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Writer: **Siv Hanne Sivertsen**	………………………………………… (Writer's signature)
Faculty supervisor: **Kjell Kåre Fjelde** External supervisor(s): **Torfinn Hellstrand, Statoil ASA**	
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This master's thesis completes my degree in Industrial Economics (M.Sc.) at the University of Stavanger with Drilling and Project Management as fields of study.

This thesis has been a great opportunity for me to combine my fields of study with my Bachelor's degree in Information Technology, engineering specialization in Drilling together with my interest in analysis and statistics.

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Stavanger, 24 November.

Siv Hanne Sivertsen

Abstract

The cost of drilling wells at the Norwegian Continental Shelf (NCS) has increased drastically. This is one of the focal points both in the media and for the operating companies when it comes to the future of the NCS. For Statoil it is crucial to disclose a reason for increased time consumption on drilling operations. To be able to achieve this, a quantitative breakdown and analysis of the operations on a drilling section must be performed.

This thesis aims to identify and quantify the operations contributing to the diminished performance on the selected fields Smørbukk and Smørbukk Sør in the Norwegian Sea. The time period spans from year 1996 to 2014 and all the 58 12 ¼'' sections drilled are included. The fraction of time spent on the 12 ¼'' drilling section is somewhat above one third of the total time spent on all of the drilling sections. A higher efficiency in this drilling section will have a high impact on the cost effectiveness and the ability to deliver a well faster.

The data set has been divided into two intervals, Interval 1 and Interval 2. This is due to a two year drilling break from year 2002 – 2004. Interval 1 is before the drilling break and interval 2 is after.

It is difficult to identify exactly what is the reason for the increased amount of time spent on drilling wells. To be able to analyze the data all the operations in the 12 ¼'' section were extracted from the drilling reporting system (DBR) and carefully categorized manually. The development of the drilling performance has been investigated and visualized utilizing several different approaches;

- Displaying the average percentage time distribution on operations in both Interval 1 and Interval 2 by use of pie charts
- Quantify the average change in the time distribution between the two intervals
- Showing the change in the trend of the long time performance development for the total time period
- Comparing the performance in the end of both intervals
- Showing the learning and batch drilling effects in Interval 1
- Outline of the performance of the rigs working on the fields in Interval 1 and 2

The analysis revealed that there was a clear improvement in the drilling and circulation performance itself, but all of the other operations done in the section are contributing towards a declined total performance. Some of the key findings were:

- The average time spent on the 12 ¼'' section in Interval 2 has increased by 39,09 hours.
- Interval 1 was a period of steady improvement and positive development. In the end of the period the performance was at an all-time high.
- Interval 2 started off at a lower point with regards to performance. There was a decline in performance on all operations from the end of Interval 1 to the start of Interval 2. The good performance gained from learning effects, knowledge

transfer and frequently drilled wells were lost when operations resumed in Interval 2.

- Average downtime percentage has increased from 8,8 % in the first interval to 13,6 % in the latter.
- To assure improved drilling performance in the future the effect of batch drilling and continuous operation should not be underestimated. If there is a possibility for having more than one rig drilling at the same time this can provide a competitive environment and synergies with regards to knowledge transfer.

Microsoft Excel has been used as a tool for analysis of the data and the graphs presented in this study. In addition Statoil's reporting system (DBR) and its automated extracts have been utilized. All of the background material is added as appendices in 'Appendix B - Breakdown of operations of all wells analyzed'.

Table of Contents

List of figures

List of tables

List of equations

List of appendices

Abbreviations

A2A	Ambition to action – Statoil's performance management system
ALARP	As Low As Reasonable Practicable
BHA	Bottom Hole Assembly
DBR	Statoil's drilling reporting system
DOP	Detailed Operational Procedures
FIT	Formation Integrity Test
IOR	Increased Oil Recovery
KPI	Key Performance Index
LD	Laid Down
LOT	Leak-off Test
MIS	Internal system for following up the performance and KPIs
MSL	Mean Sea Level
NCS	Norwegian Continental Shelf
NPV	Net Present Value
OBM	Oil Based Mud
OPS(f)	Operational factor. Percentage of uptime.
POOH	Pull Out Of Hole
PU	Picked Up
PUD	Plan for the development and operation of petroleum deposits (Plan for utbygging og drift)
ROI	Return Of Investment
ROP	Rate Of Penetration
RPM	Revolutions Per Minute
TD	Target Depth
WBM	Water Based Mud
WOB	Weight On Bit

Table 1 - Abbreviations

1. Introduction

Drilling performance is important as a great part of the time usage and cost of the wells are related to the operations in the drilling operation. The cost of extracting the oil and gas from the reservoirs is increasing, and it is important to increase the drilling performance in order to reduce the well construction time.

In 'Figure 1 - Average well cost by Petoro' the average development in well cost over the years is displayed. According to Petoro the average cost of a well drilled by a mobile rig has tripled the last ten years.[i] In addition to the tripled cost, Petoro is claiming that the time spent on drilling operations has doubled in the last 20 years.[vii] The primary objective of this thesis is to study the drilling performance in the whole lifetime of the Smørbukk and Smørbukk Sør fields to reveal which operations are taking longer than before and if the time distribution has changed over the years.

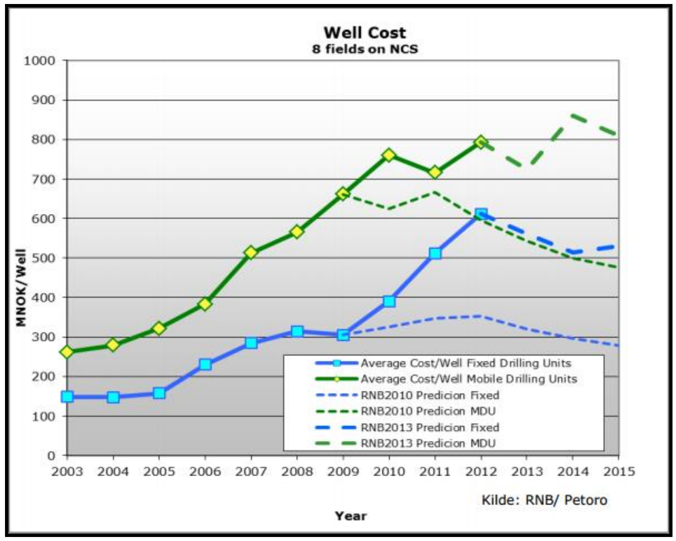

Figure 1 - Average well cost by Petoro

The data set has been divided in two intervals, Interval 1 and Interval 2. This is due to a two year drilling break from year 2002 – 2004. Interval 1 is before the drilling break and interval 2 is after.

To be able to analyze the drilling performance all the operations in the 12 ¼'' section has been extracted from the drilling reporting system (DBR) and carefully categorized manually. The performance of the different operations on the wells has been visualized in a variety of figures. The figures are as a main rule shown for the whole period first, and then divided up in Interval 1 and 2 in the next figure.

In the discussion of the findings the following different approaches have been used to verify the direction of the performance development:

- Displaying the average percentage time distribution on operations in both Interval 1 and Interval 2 by use of pie charts
- Quantifying the average change in the time distribution between the two intervals
- Showing the change in the trend of the long time performance development for the total time period
- Comparing the performance in the end of both intervals
- Showing the learning and batch drilling effects in Interval 1
- Outline of the performance of the rigs working on the fields in Interval 1 and 2

1.1. Layout

Chapter 1, **Introduction,** gives an introduction to the thesis and the background. A summary of Statoil's corporate strategy is provided before there is a go-through of the factors influencing the drilling performance. Finally the problem statement is discussed.

Chapter 2, **Basis for analysis,** presents theory needed in the analysis. It starts with an overview of the Smørbukk and Smørbukk Sør fields before an introduction to Statoil's reporting system DBR is provided. It continues with an outline of Rushmore in Statoil, with the corresponding definitions of sections included in the benchmarking and a definition of meters per day. Finally in this chapter there is an overview of the definitions of used activity codes in DBR and an overview of the operations that are included in the 12 ¼'' drilling section.

Chapter 3, **Analysis,** opens with a short introduction to the chapter and continues with a discussion of the data set. The difference between directly extracted data from DBR and manually categorized data is emphasized. For the analysis part it kicks off with an overview of the time distribution before defining the performance targets and presenting how the operations have been organized in sub-operations. All of the sub-operations are presented in graphs for the total period and graphs divided in Interval 1 and 2.

Chapter 4, **Results from analysis,** gives an introduction to which approaches will be utilized to discuss the results from the analysis in chapter 3. An overview of the average time distribution will be provided before going in depth on the result with the different approaches. Essentially the average values and the trending values from the graphs will be utilized for visualizing the change in drilling performance.

Chapter 5, **Discussion,** is a study of the results in chapter 4 with corresponding reasoning as to why this is the result.

Chapter 6, **Conclusion,** provides the conclusions of the study.

Chapter 7, **Future work,** contains recommendations for further study.

Chapter 8, **Appendices,** gives the relevant appendices used in the thesis.

Chapter 9, **References,** gives the references. The bibliography and other sources of information utilized in this thesis have been referenced.

1.2. Background

Norway's oil history started right before the year of 1970 and has expanded in great speed after. The petroleum business has been one of the major contributors to the great economic growth we have had in Norway. As a result of development and learning during all these years, naturally there is an increased focus on the following:

- Use of new and better technology
- Optimization of the planning process

- Learning and knowledge transfer
- Focus on avoiding downtime
- Streamlining of activities
- Increasing the safety for the personnel involved in the process by revising the work procedures.

All of these factors can possibly affect the drilling performance and will be part of the analysis in this thesis.

In the Increased Oil Recovery (IOR) goal launched by the Norwegian Government the drive is to increase the recovery rate from the reservoirs from each drilled well. [ii]

$$\text{Oil / gas recovery} = \frac{\text{Estimate for extractable oil / gas}}{\text{Estimate for remaining oil / gas in the reservoir}}$$

Equation 1 – Recovery rate from reservoir

The percentage of oil/gas recovery is to be increased, and funding is granted to research for realizing this goal. A key point with regards to increasing recovery is to perform infill drilling.[iii] As most reservoirs are segmented there is a need for a large number of wells to get the best possible recovery from all the different zones and layers. Infill drilling is beneficial for draining a larger percentage of the reservoir and can contribute to higher earnings. On existing fields the infrastructure is already in place and the structure of the reservoir is well known. Still it is a fact that drilling an infill well contributes to a larger total cost. When the companies are calculating the investment decision and in the cases where the Net Present Value (NPV) is lower for drilling an infill well than for a new well, the operator (and the environment) benefit from the governmental incentives to drill infill wells instead of a new well. There are many methods for increasing the recovery rate, but this is one of the methods that in the short term gives the best result. [iv]

The age of “easy oil”, where the reservoirs are untouched with optimal pressure that eases the production of oil and gas is slowly coming to an end. Nowadays many of the wells are sidetracks from older wells, and the optimum well design cannot be used. A sidetrack or slot recovery well utilizes a less optimum casing shoe placement because one must perform a plug & abandonment in the mother wellbore before sidetracking. The consequence is that initial setting depth of the different casing shoes cannot be used. As a further challenge many of the reservoirs are getting depleted and special technology to increase the pressure and hence the production rate is implemented.

Wells that are more advanced both with regards to the casing and the completion design together with lower margins in the oil business overall, leads to a severe need for increasing the performance and reducing the costs. For all operators it is important to increase the efficiency to prove to shareholders that the company is worth investing in. As the oil business is very capital intense, an oil company with shortage of liquidity is not able to invest the enormous amount of capital that is required to operate. It is more important than ever to get an acceptable return of investment (ROI), as the investment risk is high.

The total oil production on the NCS reached its peak in 2004 at a total production of 263,4 million sm3 per year and has been slowly declining since. [v]

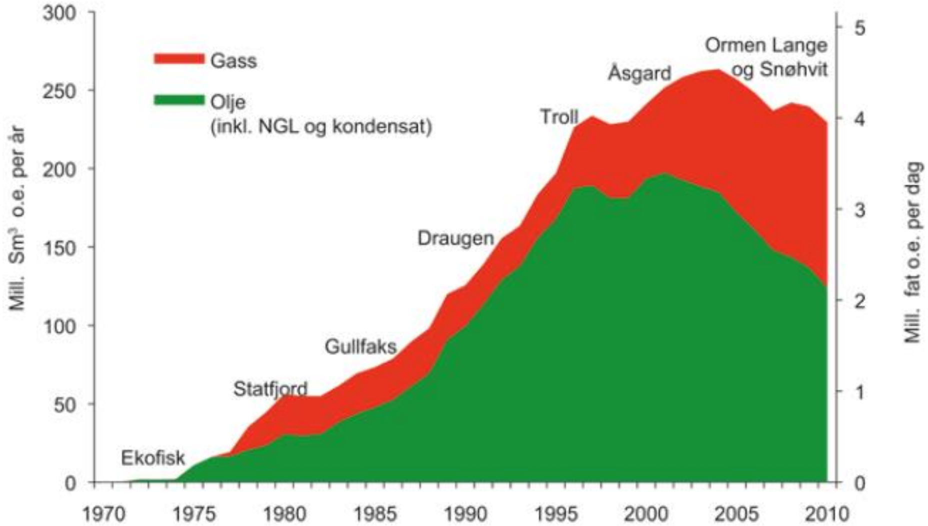

Figure 2 - Total Petroleum production NCS[vi]

In addition to the challenge of falling or stagnating oil production; the industry is also facing a decline in drilling performance, according to the referenced article by Petoro. In the article it is stated that the drilling speed is deteriorating because the industry is spending twice as much time on the drilling activities in 2014 as 20 years earlier.[vii] The article emphasizes on high costs and low efficiency and encourages the operators to have a further look into the analysis of the numbers as Petoro have limited resources in this regard.

1.3. Statoil's corporate strategy

From Statoil's Annual Report in year 2011, in the section for corporate strategy, the ambition was to produce 2.5. million barrels of oil equivalents per day in 2020. To be able to achieve the goal an annual growth rate of 2.7% over the course of the next 10 years were required.[viii]

In year 2013 the strategy in the Annual Report was revised and the focus was on a stricter prioritization of projects and a comprehensive efficiency program. The company wants to prioritize a capital distribution to shareholders and improve cash flow and profitability. [ix]

As seen from the Annual Reports, there has been a change in focus the later years from producing as many barrels of oil as possible to reducing cost. This change of focus results in capital saved from reducing cost is not used directly for prioritizing new projects and drilling new wells, but rather on increasing the cash flow and distribute to shareholders. The increased focus on efficiency and cost saving is attractive for investors, and the stock price has since the announcement of the updated strategy increased the last three years, and especially after September 2013.

Figure 3 - Statoil stock price the last three years. September 2011 – August 2014[x]

1.4. Factors influencing drilling performance

A variety of factors are tightly connected and together results in the total drilling performance for a well. An overview of some of the main contributors is listed up below.

Geology

Different geological conditions influence the drilling performance. Geological conditions, (predicted or not) can delay the drilling operation. As an example harder formations can reduce the rate of penetration (ROP) and result in a delay. Lower sand quality than expected in the reservoir may possibly lead to a sidetrack to be able to obtain a more favorable well placement.

Technology

The technology both with regards to downhole equipment and equipment on the rig itself has developed rapidly over the decades. The oil industry is considered to be conservative, but as the rig rates are high the openness and the will to try new (and hopefully improved) technology is always present. The focus on automation has been high the later years, and this is also the case within drilling automation. Statoil is currently having a pilot where automated drilling technology is utilized on one of the Statfjord platforms and if this technology proves successful it will be used on other rigs.

Research and development is playing an important role in the oil and gas industry, and the government is encouraging the companies to develop new technology by providing favorable framework conditions.[xi] As mentioned previously the age of “easy oil” is coming to an end, and the Norwegian shelf is facing new challenges with regards to fewer discoveries and depletion of the already existing reservoirs leading to more advanced well design and need for technology facilitating for example gas lift completion.

Equipment
It is a fundamental aspect that the equipment used in the operation should be reliable. All the equipment, like the top drive, the pipe handling, the mud and cement pumps and so forth will all contribute to downtime if they fail during the operation. A failure on the equipment will decrease the drilling performance as it can result in an extra trip, waiting for repairment, waiting for new equipment to be sent to the rig and so forth.

Efficiency
How fast and efficient we are able to perform the different operations influences the total drilling performance. When talking about efficiency related to drilling performance, the implication is to produce the specific outcome (drill the well) with a minimum amount or quantity of downtime, expense or unnecessary effort. Some of the operations, like for example running casing in hole with required connections and tripping are done several times during the well construction process and should be in focus when it comes to performing more efficient. Optimization of the operations will contribute towards a better performance.

Planning
The drilling program is important when it comes to the drilling performance. Among other factors, important risks should have been identified and contingency measures should be a part of the plan. Risks are categorized with criticality high, medium or low (red/yellow/green). Corrective and preventive measures are implemented to reduce risk and we always strive to get high risk (red) into the as low as reasonable practicable (ALARP) area with help of corrective / preventive measures.

The detailed operational procedures (DOP's) should be updated to reflect the current rig, equipment, operation and personnel onboard. A good plan leaves room for unforeseen events to occur and helps the operation to get into the right course fast after it has happen. A good plan is optimized and the possible parallel operations are identified. At any point in time only the needed personnel are present on the rig and the plan is written clear and concise.

Proactive operation and event recognition
The term proactive operation means to be acting *before* the problem has occurred instead of acting after the event has happened. [xii] To be able to do that one must be aware of the different situations that could possibly occur and plan accordingly. One example is to always have spare parts for the equipment to be used in the operation in case it will be needed. Another example is to make sure that the heavy lifting operation is finished before the wind is increasing in strength. By being proactive the operation can continue uninterrupted with all the required equipment.

Event recognition is to be able to understand what will happen next by analyzing the current condition. When it comes to the condition of the well itself this can require experienced personnel that have been working with many different situations in the operations and have learned from them. For example when the driller experiences that even with increased weight on bit (WOB) and revolutions per minute (RPM) the bit is not cutting as aggressively as expected. Should he then increase the WOB or RPM, increase the flow rate or even pull out of hole to inspect if the bit is in good condition? The decisions taken during the operation can either lead to increased time spent and that will decrease the drilling performance or vice versa.

Work processes
The work process in many situations guides how fast the operations can be performed and to which cost. This is because the governing documentation can contain requirements or guidelines about how an operation should be performed, which personnel should be involved, what equipment to use, how the weather conditions should be, how the work should be documented and so forth. In Statoil the technical requirements in the governing documentation is extensive and has been developed and updated from the lessons learned over the years. To be compliant with the work processes requires planning in advance and close follow-up during and after operation.

ROP
The rate of penetration, or the speed the drill bit breaks the rock under it, directly contributes to the drilling performance. When drilling softer formations, like shale, the ROP usually increases. On the opposite, when drilling harder formations, like sandstone, the ROP is usually decreasing. One cannot uncritically drill on full speed as it is important to take into consideration the actual condition in the hole and also not to impact forces at a greater level than specified as the limit that could destroy the equipment. The bit can be affected by impact damage due to for example vibration, get overheated, get wear on the cutters and so forth. A bit that is worn out will lead to poor drilling performance and a trip to change it can be required. [xiii] Another restriction for high drilling speed is the rigs ability to handle the cuttings. The volume of cuttings will be higher as the diameter of the hole is greater, so this is especially an issue in the larger sections.

