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Mechanical earth model coupled with critical drawdown pressure to mitigate sand production in the Nahr Umr Formation, Southern Iraq

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Abstract

Sand production is one of the major challenges in the oil and gas industry. This problem exists when sand is produced along with oil and gas causing relevant damage to production equipment, thus decreasing in the productivity of wells. Therefore, a comprehensive geomechanical analysis is necessary to mitigate sand production. This study aims to assess the potential of sand production across the Nahr Umr Formation using the 1-D Mechanical Earth Model (MEM). Tech-log software coupled with well log and core data have been employed to accurately determine the possible rock geomechanical parameters, in-situ stresses and pore pressure at which rock failure might occur. Once MEM is complete, the Poro-elastic method is used to figure out the critical drawdown pressure (CDDP) and accurately predict the sand production onset. Additionally, the effect of different well completion types on the value of the CDDP was examined, and thus it was concluded that cased hole completion is the first line of defense against sand production, and can also be considered as a strategy of sand control because it reduces the sand production potential and increases the operation drawdown. Furthermore, to demonstrate the effectiveness and applicability of our method and technique, a case study was conducted to illustrate the reliability of our method in predicting sand-producing intervals under different depletion rates and completion scenarios. The finding showed that the depth 2527.7 m is a potential location for sand production as the CDDP reads a positive value revealing a high potential for rock failure. Moreover, sensitivity analysis has been performed by considering different ranges of Unconfined Compressive Strength (USC), Poisson ratio, minimum horizontal stress (Shmin), maximum horizontal stress (SHmax), vertical stress, sand grain size, perforation diameter, perforation orientations, stress ratio, and hole deviation. These factors play an essential role in optimal decisions related to real-time sand control techniques. Through the results, it is clear that as the UCS, Shmin, and SHmax increase, the sand-free drawdown and depletion also increase, and vice versa. Also, results show that as the depletion rate increases, the CDDP decreases in both cased and open hole conditions, revealing that the onset sanding likely occurs as the depletion rate is elevated. Based on these findings, a necessary modification to the completion design has been made, ensuring sand-free production from a clastic reservoir located in the southern area of Iraq.

Keywords: *Sand Production Prediction; Mechanical Earth Model; Critical Drawdown Pressure; Sand management model; Single Depth Sensitivity Analysis.*

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1- Introduction

One of the most significant challenges that negatively impact the profitability of the petroleum industry is flow assurance issues. These include problems such as sand production, hydrate formation, wax deposition, asphaltene deposition, corrosion, and scale formation [1-7].

Sand production occurs when failed sand grains are transported to the wellbore through reservoir fluids [8]. This phenomenon is generally considered undesirable in terms of operation due to its potential to prevent wellbore access, lead to erosion of completion components, and disrupt the operation of downhole equipment. These problems can significantly impact well productivity [9]. The process of sand production, from the reservoir to the surface, is a complex one. A process can be divided into three stages: Firstly, the degradation of the rocks surrounding a perforation or open hole, which leads to a loss of mechanical integrity. Secondly, the hydrodynamic drag force of fluid flow causes the separation of solid particles and clumps from the degraded sandstones. Finally, the sand particles are transported to the surface through the produced fluids. Sand particles can be produced in three different conditions; transient, continuous, or catastrophic [10].

The majority of the models have been developed to predict the onset of sand production, i.e., the first stage of the sand production process or the condition for rock failure and degradation initiation. Several sand models have also been developed since 2000 that could be utilized to assess sand production severity, i.e., sanding amount and rate [8]. Some of these models are formulated based on the sand production mechanisms identified

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during the second stage of sand production [11-13], while others are formulated empirically based on laboratory or field sand production data [8, 14]. Although the strategy of combining the mechanical earth model with the critical drawdown pressure was not expressly addressed in these studies, all of them are connected in terms of predicting the production of sand.

In this study, the calculations are derived from a well-established sand prediction model developed by Schlumberger. This model has undergone extensive research, field trials, and has been successfully used in numerous field cases [15, 16]. A workflow of leveraging petrophysical raw data to generate a 1-D geomechanical model and estimation of critical drawdown pressure is proposed. The workflow serves as a guide to starting from acquiring petrophysical data in the field to utilizing these acquired data to estimate the critical drawdown pressure (CDDP is the maximum difference between reservoir pressure and minimum well bottom hole flowing pressure, min that the formation can withstand without sand being produced) required to first sand particle to mobilize.

Mechanism of Sand Production Failures: Sand production in oil wells occurs when the equilibrium of pressure surrounding the wellbore is disrupted, leading to deformation and breakdown of the rock structure in the formation. The process of rock failure includes both mechanical failure and chemical failure [17]. The occurrence of these rock failures might occur from various well activities such as drilling, stimulation, and other treatments or from changes in the reservoir due to fluid production [18]. It is noted that there are two main types of rock failure mechanisms; mechanical failures and chemical failures.

1.1. Mechanism of mechanical failure

Sanding starts with the mechanical breakdown of rocks at a perforation or wellbore. The creation of sand is dependent on the failure of the formation, which is governed by the in-situ stresses and the mechanical characteristics of the rock. Unconsolidated formation rocks are susceptible to deformation in the location of perforations and wellbores as a result of localized stress [19]. Excavation and completion have the potential to cause damage to the wellbore surface. Hence, the extraction of fluid from the reservoir and the frictional force impacting the loose sediment of the reservoir cause erosion of the sand surface. Following their separation from the matrix, sand particles enter the wellbore [20]. Fig. 1 displays a graphical representation of mechanical failure patterns [20].

The most prevalent types of mechanical failure mechanisms in sand production include:

A- Shear failure (compressive failure)

Shear failure, also known as compressive failure, occurs when drilling or perforating operations create cavities, causing a decline in radial effective stress to zero, while vertical and tangential strains remain constant or increase. Shear failure can be a result of stress variations [18]. Additionally, plastic failure along the perforation tunnel may reduce the hole size due to shear failure [21]. In narrow sandstone formations, the extreme tangential stress applied on the borehole wall can cause shear rock collapse [22]. It is essential to understand that wellbore stability is significantly affected by the mud weight below the shear failure stress, which can generate a breakout in a minimum horizontal stress, direction as shown in Fig. 2 [16].

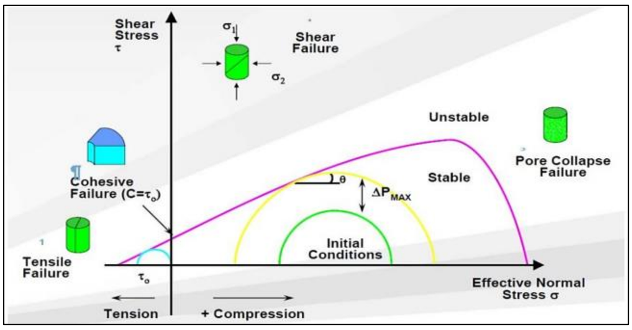

Fig. 1. Mechanical failure models [20]

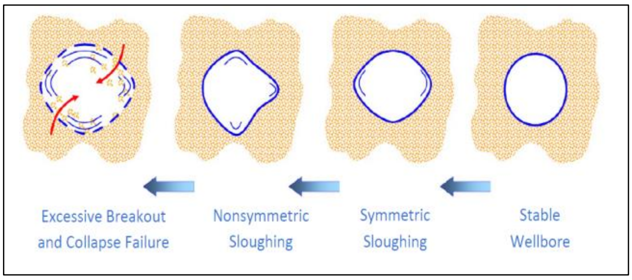

Fig. 2. Sequence of shear failures [23]

B- Tensile failure

Sand production takes place when the effective stress in the wellbore area exceeds the tensile strength of the formation. Typically, tensile failure happens at both the tip and the inner surface of the perforation tunnel [17]. Three principal factors contribute to this occurrence: regional in-situ stress, pore pressure, and tensile rock strength [18]. It is worth noting that the tensile failure mechanism is a relatively uncommon event during production in the majority of oil fields, usually associated with high production flow rates [24].

