



# Lean verdistrømsanalyse av eksisterende Mud Treatment prosess

**Sondre Buset Bjelland**

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Hovedveileder: Torgeir Welo, IPM

Norges teknisk-naturvitenskapelige universitet  
Institutt for produktutvikling og materialer



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**LEAN VERDISTRØMSANALYSE AV EKSISTERENDE "MUD TREATMENT"  
PROSESS**

**Lean Value Stream Mapping of Process for Mud Treatment**

Cameron Sense AS er en utstyrsleverandør innen offshore med hovedfokus på drilling- og borevæskestyr. Med bakgrunn i et pågående prosjekt kalt «Design-pilot», der man har som mål å kartlegge prosessene og infrastruktur rundt bruk og vedlikehold av Cameron Sense sitt utstyr, ønskes det et samarbeid med NTNU. Denne masteroppgaven vil dreie seg rundt å gjøre en verdistrømsanalyse (Value Stream Mapping, VSM) av en bestemt prosessrute ved bruk av metoder og verktøy innenfor «Lean Production». Resultatet skal føre til en detaljert oversikt over dagens praksis som skal danne grunnlaget for å foreslå forbedringer/endringer som er nødvendig for å forbedre praksis til et ønsket, framtidig nivå. Hovedmålet for Cameron Sense AS er med dette å øke sin konkurransekraft gjennom å kunne tilby bedre og mer relevant utstyr som gir økt verdi for sluttkunden. Denne studien er forventet å gi forbedret kunnskap rundt bruk av «Lean Production»-metodikk, som opprinnelige ble utviklet for konkurranseutsatt landbasert industri (automotive), til å øke fokus på systemforståelse, kontinuerlig forbedring, effektivitet og kundeverdi innen offshorenæringen. Oppgaven skal begrenses til å studere prosessen «Mud treatment» eller behandling av borevæsken etter bruk/resirkulering av borevæsken. Dette er i dag en prosess som innebærer flere steg, mye maskiner og utstyr, og en del manuelt arbeid.

Hovedmålet med den oppgaven er å gjøre en systematisk verdistrømsanalyse av «Mud treatment»-prosessen gjennom å bruke, eventuelt tilpasse bruk av, eksisterende metoder for «Value Stream Mapping». For å øke nytteverdien av arbeidet skal kandidaten ha en praktisk tilnærming gjennom selv å observere prosessen («Go-to-Gemba») og gjennomføre VSM ved å identifisere verdiskapende og ikke-verdiskapende («Waste» eller «Muda») trinn i prosessen. I den forbindelse skal han gjennomføre «Kaizen» events for kontinuerlig forbedring der nøkkelrolleinnhavere fra Cameron Sense AS skal delta. Sluttresultatet skal være en detaljerte oversikt som viser prosessetid, syklustid, ressursforbruk, effektivitet, etc. for dagens og framtidig praksis. VSM skal omfatte alle elementer knyttet til bruk av produktene (installasjon, bruk, vedlikehold og demontering). Det skal også gjøres vurderinger i hvilken grad resultatene indikerer behov for nye produktløsninger, produkter, prosesser, konseptuelle løsninger eller teknologier, og hva som eventuelt kan være potensialet for slike.

Opgaven skal ta for seg, men ikke begrenses til, følgende aktiviteter:

1. Beskrive gjeldende teori bak «Lean Production» med spesiell fokus på verdistrømsanalyse;
2. Gi en oversikt over den overordnede «Mud-Treatment» prosessen/resirkulering av borevæske;
3. Følge et produkt i bruk over en gitt tidsperiode (på plattformen);
4. Gjennomføre en systematisk VSM analyse av prosessen, og visualisere resultatene i standard format for slike analyser
5. Gjennomføre en «Kaisen»-event sammen med nøkkelpersonale i Cameron Sense AS;
6. Etabler ene felles målsetting rundt «Future State», samt en prioritert liste for forbedringstiltak basert på potensial (gap), kostnader (kompleksitet, ressurser) og i hvilken grad observert trinn representerer en flaskehals i verdiskapningskjeden;
7. Initiere forbedringsaktiviteter;
8. Vurdere i hvilken grad nye (radikale eller transformative) løsninger kan være aktuelle alternativ til inkrementelle, kontinuerlig forbedringstiltak;
9. Lage en kommunikasjonsstrategi og -grunnlag for å skape nødvendig buy-in for foreslåtte forbedringstiltak hos ledelsen i Cameron Sense AS; for eksempel, gjennom å bruke A3 visualisering/dokumentasjon.

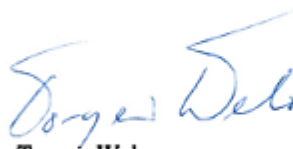
Besvarelsen skal ha med signert oppgavetekst, og redigeres mest mulig som en forskningsrapport med et sammendrag på norsk og engelsk, konklusjon, litteraturliste, innholdsfortegnelse, etc. Ved utarbeidelse av teksten skal kandidaten legge vekt på å gjøre teksten oversiktlig og velskrevet. Med henblikk på lesning av besvarelsen er det viktig at de nødvendige henvisninger for korresponderende steder i tekst, tabeller og figurer anføres på begge steder. Ved bedømmelse legges det stor vekt på at resultater er grundig bearbeidet, at de oppstilles tabellarisk og/eller grafisk på en oversiktlig måte og diskuteres utførlig.

Senest 3 uker etter oppgavestart skal et A3 ark som illustrerer arbeidet leveres inn. En mal for dette arket finnes på instituttets hjemmeside under menyen masteroppgave (<http://www.ntnu.no/ipm/masteroppgave>). Arket skal også oppdateres en uke før innlevering av masteroppgaven.

Besvarelsen skal leveres i elektronisk format via DAIM, NTNUs system for Digital arkivering og innlevering av masteroppgaver.



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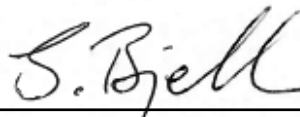
# Preface

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This thesis is written as a master thesis at the Norwegian University of Science and Technology (NTNU) in the spring of 2013. It finalizes five years of education and training in my master's degree.

The work with this thesis has proven itself to be both interesting and rewarding. Throughout the semester, I have had the opportunity to visit a drillrig in operation in the North Sea and to expand my knowledge around one of Norway's largest industries.

I would like to thank my contacts at Cameron Sense AS, Katarina Kjelland and Ranveig Stalsberg, for making this thesis possible. I would also like to thank the personnel at West Elara for answering all my questions and persevere with a curious student. Last, but not least, I would like to extend my gratitude to my supervisor, prof. Torgeir Welo at the Department for Engineering Design and Materials for guiding me throughout the process of writing this thesis.



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Sondre Buset Bjelland  
*Trondheim, 21<sup>st</sup> of June 2013*

# Abstract

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In this thesis, a field study of the mud process on the offshore drillrig West Elara is presented. The approach to this field study is linked to the theory behind value stream mapping, a lean tool for visualizing flow in a process. The use of value stream mapping as a baseline for a field study offshore is something that hasn't been done before on the Norwegian shelf.

Lean tools are well-known from land based manufacturing facilities and it is of interest for the offshore equipment supplier, Cameron Sense AS, to investigate possible offshore applications for these tools to extract experiences from the end customer (the users of Cameron Sense AS' equipment) in order to be able to provide better products and solutions in the future.

The report consists of a general presentation of the drilling industry as well as a more in-depth presentation of drilling fluids, the mud treatment- and mud mixing process. An overall presentation of lean history, philosophy and principles is included within this report.

The field study is documented with experiences, observations and pictures. The findings are discussed and the results are presented together with some proposed improvements to promote flow and reduce waste on West Elara and future rigs Cameron Sense AS is to project.

The report concludes that the approach used for the field study manages to extract valuable and useful information and experiences from the personnel on West Elara.

# Sammendrag

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I denne oppgaven presenteres en feltstudie av borevæskeprosessen på boreriggen West Elara. Tilnærmingen til dette feltstudiet er knyttet til teorien bak value stream mapping, et verktøy for visualisering av flyten i en prosess tatt fra lean produksjonsfilosofi. Bruken av value stream mapping som et grunnlag for en feltstudie offshore er noe som ikke har blitt gjort på norsk sokkel før.

Lean verktøy er godt kjent fra landbasert, vareproduserende industri. Cameron Sense AS har derfor uttrykt interesse for å undersøke om det er mulig å anvende disse verktøyene på en boreplattform for å trekke ut erfaringer fra sluttkunden (brukerne av Cameron Sense AS sitt utstyr ) slik at de kan tilby enda bedre produkter og løsninger i fremtiden.

Rapporten består av en generell presentasjon av boreindustrien, samt en mer detaljert presentasjon av hva borevæske er og miksing og behandling av denne. En innføring i lean tankegang og leane prinsipper samt historikk om emnet er inkludert i denne rapporten.

Feltstudien er dokumentert med erfaringer, observasjoner og bilder. Funnene drøftes og presenteres sammen med noen forslag til forbedringer for å fremme flyt og redusere "waste" på West Elara og fremtidige prosjekter hos Cameron Sense AS.

Rapporten konkluderer med at den tilnærmingen som brukes i dette feltstudiet er nyttig for å trekke ut verdifulle og nyttige erfaringer fra operatørene som bruker Cameron Sense AS sitt utstyr på West Elara.

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# Glossary

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## *A shortlist of terms and expressions used in this thesis*

### *Drilling:*

<b>Annulus:</b>	The space between the wellbore and casing or between casing and tubing. The space between to concentric objects.
<b>Blow-out preventer:</b>	A large valve at the top of a well. Used to close a well when control of the pressure is lost to prevent a blowout.
<b>Drill pipe:</b>	Steel tubes with threaded ends which connects with each other and makes them able to transport torque.
<b>Drill string:</b>	The combination of the drillpipe, drill bit and bottom hole assembly.
<b>Drillbit:</b>	The tool used to cut or crush rock.
<b>Marine riser:</b>	A large diameter pipe that connects the rig at the surface to the well at the sea floor.
<b>Packer:</b>	An element that expands externally to seal the wellbore.
<b>Rotary table:</b>	The revolving section of the drillfloor that provides power to the drillstring.
<b>Subsea drilling template:</b>	A template at the seabed that marks the entry of a production well.
<b>Top drive:</b>	A device that turns the drillstring while suspended by drawworks above the drillfloor. Replaces rotary table on many modern drill rigs.

### *Lean:*

<b>Gemba</b>	Japanese meaning "the real place"
<b>Gemba walk</b>	The action of going to see the actual process for oneself
<b>Genchi Genbutsu</b>	Japanese meaning "go and see for yourself" – referring to Gemba
<b>Kaizen</b>	Japanese meaning "improvement" or "change for the better"
<b>Poka-yoke</b>	Japanese meaning mistake proofing

# 1 Introduction

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## 1.1 Background

The cost of Norwegian oil production has risen the last few years due to high salaries for offshore workers on the Norwegian shelf [1]. The operating expenses on Norwegian shelf are some 45% higher than those on the English shelf [2]. This, in conjunction with the increase in American shale oil production [3], [4] and the assumption that the oil price will drop; leading to reduced income from the oil industry [5], arguments for the need to further increase the efficiency on Norwegian shelf to ensure Norway's position as an oil producing economy.

The long term goal for the companies in the industrial cluster NODE<sup>I</sup> in the southern part of Norway is to further develop its competitive advantage and its world leading position in the offshore drilling business. This is to be achieved by a stronger focus on knowledge and expertise developed by the industry itself [6].

This thesis is written in cooperation with Cameron Sense AS, more specifically Cameron Sense AS' Drilling Fluids Division. The notion is that much of the equipment for drilling fluids (mud from here on) handling is based on time-tested, but inefficient solutions and that there is a significant gain to achieve by mapping, evaluate and re-think the whole mud process. The main goal is for Cameron Sense AS to improve its product development process to be able to deliver better products and solutions for offshore mud processing in the future.

In addition to the main goal, Cameron Sense AS wants to expand its knowledge around the mud process for internal use such as training of new personnel and solid background knowledge for marketing purposes.

To achieve this, Cameron Sense AS applied for, and received, funding's from the Norwegian Design Council through the ongoing project Design Pilot<sup>II</sup>. This funding allowed Cameron Sense AS to hire a consultant, Ranveig Stalsberg, who has

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<sup>I</sup> For more information: <http://nodeproject.no/>

<sup>II</sup> For more information: <http://www.norskdesign.no/design-pilot/category8315.html>

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extensive knowledge in design driven innovation through her previous work. Ranveig Stalsberg acts as the author's person of contact in Cameron Sense AS during the work with this thesis.

## *1.2 Objective*

The objective of this thesis is to study and map the mud treatment process and identify parts of it that can be improved on the offshore drillrig West Elara for Cameron Sense AS in Kristiansand. In order to do this, tools and theory from lean philosophy will be adapted and applied in a way that suits this mission.

The study is meant to give the people responsible for product development in Cameron Sense AS' mud division better knowledge of the mud process and in lean methodology and to lay the basis for suggesting improvements and changes needed to achieve the desired future state for mud processing.

## *1.3 Scope of work*

In this thesis, the author will travel to West Elara for one week to conduct a field study of the mud process. Lean tools such as Value stream mapping and "go-to-gemba" will lay the baseline for the approach to this task.

The process overview will be mapped in advance of the trip through a series of interviews with Oddvar Birkeland who has worked as a mud engineer offshore and is now hired as a technical advisor at Cameron Sense AS. This will be done at Cameron Sense AS' headquarters in Kristiansand prior to the trip offshore.

A meeting with Statoil, the operator on the field which West Elara operates on, will take place at their research center at Rotvoll in Trondheim to include them in the Design Pilot project in order to receive permission for the trip to West Elara

In addition to this, it is necessary with several courses in order to be allowed to travel offshore. Some of them are web-based but one of them lasts for four full days. This course will be taken at Sørlandets Sikkerhets-Senter (SSS) in Kristiansand and paid for by Cameron Sense AS.

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When offshore, the mud process will be mapped through a Gemba walk and confirmed through field interviews and meetings with the operators. The findings will be collected and evaluated. Initially, this study was to revolve around the treatment process but the experiences from the field study made it natural to look at the process as a whole with an emphasis on both the mud treatment and mud mixing sub-processes. The value of the mud is created both places and so it was decided to look at them together.

If time, the findings in this thesis will be presented to key personnel in Cameron Sense AS' mud department prior to the deadline of this thesis.

### *1.4 Limitations*

The assignment text states that this thesis is to encompass all aspects of Cameron Sense AS' products for mud treatment, from installation to disassembly. This is not feasible within the limits of this thesis as the installation of Cameron Sense AS' equipment is done at yards in Singapore or South Korea mainly.

### *1.5 Previous research*

Before kick-off of this project, no previous research of this kind was found. Utilizing a value stream approach to map a process on an offshore drillrig is a new way to gain knowledge of it.

Earlier studies on utilizing value stream mapping to elicit tacit knowledge from the people involved in a process have dealt with land based production industry. A paper on "eliciting product development knowledge using value stream mapping" that is soon to be published concludes that VSM is a successful method for knowledge elicitation in tier 1<sup>1</sup> automotive suppliers [7].

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<sup>1</sup> Tier 1 suppliers is one of the largest and most well known in its field.

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## *1.6 Structure of the assignment*

Chapter 2 gives an overview of Cameron Sense AS, their current method of product development as well as some experiences on innovation in the oil business from people with long experience in the business. Theory about oil, oil exploration, drilling and mud handling is included to give the reader a basic understanding of the process and the necessity of it.

Chapter 3 presents the lean concept and philosophy as well as the history behind it. The lean tools used in this thesis are covered in this chapter.

Chapter 4 lists the methodology for the field study, pros and cons for the approach chosen and an overview on how the field study was planned.

Chapter 5 deals with the field study at West Elara. The observations and experiences gathered there are presented in this chapter.

Chapter 6 is where the findings from chapter 5 is discussed and linked up to relevant lean theory together with the author's comments and viewpoints.

Chapter 7 presents the conclusion and proposed further work.

## 2 About the industry

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### 2.1 About Cameron Sense AS

#### 2.1.1 General

In 1999 in Kristiansand, Tom Fedog and Erik Zachariassen, two engineers from Aker ASA (now Aker Solutions), founded Sense Technology where they focused on making driller cabins and control systems for offshore use. In 2004 they merged with EDM ASA who had success with their rack & pinion technology for onshore drilling. After the merger, the company was renamed Sense EDM AS and expanded business to include, but not limited to, pipe handling equipment and drilling fluids handling for offshore drill rigs, the latter one under the name Sense Mud.

In 2006, Sense EDM AS sold its sub-division Sense Intellifield to Kongsberg Maritime. Sense Intellifield developed products, systems and solutions for real-time remote operations for the oil and gas industry. In 2007, both Sense EDM and Sense Mud were acquired by the Bergen based company TTS AS forming TTS Sense AS, later TTS Energy [8].



**Figure 1 - Headquarter in Kristiansand (photo: Camilla Aadland)**

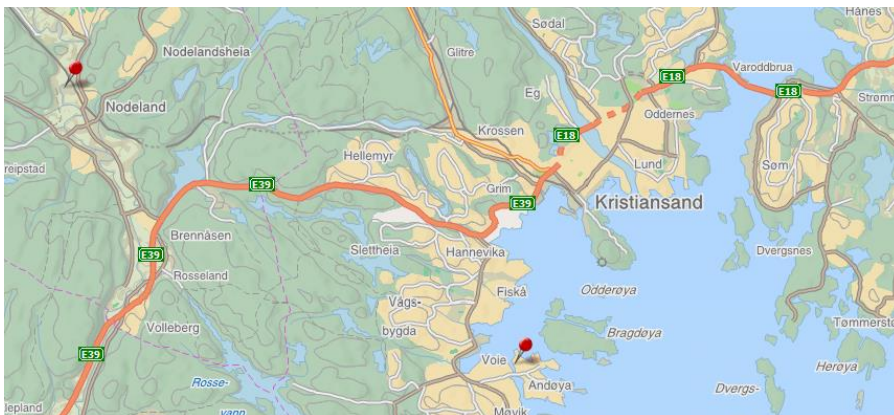
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TTS Energy delivered drilling and mud handling equipment, rig packages and rig solutions for both on- and offshore rigs to the oil and gas industry. TTS Energy products included drilling rig control systems, top drives, automated pipe handling, iron rough necks, drawworks, fingerboards, BOP handling equipment and a full line-up of mud handling equipment.



**Figure 2 - Test and assembly site in Songdalen, Vest-Agder (courtesy of TTS Group)**

In July 2012, TTS Energy AS was purchased by Cameron International Corporation in an all cash transaction for 1.5 billion NOK. The company was launched as Cameron Sense AS on the Oslo Stock Exchange with company headquarters in Kristiansand, Norway.



**Figure 3 - Map of main locations in Kristiansand and Songdalen (screenshot: finn.no)**

### 2.1.2 *Product development at Cameron Sense AS*

The strategy for product development at TTS Energy AS before it was acquired by Cameron International Corporation and renamed Cameron Sense AS, was to sell in contracts for equipment packages and then develop the products and solutions when the project was secured. There were no separate budgets for research and development purposes so all funding for such purposes had to come from the income of sold product packages. This practice can be compared building an architect-designed house. The customer decides for a house based on the architects' initial drawings and a cost framework. Then the projecting, procurement and construction of the house is carried out at the customers' expense [9].

This approach to innovation and product development places heavy demands on the sellers who sell these solutions to the customer. The advantage of this approach is that the customer gets what it wants i.e. little or no resources are used on projects that may not generate income. The immediate disadvantage is that the possibility of a radical, transformative innovation to emerge is low. The customer - a yard building a rig for a drilling contractor which has received a contract from an operator on an oilfield - may be reluctant to try new, untested solutions and the sales department at Cameron Sense may hesitate to offer radical solutions when the risk is to lose a potential contract. Contracts are what the oil service industry lives on and they individually represent a large sum of money. Losing a contract is something one wants to avoid.

At Cameron Sense AS, all development are done in-house and within a project. This enables everyone involved in a particular project to participate in the development process. The downfall is that any development work is targeted towards the ongoing project and the customers demand.

When acquired by Cameron International Corporation, Cameron Sense AS received approval of a research and development budget. This enables Cameron Sense AS to decouple product development and innovation from the framework of a customer financed project and the possible limitations following from it [9].

### 2.1.3 Innovation in the oil industry

The word "innovation" comes from the Latin word *innovare* which means to renew or to make something new. The Norwegian Ministry of Trade and Industry defines innovation as "a new product, a new service, a new production process, application or organizational structure that is launched in the market or used in production to create value [10]". In this definition, a new development process that extracts the knowledge and experience from the offshore operating personnel can be said to be innovative.

In the drilling industry, especially offshore drilling, time is money. The typical running cost of an offshore drill rig can reach amounts of several millions a day (daily running costs for West Elara on the current contract is \$358.000/day ~ 2,1 MNOK/day according to offshore.no). The benefit of this is a low payback period on new rigs and therefore a high will to invest in new ones. The downside is that the high running costs leave little room for experimenting with new solutions and equipment. The industry seems to have been stuck with a "if it ain't broke, don't fix it"-attitude. No rig owner wants to risk the large earnings opportunity for an investment in the range of 1.500+ MNOK. Thus the equipment chosen for the rig is the time-tested, safe alternative that has proven itself functional on earlier rigs [11].

Another problem is that much of the equipment is specified by engineers and technicians who have little to no experience with the work environment offshore. Also, the offshore drilling operators go about and modify the current equipment in any way they see fit to satisfy their needs and way of work without informing the designers of the system and equipment. The exchange of experience both ways is poor [11]. As the drilling section leader (DSL), one of the highest ranking executives on West Elara, with over 30 years of experience in the North Sea said it:

*«I have been working offshore since 1980, and it's always the same. We get a rig and we run it for a year before we rebuild and modify the equipment. And then, when a new rig arrives, it's exactly the same as the last one and then you have it. There seems to be no exchange of experience.»*

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## 2.2 *What is oil and how do we find it?*

### 2.2.1 *Forming of oil*

The oil commonly referred to as mineral oil, crude oil or petroleum is a compound of different hydrocarbons which stems from the remains of dead organisms from several million years ago. These hydrocarbons vary in type and chemical composition but all are entirely consisting of hydrogen and carbon.

Mineral oil is formed when dead organisms sink into the sand and mud due to tectonic activity<sup>I</sup> in the earth's lithosphere<sup>II</sup> and when layers of sand and silt transported by rivers into the ocean is deposited over organic matter on the sea floor.

As the tectonic activity progress, dead organic matter is forced downward into the earth's crust where it is subjected to large pressure and intense heat from the earth's core. This treatment distills the organic matter to hydrocarbons of different types over a timespan of several million years. The oil is often trapped in porous rock like limestone and sandstone or in larger reservoirs between layers of impermeable rock like granite or marble.

