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Casing Drilling Technique to Optimize Drilling Operations in Qarun Petroleum Fields, Western Desert, Egypt

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Abstract

Many solutions have been executed to mitigate the wellbore instability problem including improving mud inhibition with chemical additives, raising mud weight to mechanically support the wellbore, and modifying casing design to accommodate extra-large diameter surface casing with the drawback of increasing well cost. Despite these solutions, the operator is still plagued by continuous hard reaming during tripping operations, several dill string pack-off sticking incidents, and the inability to get the casing to the bottom. This paper examines the effect of implementation of Non-retrievable drilling with casing technique to optimize drilling and overcome the hole instability problems in West of Nile (WON) field is located in the Western Desert of Egypt and operated by Qarun Petroleum Company. This solution is unique in terms of adaptability and simplicity, a few adaptations are required for a standard drilling rig to be able to get casing to bottom by rotating, reciprocating, and circulating simultaneously. Applying this technique optimize drillings, reduces cost, and improves safety.

Keywords: *Drilling with Casing; Clastic deposits formation; Lost Circulation; Wellbore instability; Mud weight; Drilling mud.*

1. Introduction

Casing while Drilling (CWD), Casing Drilling (CD), Drilling with Casing (DWC), Liner Drilling (LD), and Drilling with Liner (DWL) are all terms being used interchangeably to express the same basic idea, the main principle is to utilize either a casing string or a partial liner in lieu of the conventional drill string to simultaneously drill to the planned casing point, circulate the well, and perform casing cementing operation [1-2].

The concept has been born in the 1920s and relatively enhanced in the 1960s when some operators used to drill the final hole section with a non-drillable bit attached to the lower end of the production casing string, after reaching total depth (TD), the casing was set in place along with the drilling bit [3]. The application of this concept was restricted only to the final casing string. With the advent of drillable bits, the technology was extended to be used in any section of the well.

Currently, casing drilling can be implemented using two systems:

1- Non-retrievable drilling with casing system (NRDwC).
2- Retrievable drilling with casing system (RDWC).

Fig. 1 show the difference between conventional drilling, NRDwC, and RDwC bottom hole assembly (BHA).

1.1. Non-retrievable drilling with casing system

Non- retrievable drilling with casing uses a casing drive system (CDS) connected to the regular rig Top drive system (TDS) to transfer rotary motion to the entire casing string connected to a drillable casing bit at the bottom. A single joint elevator and pipe handler in the casing drive system are used to pick up one joint of casing from the mouse hole, then it is stabbed in the casing string, the connection is then made by the casing drive system and drilling is resumed conventionally [2, 4-5].

Non-retrievable systems (fixed systems) are used to drill with full casing strings or short liners. Application of this technique is usually implemented in drilling vertical wells known with drilling problems when drilled conventionally. The limitations to these systems are mainly TD (the section must be drilled with a single bit) and the wear due to casing rotation during drilling [4, 6-7].