C- Cohesion failure by erosion

Cohesion refers to the strength that exists among formation grains, which affects rock consolidation and cement quality [18]. Various locations can have potential for cohesion failure, including perforation tunnels, wellbore surfaces with open holes, hydraulic fracture surfaces, shear planes, and boundary surfaces. Cohesion is related to cement and capillary forces. Sand is produced in formations when fluid drag overcomes formation cohesion [17]. The sand production in poorly consolidated rocks is significantly reduced when using open holes compared to perforated completion. This is due to the flow rate at the open hole area being much lower, approximately three orders of magnitude lower than the preserved perforation surface. Erosion, on the other hand, is related to tensile failure and requires a separate examination due to its distinct particle structure [22]. The major process of sand generation in unconsolidated sandstone (oil sand) is cohesive failure as it has low cohesive strength [21].

D- Pore collapse (volumetric failure)

This type of collapse occurs when the pressure of the reservoir decreases. A decrease in pore pressure within the reservoir can increase the effective stress, leading to the collapse of pores [18, 25]. Pore collapse occurs due to increased hydrostatic stress exerted on the granular rock. Fractured or loose grains can impose pressure on pore spaces, resulting in reduced porosity and compaction. Additionally, the presence of intense localized shear stresses at the point of contact between the grains might lead to failure [24].

1.2. Mechanism of chemical failure

The strength of a rock depends on two important components: the friction between grains and the cohesion between adjacent grains. However, chemical interaction can pose a significant threat by deteriorating the cementation materials, depending upon the rock fluids' content. The fluid may consist of acid, brine, or freshwater [21]. When studying the formation of sanding tendency, it is highly important to consider the following observations:

- If clay particles are present in the cementation material, the formation should be considered as potentially susceptible to water sensitivity. Furthermore, the production of water will reduce the integrity of the rock and increase the problems associated with sand formation. Consequently, when evaluating well performance and controlling well output in unconsolidated sandstone reservoirs, it is important to consider the effects of sand production and velocity sensitivity. Both velocity and water sensitivity are key elements that can affect well productivity [17].
- The use of hydrochloric acid (HCI) in completion fluids can potentially pose a risk to the integrity of the formation. This is particularly concerning when the cementation material in the rock consists of carbonate and the formation is exposed to acid, the structure of the rock will deteriorate, ultimately leading to the generation of sand. In Fig. 3, a solitary calcite crystal effectively binds a large quantity of detrital clastic grains together [14]. Only a few carbonate particles contribute to the structural arrangement of the sand grains. Consequently, removing these limited cementing crystals through acid treatment will cause a catastrophic failure, resulting in the formation of sand.

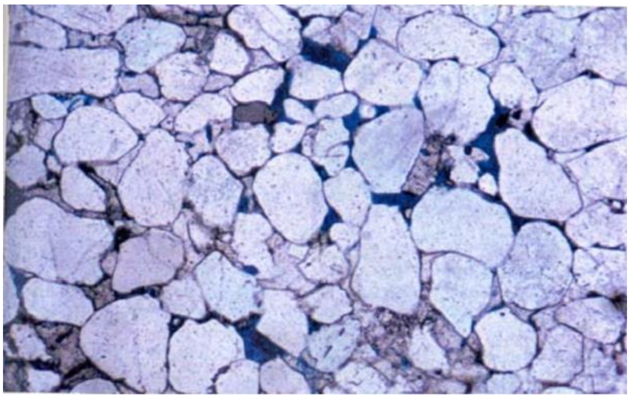

Fig. 3. The decomposition of cementation material in rocks due to acidic completion fluids [21]

2- Methodology

2.1. Sand production prediction workflow

Sand production is a common problem that occurs in the clastic reservoirs found in the oilfields of Southern Iraq [26, 27]. In the Nahr Umr formation, based on the interpretation of logs and core data, this reservoir, with a thickness of 225.5 m, has been divided into four main zones (A, B, C, and D). These zones mainly consist of sandstone, shale, and a low ratio of siltstone. A sand management model has been developed to evaluate sand production in this formation. This model aims to identify the most critical and prone intervals, and determine the downhole conditions (e.g., pressure, completion, etc.) that increase the risk [28].

The main input requirements to perform sanding analysis include the following: in-situ stress state, mechanical properties, grain size diameter, drawdown pressure, wellbore orientation, perforation diameter, and orientation. It is important to consider the uncertainty in the input parameters and their possible impact on CDDP. Fig. 4 illustrates the workflow for building the sand production analysis model.

2.2. Sand management model

The sand management model construction process involves the following steps:

a) Collecting and gathering data, conducting an audit, and preparing the data for analysis.
b) Developing a Mechanical Earth Model (MEM) specifically tailored to the target well and calibrating it using available data from mechanical core tests, wireline formation pressure testing, and other relevant sources. Ensuring a high degree of confidence in incorporating validated elastic properties and stress field properties into the sand management workflow.
c) Calculating the critical drawdown pressure (CDDP) along well for different depletion scenarios to identify the weaker points and determine the optimal perforation intervals. This will provide a depth-indexed profile of CDDP that is crucial for inducing

reservoir rock failure. In addition, it will provide an assessment of the potential impact of depletion over the field's lifespan.

d) Conducting detailed sensitivity analysis at selected intervals to evaluate the influence of various parameters, such as sand grain diameter, borehole deviation and azimuth, perforation diameter and orientation, and unconfined compressive strength (UCS) on the CDDP conditions.

e) Exploring different scenarios to determine the most suitable completion method for mitigating or reducing the risk of sand production. In the case of cased-hole completion, it is essential to define the optimal perforation configuration in terms of orientation, diameter, and other relevant factors.

