Appendix №24

The results of the repeated interpretation of the hydrodynamic surveys of Well 93

The productive formation $Ю_1^{3-4}$ in well p-93 was tested by means of two facilities.

Facility III. The perforation was performed in the interval of 2209-2211 m using charges ПКС-103. The well development was accompanied by a waterflood, a drawdown and a debugging of the well in flowing state.

The surveys were carried out by tracking the level, the result being shown in Table 1. The table also shows the results of track-level processing in pseudo-steady states by iteration and contains the obtained parameters.

Water permeability is ε=1 D·cm/cP, piezoconductivity – 1336 cm²/m. Table 2 shows the processing of the level tracking curve, well start-up in an unsteady state. It shows that water permeability is lower in the bottom-hole formation zone than in the distant zone and varies between 1 to 0.7 D·cm/cP within a range of 260 m.

The flow-after-flow test results in two flowing states are given in Table 3 which shows a water permeability raise of up to 2.4 D·cm/cP following a debugging and cleanup of the bottom-hole formation zone.

Cleaning the bottom-hole formation zone increased water permeability and piezoconductivity to some extent during the natural flow and when operating in states. Processed PBC are shown considering the influx. Table 4 shows the formation to be a fractured zone which was intensively mudded during the perforation. Water permeability is approximately 0.7 D·cm/cP in the bottom-hole formation zone and it goes up to 2.4 D·cm/cP in the distant zone.

The ratio of all the parameters that varied during the survey is indicated in Table 5 and Figure 1 which show that the order of defining water permeability between 1.0-2.5 was retained at every survey, and it tends to increase during state operations.

Facility IV was tested in the interval of 2209-2216 m following a reperforation of the bottom part of the formation using charges ПР-43. The well development was also accompanied by a waterflood and a drawdown with a further debugging in flowing state.

The well survey was carried out by the flow-after-flow method in three flowing states as shown in Tables 6 and 7 as well as by the PBC method.

After the reperforation production rates and, consequently, water permeability increased. Other parameters are indicated in Table 8.

Figure 2 shows the survey results processed by the PBC method.

The ε-f(R) diagram shows that water permeability in the bottom-hole formation zone increased after reperforation and a repeated development and decreased further from the well wall (deep mudding zone) ultimately reaching a constant value of approximately 3 D.cm/cP.

A further cleanup of the formation and preventing the deformation of the fractured system in the bottom-hole formation zone will allow for double increase in the oil production rate at a production testing. To this end, a slot drilling of the formation needs to be conducted by means of hydraulic jet perforation.

Hydraulic Jet Perforation Technology

In order to perform a slot drilling it is necessary to make hydraulic jet perforators according to the principle pattern worked out by "Sibneftegazinnovacia" CJSC. This pattern is remarkable in that high pressure jets of abrasive slurry are turned upwards at angle of 45^0 relative to the axis. Nozzle bushings being arranged in this manner provides for a higher degree of formation and microcrack exposing by means of having a deep aperture instead of a horizontal wedge-shaped hole, which is formed as a result of a jet perforation.

Slot drilling reallocates hoop tensions from wellbore walls to the end of the aperture thus increasing water permeability in the bottom-hole formation zone.

In compliance with the guidelines on hydraulic jet perforation it is necessary to create a pressure of approximately 300 kilogauss/cm^2 on the jet device nozzles; considering the tubing friction loss at a feed rate of 10 l/sec, around 80 kilogauss/cm^2 will be produced. Thus opening-up must be done using the assembly AH-700. It is recommended to use barium sulfate and hematite (clay mud heavers) or local bank sand of quartz-polymictic composition, sized 0.02-0.04 mm, as abrasive.

When used with heavier, clay mud is additionally processed with КМЦ gel-former.

The amount of the mud must be half as much as the volume of the well.

Hooking up the pipes of the blowing unit and the wellhead must provide for the degassing of the return mud through the ГС-600x40 separator, directing it further to a service tank (50m^3). The cutting duration at each position must exceed 30-40 mins with a smooth raise in the operating pressure from 200 to 400 kilogauss/cm^2 after a disintegration of the drilling string detected by a pressure jump.

The perforator is installed by a subsurface connection based on the recording of the collar locator and gamma log in the tubing.