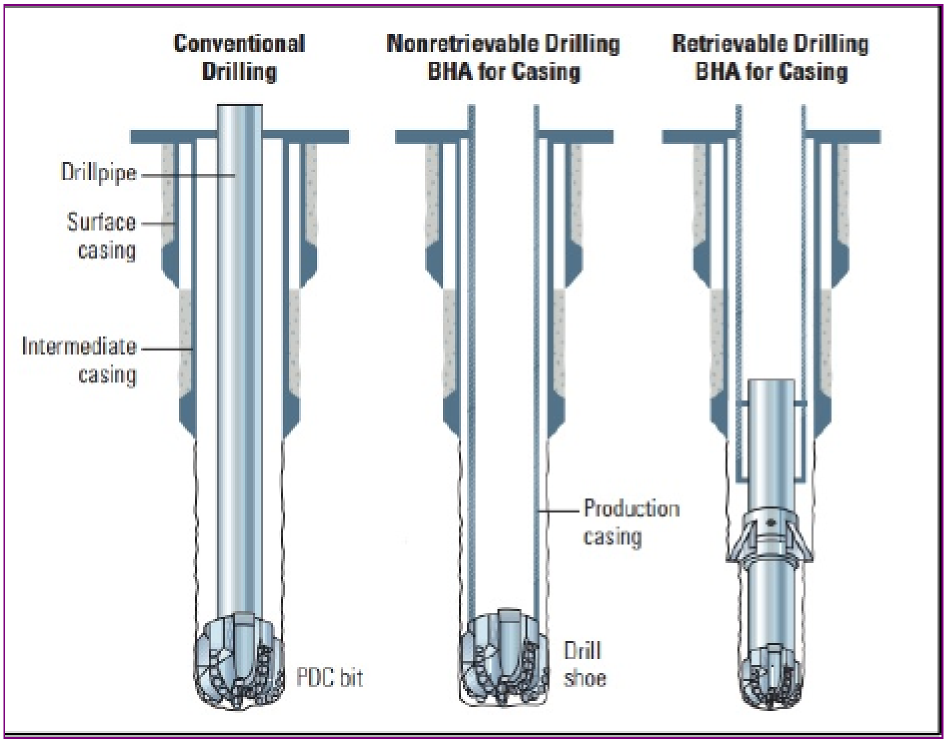

Fig 1. Conventional drilling, NRDwC BHA, and RDwC BHA

1.2. Retrievable drilling with casing system

Retrievable drilling with casing system is used in directional wells, casing string stays in the hole while a retrievable drilling BHA is run and retrieved by smaller drill pipe string, coiled tube, or heavy-duty wireline cable. This will allow the usage of MWD, LWD, drilling motor, and RSS, also they can be tripped at any time up to inclination 90 deg [4, 8-9].

Retrievable DWC facilitates utilization of directional control, logging while drilling the well, and in vertical wells that require multiple bit runs to reach TD [10-11].

The drill pipe retrieval method is simple but needs the casing to be static during the operation, but the wireline retrieval system can be performed while maintaining the reciprocating of the casing string to avoid potential stuck issues [3, 10, 12].

2. Conventional drilling sequences and the problem

From the starting of the drilling phase in the West of Nile (WON) field, the exploration team encountered a problem in recognizing the formations from the surface to Abo Roash-A (A/R" A") formation. Formations were completely different from Mohra, Dabaa, Apollonia, and Khoman formations normally found in the Western Desert of Egypt which are mainly loose sand, clay, limestone, and dolomite respectively.

Clastic Deposits formation has also been named as the Ancestral Nile river fill, it is a huge erosional geological feature during which uplift with subsequent erosion has replaced Mohra, Dabaa, Apollonia, Khoman, and Abo Roash-A formations with relatively young tertiary clastic sediments. Fig. 2 shows the structural cross-sectional map for the WON field. The erosion happened during the Miocene age, 7 million years ago [13].

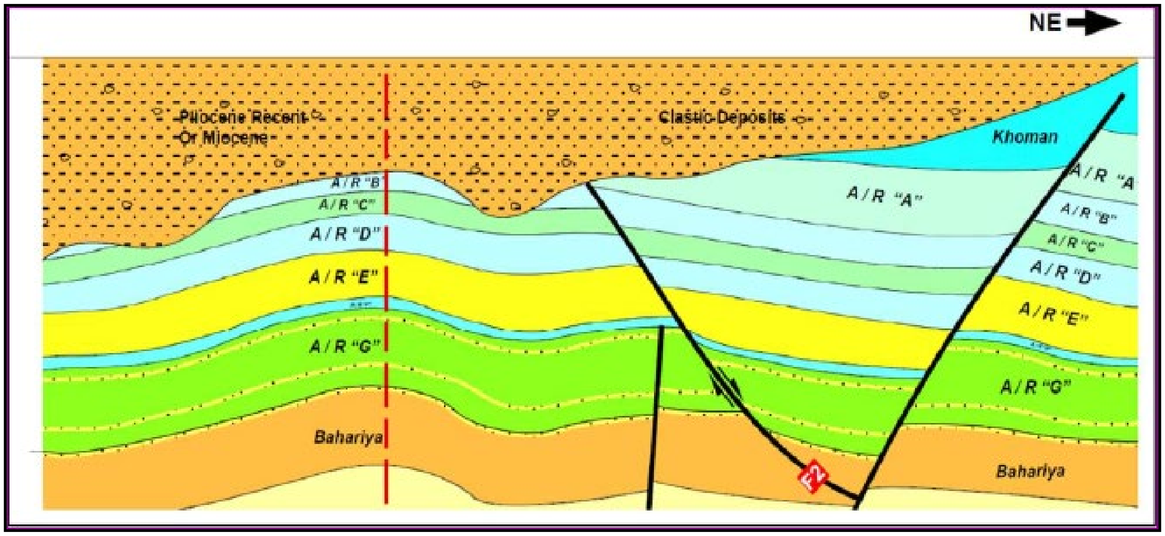

Fig 2. WON structural cross-sectional map

The relatively young clastic deposits formation starts at the surface and extends to +/- 4600 ft, it is composed of two sections, the upper section is from the surface to 1500 ft and it consists of permeable loose sand interbedded with stringers of siltstone and clay where losses may occur during drilling, The lower section is from 1500 ft to +/- 4600 ft and it primarily consists of siltstone interbedded with stringers of shale and dolomite and this is where severe wellbore instability problems have been encountered [13]. Table 1 provides the WON field lithology.