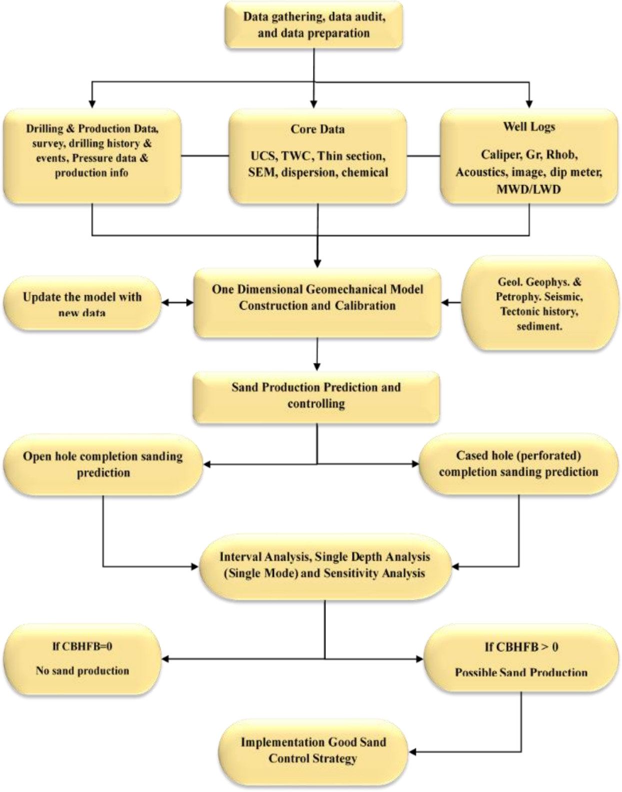

Fig. 4. Sanding analysis workflow

2.3. Building a 1D mechanical earth model

A Mechanical Earth Model (MEM) is a thorough representation of the mechanical properties of the reservoir and overburden formations, that includes characteristics such as rock strength, elasticity, and the conditions of in-situ stresses and pore pressure[29, 30]. The MEM serves as the foundation for other geomechanical analyses, including wellbore stability analysis, sanding prediction evaluation, hydraulic fracture design, and more. In this study, the MEM has been constructed using Tech-Log 2018 software. Once the MEM has undergone rigorous validation, the model can be used to identify geomechanical problems during drilling, completion, and production [31, 32]. It also aids in devising contingency plans for the planned well by conducting a sand management analysis along well trajectory and perforations[30, 33]. Once the initial geomechanical model is constructed, it is validated and verified against drilling experience and borehole quality from well logs at various formation intervals of different study wells throughout the field. The final geomechanical model, along with the initial reservoir pressure, and rock strength profile are used for the sanding evaluation [34]. Fig. 5 illustrates the outputs of 1D Geomechanical Modelling that will be utilized as inputs to build the sanding model.

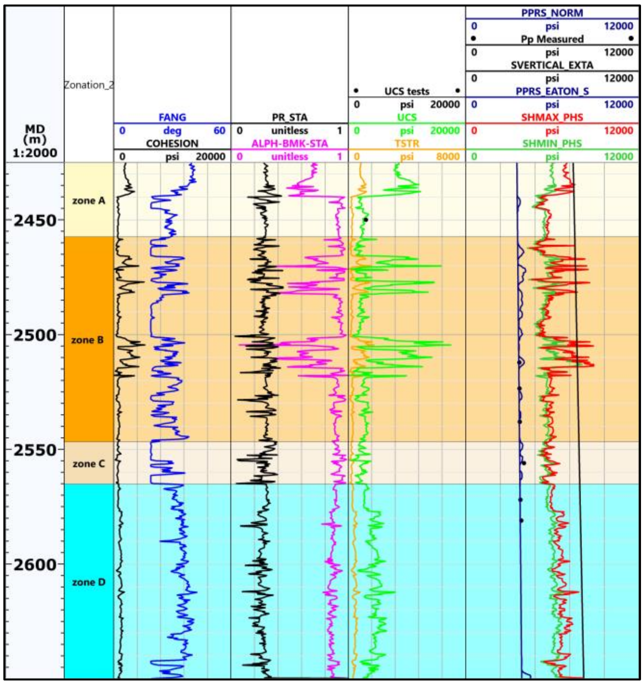

Fig. 5. Outputs of the 1D geomechanical model

2.4. Critical drawdown pressure (CDDP)

CDDP refers to the maximum difference between reservoir pressure and minimum well bottom hole flowing pressure (PHFP) required to prevent the production of solids from a sand reservoir [33]. To determine CDDP, we rely on the outputs of 1-D MEM at various depletion rates. These rates represent the time dependency based on the depletion rate of a chosen field/formation [10, 35]. The formulation suggested by Willson et al. is commonly utilized to calculate the onset of sand production. This aspect of the study focuses solely on the sand production caused by the failure of the formation rock due to shear forces during production.

It is important to note that such shear failure can have a catastrophic consequences [36]. The CDDP can be calculated in psi as follows:

$$\mathrm{CDDP} = \frac{1}{2-\mathrm{A}}(2\mathrm{P_P} - (3\mathrm{S_{Hmax}} - \mathrm{S_{hmin}} - \mathrm{U}) \tag{1}$$

Where A is a poro-elastic constant and represents by:

$$\mathrm{A} = \frac{\alpha(1-2\mathrm{PR})}{1-\mathrm{PR}} \tag{2}$$

α is Biot's constant given by:

$$\alpha = 1 - \frac{C_r}{C_b} \tag{3}$$

Where Pp is pore pressure, SHmax is maximum horizontal stress, and Shmin is minimum horizontal stress. In Eq. 1, the formation compressive strength (U) doesn't have its value directly, so we will calculate it from the thick wall cylinder test (TWC), which represents a fundamental strength measure for unsupported boreholes and perforations. Calculation of the formation compressive strength (U) is based on the TWC, which is calculated using the UCS from the Mechanical Earth Model.

TWC is calculating based on UCS as follows:

$$\text{TWC} = 9.1\ \text{UCS}^{0.61} \tag{4}$$

The formation compressive strength (U) can be determined from the thick wall cylinder model (TWC) in pounds per square inch (psi):

For open-hole completion;

$$U=2.5*\text{TWC} \tag{5}$$

And for cased and perforated completion;

$$U = 3.1\times \text{TWC} \tag{6}$$

3- Results and discussion

3.1. Estimating critical drawdown pressure (CDDP)

The mechanical earth model illustrated in Fig. 6 has been constructed for the purpose of this study. This model also includes the CDDP profile, which showcases the depletion rates in both cased and open hole completions. As shown in Fig. 6, the CDDP profile varies across different reservoir zones due to variations in the mechanical properties, surrounding stresses, and reservoir conditions. It is worth noting that there are several intervals where the CDDP indicates the presence of sand production, regardless of the applied CDDP. This finding is crucial in identifying sand-prone zones that require further isolation.

In the scenario of 0% depletion at zone B, the maximum drawdown pressure that can be applied for sand-free production from this reservoir is 3765 psi. On the other hand, in the 35% depletion scenario, the maximum drawdown pressure for sand-free production is 2446 psi. Fig. 6 clearly demonstrates that the use of casing enhances CDDP values, thereby reducing sand production. However, it is worth noting that despite the presence of casing, the problem persists at certain intervals. Therefore, it is important to address and control this problem at these depths using single depth analysis.

3.2. Single depth analysis (sand-face envelope)

In a single depth analysis plot (Fig. 7), the computation of BHFP is conducted as a function of the depletion rate, ranging from 0-100%. The green-shaded zone on the plot indicates the range of bottom hole flow pressures where sanding is not expected to occur, while the red-shaded zone signifies the potential or sand production. It is worth to mention that in Fig. 7, the Left Y-axis represents BHFP, while the right Y-axis allows for the determination of the critical bottom hole flowing pressure (CBHFP) and the X-axis represents the reservoir pressure. Well-X, which has been selected to be evaluated in our study, is completed with a cased hole. Therefore, it is crucial to analyze the perforation depths of this well to identify any intervals that may be prone to sand problems and recommend an appropriate solution. For this well, the perforated intervals range from 2519 to 2531 m and from 2540 to 2546 m.

