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Hydraulic Fracturing Design in a complex clastic reservoir: Case Study Southern of Iraq

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ABSTRACT: Hydraulic fracturing is one of the most important stimulation methods that has been widely utilized in both conventional and unconventional reservoirs to enhance the wells productivity, through increase the conductivity. Furthermore, the process of hydraulic fracking has become progressively common in high permeability oil and gas reservoirs to overcome skin damage at that point to enhance the wells efficiency. This study demonstrates that the hydraulic fracturing procedure applies to complex reservoirs to improve the productivity of limestone formation in the south of Iraq fields. Several fracturing operations have been conducted in the south of Iraq fields, in these operations, different types of fluid and proppant were used. The offset data of the treatments were collected and companied with post-fracturing wells productivity. Then, post-fracturing information of the performance of the well was reviewed to compare with the pre-fracture productivity and investigate the effect of the treatment. This work benefits the petroleum industry by: first, conducting a productivity data analysis of completed and stimulated wells to determine the importance of hydraulic fracturing in high permeable oil reservoirs. Second, Establishing the essential elements of reducing skin

1. INTRODUCTION

The hydraulic fracturing is paramount process in oil and gas industries to increase the production/injection rates or to solve crucial production/injection problems. The sand control mitigation and wellbore damage reduction are among the most significant factors that can be treated by selecting the appropriate hydraulic fracture design. The optimum frac job design is a multidiscipline process that related to the reservoir geomechanical properties, reservoir characterizations, production / completion criteria. Furthermore, the designer should carefully consider several factors such as the augment in production for varies fracture lengths and conductivities, the required fracture geometry, the types of fluid/ material being used in the fracture jobs, and the operational design parameters. Thoroughly investigation should be also conducted to the relationship between the hydraulic fracturing ultimate production fold of increase and the cost of fracture operations being implemented. It is well recognized that the higher the reservoir permeability required wider fracture width while the lower reservoir permeability necessitate longer fracture half-length that eventually controlling the selection of the design variables. A significant improvement in hydraulic fracturing jobs has been achieved by combined the offset wells post frac jobs experience and the extensive analysis for the frac data. In this paper, A field in southern Iraq has been studied based on the recently conducted acid and proppant fracture jobs to the two giant reservoirs Zubair (sandstone), and Mishrif (Limestone). These fracture stimulations have revealed a miner improvement in the productivity index and remediation in skin damage. Thus, a new design has been proposed based on finite element fracturing model by using a commercial software. All necessary input data for constructing fracture geomechanical model have been fed to the software that originally obtained from the pre and post fracture job analysis. The rock mechanical proprieties and the regional in-situe stresses have been collected and filtered to be manipulated in the constructing of the fracture geomechanical model. A unique pumping schedule and fracturing fluid/ material have introduced to enhance the fracture geometry and post fracture result. It can be observed a magnificent improvement has been attained in the following parameters, the fracture half-length/ width and ultimately the fracture conductivity in the anticipated design. Finally, different facture half-lengths have been investigated to illustrate the increase in production obtained in order to use as guide line in the upcoming fracture jobs in the southern Iraq fields for the target formation.

2. CASE STUDY

The proppant and acid fracturing are recently performed in southern of Iraq fields to increase the productivity and reduce the wellbore damage. These fracture jobs were conducted mostly in Mishrif formation, which is essentially consisting of limestone and the Zubair formation that basically consisting of sandstone. Mishrif formation is comprised of three intervals, upper Mishrif, middle Mishrif, and lower Mishrif as shown in Figure (1). An offset well was selected to evaluate acid fracturing operation and it can be observed there were two well tests performed before fracturing job in Mishrif formation intervals. The First test was conducted for upper and middle Mishrif intervals that showed: an average formation pressure of 3080 psia, permeability (k) of 13 md, and productivity index (PI) about 0.75 stb/d/psi. The second test was conducted to all Mishrif formation interval resulted in average formation pressure of 3203 psia, permeability (k) about 28 md, and productivity index (PI) around 1.3 stb/d/psi.

