

Water Base Mud (WBM): An appropriate choice in Caspian Sea deep water wells - A case study: Sardar Jangal Field

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Abstract

Deepwater drilling is a complex and costly undertaking. The issues and problems are unique and require careful planning and consideration. Caspian Sea is one of the well-known region where consist huge reserves of Oil & Gas deposits and Iran has attempted to explore Oil & Gas from the southern area of this vast reservoir since 50 years ago. Drilling operations were performed by KEPCO in Sardar Jangal field where is located in very high depth water region of the Caspian Sea. With consider to complexities of the formations structure in this area a proper design of drilling fluids is key parameter to achieve a successful drilling operation, therefore MI Services developed a comprehensive drilling fluids program including different options and alternatives to meet desired targets in accordance with the well conditions. Basically SOBM is being used to drill holes in closed circulation system in the Caspian Sea, however considering several reasons/restrictions such as Costs, Logistics, Environments and Sanctions both MIS and KEPCO agreed to utilize WBM in this field. Based on the results, obtained through drilling the wells SRJ-X1F and SRJ-X2C, High-performance water base mud is able to optimize hole cleaning, borehole stability and the inhibition of unstable formations with minimum cost (20% of SOBM cost).

Keywords: Deep Water Drilling , Drilling Fluids , Water Base Mud , Synthetic Oil Base Mud , M-I Services Company , Khazar Exploration and Production Company

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1. Introduction

1.1. Geographical Information

The Caspian Sea is the largest enclosed inland body of water on Earth by area, variously classed as the world's largest lake or a full-fledged sea. (fig 1) The sea has a surface area of 371,000 km² and a volume of 78,200 km³. It is in an endorheic basin (it has no outflows) and located between Europe and Asia. It is bounded to the northeast by Kazakhstan, to the northwest by Russia, to the west by Azerbaijan, to the south by Iran, and to the southeast by Turkmenistan. The Caspian Sea lies to the east of the Caucasus Mountains and to the west of the vast steppe of Central Asia. Its northern part, the Caspian Depression, is one of the lowest points on earth. The ancient inhabitants of its coast perceived the Caspian Sea as an ocean, probably because of its saltiness and seeming boundlessness. It has a salinity of approximately 1.2% (12 g/l), about a third of the salinity of most seawater.



Fig1: Southern Caspian Sea

1.2. Oil/Gas History of Caspian Sea

U.S. Energy Information Administration (EIA) estimates 48 billion barrels of oil and 292 trillion cubic feet of natural gas in proved and probable reserves in the Caspian basins. Almost 75 percent of oil and 67 percent of natural gas reserves are located within 100 miles of the coast. Territorial disputes and limited exploration in offshore areas make it difficult to determine the total amount of hydrocarbon resources. Using field-level data, EIA estimates 48 billion barrels of oil and 292 trillion cubic feet of natural gas in proved and probable reserves in the wider Caspian basins area, both from onshore and offshore fields. Because the reserve figures include both proved and probable reserves, the figures are closer to a high-end estimate.(fig 2)

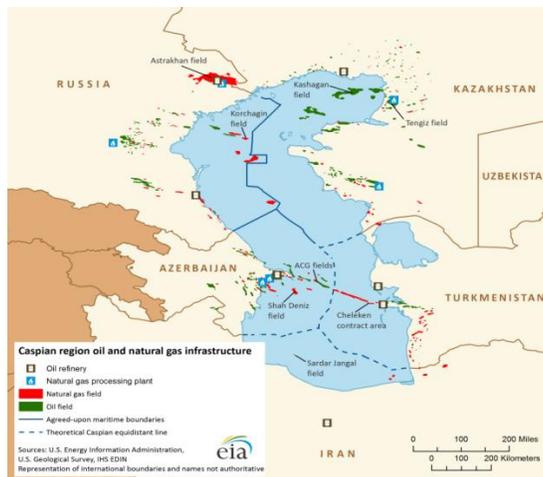


Fig2: Caspian Sea Oil/Gas Map

1.3. Oil/Gas History of Southern Caspian Sea (Iran portion)

The initial investigations & studies in southern Caspian Sea basin were begun about 50 years back when 2D Seismic studies were performed across 11200 km of Caspian Sea shore area inside Iran, meanwhile 16 cat wells were drilled at the particular locations in this area by National Iranian Oil Company(NIOC). A semisubmersible rig (Amir Kabir) as well as other required facilities such as 3 ports, logistics bases,... were built during 1990 - 2000. The type of rig Amir Kabir is GVA 4000 and can operate at 1000 m depth of water according to GVA’s specification data.

With consider to Iran dramatic leeway (Fig3) to explore and produce Oil/Gas reserves particularly in shared/common fields, Khazar Exploration and Production Company (KEPCO) has been established on 1998 in order to speed up Caspian Sea operations as an individual oil company. This company is one of the five major branches of NIOC in upstream Oil&Gas industry that is responsible for explore, develop and produce hydrocarbon reservoirs in Iran section of Caspian basin including offshore and onshore regions where are lied in three provinces of northern of Iran territory.

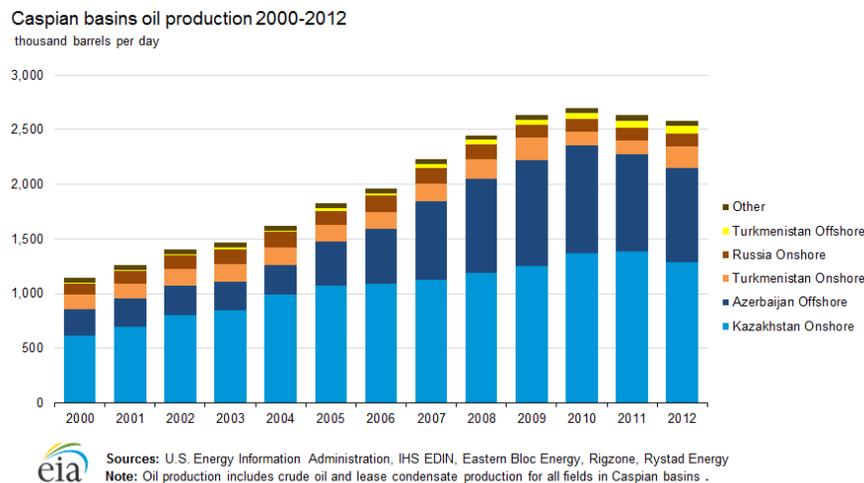


Fig3: Caspian Basin Oil Production 2000-2012

1.3.1. Sardar Jangal Field

Sardar Jangal field is located in the Southern part of the Caspian Sea, approximately 170 km North of Nowshahr city in Iran. The South Caspian region represents a great depression, where the sedimentary deposits reach to 20 – 25 km thick. The expected reservoir is located in the Cheleken Series, Sequence that is believed to represent the Upper Pliocene. Water depth varies from likely range for seawater surface temperatures is between 27° C and 6° C. Temperatures at mid water depth range from 7.3° C to 6° C and temperatures at mudline range from 7° C to 5° C. The Expected reservoir temperature is about 110° C.

The first Oil was flowed by KEPCO where well SRJ-X1F reached Oil layer at 2584m BRT on April 2012. Well SRJ-X2C was the second well that reached Oil reservoir at Cheleken reservoirs recently. Based on the experiences obtained during 6 years drilling operations in this field, there are very problematic challenges for drilling operations in this field due to mainly geological restrictions e.g. unconsolidated formations, severe influxes, mud volcano, ... that have pushed operations to revise the initial programs several times with accordance to hole condition.

2. Drilling fluids Solutions in Sardar Jangal field

With regard to the special conditions of drilling operations in southern Caspian Sea region in terms of water depth, formations complexities, environmental restrictions, etc. drilling fluids related requirements such as fluids design, drilling waste management, and logistics preparations were key parameter to succeed drilling operations in this field.

M-I Services Ltd. developed two types of drilling fluids plan/scenario in order to meet desired targets with accordance to the mentioned limitations. In order to comply above needs comprehensive facilities/supports were dedicated in three divisions inside the KEPCO's Base in Neka. These facilities/supports include a 1500 m² open area and 2x1000 m² covered areas to store required products and equipment as warehouse, 9 pressure vessels (Silos) as well as two cutting bottles with total capacity of 350 m³ and totally 29 liquid storage tanks with total capacity of 14000 bbls Fluids including 2 mixing tanks and relevant equipment. These facilities are available to be utilized for any upcoming project. (Fig4)



Fig 4: Ware House; Bulk Plant and Mud Plant of MIS base in Neka

MIS Company as drilling fluids and waste management Service Company has planned to have both types of mud system (WBM & SOBM) with accordance to well condition in this project as following:

2.1. SOB^M: The Conventional mud program in South West of Caspian Sea region

Based on the initial drilling programs which are being followed in the south west of Caspian Sea the conventional mud type is mostly Synthetic Oil Base Mud (SOBM) in this region where riser gets installed while drilling holes below 20" casing size as a closed system.

