with their help as information is accumulated and clarify geological and physical parameters.

The statistical methodology is based on identifying patterns of technological indicators in the process of field development, which include such parameters as production, oil and liquid flow rates, water cut and reserve development rates. The most optimal parameter for calculation is selected based on the characteristics of the field: when developing a deposit in an active water-pressure mode, the determining factor is the water cut of the produced product; and when the deposit operates in an elastically closed mode, the parameters of liquid flow rate and annual withdrawals become determining for development as a whole, which is determined by the energy characteristics of the deposit. Also an important criterion is the approximation coefficient, which characterizes the preservation of the pattern in the trend of changes in parameters over time, which should not be lower than 0.8 fraction of units.

The most common technological indicator characterizing the pattern of reservoir operation for most fields is oil production, which is very universal and suitable for a wide variety of types of deposits and their operating modes. Forecasting field development based on oil flow rate is performed according to an exponential equation derived from the historical flow rate dynamics. Thus, the application of the statistical methodology [7] requires a sufficiently long development history, during which the development indicators of the object in question will have a certain tendency and line up in a clear trend while maintaining a certain pattern, which will become a condition for further forecasting. *Figure 8, 9* shows an example of determining a pattern in changes in oil flow rate within a historical period.

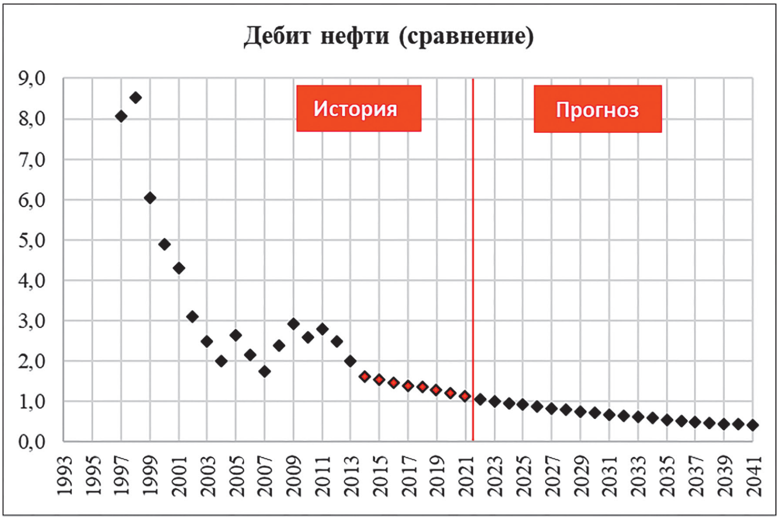

Figure 8 – **Example of determining the pattern of change in the flow rate from the historical period**

The methodology for using the statistical approach itself is simple and involves the derivation of an exponential equation and further forecasting of oil production based on it. *Figure 4* shows an example of deriving an exponential equation.

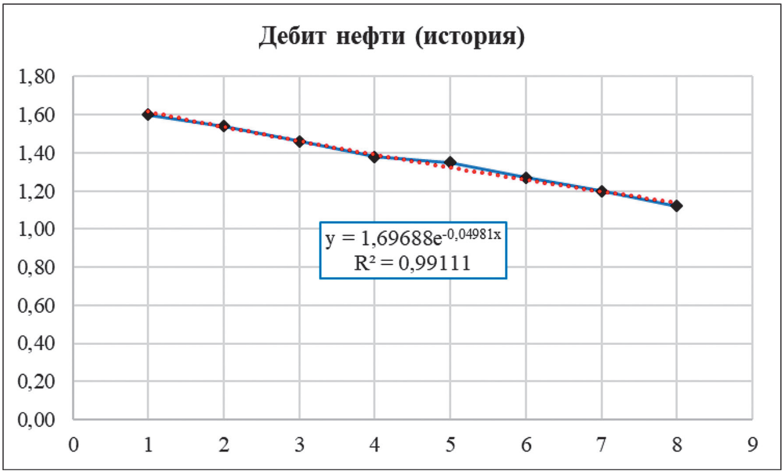

Figure 9 – **Example of determining the decline rate based on historical oil production**

As can be seen from the example, the rate of decline is -0.04981. Now we can use this rate of decline to calculate forecast technological indicators. To do this we use the following formula:

$$q=\frac{qc}{тп} * n$$

where:

q – oil flow rate;

qc – starting oil flow rate;

RD – rate of decline;

n – unit of measurement of the forecast period (year, month).

The use of a specifically exponential equation is typical specifically for forecasting based on oil production; when other technological indicators, such as production, water cut or production rates, are used as a determining parameter, other equations for deriving a trend line, such as linear or logarithmic, can be used. The subordination of the oil flow rate dynamics to an exponential pattern, rather than being described by a linear dependence, is due to the formation mechanism of this flow rate, the value and rate of change of which are most influenced by multiphase flow conditions, expressed by the logarithmic dependence of the relative phase permeability, as well as the energy characteristics of the reservoir, depending on the rate of decline in reservoir pressure, which, due to the presence of artificial RPM, boundary recharge and volumetric expansion forces, is also described by an exponential dependence.

In the course of this work, all geological and geophysical work carried out on the territory of the X deposit and the results of these works were analyzed.

The ORF values of the Triassic horizons approved today were calculated for a development system in an active water-pressure mode with artificial RPM and the drilling of 16 new production wells, as a result of which the current transition to the development of deposits in a natural mode required a revision of the approved oil recovery factors.

Given the current depletion of reserves for the field as a whole is 44.7% and the presence of residual oil reserves, the reserve ratio for further development of the field will not exceed 42 years.

Conclusions. As a result of the work carried out, the following conclusion can be drawn. First of all, the need to reduce the approved oil recovery factor was influenced by the transition from an active water-pressure mode to a natural depletion mode, stopping the maintenance of reservoir pressure by injecting water. Due to cause-and-effect relationships, the refusal to drill new wells also had a significant impact on the final ORF.

Taking into account all the above reasons, a technical and economic analysis of development options was carried out which showed that the most effective and recommended for implementation is the second option - which involves drilling a development and appraisal well at object II and carrying out hydraulic fracturing at production wells. Also, in order to increase the coverage of drainage zones of reserves and involve these reserves in development, it is additionally envisaged to increase the number of geological and technical measures for additional drilling and transfer of wells between objects.

Comparing the two methods for calculating ORF, the following conclusions can be drawn; Table 2 shows a comparison of the results of the two methods. If V.N. Martos' method is more based on reservoir parameters, then the statistical method, in simple words, is based on historical data. Using both methods, the technological ORF was calculated, which in the future will also be passed through economic calculations. As can be seen from the table below, the differences in the calculation results are insignificant.

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