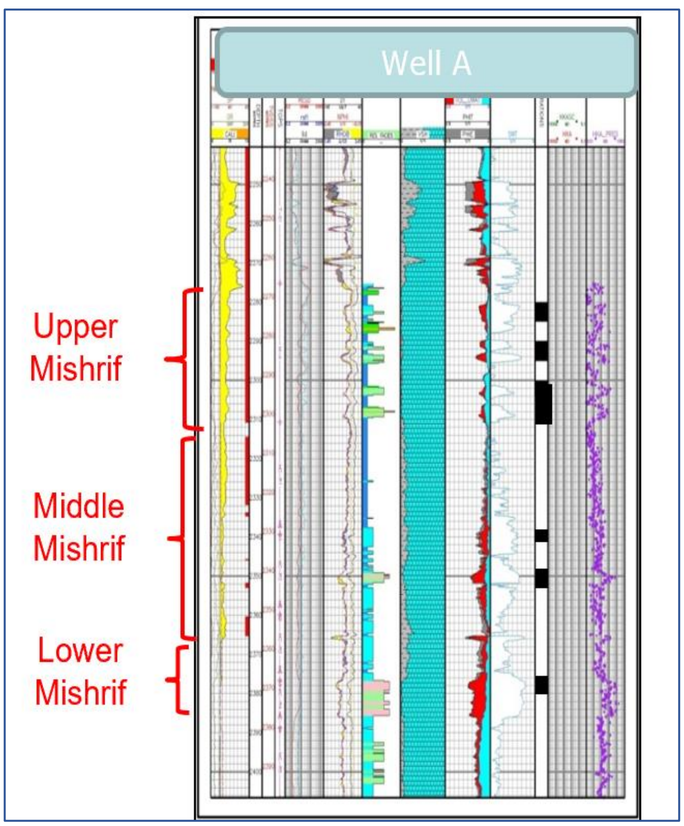

Figure 1: Mishrif formation intervals

After the well was fractured, the productivity index was calculated and compared with pre-frac in Mishrif formation of both taken intervals, first upper and middle Mishrif was consider as one interval, second all Mishrif was treated as separate intervals. Figure (2) shows increase in productivity in the post-frac test compare with pre frac test. The productivity index was increased more than 50% result in 2.3 stb/b/psi productivity index (test #3) compare with the first test as illustrated in the Figure(3). While it was increased to 2.5 stb/b/psi (test#4) compare with the second test .

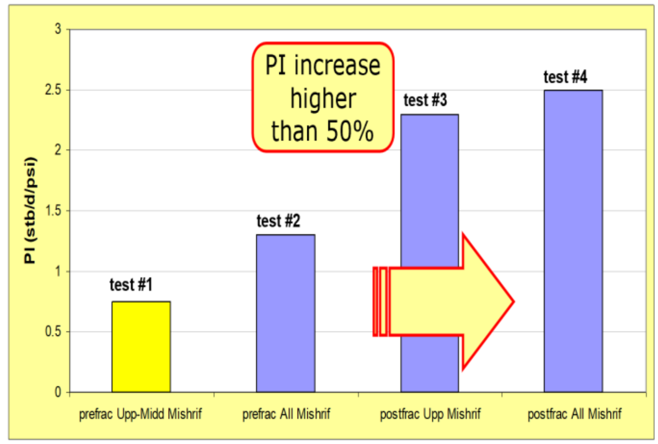

Figure 2: the productivity index for different tests in Mishrif limestone of fractured well

Also, the conducted fracturing operation led to remove the skin damage and convert positive skin to negative skin. Figure (3) shows how the fracturing reduces the skin damage from about + 4 to be -2.6.