### 2.2.2 *How to find oil?*

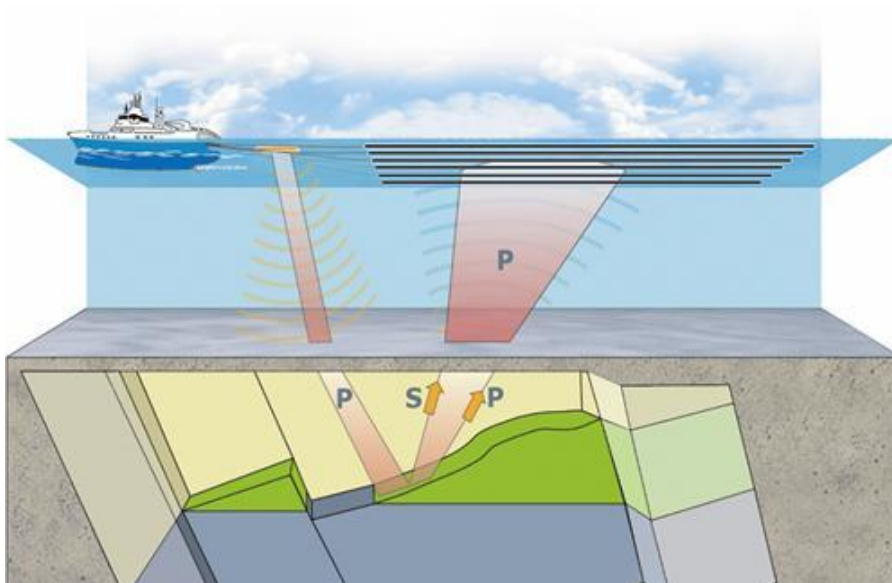
Geological conditions like traps and pockets that can hold hydrocarbons are often the first indicator for where oil can be found. Geologists and geophysicists uses these conditions together with seismic data, satellite images, gravity meters and magnetometers which sensors changes in the earth's gravitational pull and magnetic field, parameters that can indicate flow of oil, to create a map of possible oil deposits.

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<sup>I</sup> A scientific theory that describes the large-scale motions of the earth's lithosphere.

<sup>II</sup> The earth's rocky, outer shell comprised of the crust and the upper mantle.

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**Figure 4 - Sketch of marine seismic survey (source: Statoil)**

The most common tool for charting the different layers below ground is with seismic survey. Seismic survey can be conducted both on land and at sea. On land, explosives and specially equipped Vibroesis<sup>1</sup> trucks are used. The shockwave from a blast of dynamite or the vibration from such a Vibroesis truck is reflected by the ground and the echo is picked up by a recorder truck. Dynamite produces the best image quality because it's a near perfect impulse function but it comes with severe environmental impacts. Vibroesis trucks are a cheaper and more efficient and environmentally friendly way of conducting seismic survey on land.

At sea the seismic data is collected by a seismic vessel sending blasts of compressed air down towards the sea floor and picking up the echo with an array of hydrophones. These arrays can be up to 8 kilometers long and consist of twelve or more cables beside each other.

Regardless of how the seismic data is collected, a seismic reflection data sheet is produced and the geologists and geophysicists use this data to map the subsurface of the earth. Potential petroleum reservoirs are marked and exploratory drilling is started.

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<sup>1</sup> Initially a trade name, but as the patent expired, the name is now an ordinary term.

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### 2.2.3 *The drilling process*

The step after the geophysicists have found signs of oil is exploratory drilling. Exploratory drilling is carried out both by mobile drilling rigs or drillships and they usually drill for core samples of the ground at first to further investigate the chance of hitting oil.

If the results from the exploratory drilling proved satisfactory, the time has come to drill a production well. A subsea drilling template is placed on the sea bed, marking the placement of where the drill string will enter. A flexible tube called a marine riser is transported down from the platform to the drilling template and it is inside this flexible tube that all the equipment (i.e. the drillbit and the casing for the well wall), the drilling fluid or mud and the oil is transported. The blow-out preventer (BOP) is installed at the seafloor where the drill string enters the borehole if the rig is fixed or installed on the rig if it is a floater or jack-up rig. The BOP prevents any chemicals and fluids used in the drilling process as well as oil from the well to contaminate the seawater by closing the well should there be an uncontrolled rise in pressure.

The drillbit, connected by several drill pipes screwed together called a drill string, is hoisted down through the riser and starts drilling when it hits the sea floor. The rotary motion is provided either by a rotary table or a top drive on the platform. Mud is pumped down the drill string to the drillbit and flows back up again between the drill string and the riser. This space is called the annulus.

The drilling operation is performed step-wise. First, a large diameter hole (18 inches, approx. 460mm) is drilled several hundred meters down into the ground. Once this is finished, the drilling personnel removes the drillbit and drill string and sends down steel pipes called casing which then is cemented to the well. A new, smaller drillbit is sent down the well, making a hole with a diameter of 12 inches (approx. 300mm). This section is drilled even deeper than the first section. When this section is finished, it undergoes the same procedure as the previous section with steel casing cemented to the well wall. The depths of the different sections

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vary with the total depth of the well as well as the different geological surroundings of the well.

The last section is called the bottom hole. This is lined with intermediate casing of a smaller diameter, for example 8 inches (approx. 200mm). When this is installed, a machine called a packer is sent down along the well wall securing the well against leakage by applying pressure to the wall.

When the well has hit an oil deposit, a last bit of pipe called the production casing is sent down and installed at the bottom of the well. This casing is sealed shut at the bottom effectively closing the well. Then, explosives are sent down, perforating the production casing to allow oil and/or gas to enter the well. This is done to reduce the pressure the oil and/or gas enters the well with, making the task of controlling the pressure and velocity of the rising oil easier.

At this point, the drilling operation is finished and the oil rig starts producing oil and gas. At first the initial pressure in the well is enough to transport the oil up to the platform for processing, but after some time the pressure equals out. To continue to produce oil from the well, water or gas is sent down to increase well pressure. Compressed air is also used and sometimes steam to heat up the remaining oil and increase pressure is put to use. There is a lot of research going on today to enable us to further utilize old wells which today is no longer economically feasible to tap. Eventually though, an oil well turns dry. The well is plugged and the platform is either transformed into a production facility for nearby rigs or transported into land for re-use or scrap metal. If it's an old concrete colossus, it may be blown of its base plate with explosives or the underbody is just abandoned to be overtaken by nature. The old well is sealed of permanently with concrete.

The oil that emerges from the well is not pure petroleum, but a mixture of crude oil, natural gas, water and minerals. Sometimes, this mixture is sent directly onshore for further processing and sometimes the platform itself has a full production facility. If the platform is located far from shore, the crude oil may be loaded onto tanker ships which may or may not boast production facilities on board to remove any unwanted substances from the petroleum.

Gas that emerges from a well is either dry or wet. Dry gas is transported directly to land by ship or blown ashore by underwater pipelines. Wet gas however, needs to get the various vaporized liquids or gas condensate filtered out before it is sent to land. Some of these gas condensates are not only highly contaminant but also highly corrosive. These include, but are not limited to, hydrogen sulfide (H<sub>2</sub>S), carbon dioxide (CO<sub>2</sub>), cyclohexane (C<sub>6</sub>H<sub>12</sub>) and aromatic hydrocarbons.

## 2.3 *Drilling fluids, or mud*

### 2.3.1 *What are drilling fluids?*

Most on- and offshore drilling is performed by so-called rotary drilling. Rotary drilling is characterized by a drillbit crushing and grinding the different layers down the borehole, producing vast amounts of cuttings that need to be removed. As explained in the previous section, the mud is injected into the well through the drillstring's interior. It flows past the drillbit removing cuttings from it and transports these cuttings to the surface through the annulus and riser. Aside from removing the cuttings from the drillbit and release them at the surface, the mud needs to satisfy the following [12].

- Suspend cuttings when drilling halts
- Provide counter pressure against the wells initial pressure
- Provide counterweight to the well wall to control well stability
- Seal off any permeable rock to prevent leakage
- Act as a cooling and lubricating agent for the drillbit
- Deliver hydraulic energy to the drillbit assembly
- Minimize reservoir damage
- Provide necessary information from well to evaluate the formation
- Provide corrosion resistance
- Ease the process of installing cement fittings in the well
- Provide a first line of defense against environmental impact
- Hinder the formation of gas hydrate

Of these tasks, the most crucial one for drilling performance are the removal of cuttings from the drillbit. To be able to perform well, the cuttings need to be taken away from the mud continuously and efficient. Large cuttings that are not removed from the mud is sent down the drill string to the drillbit again and again until it's grinded to an abrasive compound which wear the different machinery in the mud circulation system excessively. Another important task is to maintain downhole pressure to prevent blow-out and to stabilize the well wall to prevent collapse of the well. This is achieved using weight agents to increase the mud's specific gravity.

### 2.3.2 *The different types of mud*

The fluids used for drilling is often referred to as mud. The term mud may give the impression that the fluids in question are some low-tech, primitive ones but this is far from the truth. The term has been carried over from the early days of drilling when the fluids used consisted of little more than earth, clay and water. The "mud" of today's drilling operations is a high-tech fluid, specially designed to accommodate the needs of increasingly difficult well conditions.

Mud is in general divided into two different types, oil based mud (OBM) and water based mud (WBM). Water based mud is made with either fresh-water or salt-water (brine). In offshore applications, salt-water is most commonly used as the continuous phase. The different components common in WBM is reactive fractions for adjusting the viscosity and yield point according to the Bingham-plastic model, non-reactive (inert) fractions who adds weight to the mud, and chemical additives to alter the muds properties like corrosion resistance and such.

Oil based mud consists of a base oil; often diesel or crude oil, water, and emulsifiers such as soap. Different additives are mixed in to control the mud's parameters, both reactive and inert.

WBM is used in the spudding process. Spudding is the start-up of drilling a new well. It is usually seawater or a mixture of seawater and bentonite. Whilst spudding, the mud is released into the ocean after passing the drillbit, effectively render the use of OBM impossible due to environmental regulations. WBM is also used where the rock formations consists mostly of shale to minimize the environmental impact.

OBM has proven itself as a much more suitable drilling fluid than WBM because of its advantages in lubrication and temperature stability and for a low formation damage potential (oil based mud tend to extract water out from clay and shale formations which are sensitive to high water content for maintaining its integrity).

### 2.3.3 Common additives used in mud

The most common types of mud are listed in table 1 below, description of the principal components are listed in table 2 on the next page.

**Table 1 - Common types of mud [12]**

<i>Fluid type</i>	<i>Principal components</i>	<i>Area of use</i>
<i>Water-based mud (WBM)</i>		
<b>Simple seawater</b>	Seawater	Surface hole (spudding)
<b>Spud fluid</b>	Bentonite, water	Surface hole (spudding)
<b>Saltwater</b>	Seawater, brine or saturated saltwater; saltwater clay, starch and cellulosic polymer	Salt formations
<b>Lime or gypsum</b>	Fresh or brackish water; bentonite, lime or gypsum, lignosulfate	Shale drilling, high temperature, salt tolerant
<b>Lignite or lignosulfate</b>	Fresh or brackish water; bentonite, caustic soda, lignite or lignosulfate	Shale drilling, high temperature, salt tolerant
<b>Potassium</b>	Potassium chloride; acrylic, bio or cellulosic polymer, some bentonite	Hole stability, low tolerance to solids, high pH
<b>Low solids</b>	Fresh to high saltwater; polymer, some bentonite	Hole stability, low tolerance to solids and divalent salts
<i>Oil-based mud (OBM)</i>		
<b>Oil</b>	Weathered (oxidized) crude oil; asphaltic crude, soap, water (2-5 %)	Moderate to low pressure wells, strong environmental restrictions
<b>Asphaltic</b>	Diesel oil; emulsifiers, water (2-5 %)	High temperature wells (<315 °C), strong environmental restrictions
<b>Invert emulsion</b>	Diesel, mineral or low/nonaromatic mineral oil; emulsifiers, organophilic clay, modified resins and soaps, 5-40 % brine	High temperature wells (<230 °C), environmental restrictions
<b>Synthetic</b>	Synthetic hydrocarbons or esters; other products same as invert emulsions	High temperature wells (<230 °C)

**Table 2 - Categories of common additives**

<i>Category</i>	<i>Description</i>
<b>Weighting materials:</b>	To maintain the downhole pressure, weighting agents are added to the mud. These include minerals such as barite (Specific Gravity: 4,3 – 5,0), ilmenite (SG: 4,7 – 4,8), hematite (SG: 5,5 – 6,5), magnetite (SG: 5,2), siderite (SG: 3,9 – 4,0), dolomite (SG: 2,8 – 2,9) and calcite/limestone (SG: 2,7).
<b>Viscosifiers:</b>	To control the viscosity of the mud, different additives such as bentonite, organic polymers (starch, guar- and xanthan gum, cellulose and lignosulfate/lignite) and phosphates are supplied to the mud.
<b>Alkalinity and pH-control:</b>	Caustic soda (sodium hydroxide), baking soda (sodium bicarbonate) and soda ash (sodium carbonate) are all used for adjusting the muds pH-values. A range of different acids are also used in addition to some oxides and hydroxides.
<b>Lubrication:</b>	To lubricate the drillbit assembly, the mud sometimes carries with it glass or polystyrene beads or graphite. In WBM, glycol is added and in OBM, different oils are added.
<b>Shale stabilization:</b>	To hinder shale formation damage, the salinity of the mud must be controlled. Different salts are added to the mud such as sodium chloride, calcium chloride and potassium chloride to name a few. The salinity of the mud is important to ensure a stable shale formation. If the salinity of the mud is lower than that of the formation water in the shale, water will travel from the mud and into the shale formation. This is unfortunate as it makes the shale formation more unstable. One wishes to keep the chemical potential equal to or lower than that of the shale formation water so that the shale is kept at a constant wetness or is dried out. A dry shale formation helps keeping the wellbore stable and in good condition [13].
<b>Other:</b>	Other additives are introduced to the mud to help with contaminant removal. Chrome or ferrochrome lignosulfate for de-flocculation (flocculation is a process of contact and adhesion whereby the particles of a dispersion form larger-size clusters – IUPAC definition), phosphate for the removal of calcium, corrosion inhibitors, detergents, emulsifiers and foamers/de-foamers is some of the many additives used to design a mud. Asphalt and cellulose fibers are also added as bridging materials. Bridging material acts as filler on the fractured borehole wall to prevent excessive mud loss.

### 2.3.4 *Treatment of recovered mud*

When the mud returns to the drillrig, it contains gas, cuttings from the wellbore, sand and silt. All these are regarded as contaminants and need be removed from the mud. As the mud itself is composed of a variety of different chemicals; some of them toxic and some of them expensive, it is the wish of both the operator and the environmental governing power to reuse the mud and to minimize the loss to sea.

The mud treatment system consists of a mud/gas separator, a shale shaker, a sand trap, a degasser, a de-sander and a de-silter or a mud cleaner. The typical route for used mud is through the bell nipple (a large diameter pipe on the top of the blowout preventer that diverts the returning mud to the treatment line) and to a mud/gas separator if the gas content is high (typically above 2%) [14]. The mud/gas separator is a vessel similar to that of a distillation column. The mud flows from the top of the vessel and over some baffle plates inside, agitating the mud to such an extent that some of the gas dissolved in the mud evacuates. After the mud/gas separator, the mud is sent through the shale shakers where larger cuttings are removed. The shale shaker is regarded as the most important piece of equipment in the solids removal process. The performance of the subsequent process steps relies on the shale shakers ability to clean the mud for cuttings. The shale shaker itself is made up of the following parts:

- Hopper
- Feeder
- Screen basket and shaker screen panels
- Basket angling mechanism
- Vibrator

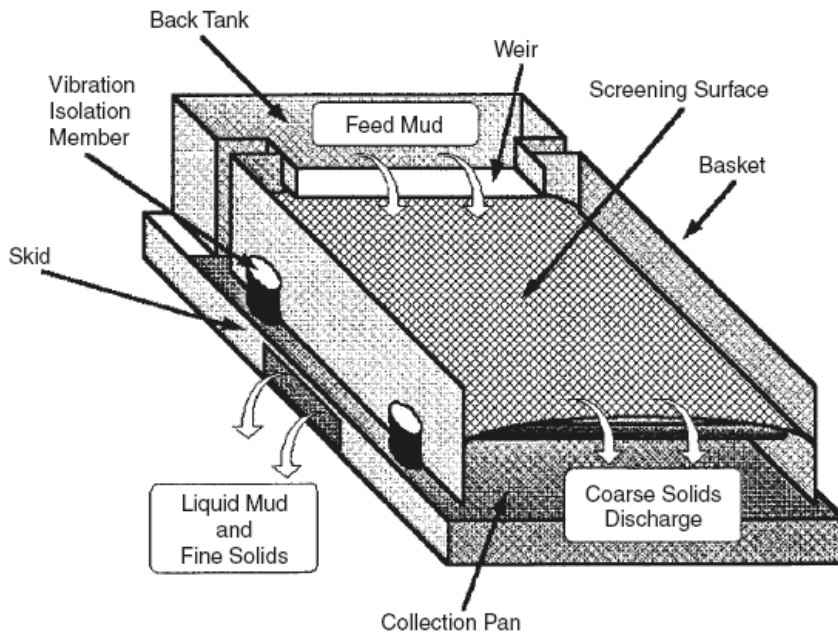
The hopper is the base of the shale shaker. It acts as a platform for the whole mechanism and a collection pan for the mud processed by the shale shaker. The feeder is nothing more than a collection pan placed before the screens. It collects up a certain amount of mud and distributes it evenly over the shaker screens. The screen basket is the mechanism responsible for holding the shaker screen panel in place and to transfer the vibratory motion to the screen. This mechanism is often called the screen bed and is the most important part of the machine. It should be easy to replace the shaker screen, durable and easy to maintain. The mud flows over

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the shaker screen panels and through the mesh in the screen. The mesh can be adjusted by changing the screen to accommodate the different cuttings size. The basket angling mechanism is there to make the shale shaker able to adjust its angle to accommodate different flow rates of unprocessed mud. The unprocessed mud "slurry" is categorized in one of two categories. The "pool" category is where the used mud mostly consists of drilling fluid with cuttings suspended in it. The "beach" category is where the cuttings starts to pile up and most of the fluids have been removed. Typically, the correct angle of the shaker bed is the one that has a ratio of 80% "pool" and 20% "beach" [12]. The vibrator is the driving force behind the vibratory motion. It uses one, two or three electric motor(s) to provide rotary motion (circular or elliptical motion of the screen bed) and another one with eccentric weights to provide the vibratory force.

In figure 5, a principal drawing of a shale shaker is presented showing the flow of the mud and the flow of the separated solids through the machine.



**Figure 5 - Principle drawing of a typical shale shaker (J. Merrill, L. Robinson 2005)**

After passing the shale shaker, the mud is then transported to a sand trap. The sand trap is an open tank where the mud is stored for a period of time so that particles that went through the mesh in the shale shaker settles on the bottom.

Even though the mud may have traveled through a mud/gas separator before entering the shale shaker, there may be some gas content left. The degasser step is designed to take care of that. Two major types of degassers exists; the vacuum degasser and the atmospheric degasser. The vacuum degasser creates an under pressure to extract the unwanted gas dissolved in the mud (concentrations lower than 2%) [14]. The atmospheric degasser is of the same design as a mud/gas separator. After the degasser step, the mud is transported to a set of centrifuges called a de-sander and a de-silter. They are either hydrocyclones or settling tanks that removes solids that the shale shaker is unable to remove. The de-sander typically removes solids in the range of 45 ~ 74 $\mu$ m and the de-silter removes solids in the range of 15 ~ 44 $\mu$ m. The de-sander is placed before the de-silter and the mud is pumped through these hydrocyclones by a standard centrifugal pump.

Sometimes, the de-sander and de-silter are replaced by a mud cleaner. It is a combination of a de-sander and de-silter and incorporates a fine screen mesh in which the processed mud is transported over after travelling through the hydrocyclones in the mud cleaner.

### *2.3.5 Laws and regulations applicable to mud handling*

Laws and regulations for disposal of mud into seawater are specified in the regulation of the execution of activities in the petroleum industry of 2010, chapter 11. It states that all water containing over 30 milligrams of oil per liter of water must be processed and cleaned. This ensures that no OBM is released to the sea. Some of the fluids and cuttings that are allowed discharged into the sea are listed in the PLONOR-list (**P**ose **L**ittle **O**r **N**O **R**isk) formulated by the OSPAR-convention in 1992. Most countries lean on this list for determining which substances to allow for discharge. The substances on the PLONOR-list is evaluated considering marine persistency, bioaccumulation potential, acute toxicity and the possibility of endocrine effects (hormone disturbances) [15].

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## 2.4 *The mud process*

### 2.4.1 *Structure of the mud process at West Elara*

The mud process at West Elara is organized into different areas with different functions. The first area is the bulk storage area where base oil and weighting agents such as barite is stored. This area is mostly operated remotely from the derrickman's shack (the derrickman is the operator in the pump room and mud mixing room), but some manual line up of valves is necessary when adding bulk materials to the mud. The next station in the mud process is the sack store and mud mixing room. The sack store is the storage room for smaller quantities of specialty chemicals such as viscosifiers, alkalinity control and other. They are stored in sacks up to 25 kg or in tanks up to 1.000 liters. The powdered chemicals are added to the mud using a Sack Dosing Unit (SDU) placed in the mud mixing room. If necessary, the powdered chemicals can be added to the mud using a manual feeder, a hopper with a venturi tube. The liquid chemicals is added using a Liquid Additive Skid (LAS). At West Elara, these two rooms are divided into one WBM side and one OBM side physically placed apart from each other on the port and starboard side of the rig.

The next area is the mixing tanks. The mixing tanks are large tanks with agitators in them. They can be used to shear the mud by circulating it between them by using a high pressure pump when mixing new mud. The mixing tank system consists of several tanks that can be used independently of each other so that new mud can be mixed while the current mud is still circulated in the well.

The mud is then sent to the well by one of the high pressure pumps in the pump room. On West Elara there are three pumps. The mud is sent down the drillstring and returns through the annulus with cuttings. It flows through the Blow-Out Preventer (BOP) and the flow divider to the shaker room. In the shaker room, the mud is sent through the shakers before entering the sand trap, de-sander and de-silter. After that, it re-enters the active tank and is sent through the well again. The active tank is the trip tank that is set off for drilling.

