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A comparative Approach to Differentiate Between the Amount of Rock Cuttings Generated in ERD and Conventional Drilling

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Abstract

Extended Reach Drilling is one of the drilling techniques that is used to drill horizontal wells to very long distances. These types of wells have many applications and advantages over conventional drilling techniques. The paper concentrates on one of the environmental advantages of ERD wells over conventional drilling. Since an oil and gas well can generate thousands of barrels of drill cuttings, it is important to know how much cuttings will be generated per well. What is the calculation method, and what are the parameters involved in cuttings amount generation. Additionally, the article compares the amount of drill cuttings generated in both ERD wells and conventional drilling. An accurate drilling technique is used to calculate the amount of cuttings generated while drilling both types of wells. The factors and parameters control the amount of cuttings generation is explained and showed how ERD project minimizes the amount of cuttings. A mathematical method is used to determine the amount of cuttings generated per each section of well drilled. Parameters involved in drilling cuttings calculation are explained. M-16 ERD well of Wytch Farm and a real conventional well from Iraq are used to calculate the amount cuttings generated. The total amount of cuttings generated during drilling deeper sections is bigger, although they have small diameters. For M-16 ERD well, the larger amount of cuttings appeared during drilling 12.25'' hole section while it appeared in the conventional well during drilling 17.5'' hole section.

Keywords: *ERD; Rock cuttings; Comparative study; Wellbore trajectory; Factors influencing cuttings waste .*

1. Introduction

An extended reach well is considered as a special type of long radius horizontal well in which the ratio of the measured depth (MD) is twice the true vertical depth (TVD). ERD assists in facilitating drilling into potential reservoirs situated in environmentally sensitive fields, which have very sharp rules not favorable for setting up a rig there. With ERD (Extended Reach Drilling), a drilling rig can be set 10 kilometers from the sensitive area. ERD patterns generally are deep (MD), with long horizontal displacements between the surface location and the bottom of the hole. ERD is one of the techniques that oil companies apply to effectively drill wells to long distances, from onshore to offshore locations. The amount of extended reach drilling is getting increasing day by day. This is due to the fact that using ERD techniques has many advantages over conventional drilling methods. ERD has many applications that improve environmental efficiencies. Some of these applications are; It reduces environmental footprint in offshore environments, It limits drilling operation effects on the environment, It reduces underwater noise and other activities, It eliminates interaction with the marine environment while drilling from land to oceans, It decreases the need for installing the number of platforms needed to develop an offshore field, this is due to the fact then, multiple wells can be drilled in the same platform, thus eliminating the number of platforms. In many papers and text-books, the environmental benefits of drilling an ERD well are extensively explained. Environ-mental consideration has been one of the most important aspects of well engineering and design. Recently, many papers and articles are published about extended reach wells. Existing extended reach technologies have been reviewed and summarized. Principles and mathematics of ERD, horizontal, and directional drilling have been presented [1-11]. An overview of the drilling issues is provided, and the completion issues as relevant for a gas production well are examined [12]. Woodside Offshore Petroleum Company presented and studied the drilling extended reach wells in the Northwest Shelf in Australia [13]. The development of multilateral wells and long reach wells has been explained on how to maximize recovery for many oil fields [14]. Three main principles on the design of ERD well trajectory were studied by optimizing the build section within nine types of shapes [15]. The results illustrated that sideway curves, curvature reducing curves, and circular arc are better than others. Additionally, the obtained results are essential guidelines for the design of ERD trajectory. Moreover, a hole cleaning program of a ERD field was developed by Amoco UK over the course of three ERD wells. This program proved its effectiveness in cleaning the hole as well as increasing drilling progress [16].