After the formation exposing the jet device is run 10 m below exposure interval, and a bottom-hole flushing is implemented through a reverse circulation during which the ball in the shutoff valve is washed over.

The well development is conducted with a change to water, with its further substitution by dead oil.

Bring the well to a natural flow and star a production testing.

Table 1

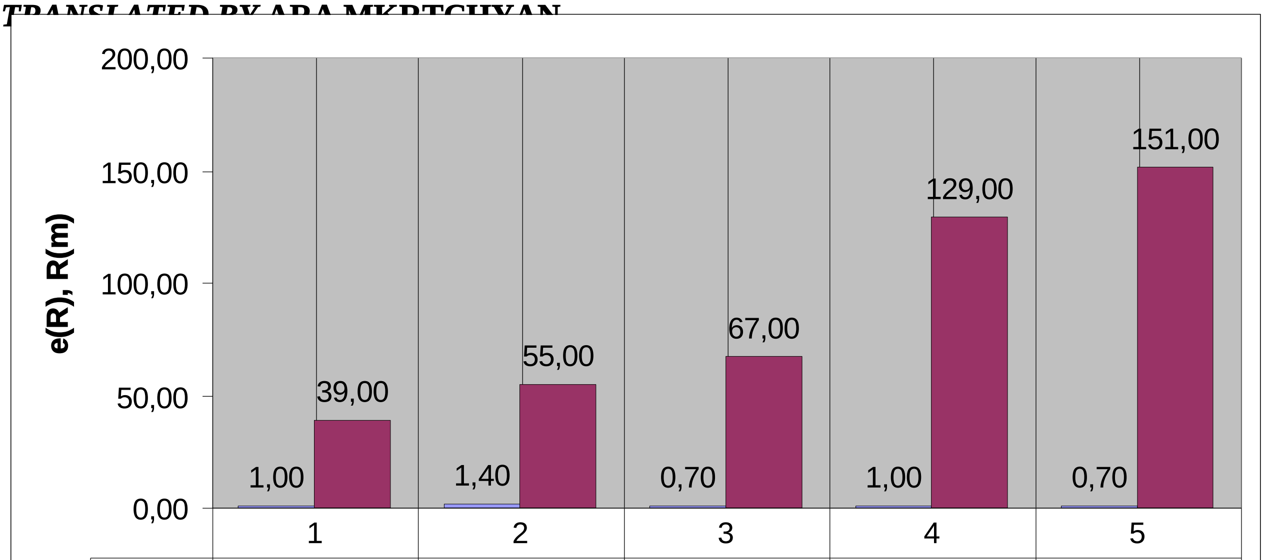
GORSTOVOYE FIELD Well 93; formation Ю$_1^{3\text{-}4}$ (oil); Facility 3; perforation interval – 2207-2210 m; level tracking, iteration processing

Nozzle diam, (mm)	Oil pr. rate (m^3/day)	Oper. time (hour)	Product. factor	P_{form} (atm)	P_{btm} (atm)	P_{form}-P_{btm} (atm)	ε D·cm/cP	χ cm^2/sec
8	12.15	1.0	0.109	221.5	103.19	118.3		
3	15.94	1.0	0.140	221.5	107.73	113.8		
5	7.71	1.0	0.070	221.5	111.46	110.0		
8	8.23	8.0	0.084	221.5	123.12	98.4		
10	5.01	4.0	0.059	221.5	136.73	84.8		
		1.0	0.092				1.603	1336.21

Table 2

GORSTOVOYE FIELD Well 93; formation Ю$_1^{3\text{-}4}$ (oil); Facility 3; perforation interval – 2207-2210 m; level tracking, iteration processing, well star-up

P_{btm}	t, sec accum	LN (t) accum	PC(t) – P_0	$\Delta P_{form}(t)$ = 221.5 – P(t)	q(t) m^3/day (comp. w/ C_{prod})	$\Delta P_w(t)/q(t)$ cm^3/sec	i	hydro	R (m)
				start-up					
103.19	3600	8.19		118.31	12.85	0.64484	0.07875	1.0	39
107.73	7200	8.88	4.54	113.77	15.94	0.49991	0.05628	1.4	55
111.46	10800	9.29	8.27	110.04	7.71	0.99969	0.10764	0.7	67
123.12	39600	10.59	19.93	98.38	8.23	0.83726	0.07909	1.0	129
136.73	54000	10.90	33.54	84.77	5.01	1.18513	0.10876	0.7	151



