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# MASTER'S THESIS

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Yours sincerely,

Eivind Sorger Lenning

# Abstract

The petroleum industry on the Norwegian Continental Shelf is in a time with well construction time and cost as an increased challenging factor. The operators desire to discontinue this trend and are currently cutting cost. Consequently, a contractor similar to COSL Drilling AS meets a demand for a more efficient operation.

This thesis presents an overview over the responsibility distribution between the different parties associated with the drilling operation. Wells drilled by the semisubmersible rig, COSL Pioneer is analyzed. The operation is divided into groups to give an overview over the operation and reveal where time is spent and where the potential for improvement is high. The relationship between the technical limit and the invisible lost time in the drilling operation is analyzed, and the possible advantage of reducing the invisible lost time to a minimum is presented.

To find one specific area that would drastically improve the operation efficiency is difficult. For COSL Drilling AS to fulfill the vision of being the preferred supplier of drilling services in the North Sea, they need to be best in all work processes and small parts of the operation. Specific improvement potentials related to the drilling contractor have been found and pointed out in this thesis.

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# Abbreviations

COSL – China Oilfield Services Limited

NCS - Norwegian Continental Shelf

BHA – bottom hole assembly

BOP – blow out preventer

ROP – rate of penetration

DD – directional driller

ROV – remotely operated vehicle

DDR – daily drilling report

WOW – waiting on weather

RIH – Run in hole

POOH – Pull out of hole

OWS – Odfjell Well Services

TT – Trip tank

M/U – Make up

B/O – Break out

CH – Cased hole

OH – Open hole

# 1. Introduction

## 1.1 Background

In the late 1950s, few people believed that the Norwegian Continental Shelf (NCS) concealed rich oil and gas deposits. However, the gas discovery in 1959 at Groningen in the Netherlands led to enthusiasm around the petroleum potential in the North Sea. Three years later, Phillips Petroleum sent an application to the Norwegian authorities, for exploration in the North Sea. Following the Ekofisk discovery in 1969, the Norwegian oil adventure began. June 15$^{th}$ 1971 the first oil was produced from the Ekofisk field. The petroleum activities on the NCS led to economic growth and contributed to financing the Norwegian welfare state [1].

Today, increasing costs represent a challenge for the petroleum industry on the NCS. A standard drilling operation takes twice as long as it did 20 years ago, despite new technology and increased competence [2]. Professor of Strategy and Industrial Competitiveness at BI, Torger Reve stated under Statoil's energy seminar in 2014: "If we are not the best anymore, we have a problem. Then we are just the most expensive" [3].

The operators on the NCS are currently looking for ways to turn this trend around and cut costs [4]. The former CEO of Statoil on the NCS indicated in 2013 that the high activity on the NCS demands that everybody works more efficiently [5]. Consequently, the operator introduce performance-based contracts for their suppliers to increase the efficiency and quality of the deliveries [6].

To be a preferred supplier of drilling services on the NCS in today's market, an effective operation is vital. Hence, it is important for the contractor to have a well working system for evaluating drilled wells and to implement measures to achieve the most effective operation possible.

This thesis investigates the drilling operation from the point of view of a contractor company. The aim is to identify the parts of the drilling operation controlled by the contractor and where time is spent. Furthermore, to determine possible measures that the contractor can implement to operate in a more effective and safe way. The input for the work is taken from the author's daily experience from the drilling operation and from daily drilling reports from the semisubmersible rig COSL Pioneer.

## 1.2 Authors background

The author of this thesis has worked offshore for contractor companies for six years. Both for Odfjell Drilling and COSL Drilling. He also holds a Bachelor's degree in Mechanical Engineering.

## 1.3 Structure and limitations of the thesis

Chapter 1 gives the reader and introduction to the thesis and the statement of the thesis is presented and elaborated. Furthermore, Ch. 2 presents specific equipment and terms needed for reading this thesis. A typical sequence of a drilling operation is presented through all sections from 36in. to commence of the 8 ½ in. hole. In addition the drilling crew together with the parties involved in the drilling operation are presented.

A brief presentation of the contractor company, COSL Drilling Europe AS is found in Ch.3. Whereas Ch.4 gives an introduction to the routines, procedures and problems regarding an effective operation offshore today. Furthermore, Ch.5 summarizes the methodology of benchmarking and management of change.

Chapter 6 explains the work behind the collection of data and how the data has been processed, analyzed and presented. This chapter is followed by Ch.7 incorporating the result of the analysis. In Ch.8 possible improvement areas related to the drilling operation are pointed out. Lastly, Ch.9 includes the conclusion and thoughts for further work.

This thesis is focusing on the drilling operation from a contractor's point of view. This means that down hole conditions, drilling parameters, mud weight etc. are not relevant for this thesis, since this represents the operators responsibility [7].

This study is limited to the operation of the 36", 26", 17 ½" and 12 ¼" section of the drilling operation. The 8 1/2" section will not be covered in this thesis.

All wells studied in this thesis are drilled by COSL Pioneer.

## 1.4 Related work

### Modern Well Design

In the book Modern Well Design [8], Bernt S. Aadnøy breaks down the time used on each hole section in six pre drilled wells and all activity are grouped into 12 different operations (Table 1).

*Table 1 Bernt S. Aadnøy's operation grouping in Modern Well Design*

| | | | |
|---|---|---|---|
| BOP/wellhead eq. | Casing | Circ./cond | Ream |
| BOP activities | Survey | Drill | Trip |
| Other | Press detection | Hole open | Underream |

The data is normalized in min./meter to make the data directly comparable despite different length of the hole sections. The best result for each operation can then be found. All time consumption due to unforeseen events similar to waiting on weather, hole problems, fishing operations, maintenance etc. are presented in a separate table. The author then uses the best times from each operation, from each hole section to generate an ideal time consumption for a total well.

In this thesis a similar grouping and normalizing is done. The construction of the well has been broken into different sections. The goal is not to generate an ideal time consumption similar to Aadnøy, but to look at the drilling operation from a contractor's point of view. Aadnøy looks in addition at down hole conditions, well problems etc. This will not be covered in this thesis.

By means of comparing the specific time consumption from each operation it should be possible to get an overview of what takes time during the period of the operation and reveal possible operations to improve.

### SPE Paper 92235

Hugo Valdez and Jurgen Sager look at practical application of continuous improvement and benchmarking techniques that can improve operational efficiency and reduce well cost. They do a benchmarking analysis on the tripping process and use the result from the best rig to determine improvement areas on the other rigs.

The authors define activities that is controlled by the contractor alone as *Key Steps*. In the wells studied by Valdez and Sager, the *Key steps* represented more than 30% of the well construction time [7].

This thesis presents a similar study of wells drilled by one single rig. The different operations have been divided into groups by responsibility similar to the one presented by Valdez and Sager (Fig. 22). Additionally groups have been made to fit the purpose of this thesis (Table 5).

# 2. Drilling operation

## 2.1 The drilling crew

A typical rig crew consist of a driller, assistant driller, roughnecks and a derrick man. The driller is the supervisor of the drilling crew and operates the major rig systems [9]. The roughneck reports to the driller and is responsible for maintaining and repairing much of the equipment found on the drill floor [10]. In addition the roughneck is the operator of the Catwalk machine, Ironroughneck and X-Y Hydraracker. The derrick man is responsible for the mud pumps and the fluids pumped down the well.

The toolpusher is the drilling supervisor for the drilling contractor and his job is largely administrative. He ensures the rig has sufficient materials, spare parts etc. and that the drilling operation is done safely and effective [11].

## 2.2 Drilling equipment

### Bottom hole assembly (BHA)

The connected lengths of drill pipe that are run into the hole are collectively called the drill string [12]. The BHA is the term for the bottom part of the drill string. Drill collars, stabilizers, reamers, heavy-wall drill pipe, measurement while drilling (MWD) tools, jar, accelerator and the drill bit is together termed the BHA [12]. Drill collars are extra-heavy length of pipe that provide additional weight on the bit and add stability to the drill string [9]. Reamers and stabilizers are run depending on the predicted hole conditions and drilling plan. Stabilizers are used in the BHA to guide the drill bit and force it to rotate in the center of the hole. A reamer is similar to a stabilizer but has rolling cutters instead of blades. Thus allowing it to enlarge a hole already drilled by a bit below it [12]. The MWD is a unit to measure various drilling parameters like direction, pressure, temperature, vibrations etc. [13]. The jar is a mechanical device used in case of stuck pipe to shock the drill string. The accelerator is placed above the jar in the BHA and is used to increase the effect of the jar [13].

### Red zone

The red zone or “no-go zone” is a defined zone on the drill floor that is only entered when highly necessary or by authorized personnel. Normal traffic is prohibited during the time that well activities are performed or at times where well activities can occur. The red zone is controlled by the driller and the driller should know who is inside the red zone at all time. The red zone covers most of the drill floor, especially where there is moving machinery and there is risk of dropped objects from above. No stay in the red zone is authorized during the period that equipment is moving [14]. Figure 1 illustrates the red zone inside the red lines and the blue circle indicates the well center on drill floor.

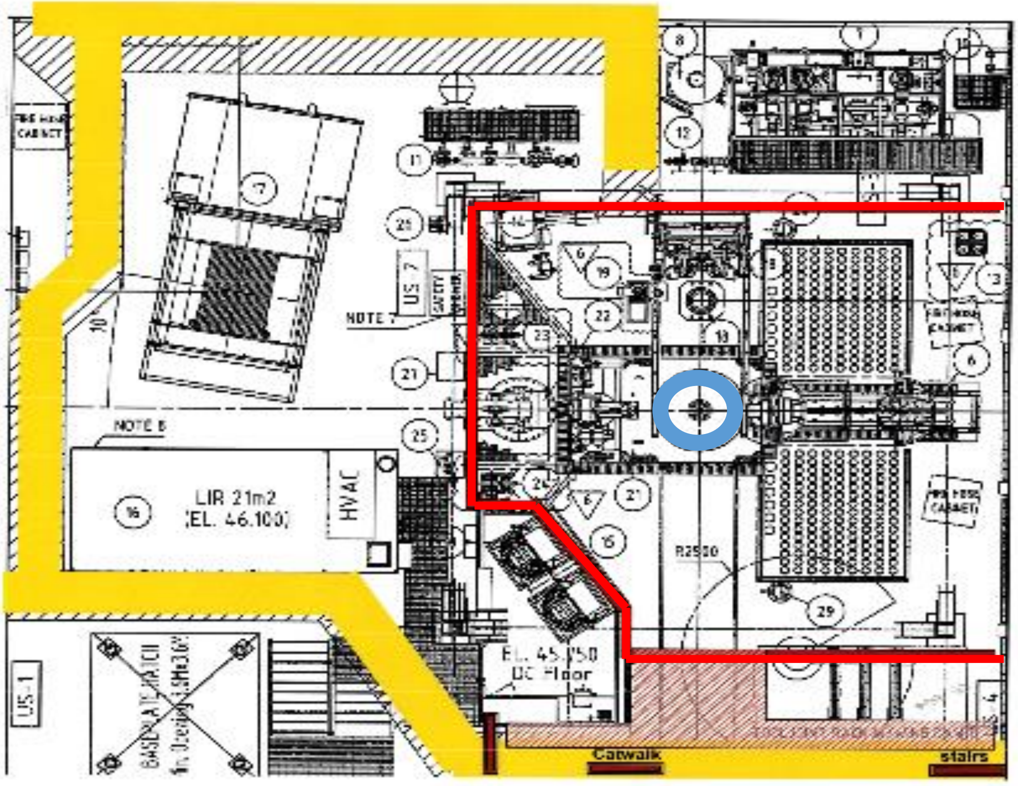



*Figure 1 The red zone on drill floor [14]*

## Catwalk Machine

The Catwalk Machine is a pipe and riser handling system which safely transports tubular and miscellaneous equipment in and out of the drill floor [15]. The catwalk machine handles all pipe/riser/casing in horizontal position. The tubulars are lifted from the pipe deck on to the catwalk, which is leveled with the drill floor. This makes it possible to run casing and pipe in and out from the drill floor. The bottom left picture in Fig. 2 shows the catwalk machine with a riser joint. The bottom right picture in the same figure show how the catwalk machine is placed on the level with drill floor and above the pipe deck.

*Figure 2 The catwalk machine showed in different scenarios [16]*

## Iron roughneck

The Iron roughneck is used for spinning pipe together and making the pipe connections up to the correct torque. Similar it is used to break out pipe when tripping out of the hole. The Iron roughneck is semi-automatic and operated from the driller's cabin. As seen in Fig. 3 the Iron Roughneck run on tracks from parked position and to the well center in the middle of the blue square. The right picture in Fig. 3 illustrates the Iron Roughneck making up a connection.

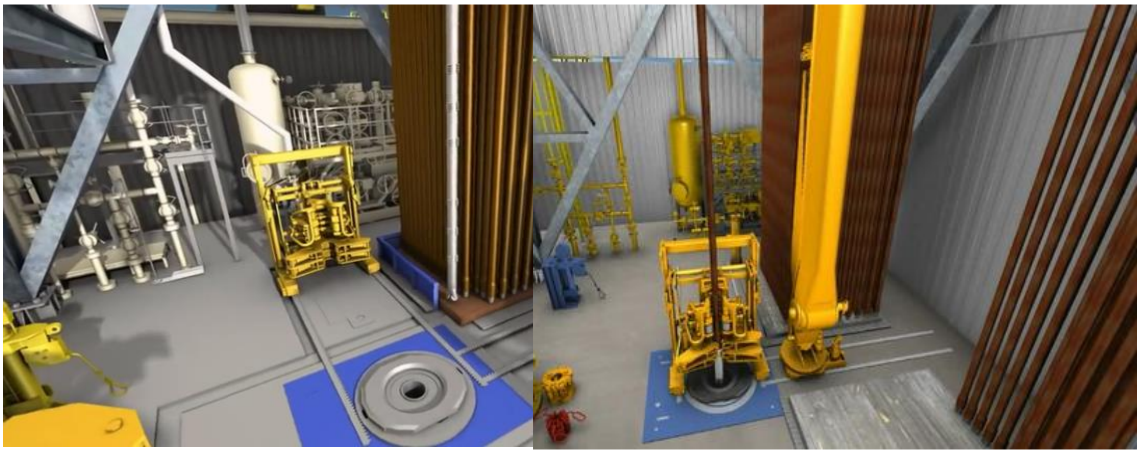


*Figure 3 Iron roughneck on the drill floor in parked position (l.s) and while making up a connection (r.s) [17]*

## Manual rig tongs

The manual rig tongs are self-locking wrenches used to apply torque on drill string components [18]. The tongs are used in case the Iron Roughneck is not able to make/break a connection. This can be for the reason that the BHA is in unsuitable lengths or that parts of the pipe has a large diameter that come in conflict with the

Iron Roughneck. The manual rig tongs requires manual handling and personnel inside the red zone as illustrated in Fig. 4. There is also a great risk for finger injuries. The use of rig tongs should therefore be kept to a minimum.

*Figure 4 Drilling crew breaking out a connection using manual rig tongs [19, 20]*

## Odfjell Well Services (OWS) Casing tong

The OWS casing tong illustrated in Fig. 5 are used for spinning casing together and making the casing connections up to the correct torque, similar to how the Iron Roughneck is used for pipe. The casing tong is remote-operated and operated by a separate casing crew hired by the operator. The casing tong is not permanently located at the drill floor, but is rigged up and down in connection with each casing section.

*Figure 5 The Odfjell Well Services (OWS) casing tong [21]*

## X-Y Hydraracker

The X-Y Hydraracker handles pipe in vertical position and is designed for racking back pipe when running out of the hole or getting pipe in to the well center from the fingerboard when running pipe in the hole. Figure 6 illustrates the X-Y Hydraracker lifting pipe to well center and lifting pipe from the fingerboard. The X-Y Hydraracker is as the Iron Roughneck semi-automatic and is run from the driller's cabin. The X-Y Hydraracker is an important part of tripping pipe in and out of the hole.

*Figure 6 The X-Y Hydraracker lifting pipe to the well center (l.s) and seen from above getting pipe from the fingerboard (r.s) [22, 23]*

## Fingerboard

The fingerboard (Fig. 7) consists of several steel fingers with slots between them that keep the tops of the drill pipe in place [24]. The fingerboard makes it possible to rack drill pipe in stands of 2 pipe (Range 3) or 3 pipe (Range 2). Range 3 pipe is longer than range 2 pipe and is therefore racked in the fingerboard in stands of 2 pipes joined together. This saves rig time during a tripping operation due the fact that the contractor only have to make up half or one third as many connection as if each single pipe was picked up from the pipe deck. The steel fingers in the fingerboard are automatically operated in combination with the XY Hydraracker.

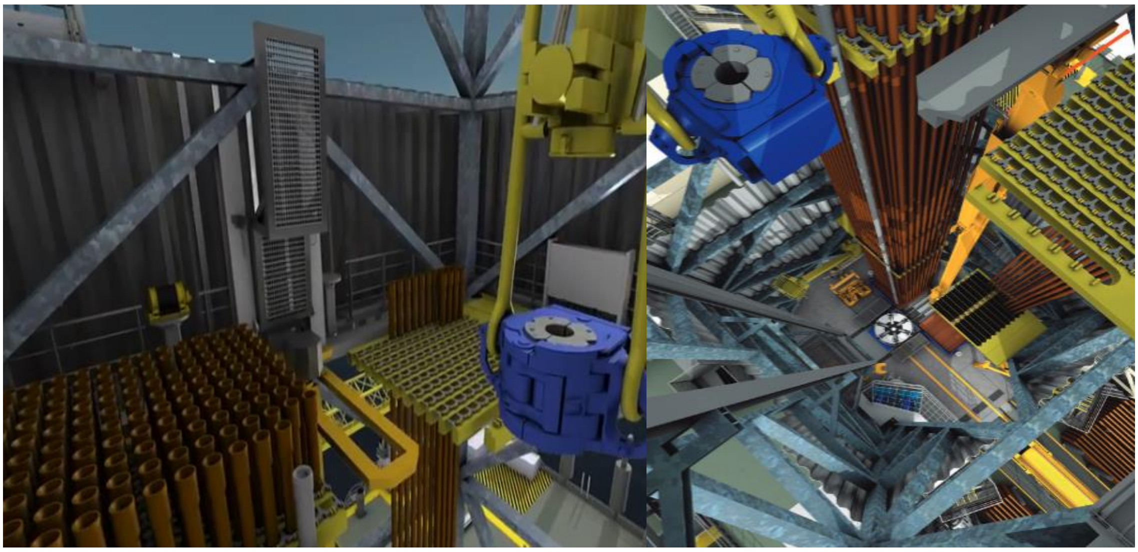


*Figure 7 The fingerboard from two different views [17, 25]*

## Slip joint

The slip joint permits the rig to heave without affecting the riser connected to the BOP below [26]. A donut packer with pressure behind is placed between the inner barrel (the black slick tube in Fig. 8) and the outer part of the slip joint. The inner barrel follows the rig heave. It is stripped through this packer and this system is providing a closed system between the seabed and the rig. Without this packer mud would spill to sea through the space between the inner and outer barrel. The inner barrel is connected with the flex joint and diverter, that is attached to the rig's substructure [27].