Well design
The well design is to specify and design the physical materials and dimensions for the well.[xiv] The design includes information of how deep each section should be drilled, which quality casing to use, which threads on the casing to use, which bottom hole assembly (BHA), bit and other equipment to use, the parameters of the cement job, the mud type and mud weight and so forth. All of the factors decided in the well design can influence the drilling performance.

Batch and learning effects
A drilling operation is complex and requires a variety of operations to be performed in order to be able to finish the work. When the operations are performed in batch it leads to the drilling crew and the planning engineers repeating an operation. This makes it easier to take into consideration all the learnings from the last job.[xv]

When more than one rig is working on a field it will also create a learning environment as the personnel at the different rigs are exchanging experiences and learnings, and at the same time it is a competitive environment as both of the rigs compete to have the best performance.

Incentives and Key Performance Indexes (KPI's)

The incentives and KPI's are meant to motivate and to get the individual to perform their job in a specific way.[xvi] The goal for the incentives is to provide value for money and to contribute to a safe and efficient operation. How the contracts are formed leads to a standard for how the personnel will work and prioritize. If the contracts are formed to encourage taking risks to be able to perform faster, this will lead the personnel in that direction. If the contracts are formed so that any risk taking that goes wrong will lead to a punishment of the companies, the personnel will strive not to take any risk and will take any precaution possible.

The incentive structures can have a great impact on how the contracts are formed and how the personnel work. As it is hard to predict all the consequences from creating an incentive it can be tricky to set it up in a good way. An incentive can possibly lead to the organization acting in an unexpected way or a skewed focus.

1.5. Problem statement

This thesis aims to identify and quantify the operations contributing to the diminished performance on the selected fields Smørbukk and Smørbukk Sør in the Norwegian Sea. The goal is to reveal which operations are taking longer than before and if the time distribution has changed over the years. With new technology and increased experience; Why are we less efficient with regards to meters drilled per day during the drilling phase?

To be able to analyze the drilling performance a manageable dataset is necessary. The investigated section is the 12 ¼'' drilling section. Two wells have been removed from the full list of wells to keep the dataset consistent and remove the extremes. The first well is removed due to exceptionally poor performance and the other one due to extraordinarily good performance. The two wells are the following ones:

- 6506/11-4 S
- 6506/12-H-4 H

The two wells are both part of Interval 1. The full well list of 58 wells is therefore reduced to 56 wells throughout the analysis. The details of the wells are to be found in 'Appendix B - Breakdown of operations of all wells analyzed'.

A plot showing the entire picture with regards to drilling performance (meters drilled per day) on the whole life span of the Smørbukk and Smørbukk Sør field has been created in the next figure.

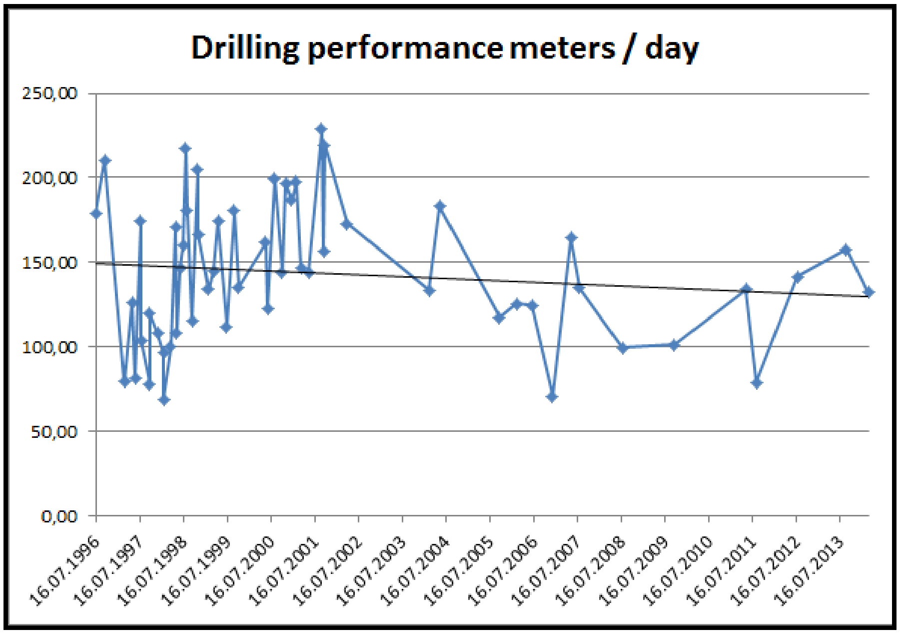

Figure 4 - Drilling performance meters/day on the 12 ¼'' section

The trend line in 'Figure 4 - Drilling performance meters/day' shows the trend for meters per drilled day of the 12 ¼'' section in chronological order of the wells. One dot represents one 12 ¼'' section in a well. It is evident that the drilling performance is developing in negative direction with a starting point at nearly 150 meters drilled per day in year 1996 and ending up at 130 meters drilled per day in year 2014.

In the Smørbukk and Smørbukk Sør fields there was a drilling stop from the well 6506/12-M-4 H was finished in April 2002 until the well 6506/12-N-1 H was started on in February 2004. As mentioned, the time period is divided into two periods, Interval 1 and Interval 2. Interval 1 starts with the first well in year 1996 and ends with the last well in year 2002. Interval 2 starts in year 2004 and ends in year 2014.

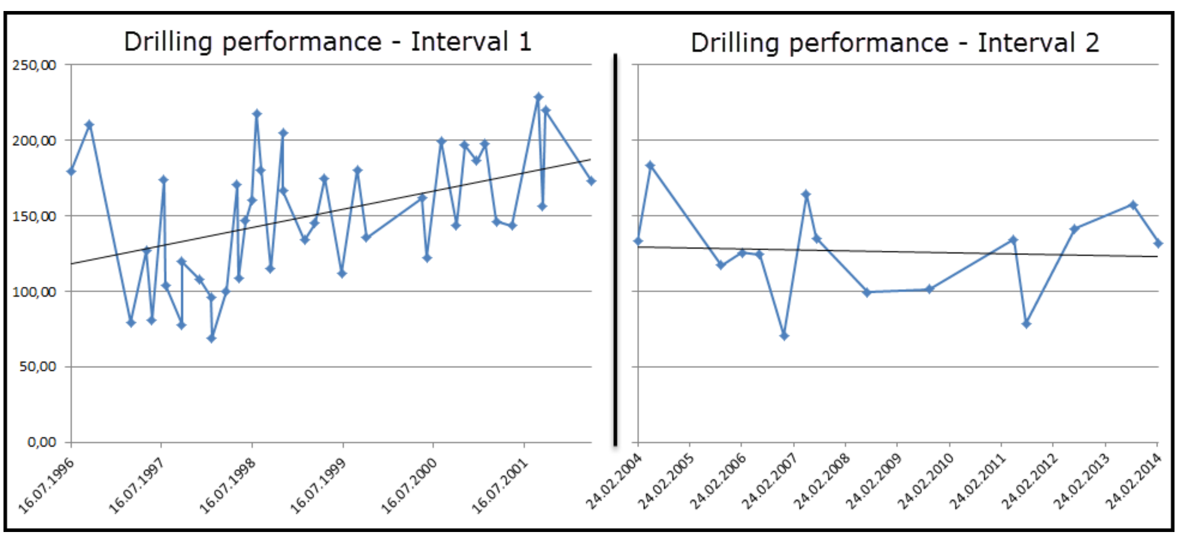

Figure 5 - Drilling performance meters/day on the 12 ¼'' section - Interval 1 and 2

In ‘Figure 5 - Drilling performance meters/day on the 12 ¼’’ section - Interval 1 and 2’ the trend line in Interval 1 shows a very positive development, while the trend line in Interval 2 shows a slightly negative development. The end point for the trend line in Interval 1 is at about 186 meters drilled per day, while the end point of the trend line in Interval 2 is at about 123 meters drilled per day. In addition the trend for Interval 2 is starting at a much lower performance than what the first interval ended in.

The top years with best drilling performance is around year 2000 – 2002 where the average meters drilled per day was around 185 meters. From year 2006 – 2014 the average was around 120 meters per day. See ‘Appendix A - Full well list (including meters / day) for all wells analyzed’ for more details.

From the trend curve in Interval 1 it seems as the operation was continuously improving. This can possibly be due to learning and implementing needed measures, factors that can make it possible to perform better. This was the case until a certain level. There was a 2-year drilling stop and the trend of improved performance disappeared. The starting point of the trend line in Interval 2 is starting off at a lower value than what it ended on in Interval 1, and it keeps developing in negative direction. Why is this case? Which operations are slowing us down and what happened to the positive trend? Has the time distribution changed? Are there any major changes to the way things are done in Interval 2 and onwards?

Improvement and cost reduction is high on the agenda for Statoil and the oil business in general. The time spent on keeping the rig in operation is one of the primary cost drivers for the industry and due to years of increasing activity on the Norwegian shelf and continued investments; the drilling contractors have increased the rig rates significantly.[xvii] An analysis of the factors leading to increased time spent on the drilling operations and why the industry experiences a reduced drilling performance is important. This analysis will be based on a manual inspection and categorization of daily drilling reports by Statoil on Smørbukk and Smørbukk Sør for 56 wells from year 1996 until 2014.

2. Basis for analysis

2.1. The Smørbukk and Smørbukk Sør fields

The Statoil operated Åsgard field is producing oil, gas and condensate and is located at Haltenbanken in The Norwegian Sea around 200 kilometers from the coast of Trøndelag. The nearest Statoil operated field is the Heidrun field to the north. Other fields nearby are Kristin / Morvin on the west side, and Tyrihans / Mikkel in the south.

Figure 6 - The location of the Åsgard field[xviii]

The first exploration well was drilled in year 1983, while the drilling of development wells started in the year 1996. The oil production started a few years later in May 1999. Åsgard is one of the largest field developments on the NCS and consist of three connected licenses; Midgard, Smørbukk and Smørbukk Sør. In addition two gas fields; Mikkel and Yttergryta, are connected to Åsgards infrastructure. The water depth in the area is from 240 – 310 m. In total, in all of the connected licenses, 112 production- and injection wells have been drilled in the period from July 1996 to March 2014[xviii]. In this analysis exclusively the wells for Smørbukk and Smørbukk Sør are taken into consideration, see the full well list in 'Appendix A - Full well list (including meters / day) for all wells analyzed'.

2.1.1. Exploration wells and "PUD" on Åsgard

For the first exploration well on Åsgard the 12 ¼'' section was drilled with wated based mud (WBM) and with a performance of 2 – 4 meters drilled per hour. 15 bit runs was needed to finish the drilling section. There was uncertainty with regards to the profitability of the field and if it could be invested in and established with infrastructure. The next exploration well was drilled with oil based mud (OBM) and had a significantly improved performance with around 30 meters drilled per hour and only one bit run needed. This turning point made it possible to invest in Åsgard and sign off the plan for the development and operation of petroleum deposits (the "PUD"). [xix]

2.2. Statoil's reporting system (DBR) and the dataset.

DBR is Statoil's drilling and well reporting system. The application automatically transfers required reported data to the Norwegian government every day. DBR is internally developed and maintained, and was implemented in Statoil first in the early

80’s. It has been developed from use on a mainframe computer to being a standard Windows 7 application as it is today. It is still in development and the next step is to make it a web-based application where it will enable users to report the operation when they are offline or in remote location with low or reduced Internet access.

The database of DBR has been the same the whole time, so all the reported data should be available and searchable for all users to find. The reporting data from Saga and Hydro was transferred to DBR after the mergers in 2007.

Smørbukk and Smørbukk Sør, part of the Åsgard field, is chosen as the field in this analysis due to several factors. It is a fairly new field and there are very few technical sidetracks done in order to be able to reach the objective of the well. There have been several different rigs drilling the wells, and also different companies being responsible. As it is a new field we get a consistent dataset where all the details can be found in DBR. The 12 ¼’’ drilling section is chosen because it was the most troublesome and time consuming drilling section in the exploration phase of Åsgard. Finally the section is also quite similar and comparable from well to well in the same field.

The basis for the analysis, the full well list, is put together from DBR and NPD’s fact pages[xx], and consists of 86 development wells in total. Out of these 86 development wells there are 58 of the 12 ¼’’ sections drilled. The reason for not having 86 of the 12 ¼’’ sections is because some of the wells are sidetracks starting at a smaller diameter and some of the wellbores are multilateral sidetracks with 8 1/2’’ diameter. The full well list with the 12 ¼’’ sections is added as ‘Appendix A - Full well list (including meters / day) for all wells analyzed’. Three of the wells in the list were previously classified as exploration wells, but have been re-classified as development wells at a later stage:

- 6506/11-5 S
- 6506/11-4 ST2
- 6506/12-11 S

The wells drilled on Midgard are not part of the full well list, as the field is a gas deposit and divided into four structural segments at another depth (shallower) than the rest of the Åsgard field. This results in the data on Midgard not being directly compatible with the rest of the data for Smørbukk and Smørbukk Sør, and would introduce other sources of error. In addition wells that are exclusively producing gas are subject to other challenges and well design than wells producing oil, condensate and gas.

As the data are reported manually there is always uncertainty related to the data. This can be due to many reasons, for example, but not limited to, one or more of the following:

- Personnel misinterpreting the information and therefore reporting it wrongly.
- Misspellings.
- Stress and time pressure.
- Other factors.

2.3. Rigs operating on Smørbukk and Smørbukk Sør.

Rigs that have operated on the field field on the 12 ¼'' section are the following ones:

Rig name	Type of rig	Rig manager
Aker Spitsbergen	Semisub, 6th generation	Transocean Ltd.
Deepsea Bergen	Semisub, 3rd generation	Odfjell
Ocean Vanguard	Semisub, 3rd generation	Diamond Offshore
Scarabeo 5	Semisub, 4th generation	Saipem
Stena Don	Semisub, 4th generation	Stena Drilling
Transocean Artic	Semisub, 4th generation	Transocean Ltd.
Transocean Leader	Semisub, 4th generation	Transocean Ltd.
Transocean Searcher	Semisub, 3rd generation	Transocean Ltd.
Transocean Winner	Semisub, 3rd generation	Transocean Ltd.

Table 2 - Rigs that have operated on the Smørbukk and Smørbukk Sør fields[xxi]

2.4. Rushmore in Statoil.

All drilling reporting in Statoil is done according to the Rushmore Review definitions. Rushmore is collecting information to be able to create a central database with offset data that can easily be compared across different operators. To be able to do this kind of comparing a set of rules (in form of a spreadsheet) for what to include in the different sections of a well has to be followed. This is called benchmarking.

Having a standard definition of what to include in each section is beneficial for the planning process of a well where the engineer can verify comparable offset data on the webpage of Rushmore from several other operators in the same area. It is also beneficial to analyze the competitive performance of a company towards its peers. Many of the operators are participating in Rushmore, among them Statoil, Shell, BP, Conoco Phillips and so forth.

2.4.1. Overview of sections included in 'drilling benchmark'.

The full list of type of sections included in the Rushmore 'drilling benchmark' is as follows:

- Pre-Spud
- Conductor
- Prepare Multilateral Sidetrack
- Prepare Technical Sidetrack
- Prepare Contingency Geological Sidetrack
- Prepare Sidetrack from Locator Well
- Drilling sections of all diameters
- Bypass Coring

2.4.2. Definition of meters per day

In DBR the Rushmore definition has been coded in the background of the software. DBR automatically pics up the benchmarking sections for Rushmore and the collected information will be sent to Rushmore Reviews. In addition a manual check of the data is performed every year.

The definition of the drilling operation for any section is as follows: "The time spent (days) from spud to target depth (TD), (or to end of logging at TD or to end of reaming / under-reaming following TD, whichever is later)."

Section start: when the activity code for drilling new formation with drilling BHA after successful formation integrity test (FIT) / leak-off test (LOT) of the previous section is performed.

Section end: After successful FIT/LOT is performed. If the section is a reservoir / last section the end time will be when the logging tools are rigged down after TD logging. Where TD logging is not carried out, again for most wells, the clock will stop when the bit is returned to the drill floor after TD'ing.[xxii]

The formula used for calculating the meters drilled per day is:

$$\text{Meters per day} = \frac{\text{Drilled length (section length) (m)} * 24}{\text{Operational hours (hrs)}}$$

Equation 2 – Meters per day

Drilled length: The total length drilled in the section, the section length.
Operational hours: The total hours registered on the drilling section, according to the Rushmore definition. This includes uptime, downtime, quality time, waiting time and waiting on weather.

2.5. Definition of activity codes in DBR

Activities in DBR are reported as:

- Up time (U)
- Downtime (D)
- Waiting time (W) – Includes both regular waiting (V) and Waiting on Weather (WOW)
- Quality time (K) – In the old code set. Stopped using this in year 2010, when 'quality time' instead is being reported as 'up time'.

2.5.1. Activity code "Up time (U)"

All activities carried out according to plan and with no issues with regards to equipment failures, injuries, kick, stuck pipe and so forth are reported as up time.

2.5.2. Activity code “Downtime (D)”

The process owner group Drilling & Well in Statoil is in the fall 2014 working on a revised document for downtime definitions that is going to be formally approved and added to the documentation in the management system. As this is ongoing work when this thesis is being written the current definition of downtime will be used:

“Down time related to drilling and well operations are defined as: Failure due to equipment or operational problems and the time spent to correct such events.

Activities not to be reported as down time:

- Activities to improve hole conditions, e.g. wiper trips, circulation to clean the hole, back reaming, reaming of side track windows etc.
- Planned contingency measures during completion, workovers and P&A, e.g. clean-up runs, extra runs to cut and pull casing, etc.

  Contingency geological sidetracks for the following reasons:
    - New target location
    - Found unsatisfactory reservoir
    - Found no reservoir

Downtime operations are operations used for recovering from the failure situation and marked with an activity code ending with the letter ‘D’ in DBR. All downtime operations are linked to an incident. Related downtime is connected to the same incident (and linked to the Synergi incident reporting system).” [xxiii]

2.5.3. Activity code “Waiting time (W)”

Waiting time includes the waiting on weather (WOW) and all other waiting (V). Other waiting could for example be to wait for the cement to set, wait for equipment on ship or wait for the crane to transfer the required equipment. The reporting in DBR is built up in the same way as for downtime reporting.

Waiting codes are added to the already planned operations if waiting occurs. The operation is reported as “waiting” until it is possible to resume the work. When adding ‘waiting’ to the activity code one must fill in the reason for waiting (“wait reason”) so that analysis can be performed on why time is spent on waiting.

2.5.4. Activity code “Quality time (K)”

Before a new code set was implemented in DBR in November 2010 an additional activity was possible to report, called ‘Quality time’. Quality time was reported in DBR as a ‘K’. It was only within the drilling sections that is possible to select “K”, and not within completion, intervention or other operations.

The time spent on this activity was related to preventive measures. The background for implementing quality time was that the operation should not be “punished” for spending time on measures that could prevent issues later on. The activities coded as “K” were for example a wiper trip before running casing and time spent on logging. This wiper trip could be unnecessary (if the hole was clean enough), but this is in many cases impossible to determine before the operation has been performed, or even after. When searching in DBR for activities added with “K” time, a list of operations that were performed, but possibly could be left out, is accessible.