	1	2	3	4	5
hydro	1,00	1,40	0,70	1,00	0,70
R (m)	39,00	55,00	67,00	129,00	151,00

Fig. Diagram of water permeability allocation in the range of borehole influence in Well 93, Gorstovoye field

Table 3

GORSTOVOYE FIELD Well 93; formation Ю$_1^{3-4}$ (oil); Facility 3; perforation interval – 2207-2210 m; FFT survey, iteration processing

Nozzle diam, (mm)	Oil pr. rate (m^3/day)	Oper. time (hour)	Product. factor	P_{form} (atm)	P_{btm} (atm)	P_{form}-P_{btm} (atm)	ε D·cm/cP	χ cm^2/sec
4	7.5	56.0	0.155	221.5	173.20	48.3		
PBC								
5	11.5	30.0	0.161	221.5	150.00	71.5		
		30.0	0.158				2.431	3055.10

Table 4

GORSTOVOYE FIELD Well 93; formation $Ю_1^{3-4}$ (oil); Facility 3; perforation interval – 2207-2210 m;
(PBC after operating with a 4 mm nozzle $P_{btm, intl}$ = 173.2 atm, P_{form} = 221.5 atm, Q_0 = 7.5 m³/day, v = 1.243) influx-specific processing

t	P (t) atm	ΔP=P(t) – P_0	In(t)	ΔP=P_{form} – P(t), atm	Q_0-q(t) cm³/sec (avg. $C_{prod.}$)	ΔP/Q_0 – q(t) atm/cm³/sec	i (slope)	ε (slope) D*cm/cP	R (m)	ε (R) D*cm/cP	ε $_{FFT}$ D*cm/cP
0	173,20										2,43
900	175,40	2,20	6,8024	46,10	3,09	0,7127	0,1048	0,76	62	0,76	
1800	175,40	4,00	7,4955	44,30	7,15	0,5597	0,0747	1,07	88	1,81	
2700	177,20	5,70	7,9010	42,60	10,98	0,5190	0,0657	1,21	108	1,86	
3600	178,90	7,10	8,1887	41,20	14,14	0,5021	0,0613	1,30	124	1,86	
5400	180,30	10,60	8,5942	37,70	22,04	0,4810	0,0560	1,42	152	1,97	
7200	183,80	13,60	8,8818	34,70	28,80	0,4722	0,0532	1,50	176	1,98	
9000	186,80	17,20	9,1050	31,10	36,92	0,4658	0,0512	1,56	196	2,05	
10800	190,40	19,80	9,2873	28.50	42,79	0,4627	0,0498	1,60	215	2,03	
12600	193,00	22,00	9,4415	26,30	47,75	0,4607	0,0488	1,63	232	2,05	
14400	195,20	24,20	9,5750	24,10	52,71	0,4591	0,0479	1,66	248	2,08	
18000	197,40	28,10	9,7981	20,20	61,51	0,4568	0,0466	1,71	278	2,11	
25200	201,30	32,50	10,1346	15,80	71,44	0,4549	0,0449	1,77	329	2,13	
32400	205,70	36,00	10,3859	12,30	79,33	0,4538	0,0437	1,82	373	2,18	
39600	209,20	39,10	10,5866	9,20	86,33	0,4529	0,0428	1,86	412	2,23	
46800	212,30	40,80	10,7536	7,50	90,16	0,4525	0,0421	1,89	448	2,25	
54000	214,00	42,20	10,8967	6,10	93,32	0,4522	0,0415	1,92	481	2,28	
61200	215,40	43,00	11,0219	5,30	95,12	0,4520	0,0410	1,94	512	2,29	
68400	216,20	43,90	11,1331	4,40	97,15	0,4519	0,0406	1,96	541	2,32	
82800	217,10	45,70	11,3242	2,60	101,22	0,4515	0,0399	2,00	596	2,35	
90000	218,90	46,10	11,4076	2,20	102,12	0,4514	0,0396	2,01	621	2,36	
97200	219,30	47,00	11,4845	1,30	104,15	0,4513	0,0393	2,03	645	2,39	
108000	220,20	47,40	11,5899	0,90	105,05	0,4512	0,0389	2,04	680	2,39	

