academicJournals

Vol. 6(1), pp. 1-9, January, 2015
DOI: 10.5897/JPGE 2013.0180
Article Number: 3C2A1DC50083
ISSN 2141-2677

http://www.academicjournals.org/JPGE

Journal of Petroleum and Gas Engineering

Full Length Research Paper

Factors that affect pressure distribution of horizontal wells in a layered reservoir with simultaneous gas cap and bottom water drive

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Received 1 October, 2013; Accepted 5 November, 2014

Understanding the behaviour of pressure distribution completed in two layered reservoir subject to both active gas cap and bottom water drive mechanisms is very important in reservoir management. To determine the factors that affect pressure distribution of horizontal wells in a layered reservoir subjected simultaneously with a gas-cap at the top and bottom water drives, well completion was carried out in a particular layer and one of the parameters was varied while the others were kept constant. The results show that the following factors: (i) Wellbore radius (ii) Well Length and (iii) Pay thickness affect pressure distribution in two-layered reservoir subject to both active gas cap and bottom water drive which affect pressure distribution.

Key words: Well, pressure, layer, reservoir, well.

INTRODUCTION

A lot of work has been done on pressure distribution for both vertical well and wells (Abbaszadeh and Hegeman, 1990; Kuchuk et al., 1991; Owolabi et al., 2012; Clonts and Ramey Jr., 1986), however, much work has not been done on this subject we are considering in this paper. A good knowledge of effect of well parameters on pressure distribution of horizontal wells in a layered reservoir subject to simultaneous top gas-cap and bottom water drive is an important tool in reservoir management in the production of oil and gas (Ozkan and Raghavan, 1990; Oloro et al., 2013) hence it became an urgent need for this study to be carried out. In this study, the effect of the following factors on pressure distribution on horizontal wells in a two-layered reservoir which is being subjected simultaneously with gas cap and bottom water drive were considered: (i) Wellbore radius (ii) Well Length and (iii) Pay thickness. In determining the effect of these factors, a model that was developed previously in my paper titled ”Pressure distribution of horizontal wells in a layered reservoir with simultaneous gas cap and bottom water

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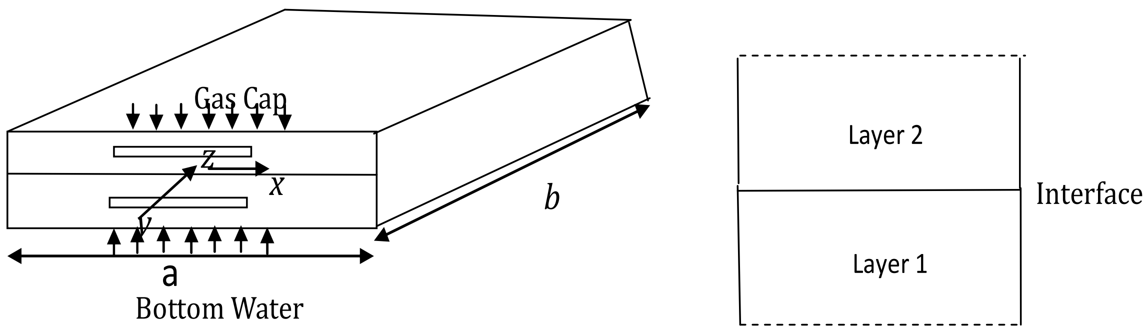

Figure 1. Two-layered reservoir system containing horizontal wells.

Table 1. Reservoir and well properties.

LD1	**LD2**	**ZWD1**	**ZWD2**	**ZD1**	**ZD2**	**DZ (ft)**
0.19764	0.194	0.995	0.788	0.005	0.004	2.5
h_{D1}	**h_{D2}**	**X_{wD1}**	**XwD2**	**YeD1**	**YeD2**	**DX (ft)**
4.785	2.5298	0.99244	0.795	0.0015	0.0215	2.00E+02
XeD2	**XeD1**	**K2 (Md)**	**Kx2 (Md)**	**k1 (mD)**	**kx1 (mD)**	**Dy (ft)**
0.0215	0.14	10	10	8.94427	10	21
Ct_1 (psi-1)	**ct_2 (psi^{-1})**	**L1 (ft)**	**L2 (ft)**	**h1 (ft)**	**h2 (ft)**	
4.00E-06	3.00E-06	250	250	200	100	
YD1	**YD2**	**Ø1**	**Ø2**	**YWD1**	**YWD2**	
8.00E-03	6.00E-03	0.23	0.23	9.92E-01	8.94E-01	
XD1	**XD2**	**µ1 (cp)**	**µ2 (cp)**	**hD2**	**hd1**	
0.00757	0.0065	0.5	0.2	2.5298	4.785	