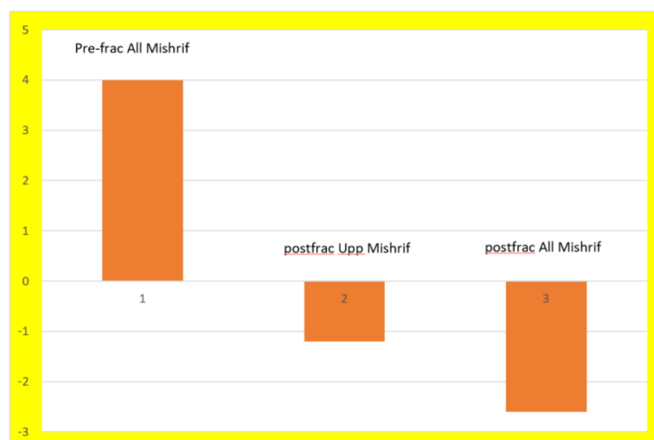

Figure 3: shows how the fracturing reduces the skin damage in Mishrif formation

3. FRACTURE SIMULATION DESIGN

Fracturing jobs data of offset wells were collected from Mishrif limestone Formation in southern Iraqi fields. The data include dipole sonic log, mini-frac data, and fracture design data also it involved petrophysics information of the well. A 2D Finite Element Model (FEM) was used in this project by using a commercial software. The shear and compressional travel times were employed to calculate the Poisson's Ratio, Young's Modulus and the shear modulus. Geomechanical model was built based on the density log and sonic log. The average static Young's modulus and Poisson ratio were obtained from a core analysis and it was found out to be 4.6×10^6 psi and 0.3 for the young modulus and Poisson's ratio respectively. The Gamma ray log was used to identify the formation lithology of three different layers which are Shale, Limestone, and Shaly-Limestone. The mini-frac files were introduced into the analysis to obtain measurements of the instantaneous shut in pressure (ISIP), closure pressure (CP), and the fracture fluid efficiency (FFE). These data were incorporated into the software and the finite element model simulations were conducted.

The net treating pressure data from the mini-frac tests were history matched and the in-situ stress gradient and leak-off coefficient for each layers lithologies has been determined. Figure (4) shows the geological model of the well.

Layer	TVD Depth to Top of Zone (m)	Type	Stress Difference (psi)	Stress Gradient from Surface (psi/ft)	Stress at Top of Zone (psi)	Stress Gradient (psi/ft)	Stress at Bottom of Zone (psi)	Modulus (MMpsi)	Poisson's Ratio	K-Ic	Fluid Loss Coefficient (ft/root (min))	Spurt Loss (gal/100ft^2)	Proppant Embedment (lb/ft^2)
26	2237.6	Limestone	768.8	0.657	4821.9	0.750	4827.6	4.600000	0.30	2000.0	0.000100	0.00000	0.20000
27	2239.9	Limestone	-256.6	0.622	4571.0	0.750	4573.5	4.600000	0.30	2000.0	0.000100	0.00000	0.20000
28	2240.9	shaly limesto	175.4	0.646	4748.9	0.750	4754.8	4.600000	0.25	2000.0	0.000050	0.00000	0.20000
29	2243.3	Limestone	-397.2	0.592	4357.6	0.750	4379.5	4.600000	0.30	2000.0	0.000100	0.00000	0.20000
30	2252.2	Limestone	148.0	0.613	4527.5	0.750	4535.9	4.600000	0.30	2000.0	0.000100	0.00000	0.20000
31	2255.6	Limestone	-88.8	0.601	4447.1	0.750	4488.2	4.600000	0.30	2000.0	0.000100	0.00000	0.20000
32	2272.3	Limestone	-72.8	0.592	4415.4	0.750	4424.0	4.600000	0.30	2000.0	0.000100	0.00000	0.20000
33	2275.8	Limestone	95.9	0.605	4519.9	0.750	4523.6	4.600000	0.30	2000.0	0.000100	0.00000	0.20000
34	2277.3	Limestone	-176.1	0.582	4347.5	0.750	4359.8	4.600000	0.30	2000.0	0.000100	0.00000	0.20000
35	2282.3	Limestone	394.0	0.635	4753.8	0.750	4762.9	4.600000	0.30	2000.0	0.000100	0.00000	0.20000
36	2286.0	shaly limesto	-111.8	0.620	4651.1	0.750	4654.1	4.600000	0.25	2000.0	0.000050	0.00000	0.20000
37	2287.2	Limestone	7.3	0.621	4661.4	0.750	4715.3	4.600000	0.30	2000.0	0.000100	0.00000	0.20000