Analysis of the time spent on ‘K’ time indicated that the wells with the highest percentage of this activity type had worse performance with regards to meters per day. It was a common belief that one should reduce the time spent on quality to be able to drill a well more efficiently. The operational teams were encouraged to spend enough time on quality, but not more time than necessary. This was a balancing act, and the incentives were directed to help with reducing time on quality codes.

After 2010 the activity code ‘K’ was removed from DBR, and preventive operations are added to the activity code for uptime ‘U’.

2.6. General information about casings and the 9 5/8’’ casing.

A well consists of a set of casings, enabling the well to reach its objectives. It is important with a casing design suited for the geological challenges and the well objectives. The casings must have sufficient strength and functionality.

Casing is the major structural component of a well, and has several purposes, as the following:

- Maintain borehole stability
- Prevent contamination of water sands
- Isolate water from production formations
- Avoid hydrocarbon leakage to surface
- Control well pressures during drilling, production and workover operations[xxiv]

The standard types of the casing strings with the common diameters are the following:

- Conductor casing (30’’)
- Surface casing (20’’)
- Intermediate casing (13 3/8’’)
- Production casing (9 5/8’’)
- Production liner (7’’)

The production casing is the last set casing before drilling into the reservoir and the pay zone. In addition to the requirements mentioned over, the casing has the following most important functional requirements:

- Isolate all formations (unstable hole sections, lost-circulation zones, low-pressure zones, production zones) up to the intermediate casing shoe so that the next hole section can be drilled safely and efficiently through the pay zone

- Give sufficient well integrity for drilling the pay zone or any abnormally pressurized zones as requested by the drilling program
- Fulfill production casing design requirements if only a production liner is planned below [xxv]

2.6.1. Operations included in the 12 ¼'' section

When calculating meters per day all the hours used on any operation included in the drilling section will be reflected. As stated in chapter '2.4.2 - Definition of meters per day': According to Rushmore, the section starts when the activity code for drilling new formation with drilling BHA after a successful FIT/LOT of the previous section is performed. The section ends after a successful FIT/LOT is performed. If any logging is to be performed, this is also included in the total time of the section.

The following operations are the standard operations used for carrying out a 12 ¼'' drilling section:

1	Drill to TD
2	Circulate hole clean, wiper trip if necessary
3	POOH and LD 12 ¼'' BHA
4	Retrieve 13 3/8'' wear bushing
5	Rig up for running 9 5/8'' casing
6	RIH with casing
7	Make up casing hanger and cement stand
8	Perform cement job
9	Set and test seal assembly
10	POOH
11	RIH and install 10 ¾'' wear bushing
12	MU 8 1/2" assembly
13	Perform FIT / LOT

Table 3 - Standard operations of 12 1/4" drilling section

This table is set up based on observation of the drilling programs of the following wells:

- 6506/11-F-3 H
- 6506/11-G-3 HT2
- 6506/12-M-2 H

In addition it is quality checked towards the table for "Sequences of a drilling operation" in the referenced book by Bernt Aadnøy.[xxvi]

3. Analysis

3.1. Introduction

In the graph presented in ‘Figure 5 - Drilling performance meters/day on the 12 ¼’’ section - Interval 1 and 2 ’ the wells in Interval 1 were drilled in a time period of six years. For Interval 2 the drilling period is over a span of 11 years. The period of time the analysis is based on is therefore of different lengths, and the amount of wells drilled in each of the intervals is also not the same.

The amount of 12 ¼’’ sections drilled in this period is 58 whereas 43 of them are in or before year 2002, and 15 of them after 2002.

The analysis is performed on the whole timespan of the Smørbukk and Smørbukk Sør fields, and covers the period from 1996 to 2014. The analysis starts off with an introduction to the dataset. Secondly an overview of the time spent on the drilling sections in provided. After that a break-down of all operations performed on the 12 ¼¨ section is displayed before all the different contributors to the drilling performance is gone through in separate plots. Each section will have an introduction of what is included in this specific analysis. It is divided in this way in order to detect the factors that are contributing the most to reduction of performance.

All of the wells on Smørbukk and Smørbukk Sør are placed near each other in approximately the same geological area. That results in the wells being comparable to each other. The 12 ¼’’ sections are drilled in roughly the same geology and lithology. The total length of the section is however varying from 1778 m to 3585 m.

3.2. Dataset for Smørbukk and Smørbukk Sør.

The dataset is all 12 ¼’’ sections drilled on Smørbukk and Smørbukk Sør from 1996 and until first half year 2014. Some of the wells initially had to be removed from the dataset due to inaccurate reporting according to the Rushmore definitions. There were sections starting on the wrong operation or ending with the wrong operation. All of the wells have been manually examined and if it has been wrongly reported, for example starting at drilling out shoe track and not drilling formation, the well has been kept in the dataset and has been adjusted manually.

The dataset is complete. All of the wells have been manually inspected and corrected and are part of the analysis, except the two extremes as previously informed in chapter ‘1.5 - Problem statement’.

3.2.1. Directly extracted data from DBR and manual categorization of the data.

It is important to note that in chapter ‘3.3 - Time spent on the drilling sections.’ and in chapter ‘3.4 - Overview of time distribution (Uptime, downtime, waiting time, quality time).’ the numbers have been <u>directly extracted</u> from DBR and is also containing the two aforementioned removed wells. As the values in the rest of the analysis, from chapter ‘3.5 -

Performance and performance targets' and onwards have been extracted manually, the consequence is that the values in these two chapters cannot be directly compared to the rest of the analysis. This is because corrections has been done when the data has been manually examined, and when operations reported as uptime should have been downtime or sections starting / ending in the wrong place, this has been manually corrected. From the aforementioned chapter '3.5' and onwards the reader is referred to the 'Appendix B - Breakdown of operations of all wells analyzed' for the full data basis.

3.3. Time spent on the drilling sections.

An overview of the total time in hours spent on all of the drilling sections on the wells has been extracted from DBR and is shown in the following tables. The hours are split into the different activity codes reported;

- Uptime 'U'
- Downtime 'D'
- Waiting time 'W'
- Waiting on weather 'WOW'.

Field	Sum time (hrs)	U hrs)	D (hrs)	W (hrs)	WOW (hrs)	TIME_PERIOD
SMØRBUKK	35821,8	30550,99	4457,56	115,75	629	(01.01.1996 - 31.12.2014)
SMØRBUKK SØR	26654,52	21356,77	3968,33	211,5	1114,92	(01.01.1996 - 31.12.2014)
EXPLORATION	4527,5	3013	1103,5	17	110	(01.01.1996 - 31.12.2014)
Total	67003,82	54920,76	9529,39	344,25	1853,92	(01.01.1996 - 31.12.2014)

Table 4 - Time spent on all drilling sections

'Table 4 - Time spent on all drilling sections' shows the sum time used in hours for all of the drilling sections. The table is divided into fields and covers the whole time period from 01.01.1996 – 31.12.2014 (as far as we have come this year).

Field	Sum time (hrs)	U (hrs)	D (hrs)	W (hrs)	WOW (hrs)	TIME_PERIOD
SMØRBUKK	14228,26	12094,01	1861,5	73,75	199	(01.01.1996 - 31.12.2014)
SMØRBUKK SØR	10677,53	9083,03	1116,5	0	478	(01.01.1996 - 31.12.2014)
EXPLORATION	1527,5	912,5	583	0	32	(01.01.1996 - 31.12.2014)
Total	26433,29	22089,54	3561	73,75	709	(01.01.1996 - 31.12.2014)

Table 5 - Time spent on 12 1/4" drilling section

'Table 5 - Time spent on 12 1/4" drilling section' shows the sum time used on the 12 ¼'' drilling section divided into fields. The three exploration wells in the list were as already mentioned re-classified as development wells and are therefore included in the data set.

The percentage of time spent on the 12 ¼'' section on the different fields is established by calculating the amount of hours spent on this section towards the total time spent on all drilling sections in the well. The result is as follows:

Smørbukk: 14228,3 hrs / 35821,8 hrs = 39,7 %
Smørbukk Sør: 10677,5 hrs / 26654,5 hrs = 40,5 %
Exploration: 1527,5 / 4527,5 hrs = 33,7 %

The fraction of time spent on the 12 ¼'' drilling section is somewhat above one third of the total time spent on the drilling sections. This indicates that a higher efficiency in this drilling section will have a high impact on the cost effectiveness and the ability to deliver a well faster.

3.4. Overview of time distribution (Uptime, downtime, waiting time, quality time).

An overview of the time distribution reported on the drilling sections and especially on the 12 ¼'' on Smørbukk and Smørbukk Sør will be provided. The automated reports from DBR in the following appendices have been used as data basis for the plots:

- 'Appendix C - Overview of time distribution on all drilling sections'
- 'Appendix D - Overview of time distribution on the 12 1/4'' drilling section'
- 'Appendix E - Overview of time distribution on the 12 1/4'' drilling section in Interval 1'
- 'Appendix F - Overview of time distribution on the 12 1/4'' drilling section in Interval 2'

3.4.1 Overview of time distribution on all drilling sections and on 12 ¼'' drilling section

To get an outline of what kind of status on operation (uptime, downtime, waiting on weather, other waiting and quality time) that have been reported in the drilling phase for all the wells a plot has been created showing the percentage of time spent on the different statuses. This plot gives an overview of all the reported time on all the drilling sections. All other sections as completion, P&A, Intervention and so forth are not included in the time.

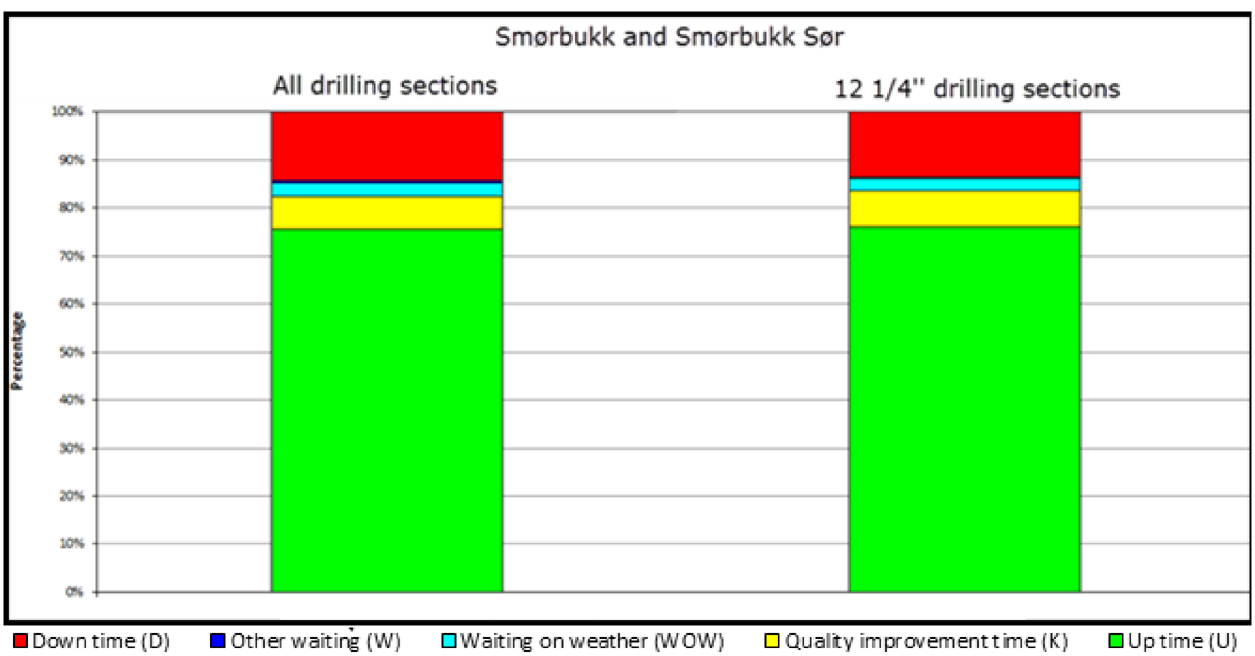

Figure 7 - Overview of reported time - Drilling sections and the 12 ¼'' drilling section

The result for all drilling sections is displayed in the following table:

Operation reported as:	Percentage:	Days:
Downtime (D)	14,3 %	396,8
Other waiting (W)	0,05 %	14,3
Waiting on weather (WOW)	2,8 %	77,2
Quality improvement (K)	6,7 %	190,7
Up time (U)	75,5%	2097,6
Total	**100%**	**2776,7**

Table 6 - Total overview of reported time on all drilling sections

To be able to see how the performance of the 12 ¼'' drilling section is compared to the total performance of the drilling the plot to the right in 'Figure 7 - Overview of reported time - Drilling sections and the 12 ¼'' drilling section' shows the time distribution for these sections.

The result for the 12 ¼'' drilling sections is displayed in the following table:

Operation reported as:	Percentage:	Days:
Downtime (D)	13,5 %	148,1
Other waiting (W)	0,03 %	3,1
Waiting on weather (WOW)	2,7 %	29,5
Quality improvement (K)	7,6 %	83,4
Up time (U)	76,0%	837,0
Total	**100 %**	**1101,1**

Table 7 - Total overview of reported time on 12 1/4" drilling section

As seen in table 'Table 6' and 'Table 7' the total downtime reported on the 12 ¼'' is fairly consistent with the downtime reported on the total of the drilling sections. For all the drilling sections in total there is 14,3 % downtime, while on the 12 ¼'' there is 13,5 %. We have a negligible discrepancy when it comes to spending more time on waiting on weather and on activities related to quality improvement for the 12 ¼'', but this is minor percentages.

From the two fore mentioned tables it can be concluded that the 12 ¼'' drilling section is fairly consistent with the other drilling sections, and does not stand out with regards to any of the reported operations. It has a slightly lower percentage of time spent on downtime, and a slightly higher uptime percentage, so all over it is a section where we are performing at a somewhat better level than the average drilling section.

3.4.3 Overview of reported status on the 12 ¼'' drilling section in Interval 1 and Interval 2.

In a further investigation of the data, the reported statuses on the 12 ¼'' section have been divided into Interval 1 and 2.

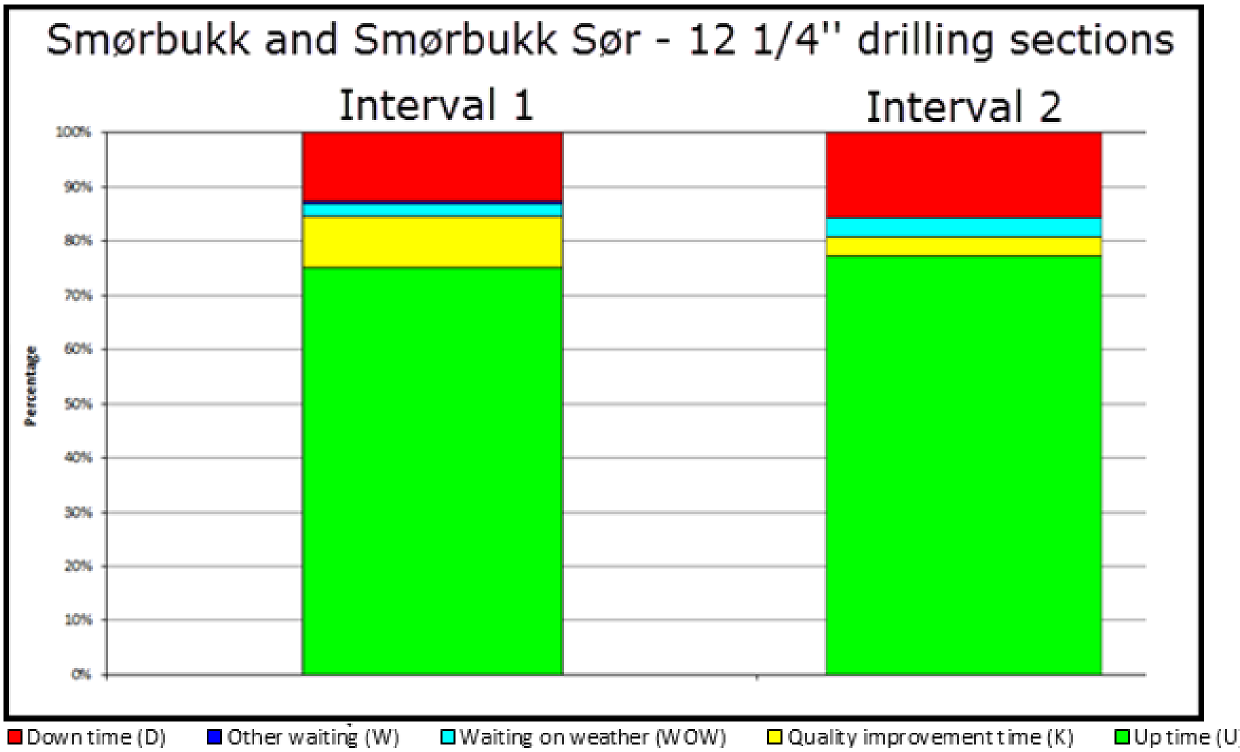

Figure 8 - Total overview of reported time for all drilling sections – Interval 1 and 2.

The result for Interval 1 is displayed in the following table:

Operation reported as:	Percentage:	Days:
Downtime (D)	12,7 %	98,2
Other waiting (W)	0,04 %	2,75
Waiting on weather (WOW)	2,4 %	18,2
Quality improvement (K)	9,4 %	72,4
Up time (U)	75,2 %	580,1
Total	**100 %**	**771,7**

Table 8 - Overview of reported time on 12 ¼'' in Interval 1

The result for Interval 2 is displayed in the following table:

Operation reported as:	Percentage:	Days:
Downtime (D)	15,6 %	48,8
Other waiting (W)	0,01 %	0,3
Waiting on weather (WOW)	3,6 %	11,3
Quality improvement (K)	3,5 %	11,0
Up time (U)	77,2 %	241,9

Total	100%	313,4

Table 9 - Overview of reported time on 12 1/4" in Interval 2

As seen in 'Table 8 - Overview of reported time on 12 ¼'' in Interval 1' and 'Table 9 - Overview of reported time on 12 1/4" in Interval 2' the uptime in Interval 2 has increased from 75,2 % to 77,2 %. Time spent on other waiting has decreased a touch. Waiting on weather has increased negligibly and the downtime has increased from 12,7 % in Interval 1 to 15,6% in Interval 2.

The major discrepancy between the statuses in Interval 1 and Interval 2 is the time spent on quality improvements. This time has decreased quite significantly from 9,4 % to 3,5 %. As mentioned in chapter 'Activity code "Quality time (K)"' the activity code "K" was removed in 2010 and all of the time spent on quality measures were instead added to the activity code "U".

When summing up the hours for "U" time and "K" time in Interval 1 we get a total of 84,6 %. When summing up the same for Interval 2 we get a total of 80,7 %. These percentages indicate that there are more problems in the wells in Interval 2, but does not categorize it in equipment problems, downhole problems or other problems.

As mentioned in the introduction to this chapter these numbers have been directly extracted from DBR and the values in chapter 3.3 and 3.4. cannot be directly compared to the rest of the analysis.