Table 1. WON field lithology

Age		Formation		MD	TVDSS	Lithology
Tertiary	Miocene	Clastic Deposits		Surface	Surface	Siltstone with sand, shale, limestone, dolomite, clay & chert bands
Upper Cretaceous	Turonian - Santonian	Abu Roash	A	4649'	4530'	Limestone with shale, siltstone & sandstone streaks
			B	5136'	5010'	Limestone with shale streaks
			C	5251'	5124'	Limestone with shale, siltstone & sandstone streaks
			D	5471'	5344'	Limestone with shale, siltstone & sandstone streaks
			E	5792'	5665'	Siltstone with sand, shale and limestone streaks
			F	6402'	6275'	Limestone with shale streaks
Late Cretaceous	Cenomanian		G	6498'	6371'	Shale with siltstone, limestone and sandstone streaks
		Bahariya	UBAH	7403'	7276'	Siltstone with sandstone, limestone and shale streaks

The drillability of clastic deposits formation is not an issue, high penetration rate (ROP) can be easily achieved with minimum drilling parameters. The main problem is the inability to trip out of the hole after reaching the casing point due to the severe wellbore instability. Several condition trips with hard back reaming have been necessary to obtain a usable hole which results in non-productive time (NPT) increase, stuck pipe incidents, fishing operations, and sidetracks [13].

Although mud weights have been increased to 11.5 ppg along with improving shale inhibition by mud additives, the wellbore instability issue persists. One solution was to add extra 20" casing to drill the clastic deposits formation with two sections as shown in Fig. 3, this solution has been proven to be ineffective with additional incurred costs.

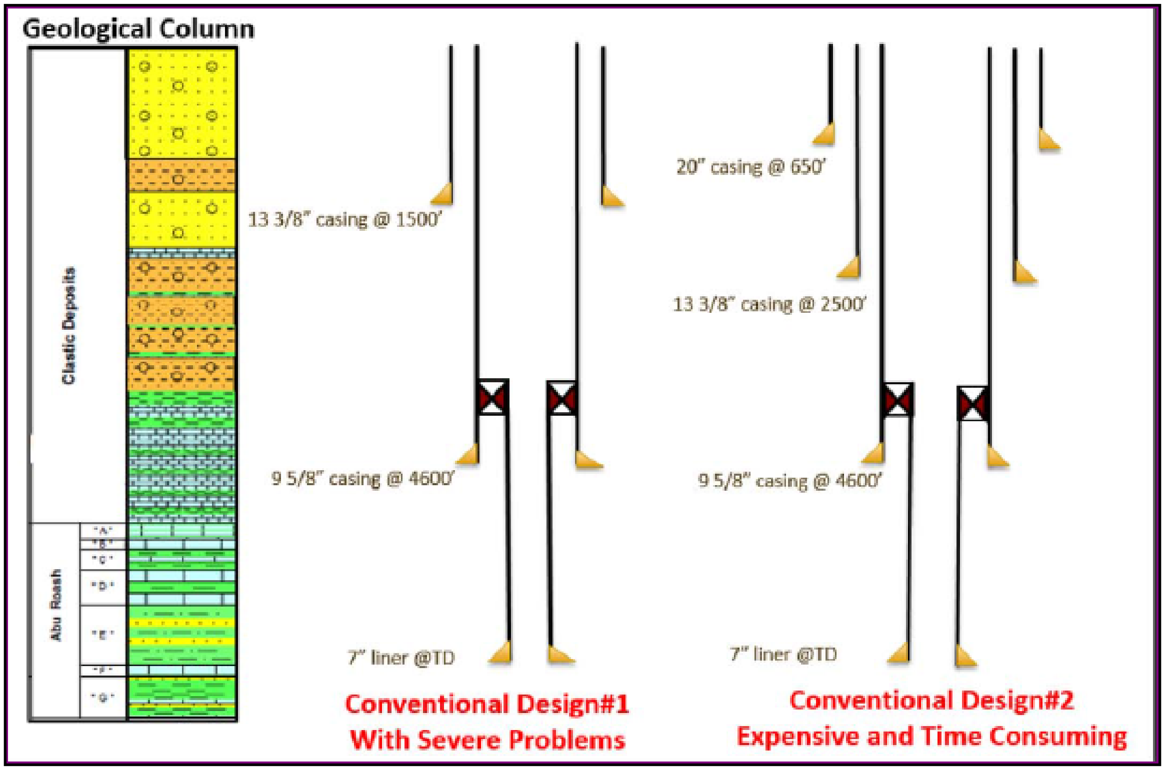

Fig 3. WON conventional well design [13]