Applications of ERD Oil companies have always searched for new techniques and new development in drilling methods to best exploit oil and gas reserves, for that they spend millions of dollars on technical researches and development projects to find the most economical and convenient ways to drill oil and gas wells. The applications and benefits of ERD wells encouraged drilling engineers to further develop techniques to drill such challenging wells. This helped oil companies to reach extremely difficult and critical geological targets. Below lists some of the applications and benefits of ERD wells:

- Used to drill oil and gas wells in complex and challenging environments such as the Arctic
- Drilling wells from a location on land to the oil and gas under the ocean, example in Russia, Sakahlin-1 project
- Guiding the wellbore to the extreme distance in the pay zone, which increases the recovery of hydrocarbon and it is dramatically increasing production rate and reservoir drainage
- Reducing environmental footprint and, in offshore applications and It limits our presence in the marine environment
- Reducing underwater noise and other activities
- Eliminating interaction with the marine environment while drilling from land to oceans by using ERD techniques
- Reducing cost for developing the field and minimizes impacts on the marine environment by decreasing the number of platforms needed because it uses a single structure to develop a field
- Drilling and producing the reservoir from a remote location

Obviously, most of these papers concentrate on operational aspects and drilling efficiencies of these types of wells. There are little, if not any, publications about the environmental benefits of extended reach wells, especially drill cuttings waste minimization. Therefore, this paper tries to compare the amount of cuttings generated per well for each ERD well project and a conventional well. The paper also tries to demonstrate how much cuttings can be generated per drilling and oil and gas well. How an ERD project minimizes the amount of environmental damage by decreasing drilling waste generation. How these amounts of cuttings are calculated, and what are the parameters involved in drilling waste calculations. What are the factors that control the amount of waste generation?

Furthermore, this article is shedding light on one of the most important applications of extended reach drilling, which it is the amount of cuttings generated while drilling a specific well. With the rise of the environmental protection movement, the petroleum industry has placed greater emphasis on minimizing the environmental impact of its operations [17]. Both Governments and International oil companies are always trying to develop drilling techniques that best serve the environment and, at the same time, cost-effective.

2. Cuttings Amount Determination

A typical well can generate several barrels of fluid and cuttings per foot of hole drilled. In 1992, the number of hole feet drilled was 115,903,000 in the USA. If we consider an average hole size of 12 ¼ hole size with zero access and zero porosity, this will give an amount of 16,895,953 bbl of cutting generation per year in USA [17]. This is a huge amount of cuttings to be treated and environmentally disposed. Therefore, the basic mathematics of cuttings amount calculation requires a straightforward equation that is simple, easy to understand, and use. Normally these kinds of calculations are performed while planning oil and gas wells to estimate the open hole size, amount of cement plug needed to cement a portion of open hole, hole volume for drilling fluids, well-killing operation in case of a well kick and amount of cuttings that will be generated while drilling of each open hole section. In order to determine the amount of cuttings generated while drilling oil and gas wells, the following equations are used.

$$V_c(bbl) = \left[\frac{(D_h)^2}{1029.4}\right].L \quad (1)$$

$$V_c(bbl) = \left[\frac{(D_h)^2}{1029.4}\right] L\,(1-Ø) \quad (2)$$

Another factor to be considered while calculating the amount of cuttings generation is the access size of the open hole. While drilling oil and gas wells the size of the hole is over-gauged in most of the cases by an amount that can be estimated either by experience while drilling the same section in the area or by using wire line method technology called caliper log. For the sake of simplicity, in this paper, an average amount of 15% is added to actual hole size. The equation for calculating amount of cutting will have another parameter.

$$V_c(bbl) = 1.15\left[\frac{(D_h)^2}{1029.4}\right] L\,(1-Ø) \quad (3)$$

where: V_c is volume of cuttings in bbl; D_h is diameter of the hole, normally drilling bit size in inches; L is length of section drilled in feet; Ø is porosity of the rocks drilled; 1.15 is 15% extra hole size added to the original hole size.

First, for the sake of simplicity, the amount of porosity will not be integrated to the equation, but later correct values of porosity will be used to have better results. The amount of cuttings generation will be calculated for each section of the hole drilled.