Figure 4: the geological model

4. SELECTING OPTIMUM MATERIALS AND PUMP SCHEDULE

Pump schedule was proposed using a proppant type that provide a good conductivity in permeable formations and respectively an appropriate fluid was determined to transport the proppant efficiently. In this work, the proppant that was proposed is BauxLite 12-18 in order to obtain a high conductivity that can be distinguished by the manufacture as high strength, uniform size, and shape. On the other hand, the fluid being injected is cross-linker #30 which offers a good proppant transportation, stable fluid rheology at high temperatures, low fluid loss agent, and efficient cleanup material. The proppant concentration is increased gradually from 0 to 18 PPG, while the pump rate was stabilized at 50 BPM. Figure(5) show the design pump schedule and Figure(6) show graphical representation of the surface parameters. The pump schedule ended up fluid being pumped about 300 bbl and the total proppant volume of 1086.8 M- Lbs.

Stage	Slurry Volume (BBL)	Fluid Volume (BBL)	Proppant Conc (PPG) Start	Proppant Conc (PPG) End	Rate (BPM)	Fines Conc. (Vol Fraction)	Proppant (M-Lbs)	Pump Time (min)	Cum Time (min)	Fluid Type	Proppant Type
1	300.000	300.000	0.00	0.00	50.00	0.000000	0.0	6.000	6.0	Slickwater	BauxLite Plus 12-18
2	104.212	100.000	1.00	1.00	50.00	0.000000	4.2	2.084	8.1	30#_X-Link_HPG	BauxLite Plus 12-18
3	108.424	100.000	2.00	2.00	50.00	0.000000	8.4	2.168	10.3	30#_X-Link_HPG	BauxLite Plus 12-18
4	112.637	100.000	3.00	3.00	50.00	0.000000	12.6	2.253	12.5	30#_X-Link_HPG	BauxLite Plus 12-18
5	172.114	150.000	3.50	3.50	50.00	0.000000	22.1	3.442	15.9	30#_X-Link_HPG	BauxLite Plus 12-18
6	175.273	150.000	4.00	4.00	50.00	0.000000	25.2	3.505	19.5	30#_X-Link_HPG	BauxLite Plus 12-18
7	181.592	150.000	5.00	5.00	50.00	0.000000	31.5	3.632	23.1	30#_X-Link_HPG	BauxLite Plus 12-18
8	187.910	150.000	6.00	6.00	50.00	0.000000	37.8	3.758	26.8	30#_X-Link_HPG	BauxLite Plus 12-18
9	194.228	150.000	7.00	7.00	50.00	0.000000	44.1	3.885	30.7	30#_X-Link_HPG	BauxLite Plus 12-18
10	200.547	150.000	8.00	8.00	50.00	0.000000	50.4	4.011	34.7	30#_X-Link_HPG	BauxLite Plus 12-18
11	206.865	150.000	9.00	9.00	50.00	0.000000	56.7	4.137	38.9	30#_X-Link_HPG	BauxLite Plus 12-18
12	213.183	150.000	10.00	10.00	50.00	0.000000	63.0	4.264	43.1	30#_X-Link_HPG	BauxLite Plus 12-18
13	219.501	150.000	11.00	11.00	50.00	0.000000	69.3	4.390	47.5	30#_X-Link_HPG	BauxLite Plus 12-18
14	225.820	150.000	12.00	12.00	50.00	0.000000	75.6	4.516	52.0	30#_X-Link_HPG	BauxLite Plus 12-18
15	232.138	150.000	13.00	13.00	50.00	0.000000	81.9	4.643	56.7	30#_X-Link_HPG	BauxLite Plus 12-18
16	238.456	150.000	14.00	14.00	50.00	0.000000	88.2	4.769	61.5	30#_X-Link_HPG	BauxLite Plus 12-18
17	244.775	150.000	15.00	15.00	50.00	0.000000	94.5	4.895	66.4	30#_X-Link_HPG	BauxLite Plus 12-18
18	251.093	150.000	16.00	16.00	50.00	0.000000	100.8	5.022	71.4	30#_X-Link_HPG	BauxLite Plus 12-18
19	257.411	150.000	17.00	17.00	50.00	0.000000	107.1	5.148	76.5	30#_X-Link_HPG	BauxLite Plus 12-18
20	263.730	150.000	18.00	18.00	50.00	0.000000	113.4	5.275	81.8	30#_X-Link_HPG	BauxLite Plus 12-18
Flush	275.000	275.000	0.00	0.00	[illegible]	0.000000	0.0	9.167	91.0	Slickwater	
	4089.909	3000.000	Avrage (PPG)		8.63		1086.80	81.797	Constant PPG Steps	Fill Down	