Based on the low CDDP and UCS, there is a likelihood of sand problems occurring within the current perforated intervals of Well-X, particularly when the depletion rate is zero. These intervals are located in zone B within the studied area. This zone exhibits high oil saturation and is relatively free of shale, resulting in favorable petrophysical properties. By examining the CDDP depletion rates at various levels, (0%, 15%, 25%, and 35%), it has been determined that the optimal depth of the sand problem within these intervals is 2527.7 m.

As shown in Fig. 7 and Table 1, the selected depth in Well-X is 2527.7 m. This indicates the potential for sand production under certain conditions. The maximum CDDP in this well is 2400 psi. The conditions were obtained based on perforation diameter of 0.3 in, and a direction of 0°, while the adopted maximum stress direction was 50°. To establish a sand-free production zone, it is necessary to optimize these parameters through sensitivity analysis of the multiple influencing factors. Once the reservoir pressure reaches 2452 psi, any further pressure reduction poses a significant risk of sanding.

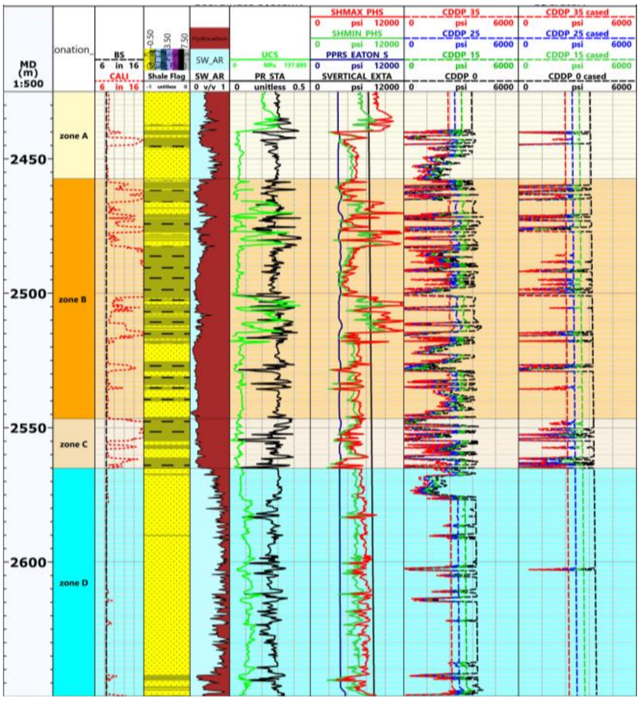

Fig. 6. Reservoir pressure depletion impact on CDPP along the depth profile for well X in the Nahr Umr Formation at depletion rates of 0%, 15%, 25%, and 35%

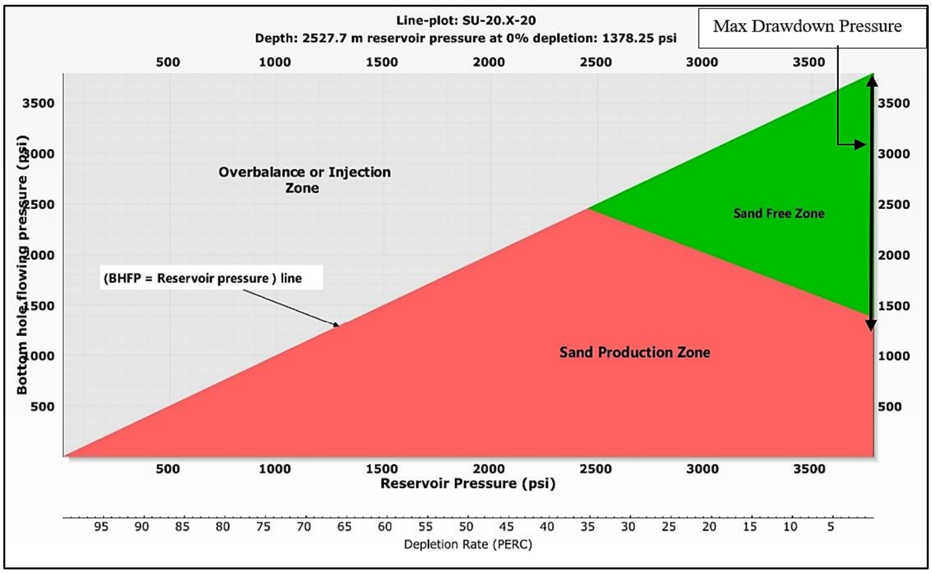

Fig. 7. CDDP prediction for Well-X at 2527.7 meters

Table 1. Limits of CBHFP for producing from depth of 2527.2m for Well-X

Well Name	Perforation Depth (m)	Initial Conditions		Production Limits Without sand	
		P_R (psi)	CBHFP (psi)	P_R (psi)	CBHFP (psi)
X	2527.7	3784	1382	2452	2445

As shown in Fig. 7, it is evident that CDDP decreases as it moves towards the upper left. In other words, the CBHFP increases as the reservoir pressure depletes during this process. Consequently, it is not possible for hydrocarbon to be produced from the free sand zone below the CBHFP values under both initial and production conditions, considering the reservoir pressure.

However, it is important to note that all the remaining intervals do not exhibit a decrease in CDDP and can be produced without the risk of sand production. This is due to the fact that these intervals were drilled in areas with formations that withstand high stresses. To understand this concept, we can select any depth within the perforated intervals (2519 to 2531 m) and (2540 to 2546 m). for the purpose of analysis, the 2544 m depth has been chosen to be visually illustrated in Fig. 8.

3.3. Influence of well completion types on CDDP

As mentioned above, casing plays an essential role in improving CDDP values, thereby decreasing sand production, as shown in Fig. 6. In the study conducted by Vimolsubsin et al., the effects of critical depletion pressure on well completion, time-dependent rock matrix stress, and pore pressure were examined.

To demonstrate the effects of completion methods, points in zone B with high oil saturation have been selected to focus on this purpose. These points are located within current perforation areas. Fig. 9 and Table 2 show further supporting to the notion that the casing improves CDDP values.