*Figure 8 Slip joint [28, 29]*

The 8 wires mounted to the ring around the slip joint keeps the risers in tension, these are marked with red color in Fig. 8.

## Diverter and flex joint

*Figure 9 Diverter and flexjoint [30, 31]*

The diverter is for redirecting the flow to the flow line or overboard using a packer in case of a well control situation. The emergency sealing device in the large housing then seals off the access to the drill floor.

The flex joint or ball joint work as a knuckle and takes sideways movement. It is a flexible, pressure tight device that allow limited amount of horizontal movement of the drilling unit [12].

## Riser

The riser joints consist of a large diameter, low pressure main tube. It has in addition external lines providing the possibility to circulate fluids to the BOP and power and control lines for the BOP. The external kill and choke lines are high pressure rated and provides the possibility to circulate through the small diameter lines with a closed BOP in case of a well control situation [32]. As illustrated in Fig. 10 a riser joint is picked up from the catwalk and lowered through the spider. The

4 blue latches on the spider are for landing the riser joint while lifting up the next one. After one joint is landed in the spider, the next joint is picked up from the catwalk and connected to the first. Hence Fig. 10 shows the scenario of the first joint due the fact that no riser joint is as of yet landed in the spider. The first riser joint is connected to the BOP in the moon pool underneath the drill floor. The connection point on the BOP is showed in Fig. 11 by the yellow arrow

*Figure 10 Riser joint picked up from the catwalk machine (l.s) and ran through the spider (r.s) [33]*

## Blow Out Preventer

The BOP enables well control. Fig. 11 shows the approximately 15m tall BOP inside the red square. The yellow arrow point at the connection point for the first riser joint. The BOP enables the rig crew to shut the well in emergency scenarios. It is basically a set of large valves and RAMS that can seal off an oil or natural gas well being drilled or worked on [34]. The BOP is installed onto the wellhead at seabed after the 20 in. casing is set and stays subsea during the rest of the well operation (ref. Ch. 2.2 Drilling operation sequence).

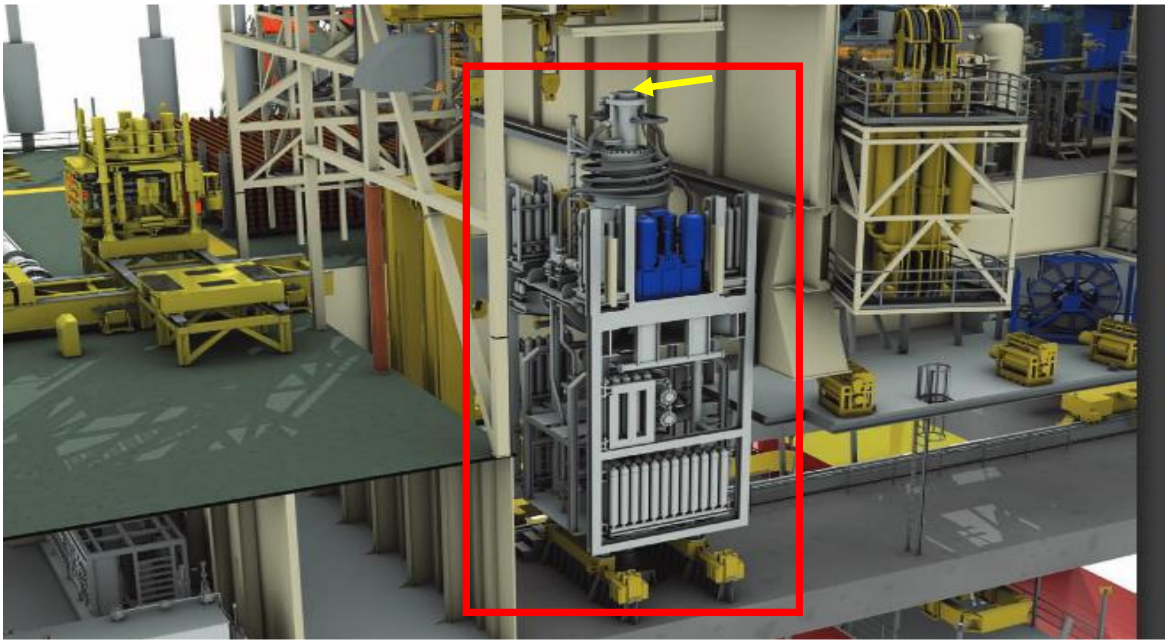


*Figure 11 The BOP in parked position on the rig [35]*

## 2.3 Tripping

Tripping is by definition the process of running drill string (drill pipe) in or out of the hole [36]. Tripping covers numerous different work operations. Table 2 presents some of the subgroups related to the tripping operation. Full overview of all subgroups related to the tripping operation can be found in App. A.

*Table 2 Tripping related work processes*

| Task/Subgroup | Description |
|---|---|
| Pick up (P/U) or Lay down (L/D) pipe while run in hole (RIH) | Picking up or laying down pipe, one by one from pipe deck while running in hole. This is necessary if the pipe is not racked in the derrick or if a single pipe is needed to space out through the BOP etc. |
| Flowcheck | Flow check is to discontinue the tripping operation and monitoring the trip tank, checking that the well is static, usually for 10 minutes. This is done before a trip or before pulling the bottom hole assembly (BHA) through the BOP. Additionally if the change in trip tank volumes does not match the steel displacement while tripping in/out. |
| Empty trip tank | While RIH the trip tank volume will increase since the pipe will displace fluid. When the trip tank is full, the tripping process is stopped and the tank is emptied. This is to keep volume control at all time. |
| Fill trip tank | While pulling out of hole (POOH) the trip tank volume will decrease since pipe is removed from the well. When the trip tank is close to empty the tripping is stopped and the tank is filled up again. |
| Unrestricted tripping | Tripping is done with no restriction on speed, either in open hole or inside an already cased section. |
| Restricted tripping | Tripping is done with restriction on pulling/running speed due to ex. risk of swabbing |

### Trip tank

When tripping pipe after the BOP is landed the well is on trip tank. This means there is a closed system with the well and the trip tank. This makes is possible to track the volume of the mud replacing the volume of drill string while tripping out of the hole in a very detailed way. During the period of tripping in the hole the trip tank makes it possible to continuously keep track of volume gain. The expected gain is calculated in advance and should be equal to the displacement volume of the string [38]. An overview of a well on trip tank is shown in Fig. 12. Here the pipe is tripped out of the hole. The trip tank pump is supplying the well with mud as the pipe is being removed from the well. If the tripping were stopped and the well was static the trip tank would circulate through the trip tank pump and through the return line back to the trip tank with constant volume. In a situation where pipe is being tripped in the hole the well would overflow through the return line into the trip tank with the same volume increase as the pipe displacement.

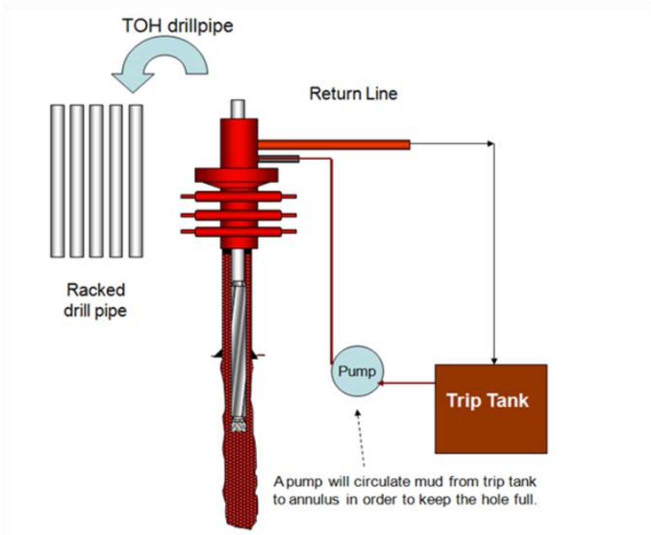



*Figure 12 Trip tank working process during tripping out of the hole [37]*

## 2.4 Typical operation sequence

This section describes the process of the drilling operation that is controlled by the contractor. This is the part of the drilling operation that COSL Drilling directly influences and have the responsibility for. There will always be differences in the drilling procedures and the sequence equipment is run. On fixed platforms and jack-up rigs the wellhead and BOP are installed on the cellar deck of the rig. This will therefore affect the order of running the equipment [12]. The operation sequence described in this thesis are valid for a semi-submersible rig where the wellhead and BOP are installed on the seabed.

*Table 3 Example of typical targets depth for each hole section [8]*

| Drilled section | Casing size | Depth below seabed (m) | Typical mud weights (s.g.) |
|---|---|---|---|
| **36 in.** | 30 in. | 100 m | Seawater |
| **26 in.** | 20 in. | 700 m | 1.20 |
| **17 ½ in.** | 13 3/8 in. | 1300 m | 1.30 |
| **12 ¼ in.** | 9 5/8 in. | 2400 m | 1.60 |
| **8 ½ in.** | 7 in. | 2700 m | 1.60 |

### Drilling the 36 in. section, run and cement 30 in. conductor

The 36 in. section is the first section of a typical drilling sequence. The 36 in. BHA is made up with the 36 in. bit called a "hole opener" and tripped to seabed [12]. The leftmost picture in Fig. 13 illustrates how the 36 in. bit penetrates the seabed. The section is then drilled to target depth (Table 3) with seawater as circulation fluid through the drill string. The seawater transports the cuttings out of the hole to seabed, where the cuttings are deposited. Drill cuttings are a general term for the broken bits of solid material removed from a drilled borehole [39], the term is independent of the formation geology.


*Figure 13 Drilling 36 in. hole and run 30 in. conductor with guide base [40]*

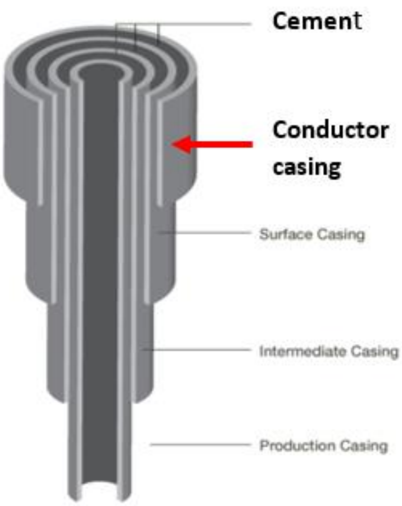



*Figure 14 Casing schematic highlighting the conductor [41]*

To improve drill cuttings transport out of the hole, a high viscosity pill is pumped on every single pipe drilled. To prevent cuttings from accumulating around the top of the hole at seabed, a pump is commonly placed at the seabed to distribute the cuttings over a larger area.

Surveys are taken at different depths on instruction from the Directional Driller (DD) for the purpose of ensuring the section is vertical and not too deviated.

The section is the foundation for the rest of the well and it is therefore important that this section is drilled, cased and cemented correctly . After the 36 in. section is drilled down to target depth, a weighted water based mud is pumped. This is done in order to keep the hole open and stable until such time the conductor shown in Fig. 14 is set and cemented. The conductor is the term of the first casing string put into the well [42].

The pipe and bottom hole assembly (BHA) is then pulled to above the seabed and the rig is moved off to safe zone for the purpose of preventing equipment falling in the hole.

Before further operation an inspection of the derrick is often performed to look for potential falling objects due to heavy vibrations during the drilling of the 36 in. hole.

The necessary equipment for running the 30 in. conductor is then rigged up and prepared. The conductor is then run by a team of "casing hands" contracted by the operator. They have their own special equipment and are flown out to the rig for this and all subsequent casing jobs. The casing team use their own tong for connecting the joints of casing [12]. The last piece is called the conductor housing, which provides a location point for the drilling guide base, and provides an interface for the wellhead (Fig. 13).

Furthermore, inner string of pipe is run through the housing and conductor. The inner string is connected to the housing with the housing running tool. The inner string is for the cement job, consequently the cement is pumped out lower in the conductor and do not have to fill the whole conductor with cement from the top.

The conductor with housing and inner string is then tripped with drill pipe down to the seabed and stabbed into the hole. It is then run down to TD.

The conductor is then cemented in place using the cement unit. This is a separate pumping unit operated by a service company. There are a large number of variations on the equipment used for the cement job. The goal is however always the same, for the purpose of allowing cement to be pumped out the bottom of the casing string and up the annulus between the casing a the wall of the hole [12].

After the conductor is cemented and left a few hours to set, the running tool is released from the conductor housing. Consequently the running tool and inner string is retrieved to surface.

The cement is verified by running pipe down to seabed and tagging the top of the cement on the outside of the conductor.

The 36 in. section ends after the 30 in. conductor is cemented and verified.

### Drilling the 26 in. section, run and cement 20 in. casing

The hole for the 20 in. casing now has to be drilled. Once again the circulating fluid and cuttings are discharged to seabed, due the fact that it is not possible with return to the rig without having the riser installed.

The 26 in. section commences with making up the 26 in. BHA. The BHA is then tripped to above seabed and the rig is moved to location. The leftmost picture in Fig. 15 illustrates the 26 in. bit above the template before it enters the conductor housing

The cement from previous section is then drilled and high viscosity pills are pumped for proper hole cleaning. The section is then drilled to target depth. Still with seawater and returns to the seabed, but with higher density than used drilling the 36 in. section. After target depth is reached the hole is circulated clean of cuttings and the well is displaced to water based mud. The string is pulled to surface (Fig. 15) and the 26 in. BHA is laid down. Necessary equipment for running the 20 in. casing are prepared and a prejob meeting is held prior to the operation.


*Figure 15 Drilling 26 in. hole and running 20 in. casing with wellhead [43]*

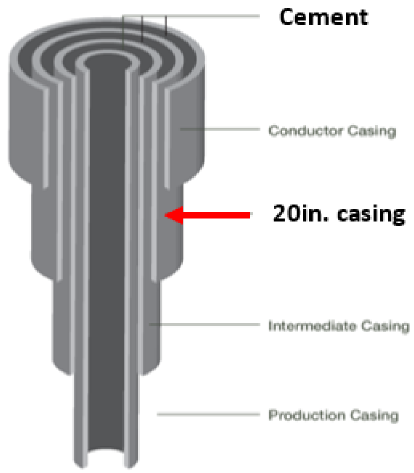



*Figure 16 Casing schematic highlighting the 20 in. casing [41]*

The casing joints are lifted from the pipe deck to the catwalk one by one. The right picture in Fig. 17 illustrates the casing string hanged of in the rotary table while a new joint is lying ready in the catwalk machine. In the picture to the right in Fig. 17, the circle identifies the person removing the protector from the externally threaded end of the casing.

During a casing operation on COSL Pioneer the person marked would be the only one to enter the "red zone". The rest of the personnel would stay outside the "red zone" due the fact that

*Figure 17 Illustration of the casing operation (from a rig in the Philippines) [44, 45]*

the casing joints are run without protector on the internally threaded end and the rest of the operation is semi-automatic. This operation is identical for all casing dimensions.

The 20 in. casing is run to above seabed and the shoe is stabbed inside the conductor housing (Fig. 15). The last piece of the casing string is the 18 ¾ in. wellhead assembly and it is connected to the rest of the casing string. The casing is then run on pipe to TD (Fig .15).

Lastly the 20 in. casing is then cemented in place (Fig. 16) and landing string with running tool is retrieved to surface.

The wellhead illustrated in Fig. 15 works as a suspension point for all following casing sections. The next operation is to land the blow out preventer on top of the wellhead. The 4 white guide posts on the guide base in Fig. 15 are used to provide guidance for the BOP down on the wellhead.

### Run and land BOP

The BOP and riser will act as a conduit for tools and for drilling fluid and cuttings circulated out of the well [12].

The BOP is skidded from park position (Fig. 11) and to the center of the moon pool (Fig 18). Two riser joints are connected together on the drill floor and are then lowered down through the rotary table and connected to the BOP (Fig 18).

*Figure 18 BOP skidded to center of moon pool (l.s) and first riser joint coming through from drill floor (r.s) [46]*

Guide wires from four winches placed in the moon pool are stabbed through the four corners of the BOP. These four wires will be, by the assistance of the ROV, connected to the guideposts (Fig. 15) at the seabed and used for guidance when landing the BOP.

Then the BOP is run through the splash zone. This is a critical phase, since a BOP of over 250 tons hanging free in the moon pool may cause large damage. After the BOP is through the splash zone the rest of the riser joints are connected, and run one by one (Fig. 10).

After all the riser joints are connected the slip joint is lifted up to the drill floor and connected to the last riser joint. Using a landing joint connected to the slip joint, the BOP is landed. The landing joint is then laid down to the pipe deck and the diverter with flex joint is connected to the inner barrel of the slip joint. After the BOP is landed it is pressure and function tested.

Further operation is in a closed system with no more emission or discharge to sea.

## Drilling the 17 ½ in. section, run and cement 13 3/8 in. casing

The 17 ½ in. BHA is made up, and tripped in the hole to the top of the cement from previous section. The 17 ½ in. section is drilled to target depth (Fig. 19), in a large number of cases with water based mud. With the BOP and riser the mud is in a closed system with volume control, but with the cuttings taken out on the shakers and dumped to sea. The leftmost picture in Fig. 19 illustrates the BOP stack at seabed.