drive" was used (Oloro et al., 2013).

METHODOLOGY

Pressure distribution of horizontal wells in layered reservoir with active top gas cap and bottom water drives models were used to determine effect of well parameters on pressure distribution (Oloro et al., 2013). This was done by varying a particular parameter which we want to know the effect on the pressure distribution and keeping other parameters constant.

The model diagram is shown in Figure 1 and model equation is given in Oloro et al. (2013). Reservoir and well properties are shown in Table 1. The derivation of Equations 1 and 2 are given in Appendices A and B (Oloro et al., 2013).

Model description and mathematical model for Layer 1

A physical description of the problem illustrated in Figure 1, is two layered reservoir, bounded on top by gas cap at the bottom by bottom water drive. A horizontal well of length L (along the x-axis), width y_w (along the y-axis) and stand-off z_w (along the z-axis) is drilled at the centre. The models used in this work and the derivation are in Oloro et al. (2013).

RESULTS AND DISCUSSION

To determine the effect of wellbore radius on wellbore pressure in Layer 1, P_{wD1} was computed for r_{WD1} values of $1.14x10^{-1}$ and $4x10^{-2}$, while keeping other parameters constant. The results are presented in Table 2 and also illustrated in Figure 2 on log-log axes. It is observed from the figure that at early $t_{D,}$ there is an obvious change in P_{wD1} with change in r_{wD1}. The change in P_{wD1} at later t_D is not obvious as it is shown in Figure 2.

Effect of change in wellbore radius of Layer 1 on pressure distribution for Layer 2 after radial flow period are presented in Table 3 and Figure 3. Results show slightly high productivity when smaller wellbore radius is used.

Effect of change in wellbore radius of Layer 1 on pressure distribution on Layer 2 at wellbore are presented in Table 4 and Figure 4. It is observed that a change in wellbore radius of Layer 1 does not have effect on $P_{wD2.}$ Effect of change in r_{wD1} on P_{wD2} after

Table 2. Effect of change in wellbore radius of Layer 1 on pressure distribution on Layer 1 at wellbore.

t_D	P_{wD1} (rwD1=1.14E-1)	P_{wD1} (rwD1=4E-2)
0.001	3.170692	7.6770781
0.01	20.9151	24.860549
0.1	38.6595	42.04402
1	56.40391	59.227491
10	74.14832	76.410962
100	91.89272	93.59443
1000	109.6371	110.7779

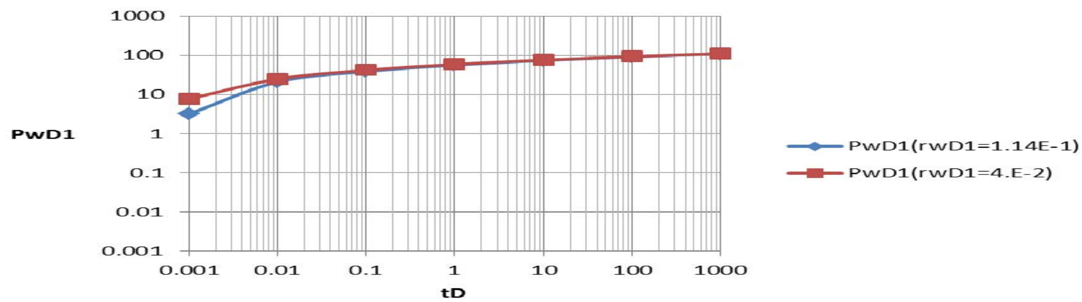

Figure 2. Effect of change in wellbore radius of Layer 1 on pressure distribution on Layer 1 at wellbore.