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While the mud circulation is in progress, the mud is weighed on both the intake and the return of the well and compared with each other to check that nothing is lost or gained through the roundtrip through the well. On the intake side it is the derrickman or the derrickman's assistant's duty to weigh the mud. On the return side, the mud is weighed after passing the shaker room by the roughneck (the roughneck is the operator in the shaker room, sometimes called shakerhand).

#### *2.4.2 Deciding on the right mud*

The composition of the mud is determined in advance by the geological personnel onshore in cooperation with the drilling officer offshore. The composition is communicated to everyone involved in the drilling process through a detailed execution schedule.

The decision making foundation for the execution schedule is seismic and geological data from the seismic survey together with analyses and tests of the current mud performed by the Mud Engineer and data logs for the drilling process provided by the Mud Logger. Both the Mud Engineer and the Mud Loggers are stationed on the rig.

The mud often needs correction or adjustments of the properties and weight. The results from the weighing of the mud in the shaker room are communicated to the driller and the derrickman. The driller orders the alterations to the mud according to mud weight and feedback from the drilling measurement systems.



**Figure 6 - The Mud Engineer in his lab (photo: Sondre Buset Bjelland)**



**Figure 7 - The Mud Loggers (photo: Sondre Buset Bjelland)**

### 2.4.3 *Mixing the mud*

The recipe for the mud is presented for the derrickman through the execution schedule. It is the derrickman who is responsible for mixing the mud in accordance with the recipe and to adjust the mud's properties at the driller's request. Chemicals are added from either the bulk system or the sack store. In the sack store/mixing room, both powdered and liquid chemicals are added manually.



**Figure 8 - Inventory of the sack store (photo: Sondre Buset Bjelland)**



**Figure 9 - Adding powdered chemicals using the SDU (photo: Sondre Buset Bjelland)**



**Figure 10 - Adding liquid chemical using the LAS (photo: Sondre Buset Bjelland)**

#### 2.4.4 Recovering the mud

The mud recovery process at West Elara starts when the mud has returned from the well. If the mud contains high levels of gas when exiting the well, it is diverted through the degasser before entering the shaker room. In the shaker room, the mud is distributed to up to eight shakers. Four is set aside for OBM and the other four is set aside for WBM. If necessary, all eight can be used for OBM or WBM but the change from OBM to WBM requires thorough cleaning in order to not contaminate the mud.



**Figure 11 - The eight shakers in the shaker room (photo: Sondre Buset Bjelland)**

The operator in the shaker room is the roughneck. The roughneck is the lowest ranking of the crew members and the position is typically occupied by a rookie. On West Elara, the supervision of the shaker room is divided between the different roughnecks on duty. The tasks of the shaker room operator are to weigh the mud, lubricate the screw conveyor that transports the cuttings from the shaker and out to the cuttings re-injection (CRI), check the magnets in the flow line, check and clean the shaker screens and replace them if necessary.



After the mud has passed the shakers, it is sent to the sand trap, de-sander and de-silter and a mud cleaner. On West Elara, these are tanks designed so that the first one has to be completely filled before the mud can flow to the next tank. This happens at a pace that allows the sand and silt in the mud to settle on the bottom. The tanks that make up this system are collectively called settling tanks. The last tank is the degasser tank which removes small quantities of gas that the mud/gas separator let pass.

Figure 12 shows the tanks as well as the CRI (Cuttings Re-Injection) blowers (orange devices) below the shaker room. These devices send the cuttings to the process that re-injects the cuttings into an underwater deposit.



**Figure 12 - The settling tanks with CRI (photo: Sondre Buset Bjelland)**

West Elara is equipped with different mud cleaning equipment. The mud does not flow through all of the equipment the entire time. The equipment is installed to cover every eventuality i.e. different contaminants in the mud and different amounts of contaminants. All the equipment is interconnected by piping and valves allowing the operators to route the mud to the equipment necessary for treatment and to pass the unnecessary equipment.

## 2.5 *Offshore laws and regulations*

### 2.5.1 *Introduction*

Everyone who has any ambition of succeeding with any new, innovative technological solution in the Norwegian oil business has to design and develop their solution according to the different laws and regulations and standards applicable. Any new product or solution on the market needs to fulfill and satisfy a number of laws, regulations, standards and best practices in order to achieve the necessary certifications needed for the Norwegian offshore business.

The main law concerning petroleum activity on the Norwegian shelf is the Petroleum Law, and two of the most important standards are the NORSOK<sup>I</sup>-standard and DNV's standards. All electrical installations have their own standards, called NEK<sup>II</sup>.

### 2.5.2 *The Petroleum Law*

The Petroleum Law (Law of 29<sup>th</sup> of November, no. 43) regulates the governmental administration of Norwegian petroleum resources. Its main field is the economic and property rights of the petroleum resources on the Norwegian Shelf, but it also contains some rules about the consideration of safety and pollution on the Norwegian shelf [16].

### 2.5.3 *NORSOK-standards*

Traditionally, the different actors on the Norwegian shelf have had many different specifications to act in accordance with, specifications on how to design different technical solutions on offshore installations. The work on standardizing and systemizing these specifications started in 1993. The cause was to simplify the tender process and to reduce the time spent on projecting new rigs and platforms. It was also desirable to standardize maintenance and safety routines so that personnel easily could be transferred between offshore installations driven by different

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<sup>I</sup> An abbreviation of "Norsk Sokkels Konkurranseseposisjon"

<sup>II</sup> An abbreviation of "Norsk Elektroteknisk Komité"

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operators. This work resulted in the NORSOK-standards and it was in collaboration between the different actors in the Norwegian petroleum industry and The Norwegian Oil & Gas Association (former OLF), The Federation of Norwegian Industries and the Norwegian Government that these standards were defined. The NORSOK-standards contains national guidelines for technical solutions on offshore installations to ensure a satisfactory HSE-level (Health, Safety and Environment). Today, the NORSOK-standards is administrated by Norsk Standard and everyone who is comprised by these standards are welcome to participate in the continuous development of them by suggesting modifications of the standards and proposing new ones [17].

#### *2.5.4 DNV offshore standards*

DNV stands for "Det Norske Veritas" or The Norwegian Veritas. It's an independent, owner-occupied foundation who performs classifications, certifications, verification and research activities related to quality and safety on ships and offshore installations. DNV has developed a range of requirements that lay the basis for a DNV classification of ships and offshore installations [18].

#### *2.5.5 NEK standards*

Two collections of best practice for electrical installations on offshore installations exist, the NEK 410 and the NEK420. The NEK 410 is a collection of requirements for general electrical installations on ships and offshore installations and the NEK 420 is comprised of requirements for electrical installations in hazardous areas with danger of explosion (EX-areas). The NEK standards are a sub-division of Norsk Standard [17].

#### *2.5.6 Operator demands and specifications*

The different operators on the Norwegian shelf often have their own specifications on top of those imposed by the preceding regulations. These specifications often describes which "best practices" and classifications everything shall be built after as well as determining makers and suppliers of specific components.

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## 2.6 Stakeholders

### 2.6.1 Who are involved in a rig?

In Norwegian territory it is the Ministry of Petroleum and Energy that issues licenses for drilling and production on each field. These licenses are given to an operator company such as Statoil, Conoco Phillips, Total, BP and its likes. The responsibility that follows such a production license provides a risk and it is therefore common for different operators to join forces in order to spread the risk.

When a license is granted from the government, the operators divides a field into blocks and polygons and each operator in the cooperation runs these blocks on their own. This is done either by renting a rig from a rig company or by buying a rig and outsource the daily operation of it.

The rig owner companies such as Seadrill and Kosel Drilling receives an order to run a rig, either self-owned or operator-owned (Depends on the timespan of the contract and if the rig is fixed or mobile. Fixed rigs are operator owned). The rig may be specified by the operator and the rig owner supplies a rig after their specification or by the rig owner company. Some rigs are built on speculation. It is anticipated what the drilling market needs and rigs are built in advance based on market trends and political decisions.

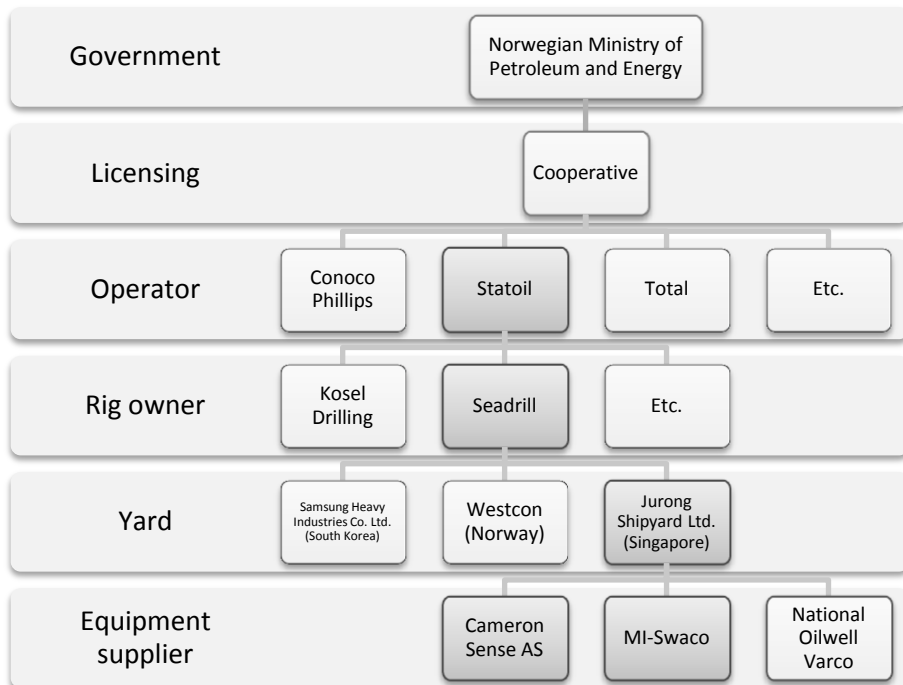
Offshore drillrigs are subject to strict regulations and certifications. Therefore, a new rig is often based on drawings from a marine construction company that have different classes of certified rig designs. West Elara belongs to the CJ70-X150A class developed by GustoMSC [19]. This is a harsh environment classified jack-up rig and it is built at Jurong Shipyard Ltd. in Singapore. The rig owner often specifies the requirements of the rig and then the yard building it chooses a supplier of the different equipment the rig needs. On this level, the supplier level, companies like National Oilwell Varco, Aker Solutions, Cameron, Halliburton and MI Swaco are present. These companies develop and deliver equipment packages for drilling, mud processing and cranes and drawworks. Often, these companies cooperate to

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deliver a complete solution for the rig. Cameron Sense AS cooperates with MI-Swaco, a sub-division of Schlumberger.

When the rig is finished and put into operation, the operator sometimes chooses to outsource the operation of some of the equipment to the suppliers. This is called a split contract and these are the responsibility of the rig owner to manage as the operator has ordered a complete rig with crew. If the operation of a rig is not split up, the rig owner uses its own employees to run the rig. Outsourcing versus insourcing of these tasks is mainly a concern between economists on the one side and the labor unions on the other side. The union wants permanent employment and the rig owner wants flexibility to be able to adapt to a fluctuating market [14].

### 2.6.2 Stakeholder map for West Elara



**Figure 13 - Stakeholder map for West Elara [14]**

The stakeholder map shows the parties involved in West Elara in the different levels in grey in figure 13.

## 3 Lean theory

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### 3.1 *Introduction and history*

#### 3.1.1 *What is lean?*

The word lean has different meanings. When a farmer talks about lean years, he talks about meager crops and little productive farming, when a person's body is described as lean, it means that he/she has little body fat. When talking about lean in relationship with production or product development, it does not mean to make cutbacks in budgets or to get rid of employees. Lean stands for making the most out of available resources and not using any efforts to produce waste. It is a holistic approach to virtually any process or operation that creates a product or a service, an approach that focuses on maximizing customer value without wasting resources.

Lean production, lean manufacturing or just lean for short, is a production philosophy, a mindset that sees any use of resources that does not provide any value as waste. In the same mindset, all waste should be eliminated. The perspective is down-up meaning that any action, any feature or any service rendered that the customer is willing to pay for is value, everything else is waste. The phrase "the customer is always right" holds for this philosophy.

Many of the basic ideas in lean thinking, like waste minimization, flow, just-in-time and continuous improvement is based upon the thoughts and work of some notable, historical figures.

#### 3.1.2 *Early thoughts of thrift and efficiency*

The start of lean thinking can be traced back to the eighteenth century. Early documents written by Benjamin Franklin (1706 - 1790) shows that one of the cornerstones in lean thinking, waste reduction, already were an established thought. Benjamin Franklin, a statesman, inventor and publisher, published a yearly almanac called "Poor Richard's Almanack" in which he presented ideas and sayings on

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topics like thrift, practical housekeeping and economy. In this almanac, Benjamin wrote the following on wasted time and money:

*"He that idly loses 5 shillings worth of time, loses 5 shilling and might as prudently throw 5 shilling into the river. A penny saved is two pence clear. A pin a-day is a groat<sup>1</sup> a-year. Save and have."*

Later, Franklin collected many of his economic and financial sayings in his book "The Way to Wealth". In this book, the following is written about unnecessary inventory:

*"You call them goods; but, if you do not take care, they will prove evils to some of you. You expect they will be sold cheap, and, perhaps, they may be bought for less than they cost; but, if you have no occasion for them, they must be dear to you. Remember what Poor Richard says, 'Buy what thou hast no need of, and ere long thou shalt sell thy necessaries.' In another place he says, 'Many have been ruined by buying good penny worths'."*

One of the pioneers in lean thinking, Henry Ford, cited Franklin as one of his largest influences on his own business practice.

A pioneer of another cornerstone in lean thinking, the concept of flow, was Fredrick Winslow Taylor (1856 - 1915), by many called the father of scientific management.

Frederick Winslow Taylor created and advocated a theory of management that analyzed and synthesized workflows. He was one of the first to apply scientific methods to the engineering of processes and management. The main objective was to improve economic efficiency and labor productivity.

What Taylor did was to carefully analyze how the workers at Midvale Steel, where Taylor worked as a lathe operator and supervisor, differentiated in productivity between each other. He saw that some workers showed talent and motivation for the work whereas others just "got through the day". As a result of these observations, he devised a practice where all of the process steps were synthesized

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<sup>1</sup> Groat is a traditional name for the old English silver coin worth four English pence.

and standardized. All methods based on tradition or "rule-of-thumb" was replaced with precise and concrete procedures developed after meticulous studies of an individual at work, and time and motion studies.

Shigeo Shingo, one of the architects behind Toyota Production System, cites "Principles of Scientific Management" by Fredrick Winslow Taylor as one of his inspiration.

### *3.1.3 New ideas set into motion*

The earlier American financial giants John D. Rockefeller, Andrew Carnegie and J.P. Morgan, founders of such companies as Standard Oil, Carnegie Steel and General Electric, had built their enterprises by means of intimidation, undercutting products and services to squeeze the competition and acquiring them by hostile takeovers. This enabled them to build gigantic enterprises that were massively profitable and made these men wealthy beyond riches. It is assumed that John D. Rockefeller, said to be the richest man in the history of the world, had a personal net worth of over \$660 billion in today's money [20].

These businesses were efficient by an economical point of view in that they had a high profitability, but they were far from lean. The workers often had to work 12-hour days, six days a week for below par payment. When the twentieth century arrived with its anti-trust legislation (most notably, the Sherman Anti-Trust Law), many of these enterprises were forced to break up into smaller fractions. Standard Oil was broken up into 90 different companies, companies that grew to modern enterprises such as ExxonMobil, Chevron and ConocoPhillips. It was in this time that the pronounced anti-monopoly man Henry Ford started his automobile making business and with it, many of the principles which today are still found in the lean philosophy.

Henry Ford developed and built several "horseless carriages" before starting the Ford Motor Company in 1903. The first successful car was the Ford Model A, but it was with the Model T that Ford was able to present to the American public a car that was affordable and reliable. Henry Ford called it "a car for the great multitude":

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*"I will build a car for the great multitude. It will be large enough for the family, but small enough for the individual to run and care for. It will be constructed of the best materials, by the best men to be hired, after the simplest designs that modern engineering can devise. But it will be so low in price that no man making a good salary will be unable to own one – and enjoy with his family the blessing of hours of pleasure in God's great open spaces."*

Henry Ford did not invent the automobile, but he did invent the modern assembly plant. Before the Model T Ford, cars were built in specialist workshop one at the time. They were expensive to buy, expensive to maintain and often required a driver to chauffeur and tend to the car. This limited ownership of a car to the wealthy. For Ford, it was important that the car he would manufacture was affordable and provided ease of ownership so that the growing middle class at the time could enjoy the freedom that the car could provide. He saw the automobile as more than just another toy for the elite but to set his vision into life, he had to rethink the whole manufacturing process.

In socio-politic terms, the ideas of Henry Ford and the way he conducted his business is called Fordism. In this –ism, three main principles is central.

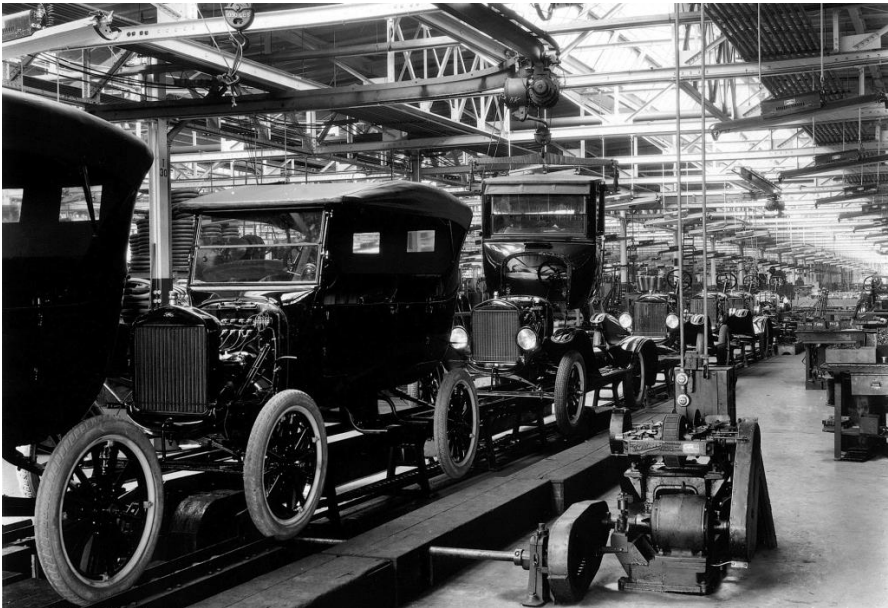
1. Standardization of parts
2. Use of speciality tools
3. Workers paid sufficiently so that they can buy what they are making

All the parts used for assembling a Model T Ford were built using dies and machines, not by specialist craftsmanship. Complex operations were broken up into easy sub-tasks and difficult-to-handle parts and assemblies were made easy with the use of special tools. In a day when the average daily salary for a factory worker was \$2 a day, Ford paid his workers \$5 a day and demanded only a 40 hour workweek were the others were demanding 60 hour workweek [20].

Ford was able to do this due to his persistent reduction of manufacturing waste. He got more out of the workers by breaking the complex task of building an automobile into simple tasks that an unskilled worker could learn with little or no training. Ford created the assembly line with different working stations with

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workers who were trained only in the operation needed for that particular step in the manufacturing process.



**Figure 14 - Model T assembly line circa 1924. Marriage of chassis and body (courtesy of Wikimedia Commons)**

Henry Ford focused on good arrangement of the workplace to minimize the time needed for walking or searching for the right tools, designing parts for manufacturing and reduction of waste, all of which are key concepts of lean thinking today.

### *3.1.4 Toyota Production System*

The Japanese car manufacturer Toyota stems from "Toyoda Automatic Loom Works", a textile company founded by Sakichi Toyoda in 1926. Toyota Motor Corporation was formed in 1933 by Kiichiro Toyoda who traveled to Europe and America to study the automotive industry. During the Second World War, the company was focusing on producing army trucks for the Japanese army, but after the war was ended, Toyota Motor Corporation started making cars for the consumer market. Business was tough for Toyota as post-war Japan suffered extreme economic difficulty and by June 1950, the company had only produced some 300

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trucks and was on the brink of bankruptcy. The start of the Korean War in June 1950 resulted in an order for over 5.000 military vehicles from the US military and thus, the company was revived.

Toyota Motor Corporation had learned process improvement and employee development by the American War Department's industrial training program, a program that was abandoned by the US in 1945 but continued to be developed in Japan [21]. Notable persons such as Eiji Toyoda (1913) and Taiichi Ohno (1912 – 1990) continued on the initial ideas from USA and eventually defined many of the concepts that are now known as lean thinking. Concepts like Kaizen (continuous improvement), Just-In-Time (reducing in-process inventory) and Jidoka (intelligent automation) have their roots in the Toyota Production System – TPS – developed by Eiji Toyoda and Taiichi Ohno. TPS was developed after Eiji Toyoda visited Henry Ford's Rouge plant in Detroit in the spring of 1950. The experiences he made visiting Ford's plant he took home to Japan and together with Taiichi Ohno, they modified Ford's way of manufacturing cars into a way that could suit Japan's culture.

Japan's domestic market was substantially smaller than that of the United States and required a wide range of different vehicles. The workers in Japan were also not willing to be treated as "interchangeable parts" as the unskilled workers at Ford's manufacturing plants. Because of this, Eiji Toyoda and Taiichi Ohno quickly concluded that mass production as Ford did it would never work in Japan. They had to rethink the whole manufacturing process.

Taiichi Ohno first set out to tackle the process of sheet metal stamping. The industry standard was to stamp a million or more units a year of a given part, but this was not an alternative for Toyota whose production was to be a few thousand vehicles a year. Taiichi developed the interchangeable dies and simple die change techniques. Toyota was now able to change dies every two or three hours instead of every two to three months. A smaller number of parts could be produced at a low cost and the need for an inventory ceased. This approach to sheet metal stamping lead to a quicker discovery of defects. Faulty parts were discovered much earlier in

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the process instead of being sent to inventory and stored for months before checking and thus needing rework to be useable [22].

Taiichi Ohno developed the concept of waste that is a key element in today's lean thinking. He defined three types of waste called "muda", "muri" and "mura". "Muda" is Japanese for futility, uselessness, idleness, superfluity, waste, wastage and/or wastefulness according to the Kenkyusha's New Japanese-English Dictionary. "Muri" means unreasonableness, impossible, beyond one's power, too difficult, by force, perforce, forcibly, compulsorily, excessiveness and/or immoderation and "mura" means unevenness, irregularity, lack of uniformity, non-uniformity and/or inequality. In TPS, "muda" is comprised of the seven wastes presented below, "muri" is any unreasonable work tasks that stems from poor planning of any process such as carrying heavy weights, work in an uncomfortable or unhealthy position, pushing a person or machine beyond its limit etc. and "mura" is overproduction due to uneven performance in the different process steps.