Figure 5: the designed pump schedule

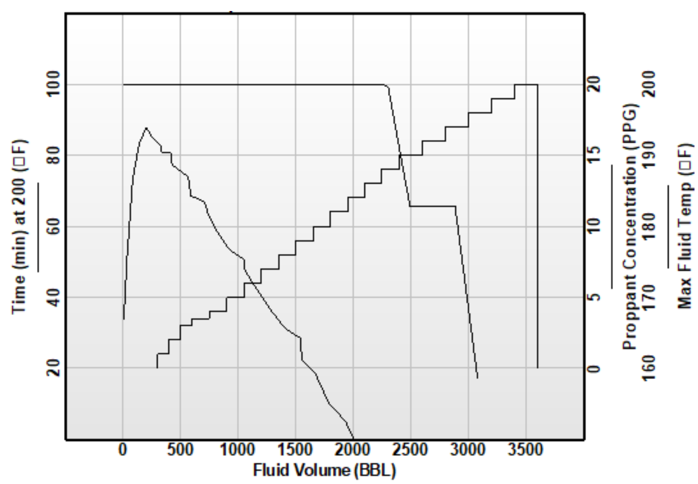

Figure 6: graphical representation of pump schedule

5. HYDRAULIC FRACTURING RESULTS

The fracture simulator was run, and the results of the simulation included a summary plot display the fracture geometry and dimensions as shown in the Figure (7). The plot clarifies that the fracture is contained in the targeted formation with noticeable growing in the length. The proppant covers most of the hydraulically fractured area which is obviously emphasis the fluid efficiency by delivering a good proppant transportation. The left side in the plot shows the geological formation, as shown in the green color representing limestone formation whereas the red representing shaly limestone. The calculated results showed the hydraulic half-length is 604.7 m while the propped half-length is 419.8 m. The maximum fracture height is 250.2 m whereas the fracture conductivity is

10353. The fracture dimensionless conductivity Fcd of 2.4 was obtained indicating an excellent fracture conductivity which is fairly near to the optimal value in oil reservoir. Table (1) summarizes the calculated results of fracturing simulation and comparing it with result obtained from previously conducted acid fracture job. The important fracture parameters such as net pressure, fracture width, fracture length, and penetration for the proposed design have illustrated in Figure (8).