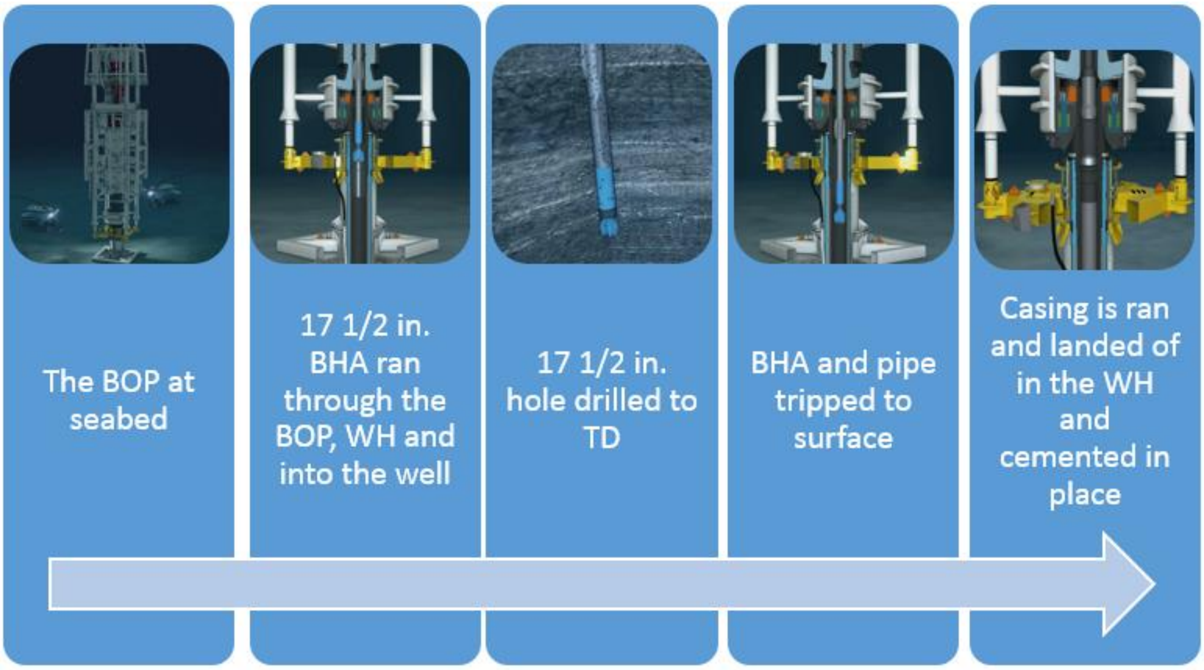



*Figure 19 Drilling the 17 1/2 in. section, run and cement the 13 3/8 in. casing [47]*

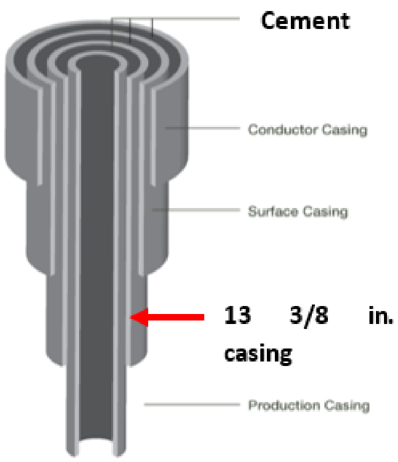



*Figure 20 Casing schematic highlighting the 13 3/8 in. casing [41]*

After the section is drilled to TD the pipe with BHA is tripped to surface. The casing equipment is rigged up and casing is run and landed off in the wellhead. The 13 3/8 in. casing is then cemented for the purpose of sealing the wall of the 17 ½ in. hole drilled (Fig. 20).

The cement is verified and it is ready for the 12 ¼ in. section.

### Drilling the 12 ¼ in. section, run and cement 9 5/8 in. casing

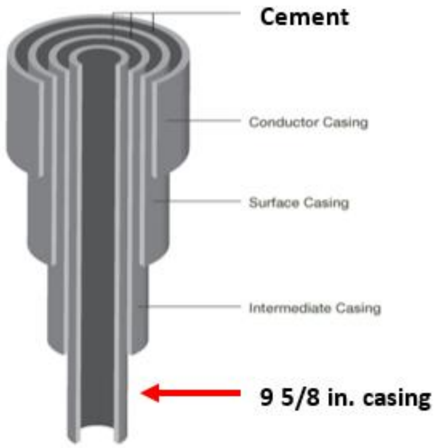



*Figure 21 Casing schematic highlighting the 9 5/8 in. casing [41]*

The 12 ¼ in. BHA is made up and tripped on pipe down to the top of the cement from the previous section. Afterwards the cement and shoe track is drilled out and the well is displaced to desired mud weight. Finally the section is drilled to TD and the string is pulled to surface.

The wear bushing is retrieved and the 9 5/8 in. casing equipment is then rigged up and the casing is run and landed in the wellhead similar to the previous section and cemented in place (Fig. 21). After the cement has hardened it is verified by pressure testing it against a closed BOP.

Finally an 8 ½ in. section is drilled, which is the phase where the reservoir is usually penetrated. Then the well is either plugged back or made ready for completion. The 8 ½ in. section and the completion phase is past the scope covered in this thesis. However completion is basically completing the well and preparing for production.

## 2.5 The parties involved

### Operator

There are in the majority of instances several owners in an oil or gas well. In this case one of the owners will be designated as the operator of the well by agreement of all the owners [9]. The operator (oil company) holds the licenses and rights required to drill on a specific location [12]. The operators not often own their own drilling rigs and prefer that specialist drilling contractors provide the drilling rig and drilling service.

### Drilling contractor

The contractor owns and operates the drilling rig and usually charges a fixed daily rate for the rig and services [48]. The drilling contractor rarely has equity interest in the well, but is contracted to the operator exclusively to drill the well to a required depth and nothing more [9].

### Service companies

A wide variety of companies are necessary during the period of the drilling operation to complete the well [9]. Specialized services including casing installation crews, casing equipment, cementing, directional drilling, logging etc. are required to drill a well. The operator directly contracts the service companies similarly to the drilling contractor [12].

## 2.6 Reporting system

Each small step in the drilling sequence described above is logged and the time used for each step is written in the daily drilling report (Fig. 29) by the driller or assistant driller. All reports are saved and all data are available in the Rig Manager system (covered in Ch. 6).

## 2.7 Business metrics and KPI's

Operators (oil companies) uses key performance indicators (KPI's) for the purpose of measuring their contractors on speed and effectiveness on chosen operations. This is typically tripping, slips to slips, running of BOP, running of casing etc. This is a typical practice in the industry that leads to a natural competiveness. When one contractor becomes aware of that there is another contractor doing the same operation faster, it becomes a natural reaction that they desire to take steps to improve themselves.

In these days the operators have more focus on the "flat spots", meaning the time between each operation. This is time that is e.g. used for rigging up equipment prior to a job, prejob meetings, waiting on weather etc. Except from waiting on weather, these are operations that the drilling contractor have direct influence on and is able to improve.

Activities solely controlled by the drilling contractor are typically represented by more than 30% of the well construction time [7]. Hugo Valdez and Jurgen Sager (Transocean) presented the overview in Fig. 22 concerning the responsibility between the operators and drilling contractor during a well operation.

| Drilling contractor's responsibility | Shared responsibility | Operator's responsibility |
| --- | --- | --- |
| ♦ **Key Steps**<br>○ Tripping DP (Non-restricted)<br>○ Run Casing<br>○ Run Riser<br>○ Pull Riser<br>○ M/U & L/O BHA<br>○ Positioning<br>○ Pre-Spud Activity<br>○ BOP Subsea Test<br>○ Surface Eq. Test | ♦ **Key Steps**<br>○ Drilling<br>○ Circulating | ♦ WD<br>♦ MD<br>♦ TVD<br>♦ Horizontal Disp.<br>♦ Mud Type<br>♦ Mud Weight<br>♦ Hole Diameter<br>♦ Bit Type<br>♦ BHA's<br>♦ # Casing Strings<br>♦ Csg. Complexity<br>♦ KDF's<br>○ Shallow water<br>○ Shallow gas<br>○ Hydrates<br>○ H2S/CO2<br>○ Salt drilled |
| ♦ HSE Proactive Duties<br>♦ Rig Maintenance<br>♦ Rig Crew Training<br>♦ Housekeeping | ♦ Horizontal Displacement<br>♦ Drilling Parameters<br>○ WOB<br>○ RPM<br>○ Pump Rate<br>... | |

*Figure 22 Overview of operation responsibility [7]*

# 3. Presentation of COSL Drilling

## 3.1 COSL Drilling Europe AS

COSL Drilling Europe AS is a subsidiary of China Oilfield Services Limited (COSL) Beijing, China. The company holds three drilling units on the NCS and two accommodation units (Fig. 23). The drilling units COSL Pioneer, COSL Innovator and COSL Promoter were delivered respectively from CIMC Raffles Offshore Yantai 2010, 2011 and 2012. A 4th drilling unit, COSL Prospector will be delivered Q3 2014.

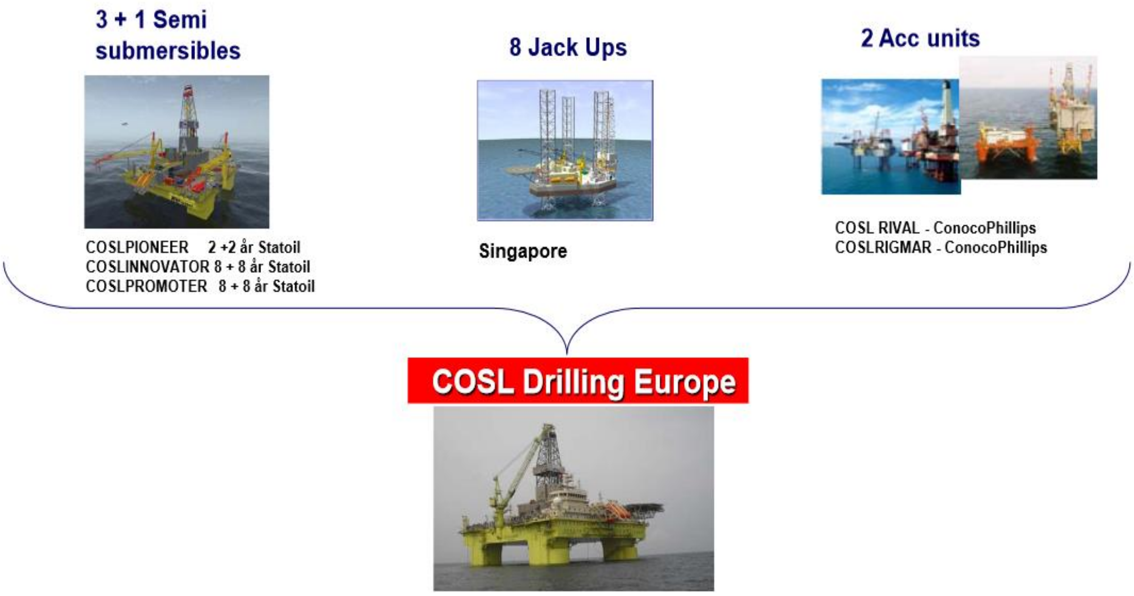



*Figure 23 COSL Drilling Europe AS [49]*

## 3.2 Vision and philosophy

COSL Drilling has a zero philosophy with regard to; personnel injuries, damage to the environment, equipment and assets. This has to be taken into account when changing activities and work processes for a more efficient operation.

### Core values [50]

- "Honesty – creates security and confidence. Honesty and openness among workers creates good relations. No hidden agenda, saying what we think – and we mean it."
- "Motivation – motivation creates satisfaction and growth. Motivation makes us thrive. Motivation is the soil in which our ideas grow. When our ideas grow, dreams come true. Motivation is our motive force."
- "Co-operation – co-operation creates results. Co-operation creates an organization of winners, pride and determination. When we co-operate, you will develop – and so will we."

COSL Drilling believe that all work activities should be planned, with no exceptions [51]. The RISK Card (Fig. 24) is structured for the purpose of helping through the planning process. The back of the card is used to evaluate the result after the work is finished.

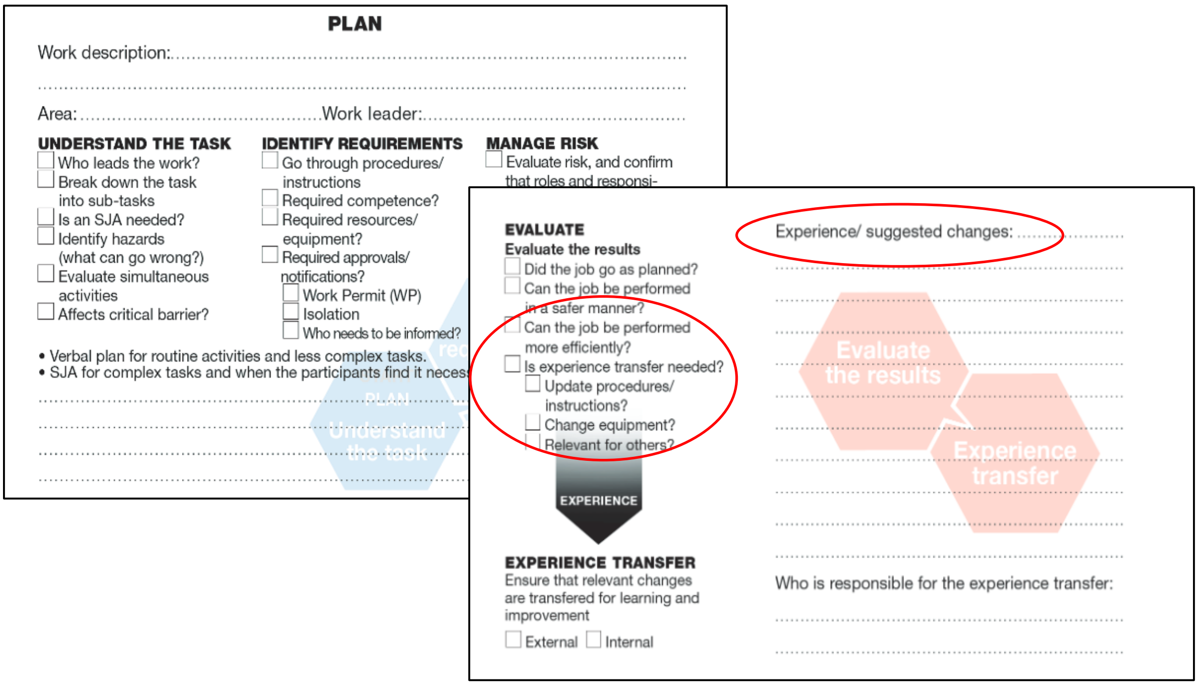



*Figure 24 Front and back page of the RISK card, COSL Drilling's tool for safe work planning and execution [51]*

## 3.3 The fleet

The rigs COSLPioneer, COSLInnovator and COSLPromoter are all rigs of the type GM 4000 and designed for the purpose of operating in water depths up to 750 meter. National Oilwell Varco has delivered the drilling package to all three rigs.

### COSL Pioneer

*Figure 25 COSL Pioneer [25]*

COSL Pioneer (Fig. 25) was built in 2010 at Yantai Raffles Shipyard, China. The semi-submersible drilling rig is designed for world-wide use in harsh environments. The rig has a GM4000 design with drilling structure and mud module delivered by National Oilwell Varco and Nymo, Norway [52].

COSL Pioneer is currently working on Visund, on a 2+2 year contract for Statoil.

### COSL Innovator

*Figure 26 COSL Innovator [53]*

COSL Innovator (Fig. 26) was built in 2011 at Yantai Raffles Shipyard, China. The semi-submersible drilling rig is designed for world-wide use in harsh environments. The rig has a GM4000 design with drilling structure and mud module delivered by National Oilwell Varco and Nymo, Norway [54].

COSL Innovator is currently working on the Troll Field on a 8+8 year contract for Statoil.

### COSL Promoter

*Figure 27 COSL Promoter [55]*

COSL Promoter (Fig. 27) was built in 2012 at Yantai Raffles Shipyard, China. The semi-submersible drilling rig is designed for world-wide use in harsh environments. The rig has a GM4000 design with drilling structure and mud module delivered by National Oilwell Varco and Nymo, Norway [35].

COSL Promoter is currently working on the Troll Field on a 8+8 year contract for Statoil.

# 4. What are to be studied?

## 4.1 Today's process

The operation today may seem effective, but according to Petoro a standard drilling operation takes twice as long time as it did 20 years ago [2]. Operators currently desire their contractors to work more effectively and decrease the time of each well [5].

## 4.2 Where to improve?

The aim of this thesis is to determine potential improvement areas in today's drilling operation for COSL Drilling. Is there one thing that could drastically decrease time spent on each well?

COSL Drilling's vision is being the preferred supplier of drilling service in the North Sea. The goal is to perform the operation more effective, without reducing the safety. At no other time has it been more important to demonstrate an effective and competitive operation [56].

Figure 28 illustrates the actual duration of a well. The figure is not in scale, but it gives an indicator between the technical limit, invisible lost time and the conventional lost or down time (waiting on weather (WOW), down time due to equipment failure etc.).

WOW is difficult to influence and improve without changing the operator limitations on the different equipment. E.g. the operator limits were changed on the heave compensated draw work allowing to land the BOP in 3,5 meters heave instead of 2,5 meters. This would obviously reduce the WOW related to landing of BOP, but this will not be covered in this thesis. Therefore WOW will be defined as an external factor that the contractor is not able to influence.

Invisible lost time (Fig. 28) is mainly associated with efficiency improvements in rig crew activities and drilling optimization. The drilling contractor is responsible for parts of the invisible lost time, and hence, can reduce invisible lost time by improving the efficiency of their operation. By doing the same operation as today, but faster, more effectively and with a minimum of delay the invisible lost time can consequently be reduced to a minimum.

"A close analogy of the technical limit is a world record in athletics"[57].

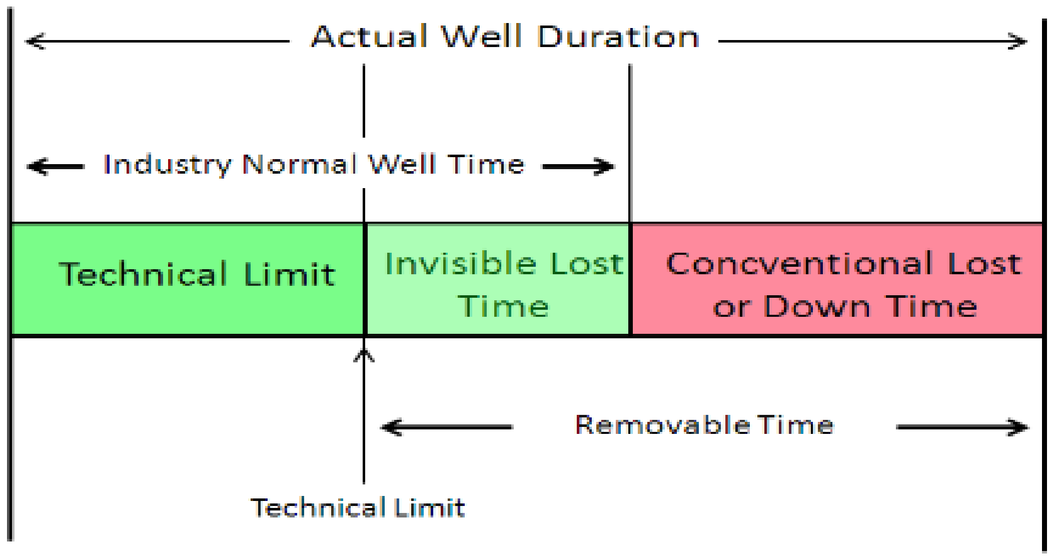



*Figure 28 The relationship between actual well duration, technical limit, invisible lost time and conventional lost time/down time [57]*

# 5. Methodology

## 5.1 Benchmarking

Benchmarking is a continuous and systematic process for the purpose of comparing a company's own efficiency in form of productivity, quality and working process with the companies and organizations that is identified as the best practices [58].