The seven wastes, "muda" in Japanese, in TPS are [23]:

- Transport (moving of products that are not required for processing)
- Inventory (all components that are not being processed)
- Motion (people or equipment moving or walking more than required)
- Waiting (waiting for the next production step)
- Overproduction (production ahead of demand)
- Over-processing (resulting from poor tool- or product design)
- Defects (the effort involved in inspecting for and fixing defects)

In later times, a proposed eight type of waste - underutilized people – has been considered by many in the lean community.

Taiichi Ohno also came up with a problem solving technique called "The Five Why's". Everyone involved in TPS were trained to trace any problem back to its root cause by asking why five times. When the root cause was defined, the workers were to devise a fix so that the error would never occur again. This approach to problem solving helps reducing "muda" or defects from the production.

In the book "The Machine That Changed the World" from 1991, the three authors James P. Womack, Daniel T. Jones, and Daniel Roos presents their findings after

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studying TPS over a five year period (from 1984 to 1990). The book offers an extensive presentation of TPS and how Lean has developed from it.

### 3.1.5 *Lean today*

The term lean was first used by John Krafcik in his article "Triumph of the Lean Production System" from 1988 based on his master thesis at MIT Sloan School of Management. Lean today can be seen on as a set of tools that can be applied to virtually any process to locate, reduce and ultimately eliminate process waste. Because of the great advantages experienced with lean techniques in manufacturing companies, lean thinking has been adopted and adapted by different business areas such as education, governmental services and product development.

Central in lean thinking and lean methodology today is to create more value for the customer with less use of resources, with customer being a loose definition. The underlying goal is to increase commercial profitability.

Lean can be seen both as a general philosophy for the organization and coordination of tasks and as a number of tools that can be implemented on a more operational level. Both approaches are considered essential for success in improving processes. There are many models that describe lean from a philosophical point of view, but a key feature is that they have their emphasis on a long term perspective where improvement efforts is well established at all levels of an organization. This is achieved by focusing on the people in the process and a mutual respect between them, delegation of challenges and cultivating the best in each individual and interacting with processes and its input and output. With this basis in mind, one can achieve positive effects of a continuous improvement with emphasis on the principles, methods and tools of lean on an operational level. Specific challenges in the operation is highlighted and a better solution than the existing one is searched after by collaborating across organizational functions and areas of expertise and using appropriate problem solving tools

Of the tools available in the "lean toolbox" of today, this thesis will focus on value stream mapping (VSM), Genchi Genbutsu and continuous improvement techniques such as Kaizen events.

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## 3.2 *Lean tools*

### 3.2.1 *Value Stream Mapping*

What is a value stream? Mike Rother and John Shook define a value stream to be "all the actions (both value-creating and nonvalue-creating) currently required to bring a product or service through the main flows essential to it" [24].

A value stream perspective is to work on the big picture and improving the whole process, not just optimizing the parts or equipment in the process.

Value stream mapping (VSM) is a lean management method used to analyze, illustrate and design the flow of materials and information in a process. The method has its roots from Toyota where it's called "material and information flow mapping" [24]. The purpose behind a VSM is to define value and waste and to identify bottlenecks in the process. The map will serve as a way of communicating the process to everyone involved in the design of it and to establish a baseline for measuring improvement in later designs.

VSM is a quantitative method in that it shows the physical steps in a process, the process time for each step, the information that flows between the steps and the amount of operators and products in the process.

Figure 15 shows an example of a current state VSM. A current state map is important to establish a common ground and to give everyone involved in the process a solid understanding of the whole, not just the part they are involved in.

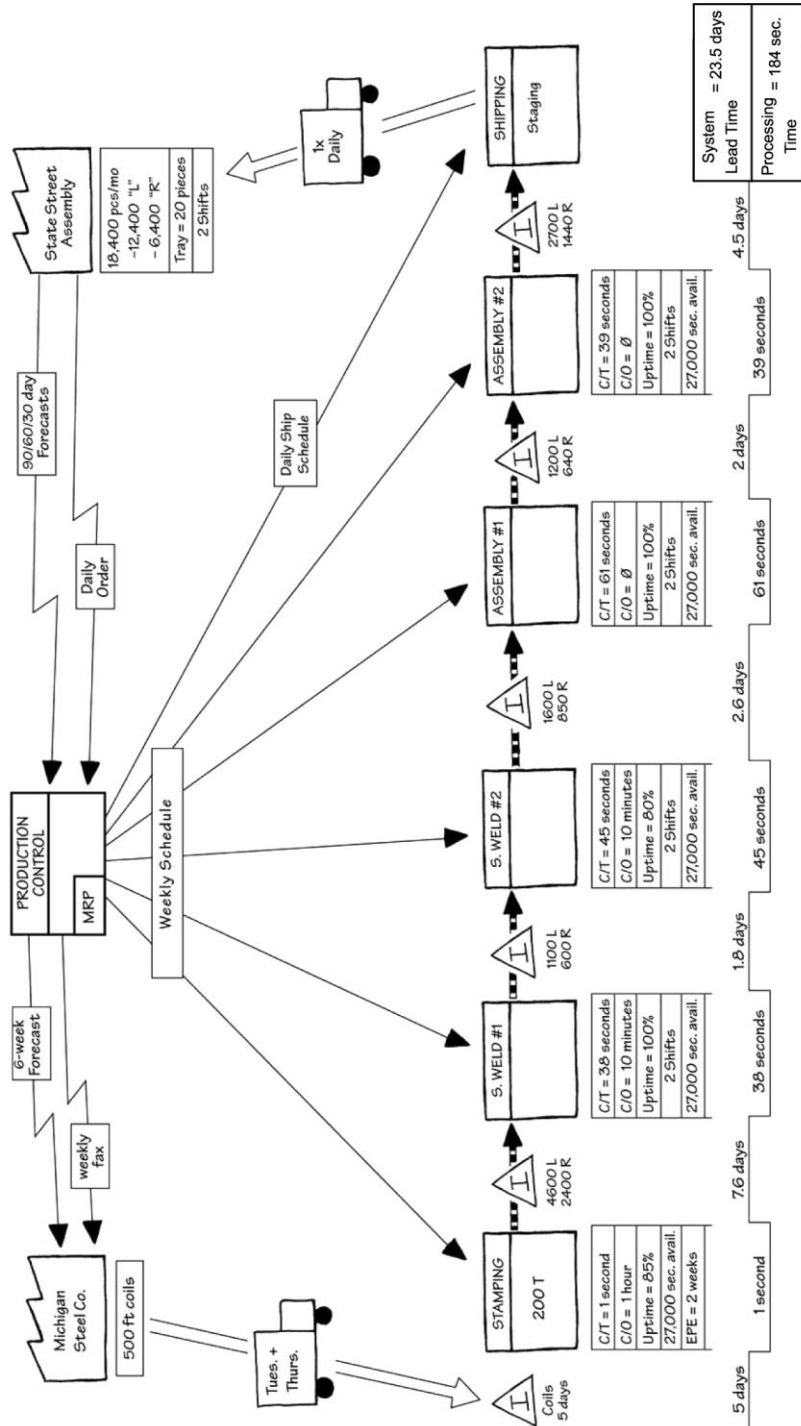


Figure 15 - Example of current state VSM (M. Rother, J. Shook 2003)

To make such a map as shown in figure 15, there are a number of steps to follow. The first one is to calculate the takt time; the time that sets the pace for the process. Takt time is given by [24]:

$$T = \frac{T_a}{T_d}$$

Where  $T$  is the takt time – the time available per unit,  $T_a$  is the net time available to work and  $T_d$  is the units required per period. On West Elara, there is a total of 12 hours per shift minus one and a half hour break per shift. There are 2 shifts per day. Net time available to work is then:

$$T_a = \left(12 - 1,5 \frac{\text{hours}}{\text{shift}}\right) \times \left(2 \frac{\text{shift}}{\text{day}}\right) \times \left(60 \frac{\text{minutes}}{\text{hour}}\right) = 1260 \frac{\text{minutes}}{\text{day}}$$

If the daily use of mud is, let's say, 120 cubic meters a day:

$$T_d = 120 \frac{\text{m}^3}{\text{day}}$$

then the takt time,  $T$ , for the mud treatment becomes:

$$T = \frac{1260 \frac{\text{minutes}}{\text{day}}}{120 \frac{\text{m}^3}{\text{day}}} = 10,5 \frac{\text{minutes}}{\text{m}^3}$$

According to this takt time example, the mud treatment needs to be able to successfully process 1 cubic meter of mud every 10 minutes and 30 seconds or approximately 5,7 cubic meters per hour.

When a takt time is established, the next step is to walk the process through. This is important to get an understanding of the general flow and to establish a defined starting point and endpoint of the process that are to be mapped. Establish the customer of the process and the demand of the customer as well as the supplier of raw material. Common practice is to visualize these with a "factory looking" box.

When the process has been walked through and the customer has been established, common practice is to draw the process from end to start. All process steps should



be defined and given its own data box in the map as shown by the six boxes, "stamping", "s.weld #1", "s.weld #2", "assembly #1", "assembly #2" and "shipping" in figure 15. These data boxes should include information on cycle time i.e. the time used for each process step.

After the process steps have been mapped, focus on the flow of materials in the process. For the mud process at West Elara, the material is the mud flowing through the mud cleaning equipment. For a manufacturing plant, the material is the unfinished goods travelling from one process step to the next until it is finished and ready for shipping. Material flow (push) is visualized by dotted black and white arrows. If the unfinished goods are stored between the different process steps, the inventory is visualized with a triangle. The material flow should include data on how long the unfinished goods wait between the different process steps and the inventory time if applicable.

The next step is to map the flow of information. Is the information manual? Use a straight arrow. Is the information electronic? Use a "lightning"-arrow. Include the different managerial functions that the information flow passes through. In figure 15, the managerial function is labeled "production control". The different information arrows are labeled according to which kind of information it is. The flow of information is something that differ VSM from a typical process map and makes a VSM able to visualize more on how the process actually works and how the different process steps interacts with each other.

The last step to complete a current state VSM is to add in the timeline. The timeline is the alternating line on the bottom of the map that sums the value added time and the waiting time. Value-added time is the time used to manipulate raw material into something the customer holds as value. The waiting time is also called nonvalue-added time because the customer cannot benefit from the time spent in inventory (unless it is a matured cheese or a twelve-year old single malt whiskey in which case the time spent in inventory is something of value to the customer).

The data from the timeline is summarized, keeping value-added time and nonvalue-added time apart. This data is used to calculate the process efficiency by dividing value-added time with the nonvalue-added time.

These steps create what is called a current state map of the process. In VSM methodology, such a map functions as a baseline for a future state map. A future state map is a proposal for a more ideal value stream than the one mapped in the current state VSM. It is often developed in what is called a kaizen event and the aim is to establish a process route with a better flow, a reduced inventory and work in progress and a shorter waiting time between the process steps to reduce the lead time of the process and increase the process efficiency. The development of a future state VSM should be carried out by an interdisciplinary team consisting of representatives from all parts of the process.

### 3.2.2 *Genchi Genbutsu*

Genchi Genbutsu is Japanese for "go and see for yourself". It is also called a Gemba attitude or "to do a Gemba walk. Gemba is Japanese meaning "the real place" or "the place where the work is done". It literally means to go and see the process with one's own eyes in order to fully understand it and to get a clear view on how a typical workday for the people involved in the process takes place.

### 3.2.3 *Kaizen event*

Kaizen is Japanese for improvement. It refers to the continuous improvement philosophy from TPS. A kaizen event is characterized as any action which purpose is to improve an existing process or a product. A part of this research work was to initiate an improvement activity and in the lean toolbox, such an improvement activity is often referred to as a kaizen event.

During the field study, the researchers inquired the operators if they would be interested in participating in the development work at Cameron Sense AS. Some of them were enthusiastic about this idea and shared their contact information with Cameron Sense AS. The plan is to gather representatives from all parts of the process, operators, managers and constructors together to map out the overall

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requirements for the mud process and then use this information both as a part of training new engineers and technicians at Cameron Sense AS and to provide a broader understanding of the process so that the products from Cameron Sense AS can perform better in the future.

## 4 Methods

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### 4.1 *Research methodology*

It was decided that field interviews and observations would provide a good way of extracting experience and knowledge from the operators working on West Elara. This approach is a qualitative one whereas a value stream mapping is a quantitative method. The main principles of VSM however, were providing a baseline for the view of the process.

### 4.2 *Quantitative vs. qualitative method*

For data gathering, two main methods exist; quantitative and qualitative. The main difference between these two methods is the nature of the data gathered. Where a quantitative method gathers measurable data that can be presented by numbers, a qualitative method collects data that are not immediately measurable. Qualitative method is used to understand a process or product whereas a quantitative method can say something about the process' or product's performance.

Quantitative method relies on measurable data represented by numbers. Statistical methods are used to analyze these data and conclusions can be drawn from the results. Although statistics can be manipulated to some extent, this method is held as an objective one.

A qualitative method gathers data through observations and interviews. The data collected is usually more descriptive of why and how things are than the data from a quantitative method that are more descriptive of what, where and when. The advantage of qualitative method over a quantitative one is that a much smaller research sample is needed than that of the quantitative method. The drawback is that a qualitative method can be much more subjective and therefore colored by the researchers own meanings, feelings and ideology [25].

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### 4.3 *Observations*

Observations are necessary to achieve knowledge about a subject. The scientific method requires observations to both formulate and test hypotheses [25]. The biggest problem with observation is that the senses of the observer are both subjective and qualitative and this makes them difficult to record, compare and reproduce. Human observations tend to shifted towards the observer's conscious and unconscious expectations and view of the world. We see what we expect to see. This is called confirmation bias. Another problem with observations are that the observer can look where he or she thinks they will find results that supports his or hers initial claim. This is called observational bias. Also, the researcher can be so motivated to find results that underpin the initial hypothesis that he sees what he wants to see. This is called pathological science and it can be both conscious and unconscious [26].

Observation may affect the process that is observed. The observer's impact on the operators in the process can either make the operators work harder and more efficient, or slower if the operators have an interest in manipulating the results. If, for example, the observed party gets the impression that the observer is to rationalize and streamline the production, the operators may work in such a way that the observer gets the impression that there is a need for more operators instead of less. An interesting saying about observations is: "Considered as a physical process itself, all forms of observation involve amplification and are thus thermodynamically irreversible processes, increasing entropy".

To strengthen the validity of the observations, they can be supported by pictures and experiences from other people. All processes described in this thesis are supported by photos from the field study.

#### *4.4 Field interviews*

Interviewing is a common way of collecting data and information. Interviews can be either qualitative or quantitative. A quantitative interview is often called a survey or a questionnaire; a set of questions with given response alternatives. A typical qualitative interview consists of a set of claims and statements that the interviewee has to consider. Typically, these interviews are based on the Likert-scale<sup>1</sup> where the interviewee answers with a number value between 1 and 5 where 5 means "strongly agree" and 1 mean "strongly disagree".

A qualitative interview is the typical interview where the interviewee and the interviewer have a dialogue where the interviewee answers questions from the interviewer. This method is more suited to extract experiences and knowledge from the interviewee because factors that the interviewer hadn't considered may come to light during the interview. This kind of interview however puts an additional responsibility on the interviewer in contrast to the survey based method. The interviewer needs to be able to adapt the questions as the interview progress in order to get the most out of the interviewee and not to ask leading questions. This calls for an interviewer with some knowledge of the subject discussed and with an unbiased approach to it.

The latter method were used for field interviews for this thesis as the objective is to extract experiences and elicit tacit knowledge from the operators that uses Cameron Sense AS' equipment on a daily basis. In a later attempt to check and verify the findings from the Design Pilot project and this thesis, a qualitative web-survey can provide a fruitful method to gather information and data.

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<sup>1</sup> A scale from 1 to 5 developed by psychologist Rensis Likert to scale responses in a survey.

### *4.5 Value stream mapping approach*

It was established that the mud recovery process was little time consuming in comparison to the drilling process. The mud treatment process is a supporting process to the drilling process which sets the pace for every other process on the rig. Because of this, the actual value stream mapping of the mud treatment process was omitted. Instead, the principles from VSM were adapted to describe the process at a higher level, with a higher level meaning incorporating operator satisfaction. This makes the results from the field study both quantitative and qualitative. Since process time and output demand vary so much in the mud process on an offshore drillrig, it was decided to look at the process this way instead on focusing on process time.

### *4.6 Schedule for field study*

The execution of the field study is planned to contain the following:

- Walk the process from start to end.
  - o Mud treatment.
  - o Mud mixing.
- Identify and evaluate process waste.
  - o Excessive movement.
  - o Underutilized people.
  - o Excessive inventory.
  - o Defects.
  - o Waiting.
  - o Overproduction.
  - o Over processing.
  - o Transport.
- Perform interviews with key personnel offshore.

# 5 Field study

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## 5.1 Introduction

From Wednesday the 1<sup>st</sup> of May to Tuesday the 7<sup>th</sup> of May, the author visited West Elara, a jack-up rig operating on the Norwegian Valemon-field in the North-Sea, to conduct a field study together with a representative from Cameron Sense AS. The objective was to interview personnel from the operation and to observe the process.

To be able to travel offshore, the author had to undergo four full days of training in areas such as first-aid, chemical handling, sea rescue, helicopter underwater evacuation training and firefighting. A clean bill of health and a pass on an online exam were also among the prerequisites for a trip offshore.

Before travelling to West Elara, the author together with Ranveig Stalsberg interviewed Oddvar Birkeland, senior advisor at Cameron Sense AS and Mud Engineer at MI Swaco, to establish a process map of the mud process at West Elara. The interviews was conducted over three days in the period between the 21<sup>st</sup> and 28<sup>th</sup> of February 2013. This was done to achieve a general understanding of the process flow. The process map is available in appendix C.

Statoil expressed interest in the study when they were inquired about permission to travel to West Elara. At the 6<sup>th</sup> of March, Ranveig Stalsberg and the author visited Statoil's research center at Rotvoll in Trondheim to present the scope of the project. Statoil allowed for the trip offshore in order to "be kept in the loop" in return.



## 5.2 About West Elara

West Elara is a jack-up drilling rig owned by North Atlantic Drilling Ltd., a sub-division of Seadrill. It currently operates on the Norwegian Valemon field for Statoil. The Valemon field is located in the northern part of the North Sea just outside Bergen between the oilfields Kvitebjørn and Gullfaks Sør. The field is under development and anticipated startup for oil production is in 2014. Drilling operations is planned to be finalized by 2016/17 [11].



**Figure 16 - Valemon field in the North Sea (source: Statoil)**

West Elara is one of the world's largest jack-up rigs and purpose built for the conditions in the North Sea. It is capable of operating in water depths of up to 150 meters and for drilling depths of up to 10.670 meters [27].



**Figure 17 - West Elara in the North Sea (source: Seadrill)**

**Table 3 - General information - West Elara [27]**

*West Elara Jack-Up drillrig*

<b>Length</b>	88,6 meters
<b>Width</b>	97,2 meters
<b>Gross tonnage</b>	25.008 metric tons
<b>Accommodation</b>	120 persons
<b>Diesel capacity</b>	2.040 m <sup>3</sup>
<b>Drill water capacity</b>	3.557 m <sup>3</sup>
<b>Liquid mud capacity</b>	854 m <sup>3</sup> (OBM), 854 m <sup>3</sup> (WBM)

Appendix A presents complementary information about West Elara.

Cameron Sense AS has delivered the drilling equipment and much of the equipment for mud handling under the brand name TTS Energy as the equipment was delivered prior to Cameron International Corporation's acquisition.

Between the 1<sup>st</sup> and 7<sup>th</sup> of May, the well currently being drilled was of a depth around 4.400 meters. The well conditions were described as "HTHP", meaning "High Temperature, High Pressure". This meant that the drilling operation is difficult to log and the conditions in the well difficult to anticipate.

### 5.3 *General observations*

The first thing that was experienced when arriving on the rig was the meticulous attention to safety and potential hazards. No one is allowed on deck without a safety helmet, protective gloves and eyewear, a personal gas detector (due to the camera), safety boots and coverall. Every task that is not directly linked to the daily operation needs a work permit and a risk assessment called a safe job analysis (SJA). Taking pictures with a digital camera required a work permit to be signed and approved by the rig manager, the Drilling Section Leader (DSL) and the site manager for the area where the pictures would be taken at the start of the shift and signed again when the shift ended. The reason for this is to have a complete and total overview of what work is being done in which sectors at what time. The whole rig except the living quarters is categorized as an EX-area zone 1. This is defined by the presence of explosive gases present under normal operating conditions. Since a digital camera contains batteries, taking pictures is categorized as hot work and needs a work permit.

The tour around the rig with the Drilling Section Leader (DSL) on the first day revealed some things they were dissatisfied with. The DSL mentioned that they were having some problems with the mud mixing and mud treatment equipment. He mentioned problems with loading barite from the bulk system and pumping mud through the trip tanks. He also mentioned problems with the SDU and manual feeders in the mixing room and what he called "miserable conditions" in the shaker room. During this tour, both researchers took note of the poor layout of the rig and the time spent on walking from one part of the process to another. This was later confirmed by the drilling manager from Statoil. It was told that the rig was bought through a bankruptcy sale and that it was specified after one investor's idea on how a drillrig should be arranged. In general, the feedback from the management on the rig was quite negative. They mentioned that the rig was specified after "what the economists and engineers on shore thought was a good idea" and that they "didn't know anything about the drilling process but just focused on the equipment and how it functioned on the drawing board and in a controlled environment."

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## *5.4 Observations and experiences – Mud treatment*

The mud treatment process was observed over two days. During these days it was confirmed that much of the equipment and procedures appeared to not have changed or evolved much from older rigs. At first glance, the researchers took note of the many different control panels that had to be operated manually outside of the control room in the shaker room and many tasks needed brute force and heavy labor to execute. The weighing of mud, changing of the shaker screens, start-up and shutdown of degasser, flow check, all these operations were done by the roughneck manually.

### *Weighing mud*

The mud weighing process is to be done every 15 minutes while drilling. The hatch for catching mud samples are on the opposite side of the room as the control room and the weighing station. The roughneck needs to pass all eight shakers in order to reach the sample hatch. The mud is weighed in a cylindrical container attached to a slide weight and the readings are corrected for different temperature by a sheet listing the specific gravities at different temperatures. In total, this operation was observed to take between four to six minutes.