In order to meet desired SOB^M related specification unique mud system was developed by using the best available products and several experimental lab tests. The main additives in oil phase of this system are mentioned in table 1:

Table 1: Additives in oil phase of SOB^M

Product	Function
EDC 99 DW	Deep Water Base Oil
MI EMUL P-DW	Primary Emulsifier
MI EMUL S-DW	Secondary Emulsifier and Oil Wetting agent
MIOVIS DW	Viscosifier
MI FL DW EU	Fluid Loss Reducer
HRP	Secondary Viscosifier

The descriptions of products in table 1 are as below:

2.1.1 EDC 99 DW

EDC 99 DW is specialized base oil designed for drilling wells in deep water. When utilized with the new products provide a fluid that exhibits superior rheological properties and enhanced chemical properties as separately described in the following chemical descriptions. The base oil has a lower viscosity, lower pour point, lower aromatic content than other base oils.

2.1.2 MI EMUL P DW & MI EMUL S-DW

The primary and secondary emulsifiers have been designed to work synergistically with the base oil and produce a highly stable invert emulsion fluid with excellent emulsion stability, preferential wetting of solids by the continuous oil phase, filtration control and temperature stability. They are extremely effective over a wide range of oil/water ratios and mud weights.

2.1.3 MI FL DW-EU

MI FL DW EU has been specially designed to complement the emulsifiers and provide a tight HTHP fluid-loss control at low concentrations, with a very low and water free filtrate.

2.1.4 MI OVIS-DW

MI OVIS DW is an organoclay that increase the yield point and mud viscosity, improves the carrying capacity and suspension properties of the oil based fluid, and provides a gel structure to avoid the settling of the weighting material.

2.1.5 HRP

HRP is a gellant that provides an elevated yield point and gel strength with a minimal increase in the plastic viscosity of the fluid. It can be used for an immediate aid in hole cleaning, not requiring the time, temperature and shear the organoclays require. It has proved effective when used in sweeps in directional or horizontal wells, and for gelling freshly prepared mud's being sent to the well site. It can provide immediate rheology for a freshly mixed fluid that would otherwise require time and shear to provide the necessary viscosity. Time and shear can be used to later thin the fluid as the organoclays start to yield. It is a versatile additive which works in conjunction with the organoclays and can be used to minimize the amount of clay in a particular formulation.

Based on the several lab tests, conducted in an equipped drilling fluids laboratory the best recipe was designed in case of need for SOBM.

2.2 WBM: An alternative mud system

In order to illustrate WBM benefits with compare to OBM, it is necessary to describe OBM applications in drilling operations. Basically OBM is being utilized in those holes where below situations exist:

- Very unstable shale layers.
- Wells with high drag/torque friction forces.
- Very sensitive formations (reservoirs) that WBM causes irreparable damage to production zone.

With consider to the recent progress in WBM technology, various high-Tech systems have been widely developed in the world as these types of WBM are capable to cover unique functions of OBM in particular areas. Some of these types of fluids/additives are as following:

- Inhibitive products/additives to prevent shale swelling such as: potassium Chloride ; Glycol ; Polly Anionic Cellulose (PACs)
- Lubricant/Detergent products such as Radia green and Drilling Detergent.
- Advanced Polymers to minimize formation(reservoir) damage as Drill-In Fluids systems such as Driplex, Floplex, Dipro, ...

Due to below four significant reasons, KEPCO and M-I Services have agreed to use WBM for drilling wells in Sardar Jangal field.

2.2.1 Excessive cost of SOBMs

Obviously the cost of SOBMs related materials/additives are higher than WBM. This fact will be more highlighted when drilling operations get performed into formations/layers with the high risk of mud loss and influx that would result in consuming huge volume of mud in order to maintain mud properties within the desired ranges.

2.2.2 Preparations/Logistics limitations

Preparations and transportation of SOBMs is very time consuming process that require an adequate schedule in terms of mud plant mixing/storage program and also shipment related coordination of required mud volume to the rig site in different status of weather condition.

2.2.3 Environmental concerns

Awareness of the environment among the public, regulatory agencies, customers and service companies has made environmental concerns a key factor in drilling operations. Environmental issues are broad-based and complex, influencing all aspects of drilling fluid system design and use. Health, Safety and Environmental (HS&E) regulations overlap to some degree, but they consider the issues from different perspectives. Health and safety issues deal primarily with worker protection, while environmental issues deal with any impact to the environment and/or the health of the community exposed to the effects of drilling operations. Preventing pollution and minimizing environmental impact in a cost-effective way are the foremost tasks confronting the industry today. Like all chemicals, SOBMs can be health hazards if handled improperly. The synthetic liquids used to make SOBMs are less toxic and less irritating than the oils used in oil-base muds. However, SOBMs are difficult to remove from the skin, and contain some irritating chemicals such as calcium chloride and lime. This means that SOBMs can be quite irritating to the skin and eyes if certain precautions are not taken. Likewise, mist and vapor from SOBMs, especially in the area around the shakers, can be irritating to the respiratory system. In addition, environmental impacts related to this type of drilling fluids would be great concern particularly while working in such sensitive area (Caspian Sea) where there is no connection to the free waters on the earth.

2.2.4 Sanctions restrictions

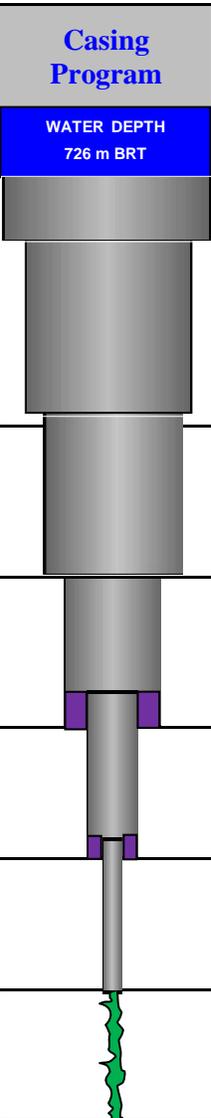
Apart from all common restrictions and issues with conjunction to SOBMs utilization, embargo is another major unusual limitation for using this type of mud in Iran which has been conditioned against Iran Oil & Gas industries strictly. Since most part of SOBMs products for deep water operations being imported from abroad, these sanctions have got significant negative effect to provide SOBMs for Caspian Sea operations.

With respect to the above justifications and based on the previous practical experiences / lesson learnt, obtained during more than 6 years involvement in Caspian Sea project, MIS designed a simple and economic type of WBM to overcome the relevant problems. The key point to successfully apply this system is a closed monitoring of well conditions in order to take required action to change and modify mud properties with accordance to drilling operations.

3. SRJ-X2C Operations

Well SRJ-X2C was vertically drilled to the total depth (TD) at 3488m by using WBM successfully. The well schematic is shown in table 2. The mud operations, employed whilst drilling this well are briefly described as interval discussions.

Table 2: Well Schematic of SRJ-X2C

Hole Size (in)	Casing Size (in)	Casing Program	Formation	Mud System
36"	30"	 WATER DEPTH 726 m BRT	<u>SC800</u> New Caspian Deposits. <u>SC700</u>	Sea Water/ PHB Sweeps
26"	20"		<u>SC700</u> Khvalynian;Khazarian; Bakunian; <u>SC600</u> Apsheronian	Sea Water/PHB Sweeps
21" x 17 ½"	13 3/8"		<u>SC600</u> Apsheronian <u>SC500</u> Akchagyl stage	PHB & Salt / KCl / Polymer mud
14 ¾" x 12 ¼"	9 5/8"		<u>SC400</u> Upper Cheleken Series <u>SC300</u> Middle Cheleken Series	Salt / KCl / Polymer mud
8 ½"	7" Liner		<u>SC300</u> Middle Cheleken Series	Salt / KCl / Polymer mud
5 7/8"	5" Liner		<u>SC300</u> Deeper Cheleken Series	Salt / KCl / Polymer mud
4 1/8"	Open Hole		<u>SC300</u> Deep Cheleken Series	Salt / KCl / Polymer mud

3.1 Holes: 36" & 26"

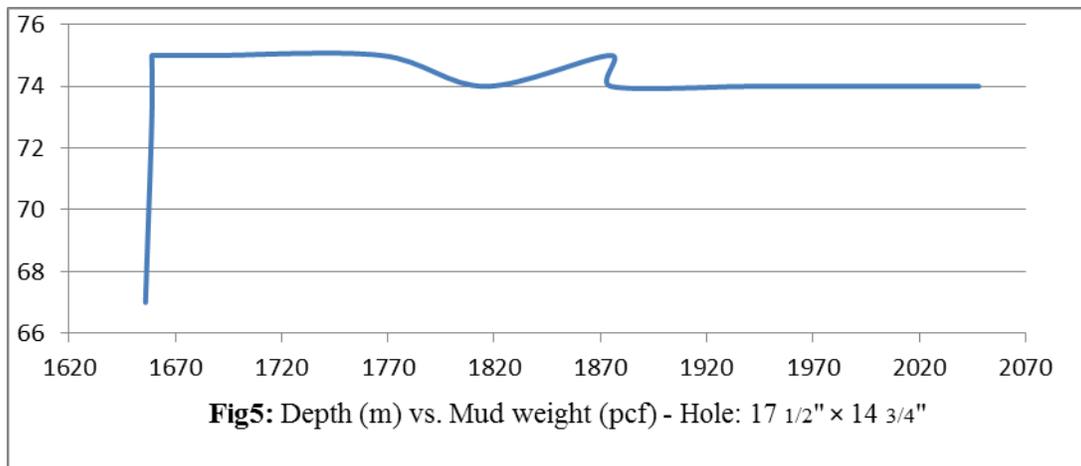
These two hole sizes (top holes) were drilled without mud return as riserless from sea bed to 1190m where 20" casing was set. The conventional type of drilling fluids in these sections are Prehydrated Bentonite(PHG) sweeps followed by inhibitive spot muds prior tripping and Casing running operations in order to minimize tight spots and influxes. This method are being used in all similar wells operations in Caspian Sea.