3.5. Performance and performance targets

The list of wells in 'Appendix A - Full well list (including meters / day) for all wells analyzed' has been manually quality assured as part of this analysis and will be the data basis for all the following chapters.

The mandatory requirement from the authorities is that the reports must be issued in the morning every day containing the last 24 hours of operation. The report contains activity codes, and as part of the analysis all of the hours reported in the daily reports has been examined and categorized utilizing the tool Excel. A full overview of the breakdown of the wells is added to 'Appendix B - Breakdown of operations of all wells analyzed

The table on the next page shows a list of all the operations that has been summarized for each well:

	Operation	Description	Part of perfomance analysis (Chapter and title of chapter)	Colors used in graphs
1	MU PU all drilling equipment	Making Up and Picking Up all drilling equipment. Not included R/U P/U equipment for logging, cement job, running casing, coring, and fishing.	3.5.8 - Other operations performance	
2	Drilling hours (make hole)	Activity code for 'drilling formation' is used.	3.5.1 - Drilling performance 3.5.1.3 - Drilling to circulation hours ratio	
3	Flowcheck and circulate open hole	Activity code for "flowcheck" and "circulate" is used when in open hole.	3.5.1 - Drilling performance 3.5.1.3 - Drilling to circulation hours ratio	
4	Flowcheck and circulate cased hole / displace mud	Activity code for "flowcheck" and "circulate" is used when in cased hole.	3.5.1 - Drilling performance 3.5.1.3 - Drilling to circulation hours	
5	RIH	Activity code "RIH" used. Not included RIH for logging, cement job, running casing, coring, and fishing.	3.5.2 - Tripping performance	
6	POOH	Activity code "POOJ" used. Not included RIH for logging, cement job, running casing, coring, and fishing.	3.5.2 - Tripping performance	
7	Cut and slip drill-line	Operation performed at a regular interval.	3.5.8 - Other operations performance	
8	Ream and wash	Activity code for 'ream' or 'wash' is used in open or cased hole.	3.5.1 - Drilling performance 3.5.1.3 - Drilling to circulation hours ratio	
9	L/D all equipment	Laid down all drilling equipment. Not included L/D equipment for logging, cement job, running casing, coring, and fishing.	3.5.8 - Other operations performance	
10	Pre job meeting, drills, infomeetings and washing on drillfloor		3.5.8 - Other operations performance	
11	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	All rigging up connected to casing running and release / set wearbushing.	3.5.3.3 - Casing operations not in hole performance	
12	Run 9 5/8" casing (inc pressure testing, circulating and other work inbetween)	All running of casing and work inbetween.	3.5.3.1 - Running casing in hole performance total	
13	Cement job	All rigging up, performing job and rigging down and waiting for cement to set.	3.5.4 - Cement performance	
14	Pressure test seal assembly and POOH	Rigging up, performing pressure test, and rigging down after seal assembly test.	3.5.7 - Pressure testing performance	
15	Pressure test / function test BOP	Rigging up, pressure testing and rigging down after BOP test.	3.5.7 - Pressure testing performance	
16	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)	Rigging up, pressure testing and rigging down after pressure testing.	3.5.7 - Pressure testing performance	
17	RU, perform and LD coring	Rigging up, performing and rigging down equipment for coring.	3.5.6 - Data acquisition	
18	Fishing (waiting on equipment and all time spent)	All rigging up, performing job and rigging down after fishing job	3.5.8 - Other operations performance	
19	FIT	Taking the FIT	3.5.8 - Other operations performance	
20	Other	Includes inspection of drilline, derrick and top drive, MWD data dump, orient hole, change bails, wash riser, BOP and below WH, grease wear plate, pump slug, remove radioactive sources on BHA, change washpipe in topdrive, verify undergauge in position and other operations not belonging in any other category.	3.5.8 - Other operations performance	
21	Incidents w/downtime - hole problems	Downtime reporting connected to a hole problem	3.5.5 - Downtime performance	
22	Incidents w/downtime - Equipment problems and other problems	Downtime reporting connected to equipment problems or other problems.	3.5.5 - Downtime performance	
23	Cement logging (rigging up, logging, rigging down)	Rigging up, performing and rigging down equipment for cement logging. Mostly done in combination with other logging, so most of the times a part of "Logging, surveys or coring inc cluster shot")	3.5.6 - Data acquisition	
24	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)	All rigging up, performing job and rigging down after logging.	3.5.6 - Data acquisition	
25	Waiting on weather	Activity code for 'waiting on weather' is used.	3.5.8 - Other operations performance	
26	Other waiting	Activity code for 'waiting' is used.	3.5.8 - Other operations performance	
27	Total operational hours	All hours on line 1 - 26 added up as total operational hours on the section.		

Table 10 - Categories for breakdown of all operations

All the hours spent on the operations contributes to the total hours spent, the “Total operational hours”, in line 27 in the ‘Table 10 - Categories for breakdown of all operations’. To be able to increase the drilling performance, the total operational hours have to be reduced.

‘Table 10 - Categories for breakdown of all operations’ is color coded in the right column according to the colors used in the graphs of analysis in chapter 3.5.1 to 3.5.8.
A set of parameters to be used in the analysis is defined as follows:

- Section length – The total drilled length of the section. See Appendix B - Breakdown of operations of all wells analyzed’ for length details on each of the analyzed wells.
- Displacement – This is the vertical distance between two curves on the same horizontal axis. The displacement can be constant, decreasing or increasing. When the displacement is changing the relationship between the two curves is developing.[xxvii]

The parameters above are general definitions used in the whole analysis. The relevant KPIs used for the different performance analysis are introduced in each of the different chapters.

All of the plots in the analysis are built up in the same order, with an introduction containing a short description of what the analysis is concerning, how the data has been utilized and the KPI’s used. The first plot shows the total performance and the second plot is divided in Interval 1 and Interval 2 with their respective trend lines for the time period.

3.5.1. Drilling performance

In the analysis of drilling performance the following terminology is used:

- Drilling hours (make hole) – Time spent on drilling, reported as activity code “drilling formation”. Number of hours when the bit is on bottom and rotating / drilling. In ‘Table 10’ this is the hours added up in line 2.
- Circulation and drilling hours – Time spent on drilling (as circulation is continuously done in this phase), flow check and circulate open hole, flow check and circulate cased hole and ream and wash. In ‘Table 10’ this is the hours added up in line 2, 3, 4 and 8.
- Total operational hours – Time spent on all of the operations added together. In ‘Table 10’ this is line 1 to 26 summed up. Note that this includes all of the hours, also the hours spent on downtime both with regards to equipment problems and downhole problems.

When analyzing the drilling performance there is a need for normalizing the data according to the section length. If the section length is not taken into considerations this would lead to the shorter sections appearing to have a better performance and the longer sections would seem to have a lower performance.

The following three equations for KPI's have been set up and will be utilized:

Based on: 'Equation 2 – Meters per day' the following KPI is used:

- Meters per hour = $\frac{\text{Drilled length (m)}}{\text{Total operational hours (hrs)}}$

Equation 3 – Meters per hour

The equation for meters per hour is a measurement of how many meters we are able to finish of the well per hour normalized for the section length. As this number increases we are able to finish more meters per hour and vice versa.

- Average ROP per hour = $\frac{\text{Section length (m)}}{\text{Drilling hours (make hole) (hrs)}}$

Equation 4 – Average ROP per hour

The equation for average ROP per hour is a KPI showing the drilling efficiency. Comparing different fields with use of drilling hours per hour has not been considered to be exact as there are many diverse factors contributing to how fast it is possible to drill. Examples of these factors are formation, rigs used, different trajectories of the wells and so forth. As the wells in this analysis are in the same field and most of the factors are constant this KPI should reflect the drilling efficiency in a fair manner. As this number increases we are drilling faster per hour and vice versa.

- Average ROP and circulation per hour = $\frac{\text{Section length (m)}}{\text{Circulation and drilling hours (make hole) (hrs)}}$

Equation 5 – Average ROP and circulation per hour

The equation for average ROP and circulation per hour is showing the drilling and circulation efficiency. As this number increases we are drilling and circulating faster per hour and vice versa.

3.5.1.1. Drilling performance total

To get a full overview of the development over the years a plot showing the total drilling performance has been created.

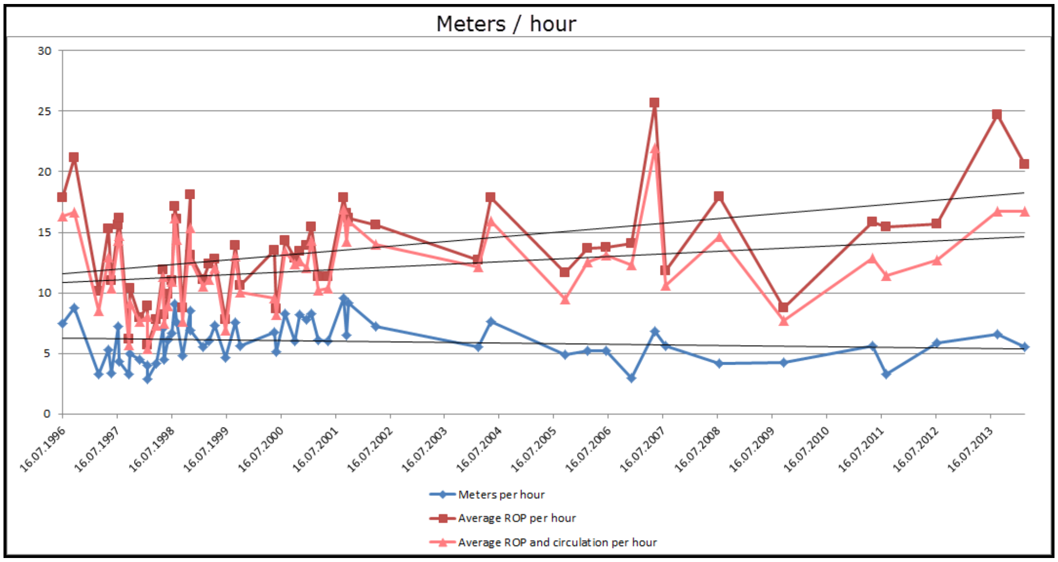

Figure 9 - Drilling operation performance (meters / hour)

'Figure 9 - Drilling operation performance (meters / hour)' is showing the three drilling performance KPI's chronologically from the first well in 1996 and until the last well in 2014. Each interval has the corresponding trend line for the KPI added.

Average ROP per hour.

From the figure it is evident that there is a positive trend when looking at the average ROP per hour. The meters we are able to drill per hour are increasing steadily and the trend line shows a distinctly increased meter per hour over the years.

Average ROP and circulation per hour.

As previously mentioned the 'average ROP and circulation per hour' is containing both the drilling hours and the circulation hours. With respect to this KPI there is also a positive trend. We are able to drill and circulate faster per hour in the wells in the later years than before.

Another observation is that the displacement between the 'average ROP per hour' and the 'average ROP and circulation per hour' has increased steadily and is at an all-time high in 2014. This means that the hours spent on circulating, flow checking and reaming / washing when we are not drilling has increased over the years.

Meters per hour.

The 'meters per hour' is showing a negative overall trend. The trend is towards being able to finish less meters per hour of the wells in the later years than what we were able to in the earlier years.

The displacement between the 'meters per hour' curve to the 'Average ROP and circulation per hour' and 'Average ROP per hour' curve is increasing over the years, indicating that increasingly more time is spent on other activities / operations outside of the drilling phase than before.

3.5.1.2. Drilling performance in Interval 1 and 2.

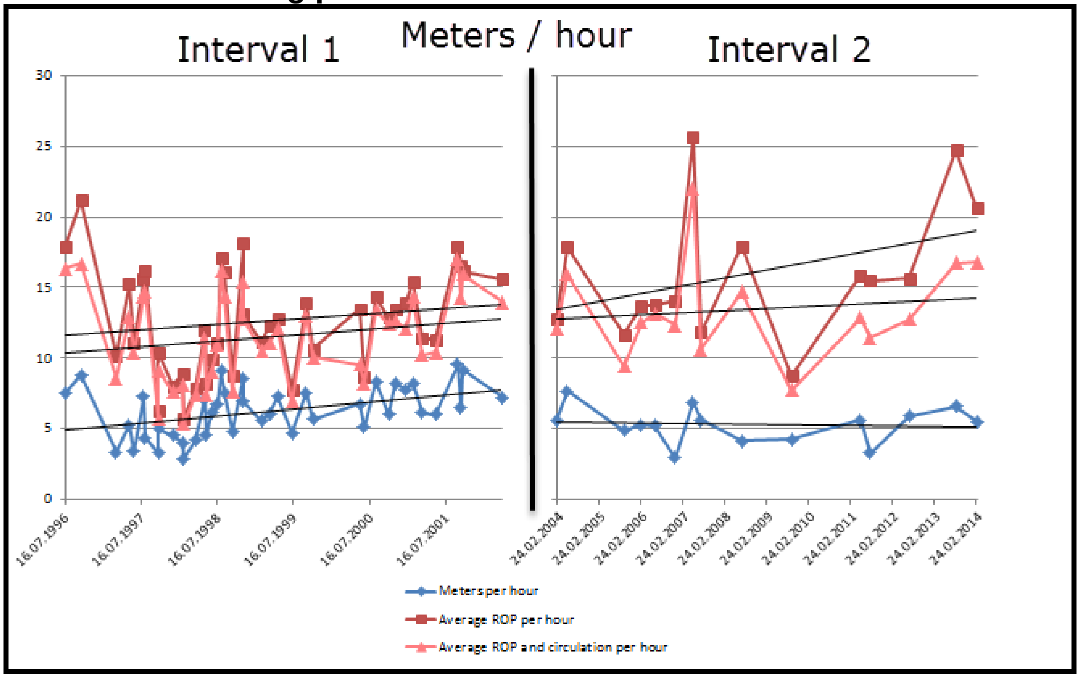

Figure 10 - Drilling operation performance (meters / hour) in Interval 1 and 2

'Figure 10 - Drilling operation performance (meters / hour) in Interval 1 and 2' is showing the three drilling performance KPI's chronologically in the two intervals.

Average ROP per hour.
Interval 1: With regards to the 'average ROP per hour' there is a positive trend. We are able to drill more meters per hour. There are several wells with very good performance in this interval as there in total are 16 out of 41 wells with a drilling performance in meters per hour above 7,1. (In meters per day this is above 170 meters.)

Interval 2: The trend is starting off at about the same point Interval 1 ends at. The 'average ROP per hour' is having a significant positive development.

Average ROP and circulation per hour.
Interval 1: The 'average ROP and circulation per hour' is having a positive trend. We are able to drill and circulate faster per meter. The displacement between the 'Average ROP per hour' and the 'Average ROP and circulation per hour' curves are about constant, but is decreasing just a little bit. This is positive, because it indicates that we are spending less time on circulation activities besides when we are in the drilling phase.

Interval 2: The 'average ROP and circulation per hour' developing slightly in positive direction, towards being able to finish less meters per hour. An observation is that the displacement between the curve for 'drilling hours per meter' and 'circulation hours per meter' is increasing quite significantly; indicating that more time is spent on circulation activities outside of the drilling phase.

Meters per hour.
Interval 1: It is apparent that there is a very positive trend with regards to the meters per hour.

Interval 2: The trend for meters per hour is at a relatively constant level, going slightly downwards towards spending more hours per meter. The displacement between operational hours per meter and circulation hours per meter is increasing. This results in other operations than drilling and circulating activities are contributing towards spending more time on the operations in total.

Most important to notice is the big adjustment between the end point of the trend line in Interval 1 and the start point of the trend line in Interval 2. Here we observe a substantial gap, pointing towards a significantly lower performance in Interval 2.

3.5.1.3. Drilling to circulation hours ratio.

As seen from 'Equation 4 – Average ROP per hour' and 'Equation 5 – Average ROP and circulation per hour' the difference between the hours drilled and the total hours circulated is the time spent on circulation and washing / reaming while not drilling. The displacement between these two curves should preferably be as low as possible, but it is a trade-off as it is important to spend the time necessary for keeping the hole clean.

$$\text{Drilling to circulation hours ratio} = \frac{\text{Drilling hours}}{\text{Circulation and drilling hours (make hole)}}$$

Equation 6 – Drilling to circulation hours ratio

The drilling to circulation hours ratio is a dimensionless parameter and shows the fraction of the total circulation hours that was used during the drilling phase. To save time and cost as few hours as possible should be used for circulating outside of the drilling phase, so the closer to 1 this ratio is, the smaller amount of hours are used on circulating outside of the drilling phase. However, there must always be some time spent on circulation outside of the drilling phase to ensure that the hole is clean and avoid consequences related to not having a clean enough hole, i.e. pack off.

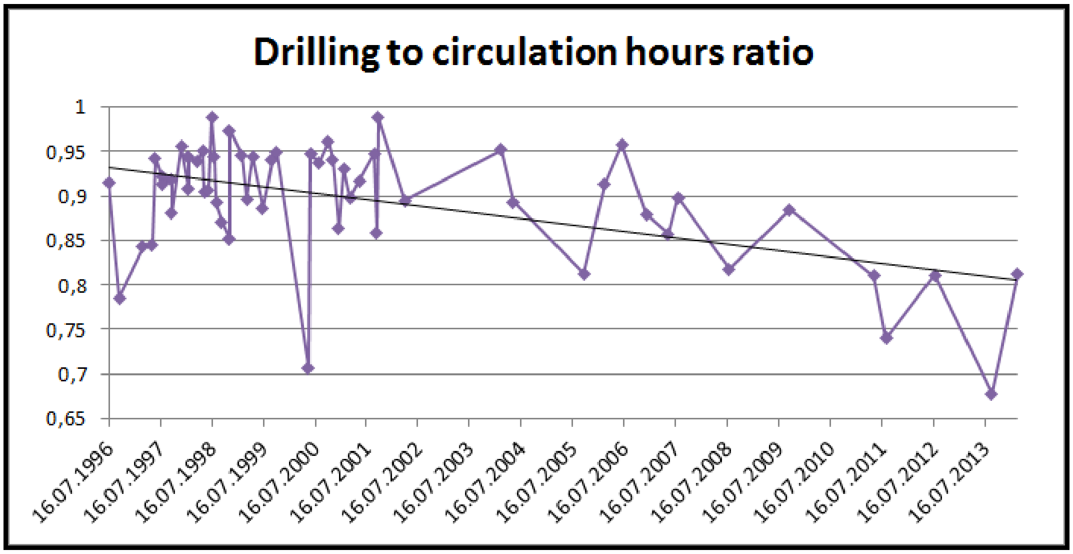

Figure 11 - Drilling to circulation hours ratio

In 'Figure 9 - Drilling operation performance (meters / hour)' we observed that the displacement between the 'drilling hours per meter' and the 'circulation hours per meter had increased. The 'Figure 11 - Drilling to circulation hours ratio' confirms this and shows that there is a distinct negative trend. Progressively more time is spent on circulating outside of the drilling phase.

3.5.2. Tripping performance

In the analysis of tripping performance the following terminology is used:

- Tripping hours – Time spent on 'Running In Hole' and 'Pulling Out Of Hole'. In 'Table 10' this is line 5 and 6 summed up.