The consistency of the results from the weighing is somewhat uneven. It was observed that the results differed according to which person performed the weighing. Because of the procedure, the probability of a faulty reading or a poorly executed weighing is present. In addition to that, it rises with increasing stress levels for the operators. Sometimes during the HTHP period, the drilling operation hits a section in the well where the conditions are difficult to anticipate. If so, the driller needs continuous readings from the shaker room operator to know if the mud transports something out of the well or if something is lost in the well. These continuous readings can put a strain on the roughneck in the shaker room and this strain can cause the operator to misread the values from, or corrupt the weighing process. The readings from the mud weighing are of high value for the driller and any inconsistencies in these readings can be treated as defects and ultimately process waste.

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**Figure 18 - Sampling mud for weighing (photo: Sondre Buset Bjelland)**



**Figure 19 - Weighing station for mud (photo: Sondre Buset Bjelland)**



**Figure 20 - Correcting mud weight for temperature (photo: Sondre Buset Bjelland)**

### *Changing shaker screens*

The shaker screens needs to be checked once every shift and replaced if necessary. This is an operation that needed some brute force and rigging to get the screens correctly in place after inspection. This operation was observed to take around six minutes. According to the roughneck, changing the screens on all eight shakers takes over one hour to do alone. This operation can be related to the Japanese term *muri* meaning "to put ones employees under stress" or "overburdening ones employees". *Muri* is one kind of waste from TPS as stated in chapter 3.1.4.



**Figure 21 - Releasing the shaker screen (photo: Sondre Buset Bjelland)**



**Figure 22 - The shaker screen comes out (photo: Sondre Buset Bjelland)**



**Figure 23 - The shaker screen after inspection (photo: Sondre Buset Bjelland)**





**Figure 24 - Brute force required to attach the screen (photo: Sondre Buset Bjelland)**



**Figure 25 - Control panel for shakers (photo: Sondre Buset Bjelland)**

### *Other operations*

The control panels for the shakers and the control panel for the screw conveyors were placed apart from each other. Also, these two control panels were not interconnected with each other. When the operator stops the shakers for maintenance, he also stops the screw conveyors. If he forgets to start the screw conveyor when he starts the shakers, the cuttings will pile up in front of the shakers and the roughneck will have to clean the area. The system has no built-in failsafeing.

Checking the flow is something the roughneck needs to do at the driller's request. There are no systems for visually checking this and the procedure states that the flow of mud is to be visually checked every time the drilling process starts up. The flow check hatch is placed on a small platform above the floor in the shaker room. The roughneck needs to climb a ladder and open a hatch in order to reach this platform. The layout of the shaker room causes excessive movement i.e. the layout doesn't promote flow of people.

The start/stop of the degasser is ordered by the driller. When the driller orders the roughneck in the shaker room to start the degasser, he has to walk to a control panel in the opposite corner of the control room. This also leads to excessive movement.

Every time a well is finished or there is a change from OBM to WBM, the shaker room must be cleaned. According to the operators on West Elara, this is an operation that takes two persons about 12 hours to complete, a full shift. If the mud has been hot and oil vapor has filled the room, the cleaning takes two persons about 24 hours to clean.



**Figure 26 - Control panel for screw conveyors (photo: Sondre Buset Bjelland)**



**Figure 27 - Warning on screw conveyor control panel (photo: Sondre Buset Bjelland)**

### *Modifications*

All eight shakers were modified by the rig welder. They were delivered without any form of shielding in front of the cuttings exit. This led much of the cuttings to land on the floor instead of into the screw conveyor. This made the cleaning operation much more time consuming according to the roughneck and the rig welder.



**Figure 28 - Retrofitted shield in front of shaker (photo: Sondre Buset Bjelland)**

The rig welder said that he had gone about and modified much of the equipment all over the rig because of poor original solutions. This additional work is a consequence of poor planning and product design, one of the wastes in TPS as described in chapter 3.1.4.

### *Overall experience from mud treatment*

Overall observations revealed that much of the time were spent waiting for new instructions from the driller. The drilling process sets the pace for all others and it is also the one that takes by far the longest time. When the tasks stated in the work procedure for every process step in the mud treatment are done, the operators retires to only monitoring the process from the control system and awaits further orders. For an ideal drilling operation, the derrickman in the mud mixing department and the roughneck in the mud treatment department only have to do some simple tasks every now and then. The net time available for work was observed to be longer than needed for many of the process steps. This ideal state helps reduce some of the observed process waste i.e. muda (defects) and muri (strain on operators), but it introduces other, namely waiting and underutilized people, the eight waste.

During the field study from the 1<sup>st</sup> to the 7<sup>th</sup> of May 2013, the temperature of the returning mud was relatively cool, around 30 to 40 °C, but according to the operators, the temperature of the returning mud can reach temperatures up to 70 or 80 °C. When the temperature is at these levels, the mud vaporizes and an oil fume or VOC's<sup>1</sup> fills the room. The condition of the shaker room when the mud is hot is described as "very unpleasant" and that "it is impossible to see from one end to the other in the room".

In table 4, the different manual operations observed in the mud treatment process are listed together with the added value to the process and waste.

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<sup>1</sup> Volatile Organic Compound. Organic compounds with a low boiling point

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**Table 4 - Table of manual operations in mud treatment**

<i>Process</i>	<i>Time spent</i>	<i>Value</i>	<i>Waste</i>
<b>Weighing mud</b>	4 – 6 minutes	Information to driller	Faulty readings, excessive movement
<b>Changing screens</b>	6 minutes (per shaker)	New screen, better separation of mud and solids	<i>Muri</i> , overburden
<b>Start/stop degasser</b>	1 minute	Degasser starts	Excessive movement
<b>Checking flow</b>	2 minutes	Information to driller	Excessive movement
<b>Cleaning shaker room</b>	12 – 24 hours	Clean room, no contaminants in new mud	<i>Muri</i> , overburden

## 5.5 *Observations and experiences – Mud mixing*

Since Cameron Sense AS delivers much of the equipment for mud mixing, it was decided to expand the scope to encompass both the mud treatment process and the mud mixing process

The mud mixing process requires a relatively high amount of manual labor compared to other processes at the rig. During the period of observation, several problem areas with regard to the flow of people, information and products was discovered. It was also observed some problems directly concerning the equipment in the process. Much of the feedback from the operators was about equipment that could not withstand the rough conditions offshore.

### *Mixing the mud*

Observation of operation of the SDU in the mixing room revealed some flaws with the design of it. When mixing several sacks of powdered chemical into the mud, problems like jamming of the empty sacks, incomplete emptying of the sacks, dust leakage and breakdowns due to excessive powder build-ups on sensors and actuators were seen. According to the derrickman and his assistant, problems like these was experienced around two thirds of the time. This is an example of process waste. The problems with the SDU can be treated as defects. The delivery of one sack into the mud cycle is defective if the operator has to either fix the problem with the machine or bypass it by adding the chemicals manually.

When the SDU is in use, it is typical to mix in 20 to 50 bags à 25 kg per operation. If the machine breaks down and the operators or the rig electrician are unable to find the problem in a reasonable amount of time, the sacks must be mixed into the system manually with the use of a hopper. This is placed one floor up from the SDU and the sacks must be carried one at the time from the pallet by the SDU, up one stair and between some narrow piping in order to get to it. Both the derrickman and his assistant complained about being totally exhausted after doing this (see figure 29 and figure 30). This is an even clearer example of muri (overburden) than the changing of the shaker screens in the mud treatment process.

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**Figure 29 - Stair from sack store to hopper (photo: Sondre Buset Bjelland)**



**Figure 30 - Manual mixing of powdered chemicals (photo: Sondre Buset Bjelland)**



Another issue with the mud mixing relates to poor placement of the equipment. Some powdered chemicals is delivered in sacks a 1.000 kg and is mixed in by the use of a forklift and what is called a Big Bag Unit (BBU). The BBU is placed just below a platform so that the gap between the top of the BBU and the platform is too narrow to get one of these bags in between. The solution is to remove the funnel on the big bag unit and place it on the floor, put the bag into the funnel, replace the funnel on the BBU and start mixing in the chemicals.



**Figure 31 - The Big Bag Unit (photo: Sondre Buset Bjelland)**

The placement of the BBU takes away much of the reason for why it was installed in the first place. The added work needed to mix in a 1.000 kg sack of chemicals can be described as waste due to poor process design, one of the seven wastes in TPS.

### *Transporting the mud*

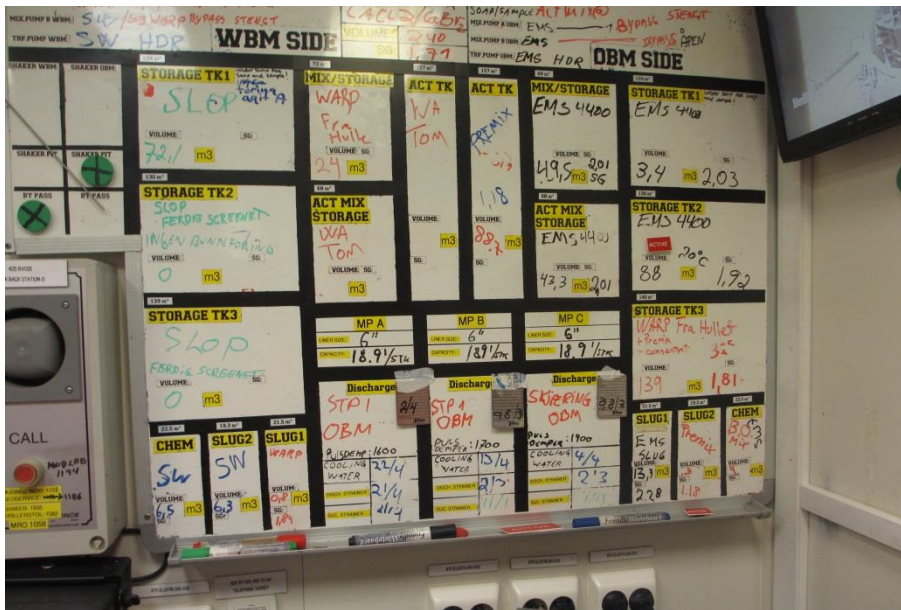
In the mud mixing process, the transport of ready-mixed mud requires some manual lineup of valves. Only some of the valves are equipped for remote operation. To route the mud from the mixing cycle to the drillfloor means that the derrickman and his assistant have to walk and manually open and close the correct valves. The area set off to mud mixing is complex. It occupies several floors and large areas. To walk between the different valves takes time and is a typical example on excessive movement.



**Figure 32 - Manual lineup of valve (photo: Sondre Buset Bjelland)**

*Mud mixing information flow*

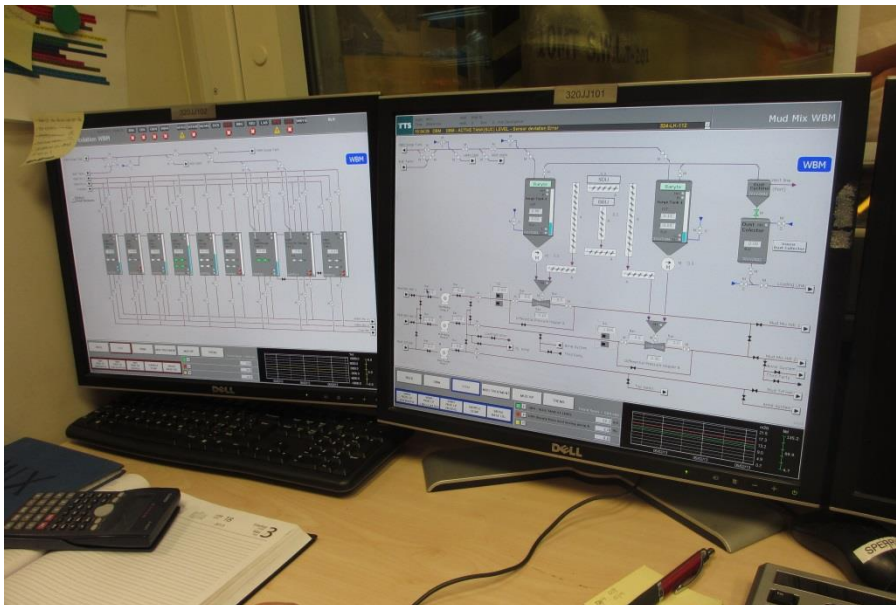
Much of the information flow occurs through the control system for the mud process. The operators have access to real time data for ongoing sub-processes for the mud process. Some of the information however is sent through walkie-talkies and over telephone. Also, some of the information needed is left out. Several valves are installed without a feedback signal so the control system does not show if the actual valve is open or closed. Some tanks are not implemented in the system so they have to use a whiteboard to keep track of which tanks are active and which are passive (active tanks are the ones used in the mud circulation while drilling). It was discovered different solutions to the lack of information in the control system. Some valves were operated with a key and the routine was to hang the key in a visible place in the derrickman's shack when closed and leave the key in the valve when open.



**Figure 33 - Whiteboard for mud tank overview (photo: Sondre Buset Bjelland)**



**Figure 34 - Valve keys for valves without feedback (photo: Sondre Buset Bjelland)**



**Figure 35 - Control system for mud mixing (photo: Sondre Buset Bjelland)**

The lack of information on the control system provides additional work for the operators in that they need to manually check the lineup of valves and update the whiteboard.

During the field study the researchers experienced some of the problems that are a direct consequence of poor information flow. At one occasion it was observed a direct miscommunication and misunderstanding between the derrickman and driller. The driller ordered a new type of mud to be ready "in time for the coffee break". The derrickman lined up the valves and made the system ready to mix and shear the new mud at four o'clock; the time he usually had his coffee break. The driller meant two o'clock because this was when he usually had his coffee break. As a result of this, the derrickman and his assistant had to run around and mix the mud manually while the driller waited for the new mud. A technical downtime for the drilling process of around one hour was registered due to this incident and downtime has to be regarded as waste.

### *Other operations*

As in the shaker room, many of the different control panels for the mud mixing process cannot be operated from the control system in the derrickman's shack and are spread around the mud mixing area. One example is the startup of the high pressure pumps used for circulating the mud through the well. The control panel is placed by the high pressure pumps, but the rate it is pumping at is shown in the control system in the derrickman's shack. The control panel shows "strokes per minute" (the pump is of piston type) so the person operating the high pressure pump needs to be in radio contact with one person monitoring the pump rate in the control system. Starting up the high pressure pump becomes a two man job

### *Overall experience from mud mixing*

The experience from the mud mixing process is that the level of activity varies a lot. If the well is stable and the mud that circulates in it is reused, the derrickmen awaits further notice. During handover from the dayshift to the nightshift, the Derrickman on the nightshift noted that "it will probably be a quiet night". As for

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the mud treatment process, the mud mixing process consists of waiting for the driller to give orders.

Table 5 lists some of the different manual operations observed in the mud mixing process.

**Table 5 – Table of manual operations in mud mixing**

<i>Process</i>	<i>Time spent</i>	<i>Value</i>	<i>Waste</i>
<b>Mixing powdered chemical manually</b>	Approx. 60 minutes	Mud to specification	<i>Muri</i> , overburden
<b>Mixing powdered chemical by BBU</b>	Approx. 20 minutes	Mud to specification	Over-processing
<b>Lining up valves</b>	1 – 10 minutes (varies)	Correct route for mud	Excessive movement,
<b>Information through control system</b>	Continuously	Correct information to operators involved	<i>Muri</i> , overburden Defects
<b>Starting HP pump</b>	3 – 6 minutes	Circulation of mud	Excessive use of personnel

## 5.6 *Voice of the customer*

The researchers were able to gather the dayshift crew from 20:00 to 21:00 on Saturday the 4<sup>th</sup> of May for a brainstorming session. The goal was to extract experiences with the equipment and elicit tacit knowledge from the crew. Done by asking some questions and make the participants discuss and write down their thoughts on a post-it note and hang them on the wall. When the first participant hanged up his notes, discussion started and soon most of the participants were active in the brainstorming session. The notes were gathered afterwards and sorted.

For mud treatment, the most common feedbacks were about the air quality in the shaker room, the noise level there and the time spent on washing the room. There were complaints about an uneven floor with different levels that acts as a trap for dirt and sand. A new solution called MudCube was mentioned. This was something that both the operators and the rig management wanted in the shaker room. The TSL (Technical Section Lead) mentioned that they were to have a meeting with the producers of MudCube when he was back on shore.

For mud mixing, the operators complained about shortcomings in the control system (valves without feedback, tag numbers not visible on computer screen), sensors that does not function, manual mud weighing and equipment that break down.

When confronting some of the constructors with the problems that came up through this meeting, they became defensive and meant that the responsibility for downtime of the equipment was due to user error.

Much of the feedback from the crew in the process was of a negative character. Several complaints on Cameron Sense AS' equipment were given by the operators from Seadrill. From Statoil however, the feedback was positive and reports of a good uptime rate when using Cameron Sense AS' equipment was collected. Statoil made a remark that much of the problems with Cameron Sense AS' equipment on West Elara are start-up problems and that these problems is not present on other rigs using Cameron Sense AS' equipment.

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**Figure 36 - Brainstorming session with the operators (photo: Sondre Buset Bjelland)**



**Figure 37 - Post-it method for brainstorming (photo: Sondre Buset Bjelland)**



The new solution that was mentioned during the brainstorming session with the crew is a radical redesign of the shale shaker called MudCube. The MudCube is not a shaker, but a conveyor screen with negative pressure on one side, sucking the liquid mud through the screen while the cuttings are transported away by the conveyor. The author contacted Cubility, the company behind the MudCube, to ask about MudCube's reception in the market. The answer they gave was that they have had some difficulties with selling the machine due to little field experience with it. They have installed MudCubes on the drillrig Maersk Giant and four wells have been drilled with MudCubes in the treatment process without any downtime that could be traced to these machines. Cubility sent over some pictures to visualize the conditions in the shaker room on Maersk Giant before and after installation of MudCubes (notice the white coverall and breathing apparatus on the operator). Cubility said that it has not been before now, with the field experience and operational data from Maersk Giant, that the interest in their product has risen.



**Figure 38 - MudCube shale/mud separator (source: Cubility)**



**Figure 39 - Before installation of MudCube (source: Cubility)**



**Figure 40 - After installation of MudCubes (source: Cubility)**

An interview with the crane operator who also is the chief health and safety officer and has several years of experience from offshore drilling operations revealed some interesting viewpoints. The interview is translated to English by the author.

*"Everything on board is so split up. There's no overall view. The engineers onshore are all experts in their own field, and design something that solves a tiny part of the process. When all these tiny parts are put together, we end up with a system that doesn't fit together logically, and this is what we'll run on."*

[...]

*"Everyone here thinks that we could've made an optimal rig if we had been allowed to design it ourselves, but it would probably not have been cheap. We would only use valves we knew would work rather than any cheap solution that breaks after a month in operation and needs replacement. The vendors are so price-focused. They buy lots of cheap crap everyone know cannot work, but it meets the specifications. If we (the operators) could decide we'd have a better layout and we'd make machines that worked. Not the "half-way machines" the engineers on land construct. The people here are probably not as creative as the engineers on land since we are used to solve problems quickly, but it would at least have worked."*

*"An ideal development project should include the user in development. How can they believe that they can make something that works when they do not talk with the users of the equipment and the process, and how can they believe that what they construct can work when they don't understand the whole process?"*

*"Automation reduces manual work - it is true, but in many ways we get heavier manual operations than before. When the machine fails, we need to operate manually, and then there is a problem because nothing is suited for manual work anymore. You have to create systems so that when a machine breaks down, you can manually operate that process step without wearing yourself to death or break your neck in an unusual position. It has*

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*to be easy to operate every process step manually so that it can be done the day the machinery breaks down. See for example the SDU. It should have been a free passage to the hoppers on the platform above, and it should have been possible to deliver a sack pallet from the sack store directly, so the derrickman doesn't have to run up and down with 150 bags and work his way between all the pipes to get to the hoppers."*

*"Remember that it isn't robots that work here. We have a lot of equipment to operate and when we see the animations in 3D from the suppliers, it looks nice. Everything happens automatically, but where are the people? In the real world, there are people around these machines, people who work. And they aren't robots. They are about 180 cm high and they don't have three meters long arms and they cannot lift 400 kg."*

*"Development is moving fast, but it is not unambiguously positive. It has become much more expensive to drill a well now that everything is so automatic and fancy. It should be possible to create machines that actually makes operation easier, faster and cheaper, shouldn't it?"*

*"None of you (equipment suppliers) invite us users in the development work. We might not always be so creative, but we should at least be involved so that we can provide our experiences. Someone should be able to connect engineering creativity with operator experience in a meaningful way so that we can get better rigs out here!"*

*We buy a product that shall deliver mud from A to Z. We get that, the rig delivers mud from A to Z, but the degree of performance for the mud process is not something that the yard that builds the rig thinks about. Many of the solutions for the transfer of mud are so cumbersome that things take much more time than necessary. We see these issues when we visit the yard, but the closer we are delivery, the less we are allowed to influence. So often we take the rig as it is, and rebuild it "the right way". When we rebuild and replace the equipment, we use equipment we know will work. It's cheaper to have us rebuild the rig than to change it at the*

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*yard. It's no fun to stand there (at the yard) and see that they are building after a bad spec when you know that we have to rebuild it straight away. We try to improve specifications for each time, but the improvements are so slow. Perhaps the whole specification process needs changing? We users have to have our voice heard I think, in one way or another."*

In general, the feedback received from many of the operators was negative. It may be because they exaggerated their experiences to make a point, but nonetheless. The experiences and knowledge drawn from the one week field trip paints a picture of a work situation that relies heavily on manual labor and creative solutions to work around any problem that occurs during operation.

## 6 Results and discussion

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### 6.1 *General*

The results from the field study supports the initial claim that much of the mud process is based on old and somewhat inefficient solutions and that there is room for improvement and changes in both the layout and equipment. Much of the problems and the waste associated by them can be reduced or even removed with some efforts from Cameron Sense AS' side. Some of the proposed solutions demands very little work, let's call them "low hanging fruits".

### 6.2 *Mud treatment*

In the mud treatment process, most of the observed process waste was about layout and process routines. In table 4 in chapter 5.4, the waste is coupled with the manual operations in the process. One can see that the value added from these operations can be achieved without the waste. From the brainstorming session on Saturday the 4<sup>th</sup> of May on West Elara, the MudCube from Cubility came up as a solution to many of the problems in the shaker room. According to Cubility, the MudCube waives the need for shaker screen change and by that frees up the operator in the shaker room to do other things. Another thing that can help reduce waste in the mud treatment process is to incorporate automatic density measuring of the mud in the mud flow line. This, in conjunction with allowing the different control panels in the shaker room to be remotely operated almost removes the need for an operator to be in the shaker room while the mud flows through it.