3.2 Hole: 21"×17 1/2"

Initially this section was drilled with 17.5" bit from 1190m to 1660m then the interval was enlarged with 21" under reamer to facilitate running 16" liner. With consider to the nature of deep water operations in terms of lithology complex (sever loss and gain problems) and mud temperature, combination of the same mud system, used for drilling open hole and KCl/Salt/Polymer mud was applied for drilling this section.

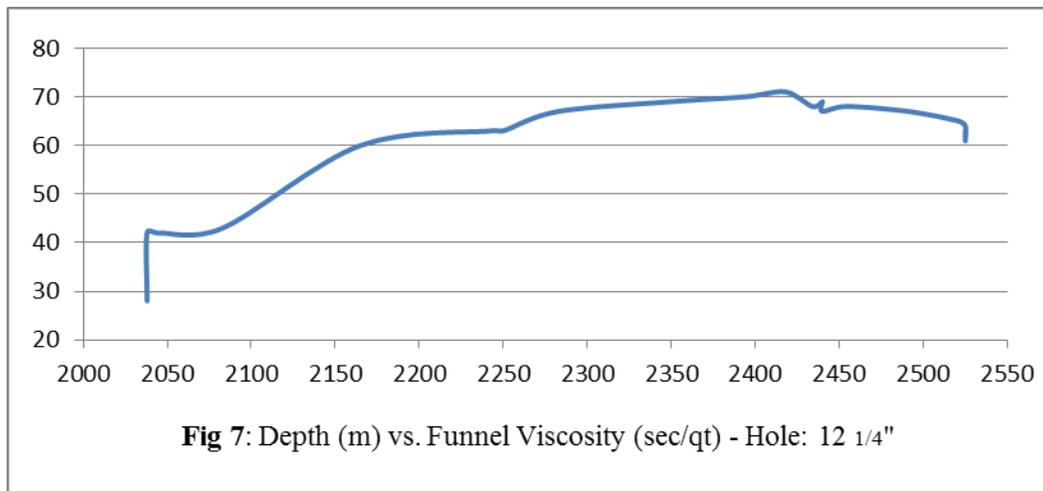
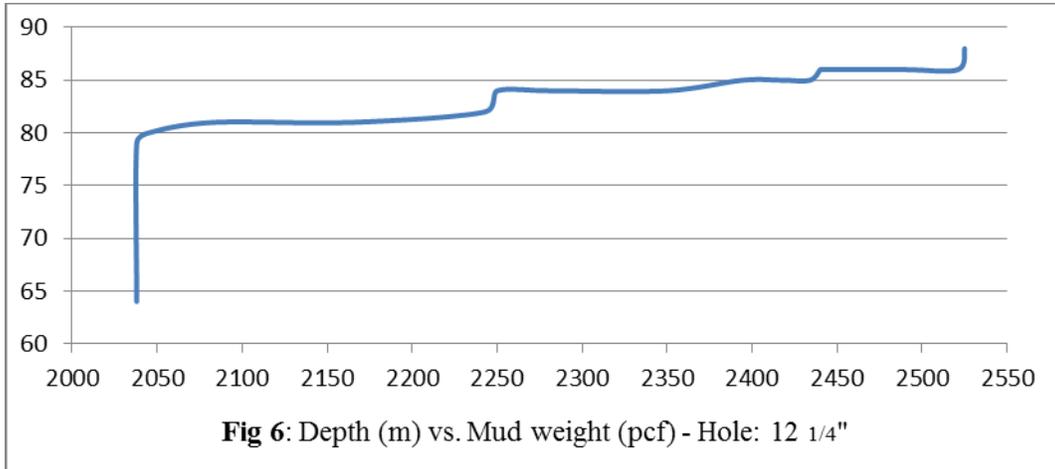
3.3 Hole: 17 1/2"×14 3/4"

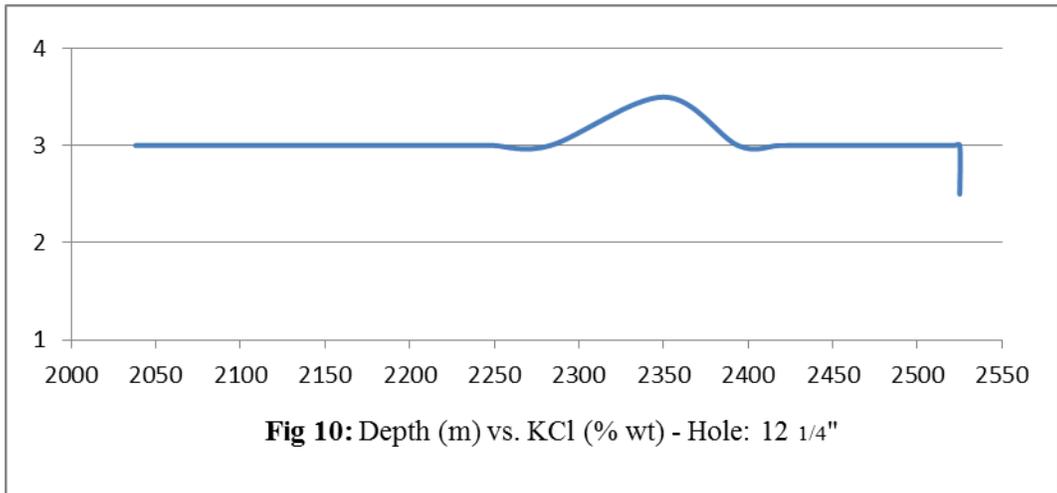
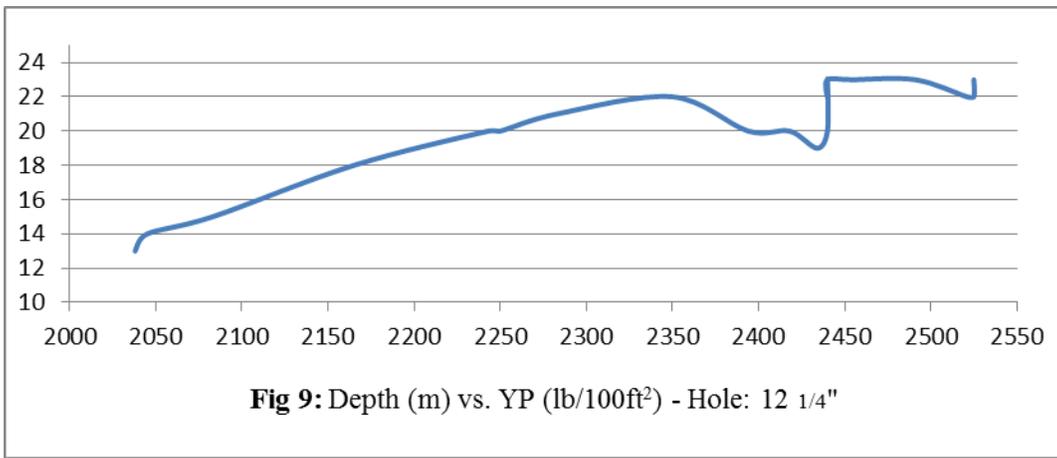
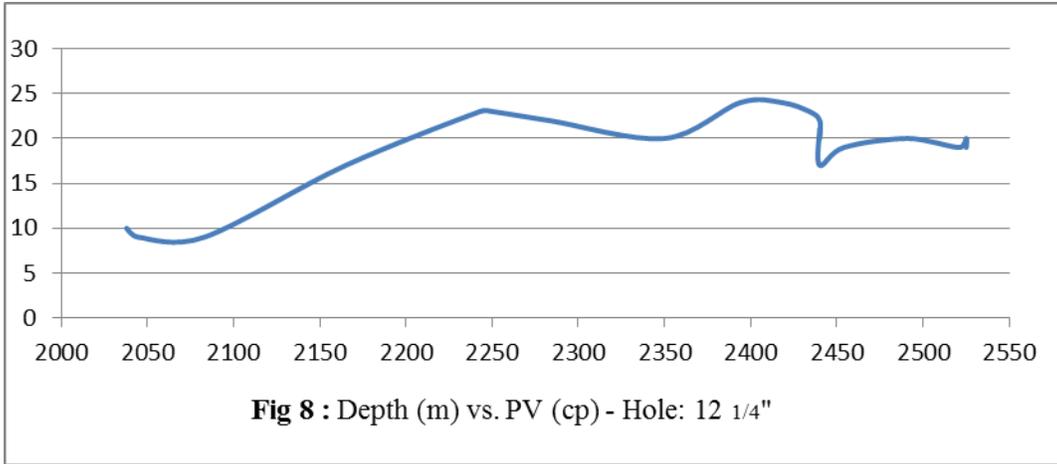
This section was drilled with 14 3/4" bit from 1660m to 2048m then the interval was enlarged with 17.5" reamer prior running 13 3/8" casing pipes. The same mud scenario that was used for drilling previous section, utilized to drill this interval too.