Table 5

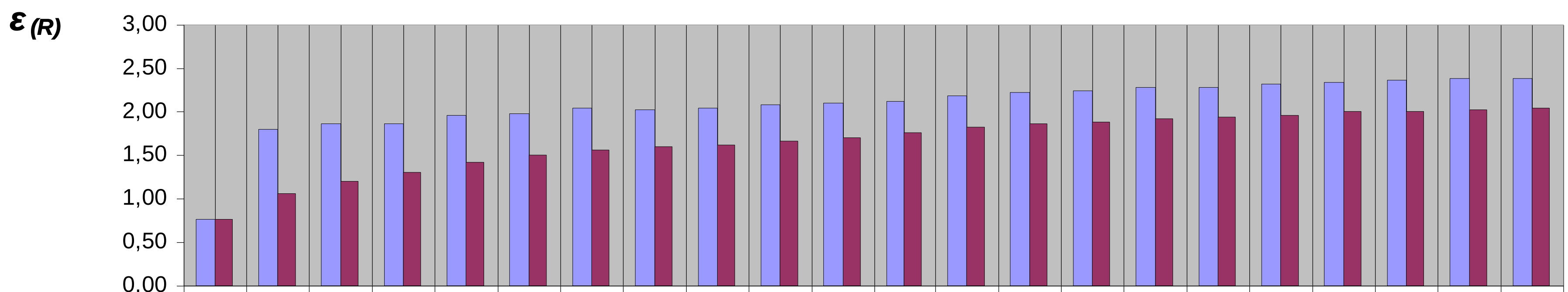
THE RESULTS OF THE HYDRODYNAMIC SURVEYS IN WELL 93 (FACILITY 3) IN THE GORSTOVOYE FIELD BY THE DP TO SNIIGGiMS PROGRAM

					LEVEL TRACKING											
					iteration								start-up			
№	Location	Well	Form.	Form. interval	η_{avg} m³/day*at m	ε D*cm/cP	χ cm²/sec	r_{pr} cm	Π_{GPP} cm	Π_{GPF} cm	h_{prod} m	R_c m	ε_1 D*cm/cP	ε_n D*cm/cP	$S = \varepsilon_1/\varepsilon_n$	$\varepsilon_{FFT}/\varepsilon_{PBC}$
1	Gorsto-voye	93	$Ю_1^{3-4}$	2207-2210	0.0092	1.06	1336	26.6	0.0008	30.6	3	38.9	1.0	0.73	1.38	1.45

FFT							
η_{avg} m³/day*at m	ε D*cm/cP	χ cm²/sec	r_{pr} cm	Π_{GPP} cm	Π_{GPF} cm	h_{prod} m	R_c m
0.158	2.43	3055	40.5	0.0008	30.6	3	322.0

PBC

ε_1 D*cm/cP	$\varepsilon_{FFT}/\varepsilon_{PBC}$		
0.8	1.19		



	62	88	108	124	152	176	196	215	232	248	278	329	373	412	448	481	512	541	596	621	645	680
e (R) D*cm/cP	0,76	1,81	1,86	1,86	1,97	1,98	2,05	2,03	2,05	2,08	2,11	2,13	2,18	2,23	2,25	2,28	2,29	2,32	2,35	2,36	2,39	2,39
e (slope) D*cm/cP	0,76	1,07	1,21	1,30	1,42	1,50	1,56	1,60	1,63	1,66	1,71	1,77	1,82	1,86	1,89	1,92	1,94	1,96	2,00	2,01	2,03	2,04

Fig. 1 Diagram of water permeability allocation in the range of borehole influence in Well 93, Gorstovoye field

Table 6

GORSTOVOYE FIELD Well 93; formation $Ю_1^{3-4}$ (oil); Facility 4; perforation interval – 2207-2219 m; FFT survey, iteration processing

Nozzle diam, (mm)	Oil pr. rate (m^3/day)	Oper. time (hour)	Product. factor	P_{form} (atm)	P_{btm} (atm)	P_{form}-P_{btm} (atm)	ε D·cm/cP	χ cm^2/sec
5	20	31.0	0.241	221.5	138.40	83.1		
pbc								
3	7.2	44.0	0.149	221.5	173.20	48.3		
4	16.5	43.0	0.211	221.5	143.30	78.2		
pbc								
3c	9.5	128.0	0.202	221.5	174.50	47		
		61.5	0.201				3.274	1259.70