Table 3. Effect of change in wellbore radius of Layer 1 on pressure distribution for Layer 2 after radial flow period.

t_D	P_{D2} (rwD1=1.14E-1)	P_{D2} (rwD1=4E-2)
0.001	7.79E+00	7.82E+00
0.01	2.49E+01	2.50E+01
0.1	4.22E+01	4.23E+01
1	5.94E+01	5.95E+01
10	7.67E+01	7.70E+01
100	9.41E+01	9.49E+01
1000	1.13E+02	1.13E+02
10000	1.13E+02	1.13E+02

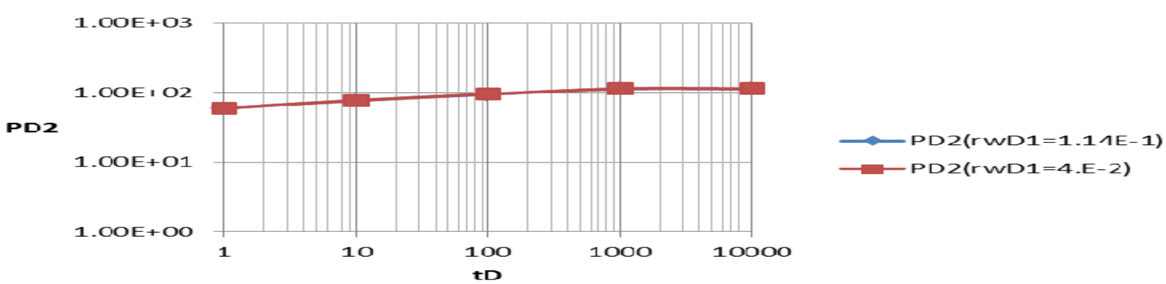

Figure 3. Effect of change in wellbore radius of Layer 1 on pressure distribution for Layer 1 after radial flow period.

radial flow period is shown in Figure 4.

Effect of change in wellbore radius of Layer 1 on pressure distribution for Layer 2 after radial flow period is shown in Table 5 and Figure 5.

It was observed that a change in r_{wD1} after radial flow period does have effect on P_{wD2}. Effect of change in r_{wD2} on P_{wD1} is shown in Table 5. It is observed that at early t_D, P_{wD1} is higher for smaller wellbore radius, but at late

Table 4. Effect of change in wellbore radius of Layer 1 on pressure distribution on Layer 2 at wellbore.

t_D	P_{wD2} (rwD1=1.14E-1)	P_{wD2} (rwD1=4E-2)
0.001	7.6770781	7.6770781
0.01	24.860549	24.860549
0.1	42.04402	42.04402
1	59.227491	59.227491
10	76.410962	76.410962
100	93.59443	93.594432
1000	110.7779	110.7779

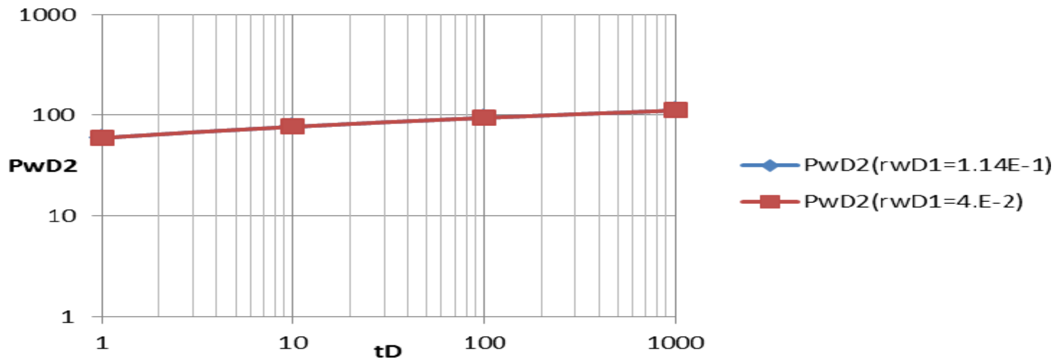

Figure 4. Effect of change in wellbore radius of Layer 1 on pressure distribution on Layer 2 at wellbore.