More than thirty wells drilled conventionally and encountered lots of NPT due to wellbore instability, cavings, excessive condition trips, washouts, pipe sticking, and losses. Clastic deposits formation starts with sand, usually, losses problem is faced during drilling the first 600 ft, but can be easily treated with LCM and drilling can be resumed either in 26" or 17.5" hole without interruption. Clastic deposits are not consistent, some areas like WON-C-300 have no problems at all. Again we can say confidently that clastic deposits are not consistent, some wells have faced losses deep in siltstone due to the presence of dolomite streaks. In one well, gases increased after cementing 13.375" casing, and well kicked during drilling 12.25" hole. In the exploration wells, the drilling plan was to set 20" casing @ -/+ 600 and drill 17.5" hole to A/R “A” with bentonitic mud, most problems were hydrated clay balls, rings, and plugged flow line due to using non-inhibited mud. Slimming down casing design and using KCL polymer mud proved to be not helpful, shale cuttings became harder, pipe sticking due to pack off started to happen. Usually tripping in big holes is easier. Clastic deposits are time-dependent, this is clearly correct. In some well after the drill string got stuck and setting sidetrack plug, we were unable to RIH with directional BHA in the old hole to sidetrack the well which required setting another sidetrack plug to cover the entire open hole and sidetrack shallower, just below the previous casing shoe. In another well 9.625" casing was set off bottom, after spending two days cementing and working on the wellhead, we were unable to RIH with 8.5" BHA to wash down in the 12.25" rate hole, also sidetrack plug was required to sidetrack just below the casing shoe and abandon the open hole. All wellbore instability problems appear only during tripping after reaching TD, probably due to losing the effect of ECD and the swabbing effect.

3. Drilling with casing as a unique solution for clastic deposits formation

The proposed solution was to drill the 12-1/4" hole through the problematic clastic deposits formation using casing string along with PDC drillable bit instead of conventional drilling. This will simultaneously drill and case off the open hole section, ensure cementing the casing right after drilling to total depth, which will reduce the open hole exposure time to the minimum, drilling with casing has been proven to eliminate losses and mitigate wellbore stability problems. One of the advantages of this solution is that it requires no major modification to rig or casing design.

3.1. Equipment selection

Standard 9-5/8" BTC casing string is used along with standard normal flow float collars. The unconfined compressive strength data of the clastic deposits formation range from 7000 psi to 20000 psi. As shown in Fig. 4, the selected bit is Weatherford Defyer PDC bit, DPA 8516X, IADC: S423, and with 8 ceramic nozzles. Casing drive system (CDS) is used to connect rig top drive system (TDS) to the casing string in order to transmit rotary and axial motion to the casing string, also it provides a positive seal inside casing for mud circulation. Casing drive system will make up casing connections safer and faster while minimizing damage to casing thread. Torque rings are to be installed to fill the gap between the pin ends to increase the torsional capacity of the buttress connections (BTC). Fig. 5 depicts the non-retrievable drilling with casing system components.

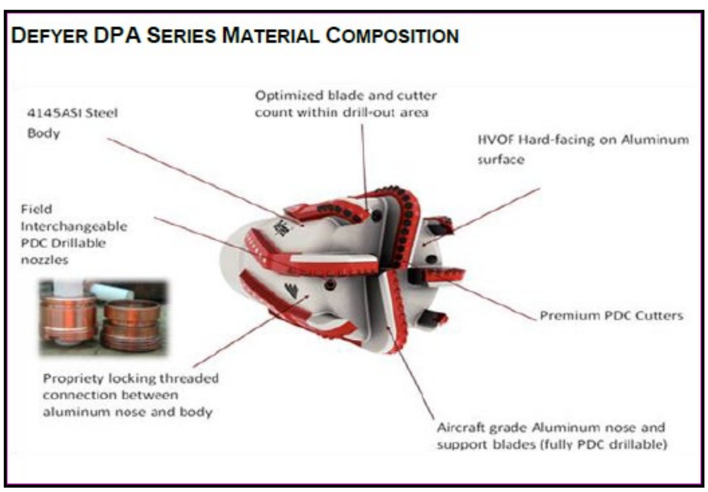

Fig 4. Weatherford drillable PDC bit [13]

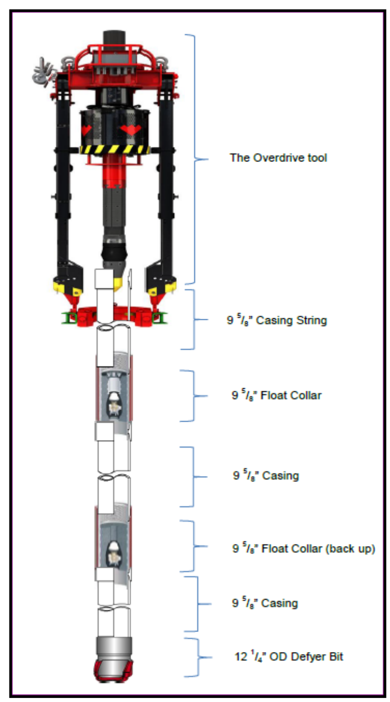

Fig 5. NRDwC system components [13]

4. Performance-based comparison

4.1. Well Performance using conventional drilling system (Well-A)

30" Conductor was hammered to 140 ft, 17.5" vertical hole was drilled 722 ft, 12.25" vertical hole was drilled to 4400 ft. Tables 2, 3, and 4 provide BHA, last casing and bit data, and mud properties respectively.