Table 7

GORSTOVOYE FIELD Well 93; formation Ю$_1^{3-4}$ (oil); Facility 4; perforation interval – 2207-2219 m; PBC ($P_{btm, intl}$ = 143.3 atm, P_{form} = 221.5 atm, Q_0 = 16.5 m^3/day, v = 1.243) influx-specific processing

t		P (t) atm	ΔP=P(t) – P_0	In(t)	ΔP=P_{form} – P(t), atm	Q_0-q(t) cm^3/sec (avg. $C_{prod.}$)	ΔP/Q_0 – q(t) atm/cm^3/sec	i (slope)	ε (slope) D*cm/cP	R (m)	ε (R) D*cm/cP	ε $_{FFT}$ D*cm/cP
0		143.30										3.27
900		144.60	76.9	6.8024	1.30	15.00	0.0867	0.0127	19	6.2		
1800	35	146.00	75.5	7.4955	2.70	19.05	0.1417	0.0189	27	4.2	-0.7	
2700	15	147.80	73.7	7.9010	4.50	24.25	0.1856	0.0235	33	3.4	-0.3	
3600	15	148.70	72.8	8.1887	5.40	26.85	0.2011	0.0246	38	3.2	2.3	
4500	15	150.00	71.5	8.4118	6.70	30.61	0.2189	0.0260	42	3.1	1.5	
5400	15	150.90	70.6	8.5942	7.60	33.21	0.2288	0.0266	46	3.0	2.3	
6300	15	151.80	69.7	8.7483	8.50	35.81	0.2373	0.0271	50	2.9	2.2	
7200	15	152.60	6S.9	8.8818	9.30	38.13	0.2439	0.0275	53	2.9	2.4	
9000	30	155.30	66.2	9.1050	12.00	45.93	0.2613	0.0287	60	2.8	1.7	
10800	30	157.90	63.6	9.2873	14.60	53.45	0.2732	0.0294	65	2.7	2.0	
12600	30	161.40	60.1	9.4415	18.10	63.56	0.2847	0.0302	71	2.6	1.8	
14400	30	164.50	57	9.5750	21.20	72.53	0.2923	0.0305	75	2.6	2.1	
18000	60	167.90	53.6	9.7981	24.60	82.35	0.2987	0.0305	84	2.6	2.6	
21600	60	175.00	46.5	9.9804	31.70	102.88	0.3081	0.0309	92	2.6	2.2	
25200	60	180.30	41.2	10.1346	37.00	118.20	0.3130	0.0309	100	2.6	2.6	
28800	60	184.70	36.8	10.2681	41.40	130.92	0.3162	0.0308	107	2.6	2.7	
32400	60	188.2O	33.3	10.3859	44.90	141.04	0.3184	0.0307	113	2.6	2.8	
36000	60	191.20	30.3	10.4913	47.90	149.71	0.3200	0.0305	119	2.6	2.9	
39600	60	194.30	27.2	10.5866	51.00	158.67	0.3214	0.0304	125	2.6	2.9	
43200	60	196.90	24.6	10.6736	53.60	166.18	0.3225	0.0302	131	2.6	2.9	
46800	60	199.60	21.9	10.7536	56.30	173.99	0.3236	0.0301	136	2.6	2.9	
54000	120	204.00	17.5	10.8967	60.70	186.71	0.3251	0.0298	146	2.7	3.0	
61200	120	206.10	15.4	11.0219	62.80	192.78	0.3258	0.0296	156	2.7	3.1	
68400	120	208.30	13.2	11.1331	65.00	199.14	0.3264	0.0293	165	2.7	3.1	
75600	120	209.20	12.3	11.2332	65.90	201.74	0.3267	0.0291	173	2.7	3.2	
90000	240	210.50	11	11.4076	67.20	205.50	0.3270	0.0287	189	2.8	3.2	
104400	240	211.80	9.7	11.5560	68.50	209.26	0.3274	0.0283	203	2.8	3.2	
118800	240	213.60	7.9	11.6852	70.30	214.46	0.3278	0.0281	217	2.8	3.2	