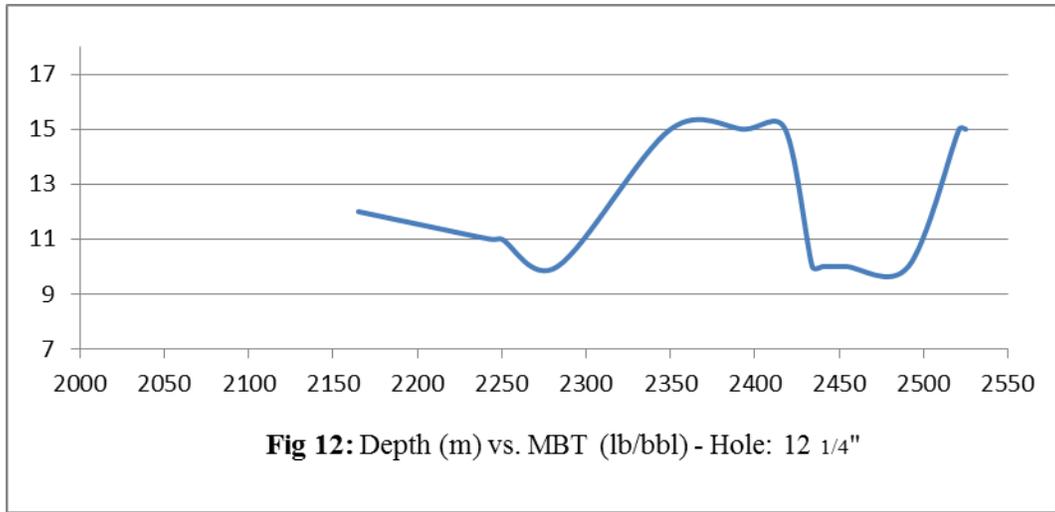
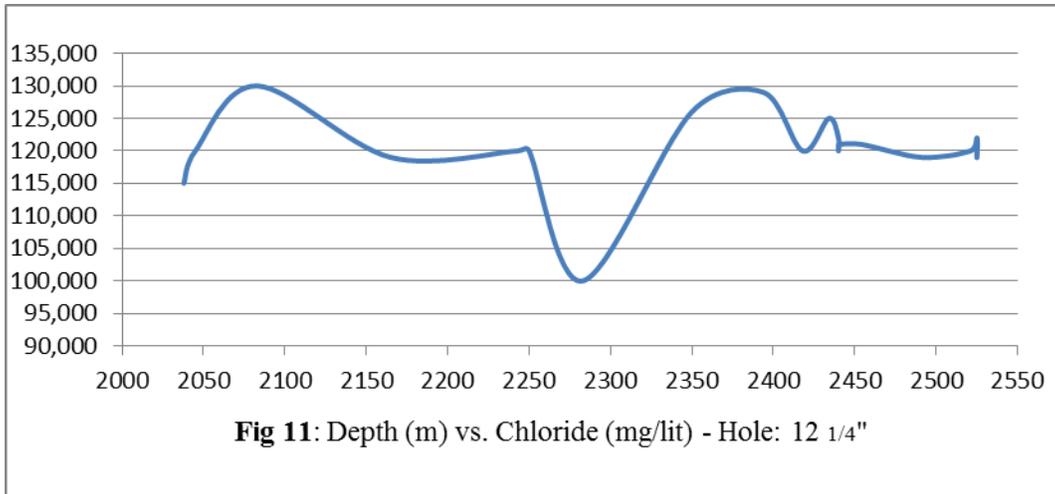


3.4 Hole: 12 1/4"

This section was drilled with 12 1/4" bit from 2048m to 2525m where the hole was cased off with 9 7/8" casing size. KCl/Salt/Polymer mud system was used in this interval too.

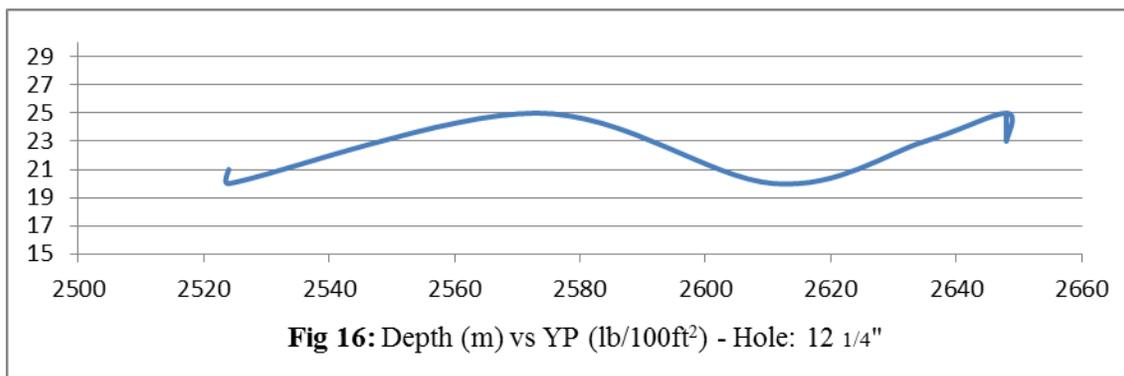
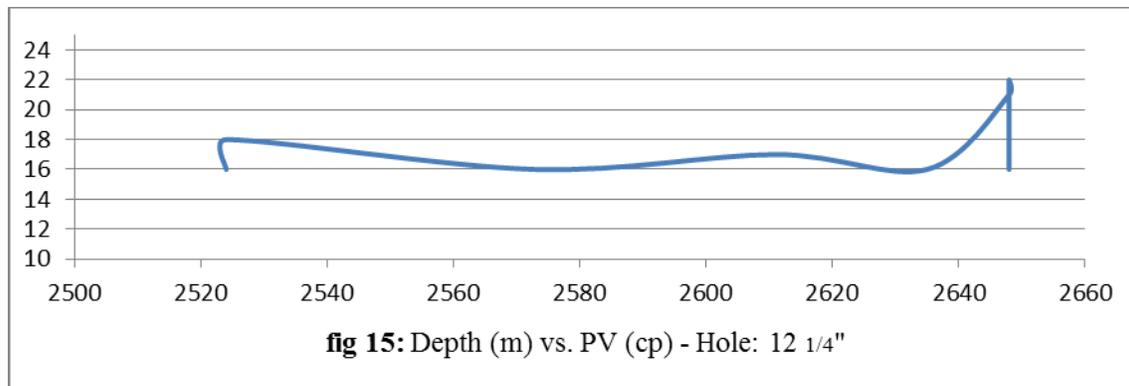
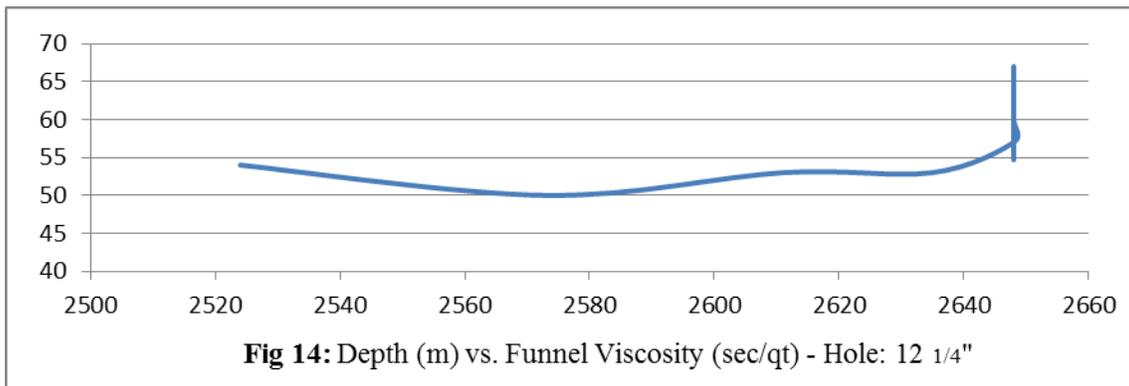
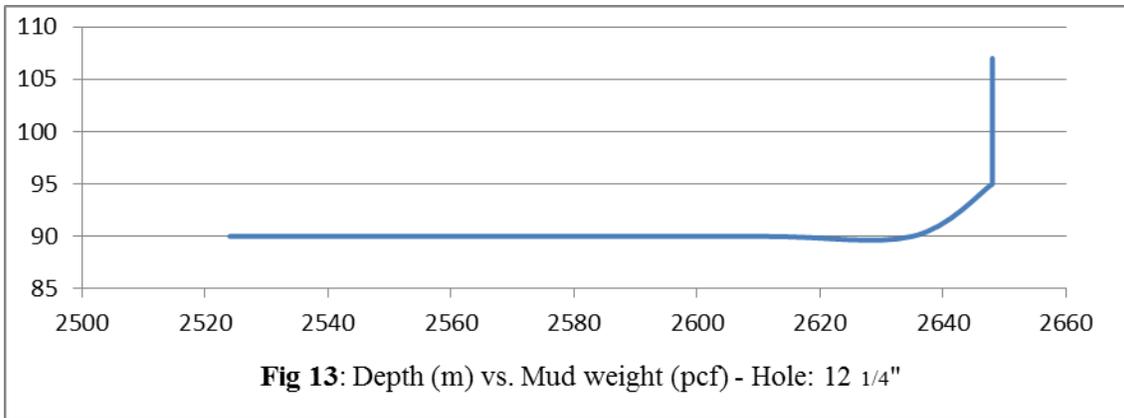