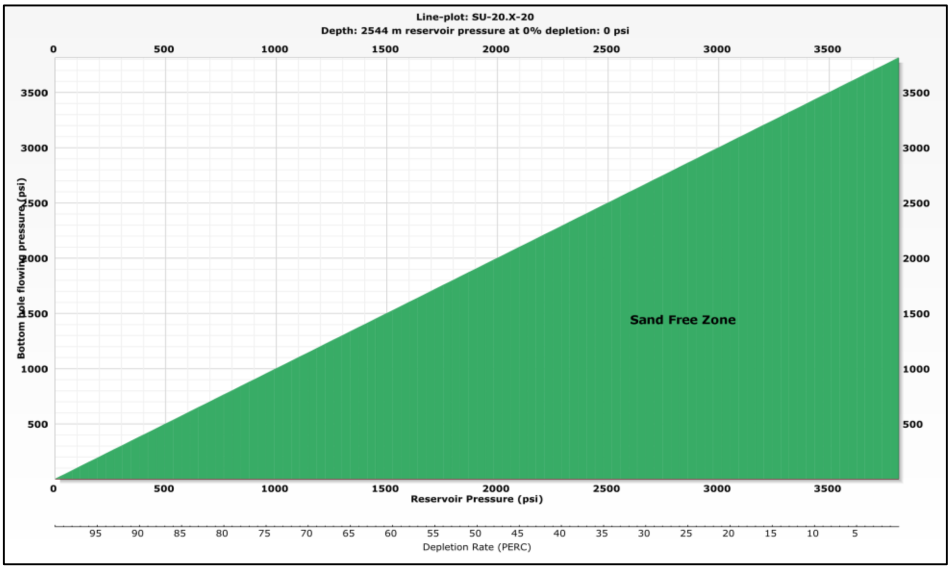

Fig. 8. CDDP analysis for depth 2544 m

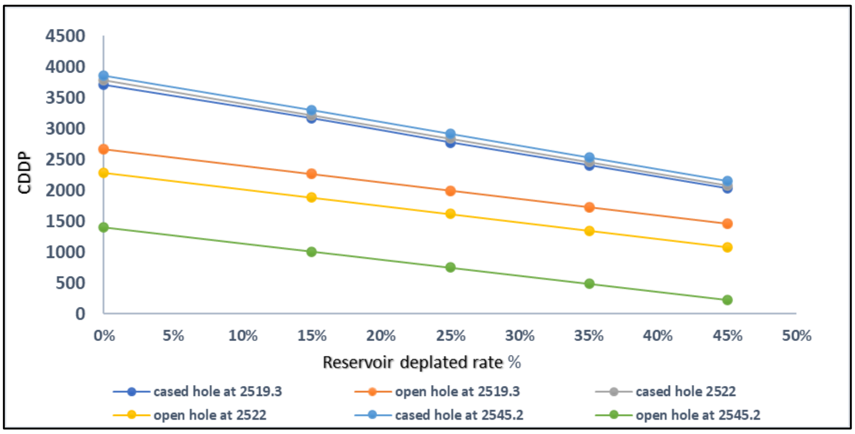

Fig. 9. Show influence of well completion types on CDDP

Table 2. Show influence of well completion types on CDDP

Completion Type		Cased			Open		
Depletion Rate	**Depth**	**2519.93m**	**2522.07m**	**2545.232m**	**2519.3m**	**2522.07m**	**2545.232m**
0%		3779.374	3780.527	3816.509	2663.299	2280.667	1398.415
15%		3212.468	3213.448	3244.032	2261.882	1881.191	1008.083
25%		2834.53	2835.396	2862.381	1994.271	1614.874	747.8615
35%		2456.593	2457.343	2480.73	1726.661	1348.557	487.6398
45%		2078.656	2079.29	2099.08	1459.05	1082.24	227.4182

3.4. Single depth sensitivity analysis

A single depth sensitivity analysis was conducted to examine the variations of CDDP and sand-free production with depletion at specific depths [33]. This analysis also aimed to forecast sanding over a wide depth range, considering the uncertainty in adopted 1D MEM parameters. When reservoir pressure drops, the stress within the reservoir may change, which in turn affects the sand-free drawdown. To optimize (or mitigate) sand production, a sensitivity analysis was performed for a depth 2527.7, as shown in Fig. 7. The parameters used in this analysis were selected based on their effect on open completion or lack therefrom in cased completion, particularly when CDDP is low at zero depleted rate.

The analysis had been done according to difference ranges of UCS, PR, S_{hmin}, S_{Hmax}, Sv, sand grain size, perforation diameter, perforation orientation, stress ratio, and hole deviation.

For open hole completion, Analysis had been done according to the difference ranges of UCS, PR, S_{hmin}, S_{Hmax}, Sv, sand grain size, stress change ratio and hole deviation. Fig. 10 shows the characteristics of the sand-free envelope plot using CPHFP for various rock strengths from 8 MPa to 14 MPa at a depth of 2527.7 m. It is clear that as the UCS increases, the sand-free drawdown and depletion also increases, and vice versa. When the rock strength increases, there is less risk of sand production because it becomes harder to fail. Therefore, accurately determining and measuring UCS is of high importance.

The selectivity of sand production in well-X at a depth of 2527.7 meters with multiple PR values (0.1 – 0.5) is shown in Fig. 11. A higher PR indicates a greater likelihood of fluid-filled sand formation because it is a sign of rock failure and deformation.

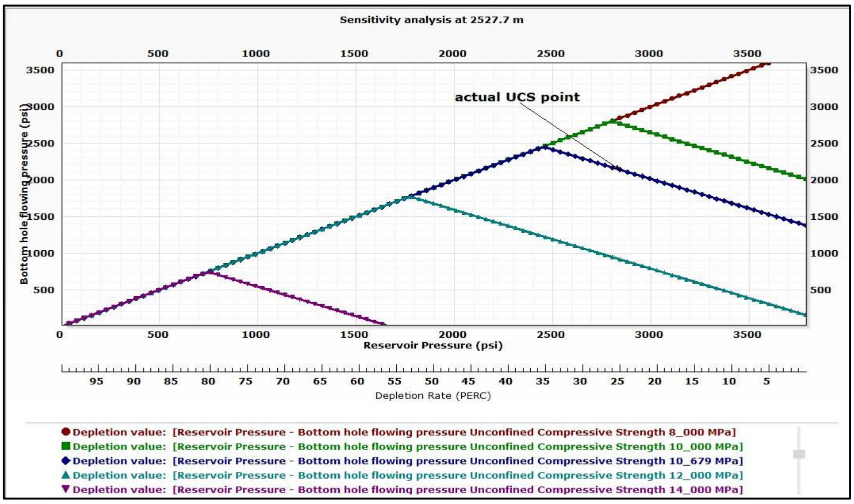

Fig. 10. Sensitivity of sand production conditions to rock strength (UCS) for Well-X

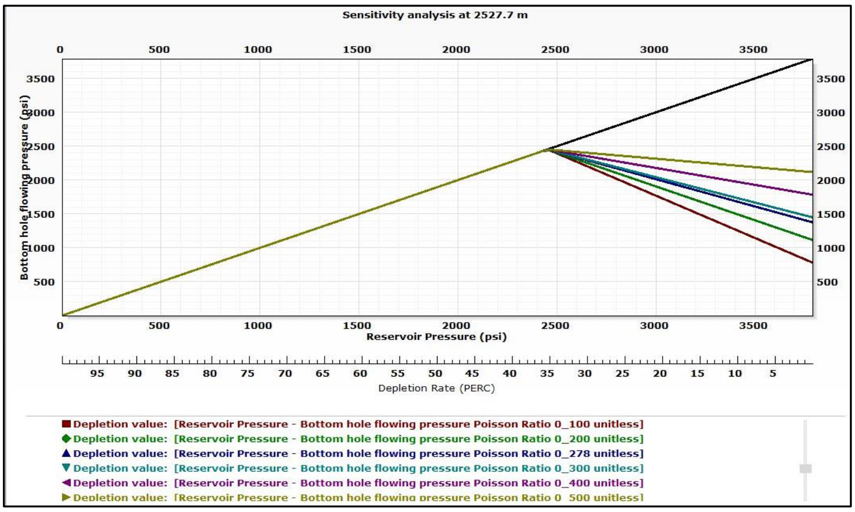

Fig. 11. Displays the results of a sensitivity analysis on sand production in Well-X, using a range of poisson's ratios

The sensitivity of sand production conditions to the well inclination for well-X is shown in Fig. 12. Sand production is heavily influenced by the well inclination. The study examines scenarios of a vertical well (0 degrees), an inclined well (30 and 60 degrees), and a horizontal well (90 deg). Both vertical and inclined wells may produce sand at a depth of 2527.7 m, with a maximum CDDP of 2400 psi for vertical wells and 3450 psi for inclined 30-degree wells. More favorable CDDP conditions for sand-free production are observed in horizontal and inclined 60-degree wells.