With internal benchmarking the access to data and information is less complicated than with benchmarking against other businesses. The potential with internal benchmarking can be significant. It is possible with increased efficiency by investigating internal factors and procedures within the company organization.

The procedure [7]

- *Identify which operations to be compared, e.g. tripping.*
- *Find internal values that can be used for comparison*
- *Find the best rig for this operation to compare with*
- *Analyze the process*
- *Identify best practice*
- *Implement/ adopt best practice*
- *Monitor*

## 5.2 Management of change

Management of Change is in COSL Drilling's 2014 HSEQ handbook defined as "the process used to manage and control technical; operational and organizational changes that may impact health, safety, security, environmental and/or other quality/ cost issues."

A challenge in the petroleum industry, or any industry is implementing change. Despite improved systems and equipment, a critical success factor is human resources. This is definitely a key factor for an effective operation.

To lead a change in a working process is one of the most important, but in addition a difficult management task. To be successful in leading changes it is important to understand the reason for resistance against change, different phases in the change process and different strategies for change [59].

Looking from a contractors point of view that want to change their work process for the reason of getting a more effective operation, there can be several reasons for resistance against change.

The most relevant reasons for resistance are listed below.

1. ***Lack of trust.*** A fundamental reason for resistance against change is lack of trust in the people attempting to implement change. Even though it is not an obvious threat, changes will be refused if people suspect there are hidden implications that will be revealed at a later time.

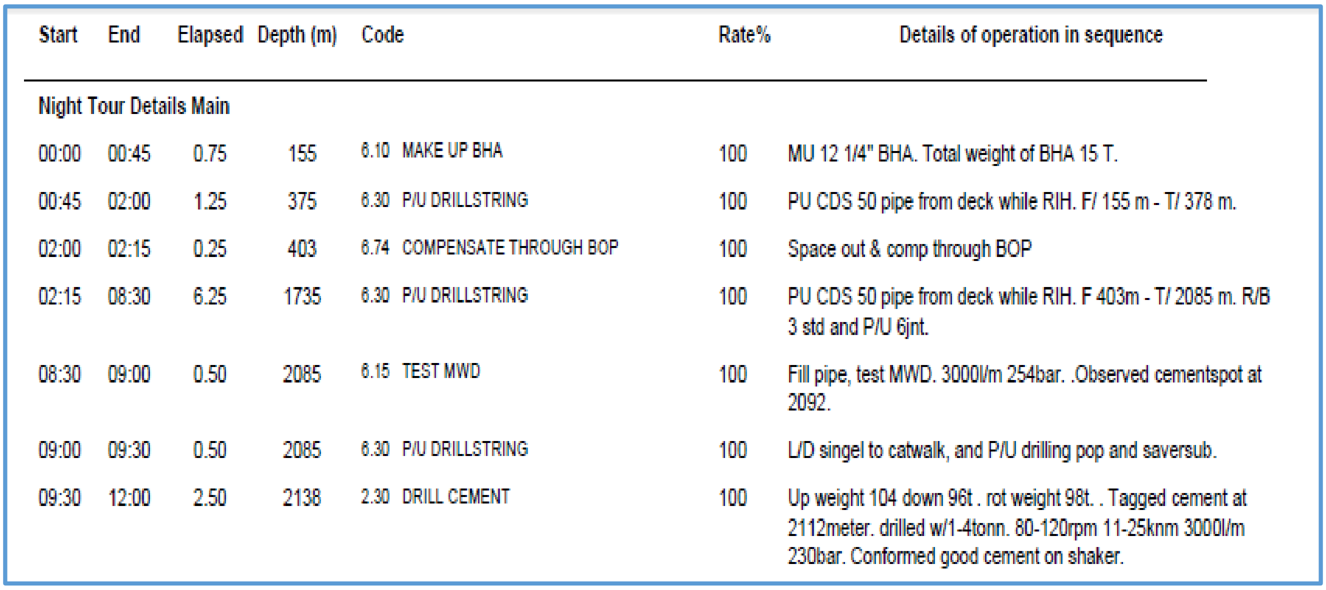
2. ***Lack of belief that changes are necessary.*** Changes are looked at as unnecessary. Changes will meet resistance if the way things have been done before has been successful and if there are no serious difficulties and no obvious reasons for change.
3. ***Lack of belief that changes are possible to accomplish.*** Even after acknowledging the difficulties a suggested change might be refused because there is no trust in the fact that change would be successful.
4. ***Fear of failure.*** People with lack of confidence will hesitate to replace well known procedures they master with new ones that might be difficult to master.
5. ***Loss of power and status.*** Changes will to greater or lesser extent lead to changes in power and status for both individuals and sub departments.

Individual's resistance against changes are not only attributable to ignorance and missing flexibility. Since it is a natural reaction for humans to want to protect their own interest and influence on their own situation [59].

# 6. Data collection and analysis

## 6.1 Daily drilling report

The daily drilling report is a overview over the operation for the last 24 hours. Figure 29 is a screenshot from a drilling report showing the operation from midnight to midday. Here the operation is reported in steps as small as 15 minutes. For intance from 00:00-00:45 the pieces of the 12 ¼" BHA was assembled together (connected and made up to the correct torque). The Driller/Ass. Driller is filling out this report during their shift. In addition to pre determined categories, e.g MAKE UP BHA the driller/Ass driller fill out a more detalied explanation in the "Details of operation in sequence" column.



| Start | End | Elapsed | Depth (m) | Code | Rate% | Details of operation in sequence |
|---|---|---|---|---|---|---|
| Night Tour Details Main | | | | | | |
| 00:00 | 00:45 | 0.75 | 155 | 6.10 MAKE UP BHA | 100 | MU 12 1/4" BHA. Total weight of BHA 15 T. |
| 00:45 | 02:00 | 1.25 | 375 | 6.30 P/U DRILLSTRING | 100 | PU CDS 50 pipe from deck while RIH. F/ 155 m - T/ 378 m. |
| 02:00 | 02:15 | 0.25 | 403 | 6.74 COMPENSATE THROUGH BOP | 100 | Space out & comp through BOP |
| 02:15 | 08:30 | 6.25 | 1735 | 6.30 P/U DRILLSTRING | 100 | PU CDS 50 pipe from deck while RIH. F 403m - T/ 2085 m. R/B 3 std and P/U 6jnt. |
| 08:30 | 09:00 | 0.50 | 2085 | 6.15 TEST MWD | 100 | Fill pipe, test MWD. 3000l/m 254bar. .Observed cementspot at 2092. |
| 09:00 | 09:30 | 0.50 | 2085 | 6.30 P/U DRILLSTRING | 100 | L/D singel to catwalk, and P/U drilling pop and saversub. |
| 09:30 | 12:00 | 2.50 | 2138 | 2.30 DRILL CEMENT | 100 | Up weight 104 down 96t . rot weight 98t. . Tagged cement at 2112meter. drilled w/1-4tonn. 80-120rpm 11-25knm 3000l/m 230bar. Conformed good cement on shaker. |

*Figure 29 Section from a Daily drilling report [60]*

## 6.2 Rig Manager

COSL drilling uses Rig Manager as a rig management software suite, a software developed by the Kongsberg group. The software gives the user full control and overview of all operational aspects. Including daily drilling reports, rig performance, experience transfer etc. [61].

## 6.3 Data collection

Well data from several wells drilled by COSL Pioneer has been collected from Rig Manager. Figure 30 illustrates the performance menu in the Rig Manager. Here it is possible to select the desired rig, well, sections and specific code similar to the ones presented in Fig. 29.

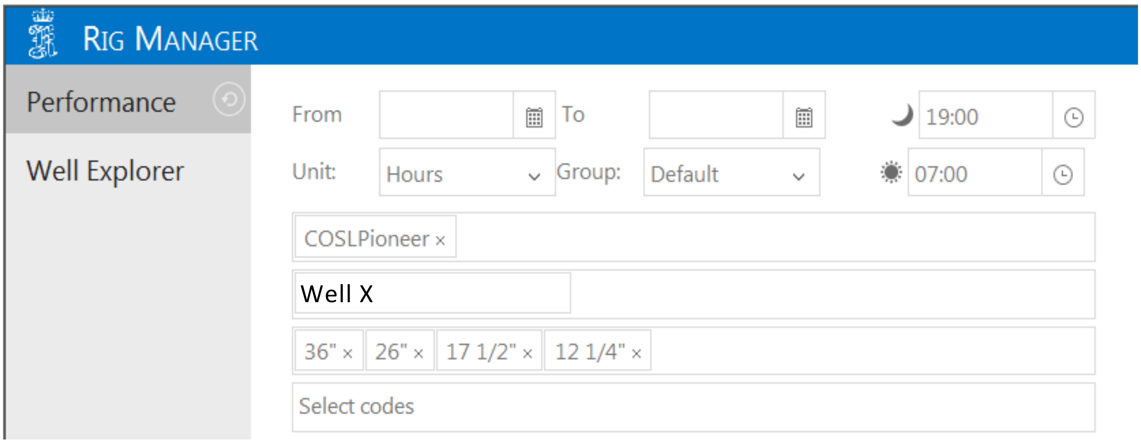



*Figure 30 Screenshot from the Rig Manager software*

If e.g. code 6.10 MAKE UP BHA were selected in Fig. 28, all hours used on MAKE UP BHA during the 36, 26, 17 ½, and 12 ¼ inch section on Well A would be presented. If no specific code is selected, all codes are presented. Figure 31 illustrates a scenario where no specific code is selected and all codes for that specific well are presented in a pie diagram. This is all the time spent on Well X, but a presentation identical to the one in Fig. 31 is not straightforward nor beneficial.

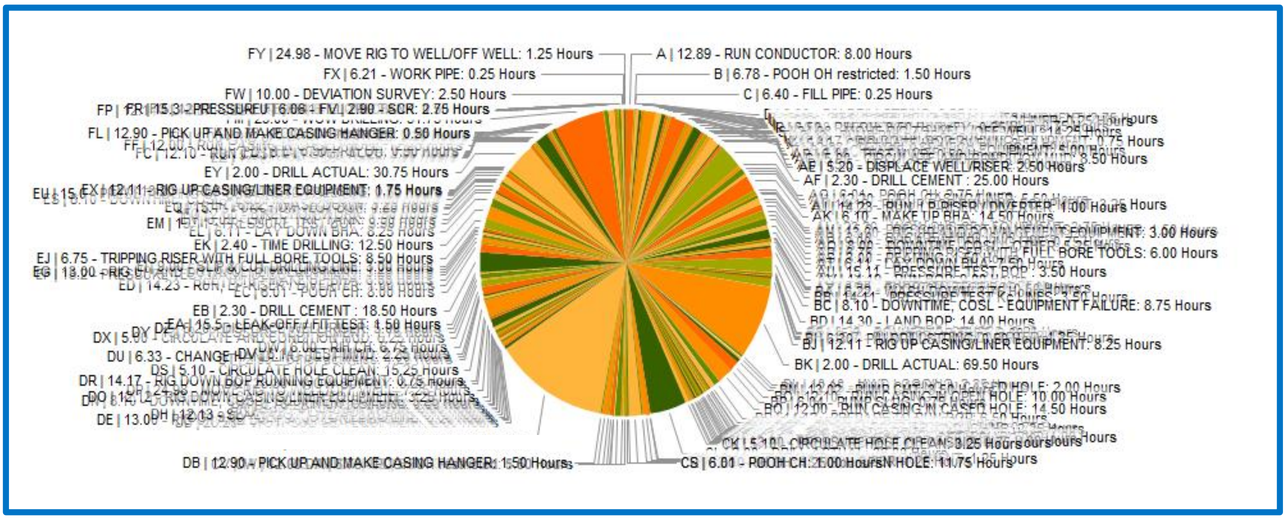



*Figure 31 Illustration of an unusable pie diagram from RigMananger showing the drilling operation with all subgroups*

In this thesis, these small steps have been grouped into larger groups. The groups are chosen for the purpose of giving a better overview of the drilling operation. By means of doing this it is possible to identify where time is spent and determine possible groups for improvement, since each subgroup alone does not give a good overall picture of the operation (Fig. 31). The groups, with explanation are presented in Table 4. A more detailed overview is given in App. A where the different groups are presented with exact names of all the subgroups following underneath.

*Table 4 Operation grouping*

| Grouping of the drilling operation | |
|---|---|
| BHA | Making up/laying down bottom hole assembly excluding MWD activities that is covered under service operations |
| Casing | Running and cementing casing. All steps related to this operation |
| Circ./cond | Displacing, weighing up mud, conditioning mud, circulate hole clean. |
| Downtime/WOW | Wait on weather, downtime due to equipment failure, waiting on operators decision regarding further operation |
| Drill | Drilling, drill new formation, drill cement |
| Flat spots | Rig up/down equipment, clean rig floor, prejob meetings, change handling equipment |
| Maintenance | Planned maintenance, cut and slip drill line, derrick inspection |
| Marine Operations | Anchor handling, move rig to/off location, deballasted. |
| Other | |
| Pressure testing/drills | Pressure testing of drilling equipment, choke drill, kick drill etc. |
| Reaming | All operation with reaming/back reaming/ under reaming |
| Service operations | Operation dependent on service personnel, MWD logging, downloading of data, Wireline logging, surveys, downlinks etc. |
| Trip | Everything which is a part of the tripping operation. Tripping (both regular and speed restricted), flow check, empty/fill trip tank and wash down. Pick up/lay down pipe to pipe deck |

Raw data from several wells have been exported to excel and saved as separate files for each well. Another file is created with one sheet for each section (e.g. 36, 26, 17 ½ and 12 ¼ in.). Figure 32 shows a clip out from the 12 ¼ in. excel sheet. The function in Fig. 32 look up data from the excel file with raw data for each well and presents the data related to the specific code. The cell selected in Fig. 32 look up *"12 1/4" 14.17 RIG DOWN BOP RUNNING EQUIPMENT"* in Excel file WellX.xlsx. For Well Y and Well Z the function would look up the excel file for those two wells respectively. If no value related to the specific code is found in the excel file of the well, the function replies an empty cell.

The description column in Fig. 32 represents the operation grouping. E.g. all cells from row 4 to 8 in Fig. 30 are “BOP activities”.

Similar sheets are made for the 36, 26 and 17 ½ in. section.

Furthermore the data has to be checked up against the drilling reports for the purpose of verifying that the data has been reported using the correct code, and that the hours match with the drilling report. It is essential that deviations are checked and corrected.

| | | | | | |
|---|---|---|---|---|---|
| 1 | 12 1/4" | | | | |
| 2 | **Description** | **Detail** | **Well X** | **Well Y** | **Well Z** |
| 3 | Transit/move rig | 12 1/4" • 24.98 - MOVE RIG TO WELL/OFF WELL • | 1,25 | | |
| 4 | BOP activities | 12 1/4" • 14.17 - RIG DOWN BOP RUNNING EQUIPMENT • | =IFERROR(IF($B4="";"";VLOOKUP("*"&$B4&"*";'https://d.docs.live.net/ | | |
| 5 | BOP activities | 12 1/4" • 14.23 - RUN, LP-RISER / DIVERTER • | 2dcaff1b42b7edf5/Documents/Master thesis/Brønner/[WellX.xlsx]Sheet1'!$B$2:$E$248;4; | | |
| 6 | BOP activities | 12 1/4" • 15.1 - FUNCTION TEST BOP • | FALSE));"") | | |
| 7 | BOP activities | 12 1/4" • 15.11 - PRESSURE TEST BOP • | 5,5 | 4,5 | 4,75 |
| 8 | BOP activities | 12 1/4" • 15.0 - PRESS.TESTING OF CSG UNDER BOP TEST • | 2,25 | | |
| 9 | Flat spots | 12 1/4" • 1.00 - RIG UP AND TEAR DOWN • | 2,75 | | 2,5 |
| 10 | Flat spots | 12 1/4" • 6.33 - CHANGE HANDLING EQUIPMENT • | 2 | 5,75 | 2 |
| 11 | Flat spots | 12 1/4" • 13.00 - RIG UP AND DOWN CEMENT EQUIPMENT • | 3,25 | 2,25 | 2,25 |
| 12 | Flat spots | 12 1/4" • 2.96 - PREMEETING • | | 1 | |
| 13 | Flat spots | 12 1/4" • 12.11 - RIG UP CASING/LINER EQUIPMENT • | 1,75 | 2,5 | 7 |
| 14 | Flat spots | 12 1/4" • 12.12 - RIG DOWN CASING/LINER EQUIPMENT • | | 0,5 | 5,5 |
| 15 | Flat spots | 12 1/4" • 2.97 - Washing, cleaning, prep for next op • | | 1,25 | |
| 16 | Other | 12 1/4" • 2.95 - Other activities • | 1,25 | | |
| 17 | Service operations | 12 1/4" • 6.12 - MWD HANDLING • | 2,75 | 0,5 | 0,25 |

*Figure 32 Function used to collect data for the 12 1/4 in. section*

An Excel pivot chart is created for each section for the purpose of presenting the data. This overview makes it possible to click on the different groups and look at the subgroups underneath, and which subgroup has the biggest impact on the values. For instance, Fig. 33 illustrates how the button adjacent to “BOP activities” can be clicked to reveal all subgroups that are connected to that exact group. Plotting these data gives the researcher an overview over the operations and deviations in either positive or negative direction can be investigated to further increase the efficiency in the operation.

| Row Labels | Well X | Well Y | Well |
|---|---|---|---|
| ⊞ **BHA** | **12,5** | **7** | **14,25** |
| ⊟ **BOP activities** | **5,75** | **5** | **10,75** |
| ⊟ **12 1/4" • 14.17 - RIG DOWN BOP RUNNING EQUIPMENT •** | **0** | **0** | **0,75** |
| ⊟ 0,75 | 0 | 0 | 0,75 |
| ⊟ | | | |
| | 0 | 0 | 0,75 |
| ⊞ **12 1/4" • 14.23 - RUN, LP-RISER / DIVERTER •** | **0** | **0** | **1** |
| ⊞ **12 1/4" • 15.0 - PRESS.TESTING OF CSG UNDER BOP TEST •** | **0** | **0** | **2,25** |
| ⊞ **12 1/4" • 15.1 - FUNCTION TEST BOP •** | **1** | **0,5** | **1,25** |
| ⊞ **12 1/4" • 15.11 - PRESSURE TEST BOP •** | **4,75** | **4,5** | **5,5** |
| ⊞ **Casing** | **35** | **41,25** | **30** |
| ⊞ **Circ./cond.** | **17,5** | **16,25** | **31,75** |
| | | | |
| ⊞ **Drill** | **57** | **52** | **61,75** |

*Figure 33 Clip out from an Excel pivot chart for a 12 ¼ in. section*

## 6.4 Presenting data

The operation has been divided into five different groups of responsibility on the same principle as the ones presented in Fig. 22. The groups are COSL, Operator, Shared, Service operations and Waiting on Weather (WOW). These groups cover the whole time cap of the operation and gives an overview of how much each group directly influence the operation.