The time spent on tripping indicates how troublesome the well is to work with and / or if there have been equipment problems. For instance will a worn bit or BHA failure lead to tripping. If many trips have been performed it will increase the total time spent on the well, and a main goal for the operating companies is to avoid extra trips. If the average tripping rate is 500 m/hour it will take about 12 hours to POOH and RIH of a 3000 meter deep well and the time spent on replacing equipment comes in addition. The tripping time related to activities when performing logging, cement job, running casing, coring and fishing is excluded from this plot because those hours are part of the operation they belong to.

Time spent on tripping should be normalized according to the length TD of the well. This is because a longer cased hole and longer open hole naturally would require longer time to be able to RIH or POOH, and vice versa. As the data basis does not indicate whether or not several trips has been performed the hours spent on tripping will be shown in a graph, and not the tripping meters per hour.
Important to note is that this plot is not taking into consideration the amount of trips done in a well. This result in wells with several trips will have a lower performance and

more hours spent on tripping. If a well has many hours spent on tripping in this curve it can be one of the following:

- More than one trip is performed in this well.
- The trip is taking long time to complete.

3.5.2.1. Tripping performance total.

The hours used on tripping should ultimately be as low as possible.

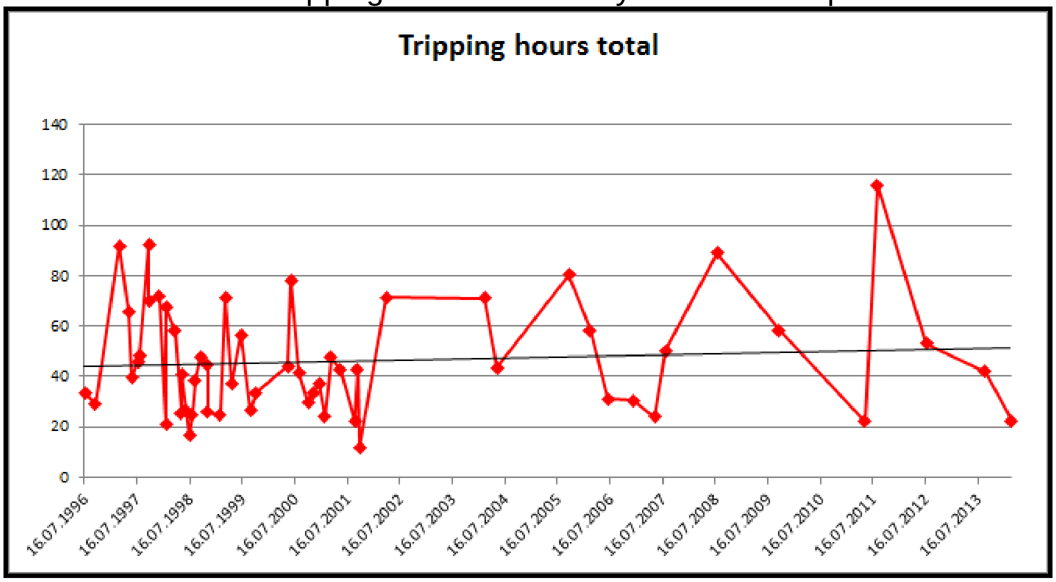

Figure 12 - Tripping hours total

The overall picture in 'Figure 12 - Tripping hours total' shows a marginally negative trend towards spending more hours on tripping.

3.5.2.2. Tripping performance in Interval 1 and 2.

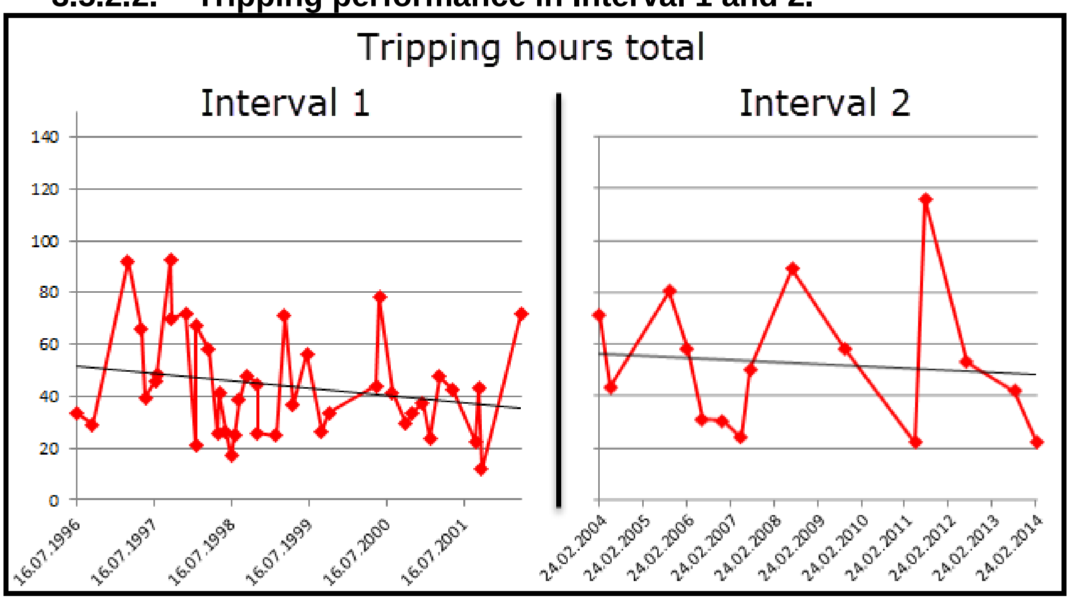

Figure 13 - Tripping hours in Interval 1 and 2

From ‘Figure 13 - Tripping hours in Interval 1 and 2’ a positive trend line in Interval 1 points to the average time spent on tripping is decreasing. The same is the case for Interval 2 where the trend also is pointing towards spending less hours tripping.

Worth to note here is that in the start of Interval 2 the trend line is starting at around 56 hours while for the end of Interval 1 the trend was ending at around 35 hours. This indicates a lowering in the performance for Interval 2. In addition the trend line in Interval 2 is never coming down to the same level as it did in Interval 1.

3.5.3. Casing performance

When categorizing the hours belonging to the casing operation in the drilling reports the operation has been divided into two groups:

- Operations in hole – Running the casing, including pressure testing of the casing, circulation and other work in between the casing running. In ‘Table 10’ this is summed up in line 11.

- Operation not in hole – Rigging up, making up, lay down equipment related to the casing operation. Release / set wear bushing and seal assembly is included in these hours. In ‘Table 10’ this is summed up in line 12.

The reason for dividing the operations in two is because the operations performed in hole is dependent on the length of the section, while the operations performed on rig floor or outside of the hole is not. This results in operations in hole needing to be normalized for the section length while not for the operations not in hole.

3.5.3.1. Running casing in hole performance total:

The following equation for KPI has been set up:

$$\text{Running casing - meters per hour} = \frac{\text{TD of section (m)}}{\text{Casing operations in hole (hrs)}}$$

Equation 7 – Running casing (meters per hour)

The ‘Equation 7 – Running casing (meters per hour)’ is a measurement of how many meters of casing that has been run per hour normalized for the section of the well. As this number increases we are able to run more meters each hour and vice versa. This is a simplified equation as the casing running is dependent on how many meters that are run in cased hole and run in open hole. This simplification is reasonable because the 12 ¼’’ sections of the wells are all starting at approximately the same depth, resulting in approximately the same length of open hole and cased hole.

To get a full overview of the development over the years a plot showing the total casing meters done per hour has been generated.

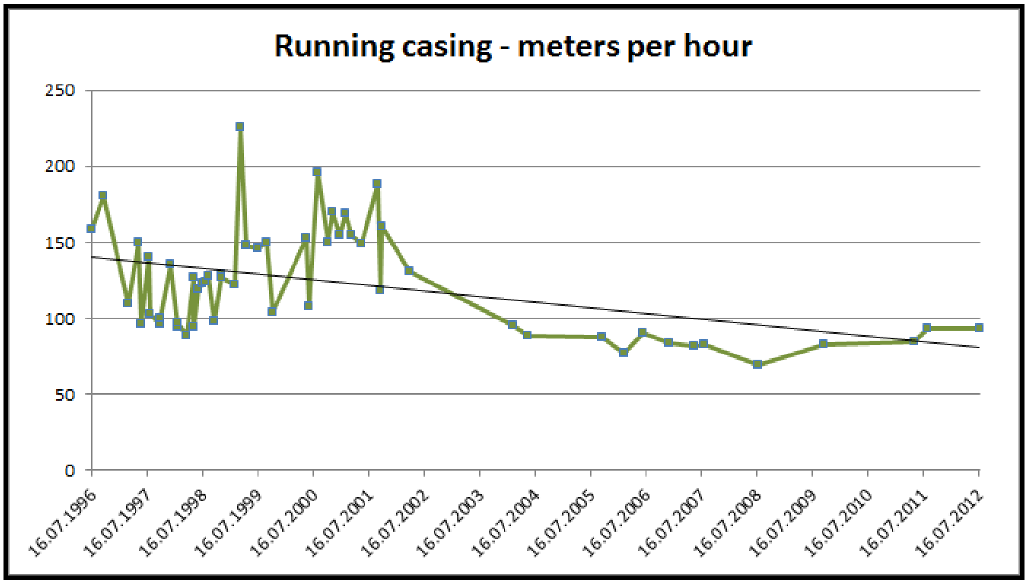

Figure 14 - Running casing – meters per hour total

'Figure 14 - Running casing – meters per hour total' is showing the casing performance KPI chronologically from the first well in 1996 and until the last well in 2014. It is evident that over the years the trend is going in negative direction, and we need more hours per meter of run casing.

3.5.3.2. Running casing in hole performance in Interval 1 and 2.

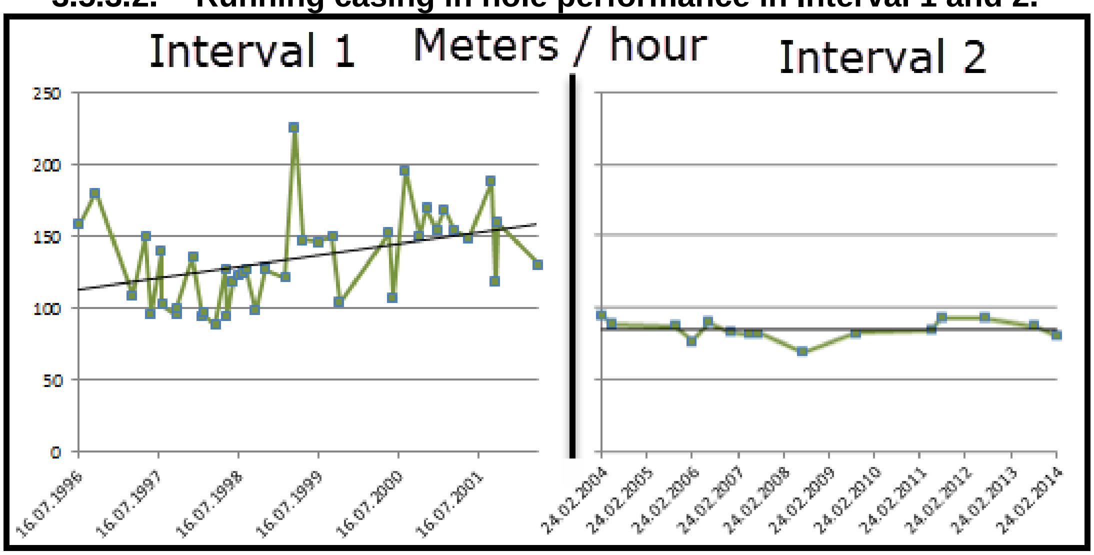

Figure 15 - Running casing – meters per hour in Interval 1 and 2

In Interval 1 in 'Figure 15 - Running casing – meters per hour in Interval 1 and 2' one of the wells is standing out with regards to extraordinarily good performance:

- Well NO 6506/12-L-2 AH with 225,7 meters / hour in year 1999.

A couple of other wells also have very good performance:

- Well NO 6506/11-5 S with 180,3 meters / hour in 1996
- Well NO 6506/11-E-3 H with 196,2 meters / hour in 2000
- Well NO 6506/12-P-4 H with 188,8 meters / hour in 2001

The other wells are fairly consistent and the trend line is slowly increasing. This is indicating that we are having a period with consistency and are able to follow the planned target time that has been set for completing the operations.

In Interval 2 in the same figure the trend is showing a distinctively different picture than the first interval. From the graph it is evident from year 2004 and onwards that the casing performance is at an almost constantly lower performance level than in the first interval.

3.5.3.3. Casing performance - surface activities.

The hours spent on activities related to making up equipment, making up the casing, preparing for running the casing, release / set wear bushing and seal assembly are all operations that are not dependent of the length of the section. The aforementioned activities are added together, and the hours spent on the activities over the years have been generated as a graph.

A full overview of the development over the years is required to be able to show the development of the casing related activities on surface.

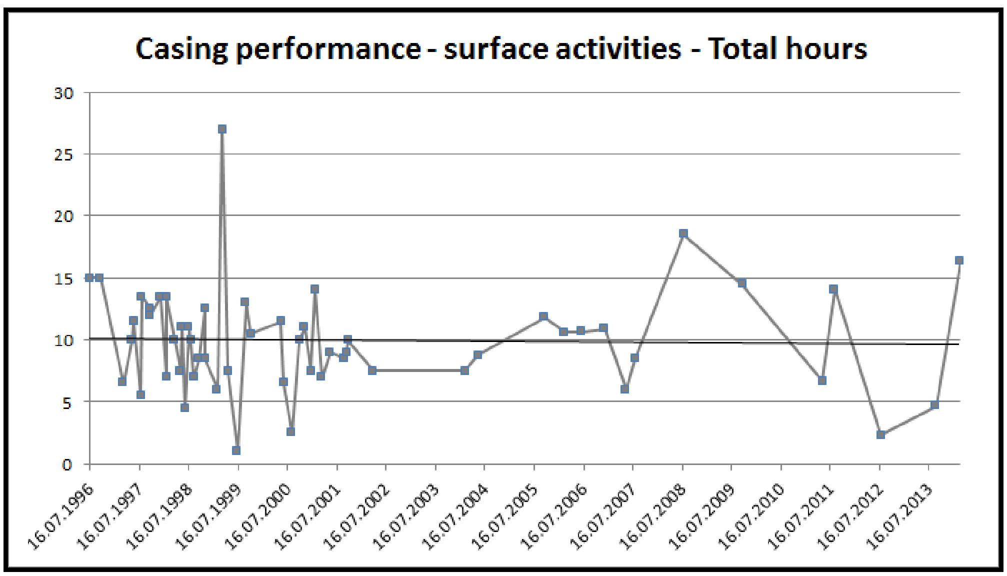

Figure 16 - Casing performance – surface activities – total hours

The trend line in 'Figure 16 - Casing performance – surface activities – total hours' is fairly consistent over the years, but we see a slight decline towards spending less hours on casing related activities not in hole.

3.5.3.4. Casing performance – surface activities in Interval 1 and 2.

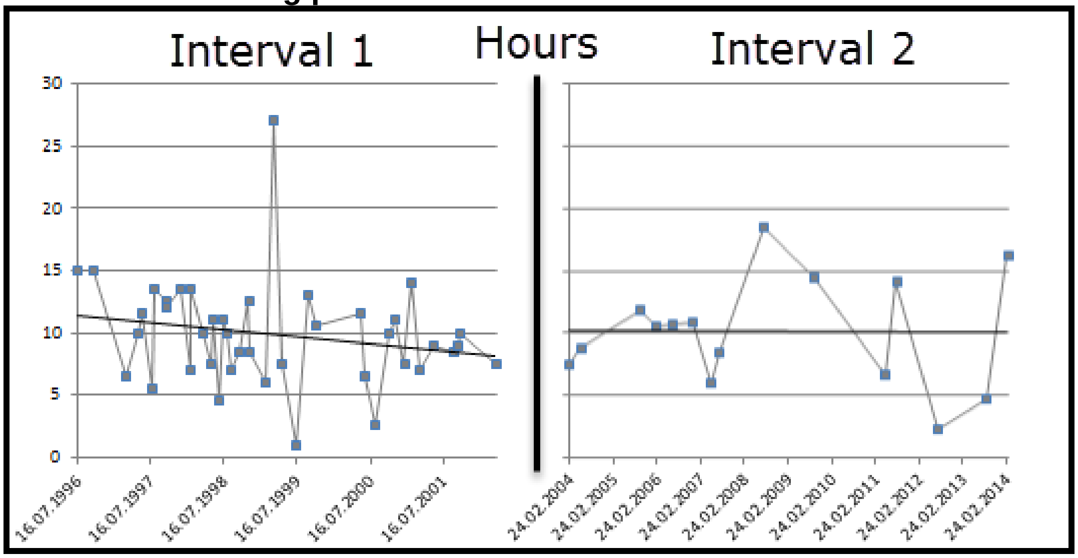

Figure 17 - Casing performance – surface activities in Inteval 1 and 2

The trend line for Interval 1 in 'Figure 17 - Casing performance – surface activities in Inteval 1 and 2' is going downwards, indicating a positive trend and that we are spending less time on the casing related activities not in hole.

In Interval 2 the trend line is staying at a relatively constant level. There is a gap from the end point in Interval 1 to the start point in Interval 2, indicating a lowering in performance.

3.5.4. Cement performance

The hours used on the cement job consists of all the operations from rigging up the equipment, loading the cement head, mixing the cement, displacing the cement, waiting for the cement to set and rigging down the equipment. As the cement job is to a large degree not dependent on the length of the section, the data has not been normalized for section length. In 'Table 10' the cement job is summed up in line 13.

3.5.4.1. Cement performance total

A full overview of the development over the years is required to be able to show the development in time usage of the cement job.

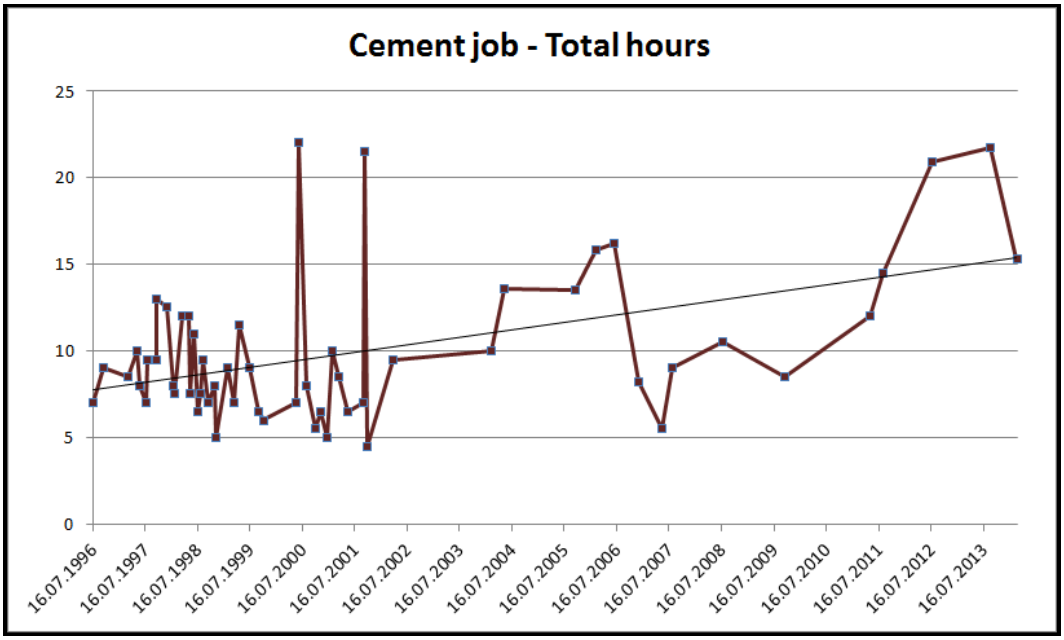

Figure 18 - Cement job total hours

The trend line in 'Figure 18 - Cement job total hours' demonstrates that the average time spent on performing the cement job is increasing.