Table 5. Effect of change in wellbore radius of Layer 1 on pressure distribution for Layer 2 after radial flow period.

t_D	P_{D2} (rwD1=1.14E-1)	P_{D2} (rwD1=4E-2)
0.001	7.79E+00	7.82E+00
0.01	2.49E+01	2.50E+01
0.1	4.22E+01	4.23E+01
1	5.94E+01	5.95E+01
10	7.67E+01	7.70E+01
100	9.41E+01	9.49E+01
1000	1.13E+02	1.13E+02
10000	1.13E+02	1.13E+02

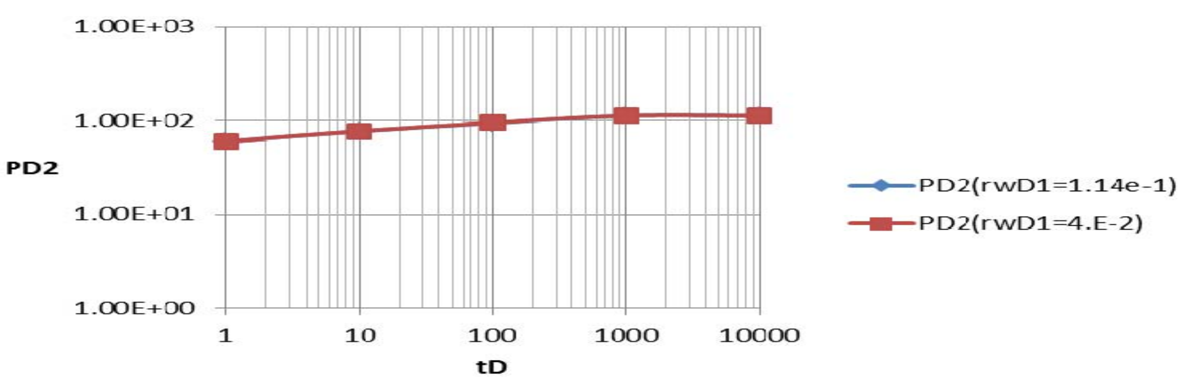

Figure 5. Effect of change in wellbore radius of Layer 1 on pressure distribution for Layer 2 after radial flow period.

Table 6. Effect of change in wellbore radius of Layer 2 on pressure distribution on Layer 1 at wellbore.

t_D	P_{wD1} (rwD2=0.032)	P_{wD1} (rwD2=0.0312)
0.001	3.170692	0.110955
0.01	20.9151	17.85536
0.1	38.6595	35.59977
1	56.40391	53.34417
10	74.14832	71.08858
100	91.89272	88.83298
1000	109.6371	106.5774

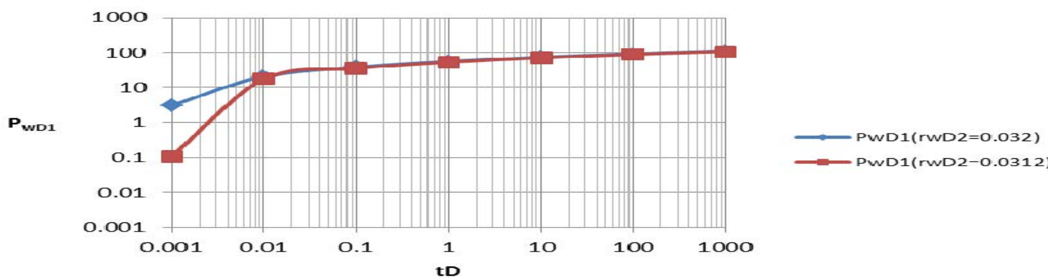

Figure 6. Effect of change in wellbore radius of Layer 2 on pressure distribution on Layer 1 at wellbore.