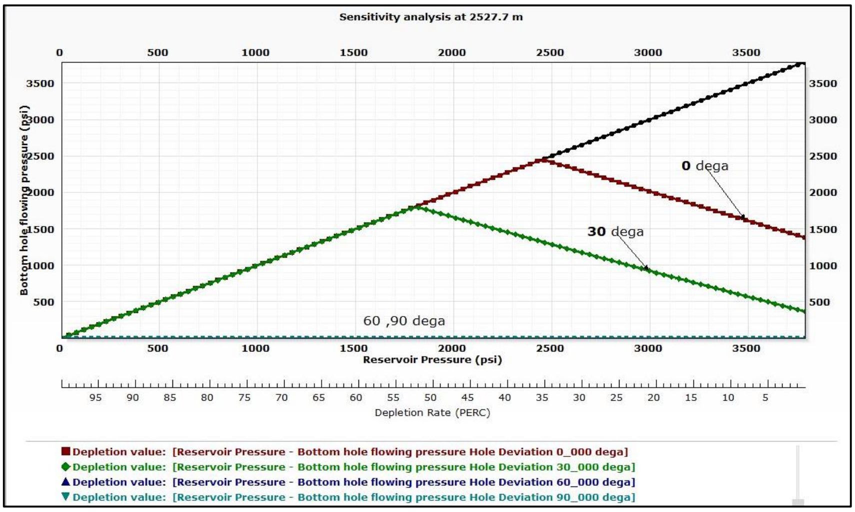

Fig. 12. Sensitivity of sand production conditions to well inclination for Well-X

As a general rule, larger sand grain diameter results in less sand production. In this study, a base case of 160 um is used. However, a broader range of grain diameters encountered in the reservoir is also considered, including diameters of 120, 140, 180, 200 µm and 350 µm. Faster sand production is expected as the grain size diameter decreases. Fig. 13 illustrates the effect of different ranges of sand grain diameter at depth a 2527.7 m in Well-X.

Overlapping the subsurface layers, lack of field data measurements, and the error associated with the instrument used to record the bulk density during well logging measurements are the main reasons for overburden stress (Sv) uncertainty. Increasing this parameter leads to increased sand production problems according to the high possibility of formation failure. In other words, if Sv is high, the possibility of producing free sand at low CBHFP is low. Fig. 14 illustrates the impact of Sv on the sand production problem.

Fig. 15 and Fig. 16 present the sensitivity of the sanding problem at a depth of 2527.7 m in Well-X to various ranges of S_{Hmax} (3000 – 7000 psi) and S_{hmin} (3000 – 6000 psi) respectively. By increasing these two parameters, the sanding problem can be minimized, resulting in a larger green zone with lower CBHFP. Higher values of these parameters allow for greater flexibility in perforating in all directions, without worrying about cavity failure during production. Additionally, it allows to produce fluids with free sand at lower values of CDDP.

Analyses the influence of the minimum and maximum horizontal stresses on the sand production prediction, as seen in Fig. 17. This ratio is defined as the value of the maximum horizontal stresses over minimal horizontal stresses. Therefore, when this ratio increases, the range of

CDDP will increase as a result of the increase in maximum horizontal stress. In this well, the 0.5 stress ratio value was used. There is no change in CDDP when we change the stress ratio in cased perforated wellbore completion.

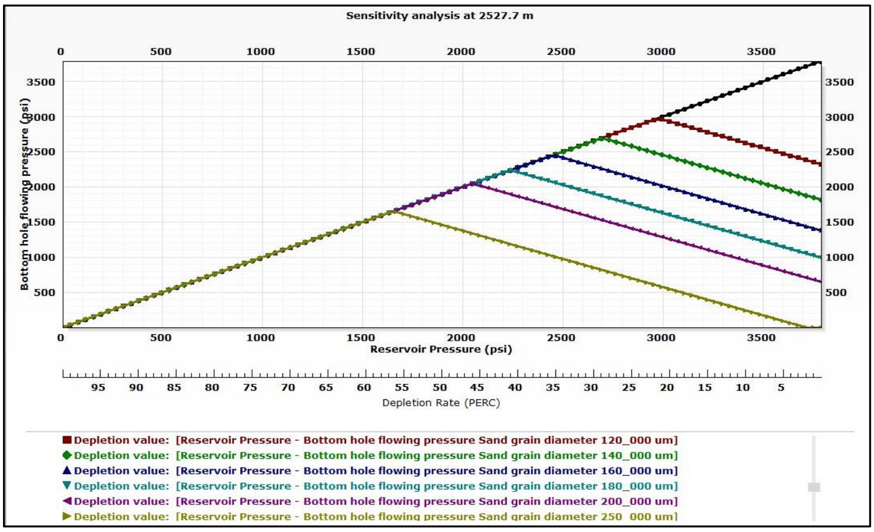

Fig. 13. Sensitivity analysis of depth 2527.7 m in Well-X to different sand grain diameter ranges

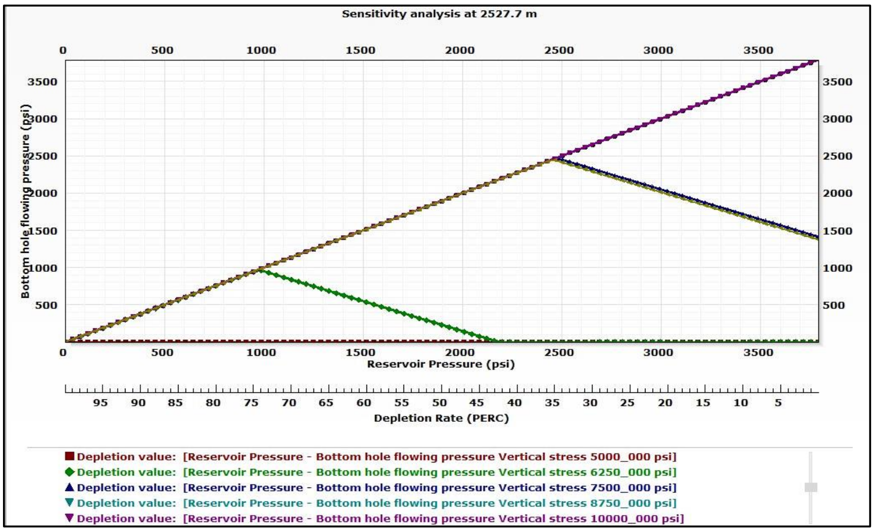

Fig. 14. Sensitivity analysis of depth 2527.7 m in Well-X to different vertical stress ranges