3.5.4.2. Cement performance in Interval 1 and 2.

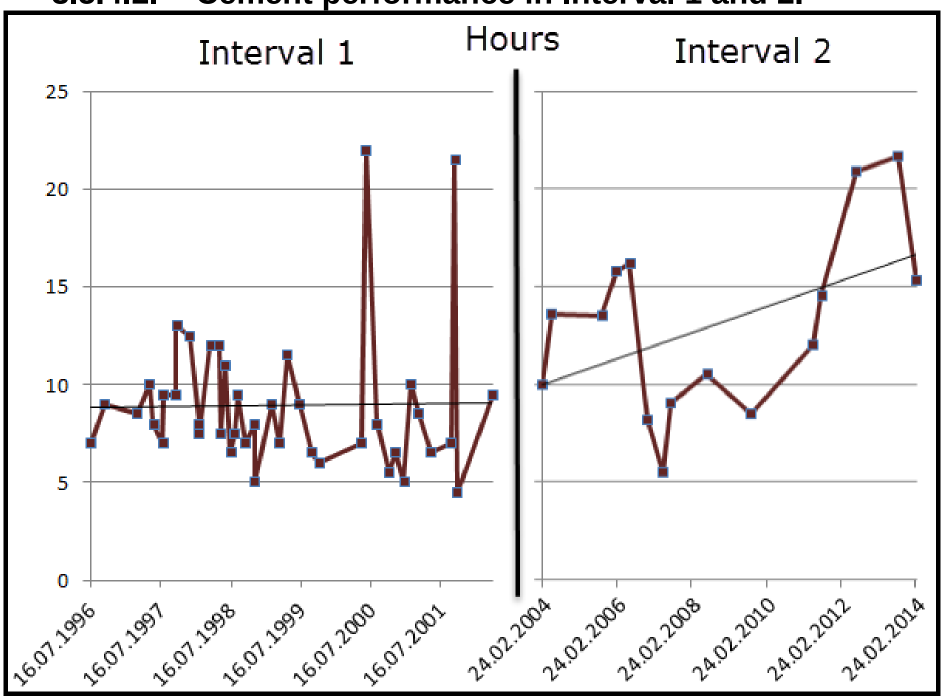

Figure 19 - Cement job hours in Interval 1 and 2

For Interval 1 the trend line in 'Figure 19 - Cement job hours in Interval 1 and 2' is so close to a straight line that it can be interpreted as constant. Two of the wells are contributing much to a worse performance:

- Well 6506/12-N-4 H in with 22 hours spent on the cement job in year 2000.

- Well 6506/12-N-2 H with 21,5 hours spent on the cement job in year 2001

The trend line in Interval 2 is going distinctively upwards, showing that the cement job is in average taking longer time. In this time interval there are two of the wells with especially poor performance:

- Well NO 6506/11-F-3 H with 20,9 hours spent on the cement job in year 2012
- Well NO 6506/12-H-2 HT2 with 21,7 hours spend on the cement job in year 2013

3.5.5. Downtime performance

When categorizing the hours used on the 12 ¼'' section all downtime reported has been added to one of the following groups:

- Incidents w/downtime - hole problems. In 'Table 10' this is summed up in line 21.

- Incidents w/downtime - equipment problems and other problems. In 'Table 10' this is summed up in line 22.

In the analysis of downtime performance the following terminology is used:
Total hours on incident – Incidents w/downtime related to hole problems and incidents w/downtime related to equipment problems and other problems summed up. In 'Table 10' this is line 21 and 22 summed up.

3.5.5.1. Total downtime percentage.

The following equation for KPI has been set up:

$$\text{Incident time as percentage of operational hours} = \frac{\text{Total hours on incident (hrs)}}{\text{Operational hours (hrs)}}$$

Equation 8 – Incident time as percentage of operational hours

The 'Equation 8 – Incident time as percentage of operational hour' shows the fraction of total operational time that is spent on unproductive time reported as downtime.

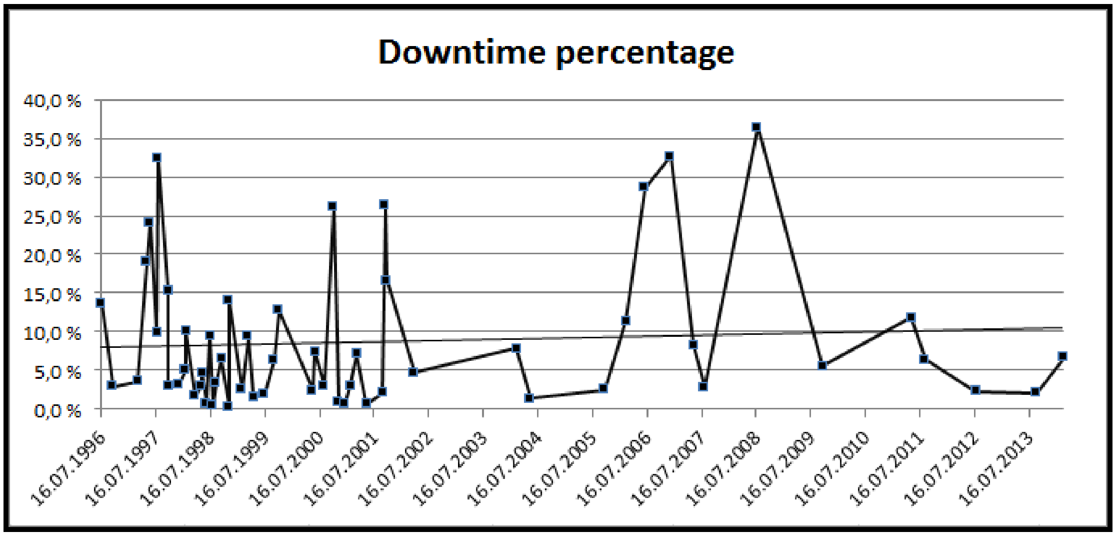

Figure 20 - Total downtime percentage

The trend line in 'Figure 20 - Total downtime percentage' shows that the average total percentage of downtime (unproductive and wasted time) is increasing from about 8 % of the total time in the start of the period and ending up at around 10,5% in the end.

3.5.5.2. Total downtime percentage in Interval 1 and 2

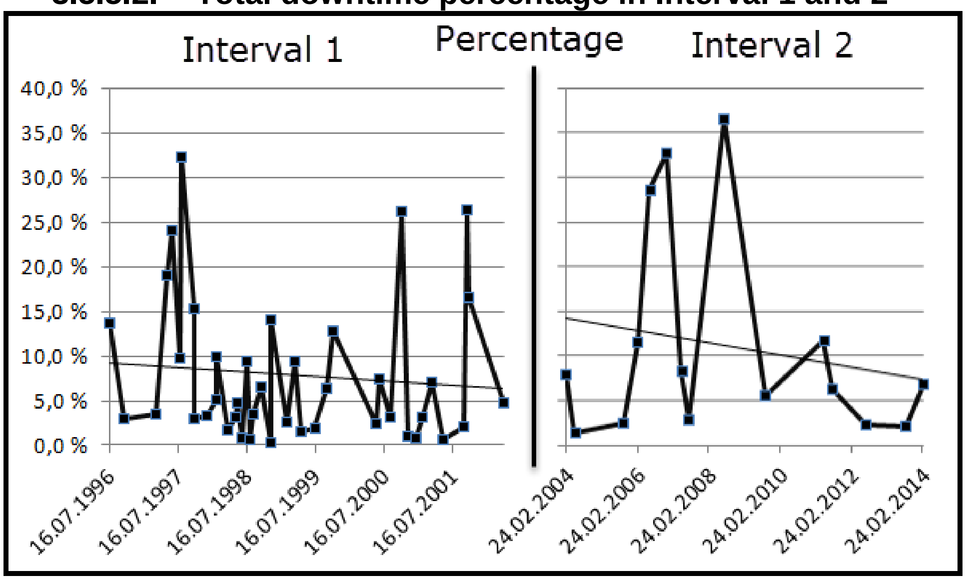

Figure 21 - Total downtime percentage in Interval 1 and 2

In Interval 1 in 'Figure 21 - Total downtime percentage in Interval 1 and 2' there is a trend towards spending fewer hours on unproductive time. The first few years there were some wells with a high percentage of wasted time:

- Well NO 6506/12-K-3 H with 32,3 % downtime in year 1997.
- Well NO 6506/11-G-3 H with 24,1 % downtime in year 1997.
- Well NO 6506/12-L-1 H with 19,0 % downtime in year 1997.

After this period in year 1997 the percentage of downtime persisted at a relatively low percentage and fairly constant until the wells NO 6506/12-H-3 H and NO 6506/12-N-2 H in year 2000-2001 with 26.2% and 26,4% downtime.

In Interval 2 the trend line also goes towards spending fewer hours on unproductive time. Important to note here is that the trend line is starting off at a higher point on just above 14%. This is higher than what we ever had in Interval 1.

3.5.5.3. Total downtime hours.

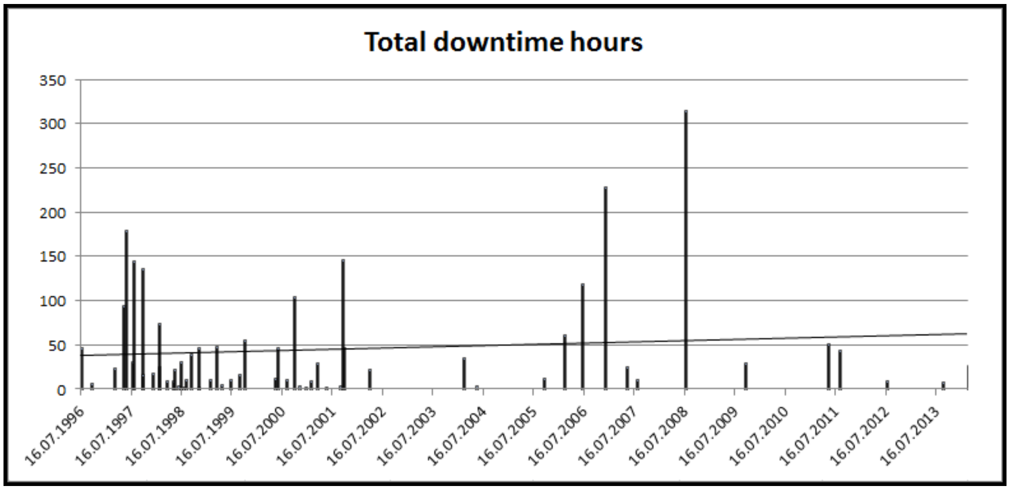

Figure 22 - Total downtime hours

In 'Figure 22 - Total downtime hours' the trend line for all downtime is increasing, meaning that the time spent on unproductive activities is increasing over the years.

3.5.5.4. Downtime hours related to equipment problems and other problems.

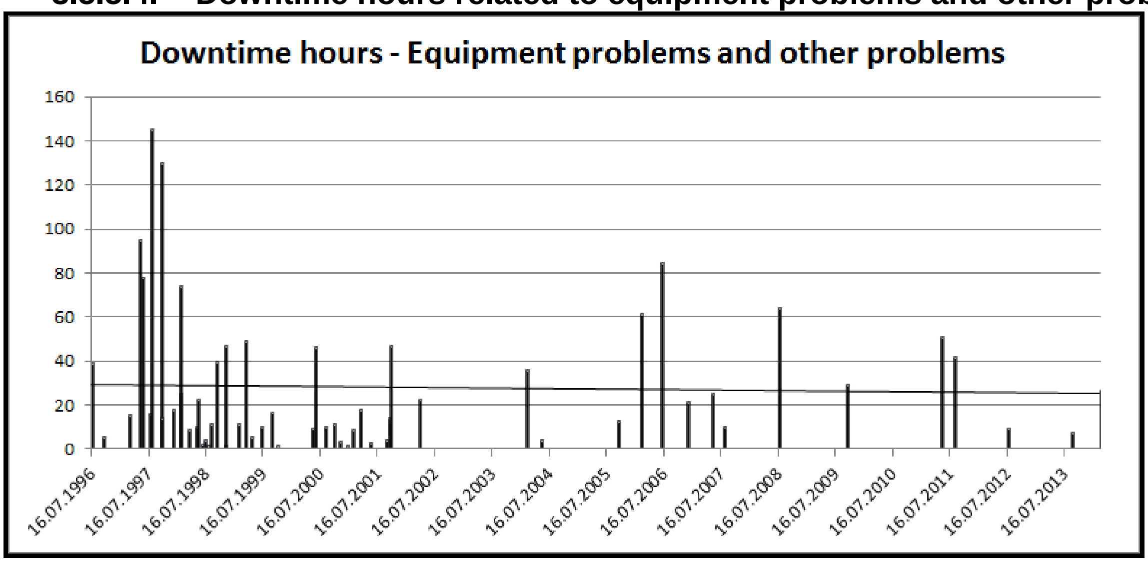

Figure 23 - Downtime hours related to equipment problems and other problems

In 'Figure 23 - Downtime hours related to equipment problems and other problems' it is evident that the time spent on downtime related to equipment problems or other problems is decreasing over the years, meaning there is no trend towards increased time spent on wasted time in this regard.

3.5.5.5. Downtime hours related to hole problems

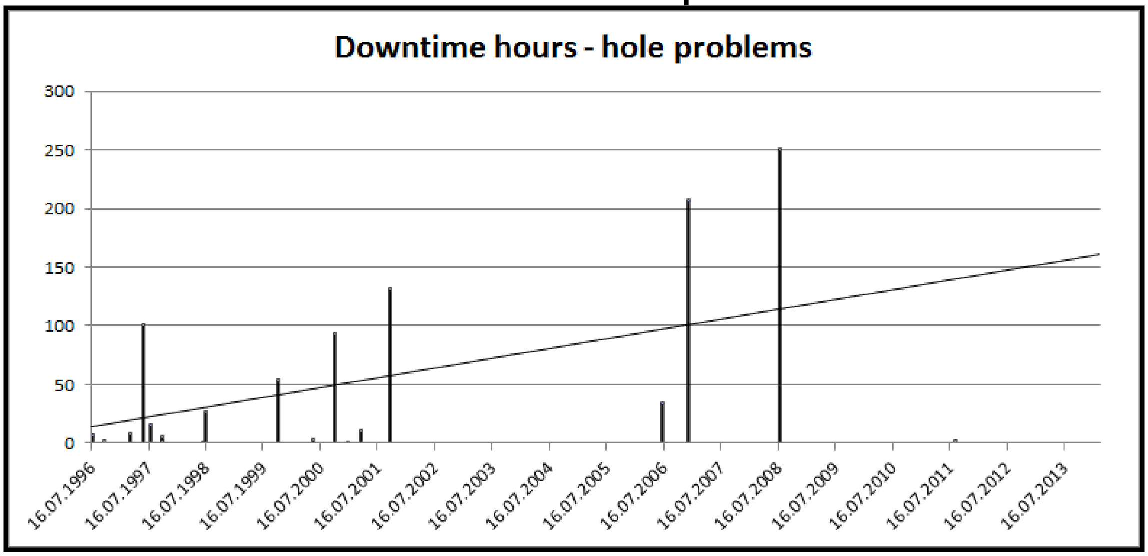

Figure 24 - Downtime hours related to hole problems

In 'Figure 24 - Downtime hours related to hole problems' it is evident that there is a trend towards spending more hours on unproductive time related to hole problems. As mentioned in chapter 3.5.5.4 there was no indication of more downtime related to equipment problems or other problems. That means that the extra hours spent on downtime must be caused by more time spent on downhole problems.

3.5.6. Data acquisition performance

When categorizing the hours used on the sections all of the hours marked with activity codes "logging", "coring", "surveys" and other type of data acquisitions has been added to one of the following two groups:

- Cement logging (rigging up, logging, rigging down). In 'Table 10' this is summed up in line 23.
- Logging, surveys or coring including cluster shot (rigging up, logging, rigging down). In 'Table 10' this is summed up in line 17 for coring and line 24 for the rest.

As technology have made it possible to perform both cement logging and other logging in the same run with the same equipment the later years the total time spent on data acquisition is summed up and the graph shows the total picture of time used.

3.5.6.1. Data acquisition performance total hours

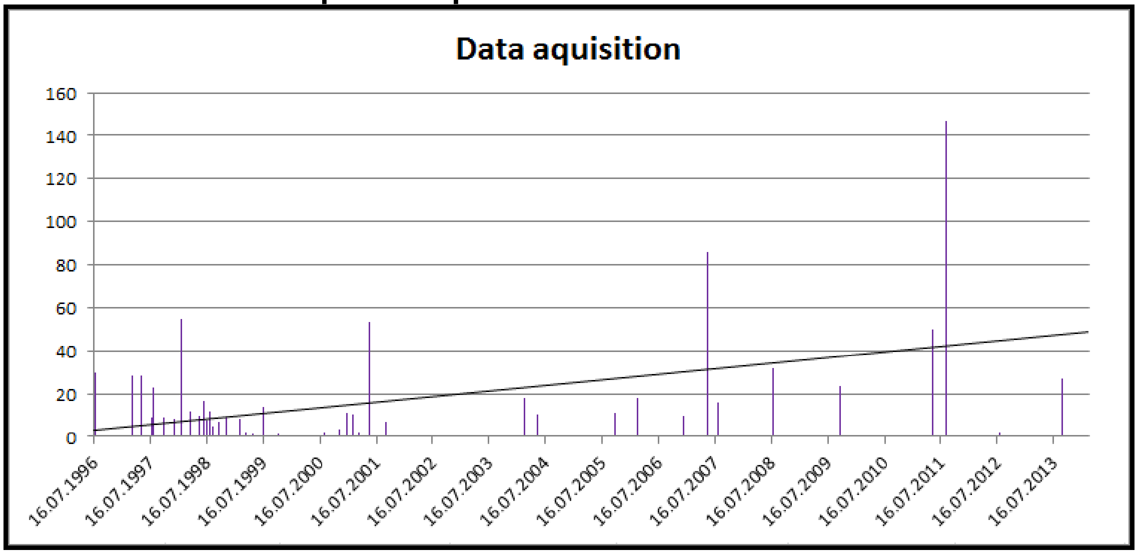

Figure 25 - Data acquisition hours

The 'Figure 25 - Data acquisition hours' shows that there is a quite significant increase of hours spent on this activity. The well NO 6506/12-P-1 AH in year 2011 is the well with most hours spent on data acquisitioning with 146,7 hours.