Each group with explanations are presented in Table 5.

*Table 5 Grouping regarding responsibility*

| Group | Description | Operations |
|---|---|---|
| COSL | *All operations that COSL Drilling directly affects and are responsible for.* | •Running, pulling, testing and landing BOP<br>•All operations related to tripping except restricted tripping since this is restrictions made by the operator.<br>•Running of casing<br>•Prejob meetings, rigging up/down equipment<br>•Downtime due to COSL equipment failure and maintenance |
| Operator | *All operations that the operator is responsible for. COSL Drilling has little or no impact on the time used on these operations.* | •Waiting on operator's decision regarding further operation<br>•Pressure test of casing<br>•Waiting on cement<br>•FIT/Leak off test<br>•Operator planned maintenance<br>•Downtime due to supply vessels/ logistics |
| Shared | *Responsibility is shared between the operator and COSL Drilling. E.g. restricted tripping where the operator has set a max pulling or running speed of pipe.* | •Drilling in general<br>•Circulation related activities<br>•Reaming/ back reaming/ under reaming<br>•Restricted tripping |
| Service operations | *All operations done by service personnel on the rig. These operations are not affected or dependent on COSL Drilling.* | •Surveys<br>•Logging<br>•Wireline operation<br>•Cementing<br>•Downtime caused by service companies |
| WOW | *This group includes all stop in operation related to waiting on weather.* | |

## 6.6 Normalization

The data collected from the drilling reports are originally given in hours. The data in this thesis are normalized on length in order to make it possible to directly compare each well and each well section. No well data in tables or plots are given in hours. This for the purpose of protecting the data. Instead the values are given in minutes per meter. This is done by means of using the length of the specific section with the seabed as datum plane [8]. This makes data for each specific section comparable. It is not possible to compare across sections since they are normalized with different reference values.

# 7. Results

## 7.1 Responsibility distribution

The responsibility of the different operations have been divided into five groups. An explanation to the different groups was presented in Table 4. The average of these values have been calculated for the wells studied in this thesis and the results are presented in Fig 34. This is done for the purpose of defining the activities controlled solely by the drilling contractor [7], in this case COSL Drilling. The rest of the groups defined in Table 4 are presented as *other* in Fig. 34. The figure illustrates that operations controlled by COSL Drilling equals on average 40% for the first 4 sections, meaning all operation from 36 in. to prior of drilling 8 ½ in. section.

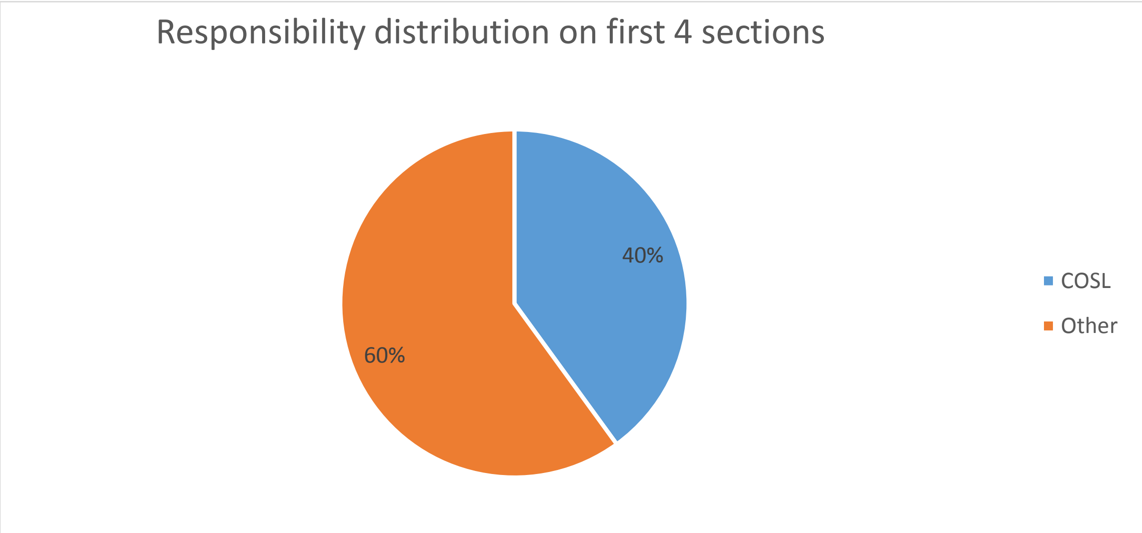



*Figure 34 Average responsibility distribution*

## 7.2 Overview of the 36 inch sections

Four wells have been compared drilling the 36 inch section. All wells are drilled on more or less the same seawater depth.

Well C and D are drilled in combination. This means the 36 inch section were drilled, cased and cemented for well C, then the rig was moved to do the same on well D. The 26 inch section were then drilled, cased and cemented for well D, before the rig was moved back to drill, case and cement the 26 inch section of well C.

Well B was drilled during the winter while Well C & D were both drilled during the summer months. Bad weather during the winter months slows down the operation.

The more time used on tripping and BHA in Well B is due to bad weather. It led to an additional trip in the hole for the purpose of checking for fill before the conductor job, since the open hole 36 inch section had been standing static during the WOW. Pipe was also picked up from deck and racked in the derrick in advance of running the 36 inch BHA, and this will also add up to the tripping time.

A lot of maintenance were done in advance of the drilling of Well B. This includes pit cleaning and explains the high time consumption on maintenance.

The peak in flat spots for Well C, in service operations for Well B and marine operations for Well A in Fig. 35 are for the same reason. The installation of the pump placed on seabed to spread the cuttings have been reported in three different ways in the Rig Manager system. The specific values are given in Table 6. Since the same operations may be reported under different sub codes in Rig Manager, all data need to be crosschecked with the drilling report where a more detailed description of each sub code is present.

- As rigging up/down of equipment and thereby covered in the flat spots category (Well C)
- As ROV operations and thereby in the *service operation category* (Well B)
- As move rig to well/off well and thereby in the *marine operation category* (Well A)

*Table 6 Specific time consumption during the period of the drilling of the 36 inch hole sections*

| | Well A | Well B | Well C | Well D | *Best possible* |
|---|---|---|---|---|---|
| BHA | 5,63 | 9,18 | 3,49 | 3,23 | *3,23* |
| Casing | 6,91 | 11,65 | 9,21 | 6,45 | *6,45* |
| Circ./cond | 2,09 | 2,29 | 1,90 | 0,97 | *0,97* |
| | | | | | |
| Drill | 11,58 | 12,71 | 10,16 | 7,90 | *7,90* |
| Flat spots | 4,34 | 4,94 | 12,06 | 6,61 | *4,34* |
| Maintenance | 0,00 | 47,29 | 0,00 | 0,00 | *0,00* |
| Marine Operations | 9,16 | 4,41 | 3,97 | 2,90 | *2,90* |
| Other | 0,00 | 0,00 | 0,16 | 0,00 | *0,00* |
| Pressure testing/drills | 0,00 | 0,00 | 0,00 | 0,32 | *0,00* |
| Reaming | 0,32 | 0,00 | 0,00 | 0,00 | *0,00* |
| Service operations | 2,41 | 5,65 | 3,33 | 4,35 | *2,41* |
| Trip | 2,73 | 12,53 | 3,17 | 2,90 | *2,73* |
| Total | 45,18 | 194,82 | 50,48 | 38,06 | *30,94* |

It is possible to avoid the large job with pit cleaning after a previous oil based section by means of drilling the top hole sections similar to well C & D simultaneously.

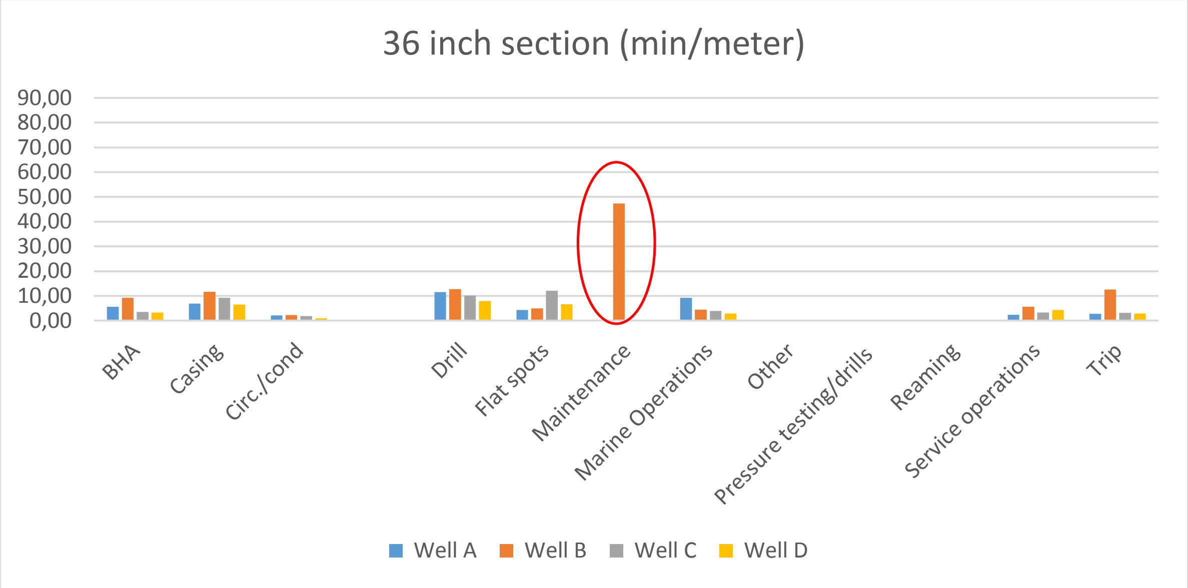



*Figure 35 Time consumption of the different operations, 36 inch section*

The stacked bar diagram in Fig. 36 gives an overview over how effective each well section is compared to the "Best possible well section". The best possible well section is a combination of the most effective operations in the wells studied. In Fig. 36 and 37 both maintenance and downtime/WOW are not included for the purpose of giving a better overview over the rest of the operations.

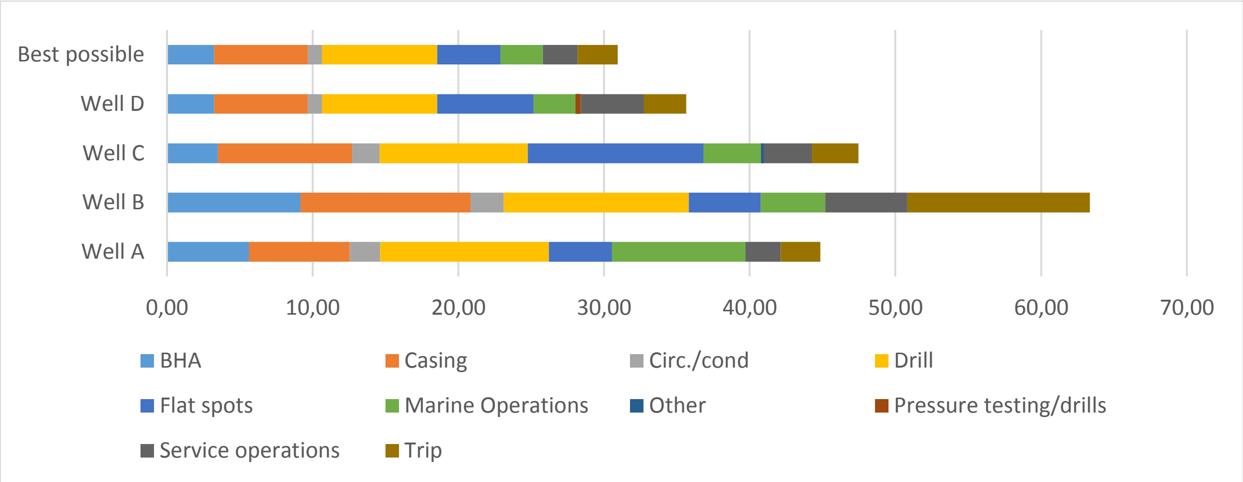



*Figure 36 Stacked bar diagram illustrating the 36 in. section excluding maintenance and WOW/downtime*

Figure 36 shows the potential of reaching COSL Drilling's technical limit based on the four wells studied. While well D is close to the technical limit, there is potential of reducing the time used on well A, B, C.

The groups that stand out in Fig. 37 is BHA, casing, drill, flat spots, marine operations, service operations and trip. Improving the efficiency of all these operations will show results in the total well time. Figure 37 indicates that it is difficult to drastically increase the efficiency by means of determining one specific operation to improve. An overall improvement is needed.

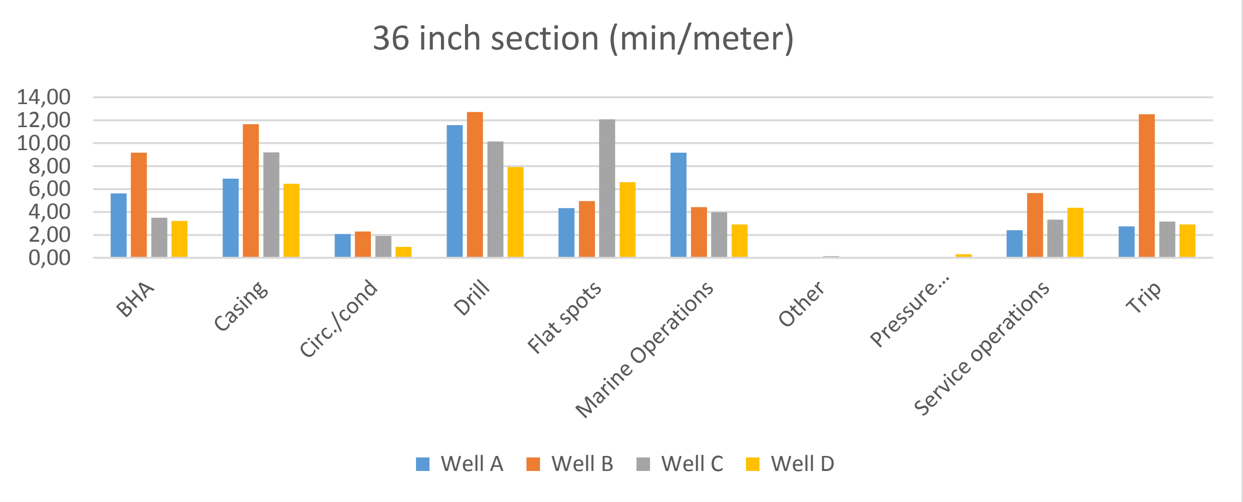



*Figure 37 The 36 in. section (min/meter)*

## 7.3 Overview of the 26 inch sections

The top column in Fig. 39 illustrates the best possible time to complete the 26 in. section based on the four wells studied. It is seen that Well C is closest to the technical limit.

Well B used more time on BHA than the other wells, as illustrated in Fig. 39. It is reported in the daily drilling report (DDR) that parts of the BHA were of unsuitable lengths. Occasionally it is not possible to make up the connection with the Iron Roughneck. It is then necessary to use manual rig tongs for the purpose of making up the connections to the correct torque. Stabilizators in conflict with the spinner tong on the Iron Roughneck were the reason for the use of rig tongs in Well B. Work with manual rig tongs is time consuming and there is a risk of finger injuries if the equipment is not handled correctly.

Both Well A and Well B had difficulties with the OWS casing tong. This affected the running speed of the casing. This is presented in Table 7.