3. Field study data

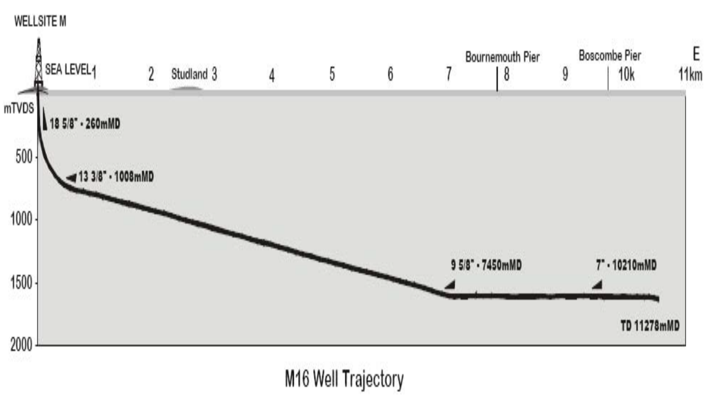

Figure 1. Actual Trajectory of 11-km ERD Well at Wytch Farm [18]

Two wells are used to do the comparative study in order to differentiate between the amount of rock cuttings generated in ERD and conventional drilling. The first well (M-16 well) is one of the most common well profile for an ERD project used for Wytch Farm which once it was a world record for longest ERD well. In order to calculate the amount of waste generated in ERD and actual well profile (Figure 1) of Wytch Farm M-20 was used for better demonstration. The second well is selected from Iraq. It is a conventional well which is drilled in the northern Iraq. The well scheme is shown in Figure 2. Details of both wells are presented in Tables 1 and 2.

Table 1. Actual Well scheme of 11-km ERD Well at Wytch Farm [18]

Depth, ft	Hole Size, in	Casing Size, in
0 – 853	24	18 5/8
853 - 3307	16	13 3/8
3307 - 15585	12 ¼	9 5/8
15585 – 37003	8 ½	7

Table 2. Actual well scheme of conventional well

Depth, ft	Hole Size, in	Casing Size, in
0 – 100	30 Conductor mostly hammered	
100 - 2625	26	20
2625 - 7218	17 ½	1 3 /8
7218 – 9843	12 ¼	9 5/8
9843 – 11484	8 ½	7

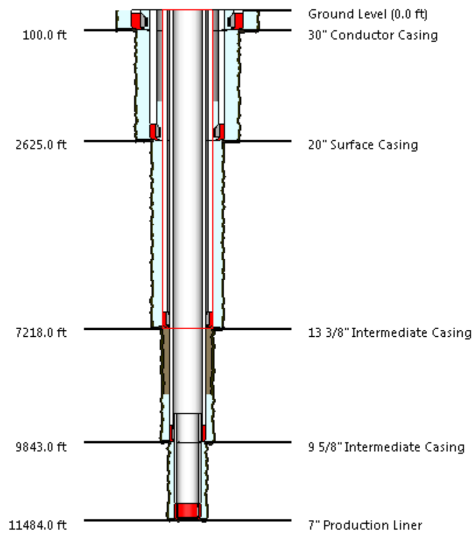

Figure 2. A typical well scheme for a conventional well

4. Amount of cuttings generated in the ERD well and the conventional well

The amount of cuttings for the M-16 ERD well and the conventional well is determined and appeared in Tables 3 through 4 and Figures 3 through 4.