Table 7. Effect of change in wellbore radius of Layer 2 on pressure distribution on Layer 2 after radial flow period.

t_D	P_{wD2} (rwD2=0.032)	P_{wD2} (rwD2=0.0312)
0.001	7.2992004	7.6770781
0.01	24.482671	24.860549
0.1	41.666142	42.04402
1	58.849613	59.227491
10	76.033084	76.410962
100	93.216555	93.594432
1000	110.40003	110.7779

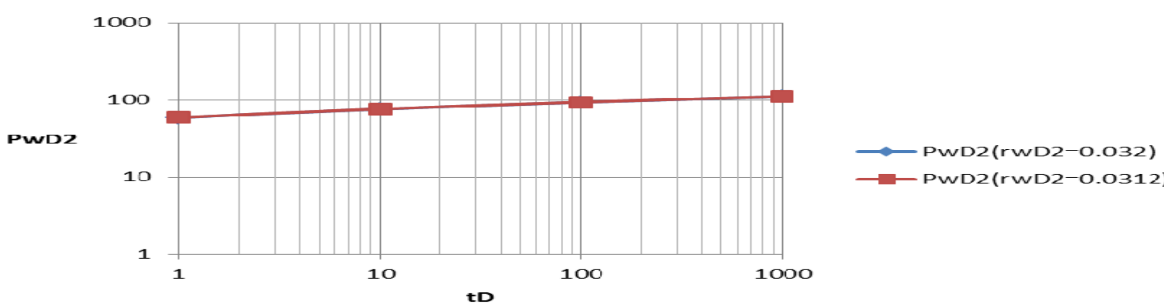

Figure 7. Effect of change in wellbore radius of Layer 2 on pressure distribution on Layer 2 after radial flow period.

t_D the effect of change in r_{wD2} is not much as shown in Figure 5.

Effect of change in wellbore radius of Layer 2 on P_{wD2} after radial flow period is shown in Table 6 and Figure 6. The effect is clearly seen in the table. It is observed that the larger the wellbore radius the higher the productivity in Layer 1.

Effect of change in wellbore radius of Layer 2 on pressure distribution in Layer 2 after radial flow period is shown in Table 7 and Figure 7. The effect is clearly

Table 8. Effect of change in well length of Layer 1 on pressure distribution on Layer 1 at wellbore.

t_D	P_{WD1} (L_{D1}=0.129764)	P_{WD1} (L_{D2}=4Xl$_{D1}$)	P_{WD1} (L_{D3}=39.53L_{D1})
0.001	19.29772	4.726915	0.488160695
0.01	37.04212	9.07335	0.937028341
0.1	54.78653	13.41979	1.385895988
1	72.53094	17.76622	1.8347636
10	90.27534	22.11266	2.28363128

Table 9. Effect of change in well length of Layer1 on pressure distribution on Layer 2 at wellbore.

t_D	P_{wD2} (L_{D1}=0.129764)	P_{wD2} (L_{D2}=4XL_{D1})	P_{wD2} (L_{D3}=6.18X L_{D1})
0.001	21.938443	21.93844299	21.93844299
0.01	39.121914	39.12191384	39.12191384
0.1	56.305385	56.3053846	56.30538468
1	73.488856	73.48885552	73.48885552
10	90.672326	90.67232	90.67232637

Table 10. Effect of change in well length of Layer 1 on pressure distribution on Layer 1 after radial flow period.

t_D	P_{D1} (L_{D1}=0.12964)	P_{D1} (L_{D2}=0.52964)	P_{D1} (L_{D1}=0.802964)
0.001	2.26E+01	2.62E+01	2.66E+01
0.01	39.6309	46.4733	47.2315
0.1	56.6558	66.2005	67.2544
1	73.691	85.2431	86.517
10	90.7309	100.82	101.933

Table 11. Effect of change in well length of Layer 1 on pressure distribution on Layer 2 after radial flow period.

t_D	P_{D2} (L_{D1}=0.12964)	P_{D2} (L_{D1}=0.52964)	P_{D2} (L_{D1}=0.802964)
0.001	2.20E+01	2.23E+01	2.23E+01
0.01	3.92E+01	3.98E+01	4.02E+01
0.1	5.64E+01	5.79E+01	5.96E+01
1	7.35E+01	7.62E+01	7.98E+01
10	9.07E+01	9.83E+01	1.08E+02

seen in Table 7. It is observed that the smaller the wellbore radius the higher the productivity.