Table 2. Well-A BHA information

Component	Length (ft)	ID (in)	OD(in)	Linear Air weight(ppf)
Bit sub with float valve	3	2.81	8.00	150
Shock sub	27	2.81	8.00	150
12 jts x 8” Drill collar	363.3	2.81	8.00	150
HM jar	30	2.81	8.00	150
12 jts x 8” Drill collar	60	2.81	8.00	150
3 jts x 6.5” Drill collar	90	2.81	6.5	92
15 jts x 5” HWDP	459.1	3	5	49.3
5” DP to surface	3367.6	4.276	5	20.89

Table 3. Well-A Last casing and bit information

Size(In.)	Weight (Lb/ft)	ID (In)	Shoe depth (ft)
13.375”	68	12.415	722
Bit size (In)	Serial No.	Type	Nozzles
12.25	1330520	HE18DJMRSV	3*16

Table 4. Well-A mud properties

Mud weight (ppg)	8.9
600 rpm reading	54
300 rpm reading	40
200 rpm reading	32
100 rpm reading	27
6 rpm reading	18
3 rpm reading	10

4.2. Well Performance using NRDwC system (Well-B)

17.5" vertical hole was drilled 513 ft, 12.25" vertical hole was drilled with 9.625" casing to 4179 ft. Tables 5, 6, and 7 provide BHA, last casing and bit data, and mud properties respectively.

Table 5. Well-B BHA information [6]

Component	Length (ft)	ID (In.)	OD(In.)	Weight (Lb/ft)
9.625 casing	37	8.755	9.625	43.5
Float collar	1	2	9.625	43.5
9.625 casing	37	8.755	9.625	43.5
Float collar	1	2	9.625	43.5
9.625 casing	To surface	8.755	9.625	43.5

Table 6. Well-B Last casing and drillable bit information

Size(In.)	Weight (Lb/ft)	ID (In)	Shoe depth (ft)
13.375”	68	12.415	613
Bit size (In)	Serial No.	Type	Nozzles
12.25	2571519	DPA 8516X	8*11

Table 7. Well-B mud properties

Mud weight (ppg)	10.6
600 rpm reading	80
300 rpm reading	54
200 rpm reading	44
100 rpm reading	32
6 rpm reading	10
3 rpm reading	8

5. Results and discussion

5.1. Wellbore instability

The implementation of NRDwC has completely eliminated the wellbore instability, which means 100% success. This success can be attributed to some explanations: As we inferred from studying the problematic wells which drilled conventionally, wellbore instability only starts after reaching TD during tripping, but NRDwC eliminates the need for tripping and its associated reaming operations. Also increasing shale exposure time will aggravate the instability problem (time-dependent process), by utilizing the NRDwC solution the open hole exposure time has been reduced by the amount of time required for normal tripping operation, troublesome tripping, and time to run casing.

5.2. Suck pipe

The common pack-off stuck pipe incidents during conventional drilling are successfully mitigated with NRDwC by eliminating tripping operation.

5.3. Safety improvement

NRDwC has interestingly improved safety in our drilling operation, by eliminating the hazards associated with tripping operation, handling BHA, and eliminating the usage of casing tong and casing stabber during running with casing. This will eliminate many potential risks like pinch point, struck point, dropped object, and potential for lower back pain during maneuvering drill pipe stands.

5.4. Well control

NRDwC has inherent benefits with regard to well control. Most well control incidents occur during tripping due to losing the annular pressure losses effect and the additional reduction in bottom hole pressure as a consequence of swabbing. With NRDwC, the casing is near the bottom all the time which removes this hazard completely. NRDWC produces a tough and less permeable filter cake due to smear effect which reduces the risk of complete loss, in many cases, the wells kick after losing return. On the other hand, NRDwC has certain cons with well control. In case of a kick, and given the same influx volume in conventional drilling and NRDwC, due to the small annular capacity in the NRDwC, the initial shut-in casing pressure will be higher, the overall annular pressure profile will be higher, and the wait and weight method will have no benefits as the kill mud will exit the bit after the influx circulated out of the annuls.

5.5. Hydraulic comparison using commercial hydraulic software

The maximum allowable circulating pressure, circulating rate, and pump's hydraulic horsepower are limited assets that can be wasted or maximized. Rheology and hydraulics calculations provide the means for adjusting the mud's properties, the flow rate, and the bit nozzles to optimize these assets under the constraints imposed by the rig equipment.

Table 8 and Fig. 6 represent bit hydraulic analysis in conventional drilling, while Table 9 and Fig. 7 represent bit hydraulic analysis in NRDwC.