### 6.3 *Mud mixing*

Table 5 in chapter 5.5 lists the manual operations the mud mixing process together with the process waste. In this process, much of the problems could be traced back to the SDU. This machine is designed by Cameron Sense AS. The machine installed at West Elara was a prototype at the time of installation, but several machines have been installed in later installations and are in active duty without any

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specific problems. Updating the prototype SDU installed on West Elara to the retail version could provide a stable solution to most of the problems and help reduce some of the waste caused by it.

Another problem that was observed was a result of inadequate specifications sent to the yard building the rig. Many of the valves used for lining up the path for mud circulation were manually operated and lacked position feedback. Excessive walking to these valves and double-checking them put a strain on the operators in the mud mixing. They wondered why not every valve could be remotely operated, and if that some valves must be manually operated due to safety regulations that they at least had position feedback to the control system. Specifying remotely operated valves with position feedback and incorporating these in the control system would remove some of the process waste due to excessive movement.

Also, by specifying a minimum height above the BBU one can prevent the BBU being installed under a platform or ceiling and this way remove the need to lift the funnel of the base every time a new 1.000 kg sack is to be mixed into the flowline.

Allowing the high pressure pumps to be started remotely or installing a screen showing the pump rate by the control panel to the high pressure pumps would remove the need for to persons to start these pumps.

The control system was the subject of many improvement suggestions. In general the operators were satisfied with the control system. It was easy to use and provided a good understanding of the flow. There were however many suggestions for minor improvements. The control system and more specific the human-machine interface (HMI) is something that maybe could benefit of a thorough mapping of the user and the users need. Many of the minor improvement suggestions were on things that could be programmed and released as an update to existing control systems. Features such as color coding to see which route the mud flows through, the possibility to show all tag numbers for all valves and he possibility to get the raw values in mA for every PLC (Programmable Logical Controller) would ease the work for both the derrickman and the rig electrician.

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### *6.4 The mud process compared to the drilling process*

For the researchers, the drilling process seemed much more modern and streamlined than the mud process. The drillers had large, comfortable chairs and the loading of new pipes were fully automated. In comparison, the control rooms for mud mixing and the one for mud treatment had small office chairs and no daylight. The mud processes is also much more dependent on manual labor than the drilling process. The drilling process appeared much more streamlined and modern than mud handling.

An explanation to why this is so may be that the drilling process is the main process and hence it has a higher status than the supporting process that is mud handling, but this thesis won't go further into details about the difference between these two areas on a drillrig.



**Figure 41 - The Driller chair (photo: Ranveig Stalsberg)**





**Figure 42 - Automatic pipe handling on drillfloor (photo: Sondre Buset Bjelland)**



**Figure 43 - The derrickman's shack (photo: Sondre Buset Bjelland)**

## 6.5 Overall experience

The value stream method used in the field study has managed to extract many experiences from the operators of Cameron Sense AS' equipment. It has proven to be a fruitful way coupling operator feedback with "eyes for waste". The problem with not presenting the findings in a value stream map, something that was omitted due to the little importance of cycle time for the different operations in both the mud treatment process and the mud mixing process and the complex flow of these, is the lack of a standardized format to present the findings in. Nevertheless, the findings in this study show that lean methodology and a value stream approach can be used on an offshore drillrig to elicit operator feedback. The act of going to see the process for one self (go to gemba) is something that can be recommended for everyone that is to construct and produce offshore drilling equipment.

# 7 Conclusion and further work

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This thesis documents the field study done for Cameron Sense AS on the offshore drillrig West Elara. The goal was to study and map the mud treatment process in order to provide the people responsible for product development at Cameron Sense AS with an overview of the process and give them a better knowledge about the daily use of the equipment they deliver by utilizing a value stream approach.

In addition to this, it was desired to provide an introduction to lean methodology and the history behind it as well as general information on drilling, drilling fluids and mud processing.

The approach used in the field study differs from the standardized value stream mapping technique due to the processes evaluated being sub processes to the drilling operation which sets the pace and takes the longest time. The focus has been on what creates value rather than the cycle time for the different tasks as the drilling operation is the one that takes the longest time.

To present the results in a standardized value stream map proved difficult due to the complex flow of mud on West Elara. Despite of this, the approach has shed light on some significant gaps between the equipment suppliers and the operators offshore regarding operator satisfaction. The value aspect in this approach changes the view from the equipment level to the process level and the tasks that need to be done in order to deliver the right mud to the drilling operation at the right time.

Suggested further work is to establish an appropriate format for visualizing the results and findings from this field study in order to use it for training of new personnel at Cameron Sense AS.

A kaizen event with key personnel from the stakeholders for West Elara mud process; Statoil, Seadrill, MI Swaco and Cameron Sense AS, were among the tasks in this thesis. This is something that has not been done within the framework of this thesis due to a lack of time. It is suggested that such a meeting is planned in the near future.

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# Appendix

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Appendix A – Technical information for West Elara

Appendix B – Daily reports from field study to Cameron Sense AS

Appendix C – Fold-out process map of mud treatment process at West Elara





## Appendix A – Technical information for West Elara



### West Elara

West Elara is constructed at Jurong Shipyard in Singapore and was delivered in Q3, 2011. West Elara is designed to operate in harsh environments, in water-depths up to 150 m with drilling depths down to 10,670 m.

For further information contact:

Marketing - Contract

Tel: +4751309000

E-mail: [marketing@seadrill.com](mailto:marketing@seadrill.com)

Web: [www.seadrill.com](http://www.seadrill.com)



#### GENERAL

Design	Gusto MSC CJ70-X150A
Built/year	JSPL / 2011
Flag	Norway
Classification	DNV
Class notations	+1A1 Self Elevating Drilling Unit E0, DRILL(N), CRANE & HELDK

#### MAIN DIMENSIONS/TECHNICAL

Length x breadth	88,6m (hull longitude) x 97,2m (hull transversal)
Design max WD	150 m*
Design min WD	25 m*
Drilling depth	10 670 m
Variable load	20,676 mT (Operational)
Helideck	HELDK, S92/ EC225
Accommodation	120

#### STORAGE CAPACITIES

Fuel	2040	m3
Drill water	3557	m3
Potable water	538	m3
Liquid mud	WBM 854	m3
	OBM 854	m3
Base oil	608	m3
Brine	889	m3
Barite/Bentonite	315	m3
Cement	228	m3

#### DRILLING EQUIPMENT

Derrick	1134 mt
Drawworks	TTS Sense Ultra Hoist 1250-5600
Racking capacity	8,260 m 6 5/8", 4,360 m 5 7/8"
BHA	744 m DC/BHA
Csg storage	13 3/8" or 9 5/8" or 7"
Top drive	TTS Sense TD 1150 AC- 2M (Dual AC) 2 x 850 kW
- continuous torque	122,1 kNm
Rotary table	1.54 m VBJ RST (60,5")
Iron roughneck	2 x JIM 20 w/ integrated pipe cleaning, doping and mud bucket

\* Subject to seabed fixation

#### WELL CONTROL

BOP	4 ram BOP - Hydril 0.467 m (18.75") 2 x double 1034 bar (15ksi) 1 Annular Hydril GX
Diverter	Vetco KFDS CSO 1,25 m (49 1/2") Diverter housing
C&K manifold	Techdrill 1034 bar (15Kpsi)

#### TENSION SYSTEM

Conductor tension	400 mt (883 kips)
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#### BOP HANDLING

BOP crane	Sense 2 x 60 mt
BOP Skid	120 sh-ton

#### MUD SYSTEM

Mud pumps	517 bar 2 x 4 MI Swaco BEM 650 Shakers
Pressure rating	Wirth TPK 7 1/2" x 14" / 2200 3 x 1,620 kW (2,200 hp)
Solids control	2 with Mud cleaning device. Segregated for WBM/ OBM handling

#### POWER

Main engines	4 x Cat C280-12
Main generators	3 460 bkW
Total power	13,84 MW
Mooring lines	Harbour mooring and rig positioning
Mooring winches	4 x 800kN winch/ 2050kN brake

#### LIFTING EQUIPMENT

Deck crane	NOV - 3 x 85 mt
Deck crane rating	85 mt
Pipe handling crane	Knuckle boom crane

#### OTHER FEATURES

Offline stand building of drill pipes and casing  
Dual mud system for both WBM/OBM, large  
storage area and long out reach.

**Appendix B – Daily reports from field study to Cameron Sense AS**

The following pages contain reports from the field study as sent to Cameron Sense AS. Names and company specific knowledge is edited out due to the report being openly available through DAIM.

All of the reports are written in Norwegian.

**Drilling Systems**

Andøyfaret 3  
4623 Kristiansand  
Norway

Telephone +47 38 00 05 70  
Telefax +47 38 00 05 71  
Web [www.c-a-m.com](http://www.c-a-m.com)

Org no 981 919 971 MVA

# Dagsrapporter fra West Elara feltstudie

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## *Dag 1 – Onsdag 1. mai 2013*

Ankom riggen ca. 1830 i full storm. De-briefing og sikkerhetsrunde med sikkerhetsoffiser for alle førstegangsbesøkende.

Utlevering av radio og personlig gassmåler. Reservasjon av sete på returflight tirsdag 7.mai v/radiokontroller. Innsjekk kl. 1730 på rigg den 7. mai.

Vi ble godt mottatt av Drilling Section Leader (DSL) og fikk omvisning/introrunde med DSL og teknisk sjef på rigg. Vi gikk gjennom pumperommene(OBM, WBM), sack store/mix (OBM, WBM), bulk, treatment, cuttings handling, drill floor, BOP, trip-tanker, samt at vi hilste på driller, derrickman og Shakerhand.

Under runden, ble det nevnt en del forhold DSL og teknisk sjef var misfornøyd med, blant annet:

- Hopperne: Ventilen mellom venturimixer og trakt stenger ikke ordentlig og mud presses opp i trakten. DSL mente dette skyldes en underdimensjonert aktuator.
- Blåsing fra bulktank: Her har de ifølge teknisk sjef problemer med tilstrekkelig tilgang på tørrluft for transport av bulkmateriale.
- Sekkekutter: Mye problemer. De nevnte spesielt emballasjeskruen, som er modifisert nå.
- Trip tank: Problemer med tømning/fylling og kapasitet på pumpe. DSL mente dette kunne løses mekanisk.
- Pumperom: Sensorer i tankene er ikke nøyaktige nok jfr. fjærsensorer og plassering av disse. De nevnte at andre firmaer er flinkere på dette.

- Shakerrom: «Ulevelig» der pga. oljedampen. De har installert provisoriske «hageslanger» fra ventilasjonsanlegget for å føre oljekondensat ut.

Av mer generell karakter, ble følgende nevnt:

*"Jeg (DSL) har jobbet offshore siden 1980, og det er jo alltid sånn. Vi får en rigg, og så drifter vi den et år og så bygger vi om og modifiserer utstyret. Og så kommer det en ny rigg, som er akkurat som den forrige, og så er det på an igjen. Ingenting endres. Det virker som om det ikke er noe erfaringsoverføring."*

*"Et eksempel er gumbobokser. De har vi ikke trengt på 15-20 år siden muden nå løser opp leira så bra. De står der splitter nye og så kan vi bare ta en skjærebrenner og kaste hele skiten på havet så vi kunne brukt den plassen på noe annet."*

*"Vi vil ha MudCube. Seadrill skal i møte med dem i Bergen i morgen. Vi må løse problemet med arbeidsmiljø i shakerrommet."*

Etter omvisningen, skaffet vi oss kontorplass, spiste lunsj og ba om et møte med riggledelsen. Deretter planla vi dette møtet, samt videre fremdrift. Vi gikk gjennom flyt-diagrammene.

Møte med ledelsen, der vi presenterte flytdiagrammene og scope for besøket ble holdt kl. 17-18. De var interesserte og tilbød seg å samle operatørene på overtid søndag kl. 2000 til 2100 for å diskutere med oss. Vi benytter tiden frem til da på å observere, intervju og diskutere med operatørene i de forskjellige delene av mudprosessen.

Det kom noen generelle tilbakemeldinger også under dette møtet:

- Statoil var generelt misfornøyd med hele layouten på riggen, klagde på at West Elara ble kjøpt fra et konkursbo og at Statoil selv ville spec'et riggen helt annerledes, sa også at det var mer av utstyret om bord han ville kvittet seg med enn det han ville beholdt
- DSL fra Seadrill klagde også på mye av utstyret er overspec'et i forhold til behov og at mye er feilplassert i forhold til flyt. Han mente dette var bedret på søsterriggen West Linus.

- Klager på hvordan rigger bygges og at endringer i byggefasen er nær umulig slik at alt må endres etter at riggen er satt i drift
- Klager på at rigger spec'es uten å ta fullt hensyn til hva som egentlig trengs (brukerbehov)
- Spesielt mye klager på gassmåling (plassering, målefunksjon, osv.)

Videre får vi P&IDs og vi får låne et kamera, slik at vi kan gå opp flowline og ta bilder fra anlegget.

Planen for i morgen er å møte derrickmann for å avtale videre arbeid i forhold til pågående arbeid og hans tidsskjema.

## *Dag 2 – Torsdag 2. mai 2013*

Vi startet dagen med å skaffe arbeidstillatelse for å ta bilder.

Dessverre har vi ikke gode fotoforhold pga. HtHp (High temperature, High pressure) situasjonen på West Elara. Det er forbudt med blitz i alle soner pga. flammesensorer som kan slå ut. Vi må også gå med gassmåler og får ikke ta med fotoapparat der det evt. registreres gass pga. batteriets eksplosjonsfare.

Deretter fant vi P&IDs og kopierte de aktuelle prosessene.

Vi brukte resten av dagen på mud mix. Vi var innom mud control room og snakket med derrickman og assistenten samt at vi snakket med elektrikerne. Senere snakket vi også med nattskiftet. Derrickmennene hadde mye på hjertet da vi fortalte at vi kom fra Cameron.

### **Kommentarer på OBM/WBM dual system:**

*"Det er bare TULL å kjøre separate systemer for OBM (olje basert mud) og WBM (vannbasert mud). Og så lager de samme skiten på West Linus! Det MÅ dere slutte med. Seriøst. Vi vil ha én sack store, og vi ønsker å kunne bruke alle pitene om hverandre. Slutt med det dual-tullet."*

### **Roughneck (merkevarenavn JIM 20):**

*"Roughnecken er en KATASTROFE! Den fungerer ikke i det hele tatt. Det er INGEN på denne riggen som kommer til å kalle ungen sin for Jim – det navnet er et skjellsord!"*

### **Sekkedoseringsmaskinen (Sack Dosing Unit – SDU):**

*"Vi mikser fra 0-200 sekker per skift. I snitt mikser vi inn 500 sekker i løpet av en uke. Det er mye forskjellige kjemikalier, men vanligvis har vi bare 5-6 typer om gangen. Det er Mud-Ingeniøren som passer på hvilke kjemikalier vi har tilgjengelige."*

*"Vi har store problemer med SDUen. Griperne inni fungerer ikke som de skal, emballasjehåndteringen fungerer ikke, den er treg (80 sekunder syklus) og vi*

*må passe på hele tiden fordi noe jammer seg etter 3-4-5 sekker. Alltid! Og det er aldri det samme som skjer. Elektrikerne har service på den nesten konstant. På WBM-siden må vi resette SDUen hele tiden, det er det eneste som fungerer der, mens på OBM-siden fungerer den ikke, der må vi inn å overstyre manuelt. Det støver masse."*

*"Hva som er problemet med SDUen? Tja... Det virker som om den tåler greit å kjøre de hvite stoffene, men den er ikke noe glad i de sorte. Kanskje den er rasist? Eller kanskje det har med at de sorte stoffene har tykkere emballasje. Det er i alle fall umulig å kjøre de sorte stoffene gjennom SDUen. Alt krøller seg når vi prøver. De med tykk emballasje har problem med at griperen ikke stikker gjennom papiret, enten på den ene eller begge sidene, og da faller ikke noe ned, og så må man passe på å ikke mate med ny sekk uten å fjerne den forrige. Hvis man ikke er obs, blir det bare rot."*

*"Et annet problem er at kompaktorskruen for de tomme sekkene jammer seg lett. Det virker som den slipper for tidlig, spesielt når vi kjører noen av de saktere kjemikaliene. Ofte må vi kjøre en ekstra omgang uten ny sekk for å få alt skrudd ut. Det er bare den ene typen sekk det gjelder."*

*"Også er det mye alarmer, men vet ikke helt hvorfor. Kanskje det er pga. støv?"*

*"Var noen sensorer som løsnet også, men tror det er fikset nå."*

*"Og filteret er en vits. Er det for lite trykkluft, kanskje?"*

*"Det er også irriterende at passordet på SDUen skifter hele tiden. Det burde ikke endre seg."*

*Derrickmann, dagskift: "Vi burde hatt reservoarer til SDUen eller hatt mulighet til å stille inn mateskruen. Med en syklus på 80 sekunder bindes én mann opp hele tiden, samtidig som vi ikke kan mate inn flere stoffer samtidig. F.eks. hvis vi skal ha inn 10 sekker på 15 min av et stoff og 10 sekker på 2 min av et annet stoff, så må vi ta først det ene stoffet og så det andre stoffet. Det hadde vi sluppet om det hadde gått fortere eller om det hadde vært reservoarer der, men sjefene i Seadrill vil ikke betale for sånt. Andre firmaer sin*

*sekkekutter funket bra der jeg var sist, og det var en helt ny rigg, også. Deres sekkekutter binder opp én mann hele tida."*

*Ass. derrickmann, dagskift "Men på Phoenix var det jo også utstyr fra andre leverandører, og der funket det ikke så bra."*

*"Noen ganger fungerer SDUen i noen dager, men generelt er det noe galt 2 av 3 ganger."*

Elektrikerne hadde også en kommentar om SDUen:

*"Det er sjeldent samme problem så det er vanskelig å vite helt hva som er feil. Noen ganger er det operatørene som bruker SDUen feil også, som for eksempel at de glemmer å trykke på begge knappene, og siden det har vært mye trøbbel tror de det er noe feil og ringer oss. Men stort sett funker den ikke så det er mye reelle feil også. Kanskje vi burde vaske og rense (nullstille) sensorene, og se hva som skjer da."*

#### **Hopperne:**

*"Ventilen stenger ikke helt. For eksempel, når trykkforskjellen er under 1 så skal ventilene stenge automatisk, men det skjer ikke. Det virket bra i begynnelsen, men nå fungerer de ikke i det hele tatt, ikke engang når alt er rensset og rengjort etter en utblåsning. Vi må bruke et gjengestag og presse den ned. Vi har bedt DSL skifte dem, men det er ikke gjort ennå. Kunne de kanskje vært knivventiler? Eller hydraulisk opp og sterke fjærer tilbake? Kan det være at de ikke tåler OBM? Eller at gummien ikke tåler OBM?"*

*"Nå som ventilen i hopperne ikke fungerer i det hele tatt, må vi manuelt stenge ventilene mellom dem, for å hindre at muden fra én hopper kommer ut i den andre. Dette skulle jo ventilene på hopperne gjort, så det er litt ekstra."*

#### **Pallebord/sack store:**

*"Vi vil ha én sack store på riggen. To sack store er helt mongo. Det er ikke noe poeng i å ha to sack stores. Vi bruker stort sett samme kjemikalier på begge*



*sider. Av og til må vi kjøre kjemikalier fra den ene siden til den andre, for eksempel når det er dårlig vær, og det er utrolig kronglete å komme frem."*

*"Pallebordet er for smalt. Det er vanskelig å få pallen inn når man kommer med den på trucken."*

### **Density Transmitter (SG-densitet i CS):**

*"Denne må kalibreres hver gang vi endrer mudvekta, og det er noe styr. Elektrikerne må gjøre det. Burde vært mye enklere. Nå løser vi problemet med å ta prøver hvert 15. minutt. Hvis density transmitteren hadde fungert som den skulle, ville vi sluppet så mange prøver, men nå stoler vi ikke på målingene dens, siden vi ikke har mulighet til å kalibrere den hele tiden. På en annen rigg (West Alpha) jeg var på, ble vekten sjekket innvendig i røret og da målte den alltid rett. Kanskje Cameron burde lage en sånn løsning? Det ble bare gjort ved at muden ble ført inn i en sløyfe, og så ble den målt på en eller annen måte inni røret."*

### **Tavle, mud control room:**

Det er en tavle på mud-kontrollrommet der operatørene logger det som C.S. ikke håndterer. Tavlen inneholder info om hvilken tank som benyttes som aktiv tank, hvordan ventiler og pumpene er linet opp, ol. Operatørene ønsket at denne innlemmes i kontrollsystemet.