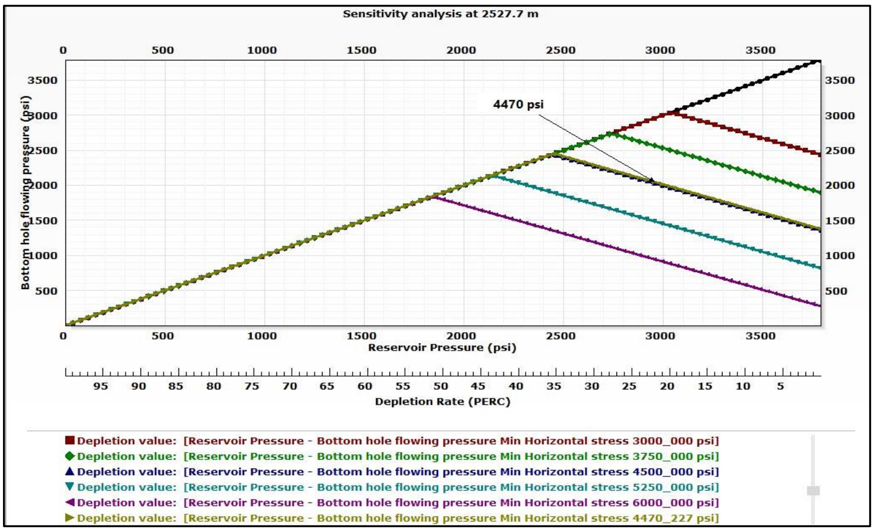

Fig. 15. Sensitivity analysis of depth 2527.7 m in Well-X to different S_{hmin} ranges

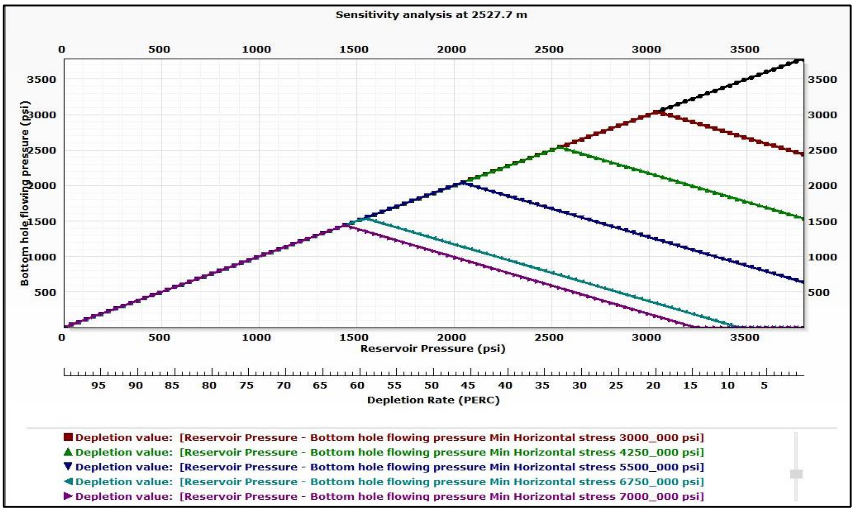

Fig. 16. Sensitivity analysis of sand production for a series of maximum horizontal stress

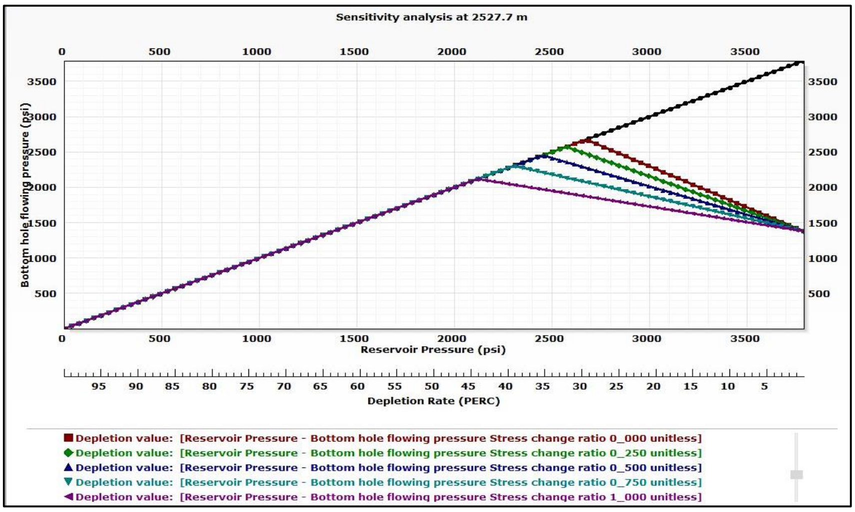

Fig. 17. Sensitivity analysis of depth 2527.7 m in Well-X to different stress ratio ranges

The effect of different parameters has been studied in the case of open completion of the well, which has a significant impact on the value of the critical drawdown, so we will move on to studying some important parameters in the closed completion process.

Large perforation diameter leads to the high possibility of tunnel perforation failure during production. Increasing perforation diameter causes the high possibility of sand production so decreasing in the green zone. Fig. 18 illustrates Sensitivity analysis to different perforation diameter ranges.

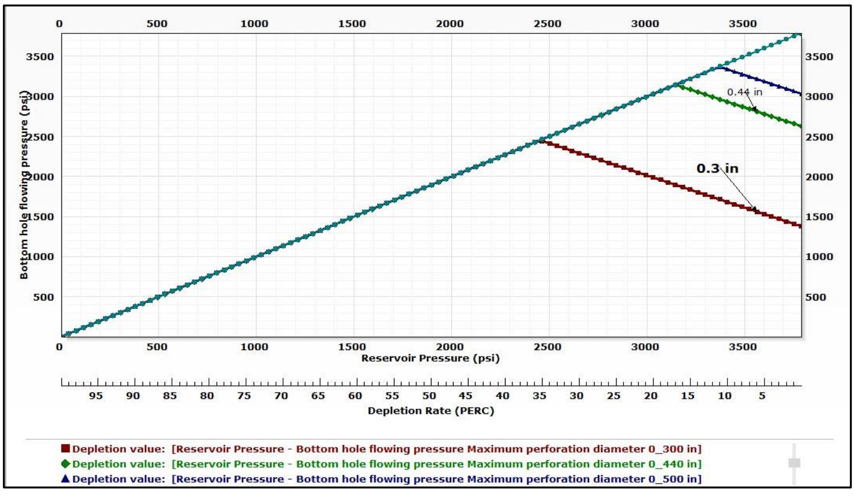

Fig. 18. Sensitivity analysis to different perforation diameter ranges

In some cases, the direction of perforation relative to stress directions can be a contributing factor in sand production. The studied interval shows a continuous normal faulting regime ($SV>S_{Hmax}>S_{hmin}$). The maximum horizontal stress in the field is around N50°E as determined from the available image logs. The influence of perforation orientations on the CBHFP in this well is significant as illustrated in Fig. 19. The closer the perforating direction is to the minimum horizontal stress observed further from the wellbore, the more likely it is that critical drawdown pressure will increase, leading to increased reservoir drawdown and decreased sand production risk.