Table 8. Bit hydraulic analysis in conventional drilling

FR gpm	Total parasitic pressure losses, psi	Max surface pressure, psi	Pressure available at bit, psi	HHP available @ bit	Percent pressure loss @ bit	Pump HHP
350	322.5	1500	1202.5	245.6	80.2	306.3
400	391.4	1500	1138.6	265.71	75.9	350.1
450	467.5	1500	1070.5	281.1	71.4	393.8
500	548.6	1500	998.4	291.2	66.6	437.6
550	634.5	1500	922.5	296.0	61.5	488.3
610	743.31	1500	826.69	294.2	55.1	533.8
650	820	1500	760	288.2	50.7	568.8
700	918.4	1500	673.6	275.1	44.9	612.6
750	1021	1500	584	255.5	38.9	656.4
800	1128.8	1500	491.2	229.3	32.7	700.1
850	1240.6	1500	395.4	196.1	26.4	743.9

Table 9 Bit hydraulic analysis in NRDwC

FR gpm	Total parasitic pressure losses, psi	Max surface pressure, psi	Pressure available at bit, psi	HHP available @ bit	Percent pressure loss @ bit	Pump HHP
350	252.37	1500	1277.63	260.8	85.2	306.3
400	280.34	1500	1255.66	293.0	83.7	350.1
450	311.47	1500	1233.53	323.8	82.2	393.8
500	344.91	1500	1211.09	353.2	80.7	437.6
550	385.43	1500	1184.57	385.6	79.0	488.3
610	422.77	1500	1160.23	412.9	77.3	533.8
650	453.87	1500	1141.13	432.7	76.1	568.8
700	493.329	1500	1116.671	456.0	74.4	612.6
750	533.38	1500	1091.62	477.6	72.8	656.4
800	577.1	1500	1065.9	497.5	71.0	700.1
850	622.52	1500	1039.48	515.4	69.2	743.9

In conventional drilling maximum hydraulic horsepower achieved at bit is 296 hp at a flow rate 550 gpm. On the other hand, hydraulic horse power available at the bit in NRDwC will be 386 hp at the same flow rate with an improvement by 30%.

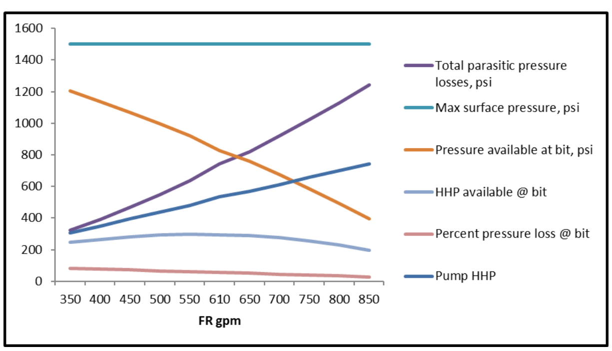

Fig 6. Bit hydraulic analysis in conventional drilling

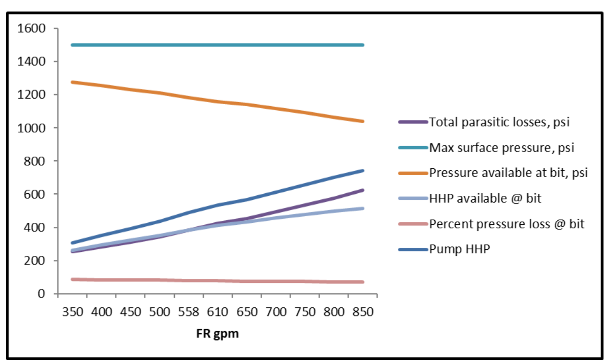

Fig 7. Bit hydraulic analysis in NRDwC

Drilling hydraulics is one of the most influential factors in drilling efficiency. Penetration rate can be significantly improved by hydraulic optimization. Drilling with casing technique is a viable option toward optimized drilling hydraulics by taking the maximum advantage of pump's horsepower, this is accomplished by reducing parasitic energy loss owing to friction in the drill string and utilized this saved energy to enhance bit hydraulic. By using actual field data to calculate pressure profile, in conventional drilling (Table 10 and Fig. 8) with circulating at 610 gpm the circulating pressure is 1549 psi, 40% of it will be used in drill string (617 psi) as frictional losses. On the other hand, the annular pressure losses will be only 4.2% (66 psi). On NRDwC (Table 11 and Fig. 9) at circulation rate 550 gpm the circulating pressure is 865 psi, drill string frictional pressure losses are 111 psi (12.8%), while annular pressure losses are 204 psi (23.5%). The percentage of parasitic pressure losses in NRDwC is lower than those experienced during conventional drilling which increases the available hydraulic horsepower at the bit. Also, the annular pressure losses in NRDwC are higher than the drill string pressure losses.