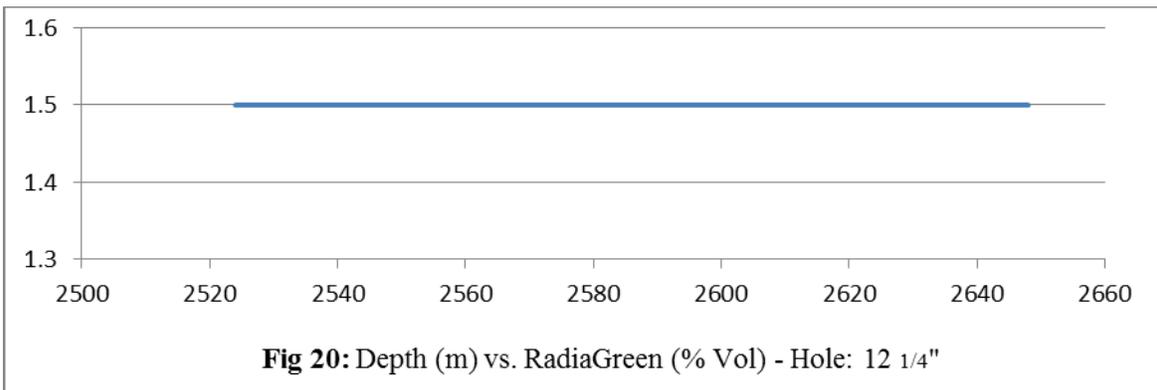
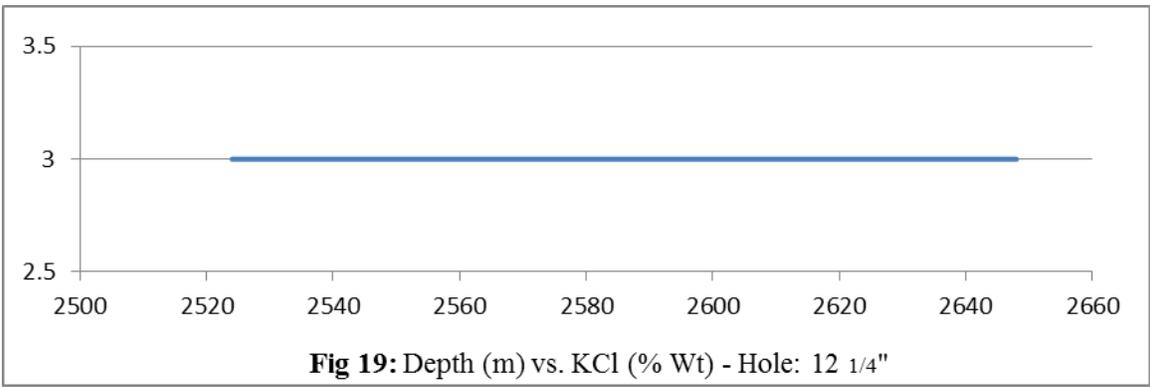
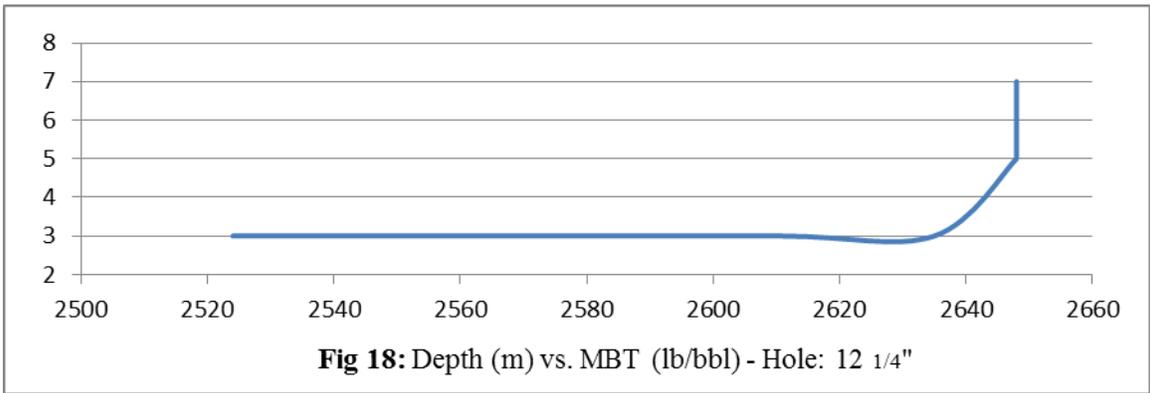
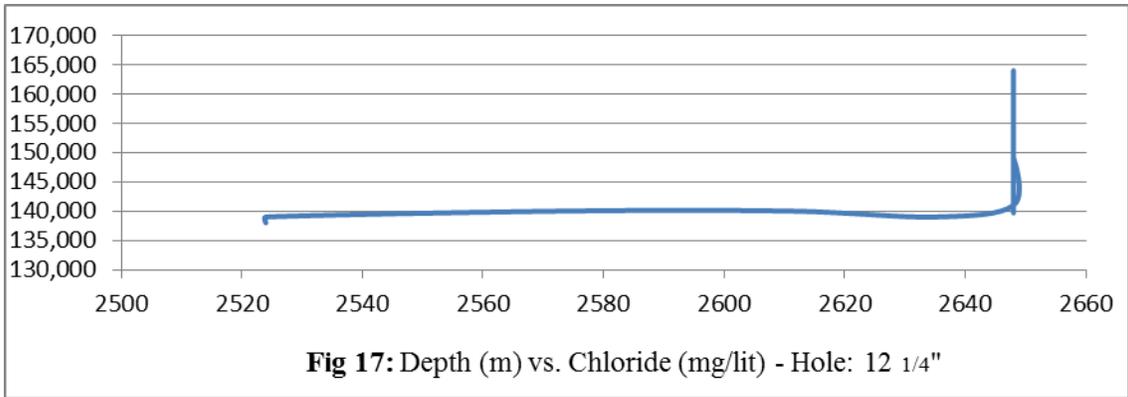