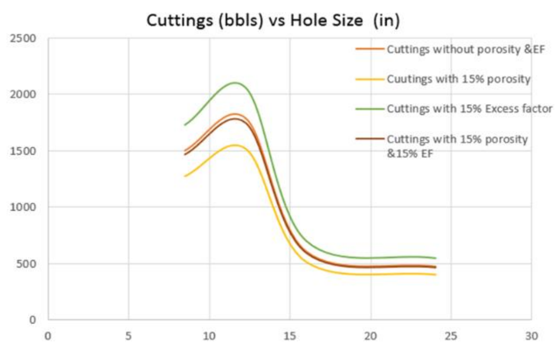

Figure 3. Amount cuttings generated in M-16 ERD well

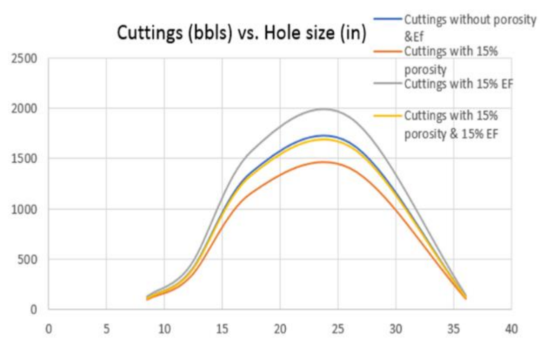

Figure 4. Amount cuttings generated in conventional well

The porosity and the excess factor are taken 15 % as a good indication for good porosity and washouts. It is found that the amount of cuttings generated for the ERD well and the conventional well are 4381, and 3648 bbls, respectively. This means the amount of waste which damages the environment for ERD is more than that of conventional drilling. However, the calculated amount of cuttings generated is not accurate; it needs some details to be considered, like the porosity of the rocks and hole washouts. Since the underground rocks are porous and not solid rocks only. This means that the fraction of rocks which it is hallow should be estimated and integrated to the equation to have a more precise amount of cuttings calculations. Therefore, the calculations are repeated including 15% for porosity, and excess factor. It is clear that the resulted values will be lower than that calculated without porosity and higher than that calculated without excess factor. The total amount of cuttings generated while drilling the ERD well and the conventional well are 5038, and 4196 bbls respectively with including only 15% excess factor and these amounts are higher than that of determined including 15% porosity, 15% porosity and 15% excess factor, or without both of them (Tables 3&4). For M-16 ERD well, the bigger amount of cuttings appeared during drilling 12.25'' hole section while it appeared in the conventional well during drilling 17.5'' hole section. Due to long hole in deeper sections, the total amount of cuttings generated during drilling these sections is bigger although they have small diameters (Figures 3&4).

Table 3. Calculations of cuttings amount generated in M-16 ERD well

Depth, ft	Hole size, in	Casing size, in	Volume of cuttings, bbl	Volume of cuttings with 15% EF, bbl	Volume of cuttings with 15% porosity, bbl	Volume of cuttings with15% porosity & 15% EF, bbl
0 – 853	24	18 5/8	477.295512	548.8898	405.7012	466.5564
853 - 3307	16	13 3/8	610.281718	701.824	518.7395	596.5504
3307 - 15585	12 ¼	9 5/8	1789.84591	2058.323	1521.369	1749.574
15585 – 37003	8 ½	7	1503.25481	1728.743	1277.767	1469.432
		Total	4380.67794	5037.78	3723.576	4282.113

Table 4. Calculations of cuttings generated in a conventional well

Depth, ft	Hole size, in	Casing size, in	Volume of suttings bbl	Volume of suttings with 15% EF, bbl	Volume of suttings with 15% porosity, bbl	Volume of cuttings with 15% porosity &15% EF, bbl
0 - 100	36	30	125.898582	144.7834	107.013794	123.0659
100 – 2625	26	20	1658.15038	1906.873	1409.42782	1620.842
2625 – 7218	17 ½	13 3/8	1366.43312	1571.398	1161.46815	1335.688
7218 – 9843	12 ¼	9 5/8	382.663748	440.0633	325.264186	374.0538
9843 – 11484	8 ½	7	115.176073	132.4525	97.8996624	112.5846
		Total	3648.3219	4195.57	3101.07361	3566.235

5. How ERD well reduces cuttings amount?

The above values are based on comparing one ERD well with a conventional well only. However, drilling one extended reach well might eliminate drilling several wells to penetrate the same reservoir vertically Figure 5.