To determine the effect of change in L_{D1} on P_{wD1}, P_{WD1} was computed at values of L_{D1}, 0.12964, 0.529764 and 5.129764. The results are shown in Table 8. It is observed that the smaller the L_{D1} the larger the P_{wD1}.

Effect of change in L_{D1} on P_{wD2} is as shown in Table 9. The results show that change in L_{D1} does not affect P_{wD2}. Effect of change in L_{D1} on P_{D1} after radial flow period is shown in Table 10. The results show that the larger the L_{D1} the larger the $P_{D1.}$

Effect of change in L_{D1} on P_{D2} after radial flow period is shown in Table 11. From the table, it is observed that the larger the L_{D1}, the larger P_{D2}.

Effect of change in L_{D2} on P_{wD1} is shown in Table 12. It is observed that change in L_{D2} does have effect on P_{wD1} as shown in Table 12.

Table 13 present the results of effect of change in well length of Layer 2 on pressure distribution on Layer 2 at wellbore. From the results, it was observed that the smaller the well length the higher the productivity of Layer 2 at wellbore and also after radial flow period as

Table 12. Effect of change in well length of Layer 2 on pressure distribution on Layer 1 at wellbore.

t_D	P_{wD1} (L_{D2}=0.134)	P_{wD1} (L_{D2}=0.334)	P_{wD1} (L_{D2}=0.534)
0.001	9.57E+00	1.00E+01	5.70E+00
0.01	26.5751	9.07947	9.07343
0.1	43.531	24.7054	14.2927
1	60.4684	31.9553	18.5834
10	77.1985	38.4888	22.8478
100	93.4722	42.8425	27.0495

Table 13. Effect of change in well length of Layer 2 on pressure distribution on Layer 2 at wellbore.

t_D	P_{wD2} (L_{D2}=0.134)	P_{wD2} (L_{D2}=0.334)	P_{wD2} (L_{D2}=0.534)
0.001	21.93844	8.806508	5.505152361
0.01	39.1219	15.695618	9.817109
0.1	56.30538468	22.589585	14.12906657
1	73.4888555	29.483553	18.44102367
10	90.6723	36.37752	22.75298077
100	107.8557972	43.271488	27.06493

Table 14. Effect of change in well length of Layer 2 on pressure distribution on Layer 2 after radial flow period.

t_D	P_{D2} (L_{D2}=0.134)	P_{D2} (L_{D2}=0.334)	P_{D2} (L_{D2}=0.534)
0.001	7.82E+00	8.88E+00	5.52E+00
0.01	2.50E+01	1.57E+01	9.82E+00
0.1	4.23E+01	2.29E+01	1.42E+01
1	5.95E+01	3.01E+01	1.85E+01
10	7.70E+01	3.64E+01	2.28E+01
100	9.49E+01	4.80E+01	2.72E+01

Table 15. Effect of change in pay thickness of Layer 1 on pressure distribution on Layer 1.

Td	P_{wD1} (h_{D1}=4.785)	P_{wD1} (h_{D1}=8.785)	P_{wD1} (h_{D1}=15.785)
0.001	11.98235	21.9989	39.527
0.01	23	42.227	75.874
0.1	34.02	62.455	112.22
1	45.03596	82.6835	148.5669
10	56.0538	102.9117	184.91
100	67.072	123.14	221.26
1000	78	143.368	257.61
10000	89.107	163.5964	293.95

shown in Table 13.

Effect of change in well length of Layer 2 on pressure distribution on Layer 2 after radial flow period is shown in Table 14. The result shows that the small the well length in Layer 2 higher the productivity in Layer 2.

To determine the effect of change in h_{D1} on P_{D1} and P_{D2}, P_{D1} and P_{D2} were computed with values of h_{D1} of 4.785, 8.785 and 15.785. While h_{D2} remain constant at 6.5298. The results are shown in Tables 15 and 16. From these tables it is observed that a change in h_{D1}

Table 16. Effect of change in pay thickness on of Layer 1 on pressure distribution on Layer 2.