3.5 Hole: 8 1/2"

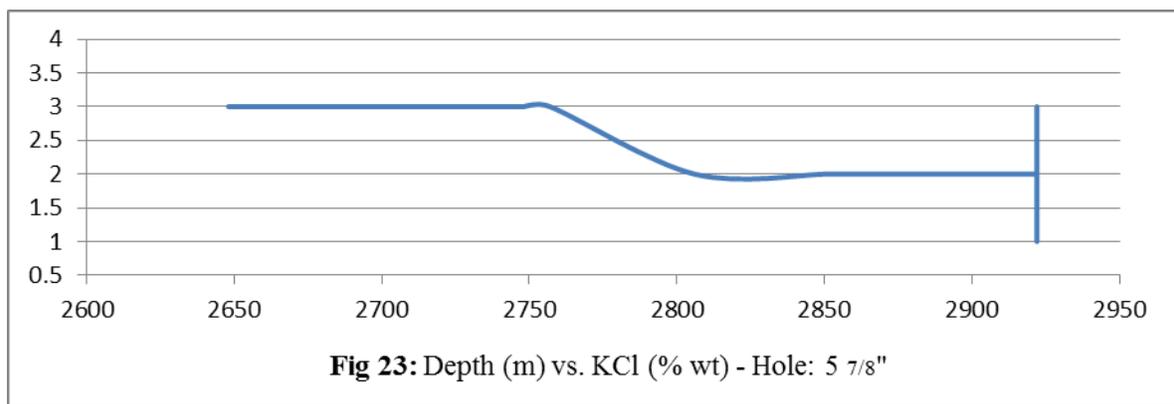
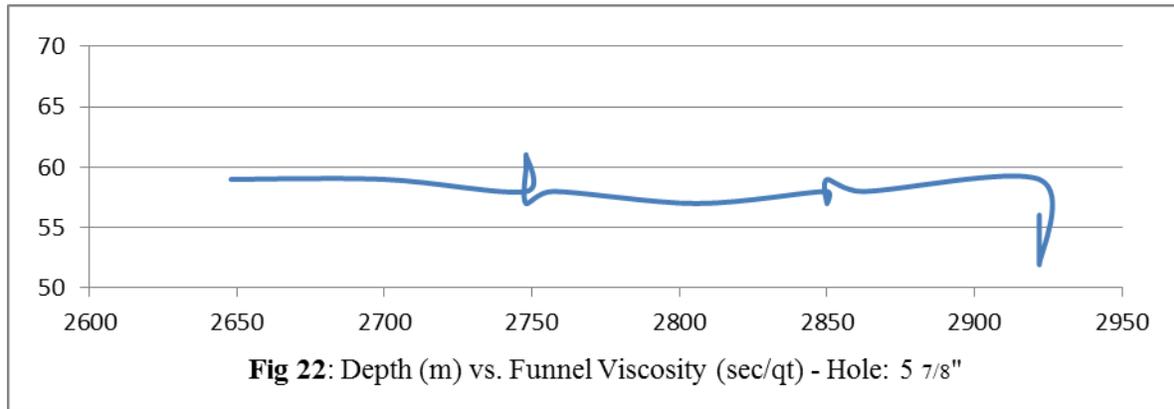
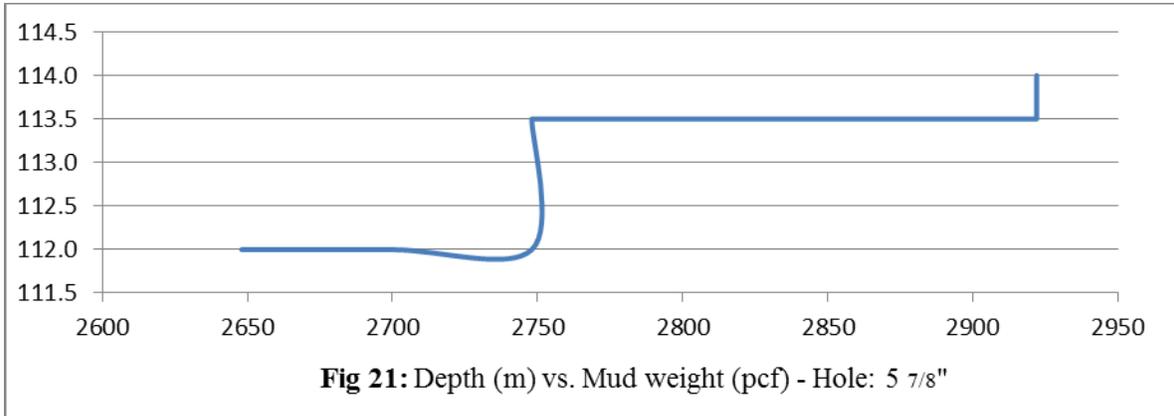
Initially this section was drilled with KCl/Salt/Polymer system from the 9 7/8" casing shoe to 2664m where the hole got packed off at 2606m. Despite of several attempts to release pipe stuck, no success was achieved therefore decided to back off drill string at 2505m in order to perform fish cementing then side track operations was done from 2334m to 2648m. At the end of drilling operations, 7" liner was set and got cemented eventually. A new lubricant product (Radia Green) was introduced to mud system to reduce torque & drag forces while 8.5" hole side tracking operations as an effective lubricant in WBM. This product meets required environmental standards as well.

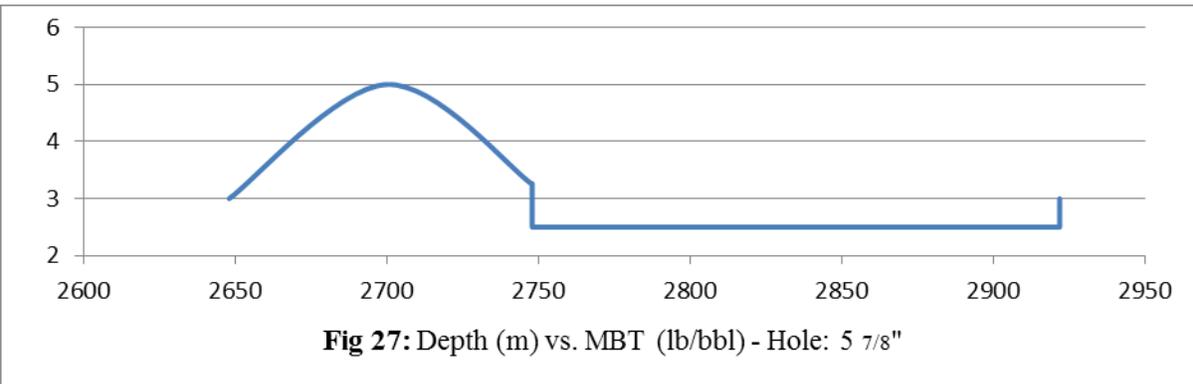
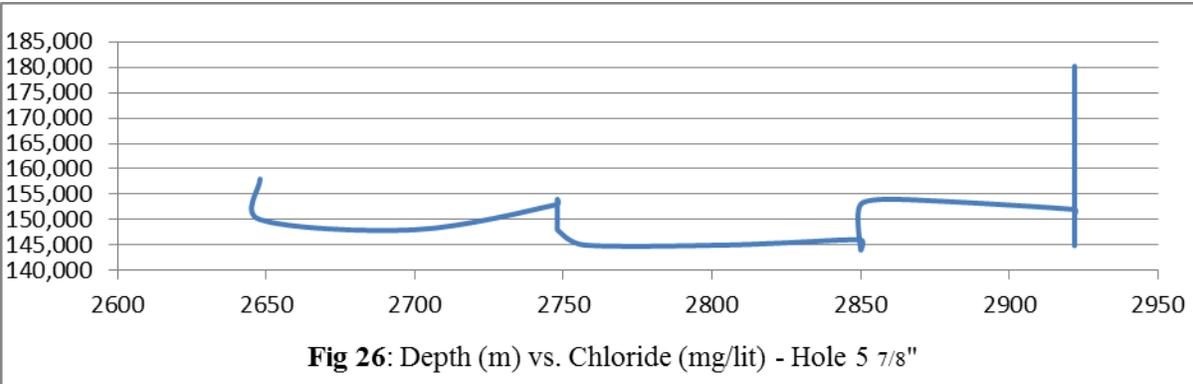
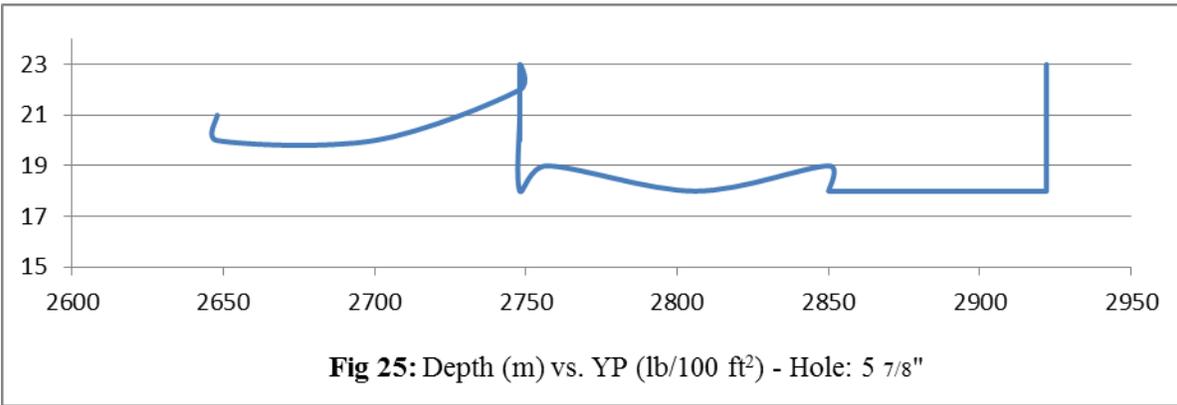
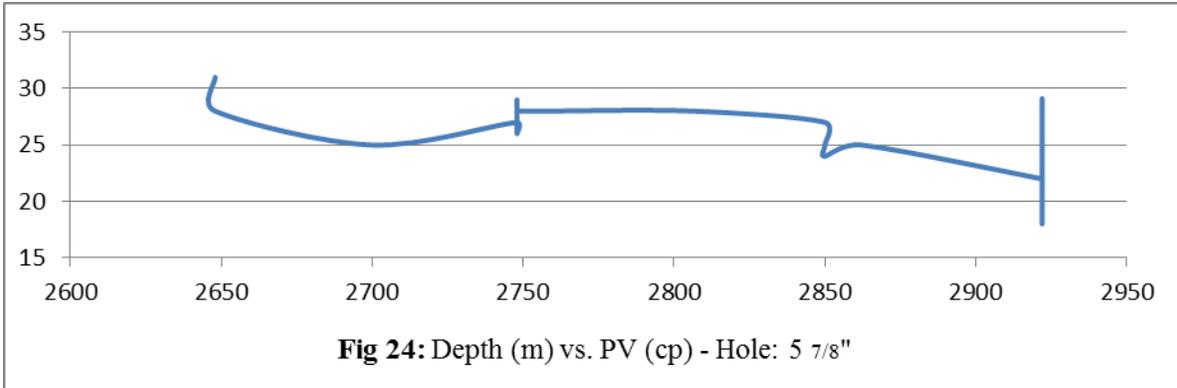