3.5.6.2. Data acquisition performance in Interval 1 and 2

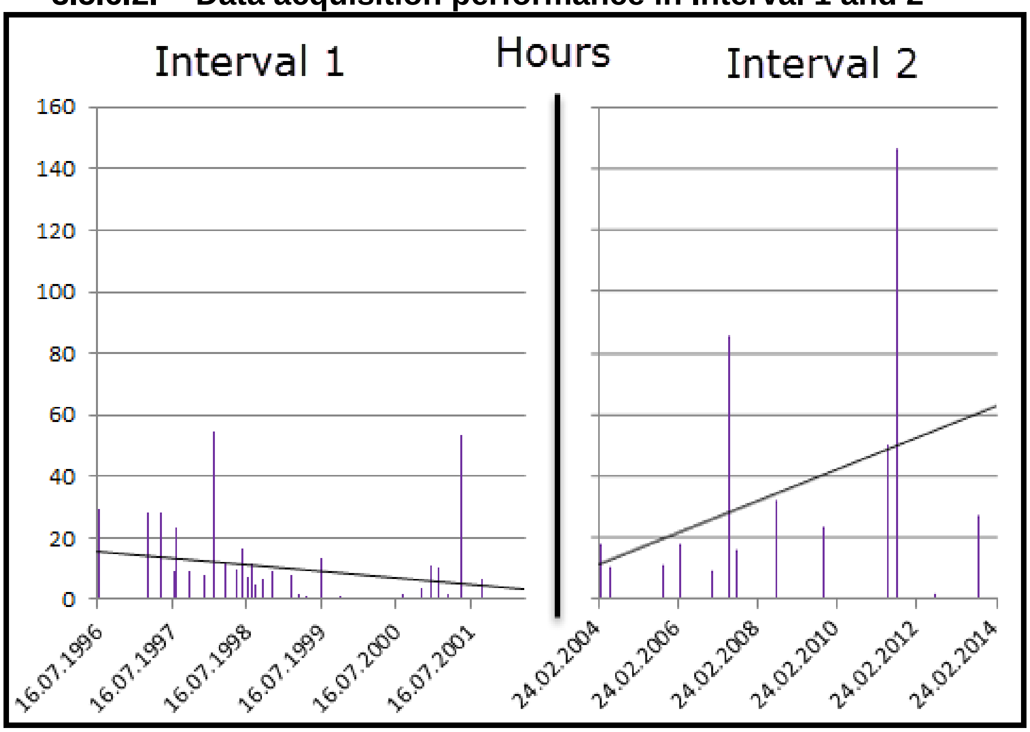

Figure 26 - Data acquisition hours in Interval 1 and 2

The trend line in Interval 1 of 'Figure 26 - Data acquisition hours in Interval 1 and 2' shows a distinct positive development.

The trend line in Interval 2 is developing very negatively and we are spending progressively more hours on logging. This is possibly not a very realistic trend as there are few wells and a few of them with extraordinarily many hours spent on data acquisition. This has a large influence on the trend line.

3.5.7. Pressure testing performance

When categorizing the hours used on the sections all of the hours marked with activity code “pressure testing” has been added to one of the following three groups:

- Pressure test seal assembly and POOH. In ‘Table 10’ this is summed up in line 14.
- Pressure test / function test BOP. In ‘Table 10’ this is summed up in line 15.
- Pressure test equipment (Kelly cock, top drive, IBOP, mud hoses, spare parts etc). In ‘Table 10’ this is summed up in line 16.

All of the three categories of pressure testing have been summed together and the graphs show the total picture of hours spent on pressure testing.

3.5.7.1. Pressure testing performance total hours

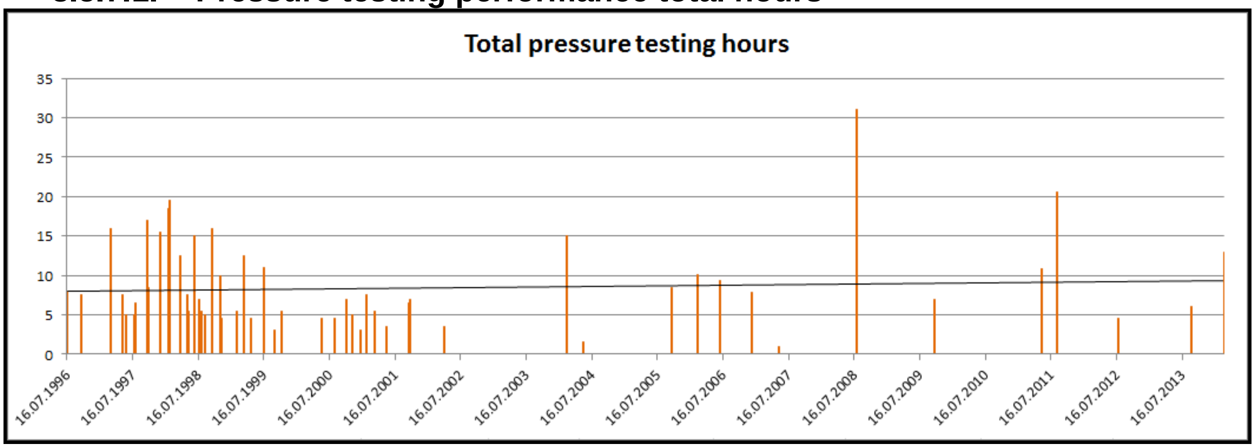

Figure 27 - Total pressure testing hours

The ‘Figure 27 - Total pressure testing’ shows a slight negative development towards spending more time on the pressure testing. We do not have a very significant increase in hours spent.

3.5.7.2. Pressure testing performance Interval 1 and 2

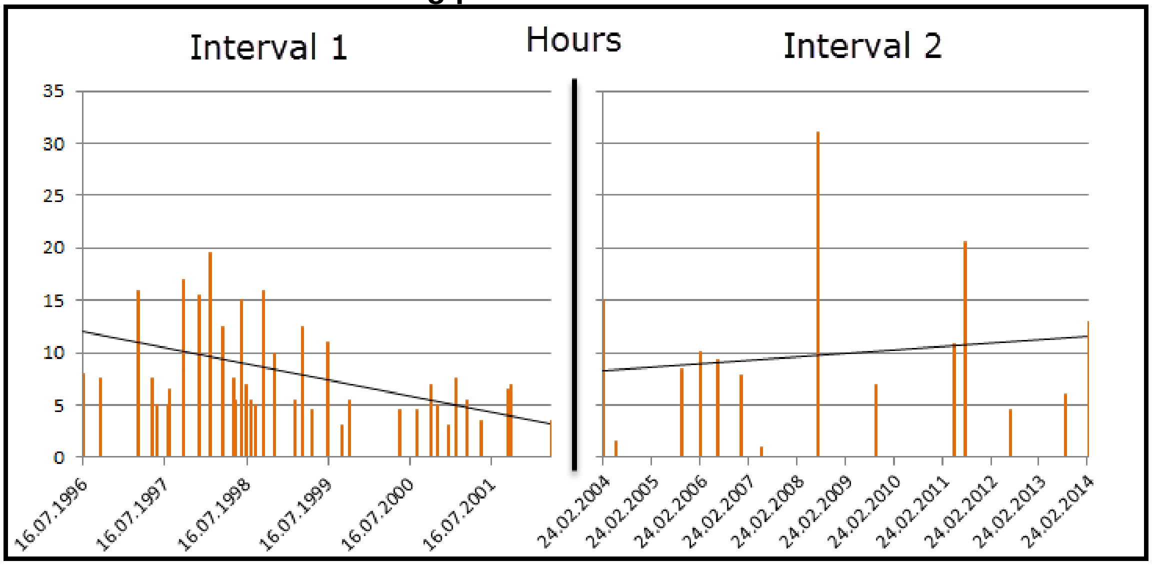

Figure 28 - Pressure testing in Interval 1 and 2

The trend line 'Figure 28 - Pressure testing in Interval 1 and 2' shows a positive development towards spending less time on the pressure testing.

In Interval 2 there is a development in negative direction towards spending more hours on pressure testing.

3.5.8. Other operations performance

The hours spent on other operations that is not belonging to the performance analysis performed in chapter 3.5.1 to chapter 3.5.7 has been summed up in a separate grouping.

In 'Table 10' we have the following operations not belonging to one of the previous chapters:

- M/U P/U all drilling equipment – Line 1 and 9
- Cut and slip drill line – Line 7
- Pre job meetings, drills, info meetings and washing on drill floor – Line 10
- Fishing – Line 18
- FIT – Line 19
- Other (Inspection of drill line, derrick and top drive, MWD data dump, change bails etc) – Line 20
- Waiting on weather and other waiting – Line 25 and 26

During the whole time period there were only two of the wells that needed to perform a fishing operation, both of them in year 1997:

- Well NO 6506/12-L-1 H
- Well NO 6506/11-G-3

Consequently we do not have a separate plot showing the progress over the years, but add it to the analysis of “other operations”.

3.5.8.1. Other operations performance total hours

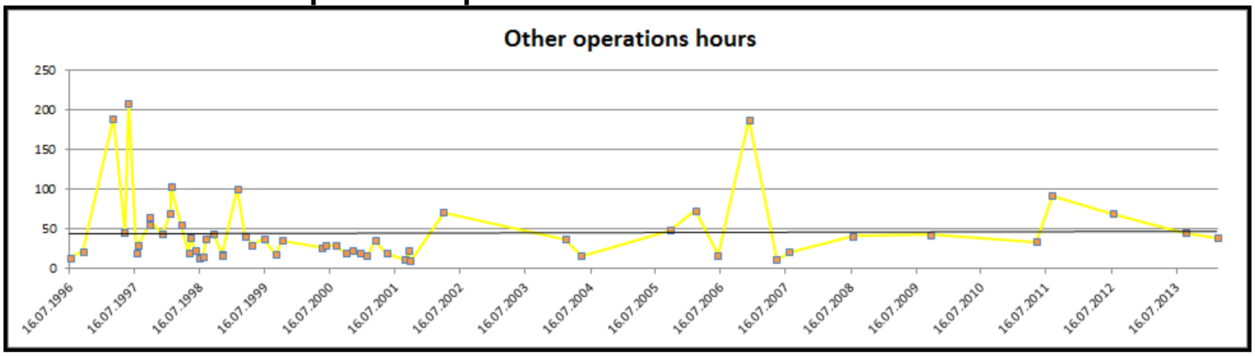

Figure 29 - Other operations hours total

The ‘Figure 29 - Other operations hours total’ is showing an almost constant trend for hours spent on other operations.

3.5.8.2. Other operations performance hours in Interval 1 and 2

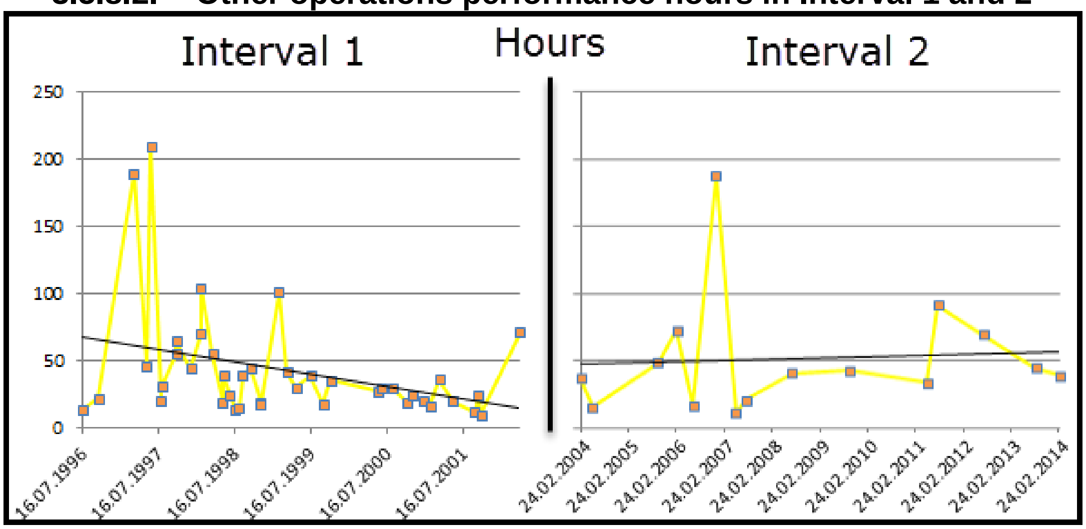

Figure 30 - Other operations hours total in Interval 1 and 2

In Interval 1 in ‘Figure 30 - Other operations hours total in Interval 1 and 2’ the trend line is developing rapidly in positive direction, towards spending less time on other operations. In Interval 2 the trend line is starting at a higher level than the trend stopped on in Interval 1, and the development is in negative direction.

4. Results from analysis

4.1. Introduction

This chapter will present the results from the analysis performed in chapter 3. It will be performed by using the following approaches:

- Chapter '4.2 - Time distribution average in Interval 1 and 2': This chapter contains average values in percentage representing the distribution of the operations and the change in distribution between Interval 1 and 2.
- Chapter '4.3 - In depth analysis of the result': This chapter contains two different approaches for quantifying the drilling performance.
    - Chapter '4.3.1 - Average values for quantifying the drilling performance': Displays the average hours spent on the operations in Interval 2 minus the hours spent on the operations in Interval 1. This clarifies which operations that we are in average spending more time on or less time on in Interval 2.
    - Chapter '4.3.2 - Trend values for quantifying the drilling performance": In this chapter the trend for hours spent on operations are displayed in four different trend line plots.
        - The first trend plot in chapter '4.3.2.1 - Long term performance development for the total time period' is showing the full trend development for all of the wells.
        - The second trend plot in chapter '4.3.2.2 - Comparing performance in the end of both intervals. ' is giving a picture of the change in the performance in the end of both intervals. Theoretically the performance after several years of learning and experience should be at a high point. This plot is showing us how the performance is in the end of Interval 2 compared to in the end of Interval 1.
        - The third trend plot is in chapter '4.3.2.3 - Effect of the drilling stop'. This plot is expressing how the performance is in the start of Interval 2 compared to in the end of Interval 1. This plot will show if there has been a change in the development and which operations have the largest gap (change) in performance before and after the drilling stop.
        - The fourth and last trend plot is in chapter '4.3.2.4 - Learning and batch drilling effects in Interval 1'. This plot shows the total performance from the start to the end in the interval. Due to the large gap shown in the third trend plot this graph was created to see if there have been any learning effects or any particular development within the interval.
- Chapter '4.4 - Performance of the rigs drilling on the fields in Interval 1 and 2': Displaying the rigs present in Interval 1 and Interval 2 with the corresponding performance with regards to meters per day and the operational factor (OPS(f)).

4.2. Time distribution average in Interval 1 and 2

A plot showing the percentage of time spent on the different operations in Interval 1 and Interval 2 has been created. It has been set up by finding the average of hours used on all of the operations on the wells in Interval 1 and in Interval 2. The average hours used on an operation has then been divided by the average operational hours to find the percentage of total time spent on that exact operation. See 'Table 11 - Average hours spent on operations in Interval 1 and 2' on next page for more details of the average hours spent.

		Average hours	
		Interval 1	**Interval 2**
1	MU PU all drilling equipment	12,57	14,74
2	Drilling hours (make hole)	216,14	158,27
3	Flowcheck and circulate open hole	14,74	16,27
4	Flowcheck and circulate cased hole / displace mud	1,40	8,01
5	RIH	23,33	26,22
6	POOH	20,66	26,59
7	Cut and slip drill-line	2,16	1,16
8	Ream and wash	5,87	3,51
9	L/D all equipment	8,13	6,52
10	Pre job meeting, drills, infomeetings and washing on drillfloor	1,89	6,05
11	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	9,88	10,13
12	Run 9 5/8" casing (inc pressure testing, circulating and other work inbetween)	37,43	53,79
13	Cement job	8,93	13,01
14	Pressure test seal assembly and POOH	0,54	0,59
15	Pressure test / function test BOP	5,46	6,33
16	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)	1,88	2,84
17	RU, perform and LD coring	0,00	4,70
18	Fishing (waiting on equipment and all time spent)	4,73	0,00
19	FIT	0,11	0,10
20	Other	2,22	5,46
21	Incidents w/downtime - hole problems	11,69	33,03
22	Incidents w/downtime - Equipment problems and other problems	26,48	32,07
23	Cement logging (rigging up, logging, rigging down)	0,00	6,15
24	Data aqcuisition. Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)	9,87	22,95
25	Waiting on weather	10,80	17,45
26	Other waiting	0,28	0,33
27	**Operational hours**	**437,19**	**476,28**

Table 11 - Average hours spent on operations in Interval 1 and 2

The operations in 'Table 11 - Average hours spent on operations in Interval 1 and 2' are set up in the same way as 'Table 10 - Categories for breakdown of all operations'. A further grouping is useful when creating an overview of the average hours, so in this specific chapter the following gathering of operations has been utilized:

Operation	**Color coding in figure 31 and 32**	**Consists of line from table 11**	**Percentage - Interval 1**	**Percentage - Interval 2**
MU/PU/LD all drilling equipment		1, 9	4,74 %	4,46 %
Drilling hours (make hole)		2	49,44 %	33,23 %
Flowcheck and circulate (open and cased hole)		5, 6, 8	5,04 %	5,84 %
Tripping		5, 6	10,06 %	11,09 %
Running casing		11	8,56 %	11,29 %
Casing - surface activities		12	2,26 %	2,13 %
Cement job		13	2,04 %	2,73 %
Pressure test		14, 15, 16	1,80 %	2,05 %
Data acquisition		17, 23, 24	2,26 %	7,10 %
Incident hole problem		21	2,67 %	6,94 %
Incident equipment problem		22	6,06 %	6,73 %
Waiting		25, 26	2,54 %	3,73 %
Other		7, 10, 18, 19,20	2,54 %	2,68 %
Total			**100,00 %**	**100,00 %**

Table 12 - Operation categories and percentage hours spent in Interval 1 and 2

These distributions are displayed graphically in the following two figures. The color coding is added to the table above. Important to note is that the graphs display the distribution in percentage of the average operational hours of the period in question; meaning that the total set of average operational hours in Interval 1 is 437.19 hours and 476,28 hours in Interval 2, as seen in 'Table 11'