133200	240	214.90	6.6	11.7996	71.60	218.22	0.3281	0.0278	230	2.9	3.3	
147600	240	216.20	5.3	11.9023	72.90	221.97	0.3284	0.0276	242	2.9	3.3	
169200	360	218.00	3.5	12.0388	74.70	227.18	0.3288	0.0273	259	2.9	3.3	

Table 8

THE RESULTS OF THE HYDRODYNAMIC SURVEYS IN WELL 93 (FACILITY 4) IN THE GORSTOVOYE FIELD

№	Facility	Location	Well	Formation	Form. interval	η_{avg} m³/day*atm	ε D*cm/cP	χ cm²/sec	r_{pr} cm	Π_{GPP} cm	Π_{GPF} cm	h_{prod} m	R_c m
1	4	Gorsto-voye	93	Ю$_1^{3-4}$	2207-2210	0.201	3.27	1260	25.1	0.0026	99.96	9.8	296.0
						PBC							
						ε_1 D*cm/cP	ε_n D*cm/cP	S = $\varepsilon_1/\varepsilon_n$	$\varepsilon_{FFT}/\varepsilon_{PBC}$				
						6.2	2.91	2.14	1.12				

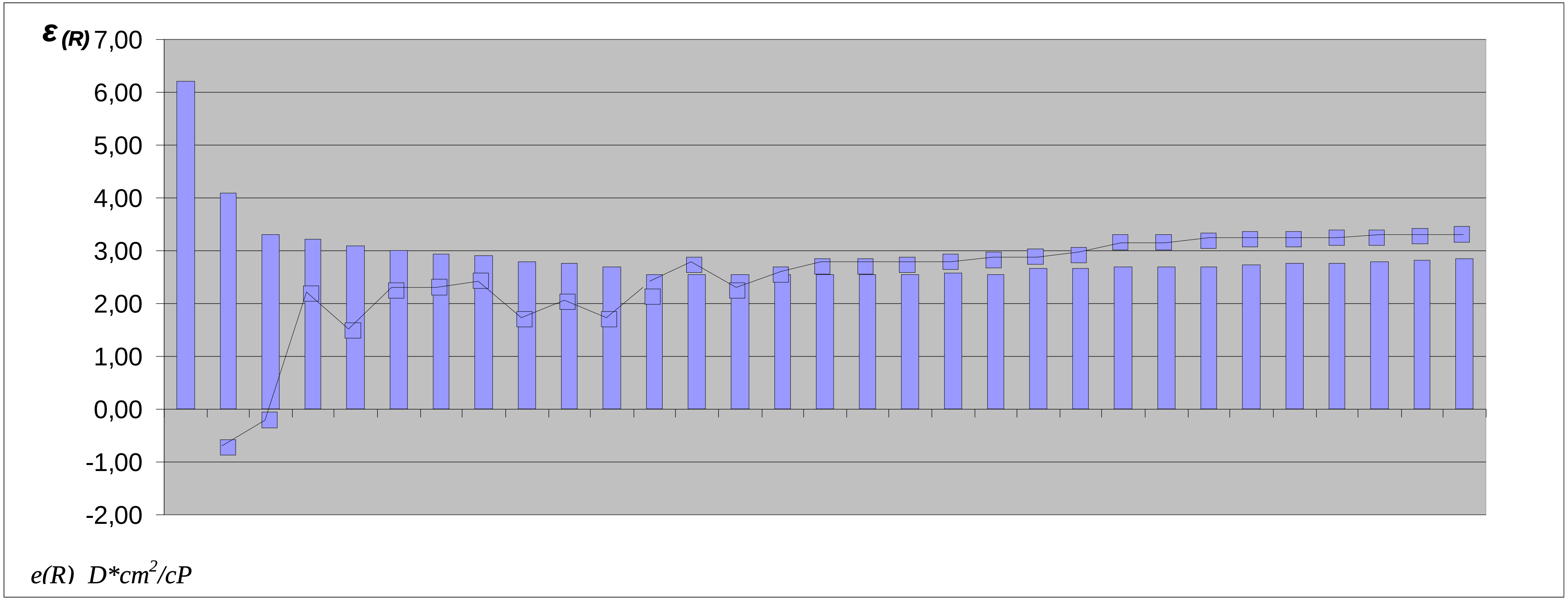


Fig. 2 PBC diagram of water permeability allocation in the range of borehole influence in Well 93 (Facility 4), Gorstovoye field