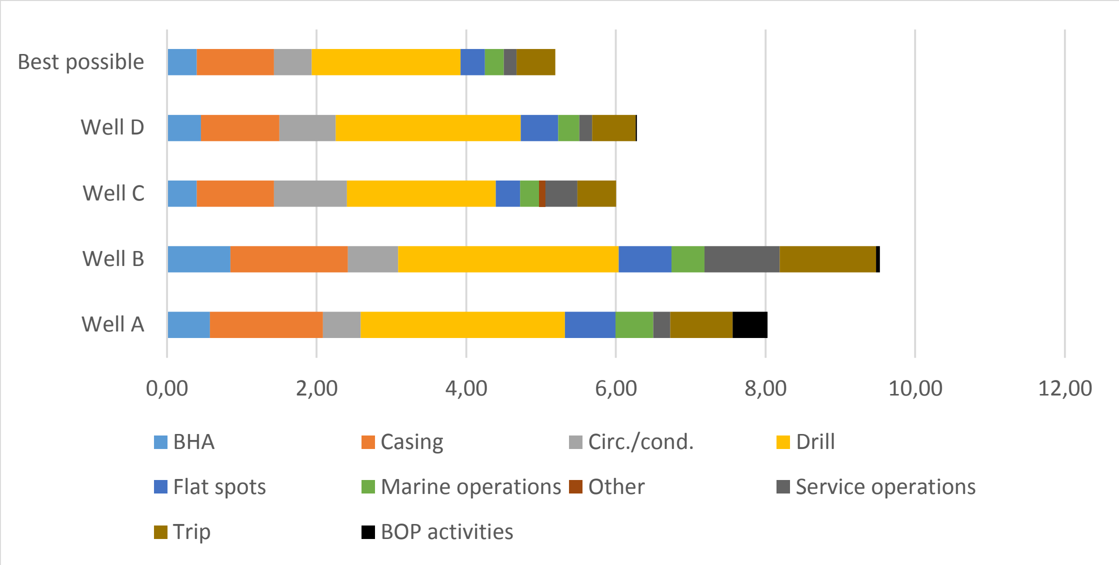



*Figure 38 Stacked bar diagram illustrating the 26 in. section excluding maintenance and WOW/downtime*

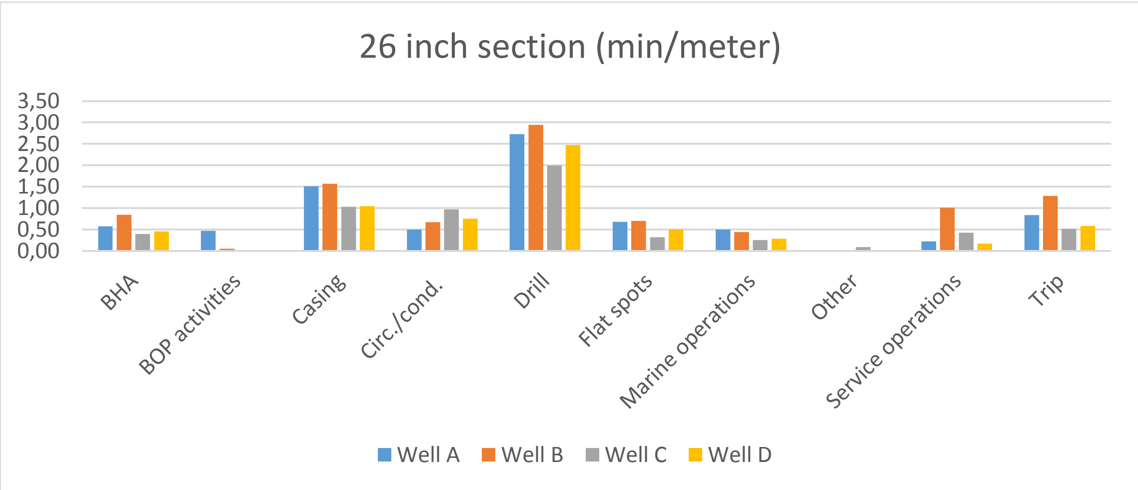



*Figure 39 The 26 in. section*

*Table 7 Specific time consumption during drilling of the 26 inch sections (min/meter)*

| | Well A | Well B | Well C | Well D | Best possible |
|---|---|---|---|---|---|
| BHA | 0,57 | 0,85 | 0,40 | 0,45 | 0,40 |
| BOP activities | 0,47 | 0,05 | 0,00 | 0,02 | 0,00 |
| Casing | 1,51 | 1,57 | 1,03 | 1,05 | 1,03 |
| Circ./cond. | 0,50 | 0,67 | 0,97 | 0,75 | 0,50 |
| Drill | 2,73 | 2,95 | 1,99 | 2,47 | 1,99 |
| Flat spots | 0,68 | 0,71 | 0,32 | 0,50 | 0,32 |
| Maintenance | 0,21 | 0,00 | 0,53 | 0,00 | 0,00 |
| Marine operations | 0,50 | 0,44 | 0,25 | 0,28 | 0,25 |
| Other | 0,00 | 0,00 | 0,09 | 0,00 | 0,00 |
| Reaming | 0,02 | 0,00 | 0,00 | 0,00 | 0,00 |
| Service operations | 0,23 | 1,01 | 0,43 | 0,17 | 0,17 |
| Trip | 0,83 | 1,29 | 0,52 | 0,58 | 0,52 |
| Total | 16,84 | 23,72 | 8,01 | 6,59 | 5,50 |

## 7.4 Overview of the 17 ½ inch sections

Due to lack of comparable data, only two wells were used for comparison for the 17 ½ inch section. Figure 40 shows that Well B was overall more effective than Well A.

Well B is drilled in more recent time, hence more routine, equipment that works well and crews knowing the operations might be the reason for the difference.

Well A uses more time on BOP activities due to testing of the new diverter and mounting it to the flex joint. These two components are normally connected together and stored on the rig, but had in this case been onshore for service/repairs.

Well A uses significantly more time on the process of making up the slip joint and making storm loops in the moon pool. This is work that needs a lot of manual handling and work with personnel above open sea in the moon pool. The present work process and handling equipment available is cumbersome and need improvement. This may in the future decrease the time of the total BOP operation.

Well A had an extra trip due the fact of difficulties with the geopilot in the BHA. This explains more time used on BHA. The BHA operation from other sections have been reported in the 17 ½ in. section since these values does not correspond with the time from the DDR.

Well A had difficulties establishing circulation through the float in the casing shoe. Pressure was building up and they had to repeat this step several times. This explains the almost twice as much time used on circulation as Well B.

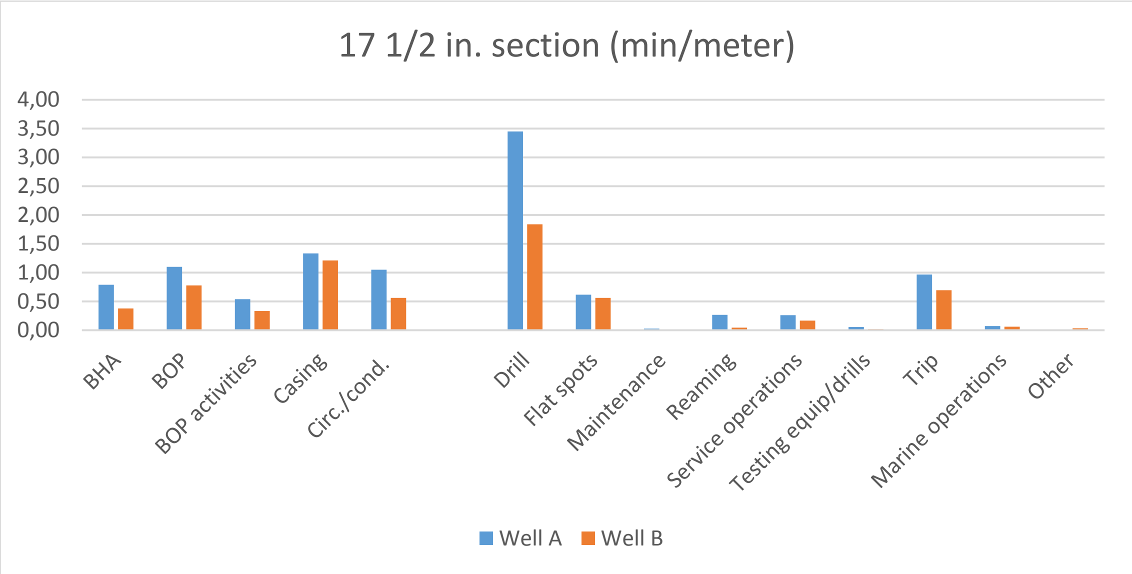



*Figure 40 Time consumption of the different operations, 17 ½ inch section*

Figure 41 illustrates how efficient the two wells are, compared to the best results. In this scenario with only two wells, the "best possible" and well B are almost equal. This indicates that Well B has done each operation illustrated in Fig. 41 more effective than well A. With only two wells, the "best possible" is not very representative since it is only based on those two wells. With more wells to compare the "best possible" get closer to the fastest operation possible for COSL Drilling, the technical limit. This can then be used for comparison with all the same well sections drilled at a later time. A presentation similar to the one for the 12 ¼ in. section in Fig. 42 will then give an overview over how effective the well section was compared to "the world record". Figure 41 can then be used for the purpose of giving more detail of where the operation failed or succeeded.

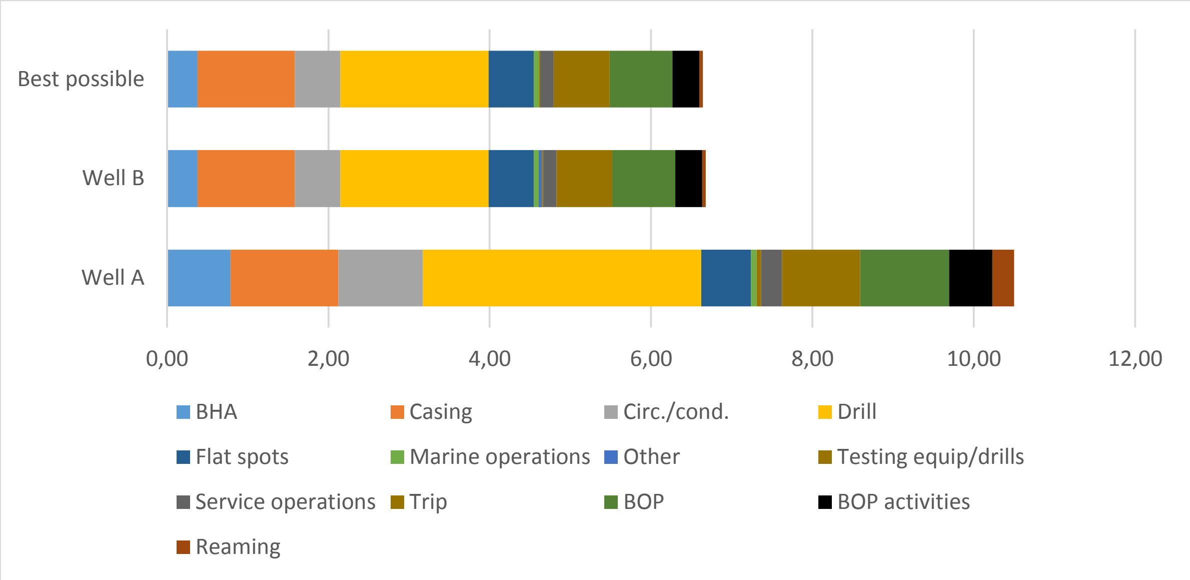



*Figure 41 Stacked bar diagram illustrating the 17 1/2 in. section excluding maintenance and WOW/downtime*

## 7.5 Overview of the 12 ¼ inch sections

Figure 42 shows the relationship between the technical limit, invisible lost time and conventional lost time/downtime for Well A. The technical limit is based on the total of the best result for each operation of the wells studied.

Invisible lost time is the total of the extra time used on each part the operation, meaning how much slower the operation is during the time of Well A compared to the best results of the other wells.

Conventional lost time/ downtime is time spent on equipment failure, waiting on weather e.g.

The technical limit and invisible lost time add up to the time of the normal operation, meaning the operation excluding downtime and WOW.

As illustrated in Fig. 42, a well operation where each part of the operation (Table 9) is optimal, and without any downtime, the well time of that specific section could be reduced to approximately 50% of actual duration.

Figure 43 gives a straightforward overview over the time consumption of the different groups. In Fig. 44 it is seen that Well B is closest to the technical limit.

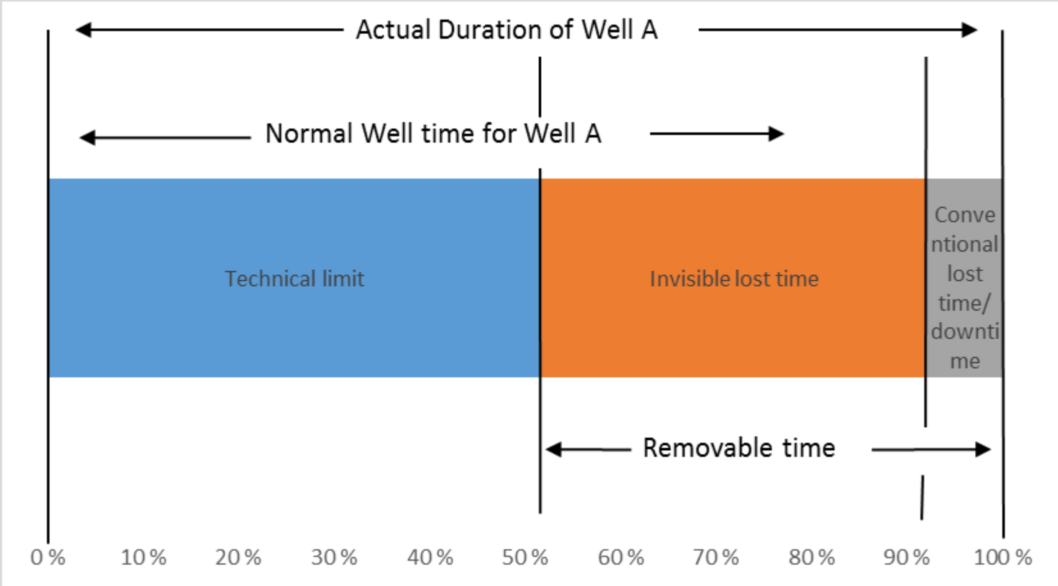



*Figure 42 Actual duration of the 12 ¼ inch section for Well A*

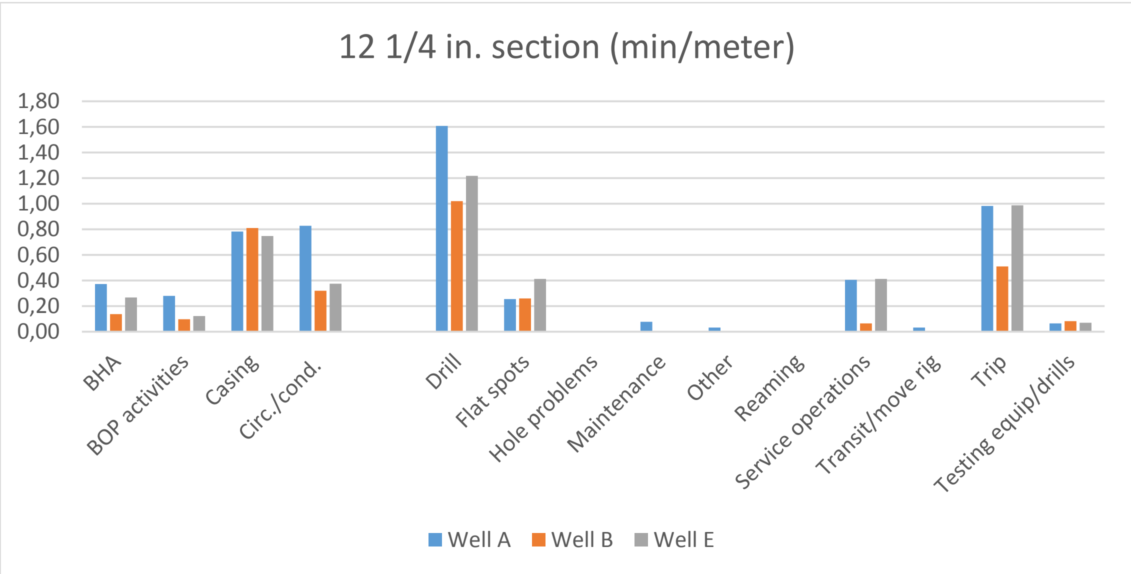



*Figure 43 Time consumption of the different operations, 12 1/4 inch section*

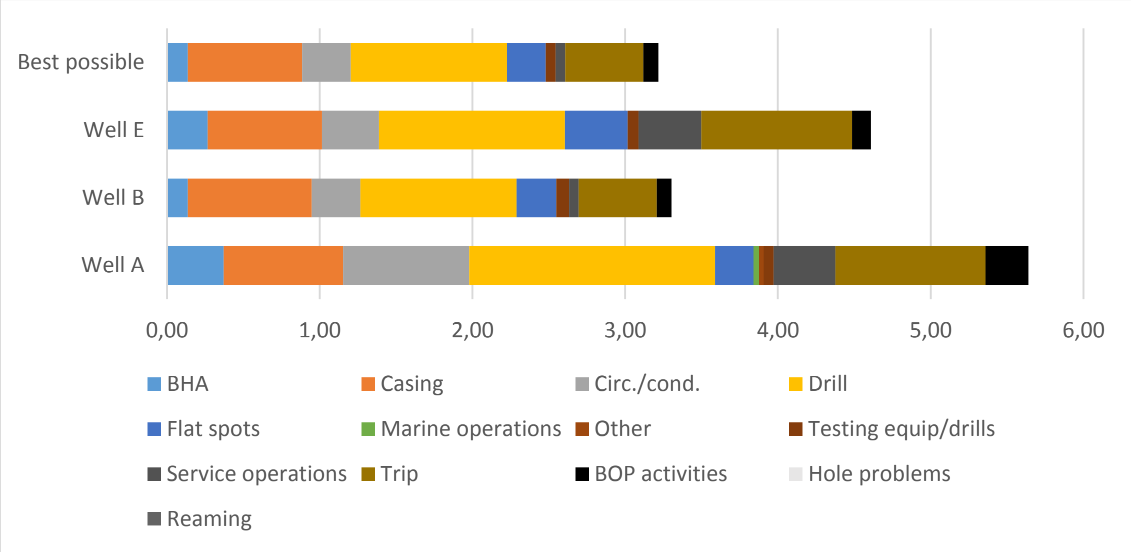



*Figure 44 Stacked bar diagram illustrating the 12 1/4 in. section excluding maintenance and WOW/downtime*

Table 8 shows the specific time consumption of the operations. In addition a responsibility column is added to illustrate the responsible instance for each operation. The groups are similar to the ones that was defined in Table 5. The groups are COSL, Shared (SH), WOW, Operator (OP), Service operations (Service).

*Table 8 Specific time consumption during the period of drilling of the 12 ¼ inch hole sections*

| | Responsibility | Well A | Well B | Well E | Best possible |
|---|---|---|---|---|---|
| BHA | **COSL** | **0,37** | **0,14** | **0,27** | **0,14** |
| BOP activities | **COSL** | **0,28** | **0,10** | **0,12** | **0,10** |
| Casing | **COSL, SH** | **0,78** | **0,81** | **0,75** | **0,75** |
| Circ./cond. | **SH** | **0,83** | **0,32** | **0,37** | **0,32** |
| Drill | **SH** | **1,61** | **1,02** | **1,22** | **1,02** |
| Flat spots | **COSL** | **0,25** | **0,26** | **0,41** | **0,25** |
| Hole problems | **SH** | **0,00** | **0,00** | **0,00** | **0,00** |
| Maintenance | **COSL, OP** | **0,08** | **0,00** | **0,01** | **0,00** |
| Other | **COSL, SH, OP** | **0,03** | **0,00** | **0,00** | **0,00** |
| Reaming | **SH** | **0,00** | **0,00** | **0,00** | **0,00** |
| Service operations | **SERVICE** | **0,40** | **0,06** | **0,41** | **0,06** |
| Marine operations | **COSL** | **0,03** | **0,00** | **0,00** | **0,00** |
| Trip | **COSL, SH** | **0,98** | **0,51** | **0,99** | **0,51** |
| Testing equip/drills | **COSL** | **0,07** | **0,08** | **0,07** | **0,07** |
| Total | | **7,21** | **3,80** | **4,78** | **3,38** |

# 8. Observations and improvement proposals

## 8.1 Casing operation

The casing joints are today lifted to the catwalk machine from pipe deck with the protector on. The casing is landed with the rear end in the “moped” marked with a blue arrow in Fig. 45. The protector is then taken off after the elevator is latched on and the rear end of the casing is lifted off and is free of the “moped” as illustrated in Fig. 17. Personnel has to enter red zone for the purpose of taking off the protector and all machinery must therefore stand still. It is possible to switch places of the two trollies in Fig. 45 and the one used is put in front prior to the job. The catwalk trolley in the right picture in Fig. 45 is used for e.g. riser handling as shown in Fig. 10. When the elevator is latched on the casing, the “moped” is put in neutral gear by the operator.

The risk is to drag the rear end of the casing joint out of the “moped” when the driller lifts up. The casing will then drop out of the “moped” and down on the catwalk (see red arrow on Fig. 45). If the casing is run without protector, there is a risk of damaging the threads.