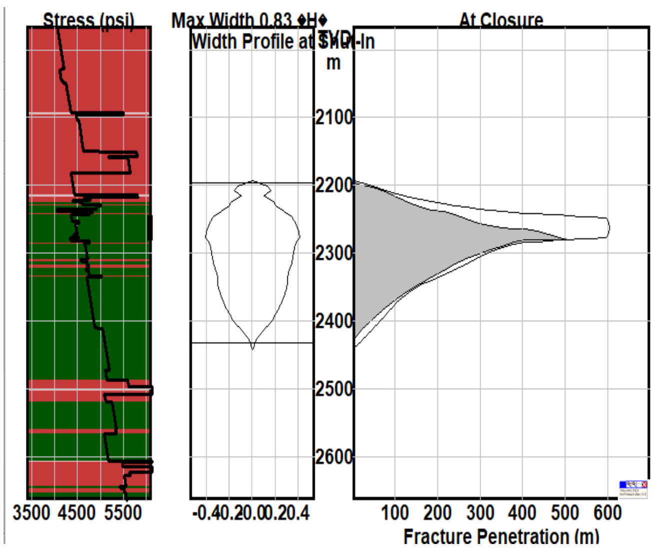

Figure 7: the fracture design in Mishrif formation

Table 1:summary of calculated fracture result

Fracture Dimensions	**New design**	**Offset well design**
Hydraulic Half Length (m)	604.7	94
Propped Half Length (m)	419.8	-
Max Fracture Height (m)	250.2	51
Avg. Width (in)	0.16	0.09
Total Fluid Volume (BBL)	3000	2400
Total Proppant Volume (M-Lbs)	1086.8	-
Average conductivity (md-ft)	10353	4021
Fcd	2.4	1

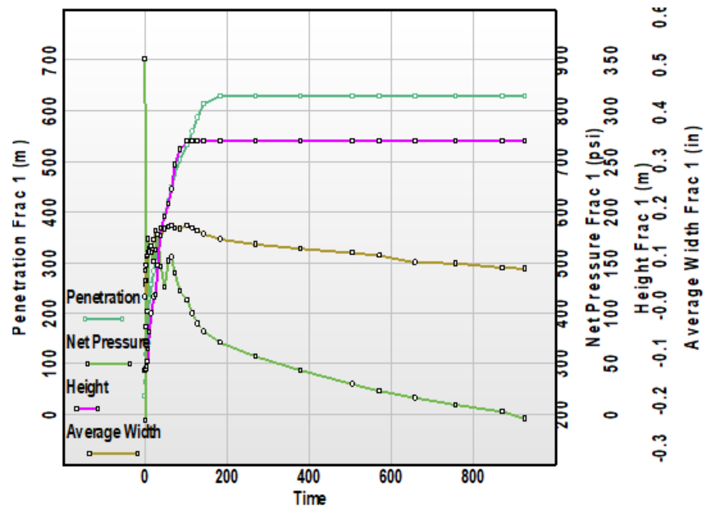

Figure 8: hydraulic fracture parameter

6. THE INVESTIGATION OF THE FRACTURE DIMENSIONS ON THE OIL PRODUCTION

A numerical reservoir stimulation was applied to inspect the effect of the hydraulic fracturing on production. Figure (9) demonstrates the cumulative production during 5 years in two cases: fracture half-length of 100 m and fracture half-length of 1000 m. As shown in the Figure, the cumulative production of 1000 m fracture half-length (the blue curve) is higher than 100 m fracture half-length (the red curve).

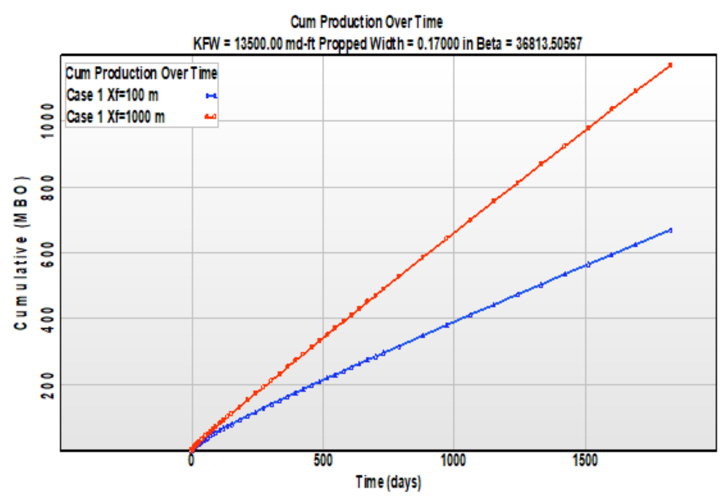

Figure 9 the cumulative production during 5 years in two cases: fracture half-length of 100 m and fracture half-length of 1000 m