### **Noen kommentarer ifht. Kontrollsystemet:**

*"CS burde vise hvilke(n) tank(er) som er aktiv(e), f.eks. gjennom at de aktive tanken(e) merkes med et "hukk", fargekodes eller utheves på et vis. Det hadde hjulpet mye. Nå må vi bruke tavlen til å markere hvilken tank som er aktiv, men det glemmes noen ganger å flytte magneten til nytt felt, og da kan vi gjøre feil, spesielt når nytt skift går på."*

*"Alle ventilene burde ha sensorer som viste i CS om de var åpne eller lukket, f.eks.grønne ventiler når åpne, sorte når stengt. Nå må vi gå ut å sjekke om*

*linjene er linet opp som de skal siden mange av ventilene er manuelle før vi starter pumpene. Det er stress."*

*"CS burde hatt en knapp som viser alle taggene. Nå må vi lete etter et tag-nummer ved å holde piltasten over en og en ventil. Når vi skal gå gjennom alle ca. hver 3. måned, betyr det mange timers arbeid. Hadde vi hatt en knapp som listet opp alle ventilene med tag nummer, så hadde det hjulpet. Det burde være enkelt å fikse?"*

*"Også når vi har nye folk, hadde det vært fint å kunne sjekke tag-nummer, for å veilede dem på radio, men nå må vi lete gjennom ventilene"*

*"Det burde vært en felles line til alle piter, og ikke separat OBM/WBM-system. Nå må vi trikse og mikse for å utnytte systemet. Alle pitene burde kunne brukes når det trenges."*

*"Det burde være mulig å autofylle med vann. Når vi driller topphull får vi ikke retur, da driller vi med sjøvann. Vi ønsker å ha autofyll av pittene da, og bare holde nivået jevnt. Nå må vi gjøre dette manuelt, og hele tiden etterfylle. Dersom vi glemmer oss og overfyller, kan det gjøre stor ødeleggelse på de andre pittene, siden det bare renner over i neste tank og så neste tank, osv. sånn som det er designet."*

### **Transferring – flytting av væske mellom tanker:**

*Derrickmann, nattskift: "Det burde være en mulighet til å fylle visse volum over fra én tank til en annen. Nå er det opplining og start stopp som kan gjøres. Dersom vi hadde hatt mulighet til å fylle til/fra og volum, samt start stopp, hadde vi ikke trengt å overvåke manuelt/sjekke nivå hele tiden. Det hadde vært veldig bra!"*

*"Dersom et autosystem hadde vært skikkelig oppe og stått, ville ventilene linet opp når man valgte til/fra, og dersom det var noe feil på ventilene, ville systemet hindret oss i å starte overføringen. Det hadde vært en ekstra sikkerhet. Det blir akkurat som på bulk/baritt."*

**Big Bag Unit:**

*"HVORFOR er det ikke BBU på OBM-siden?? Vi må løpe med opp til 50 sekker så fort vi kan opp på hopperne og fylle når sekkekutteren står, og selv når sekkekutteren funker, så er det mye med 50 sekker. Hadde vi hatt BBU kunne vi sluppet alt sekkestyret."*

*"BBUen er tullete designet. Vi må koble den fra og løfte den ned på gulvet før vi fyller. Kunne de ikke fått til en BBU som var litt lavere, så vi kunne løfte sekkene oppi fra gulvet? Det er bare 20-40 cm for høyt nå til at trucken rekker opp. Utrolig irriterende. Hva skal man egentlig med det fundamentet BBUen står på i det hele tatt? Ta den ned, så vi kan bruke truck direkte!"*

**Layout, rom:**

*"I gamle dager var hopperne designet for å opereres manuelt. Nå er det kronglete å komme til, og når vi skal bære 50 sekker opp fra sack store, og fylle manuelt, blir det støv og gris overalt. Da er vi ikke veldig glad i utstysleverandøren. Vi har ikke BBU på OBM-siden, så det er ofte MYE kjemikalier som skal inn, og de skal ofte inn kjapt. Da er det bare å løpe og fylle. HVORFOR kan man ikke i det minste gjøre det enklere å komme til, så kan man løfte en pall opp på hopper-nivå, og løfte over i hopperne. Neida. Vi har ikke BBU, vi har en SDU som ikke funker, og en hinderløype å tråle opp før vi får fylt hopperne. Etterpå er det å brette sekker og presse dem sammen, en for en, og bære dem ned. Så må hele området feies og rengjøres, for det er støv overalt. Vi har sikkert fått astma hele gjengen, bare vent og se. Til slutt er det bare å gå å skifte kjeledress. De er ikke veldig lure de som lager layouten."*

**Utstyr man ikke trenger:**

*"Hvorfor setter de fortsatt inn kaustisk mixer? Er jo minst 10 år siden vi brukte den. Den er fjernet nå, men de fortsetter å sette sånne inn på nye rigger. Hva er greia?"*

**Mud control room:**

*"Vi kunne gjerne tenkt oss ei større mudbu. Det er ikke spesielt trivelig her."*

**Noen kommentarer til utstysleverandører generelt og Cameron spesielt:**

*"Joda, utstyret virker greit når det virker, men det virker jo aldri. Kopier litt mer fra andre elverandører, så blir det bra."*

*"Han ene operatøren var så lei av deres utstyr at han sa opp jobben, og gadd ikke mer på West Elara."*

*"De må jo bruke oss som er ute, for det de tegner på kontorene rundt forbi er helt på jordet. De ANER jo ikke hva de tegner."*

*Derrickmann (nattskift) "Nei, jeg er ikke enig med deg i at ingeniører kan tenke nytt og annerledes, det er vi som jobber her som burde designe."*

*Ass. derrickman (nattskift) "Der er jeg uenig. Jeg kommer fra landindustrien, og har jobbet prosess der i alle år. Hvis vi overlater til dere som har jobbet offshore å designe utstyr, kommer det aldri til å bli bedre. Det er helt håpløst her ute, så det bør nok være noen som tenker nytt i tillegg til at dere blir med og forklarer prosessen, men utstyret bør andre designe."*

*Derrickmann (dagskift) "På en rigg en kompis av meg jobber på (West Epsilon), har de bare siloer og alt er automatisk derfra. Ingen sekker eller big bags eller noe. Det høres utrolig bra ut."*

*"Det er veldig bra at dere er ute å sjekker og snakker med oss, så er det jo kanskje håp for dere."*

*"Joda, det stemmer som dere sier at det ikke er mye nedetid på riggen, men det er IKKE pga. utstyret deres, men pga. at vi løper i ett. Av 3 roughnecker, står stort sett minst 2 og fikses på, og vi har trippet med riggtenger her også for å forhindre nedetid når alle 3 står!"*

*"Også løper jo vi på mixen som galninger for å holde utstyret i orden. Vi måtte hente en Big Bag og holde den over ei inspeksjonsluke og sprette den i bunnen og la den renne seg tom rett opp i flowline for å holde prosessen i gang."*

**Litt om HtHp-operasjonen:**

*"Er spesielt nå, at vi må føre skjemaer og logge alle nivåer så nøye, samt at til og med det å starte en agitator i pitene, så kan det gi utslag på boringa, så vi må gi beskjed om alt vi gjør til driller. Bølgene som kommer når vi stanser en agitator, kan f.eks. skape et loss på 60L i systemet, og akkurat nå er det mye."*

*"Vi kan maks kjøre med 2 aktiv-tanker nå som det er HtHp"*

*"Må ha to nivåmålinger i hver pit. Og så funker de ikke, men de var visst feilmontert, så det skal bli fikset."*

*"Må sjekke screens oftere nå under HtHp"*

**Prosesser vi gikk gjennom og fotograferte i dag:**

- Prøvetakning (derrickmann) og veing av mud, inkl. skjema for korrigering for temperatur
- Opplining for mixing på tank, kontroll av ventiler, oppstart av pumper, innkjøring av kjemikalier
- Kjøring av sekkekutter
- Big Bag Unit (WBM)
- Flytting av paller med truck (til løftebord)

Oppdatering av prosesskartet gjøres i etterkant av rigg-besøket basert på notater og observasjoner, samt bildene.

Til tross for at det er lite positivt å høre om utstyret fra operatørene, er de veldig hjelpsomme og positivt innstilt generelt sett. De er inneforstått med at West Elara er en ny rigg, og at det er "vanlig" at nye rigger ikke fungerer perfekt fra start. De mener også at mye av utstyret, som sekkekutteren, har bra potensiale dersom den fungerer som det skal. Vi er godt fornøyd med all tiden derrickmennene brukte på oss i dag, og har fått tatt bilder og kartlagt prosess på ca. halve mixeprosessen.

**Dag 3 – Fredag 3. mai 2013**

Vi startet dagen med å intervju derrickmann fra nattskiftet. Han kom igjen med noen innspill:

*"Jeg skulle ønske vi hadde oversikt over prosessen fra mudbua. Vi bør i alle fall se pumperommet, og helst også sack store. Hvis jeg må velge mellom de to, så er pumperommet viktigst, men det hadde vært fint om vi også kunne sett miksing. Det bør uansett ikke være langt å gå fra mud bua til disse stedene. Det er alt for langt her."*

*"Den riggen jeg var på sist, hadde en skjerm med joystick i sack store. Da kunne jeg stå der å følge med på pumpene og stenge dem, uten å måtte gå til pumperommet eller til mud-bua. Det burde være sånn her også, for nå ser vi ikke hva som skjer andre steder når vi er i sack store."*

*"Det er ei kontrolltavle for pumpene i pumperommet, og den ligger inn i mellom/bak selve pumpene. Det er ikke så gøy å stå klemt opp i pumpene du skal starte. Hvorfor kan jeg ikke starte/stoppe pumpene fra mudbua?"*

*"Det er helt idiotisk at vi holder på med sekker. I går fylte vi 150 sekker på kortest mulig tid. Heldigvis fungerte SDUen sånn tålelig."*

*"Jeg skulle ønske jeg kunne være med å designe en rigg fra bunnen av, så skulle den blitt sånn som jeg vil ha den."*

*"Shakerrommet er også feilkonstruert. Det er for lite plass mellom radene, så du må ha rompa inni en shaker når du drar ut shakerscreens fra en annen shaker."*

*"En annen ting er rengjøring av shakerrommet, det er vanskelig siden tankene ligger som de gjør og mud flyter over i de andre tankene som de gjør. Alt burde vært jevnt medd fall, for nå, når vi spyle, flytter bare muden seg rundt istedenfor å flyte ut."*

Etter å ha hørt så mye om hva som ikke fungerer og som burde være annerledes, utfordret vi ham på å fortelle om det som er bra. Riggen har lite nedetid, så noe må jo fungere som det skal.

*"Hvorfor det går så bra... Tja... Det er jo fordi vi løper som galninger. Og så har vi alternativer. Vi har flere mulige ruter for muden. Det funket jo på den*

*gamle riggen også, for så vidt, der vi hadde bare en line, men det er bra å ha det fleksibelt som her."*

*"Noen ganger er vi blitt reddet av å ha to sackstores. Hvis det er krise i det ene pga dårlig vær som stopper forsyningene, kan vi hente sekker fra den andre. Men vi vil ikke ha WBM side og OBM side, og vi vil ikke ha to sack store. Jeg vil bare ha én stor sackstore med alt av innhold og alt av utstyr og muligheter som de to sackstores har, men uten delingen i rom."*

### **Samtale med Toolpusher:**

*"Det som skal skje er å fjerne LGS fra væskefasen – Hvor vanskelig kan det være? MudCube med fine nok screens er det vi ønsker oss."*

*"Desiltere må ut. Samme med Gumbo. Dette er utstyr vi ikke har brukt på 20år. Det bare står der."*

*"Hydrosykloner er gammeldagse og ineffektive (desander/desilter). Sentrifuge er bedre."*

*"Hvorfor er hver eneste rigg custom made? Hvorfor er det ikke mer hylleware?"*

*"Jeg har vært offshore i 30 år, men jeg må innrømme at jeg nå begynner å bli lei, og jeg mister oversikten. De er så mye tull jeg må gjøre, som ikke har noe hensikt. De kommer med tiltak. Tiltak på problemer med utstyret. Tiltak på problemer med prosessen. Tiltak i forhold til prosedyrer, papirer, rutiner. Tiltak, tiltak, tiltak. Denne bransjen er så flink til å komme med tiltak. Tiltak på tiltak på tiltak. Men ingen aner hva PROBLEMET er! Bruk litt tid til å vite hva problemet er, før dere løser det."*

*"Prosedylene skrives av folk på land som ikke kjenner prosessene. Utstyret vi får er alt for avansert."*

### **Følge Derrickmennene på jobb:**

Vi fulgte derrickmennene rundt i dag og så dem starte pumpene etter tripping, mikse inn flytende kjemikalie fra LAS samt mikse inn bulk (baritt). Det var problemer med alle prosessene, men alt ble løst relativt kjapt:

Kl. 1430 - Derrickmen planlegger å starte opp mixing med flytende kjemikalie for å øke viskositeten slik at baritten kan blandes inn igjen i den tunge muden før HP-pumpene skal starte å pumpe ned mud etter tripping kl. 1600 - Det var problemer med ladestasjonen for truck, og vi måtte vente en stund før trucken ladet opp, deretter flyttet derrickmannen kjemikaliedunken til foran LAS/løftebordet. LAS startet imidlertid ikke, og elektriker ble tilkalt. Problemet ble løst ved å restarte HMEn på LASen. Sitat elektriker "den hadde fått en hick-up. Det skjer av og til."

Kommunikasjonen fra driller til derrickmann hadde feilet. Driller sa "vi starter å pumpe rundt kaffe". Derrickmann trodde det betydde kl. 1600, og planla å ta mudprøver og starte skjæring av mud over mudpumpene rundt 1430 for å forberede rett mud til oppstart av pumpene kl. 1600. Driller mente imidlertid kl. 1430 med "kaffe", og dermed ble det travelt i mixeanlegget, siden muden ikke var veid opp. Dette resulterte i en teknisk nedetid til 160.000 kroner per time, iflg. derrickmann.

#### **En kjapp gjennomgang av dagens hendelse:**

- LAS ble forlatt til fordel for vektprøver.
- Derrickmann assistent tok to vektprøver, og rapporterte svært lav mudvekt til Mud Engineer.
- Derrickmann stolte ikke på assistenten, og tok 3 nye prøver som viste lav mudvekt, men ikke så lav som assistenten hadde målt. Han rapporterte rett mudvekt til M.E.
- Derrickmann assistenten ble sendt for å line opp manuelle ventiler for å kjøre LAS inn i premix (sirkulasjon) over mudpumpe C. Senere måtte derrickmannen selv gå å endre begge ventilene ettersom de var satt opp feil
- Derrickmann linet opp for innmix av baritt på sirkulasjon over aktiv tank, og forsøkte å starte charge-pumpe 1 til mudpumpe A. Han ringte og ba om luft fra MHO og ringte og ba driller åpne stengte ventiler rundt chargepumpa. Ventilene fungerte ikke. Driller klarte ikke å åpne dem fra CS. Feilsøk viste at styreluft til ventilene var stengt. Noen fra nattskiftet hadde stengt en manuell ventil (uvisst årsak) på lufttilførselen til ventilen mellom fødepumpa og mudpumpa – 10 minutters arbeid.



- Da chargepumpa startet, viste det seg at hopperventilen fra baritt (se gårsdagens rapport) ikke lukket, og derrickmanssistent måtte stake opp som vist på bilder fra gårsdagens vedlegg til rapport.
- LAS ble gjenopptatt, og mixet inn i premix (over mudpumpe C) for planlagt senere å bløs inn i aktiv
- Mudvekten ble økt fra 2 til 2.05 vha baritt over mudpumpe A

*Kommentar fra ass. derrickman:* "Det er jo bare en liten detalj, men hvorfor heter fødepumpene 1,2 og 3, mens mudpumpene heter A,B og C? Burde de ikke hatt samme navn?"

### **Samtale med teknisk sjef**

*"Det er klart at når dere går rundt sånn, så får dere all driten. Det som fungerer bra glemmer de, men de glemmer også at det er utstyr de ikke trenger eller aldri bruker, så det er bra dere observerer også. Det eneste de husker og fokuserer på, er det som ikke har funket."*

*"Det er delte meninger om å kjøre to systemer. Det gjør at vi må ha mer lager og det tar plass, samtidig gjør det oss mer fleksible, siden vi i verste fall kan kjøre på det andre systemet hvis det første feiler, og vi kan alltid flytte utstyr eller finne deler fra den andre siden, hvis vi mangler deler på reservedelslageret."*

*"Det svakeste leddet her er pipehandleren. Vi har bare én, så om den ryker, står vi. På Linus får de derfor to. Vi har et prosjekt gående på pipehandleren, og jeg har vært med litt i designfasen for å løse noen barnesykdommer. Jeg skal ned på Final Acceptance Test i neste uke."*

*"Topdriven har vi også bare én av, men den har to motorer, så det er litt mer sikkerhet på den."*

### **Samtale med hydrauliker**

*"Pipehandleren har fungert VANVITTIG bra. Det har vært noen utskifninger på slanger, men ellers har den fungert non stop."*

*"Det har vært noen problemer med roughneckene, men det er jo prototyper. Når de fungerer er de jævlig bra. Når barnesykdommene er over har dere et kjempeprodukt."*

*"Det burde vært mange flere kameraer, spesielt i mixen, så de slapp å løpe sånn. Kanskje kunne de hatt bevegelsessensorer, slik at kameraene slo seg på når noe skjedde i et av rommene. Men da måtte ikke sensorene slå ut hver gang noen bare gikk forbi."*

#### **Kommentarer fra derrickmann, dagskift:**

*"Tavlen på veggen kunne vært inkludert i C.S., og i alle fall burde vi kunne skrive inn hva som er i de forskjellige tankene. Men jeg tror aldri vi blir helt kvitt tavlen på veggen – den viser tankene slik de er plassert ute, det gjør ikke C.S., og derfor er det kjappere å orientere seg. C.S. bør vise prosess, mens tavlen bør vise fysisk plassering."*

*"Jeg kunne gjerne tenkt meg et vindu som var større og gikk helt til gulvet, da kunne vi sett ut på pumperommet, og visst hva som skjer."*

*"På West Navigator har de en skjerm + joystick for styring av pumperom ved mixeanlegget. Det sparte en del løping frem og tilbake."*

*"Vi ønsker å kjøre alle pumper fra bua."*

*"Det tar cirka 4 timer for muden å sirkulere helt rundt. Totalt er det kanskje 250 kubikk mud i sirkulasjon."*

*"Hva vi vi gjør mest feil på? Trucken. I løpet av en uke kjører vi med de brede pallene rett inn i løftebordet. Noen ganger med vilje til og med, fordi vi ikke gidder å knote med å flytte sekker fra en pall til en annen når sekkene ligger skjevt på pallen. Vi har bedt om å bare få Europaller så de passer på løftebordet, men det har ikke skjedd så langt. Det tar typisk 10-20 minutter å feie etter at vi har kjørt i stykker sekker på den måte. Hvis vi i tillegg begynner å spyle, så tar det gjerne noen timer. Vi spyle ca. 1 gang i uka."*

*"Spesielt de som er nye, gjør mye feil i C.S. De ser på OBM-siden på den ene skjermen, og på WBM-siden på den andre skjermen, men merker ikke at de har feil skjermbilde oppe, og så sitter de å knoter lenge med at ingenting skjer når de legger inn kommandoer. Det er for vanskelig å skille mellom WBM og OBM i C.S."*

*"Jeg synes navnene på tankene burde være Aktiv A, Aktiv B, Slug 1, Slug 2, evt. Slug 3 og så burde resten av tankene hete Reserve 1,2,3,4, osv. Det er ikke nødvendig med andre navn. Vi kjører alle tankene om hverandre, så det er ikke noe vits å gi de andre navn, synes jeg. Men det er jo også sånn jeg er vant til det fra den forrige riggen jeg var på."*

*"De største irritasjonsmomentene i mixeanlegget er at sekkekutteren har 80 sekunders syklus, og at jeg må sitte å vente på det. SDUen burde vært kjappere, den tar for mye tid og er en flaskehals nå. I tillegg burde vi hatt reservoarer å tømme sekker i, sånn at vi kunne dosert fra reservoarene over tid, men tømt sekkene kjapt. Et annet irritasjonsmoment er at sekkestore er langt unna, tar minst 2 minutter å gå ned og vi går frem og tilbake hele tiden. I tillegg burde det vært en slaskepumpe for å overføre små volum mellom tankene som kunne styres via C.S. Nå har vi satt inn en pumpe selv, og den må lines opp manuelt, noe som tar tid, siden vi må gå ut i pumperommet og flytte slanger og så starte pumpa manuelt i ganga."*

*"C.S. burde vise hvilke liner det kjøres på. Kanskje kunne de være farget grønne når de kjøres?"*

*"Det er en del liner som ikke er med i skjermbildet. Vi trenger dem egentlig ikke, men siden de ikke er der, vet vi heller ikke om muligheten til å bruke dem, og kanskje en dag kunne vi fått bruk for dem, så vi bør vite om dem."*

*"Det er MYE det de kaller «stille avvik» i denne bransjen. Dobbeltmoral om du vil. På den ene siden sier de at de setter HMS først, men når de risikerer nedetid trenger du ikke følge noen prosedyrer - bare du holder tidsskjema. Det er tydelig at det er operasjon som går foran helsehensyn. Her på West Elara er*

*det forresten ganske bra. Mye bedre enn mange andre steder. Men bransjen er utrolig dobbeltmoralisk."*

*"Hva jeg tenkte var bra da jeg først kom på riggen? Jeg ble veldig glad da jeg så all automatikken. Den forrige riggen hadde bare 4 automatiske ventiler i mixen, alt annet var manuelt. Det er VELDIG bra med så mye automatikk. SDUen SÅ også veldig bra ut. Jeg gledet meg til å prøve den. Det er dumt den ikke fungerer, for den lovet så godt."*

*"Oj, der spurte sementeren meg om jeg kunne sende ham noe sjøvann. Det er et eksempel på at to systemer er en fordel, for nå kan jeg i teorien sende ham sjøvann direkte fra WBM-siden. Dessverre er WBM-pumpa opptatt med å kjøre til CRI, så jeg ber ham finne en annen løsning, men ja, noen ganger er det en fordel med separate system."*

#### **Kommentarer fra Toolpusher, dagsskift:**

*"Hvorfor er det en 90 graders vinkel på skruematerne fra SDU? De skruene som går rett opp MÅ jo ryke før eller siden, og hva gjør vi da?"*

#### **Kommentarer fra elektriker:**

*"Neste generasjons HMI må vise råverdiene fra PLS rett i HMien (mA, lese profibus, osv. osv.). Alt vi trenger for å redusere nedetid!"*

*"I tillegg må neste generasjons HMI inneholde en søkefunksjon, slik at vi kan finne tag. nr. enkelt."*

Videre har vi også i dag tatt bilder fra prosess i mixeanlegget, og holder på å lage tegneserie av disse. Vi er nå så å si ferdige med mikseprosessen, og fortsetter med treatment i morgen.

#### **Dag 4 – Lørdag 4. mai 2013**

- Intervju med Mudingeniør og Mudloggere
- Samtale med driller
- Omvisning i shaker room, mudlab og dekk

- Tilbakemeldingsmøte med dagskiftet etter endt skift (Drillcrew inkl. DSL, Teknisk crew inkl. TSL og Mudingeniør)

### **Mudingeniør dagskift.**

Mudingeniøren er innleid fra M.I. Swaco for å holde muden i henhold til spesifikasjon. Mudens spesifiseres på land i forkant av boring og gjelder for en hel brønn. Underveis i boringen endres muden dersom erfaringene under boring krever det.

### **Mud ingeniørens dag :**

- Handover fra forrige skift,
- Morgen/kvelds-møte med serviceingeniørene, ca. 15 min.
- Om morgenen samtale/rapportering med prosjektleder på land (før hans møte med Statoil)
- kontorarbeid (gå gjennom logistikkplaner, evt. bestillinger (ca. 2 ganger per uke, når rutebåt er satt opp), og andre planleggingsoppgaver (bestille mix, sette opp displacement plans, osv.)
- Mudsjekker 4 ganger i døgnet, 2 ganger per skift (+ tilleggster pga HtHp-brønn) – mudsjekkerne tar 2-3 timer hver gang
- Kalibrering av mudveker på treatment og mix
- RECAP-føring, (dvs. + og -, inkl. målinger fra andre på rigg) – RECAP skal ende i ca. en 1-sides sammendrag etter hver seksjon, og brukes for erfaringsoverføring til andre prosjekter.
- Vareopptelling 1 gang per døgn
- Mud-rapport skrives i løpet av dagen og avsluttes og sendes til land ved midnatt. Inneholder måletall, kommentarer, inventory (containere dekk, kjemikalier, screens, volum tørt/vått i tanker ifht shakertap)

### **Mud-ingeniørens kontaktpersoner på land:**

- Prosjektleder i MI Swaco ifbm rapporteringer
- Shippingansvarlig i Statoil ifbm bestillinger/logistikk

### **Mud-ingeniørens kontaktpersoner på rigg:**

- Boreleder (Drilling supervisor Statoil) ifbm. rapportering av problemer
- Derrickmann ifbm. mixing (mye kontakt)
- Shakerhands/roughnecks ifbm. shaker (mye kontakt)
- Mudlogger når han lurer på volum/sjekke loggen

Alle disse har toveiskommunikasjon.