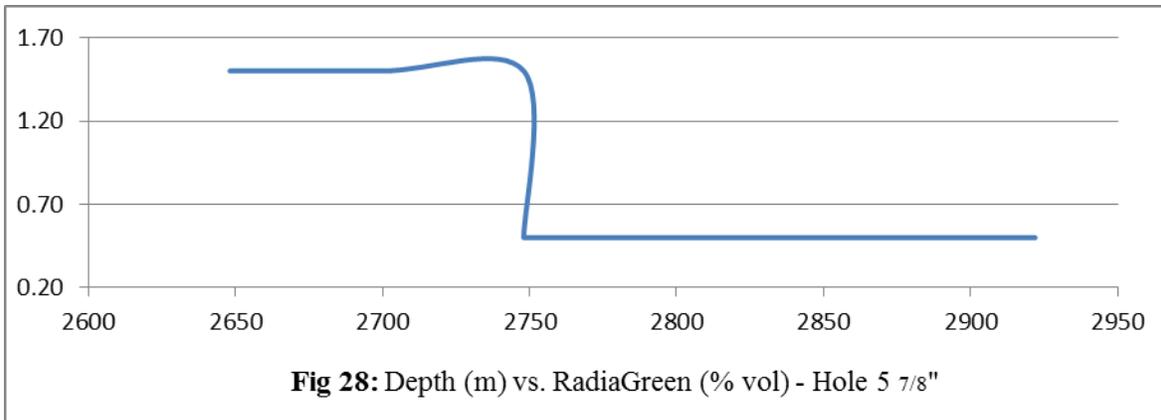


3.6 Hole: 5 7/8"

The 5 7/8" interval was drilled from 2643m to 2924m, using the same mud system of 8 1/2" hole. The 5" liner was set at 2925m.

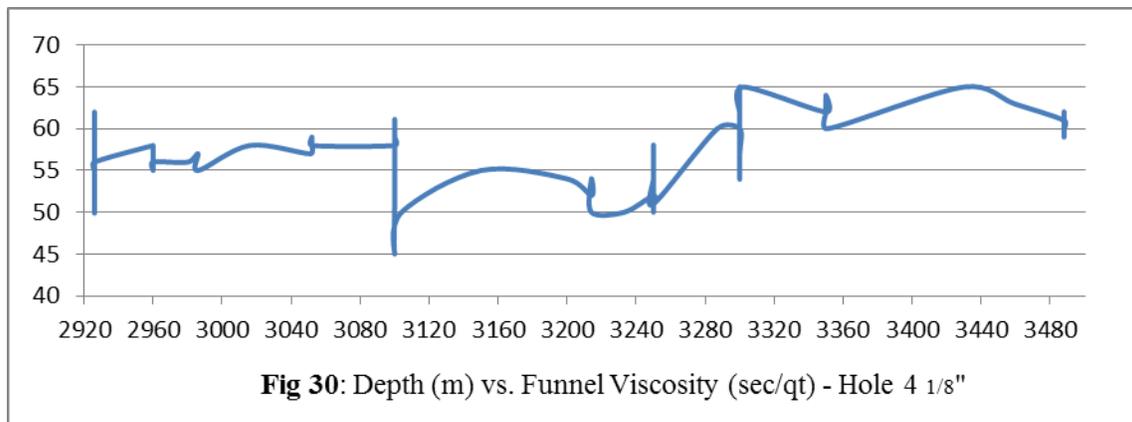
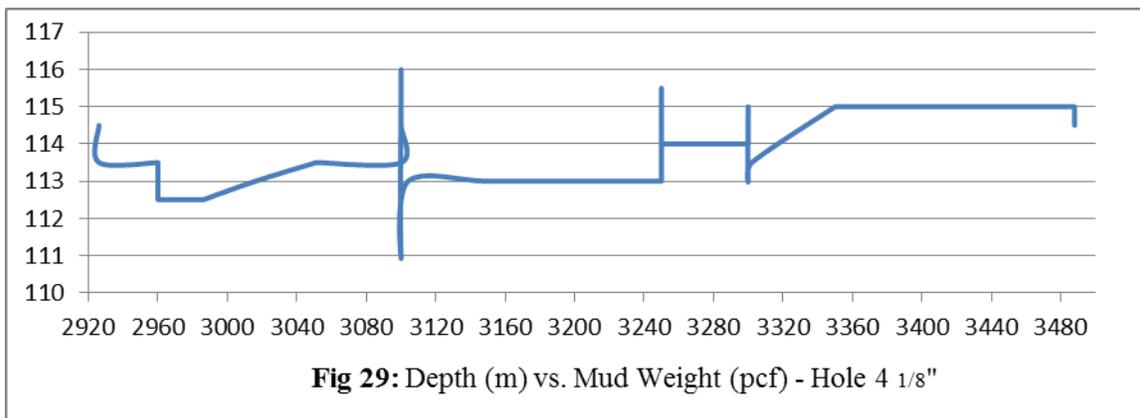


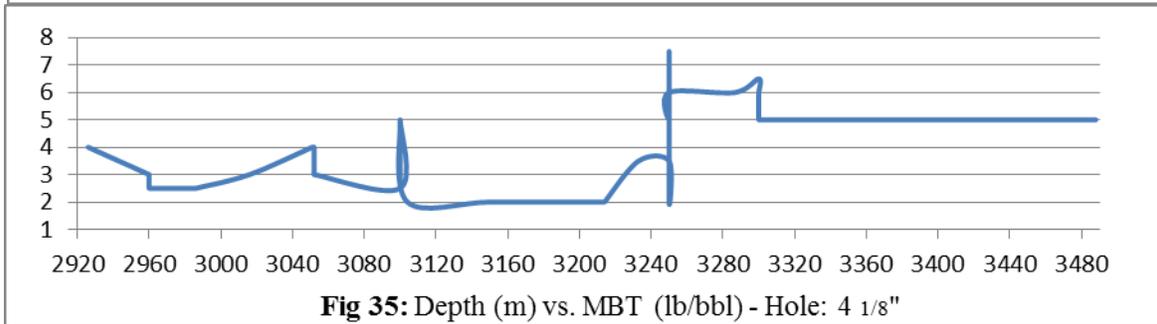
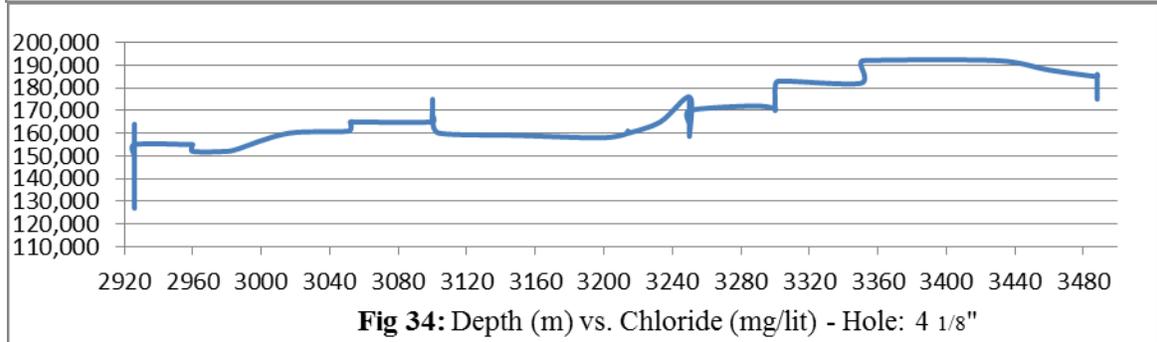
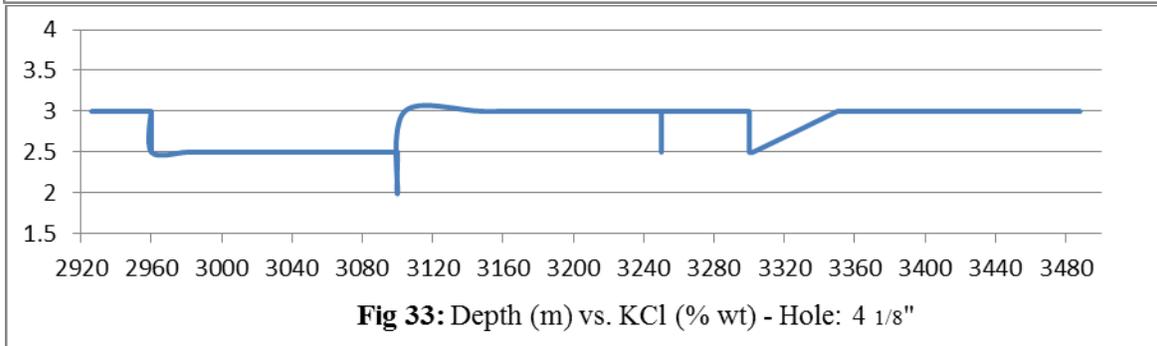
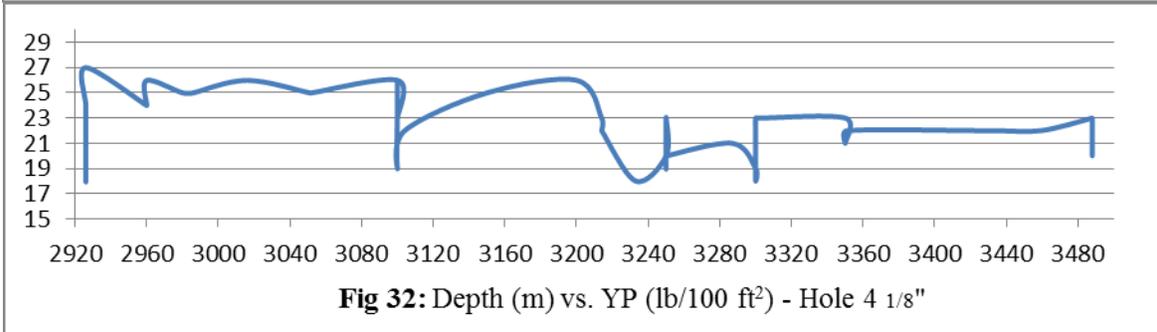
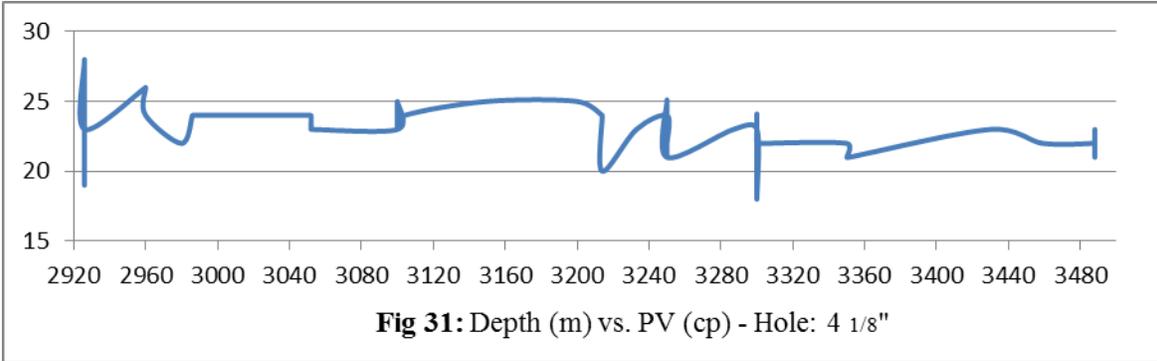