By means of rebuilding the “moped” to a lower and wider trolley, this problem may in the future be avoided and make it easier for the deck crew to land the casing. Today’s “moped” in Fig. 45 is narrow and makes the lifting operation unessesary difficult for the deck crew.

*Figure 45 Catwalk with "moped" and catwalk trolley*

A calculation of possible time savings is presented in Table 10. The calculations are done with different expected time for removing the protector on the drill floor (Fig. 17). The time spent on removing the protectors was noted during the period of running 7 in. liner. This was with an experienced crew, but they reported around

10 second per protector. This is a minimum since the 7 in. liner protectors are small and easy to handle compared to e.g. 13 3/8 in. protectors. Removal time is expected to be between 10 and 50 seconds since in a number of cases the protectors get stuck and takes more time.

*Table 9 Calculation on running casing without protectors (calculated in hours)*

| | | | |
|---|---|---|---|
| **Casing joints** | **150** | **joints** | |
| **Running speed** | **15** | **joints/hour** | |
| **Time on job** | **10** | **hour** | |
| | | | |
| **Time to remove protector [s]** | **Without protector [h]** | **Time saved [h]** | **Time saved [%]** |
| 10 | 9,583 | 0,417 | 4,2 |
| 15 | 9,375 | 0,625 | 6,3 |
| 20 | 9,167 | 0,833 | 8,3 |
| 30 | 8,750 | 1,250 | 12,5 |
| 40 | 8,333 | 1,667 | 16,7 |
| 50 | 7,917 | 2,083 | 20,8 |

The downside is increased risk of damaging the threads while lifting the casing from pipe deck to the catwalk machine. This can be limited by means of covering all metal surfaces on the new trolley with teflon or rubber.

## 8.2 Handling of BHA

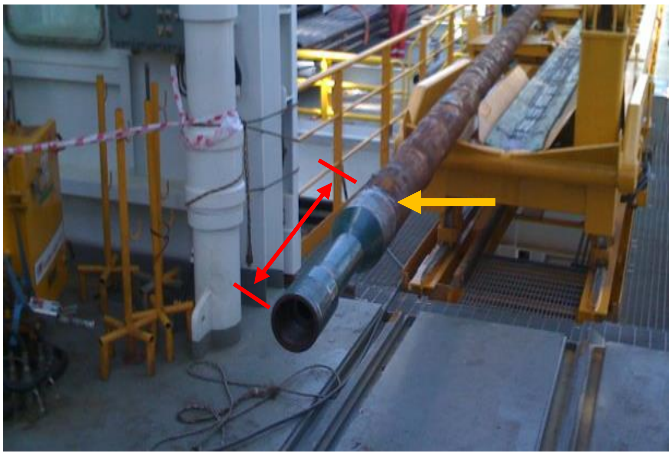


*Figure 46 Drill collar with lifting sub mounted on*

Handling of BHA is the operation that involves the most time consuming work with personnel inside the red zone. Limiting this to a minimum is in COSL Drilling's interest according to their values.

Therefore, a more effective way of handling BHA saves time and leads to an overall safer operation. Fig. 46 shows a drill collar lying in the catwalk machine with a lifting sub mounted on. The red arrow indicates the lifting sub and the yellow arrow illustrates the connection between the lifting sub and the drill collar. This lifting sub is for handling with the elevator on the drill floor (Fig. 47). The elevator latches on the narrow part of the lifting sub in Fig.46|, and the wider top of the lifting sub rests on top of the elevator. The lifting sub is for lifting on drill floor only, and will not enter the well. In a scenario where the total

*Figure 47 The elevator (red module) is ready to lift the pipe out of the catwalk*

BHA only comes with one lifting sub (Fig. 46) the rig crew have to manually spin this out and remove it after the drill collar is landed in slips. The lifting sub is then mounted on the next piece of the BHA lying in the catwalk machine. This step has to be repeated for each piece of the BHA, usually from 10-15 pieces similar to the one in Fig. 46. This process takes approximately 3 minutes if there is a moderately experienced crew (tested with a stopwatch offshore on COSL Pioneer). If every piece of the BHA has a lifting sub mounted on (Fig. 46) when they are lifted up from pipe deck to the catwalk, it is possible to save 30-45 minutes of manual handling on one BHA handling. This will reduce the time where personnel is inside the red zone.

## 8.3 Tripping

Tripping is an operation with high focus due to the KPI system. By means of comparing Figs. 17, 18, 19 and 20 it is noticed that the total tripping operation (Table 2) is a significant amount of the total time used on the latter sections, similar to the 12 ¼ in. section. In addition, it is still a high focus point for the operator and fast tripping speed is noticed positively in the industry. Authors experience and testimonials from personnel offshore indicates that the fingerboard and XY Hydraracker is the bottleneck for a more consistent and effective tripping operation.

The X-Y Hydraracker has great potential, but is today not working properly. The system is designed to run in auto-sequence where the operator only has to have a joystick in forward position for the purpose of operating the crane. Commonly, the X-Y Hydraracker has to be operated in manual mode, due to various problems. To run the X-Y Hydraracker in manual mode takes significantly longer time. To have a proper working X-Y Hydraracker would definetly improve the tripping time.

Fingerboard problems are in addition a common error that leads to waiting during the period of a tripping operation. Fingers that are stuck or damaged air hoses are common difficulties. There should be kept high focus on fingerboard maintenance. Today's system has one air supply to all fingers, with one hose to each finger. This means that if the rubber hose on one of the fingers leaks all other finger outside this one do not get sufficient air and will not open. To change a hose on a finger is a very time consuming job and is not possible to accomplish during the period of a trip or if the fingerboard is full of stands.

## 8.4 Communication, team work and efficiency in the daily operation

There is a high focus on the front page of the RISK card covering the work planning process. Additionally, it is important to focus on the back of the card, the part concerning evaluation, experience and suggested changes. After action reviews are something that is talked a lot about, but not executed much. After operations that COSL Drilling have full impact on, the crews should in some instances sit down and evaluate the job done. There is often no time for this during the period of normal operation. In this case the evauation can be taken in combination with the drilling forum that each crew has once every offshore period. If the drilling crew is informed concerning this prior to a job (typical BHA, Casing, Tripping, running/pulling BOP etc.), the back of the RISK card may be used for writing cues during the period of the operation. The crew can then present their thoughts on the after work meeting where it is important that the whole crew participates. This because the driller in numerous cases see things that the roughnecks do not manage to see, and the other way around.

It is important to make an arena where it is possible to admit where the operation stand still and have no progress. This can be everything from waiting for a colleague to get some tools, a decision from the driller, waiting on the deck crew etc. By means of doing this, an effective operation will get the focus and it will be easier to realize where to improve. This will make the crews more aware on "flat spots" in the operation.

Additionally, it is important to "educate" the deck crews and include them more in the drilling operation. Waiting on casing from deck is in the majority of instances the bottleneck running casing in the hole. This should not be necessary. This can be avoided by coordinating with the deck crews and make them realize how important they are in every operation that involves picking up and laying down pipe, casing and equipment from/on deck.

One of the more experienced roughnecks on a crew onboard said after running around 20 casing joints per hour that 25 would be no problem if they did not have to wait for the deck crew to supply with casing in the catwalk. 20 joints per hour is already above target speed. This is not an attack on the deck crew since they perform a great job. It has to do with lack of information and communication. This can be solved with better cooperation between both disciplines and a deck crew that want to be a part of an effective drilling operation.

Prejob-meetings regarding the drilling operation are normally held by the driller or assistant driller. By letting the roughnecks have these meetings they really have to familiarize themselves with the procedures and the job to be done. This may in all likelihood meet resistance in the beginning (ref. Ch. 5.2), but could make the drilling personnel familiar with the different operations faster. This will again lead to a more effective operation.

# 9. Conclusion

COSL Drilling is as a contractor responsible for approximately 30-40% of the total well operation prior to drilling the 8 ½ in. section. This is time that COSL Drilling controls alone as a drilling contractor. Meaning that this time can be reduced to a minimum by revising procedures, work processes etc. in COSL Drilling's organization without influence of the operator. The rest of the time used on a well is either the operator's responsibility, waiting on weather, downtime, service companies or a shared responsibility between the previous mentioned.

By means of grouping all the small parts of the operation, a system has been suggested to analyze and evaluate future wells against a perfect well or the technical limit. This reveals where the operation is effective and where it was ineffective compared to earlier wells. Each part of the operation can be examined further by use of the pivot chart presented since the pivot chart gives an overview over all the subgroups as well. The ambition was to make a system where the well data can be downloaded from Rig Manager and that all plots, including the pivot chart was made automatically. This worked, but since there is uncertainty and variations in the reporting in Rig Manager all data has to be crosschecked with the daily drilling reports. This makes the system more time consuming than a case where the reporting in Rig Manager is consistent.

There is uncertainty in exact time reported for each operation and there is cases where the same code have been used for reporting the same operation in Rig Manager reporting in Rig Manager using different codes for the same operation. This may in some cases lead to an ambitious presentation of the perfect wells presented. The

The plots presented reveal that BHA handling and casing operation are some of the operations that COSL Drilling as a contractor have full influence to improve. Flat spots vary from well to well. It is however reason to believe that activities related to the flat spots group are not always reported in Rig Manager.

The handling of the BHA represents the operation that involves the most manual handling by the rig personal. The work process is taking place in the red zone on the drill floor, consequently a more effective operation would in addition to saving rig time lead to a safer operation. Making sure the BHA comes in suitable lengths that is compatible with the Iron Roughneck will lead to less interruptions and more flow in the operations. Sufficient lifting subs should come with the BHA at all time to avoid having to use the same lifting subs on more than one piece. In addition the lifting subs should be mounted on the pipe deck with the knuckle boom crane and deck personal to save rig time.

It is possible to run casing without protectors. Consequently, a work process with people in the red zone is avoided and it is in theory possible to run the whole casing operation without ever having people in the red zone. Rebuilding the back trolley of the catwalk machine where the pin end of the casing is landed will make it possible to run casing without having to uses protectors. The protectors can then be taken off on pipe deck and consequently, save rig time. This again will improve safety of the operation by removing personnel from the red zone.

A modification of the trip where it is possible to empty/fill one trip tank while tripping on the other tank is requested by COSL Drilling. For the wells studied in this thesis approximately a total of one hour is used for empty/filling trip tank during the period of the 17 ½ and 12 ¼ in. sections. However, it is expected that this is not always reported in the daily drilling report. This time is saved by means of having two trip tanks with separate lines. The downside is that the time during emptying/filling trip tank is in some instances used for critical preventive maintenance/repairs to avoid downtime. E.g. changing dices on the IronRoughneck or XY Hydraracker, repair of oil leakages etc. One may assume that removing this possibility of "free time" for repairs may in the future lead to an increase in downtime due to this for COSL Drilling, but a reduction in overall tripping time.

It is important to perform after work meetings to reveal positive and negative parts of the operation. Discuss where the operation experienced "flat spots" and take all small stops in the operation into account. It is important to announce these meetings in front of the operation and encourage the drilling crew to use the back of the RISK card for small notes during the operation.

It is important arrange meetings for the purpose of advertising the start of major activities or in an effort to give recognition of what personnel have accomplished. If there are challenges, inform along the way and address what has to be done concerning them. Skeptical people may first approve when they see clear proof of progress. It is important to get through to the experienced roughnecks from each crew. It may be difficult to implement change if one of the more experienced roughnecks is against it.

## Further work

It would be interesting to look at the 8 ½ in. sections isolated since this is approximately 50 % of the total well operation [8].

As COSL's three identical semisubmersible rigs gets more experience and more well data it is possible to do an internal benchmarking analysis up against each rig.

It is possible to identify and study rigs from other contractors that is more efficient on single operations using the Statoil Pronova system, and possibly improve further through an external benchmarking analysis.

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# Appendix A Detailed overview of operation grouping

## BHA

This group includes making up/laying down the BHA. Primarily the operation of building the BHA done by the drilling contractor personal. MWD operations along the lines of downloading data from tools etc. is not included in this group.

## BOP

Primarily operation directly related to running/pulling the BOP. Includes running of riser, slip joint etc.

Connector test after landing and function test of the BOP is also included in this group.

## BOP activities

Preparing to run/pull the BOP and rigging down equipment after running/pulling. Pressure testing of the BOP

## Casing

All operation related to setting of casing. This includes running and landing the casing, pumping cement, pressure test cement and leak of/FIT test.

## Circ./cond

This group contains all operation related to circulation and conditioning of the mud. Hole cleaning, displacement, SCR's, breaking circulation and bottom ups are all covered in this group.

## Downtime/WOW

Covers everything from downtime due to equipment failure to waiting on weather.

## Marine Operations

Move rig to/off location, anchor handling e.g.

## Flat spots

Rig up/down equipment, clean rig floor, prejob meetings, change handling equipment. Generally activities that the contractor are responsible for, where there is no direct progress in the operation.

| **36 in. section** | |
|---|---|
| **Description** | **Detail** |
| Marine Operations | 36" • 24.98 - MOVE RIG TO WELL/OFF WELL • |
| Marine Operations | 36" • 24.40 - SKID • |
| Marine Operations | 36" • 6.70 - MOVE RIG TO/OFF WELL • |
| Flat spots | 36" • 13.00 - RIG UP AND DOWN CEMENT EQUIPMENT • |
| Flat spots | 36" • 6.33 - CHANGE HANDLING EQUIPMENT • |
| Flat spots | 36" • 2.96 - PREMEETING • |
| Flat spots | 36" • 2.97 - Washing, cleaning, prep for next op • |

| | |
|---|---|
| Flat spots | 36" • 1.00 - RIG UP AND TEAR DOWN • |
| Flat spots | 36" • 12.11 - RIG UP CASING/LINER EQUIPMENT • |
| Flat spots | 36" • 12.12 - RIG DOWN CASING/LINER EQUIPMENT • |
| Pressure testing/drills | 36" • 15.3 - PRESSURE TESTING KELLY COCKS • |
| Other | 36" • 2.95 - Other activities • |
| Service operations | 36" • 18.01 - ROV operations • |
| Service operations | 36" • 10.00 - DEVIATION SURVEY • |
| Casing | 36" • 12.89 - RUN CONDUCTOR • |
| Casing | 36" • 12.50 - MOVE RIG RUN PULL CASING/LINER • |
| Casing | 36" • 12.90 - PICK UP AND MAKE CASING HANGER • |
| Casing | 36" • 12.16 - RUN LINER ON LANDING STRING IN CSG • |
| Casing | 36" • 13.10 - PRESSURE TEST CEMENT • |
| Casing | 36" • 13.02 - PUMP CMT • |
| Casing | 36" • 13.01 - WAIT ON CEMENT • |
| Casing | 36" • 12.00 - RUN CASING IN CASED HOLE • |
| Casing | 36" • 17.13 - Placing/ Retrieving well tool/ Equ • |
| Circ./cond | 36" • 5.10 - CIRCULATE HOLE CLEAN • |
| Circ./cond | 36" • 5.40 - PUMP PILL • |
| Circ./cond | 36" • 5.20 - DISPLACE WELL/RISER • |
| Circ./cond | 36" • 5.00 - CIRCULATE AND CONDITION MUD • |
| Trip | 36" • 6.50 - RIH OH • |
| Trip | 36" • 6.00 - RIH CH • |
| Trip | 36" • 6.60 - POOH OH • |
| Trip | 36" • 6.01 - POOH CH • |
| Trip | 36" • 6.81 - POOH while L/D DP to deck • |
| Trip | 36" • 6.78 - POOH OH restricted • |
| Trip | 36" • 6.79 - POOH CH restricted • |
| Trip | 36" • 6.77 - RIH OH restricted • |
| Trip | 36" • 6.02 - PUMP AND POOH OH • |
| Trip | 36" • 6.40 - FILL PIPE • |
| Trip | 36" • 6.41 - FLOW CHECK • |
| Trip | 36" • 6.30 - P/U DRILLSTRING • |
| Trip | 36" • 6.31 - L/D DRILLSTRING • |
| Trip | 36" • 6.71 - STAB IN HOLE • |
| Trip | 36" • 6.02 - PUMP AND POOH OH • |
| Trip | 36" • 6.22 - WASH DOWN • |
| BHA | 36" • 6.10 - MAKE UP BHA • |
| BHA | 36" • 6.11 - LAY DOWN BHA • |
| Reaming | 36" • 3.10 - BACKREAMING • |
| Drill | 36" • 2.00 - DRILL ACTUAL • |
| Drill | 36" • 2.30 - DRILL CEMENT • |
| Drill | 36" • 2.20 - HOLE OPENING • |
| Downtime/WOW | 36" • 8.00 - DOWNTIME, COSL - OTHER • |
| Downtime/WOW | 36" • 27.01 - Waiting for Operator's personnel • |
| Downtime/WOW | 36" • 8.30 - DOWNTIME, OTHERS • |
| Downtime/WOW | 36" • 23.00 - WOW DRILLING • |

| | |
|---|---|
| Downtime/WOW | 36" • 8.10 - DOWNTIME, COSL - EQUIPMENT FAILURE • |
| Maintenance | 36" • 7.00 - PLANNED MAINTENANCE • |
| Maintenance | 36" • 7.10 - INSPECTION OF RIG • |
| Maintenance | 36" • 7.20 - OPERATOR PLANNED MAINTENANCE • |