Noen ganger: CRI-anlegget for rådgivning på tilsetning av viscosifier

Før riggen er i drift holdes det DWO-møter på land der mud ingeniøren er med i planleggingen av brønnen.

### **Info om prosess på brønn og planlegging:**

- Etter tripping, når muden skal kjøres igjen, sirkulerer man nå 800 m over bunnen for å få rett mudkvalitet før man går helt ned.
- Når mudpumpene stoppes, står det volum i hele aktiv, unntatt mellom shakere og aktiv tank, der renner mud ned. Drainback i denne brønnen nå er 2-4 kubikk (pga. dypt hull/liten diameter på hullet. Drain back i et større hull kan være 10 kubikk.
- Det tas kjerneprøver på minimum 3 m av grunnen (med 9 m tube, så i beste fall har man 9 meter grunn å sjekke) med jevne mellomrom. Disse brukes for å analysere og beslutte hvor produksjonslinjene skal gå ut til siden etter hvert.

### **Hva er bra/dårlig på riggen?**

- Mye bra folk/bra miljø
- Tungvint med 2-delt system. Det er trangt her, og med 2-delt system blir det langt å gå, mens det samtidig er trangt, spesielt på sack store. Det kan være greit med 2 liner, men de bør samles mer fysisk, dersom det er mulig.
- Ønsker seg mer lagringsplass, det er alt for trangt – sack store er alltid for små
- Gulv bør være flate/plane, spesielt i shaker rooms er det dårlig. Der tar det alt for lang tid å vaske (2 dager)

### **Eksempler på tester mud-ing tar:**

- Retorte (vann-olje-forhold, resten er solids (baritt + LGS))
- Rheologi (motstand i væske, leses av på skala)
- Elektrisk stabilitet (emulsjon)
- Ageing test (må tas, men gir ikke pålitelige resultater, så er ubrukelig iflg. Mudingeniør)
- Kjemisk test (titreringstest)
- Pilottesting (prototypetest før mixing for å estimere resultat i stor skala)

### **Mudloggere:**

Mudloggerne er innleid fra Halliburton og overvåker alle mudmålinger samt at de logger/lagrer og sammenlikner data over tid. De følger operasjonene som tripping, transfer mellom piter og oppstart av agitatorer eller pumper samt målinger av

pumpehastighet, pumpetrykk, temperatur, grunnforhold (gjennom cuttings i grafene på skjermen), og ser med en gang hvordan små endringer i bølger i en pit eller displacement av mud ved tripping påvirker systemet.

Spesielt nå som det er en HtHp-brønn må nivået overvåkes nøye. Selv små endringer som en agitator som startes i mud-rommet må rapporteres til mudloggerne.

Mudloggerne følger med på gassmålere og rapporterer evt. endringer til driller.

De holder tett kontakt med shakerrommet, samt med derrickman og driller.

### **Samtale med driller**

*"Det er veldig mye som ikke er som det skal her, men joda, det er alltid noe feil med nye rigger, så det er ikke bare dere som har barnesykdommer på en rigg. Det som er forskjellen på denne riggen og andre nye rigger, er at utstysleverandøren ofte blir på riggen med servicefolk i minst 2-3 år. Her forsvant de etter 2-3 måneder. Det var ikke så bra. Selvsagt er det fordi vi ikke har kjøpt den tjenesten, men dere burde kanskje være bedre til å selge inn sånt, for det hadde gjort oss mer fornøyde på rigg, tror jeg."*

### **Annen kommentar vi fikk off the record fra en av sjefene:**

*"Jeg synes Statoil er helt ræva. De har beslutningsvegring. Og så bare trer de på oss en haug med rutiner og prosedyrer og papirarbeid. Hvis ting hadde gått etter boka her ute, ville jeg blitt kalt illojal. Hvis jeg ikke følger rutinene, peker prosedyrene finger. Jeg kan ikke gjøre det rette. Jeg er drittlei dobbeltmoralen i denne bransjen. Vi følger en masse idiotiske rutiner for å sikre liv og helse, som ikke har noen hensikt, men som bare er der for å dekke ryggen til noen blå russ på toppen. Hadde det vært ingeniører der oppe, hadde kanskje noen tenkt fornuftig. Nå gjør vi masse arbeid som kun er spill for galleriet, samtidig som det skjer farlige situasjoner som vi MÅ gjennomføre for i det hele tatt å kunne operere, og da må jeg bare kjøre på."*

### **Dag 5 – Søndag 5. mai 2013**

- Morgenmøte med drillcrew og teknisk, m.fl.

- Møte med derrickmann ifht avklaringer med derrickmann ifht pumper, transfer og ventiler
- Samtale med DSL
- Besøk på shaker room og drill floor
- Intervju med riggsveiser
- Intervju med dekkarbeidere og fotografering av losseoperasjonen
- Intervju med kranfører
- Utarbeidelse av rapporter og bildeserier (mud mix, mud engineer og lossestasjoner)
- Samtaler med forskjellige funksjoner ombord i forhold arbeidsmiljø

### **Morgenmøte:**

Drilling Supervisor Statoil, OIM, TSL, Sikkerhetssjef, DSL samles sammen med drill crew og teknisk avdeling hver morgen for å oppsummere gårsdagens operasjoner, planlegge dagens oppgaver, gårsdagens OBS-meldinger med kommentarer, værmelding og eventuelt.

OBS-meldinger er tilbakemeldinger på observasjoner gjort på rigg. Det er satt et mål om minimum 50 tilbakemeldinger per dag. Operatørene forsøker å melde positive kommentarer om andre operatører, samt evt. problemer og faremomenter de ser i produksjonen. På akkurat dette møtet, oppfordret Drilling Supervisor fra Statoil om å se spesielt etter hydrauliske koblinger som kan komme til å ryke, samt objekter som kan falle ned fra høyden.

### **Derrickmann:**

Derrickmannen avklarte noen tilbakemeldinger etter gårsdagens gule lapper møte (se vedlegg med referat fra dette møtet, avklaringspunktene er lagt inn der).

### **Samtale med DSL:**

*"Vi har hatt nedetid to ganger de siste dagene, første gang pga misforståelse mellom driller og derrickmann (se bildeserie i vedlegg fra mud mix) og andre gang pga at driller har oversett en alarm på overfylling av trip tank. Mudlogger og driller manglet volum på systemet, og stoppet operasjonen mens de lette etter det som manglet. Så viste det seg at trip tanken var overfylt til over høy-nivå på alarmer, og da stemte ikke volummålene. Det tok tid å finne*



*ut av. Det er selvfølgelig drillers skyld, som ikke har sett alarmen, men det er ikke så lett å følge med, for alarmene går i ett. Det burde kanskje vært nivåer på alarmene, slik at de viktige alarmene blir registrert kjapt."*

*"Det som har høyest prioritet ifht utstyr akkurat nå, er å bygge om suction line fra triptankene slik at de er store nok til ikke å clogges. Det må ha sviktet totalt i planleggingen av disse, og nå kommer West Linus også. Jeg har allerede forberedt dem på at de må bygge om linene, for det er sikkert akkurat like galt der."*

*"Når det gjelder roughneckene, så kan vi ikke casing. Vi trenger et casing-crew for å sette casing. Det er liksom meningen at vi skal kunne sette det selv med roughneckene, men det kan vi ikke. Drillcrew går 2 uker på og 4 av og casing settes kanskje en gang i måneden, og da er det for lenge mellom hver gang til at vi kan gjøre det."*

*"Det manglet slurrypiter på riggen, så vi har tatt noen WBM-tanker til slurry. Det gjør jo at vi ikke har et fullt to-sidig system lenger, siden det tar bort en del muligheter på WBM-siden. I forhold til dual systemet er det for plasskrevende og for stort. Vi burde nok hatt en litt annen layout, men noen operatører er veldig fornøyd."*

### **Besøk på shaker room og drillfloor:**

Det meste var vanskelig tilgjengelig i dag – mye sperreteip/sperrekjetting. Dette pga BOP-testing (rutinemessig test hver 14. dag). Vi ferdigstiller disse prosessene i morgen.

### **Intervju med riggsveiser:**

Riggsveiseren hadde mye på hjertet og har modifisert og fabrikkert opp mye deler til riggen. Han har gjort det samme på andre rigger tidligere.

*"Ventilene på flowline for mud fra shakerne over tankene er altfor dårlige. De må være vanntette, men det er de ikke. F.eks når en skal sende vann ned i en tank forbi andre tanker, kan vannet renne ned i en av tankene foran, der det kanskje er noe oljebasert. Jeg har fabrikkert opp nye luker av tykkere aluplater*

*og håndfilt alle slik at de flukter med bunnen av flowline for å hindre dette. En stor jobb som jeg har gjort på alle rigger jeg har vært på. Problemet skyldes nok at de som tegner ventilene ikke forstår prosessen, og bare lager plater der de får beskjed om å lage plater, uten å vite at de må være vanntette. Eller så er det for å spare penger, siden ordentlige ventiler som vi vet funker er for dyre. Før forsøkte vi med densotape for å tette i bunn, men det blir aldri helt bra, så nå sveiser jeg nye plater. Det burde være krav til toleranser på slissene, og de burde vært fysisk testet før riggen sendes ut. Det spesifiseres en luke, og gutta på verftet lager en luke, men uten tanke på funksjon eller prosess. Få på plass skikkelige toleransekrav slik at lukene holder tett eller spesifiser produserte knivventiler for å åpne/lukke på flowline for mud!"*

*"Portene over heissjakten ned til sekkestore var i stål. De veide sikkert 2-300kg per stykk og kunne kappet en mann i to om wiren til motvekten røk mens en mann sto imellom. Jeg fjernet disse portene og hev dem overbord (fraktet til land) og laget til noen i aluminium. Mye lettere. Og så laget jeg til en støtte som slår ned når du åpner porten slik at de ikke kan slå igjen. Man burde bruke mer aluminium."*

*"Flowline fra cantilever og ned i mud flowline er et rundt rør. Lukene i flowline er firkantede. Når muden er varm (60 - 70 grader) damper det så mye olje av at det er uutholdelig å gå forbi. Hvorfor tenker de ikke på sånt? Jeg har laget til noen skjørt i aluminium for å blende av mellom den firkantede luken og det runde røret. Det burde være unødvendig i 2013 å gjøre slikt."*

*"Rett foran døra til sveisebua er det en luke hvor det er felt ned noen skruer ca. 10 centimeter. Jeg tråkket nedi sikkert en tre-fire ganger og vrikket beinet før jeg sveiset en tynnplate over. Snakket med en fyr fra verftet da de så på riggen og han mente det måtte være en designfeil. Uansett så er det for dårlig planlegging. Man kan ikke ha ei luke foran ei inngangsdør."*

*"Inne under dekk flasser malingen av som bare det. De står i østen og lakkere i sikkert 70-80 % luftfuktighet. Mange steder er det rett på bart stål nå. De må bruke byggtørkere og lakkere i skikkelig tørr luft slik at malingen får heft."*

*"Sensorene i pitene klarer ikke å måle skikkelig fordi agitatorene lager virvler i tanken. Jeg fikk laget til masse plater som står ved sensoren som stenger for virvelen slik at muden ligger stille over sensoren. Hvorfor er ikke det slik fra produsent?"*

*"Pitene er helt utrolig vanskelig å tømme. Nå har jeg laget opp et rørsystem med ei slaskepumpe som kan suge luft og væske. Problemet er at når det kommer bittelitt luft inn i de pumpene som er der opprinnelig, så stopper de. Slaskepumpa får til å holde suction selv når luft kommer inn og da kan vi får tømt pitene litt enklere. Pitene burde redesignes i bunn slik at vi slipper dette her. Slaskepumpa må byttes ofte da den ikke er ment å suge opp den grove muden, men det er enkleste mulighet."*

*"Alle hullcover må være i aluminium. Det er for tungt å løfte dem opp hvis de er i stål. Aluminium er bra i brann det også. Jeg liker aluminium."*

*"På shakerene var det ikke noen skjerm i front. Kaks og drit ble sendt rett utenfor skruemateren. Hadde jeg ikke fått de screenene opp hadde hele shakerrommet vært en eneste stor mudpøl. Det manglet også foring under shakerne, mellom shakeren og skruen. Der ville det falt masse dritt nedi hadde jeg ikke sveiset."*

*"De sier at nedetid koster 14.000\$ i døgnet på denne riggen, 350.000\$ koster riggen i året. Det at jeg fikser ting direkte på rigg, istedenfor å sende deler til land for modifisering, har sikkert spart riggen for et titalls nededøgn til sammen."*

### **Kommentar fra Toolpusher:**

*"Vi har jo prosedyrer, og vi følger dem, men det er mange måter å lese prosedyrer på. Det har med erfaring å gjøre."*

### **Intervju med kranfører (han er også HVO - hovedverneombud - ombord på West Elara).**

- Info om storekeeper om bord. Storekeepers oppgaver:

- Styrer lager (Vet hva vi har om bord av utstyr og delelager)
- Fyller ut papirer for skipning: såkalte manifeste – disse manifestere alt som skal inn på land igjen (pga avgiftene offshore, dvs. i internasjonalt farvann – manifestene fungerer omtrent som tollpapirer...)
- Info om DI (detaljert instruks):
- DI er prosessbeskrivelser på rutineoppgaver, og finnes f.eks. på overføring av mud fra båt til tank
- DI er et levende dokument – en mal - og inneholder ord og bilder som forklarer hvordan man utfører en rutineoppgave fra begynnelse til slutt. Dokumentet oppdateres kontinuerlig for å gjøre den mer og mer korrekt.
- DI kan være enkel eller lang
- DI brukes til erfaringsoverføring til nye operatører
- DI må signeres hver gang man bruker den der det finnes en DI, eks Mud, pga der er høyt fokus på utslipp. Områdeansvarlig (f.eks. kranfører) printer en DI for hver jobb som krever en.

### **Kranfører om innovasjon i oljebransjen:**

*"Alt ombord er så splittet opp. Det er ingen helhetstanke. Ingeniørene på land sitter og er eksperter på sitt lille felt, og designer noe som løser en bitteliten del av prosessen. Når man setter sammen alle disse bittesmå delene, ender man opp med et system som ikke henger sammen logisk, og det skal vi kjøre på..."*

*"Når man går fra manuelle operasjoner til høyteknologi på riggene skjer det noe rart. Det er så enkelt å gjøre manuelle operasjoner. Da ser man helheten, og man vet at man ikke skal løpe på en annen operatør, og man ser dersom man ikke treffer piping med nytt stand. Høyteknologien kan bare bevege seg dit eller hit, og så må man bygge store støttesystemer, som ZMS, som tar masse plass for å hindre ulykker og hendelser som mennesker ikke kommer opp i. Ingeniørene på land vet ikke om alle disse tingene som skjer i hodene på folkene her, og dermed lager de utstyr som utfører oppgaver, men utstyret er ikke tilpasset helheten. Den ser de ikke. De automatiserer kun et lite ledd. Det gjør at høyteknologien ikke fungerer bra."*

*"Alt gikk mye fortere på gamle rigger, fordi de var manuelle. Farten på alt fra tripping til boring er mye lavere på moderne rigger enn på de gamle manuelle. Dess mer vi automatiserer, dess mer tid tar det, fordi det blir så mange maskiner som order opp i det de første maskinene ikke klarte. Før var det bare*

*et menneske der, nå er det en haug med automatikk og maskiner og utstyr. Igjen tror jeg det skyldes at ingeniørene på land ikke ser helheten. Utstyret gjør ikke livet lettere her. Det gjør det bare annerledes og ting går saktere og saktere. Det er så ulogisk. Fremskrittene er ikke alltid fremskritt. Og så må de sette inn enda flere maskiner for å løse det den forrige maskinen ikke klarte."*

*"Med automatikken lærer man seg nye metoder for å få opp farten igjen. Flere maskiner betyr som oftest flere operatører, og det de gjør er å holde utstyret i gang når det feiler."*

*"Sekkene på mix, ja... Det er jo helt vanvittig at vi fortsatt bruker sekker. Pulveret burde kommet i små containere som ble plassert på dekk, og så blåste vi det bare rett derfra og inn i mixen."*

*"Alle her mener jo at vi kunne laget en optimal rigg om vi bare hadde fått lov til å designe den selv. Men den hadde nok ikke blitt billig. Vi hadde bestilt bare ventiler vi vet virker, istedenfor alle billig-løsningene som ryker etter en måned i drift, så vi må skifte dem. Leverandørene er så prisfokuserte, så de kjøper masse billig dritt alle vet ikke kan fungere, men det tilfredsstillter spec. Hvis vi fikk bestemme hadde vi hatt bedre planløsninger og vi ville laget maskiner som funket. Ikke alle halv-veis-maskinene ingeniørene på land kommer med. Folkene her er nok ikke så kreative som ingeniørene på land, siden vi er vant til å løse problemer raskt, men det ville i alle fall fungert."*

*"Et ideelt utviklingsprosjekt bør ha med seg brukeren i utviklingen. Hvordan kan de tro at de kan lage noe som fungerer når de ikke snakker nok med brukerne av utstyret og prosessen, og hvordan kan de tro at det de skaper kan fungere når det ikke forstår helheten?"*

*"Automasjon gir mindre manuelt arbeid - det er sant, men på mange måter får vi tyngre manuelle operasjoner nå enn tidligere. NÅR maskinene feiler, MÅ vi operere manuelt, og da kommer problemene, for ingenting er tilrettelagt for manuelt arbeid lenger. Dere må lage systemene sånn at NÅR en maskin går ned, kan man operere manuelt uten å bære seg i hjel eller knekke nakken i en uvant posisjon. Dere må legge til rette for manuelt arbeid den dagen maskinen*

*feiler (for vi vet jo at den ryker). Se for eksempel på sekkekutteren. Der burde det vært fri passasje til hopperne på plattformen over, og det burde være mulig å levere en sekkepall fra sack store der, så derrickmennene ikke måtte løpe opp med opp mot 150 sekker og så krongle seg frem mellom alle rørene for å komme seg til hopperne."*

*"Husk at det ikke er roboter som står og arbeider her. Vi har bare masse utstyr som skal opereres av mennesker. Når vi ser animasjoner i 3D fra leverandørene, så ser det så fint ut, og alt skjer automatisk, men hvor er menneskene? I praksis er det mennesker rundt disse maskinene, og de skal også gjøre arbeid. Og de er som sagt ikke roboter. De er omtrent 180 cm høye og har ikke 3 meter armer og de kan ikke løfte 400 kg."*

*"Utviklingen går veldig fort, men det er ikke entydig positivt. Det er blitt mye dyrere å drille et hull nå som alt er så automatisk og fancy. Det burde være mulig å lage maskiner som faktisk gjør operasjonen enklere og raskere, burde det ikke?"*

*"Ingen av dere inviterer brukerne nok med i utviklingen. De er kanskje ikke alltid så kreative, men de bør i alle fall med for å gi erfaringene sine videre. Noen burde kunne koble ingeniørkreativitet med operatørerfaring på en eller annen fornuftig måte, sånn at vi får bedre rigger her!"*

*"Vi kjøper et produkt som skal levere mud fra a til å. Verftet leverer dette – riggene leverer mud fra a til å. Men effektgraden av hvordan det skjer, ser de ikke på. Mange av løsningene for transfer og heiser og masse annet er så kronglete at ting tar mye mer tid enn nødvendig. Vi ser jo disse problemene når vi er på besøk på verftet, men dess nærmere vi er overtakelsesdato, dess mindre får vi lov å påvirke. Så ofte tar vi bare riggen som den er, og vet vi må bygge om «alt» med en gang. Da bygger vi om og skifter ut med utstyr vi vet fungerer. Det er billigere sånn, men det er ikke noe gøy å stå der og se at de bygger etter en dårlig spec, når du vet at det de installerer må ut med en gang. Og så forsøker vi å få inn bedre spesifikasjoner fra gang til gang, som tar høyde for*

*mer, men forbedringene kommer så sakte. Kanskje burde heller prosessen endres? Vi som er brukere må mer inn, tror jeg, på en eller annen måte."*

### *Dag 6 – Mandag 6. mai 2013*

- Møte med toolpusher/driller
- Mapping, flowline fra BOP gjennom treatment og ned til pumperom
- Besøk og intervjuer i drillerbua
- Besøk og intervjuer i shakerbua
- Mønstringsdrill (sikkerhetsøvelse)

#### **Møte med toolpusher/driller:**

- Info om dagens operasjoner i brønn.
- Info om nedetid pga overfylt trip tank. Tiltak: Endre suction line fra trip tank, slik at denne ikke overfylles.
- Info om plan for å bytte ut mud i løpet av dagen: «displacement plan»

#### **Mapping, flowline fra BOP gjennom treatment og ned til pumperom:**

Vi gikk opp mudprosessen gjennom shakerrommet og fikk tatt bilder.

#### **Intervju i drillerbua:**

Pga. problemer med brønnen, ble det lite tid til intervjuer, men desto mer tid til å observere operasjonene. Vi inkluderer kommentarer i bildeserien.

#### **Intervju i shakerbua:**

Her brukte vi lang tid, og kommer med en bildeserie fra prosessene i shakerbua i morgen.

#### **Mønstringsdrill:**

Det er sikkerhetsøvelse ombord på West Elara hver søndag kl. 17.



*Dag 7 – Tirsdag 7. mai 2013*

- Leverer utstyr
- Ferdigstille bilderapporter
- Planlagt videre arbeid

**Leverer utstyr:**

Pga. høyt gassnivå i mud, kunne vi ikke ta flere bilder utendørs idag (alt varmt arbeid innstilles når gassnivået er over 5%). Vi tok bilder innendørs, til dokumentasjon av arbeidsmiljø før vi leverte kamera, gassmåler og radio tilbake på radiatorrommet.

**Bilderapporter:**

Vi ferdigstilte bilderapporter fra i går så langt vi kom. Resten oppdateres når vi kommer i land.

**Appendix C – Process map of mud treatment process at West Elara**

The following pages show the process map of the mud process at West Elara. The process map is a product of interviews with Oddvar Birkeland, senior advisor at Cameron Sense AS.