3.7 Hole: 4 1/8"

This section was drilled from 2925m to 3488m where is the end point of this well. The well got completed as barefoot and then a bridge plug was set at 2889m inside 5" liner. The addition of a detergent product (Drilling Detergent) was mixed to KCl/Salt/Polymer mud system due to face to massive volume of sticky cuttings whilst drilling operations.





3.8 Completion phase

The completion equipment was rigged up and the well was perforated from 2867m to 2871m inside 5" liner where the well was tested at the first stage. The second bridge plug was set at 2609m inside 7" liner. At the second stage the well was perforated from 2600m to 2605m inside 7" liner then DST tools were assembled and ran in the hole with tubing then the well was tested meanwhile oil flow was diverted to burner boom to be burned successfully. The next bridge plug was set at 2599m and the well was perforated from 2563m to 2536m inside 7" liner where DST packer was set at 2536m and then the well was flowed for the third time successfully.

4. Cost Comparison

Table 3 and Figure 36 illustrate each section consumption as well as relative costs and dilution factors in well SRJ-X2C.

Table 3: WBM & SOBM Values

INTERVAL (in)	CONSUMPTION (bbl)	WBM		SOBM		DILUTION FACTOR
		€ / bbl	Total Cost (€)	€ / bbl	Total Cost (€)	
21 x 17 1/2	10,188	13.15	133972.2	183.81	1872656.28	NA
17 1/2 x 14 3/4	15,091	10	150910		2773876.71	3.78
14 3/4 x 12 1/4	2,578	36	92808		473862.18	5.2
8 1/2 (first hole)	5,330	25.5	135915		979707.3	77.6
8 1/2 (second hole)	3,891	72.8	283264.8		715204.71	5.19
5 7/8	18,727	38	711626		3442209.87	49
4 1/8	22,984	38	873392		4224689.04	67
Total	78,789		2,381,888		14,482,206	

With refer to these information, there is a considerable difference between the cost of WBM and SOBM (more than 6 times).

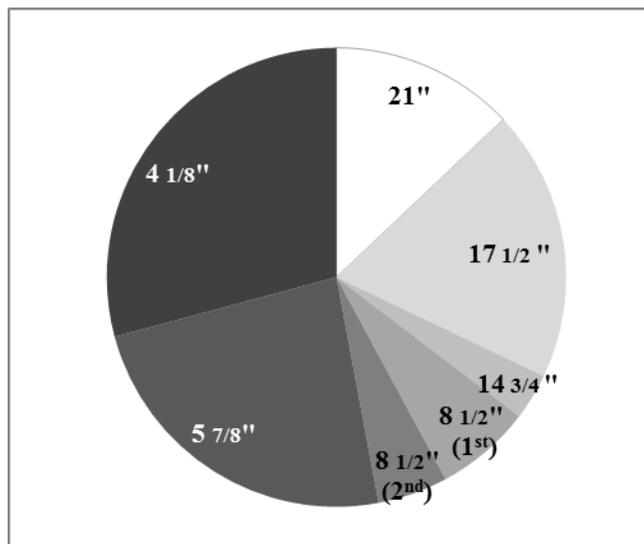


Fig 36: Mud Consumption in the Holes (closed circulation)

Figure 37 shows the actual cost of each section by using WBM which have been compared with estimated cost of the equivalent volume of SOBM as alternative. The difference values between WBM & OBM are calculated with exclusive of waste management related costs and the cost of relevant logistics/technical requirements for SOBM preparations.

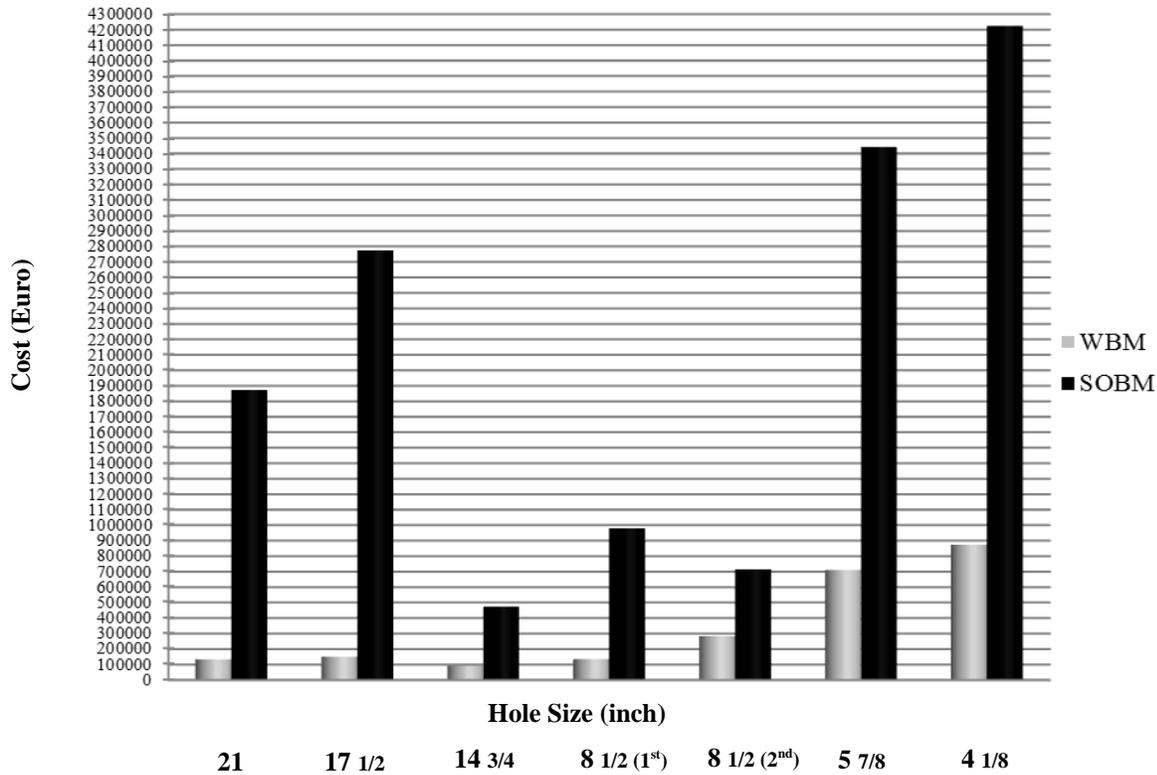


Fig 37: Cost comparison of mud types in the Holes (closed circulation)

5. Conclusion

Based on the experiences and lesson learnt, obtained during more than 5 years deep water operations in Sardar Jangal field in Caspian Sea, a proper design of WBM when combined with good drilling practices, they have the potential to deliver the greatest likelihood of success at minimum well costs and environmental impacts.

Acknowledgments

Obviously this success would not be possible without the whole team contribution such as KEPCO, NDCO including both Onshore & Offshore personnel. Although we are different entities, but having the same goal has made all of us as a successful team to complete the campaign. I would also like to take this opportunity to extend my appreciation to every individual working in this project including MIS team both on the rig and Neka Base who have had an undisputed role to make the success.