| **26 in. section** | |
|---|---|
| **Description** | **Detail** |
| Marine operations | 26" • 24.98 - MOVE RIG TO WELL/OFF WELL • |
| Marine operations | 26" • 6.70 - MOVE RIG TO/OFF WELL • |
| BOP activities | 26" • 14.18 - RIG UP BOP RUNNING EQUIPMENT • |
| BOP activities | 26" • 15.1 - FUNCTION TEST BOP • |
| BOP activities | 26" • 15.0 - PRESS.TESTING OF CSG UNDER BOP TEST • |
| Flat spots | 26" • 6.33 - CHANGE HANDLING EQUIPMENT • |
| Flat spots | 26" • 13.00 - RIG UP AND DOWN CEMENT EQUIPMENT • |
| Flat spots | 26" • 2.96 - PREMEETING • |
| Flat spots | 26" • 1.00 - RIG UP AND TEAR DOWN • |
| Flat spots | 26" • 2.97 - Washing, cleaning, prep for next op • |
| Flat spots | 26" • 12.11 - RIG UP CASING/LINER EQUIPMENT • |
| Flat spots | 26" • 12.12 - RIG DOWN CASING/LINER EQUIPMENT • |
| Other | 26" • 2.95 - Other activities • |
| Service operations | 26" • 18.01 - ROV operations • |
| Service operations | 26" • 6.14 - TEST MWD • |
| Service operations | 26" • 6.15 - TEST MWD • |
| Service operations | 26" • 2.80 - DIRECTION WORK • |
| Service operations | 26" • 10.00 - DEVIATION SURVEY • |
| Service operations | 26" • 10.10 - MWD LOGGING • |
| BHA | 26" • 6.10 - MAKE UP BHA • |
| BHA | 26" • 6.11 - LAY DOWN BHA • |
| Casing | 26" • 12.00 - RUN CASING IN CASED HOLE • |
| Casing | 26" • 12.10 - RUN CASING IN OPEN HOLE • |
| Casing | 26" • 12.90 - PICK UP AND MAKE CASING HANGER • |
| Casing | 26" • 12.14 - LAND/ PULL CSG ON LANDING STRING • |
| Casing | 26" • 13.02 - PUMP CMT • |
| Casing | 26" • 12.13 - SEAL ASSY / WEAR BUSHING • |
| Casing | 26" • 14.1 - NIPPEL UP / DOWN WELLHEAD • |
| Casing | 26" • 13.20 - PRESSURE TEST OF CASING • |
| Circ./cond. | 26" • 5.00 - CIRCULATE AND CONDITION MUD • |
| Circ./cond. | 26" • 12.20 - CIRC. CASING/LINER • |
| Circ./cond. | 26" • 5.20 - DISPLACE WELL/RISER • |
| Circ./cond. | 26" • 5.10 - CIRCULATE HOLE CLEAN • |
| Circ./cond. | 26" • 5.40 - PUMP PILL • |
| Circ./cond. | 26" • 5.50 - Circulate B/U • |
| Circ./cond. | 26" • 5.60 - Break Circulation • |
| Drill | 26" • 2.00 - DRILL ACTUAL • |
| Drill | 26" • 2.30 - DRILL CEMENT • |

| | |
|---|---|
| Drill | 26" • 2.40 - TIME DRILLING • |
| Drill | 26" • 2.20 - HOLE OPENING • |
| Trip | 26" • 6.30 - P/U DRILLSTRING • |
| Trip | 26" • 6.31 - L/D DRILLSTRING • |
| Trip | 26" • 6.01 - POOH CH • |
| Trip | 26" • 6.50 - RIH OH • |
| Trip | 26" • 6.60 - POOH OH • |
| Trip | 26" • 6.73 - POOH RISER • |
| Trip | 26" • 6.76 - RIH CH restricted • |
| Trip | 26" • 6.78 - POOH OH restricted • |
| Trip | 26" • 6.75 - TRIPPING RISER WITH FULL BORE TOOLS • |
| Trip | 26" • 6.79 - POOH CH restricted • |
| Trip | 26" • 6.77 - RIH OH restricted • |
| Trip | 26" • 6.22 - WASH DOWN • |
| Trip | 26" • 6.21 - WORK PIPE • |
| Trip | 26" • 6.04 - PUMP SLUG • |
| Trip | 26" • 6.41 - FLOW CHECK • |
| Trip | 26" • 6.71 - STAB IN HOLE • |
| Trip | 26" • 6.00 - RIH CH • |
| Trip | 26" • 6.81 - POOH while L/D DP to deck • |
| Trip | 26" • 6.40 - FILL PIPE • |
| Reaming | 26" • 3.10 - BACKREAMING • |
| Reaming | 26" • 3.00 - REAMING • |
| Maintenance | 26" • 9.00 - SLIP & CUT DRILLING LINE • |
| Maintenance | 26" • 7.00 - PLANNED MAINTENANCE • |
| Downtime/WOW | 26" • 8.10 - DOWNTIME, COSL - EQUIPMENT FAILURE • |
| Downtime/WOW | 26" • 23.00 - WOW DRILLING • |
| Downtime/WOW | 26" • 23.20 - WOW SUB SEA EQUIPMENT • |
| Downtime/WOW | 26" • 23.30 - WOW SUPPLY • |
| Downtime/WOW | 26" • 23.50 - WOW CRANE • |
| Downtime/WOW | 26" • 27.01 - Waiting for Operator's personnel • |
| Downtime/WOW | 26" • 8.30 - DOWNTIME, OTHERS • |

| **17 ½ in. section** | |
|---|---|
| **Description** | **Detail** |
| Marine operations | 17 1/2" • 24.98 - MOVE RIG TO WELL/OFF WELL • |
| Marine operations | 17 1/2" • 24.86 - DEBALLAST RIG • |
| BOP | 17 1/2" • 14.30 - LAND BOP • |
| BOP | 17 1/2" • 14.19 - RUN BOP • |
| BOP | 17 1/2" • 15.6 - CONNECTOR TEST • |
| BOP | 17 1/2" • 15.1 - FUNCTION TEST BOP • |
| BOP | 17 1/2" • 15.11 - PRESSURE TEST BOP • |
| BOP | 17 1/2" • 15.7 - FUNCTION TEST DIVERTER • |
| BOP | 17 1/2" • 14.00 - NIPPLE UP B.O.P • |

| | |
|---|---|
| BOP activities | 17 1/2" • 14.23 - RUN, LP-RISER / DIVERTER • |
| BOP activities | 17 1/2" • 14.17 - RIG DOWN BOP RUNNING EQUIPMENT • |
| BOP activities | 17 1/2" • 14.18 - RIG UP BOP RUNNING EQUIPMENT • |
| BOP activities | 17 1/2" • 14.12 - PREPARE TO RUN BOP • |
| BOP activities | 17 1/2" • 14.11 - PRESSURE TEST Kc LINES • |
| Flat spots | 17 1/2" • 6.33 - CHANGE HANDLING EQUIPMENT • |
| Flat spots | 17 1/2" • 12.12 - RIG DOWN CASING/LINER EQUIPMENT • |
| Flat spots | 17 1/2" • 12.11 - RIG UP CASING/LINER EQUIPMENT • |
| Flat spots | 17 1/2" • 2.97 - Washing, cleaning, prep for next op • |
| Flat spots | 17 1/2" • 2.96 - PREMEETING • |
| Flat spots | 17 1/2" • 13.00 - RIG UP AND DOWN CEMENT EQUIPMENT • |
| Flat spots | 17 1/2" • 1.00 - RIG UP AND TEAR DOWN • |
| Other | 17 1/2" • 2.95 - Other activities • |
| Service operations | 17 1/2" • 6.12 - MWD HANDLING • |
| Service operations | 17 1/2" • 6.14 - TEST MWD • |
| Service operations | 17 1/2" • 10.10 - MWD LOGGING • |
| Service operations | 17 1/2" • 11.20 - WL OPERATIONS • |
| Service operations | 17 1/2" • 11.10 - RIG UP OR DOWN FOR WIRELINE • |
| Service operations | 17 1/2" • 18.01 - ROV operations • |
| Testing equip/drills | 17 1/2" • 15.2 - PRESSURE TEST MANIFIOLDS AND LINES • |
| Testing equip/drills | 17 1/2" • 15.3 - PRESSURE TESTING  KELLY COCKS • |
| Testing equip/drills | 17 1/2" • 15.4 - KICK DRILL, CHOKE DRILL • |
| BHA | 17 1/2" • 6.10 - MAKE UP BHA • |
| BHA | 17 1/2" • 6.11 - LAY DOWN BHA • |
| Casing | 17 1/2" • 12.00 - RUN CASING IN CASED HOLE • |
| Casing | 17 1/2" • 12.05 - PULL CASING IN CASED HOLE • |
| Casing | 17 1/2" • 12.10 - RUN CASING IN OPEN HOLE • |
| Casing | 17 1/2" • 12.13 - SEAL ASSY / WEAR BUSHING • |
| Casing | 17 1/2" • 12.14 - LAND/ PULL CSG ON LANDING STRING • |
| Casing | 17 1/2" • 12.90 - PICK UP AND MAKE CASING HANGER • |
| Casing | 17 1/2" • 13.02 - PUMP CMT • |
| Casing | 17 1/2" • 13.10 - PRESSURE TEST CEMENT • |
| Casing | 17 1/2" • 15.5 - LEAK-OFF / FIT TEST • |
| Casing | 17 1/2" • 12.88 - SET/RELASE MECH PLUGS • |
| Circ./cond. | 17 1/2" • 5.50 - Circulate B/U • |
| Circ./cond. | 17 1/2" • 5.40 - PUMP PILL • |
| Circ./cond. | 17 1/2" • 5.20 - DISPLACE WELL/RISER • |
| Circ./cond. | 17 1/2" • 5.00 - CIRCULATE AND CONDITION MUD • |
| Circ./cond. | 17 1/2" • 5.10 - CIRCULATE HOLE CLEAN • |
| Circ./cond. | 17 1/2" • 12.20 - CIRC. CASING/LINER • |
| Circ./cond. | 17 1/2" • 2.90 - SCR • |
| Circ./cond. | 17 1/2" • 5.60 - Break Circulation • |
| Drill | 17 1/2" • 2.00 - DRILL ACTUAL • |
| Drill | 17 1/2" • 2.30 - DRILL CEMENT  • |
| Drill | 17 1/2" • 10.00 - DEVIATION SURVEY • |
| Drill | 17 1/2" • 2.80 - DIRECTION WORK • |

| | |
|---|---|
| Reaming | 17 1/2" • 3.00 - REAMING • |
| Reaming | 17 1/2" • 3.10 - BACKREAMING • |
| Trip | 17 1/2" • 6.00 - RIH CH • |
| Trip | 17 1/2" • 6.01 - POOH CH • |
| Trip | 17 1/2" • 6.80 - RIH while P/U DP from deck • |
| Trip | 17 1/2" • 6.60 - POOH OH • |
| Trip | 17 1/2" • 6.72 - RIH RISER • |
| Trip | 17 1/2" • 6.73 - POOH RISER • |
| Trip | 17 1/2" • 6.77 - RIH OH restricted • |
| Trip | 17 1/2" • 6.78 - POOH OH restricted • |
| Trip | 17 1/2" • 6.79 - POOH CH restricted • |
| Trip | 17 1/2" • 6.75 - TRIPPING RISER WITH FULL BORE TOOLS • |
| Trip | 17 1/2" • 6.76 - RIH CH restricted • |
| Trip | 17 1/2" • 6.04 - PUMP SLUG • |
| Trip | 17 1/2" • 6.41 - FLOW CHECK • |
| Trip | 17 1/2" • 6.05 - EMPTY TRIP TANK • |
| Trip | 17 1/2" • 6.22 - WASH DOWN • |
| Trip | 17 1/2" • 6.74 - COMPENSATE THROUGH BOP • |
| Trip | 17 1/2" • 6.30 - P/U DRILLSTRING • |
| Trip | 17 1/2" • 6.40 - FILL PIPE • |
| Trip | 17 1/2" • 6.02 - PUMP AND POOH OH • |
| Trip | 17 1/2" • 6.31 - L/D DRILLSTRING • |
| Downtime/WOW | 17 1/2" • 8.00 - DOWNTIME, COSL - OTHER • |
| Downtime/WOW | 17 1/2" • 8.10 - DOWNTIME, COSL - EQUIPMENT FAILURE • |
| Downtime/WOW | 17 1/2" • 8.30 - DOWNTIME, OTHERS • |
| Downtime/WOW | 17 1/2" • 23.20 - WOW SUB SEA EQUIPMENT • |
| Downtime/WOW | 17 1/2" • 27.02 - Waiting for Operator's decision • |
| Downtime/WOW | 17 1/2" • 23.00 - WOW DRILLING • |
| Maintenance | 17 1/2" • 9.00 - SLIP & CUT DRILLING LINE • |

| **12 ¼ in. section** | |
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| **Description** | **Detail** |
| Transit/move rig | 12 1/4" • 24.98 - MOVE RIG TO WELL/OFF WELL • |
| BOP activities | 12 1/4" • 14.17 - RIG DOWN BOP RUNNING EQUIPMENT • |
| BOP activities | 12 1/4" • 14.23 - RUN, LP-RISER / DIVERTER • |
| BOP activities | 12 1/4" • 15.1 - FUNCTION TEST BOP • |
| BOP activities | 12 1/4" • 15.11 - PRESSURE TEST BOP • |
| BOP activities | 12 1/4" • 15.0 - PRESS.TESTING OF CSG UNDER BOP TEST • |
| Flat spots | 12 1/4" • 1.00 - RIG UP AND TEAR DOWN • |
| Flat spots | 12 1/4" • 6.33 - CHANGE HANDLING EQUIPMENT • |
| Flat spots | 12 1/4" • 13.00 - RIG UP AND DOWN CEMENT EQUIPMENT • |
| Flat spots | 12 1/4" • 2.96 - PREMEETING • |
| Flat spots | 12 1/4" • 12.11 - RIG UP CASING/LINER EQUIPMENT • |
| Flat spots | 12 1/4" • 12.12 - RIG DOWN CASING/LINER EQUIPMENT • |
| Flat spots | 12 1/4" • 2.97 - Washing, cleaning, prep for next op • |

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| Other | 12 1/4" • 2.95 - Other activities • |
| Service operations | 12 1/4" • 6.12 - MWD HANDLING • |
| Service operations | 12 1/4" • 6.14 - TEST MWD • |
| Service operations | 12 1/4" • 10.10 - MWD LOGGING • |
| Service operations | 12 1/4" • 11.00 - WIRE LINE LOGGING • |
| Service operations | 12 1/4" • 11.10 - RIG UP OR DOWN FOR WIRELINE • |
| Service operations | 12 1/4" • 2.80 - DIRECTION WORK • |
| Service operations | 12 1/4" • 10.00 - DEVIATION SURVEY • |
| Testing equip/drills | 12 1/4" • 15.2 - PRESSURE TEST MANIFIOLDS AND LINES • |
| Testing equip/drills | 12 1/4" • 15.3 - PRESSURE TESTING KELLY COCKS • |
| Testing equip/drills | 12 1/4" • 15.4 - KICK DRILL, CHOKE DRILL • |
| BHA | 12 1/4" • 6.10 - MAKE UP BHA • |
| BHA | 12 1/4" • 6.11 - LAY DOWN BHA • |
| Casing | 12 1/4" • 12.00 - RUN CASING IN CASED HOLE • |
| Casing | 12 1/4" • 12.10 - RUN CASING IN OPEN HOLE • |
| Casing | 12 1/4" • 12.14 - LAND/ PULL CSG ON LANDING STRING • |
| Casing | 12 1/4" • 12.90 - PICK UP AND MAKE CASING HANGER • |
| Casing | 12 1/4" • 12.13 - SEAL ASSY / WEAR BUSHING • |
| Casing | 12 1/4" • 12.21 - CLEAN WH PRIOR TO RUN CASING/TUBING • |
| Casing | 12 1/4" • 13.02 - PUMP CMT • |
| Casing | 12 1/4" • 13.01 - WAIT ON CEMENT • |
| Casing | 12 1/4" • 13.10 - PRESSURE TEST CEMENT • |
| Casing | 12 1/4" • 13.20 - PRESSURE TEST OF CASING • |
| Casing | 12 1/4" • 15.5 - LEAK-OFF / FIT TEST • |
| Circ./cond. | 12 1/4" • 5.00 - CIRCULATE AND CONDITION MUD • |
| Circ./cond. | 12 1/4" • 5.10 - CIRCULATE HOLE CLEAN • |
| Circ./cond. | 12 1/4" • 2.90 - SCR • |
| Circ./cond. | 12 1/4" • 5.60 - Break Circulation • |
| Circ./cond. | 12 1/4" • 5.20 - DISPLACE WELL/RISER • |
| Circ./cond. | 12 1/4" • 5.30 - TREATING WELL • |
| Circ./cond. | 12 1/4" • 12.20 - CIRC. CASING/LINER • |
| Circ./cond. | 12 1/4" • 5.40 - PUMP PILL • |
| Circ./cond. | 12 1/4" • 5.50 - Circulate B/U • |
| Drill | 12 1/4" • 2.40 - TIME DRILLING • |
| Drill | 12 1/4" • 2.00 - DRILL ACTUAL • |
| Drill | 12 1/4" • 2.30 - DRILL CEMENT • |
| Reaming | 12 1/4" • 3.00 - REAMING • |
| Reaming | 12 1/4" • 3.10 - BACKREAMING • |
| Trip | 12 1/4" • 6.80 - RIH while P/U DP from deck • |
| Trip | 12 1/4" • 6.00 - RIH CH • |
| Trip | 12 1/4" • 6.01 - POOH CH • |
| Trip | 12 1/4" • 6.50 - RIH OH • |
| Trip | 12 1/4" • 6.60 - POOH OH • |
| Trip | 12 1/4" • 6.72 - RIH RISER • |
| Trip | 12 1/4" • 6.73 - POOH RISER • |
| Trip | 12 1/4" • 6.78 - POOH OH restricted • |

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| Trip | 12 1/4" • 6.79 - POOH CH restricted • |
| Trip | 12 1/4" • 6.75 - TRIPPING RISER WITH FULL BORE TOOLS • |
| Trip | 12 1/4" • 6.76 - RIH CH restricted • |
| Trip | 12 1/4" • 6.02 - PUMP AND POOH OH • |
| Trip | 12 1/4" • 6.77 - RIH OH restricted • |
| Trip | 12 1/4" • 6.05 - EMPTY TRIP TANK • |
| Trip | 12 1/4" • 6.06 - FILL TRIP TANK • |
| Trip | 12 1/4" • 6.41 - FLOW CHECK • |
| Trip | 12 1/4" • 6.74 - COMPENSATE THROUGH BOP • |
| Trip | 12 1/4" • 6.21 - WORK PIPE • |
| Trip | 12 1/4" • 6.22 - WASH DOWN • |
| Trip | 12 1/4" • 6.04 - PUMP SLUG • |
| Trip | 12 1/4" • 6.40 - FILL PIPE • |
| Trip | 12 1/4" • 6.31 - L/D DRILLSTRING • |
| Trip | 12 1/4" • 6.81 - POOH while L/D DP to deck • |
| Downtime/WOW | 12 1/4" • 23.00 - WOW DRILLING • |
| Downtime/WOW | 12 1/4" • 8.10 - DOWNTIME, COSL - EQUIPMENT FAILURE • |
| Downtime/WOW | 12 1/4" • 8.00 - DOWNTIME, COSL - OTHER • |
| Downtime/WOW | 12 1/4" • 23.60 - WOW NON DRILLING ACTIVITIES • |
| Downtime/WOW | 12 1/4" • 23.50 - WOW CRANE • |
| Downtime/WOW | 12 1/4" • 23.30 - WOW SUPPLY • |
| Maintenance | 12 1/4" • 9.00 - SLIP & CUT DRILLING LINE • |
| Maintenance | 12 1/4" • 7.00 - PLANNED MAINTENANCE • |
| Hole problems | 12 1/4" • 19.0 - FISHING, OTHERS • |