Further analysis was conducted to investigate the effect of hydraulic fracture half-length on production in limestone formations. The Figure (10) shows how the production rate of one month was minorly impacted with respect of increasing fracture half-length. The production rate increased from about 530 BOPD to about 800 BOPD for fracture half-length 100 m and 1000 m respectively. It is worth to state an improvement in the productivity index have been observed in the fracture high length of 1000 m comparing with the fracture half-length of 100 m as shown in Figure (11) but it is still not promising that need further economic investigation. It was demonstrated that high permeable formations required increasing in fracture width rather than fracture half length.

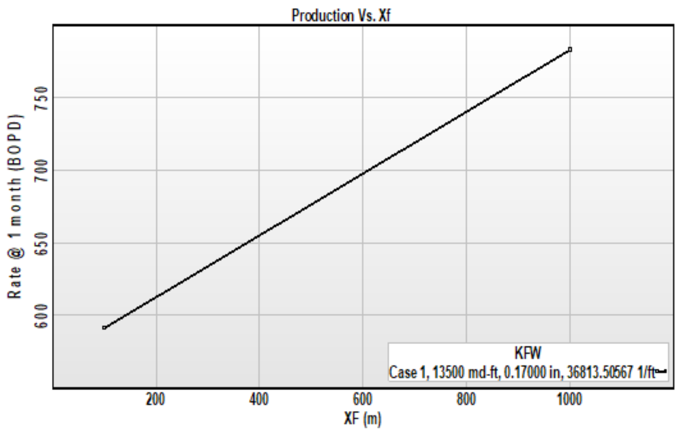

Figure 10: the effect of the production of one month on the fracture half length

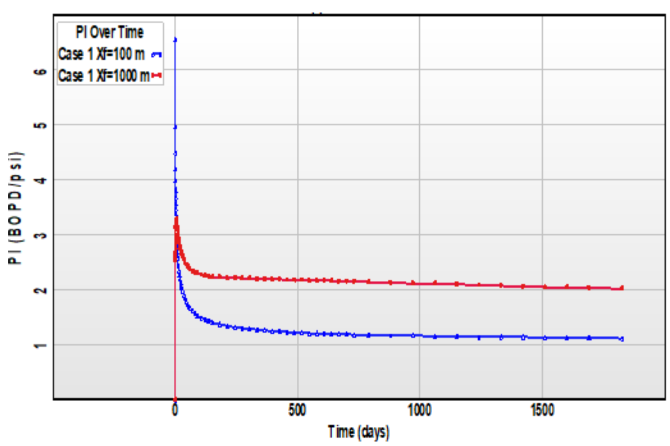

Figure 11: investigation of productivity index on fracture 100m and 1000m

7. CONCLUSION

Comprehensive investigation was conducted on offset stimulated wells in south of Iraq. The data revealed a minor impact of acid frac on well productivity and skin damage treatment. Therefore, proppant frac was designed to increase the productivity in Mishrif limestone formation. It was demonstrated there was a magnificent enhancement in well productivity index by increasing the fracture width. This enhancement was obtained by manipulating an appropriate proppant type (BauxLite 12-18) and efficient fluid (crosslinker#30) to achieve an optimum transportation to the fracture slurry. Furthermore, a thoroughly investigation was performed to show the impact of increasing the fracture half length. It was recognized that the higher permeability of Mishrif formation is not necessitating long fracture half-length to some extent but it is rather demanding a fracture width escalating.

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