Table 10. Circulating pressure profile in conventional drilling

Depth, ft	Drill string pressure, psi	Annulus Pressure, psi
0	1549.2	
3367.6	2869.4	
3826.7	2938.6	
3916.7	2943.4	
4400	2968.89	
0		0.00
722		341.3
3826.7		1815.2
3916.7		1858.1
4400		2093.0

Table 11. Circulating pressure profile in NRDwC

Depth, ft	Drill string pressure, psi	Annulus pressure, psi
0	865.0	
4103	3076.6	
4104	3047.0	
4141	3065.9	
4142	3035.2	
4179	3055.1	
0		0
613		362.5
4179		2505.6

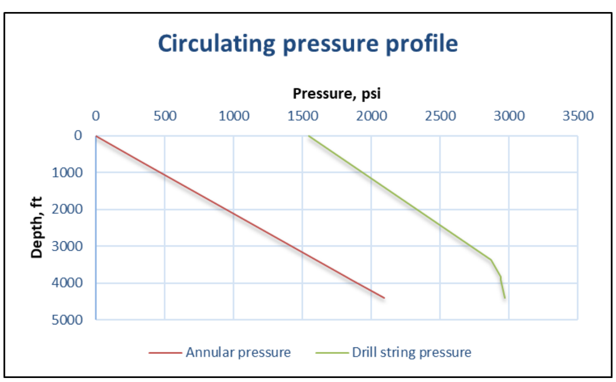

Fig 8. Circulating pressure profile in conventional drilling.

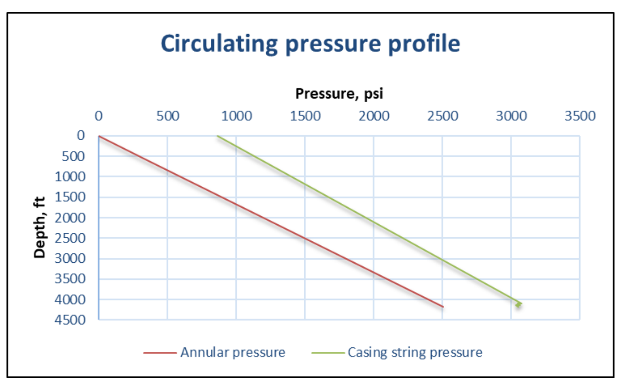

Fig 9. Circulating pressure profile in NRDwC.

Hole cleaning is achieved easier in NRDwC than in conventional drilling due to the higher annular velocity, from Table 12 and Fig. 10, there is about 110% increase in minimum annular velocity at the same flow rate. It is expected that APL will be higher in NRDwC at the same flow rate due to the higher annular velocity, this increase in APL ranges from 220% at 850 gpm to 370 % at 350 gpm. Despite the increase in APL in NRDwC, there is no increase in losses reported while drilling, possibly due to the claimed smear effect. It is thought that the composite effect of higher annular velocity, the proximity of casing to the formation face during casing rotation will lead to smooth contact between casing and wellbore, and cuttings being forced and crushed into the formation face with the consequence of producing tough, strong, and less permeable filter cake. This means that cuttings will be used as LCM and reduce losses into the formation.

Table 12. AV & APL in conventional drilling and NRDwC.

FR, gpm	Conventional drilling AVmin, ft/min	DwC AVmin, ft/min	Conventional drilling APL, psi	DwC APL, psi
350	65.84	139.3	33.4	156.78
400	75.24	159.24	37.5	169.1
450	84.6	179.14	41.9	180.78
500	94.06	199.05	46.36	191.9
558	104.97	222.14	51.7	204.21
610	114.75	242.84	56.64	214.79
650	122.28	258.76	60.54	222.76
700	131.68	278.67	65.52	232.21
750	141.09	298.57	70.63	241.47
800	150.49	318.48	75.85	250.47
850	160.09	338.38	81.2	259.22

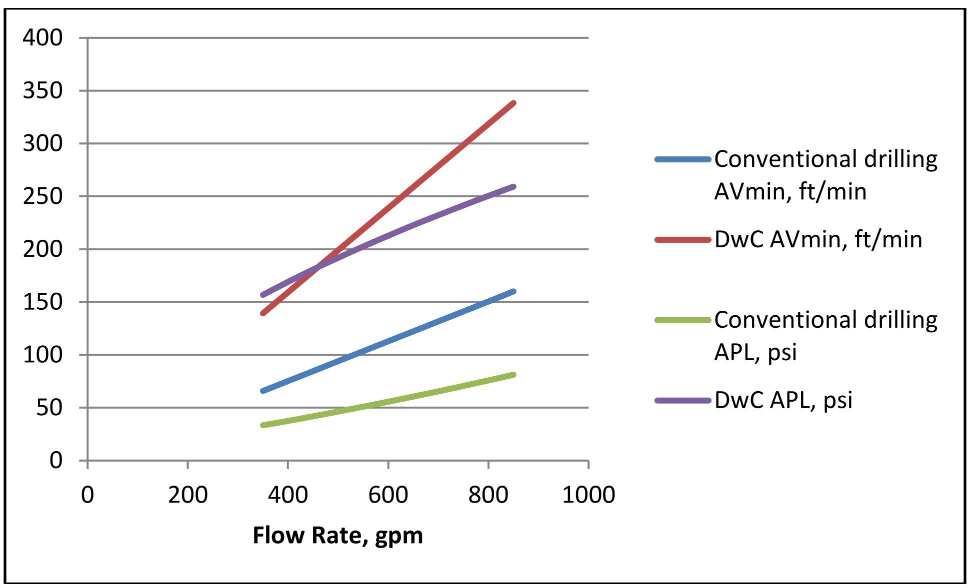

Fig 10. AV and APL in conventional drilling and NRDwC

It is supposed also that the plastering effect will strengthen the wellbore by increasing the fracture gradient of the formation near the wellbore **[14].**