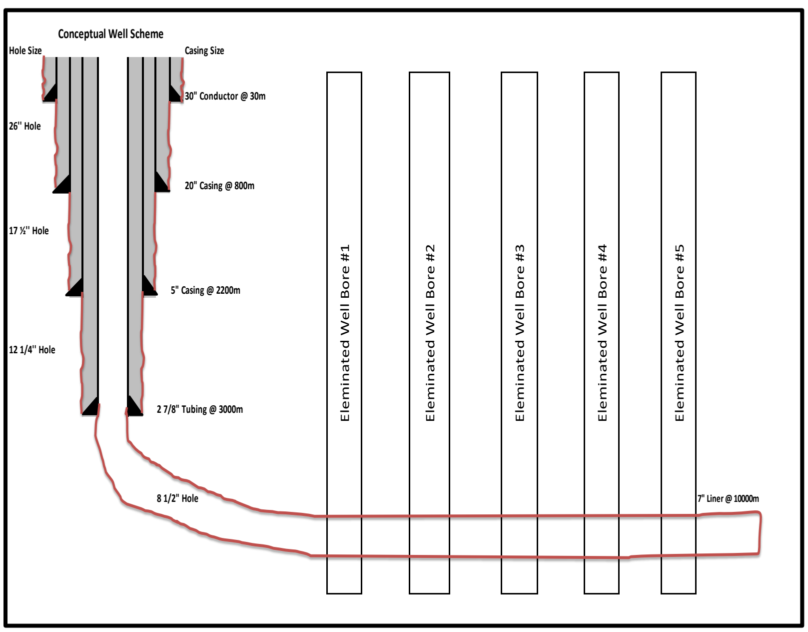

Figure 5. Conceptual Well Scheme for an ERD Project

Because the ERD well penetrates through the reservoir section horizontally for very long distances, thus drilling of several vertical wells to penetrate the reservoir section will not be needed. EDR wells might generate more drilling cuttings than conventional wells if it is compared with a single well. However, in reality, if it is compared on field level, they generates much less drilled cuttings than a conventional wells. This is due to the fact that to penetrate a specific reservoir at any targeted depth. Figure 5 tries to demonstrate how an ERD project in a specific field decreases the amount of drilled cuttings. Clearly, one ERD well will penetrate the same reservoir with 5 targets that can be drilled with 5 conventional wells. Additionally, the actual well trajectory shown in Figure 4 proves the same concept. Therefore, one ERD well saves the environment at least from 70% of the drilling cuttings generated from the 5 vertical wells passing through 5 targets: NRQ 255 6H-1, NRQ 255 6H-2, NRQ 255 6H-3, NRQ 255 6H-4, and NRQ 255 6H-5.

The drilling ERD well on field level will reduce the amount of wells needed to penetrate the same reservoirs in the filed vertically by drilling multiple wells. This proves that the amount of cuttings that can be generated in the field by drilling ERD wells is much more less than the amount of cuttings that will be generated by drilling multiple vertical wells.