Td	P_{wD2} (h_{D1}=4.785)	P_{wD2} (h_{D1}=8.785)	P_{wD2} (h_{D1}=15.785)
0.001	19.196	19.195988	19.195988
0.01	34.23	34.2314	34.2314
0.1	49.27	49.266828	49.266828
1	64.30224	64.3022	64.3022
10	79.3376	79.337	79.337
100	94.37	94.37	94.37
1000	109.4085	109.4085	109.4085
10000	124.444	124.4439	124.4439

Table 17. Effect of change in pay thickness of Layer 2 on pressure distribution on Layer 2.

Td	P_{wD2} (h_{D1}=4.785)	P_{wD2} (h_{D1}=8.785)	P_{wD2} (h_{D1}=15.785)
0.001	19.196	19.195988	19.195988
0.01	34.23	34.2314	34.2314
0.1	49.27	49.266828	49.266828
1	64.30224	64.3022	64.3022
10	79.3376	79.337	79.337
100	94.37	94.37	94.37
1000	109.4085	109.4085	109.4085
10000	124.444	124.4439	124.4439

Table 18. Effect of change in pay thickness of Layer 2 on pressure distribution on Layer 2.

t_D	P_{wD2} (h_{D2}=6.5298)	P_{wD2} (h_{D2}=8.5298)	P_{wD2} (h_{D2}=10.5298)
0.001	19.195988	19.195988	30.955
0.01	34.2314	44.72	55.2
0.1	49.266828	64.3566	79.45
1	64.3022	83.997	103.69
10	79.337	103.6378	127.938
100	94.37	123.2784	152.184
1000	109.4085	142.92	176.43
10000	124.4439	162.5596	200.675

does affect only P_{D1} and not P_{D2}.

Also to determine effect of h_{D2} on P_{D2}, P_{D2} were computed with values of h_{D2} at 6.5298, 8.5298 and 10.5298, while h_{D1} remain constant at 4.785. The results are shown in Table 18. This implies that to obtain high productivity for a particular layer the well should be positioned at a higher pay thickness.

Conclusions

From the statement of problems, objectives, and the results of study presented in the previous chapters, the following conclusions can be drawn:

(1) It is possible to analyze each layer.
(2) When there is crossflow, pressure transient in the reservoir considered is similar to the behavior of the homogeneous system.
(3) Gas cap drive is more predominant than that of water drive.
(4) Well eccentricity was not found to affect productivities.
(5) Well location further away from the top and bottom boundaries offer delayed in external fluid breakthrough for all well completions.

(6) The thicker the pay thickness of a particular layer the higher the wellbore pressure.
(7) In order to obtain high productivity, smaller wellbore radius should be used in Layer 1 and larger wellbore radius should be used in Layer 2.
(8) The longer the well length of a particular layer the higher the wellbore pressure.

Nomenclature

C_t: Total reservoir compressibility (Psi^{-1})
h: Formation thickness (ft)
h_D: Dimensionless height
L_D: Dimensionless length
P_D: Dimensionless pressure
P_{wD}: Dimensionless wellbore pressure
p_D': Dimensionless pressure derivative
S: Instantaneous source functions
t: Time (h)
t_D: Dimensionless time
x,y,z: Space coordinates
x_D,y_D: Dimensionless distance in the x and y directions
x_f: Horizontal well half length
z_D: Dimension distance in the z director
k: Horizontal permeability
k_y Permeability in the y – direction (md)
k_z: Permeability in the z direction (md)
l: Horizontal well length (ft)
r_D: Dimensionless radial distance in the horizontal plane
r_{wD}: Dimensionless wellbore radius
x_w: Well location in the x – direction (ft)
x_e: Distance to the boundary or reservoir length (ft)
x_{eD}: Dimensionless distance to the boundary
x_{WD}: Dimensionless well location in the x- direction
Z_w: Well location in the direction (ft)
z_{WD}: Dimensionless well location in the Z direction
Y_w: Well location in the y – direction (ft)
Dimensionless well location in the Y direction.

Conflict of Interest

The author(s) have not declared any conflict of interests.

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