In addition, drilling with partial losses can be continued easier in NRDwC than in the case of conventional drilling due to the smaller annular volume in NRDwC which permits minimizing the flow rate while maintaining suitable annular velocity to clean the hole and easier filling to the backside by trip tank pump if required **[14]**.

5.6. Cost comparison

As shown in Table 13 and Figs. 11 &12, The application of NRDwC technique in QPC has proven to be a cost-effective way to mitigate the wellbore instability problem in the clastic deposit, 110178 us dollars direct cost saving has been achieved, also indirect cost savings are recorded by achieving 4.5 days reduction in drilling time which permits early delivering of the well to production.

Table 13. NRDwC and Conventional drilling cost comparison

Depth	NRDwC		Depth	Conventional	
	DwC days	DwC cost		Conventional days	Conventional cost
0	0	0	0	0	0
613	1.75	$ 199,213.71	722	1.9	$ 205,907.74
4179	6.75	$ 484,703.25	4400	11.3	$ 594,881.74
Difference in favor of NRDwC			4.55 Days	110,178.49 USD	

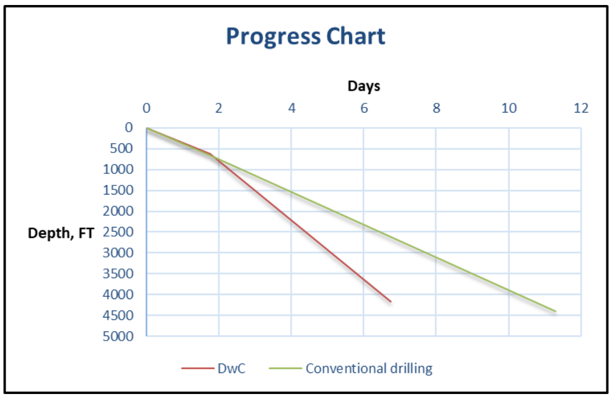

Fig 11. Progress chart comparison

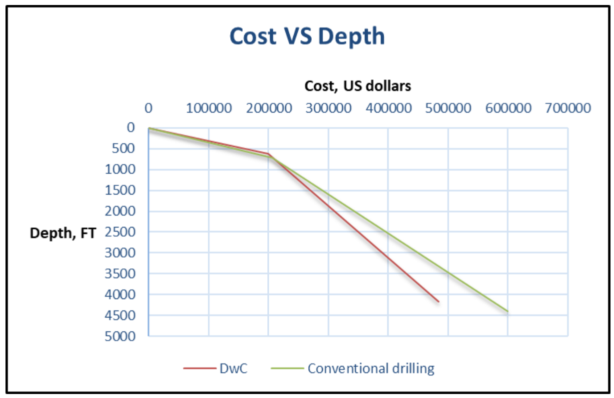

Fig 12. Cost vs. depth chart comparison

6. Conclusions

The drilling industry is on a relentless endeavor to improve drilling efficiency based on three basic criteria, maximum safety, minimum cost, and drilling a usable hole. NRDwC technique satisfies these criteria. NRDwC technique should be considered in all QPC fields even those without major drilling problems, as the technique adds to the safety of the rig operation, especially if the hydraulic pipe handler is integrated into the operation.

Application of the directional RDWC is now understudying by QPC drilling team to be implemented in wells that require directional work in 12-1/4" hole.

Acknowledgment

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Nomenclature

APL = Annular pressure losses.
AV = Annular velocity.
BHA = Bottom Hole Assembly.
BTM = Bottom.
CD = Casing drilling.
CDS = Casing drive system.
CWD = Casing while drilling.
DwC = Drilling with casing.
DwL = Drilling with liner.
FV = Funnel viscosity.
HHP = Hydraulic horse power.
KOP = Kick off point.
LCM= loss of circulation materials.
LD = liner drilling.
MBT = Methylene blue test.
MD = Measured depth.
NRDwC = Non- retrievable drilling with casing.
NPT = Nonproductive time.
POOH = Pull out of hole.
PPF = pound per foot.
PPG = Pound per gallon.
PSI = Pound per square inch.
PV = Plastic viscosity.
QPC = Qarun Petroleum Company.
RDWC = Retrievable drilling with casing.
RIH = Run in hole.
ROP = Rate of penetration.
TD = Total depth.
TDS = Top drive system
TRS = Tubular running service.
TVD = True vertical depth.
WL = API water loss.

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