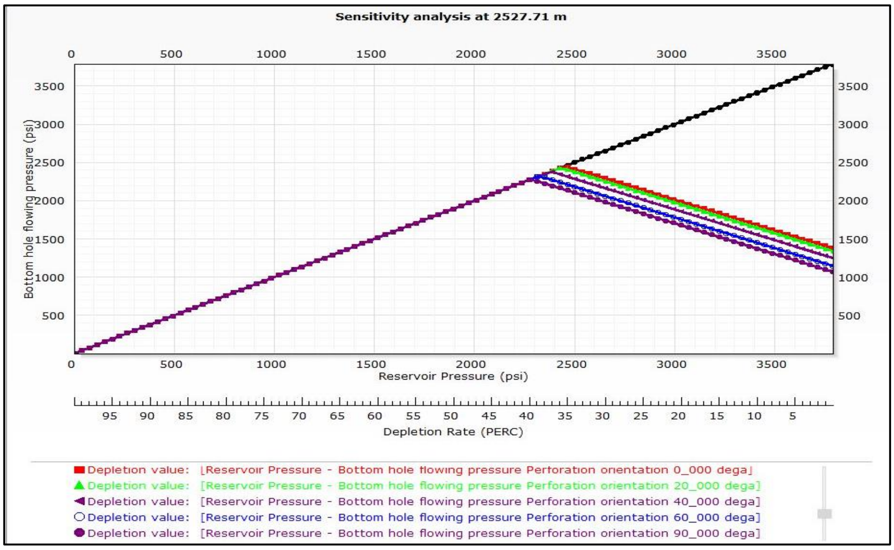

Fig. 19. Sensitivity analysis of depth 2527.7 m in Well-X to different perforation orientation ranges

4- Conclusion

A sand production prediction study was carried out for Nahr Umr formation in the South of Iraq to evaluate sanding potential zones and determine the optimal conditions for sand-free production. The utilization of a one-dimensional mechanical earth model (MEM) in conjunction with Critical Drawdown Pressure (CDDP) is essential for mitigating equipment damage and production constraints that can result from sand production. 1D Geomechanical Modeling outputs that are used as inputs for the sanding model. The influence of well completion types on CDDP has been studied, the results show that casing can improve CDDP values and therefore decreases sand production. The sand-face envelope determined that the optimal depth of the sand problem within the intervals is 2527.7 m Indicating a sand can be produced at certain conditions. The maximum CDDP in this well is 2400 psi; furthermore, any drawdown will result in a sand risk when the reservoir pressure reaches 2452 psi. Analysis of sensitivity had been conducted according to difference ranges of UCS, PR, S_{hmin}, S_{Hmax}, Sv, sand grain size, perforation diameter, perforation orientation, stress ratio, and hole deviation. Sensitivity analysis aids in determining the optimal perforation diameter and orientation to minimize sanding problems. Poisson ratio and unconfined compressive strength support the indications of elastic and strength rock properties that are indicated on weak and strong zones (As the rock strength increases, there is less risk of sand production because it becomes harder to fail; also, higher PR is a sign of rock failure and deformation).

Nomenclatures

Symbols	**Description and unit**
BHFP	Bottom hole flowing pressure (psi)
CBHFP	Critical bottom hole flowing pressure (psi)
CDDP	Critical drawdown pressure (psi)
C_o	Cohesion strength (psi)
FANG	Fraction angle (deg^o)
GR	Gamma ray (GAPI)
MD	Measured depth (m)
Pnorm	Normal pore pressure (psi)
P_p	Pore pressure (psi)
PR	Poisson ration (Dimensionless)
SHmax	Maximum horizontal stress (psi)
Shmin	Minimum horizontal stress (psi)
S_v	Vertical stress (psi)
SW	Water Saturation (%)
T_o	Tensile strength (psi)
TVD	True vertical depth (m)
U	Formation strength
UCS	Unconfined compressive strength (Mpa)
α	Biot coefficient

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ربط الموديل الجيوميكانيكي مع ضغط الإنتاج الحرج لتخفيف انتاج الرمل لتكوين نهر عمر جَنُوب العراق

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الخلاصة

يعد إنتاج الرمل إحدى التحديات الرئيسية في صناعة النفط والغاز. توجد هذه المشكلة عندما يتم إنتاج الرمل على طول النفط والغاز مما يتسبب في تلف معدات الإنتاج وبالتالي انخفاض إنتاجية البئر. ولذلك، من الضروري إجراء تحليل جيوميكانيكي شامل للتخفيف من إنتاج الرمال. باستخدام برنامج، Tech–log حيث تم استخدام البيانات الأساسية لتحديد المعلمات الجيوميكانيكية الصخرية المحتملة بدقة، الاجهادات، وضغط المسام التي قد يحدث عندها فشل الصخور. بمجرد اكتمال MEM، يتم استخدام طريقة Poro–elastic لمعرفة ضغط السحب الحرج (CDDP) والتنبؤ بدقة ببداية إنتاج الرمل. بالإضافة إلى ذلك، تم فحص تأثير أنواع استكمال الآبار المختلفة على قيمة CDDP، وبالتالي تم التوصل إلى أن cased hole completion هو خط الدفاع الأول ضد إنتاج الرمل، ويمكن اعتباره أيضًا استراتيجية للتحكم في الرمل لأنه يقلل من إمكانات إنتاج الرمل ويزيد من Drawdown. علاوة على ذلك، لإثبات فعالية وقابلية تطبيق طريقتنا، تم إجراء دراسة حالة لتوضيح موثوقية طريقتنا في التنبؤ بفترات إنتاج الرمل في ظل معدلات استنفاد مختلفة وسيناريوهات الإنجاز. أظهرت النتائج أن العمق ٢٥٢٧,٧ مترًا هو موقع محتمل لإنتاج الرمل حيث يقرأ CDDP قيمة إيجابية تكشف عن احتمالية عالية لانهيار الصخور. علاوة على ذلك، تم إجراء تحليل الحساسية من خلال النظر في نطاقات مختلفة من قوة الضغط غير المحصورة (UCS)، ونسبة بواسون، والحد الأدنى من الإجهاد الأفقي، والحد الأقصى للإجهاد الأفقي، والإجهاد الرأسي، وحجم حبة الرمل، وقطر الثقب، واتجاهات الثقب، ونسبة الإجهاد، وانحراف الثقب. تلعب هذه العوامل دورًا أساسيًا في اتخاذ القرارات المثالية المتعلقة بتقنيات التحكم في الرمل في الوقت الفعلي. من خلال النتائج يتضح أنه مع زيادة UCS وShmin وSHmax، يزداد أيضًا السحب والاستنزاف (Drawdown) الخالي من الرمل، والعكس صحيح. أيضًا، تظهر النتائج أنه مع زيادة depletion rate، يتناقص CDDP في كل من ظروف الحفرة المغلقة والمفتوحة، مما يكشف عن أن onset sanding من المحتمل أن تحدث مع ارتفاع depletion rate. وبناءً على هذه النتائج، تم إجراء التعديل اللازم على تصميم الإنجاز، مما يضمن إنتاجًا خاليًا من الرمل في التكوين الرملي الذي يقع في المنطقة الجنوبية من العراق.

الكلمات الدالة: التنبؤ بإنتاج الرمل، موديل الأرض الميكانيكية، ضغط السحب الحرج، نموذج إدارة الرمال، تحليل حساسية العمق الواحد.