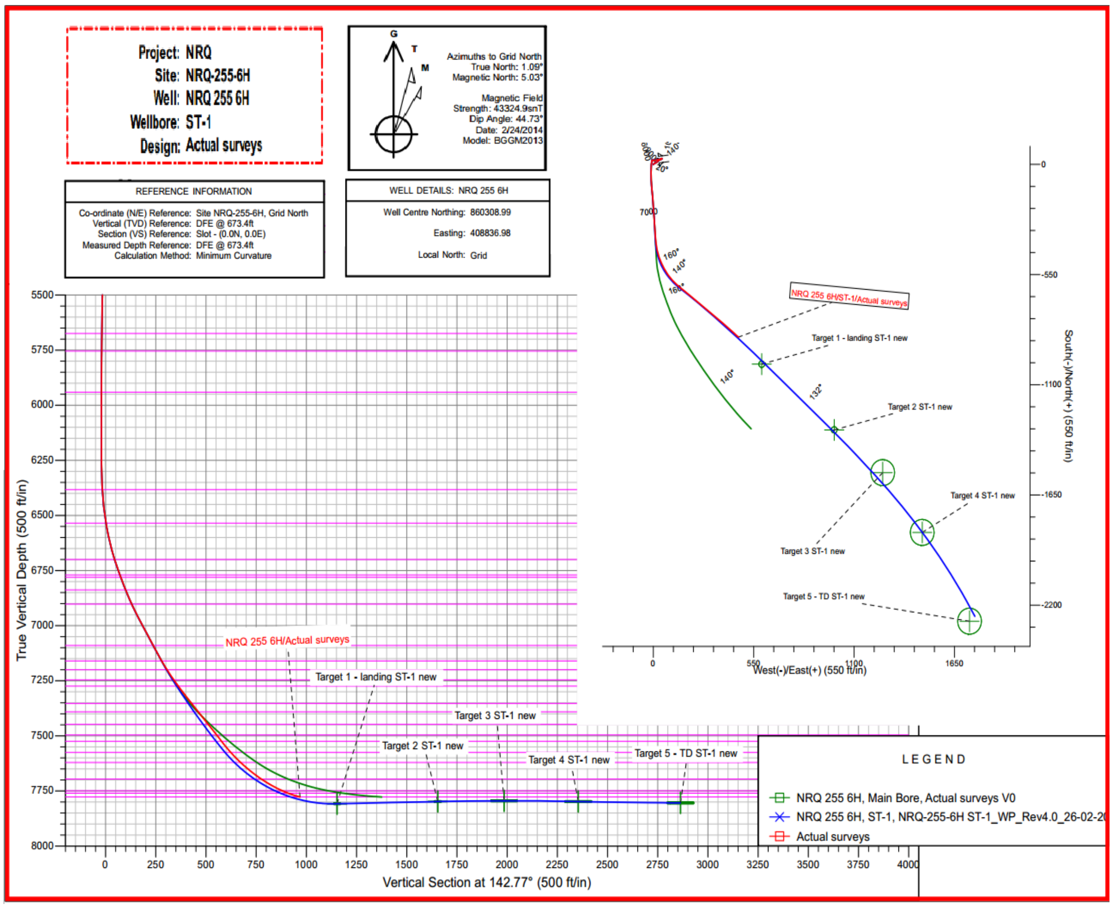

Figure 6. Actual horizontal well trajectory- the planned versus the reality [10]

6. Factors affect the actual hole size and amount of cuttings generation

There are several factors that control the actual hole size drilled, that is why, after drilling each hole size, a special logging tool called caliper logging is run down the hole so as to measure the actual hole size. The amount of cuttings generated per each section of the well depends on these factors. The factors are listed below:

- Type of drilling fluid which it is used to drill the well, normally synthetic drilling fluids system give a gauged hole, thus it produces less amount of cuttings. Meanwhile water based drilling fluid systems give bigger size of hole and more cuttings generation.

- Drilling bit gauge, if the drill bit is under gauge the hole size will be smaller, thus produces less cuttings
- Type of rocks and geological formation drilled, if the rocks are sloughing shale the hole size will become bigger and the nmber of cuttings generated will be more. Meanwhile if the geological formations are solid dolomite or limestone the hole size will be same as drilling bit.

7. Conclusion and results insights

The amount of waste generated per well is different form one well to another, there are many factors involved in waste generation percentage. Both ERD well drilling technique and conventional drilling was compared to prove that drilling ERD wells have an environmental advantage over conventional drilling in terms of drilling cuttings generation amount. Using ERD well might decrease the need for drilling several wells to access a targeted reservoir. It means that it eliminates need of drilling several wells Figures 5&6, which in turn decreases the need to drilling the very top hole sections several times. Normally drilling top hole section generates more drill cuttings, this is due to the fact that surface holes are bigger in size.

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