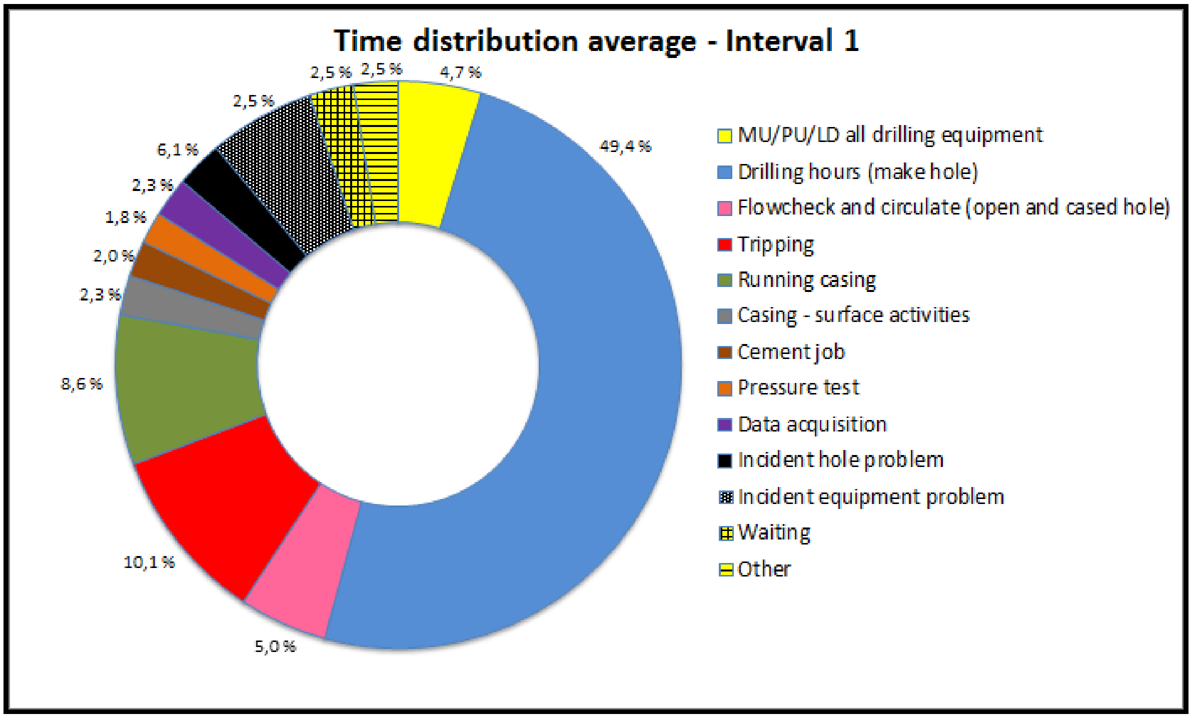

Figure 31 - Time distribution average in Interval 1

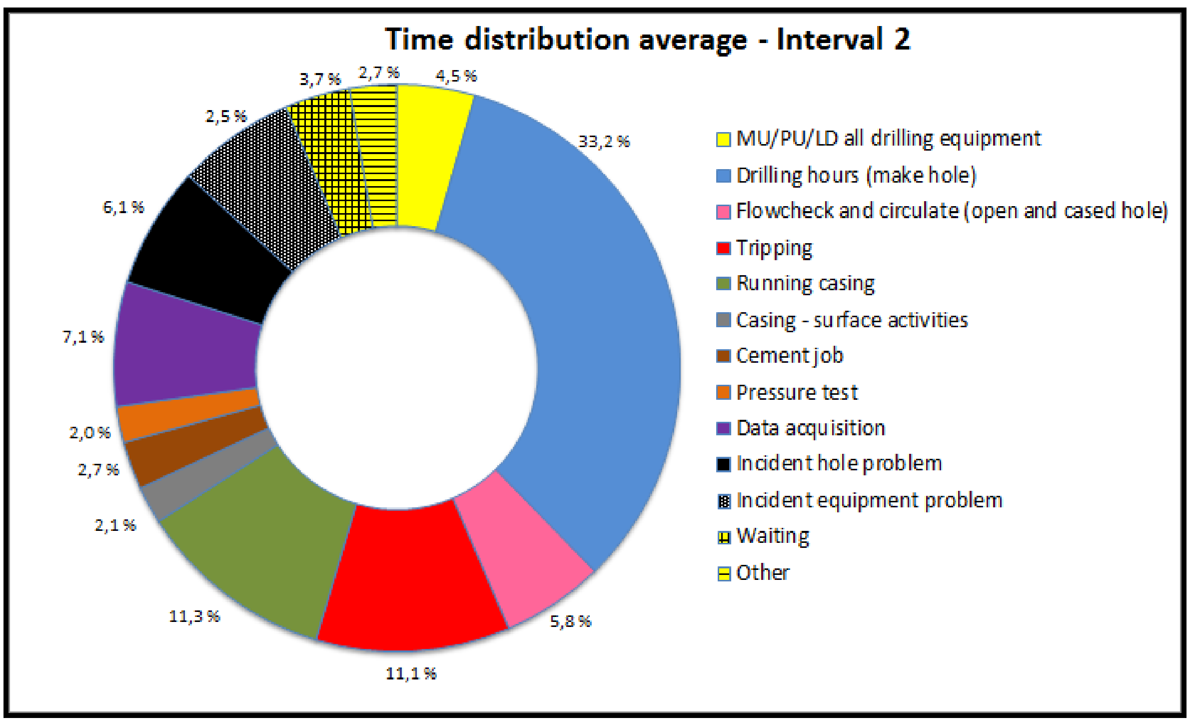

Figure 32 - Time distribution average in Interval 2

As seen from ‘Table 12 - Operation categories and percentage hours spent in Interval 1 and 2’ and figure 31 and 32 we have some significant changes in the time distribution for the different operations in the two intervals. In the following table the percentage change is ranked from the highest change to the lowest change:

Drilling hours (make hole)	-16,21 %
Data acquisition	4,84 %
Incident hole problem	4,26 %
Running casing in hole	2,73 %
Waiting	1,20 %
Tripping	1,02 %
Flowcheck and circulate (open and cased hole)	0,80 %
Cement job	0,69 %
Incident equipment problem	0,68 %
MU/PU/LD all drilling equipment	-0,27 %
Pressure test	0,25 %
Other	0,14 %
Casing - surface activities	-0,13 %

Table 13 - Change in distribution for Interval 1 and 2

When a value is negative it means that we are spending less time on that operation in Interval 2 and vice versa.

The largest changes in time usage:

- 16,21 % time less is spent on drilling hours (make hole)
- 4,84 % more time is spent on data acquisition
- 4,26 % more time is spent on downtime related to hole problems
- 2,73 % more time is spent on running casing

As previously mentioned the average operational hours on the 12 ¼’’ drilling section has increased from an average of 437,19 hours in Interval 1 to an average of 476,28 hours in Interval 2. We are spending in average 39,09 hours more on each 12 ¼’’ section on each well in Interval 2. Still we have been able to reduce the time on drilling hours (make hole) by 16,21 %. The result is that the hours we have been able to reduce on drilling activities and the 39,09 average hours extra spent in Interval 2 are all spent on other activities than drilling hours(make hole).

4.3. In depth analysis of the result

For a more in depth analysis of the results presented in chapter 3 a further investigation is necessary. The value for the operator is to identify which part of the operation is taking longer than before, and how much it is in hours. This chapter will start off with an overview of the change in average hours spent on the different operations to be able to quantify the change in chapter ‘4.2 - Time distribution average in Interval 1 and 2’. Secondly in chapter ‘4.3.2 - Trend values for quantifying the drilling performance’ an analysis based on the trends in the graphs will be performed. All of the graphs in chapter ‘3 - Analysis’ has an added trend line to be able to see which direction the trend is developing.

When quantifying the values the result will be displayed in two different ways; by average values and by trend values.

The data basis for the performance factors with average values is added in 'Table 11 - Average hours spent on operations in Interval 1 and 2'. The data basis for the performance factors with trend line is added in Appendix I - Trend line values for drilling performance factors'. The datasets have as before been divided into Interval 1 and Interval 2.

For '4.3.1 - Average values for quantifying the drilling performance' the average hours are summed up based on the operations as displayed in 'Table 14 - Operation categories and color coding for use in chapter 4.3.1 and 4.3.2'.

For '4.3.2 - Trend values for quantifying the drilling performance' an average example well has been created. The average well is created by adding up the section start depth, section end depth and section length for all the wells and dividing it by the total number of wells (58 wells initially, 56 wells after the two wells with best and worst performance were removed, as stated in chapter '1.4 - Problem statement'). In other words, the example well is set up as the average value for both the section length and the average hours spent on each 12 ¼'' drilling section.

The example well generated from the dataset in 'Appendix B - Breakdown of operations of all wells analyzed' is as follows:

	Sum of all wells	Sum of all wells / Number of wells
Section start depth	130584 m	2244,0 m
Section end depth	272254 m	4705,0 m
Section length	141670 m	2461,0 m
Average hours	26208 hrs	455,1 m

Figure 33 - Example well

The purpose of creating an average well is to use it when calculating the trend values to be able to gather the results from the analysis so far in chapter 3 and show where we have a difference in performance.

The example well in 'Figure 33 - Example well' has been used to calculate the hours spent on the different operations. The values are calculated one of the following three ways:

- If value is in hours: Calculated the average value during the time period in question.
- If the value is in meters per hour: Find the average meters / hour and multiply by the average section length.
- If the value is in percentage: Calculate how many hours spent by using the example well and the average hours used per well.

After the average hours and the trend hours spent on an operation have been calculated:

The average hours / the trend hours used in Interval 2 are subtracted from the average hours/ trend hours used in Interval 1.

- If this is a positive number it means that the time spent on this operation has increased in Interval 2.
- If this is a negative number it means that the time spent on this operation has decreased in Interval 2.

The following color coding has been used in chapter' 4.3.1' and '4.3.2':

	Operation	Color code
1	Drilling and circulation performance average	
2	Tripping performance average	
3	Casing performance in hole average	
4	Casing performance - surface activities	
5	Cement performance average	
6	Downtime performance downhole problems average	
7	Downtime performance equipment problems average	
8	Data acquisition average	
9	Pressure testing performance average	
10	Other operations performance average	

Table 14 - Operation categories and color coding for use in chapter 4.3.1 and 4.3.2

This table is set up according to the colors shown in 'Table 10 - Categories for breakdown of all operations'. The reader is referred to 'Appendix G - Mapping of operations for chapter 4.3.1 and 4.3.2' for further information of the grouping.

4.3.1. Average values for quantifying the drilling performance

The next graph is set up by showing the average value in hours for the operation in Interval 2 subtracted by the average value in hours for the operation in Interval 1.

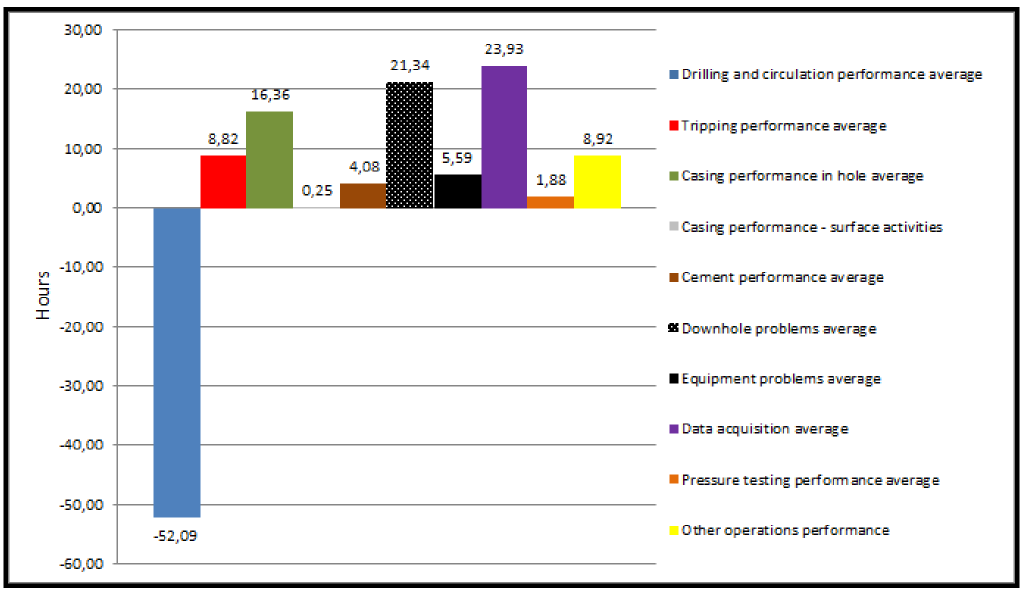

Figure 34 - Average performance per well compared for Interval 1 and 2

The 'Figure 34 - Average performance per well compared for Interval 1 and 2' demonstrates that all of the operations, except drilling and circulation, are in average contributing to increased time spent in Interval 2 compared to Interval 1.

The following table has been set up to show the average hours spent on the different operations and the total result in hours spent:

Drilling and circulation performance average	-52,09	hrs
Tripping performance average	8,82	hrs
Casing performance in hole average	16,36	hrs
Casing performance - surface activities	0,25	hrs
Cement performance average	4,08	hrs
Downtime performance downhole problems average	21,34	hrs
Downtime performance equipment problems average	5,59	hrs
Data acquisition average	23,93	hrs
Pressure testing performance average	1,88	hrs
Other operations performance average	8,92	hrs
Sum	39,09	hrs

Table 15 - Overview of average hours spent on the different operations.

The total sum shows us that the average time spent on the whole 12 ¼'' drilling section has increased by an average of 39,09 hours per well in Interval 2.

Drilling and circulation performance average:
At average 52,09 hours less are spent on drilling and circulation per well.

Tripping performance average:
At average 8,82 hours more are spent on tripping per well.

Casing performance in hole average:
At average 16,36 hours more are spent on running the casing in hole per well.

Casing performance not in hole average:
At average 0,25 hours more are spent on casing operations not in hole per well.

Cement performance average:
At average 4,08 hours more are spent on the cement job per well.

Downtime performance downhole problems average:
At average 21,34 hours more are spent on downtime related to downhole problems per well.

Downtime performance equipment problems or other problems average:
At average 5,59 hours more are spent on downtime related to equipment problems or other problems per well.

Data acquisition performance average:
At average 23,93 hours more are spent on logging per well.

Pressure testing performance average:
At average 1,88 hours more are spent on pressure testing per well.

Other operations performance average:
At average 8,92 hours more are spent on other operations per well.

The operations contributing to the most significant growths in hours on operations are sorted from greatest to least significant. This is done by summarizing all the extra average hours spent on the different operations in a total sum and then calculating the percentage of total time spent on the different operations:

Operation	Percentage
1. Data acquisition performance average	26,25 %
2. Downtime performance downhole problems average	23,41 %
3. Casing performance in hole average	17,94 %
4. Other operations performance average	9,78 %
5. Tripping performance average	9,67 %
6. Downtime performance equipment problems average	6,13 %
7. Cement performance average	4,48 %
8. Pressure testing performance average	2,06 %
9. Casing performance - surface activities	0,27 %
Sum	100,00 %

Table 16 - Operations contributing to increased hours spent on well

The three most significant developments are the data acquisition performance, downtime performance related to downhole problems and casing performance in hole. These operations has increased respectively with 23,93 hours, 21,34 hours and 16,36 hours.

4.3.2. Trend values for quantifying the drilling performance

As mentioned all of the curves have an added trend line. When quantifying the drilling performance with use of the trend values we get a representation of the direction of the development.

The first part in chapter 4.3.2.1 will consist of a plot showing the total trend for the whole period. This will be set up by using the plots for the whole period. The value for the start of the trend line and the value for end of the trend line will be used as basis for this curve. The value for the end point of the trend line will be subtracted from the value of the start point of the trend line, resulting in negative numbers representing fewer hours spent on this operation in the later years and vice versa.

The second part in chapter 4.3.2.2 will consist of a plot set up by using the end point of the trend lines in the graphs for Interval 1 and Interval 2. The value for the end point of Interval 2 will be subtracted from the corresponding value for Interval 1. A positive number shows that more hours are spent on this operation in the end of Interval 2 and vice versa.

The third part in chapter 4.3.2.3 will consist of two plots set up by using the start point of Interval 2 and subtracting it by the end point of Interval 1. This will show if there has been a change in the direction of the development and if there is a gap between the performance in Interval 1 and Interval 2. A negative number shows that fewer hours are spent on this operation in the start of Interval 2 and vice versa.

The last part in 4.3.2.4 Learning and batch drilling effects in Interval 1 will have a closer look at the batch effects and learnings in the first interval. This is set up by taking the trend line in the end point of the interval and subtracting it from the start point. This will show if there has been any batch effects or learning effects in this period of time. A negative number shows that fewer hours are spent on this operation in the end of the interval than in the start of the interval and vice versa.

4.3.2.1. Long term performance development for the total time period

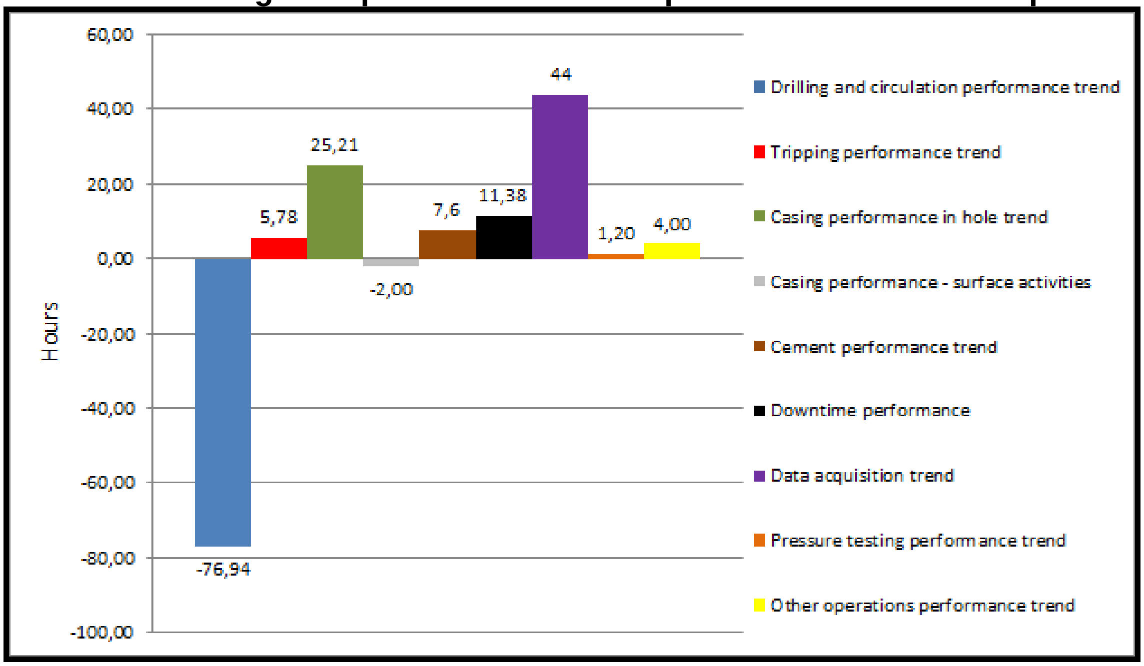

Figure 35 – Long time performance development

'Figure 35 – Long time performance development' is set up by subtracting the value in the end point of the trend line in the total period from the value in the start point of the trend line.

Drilling and circulation performance trend	-76,94	hrs
Tripping performance trend	5,78	hrs
Casing performance in hole trend	25,21	hrs
Casing performance - surface activities	-2,00	hrs
Cement performance trend	7,6	hrs
Downtime performance	11,38	hrs
Data acquisition trend	44	hrs
Pressure testing performance trend	1,20	hrs
Other operations performance trend	4,00	hrs
Sum	20,23	hrs

Table 17 - Overview of hours for long time performance development

The overall picture demonstrates that we are going in the direction of spending more time on the different operations. The most significant developments in negative trend are the data acquisition performance and casing performance in hole. As previously shown the drilling performance average is contributing positively towards better performance, and this is also the case for the long time performance development for the total period.

4.3.2.2. Comparing performance in the end of both intervals.

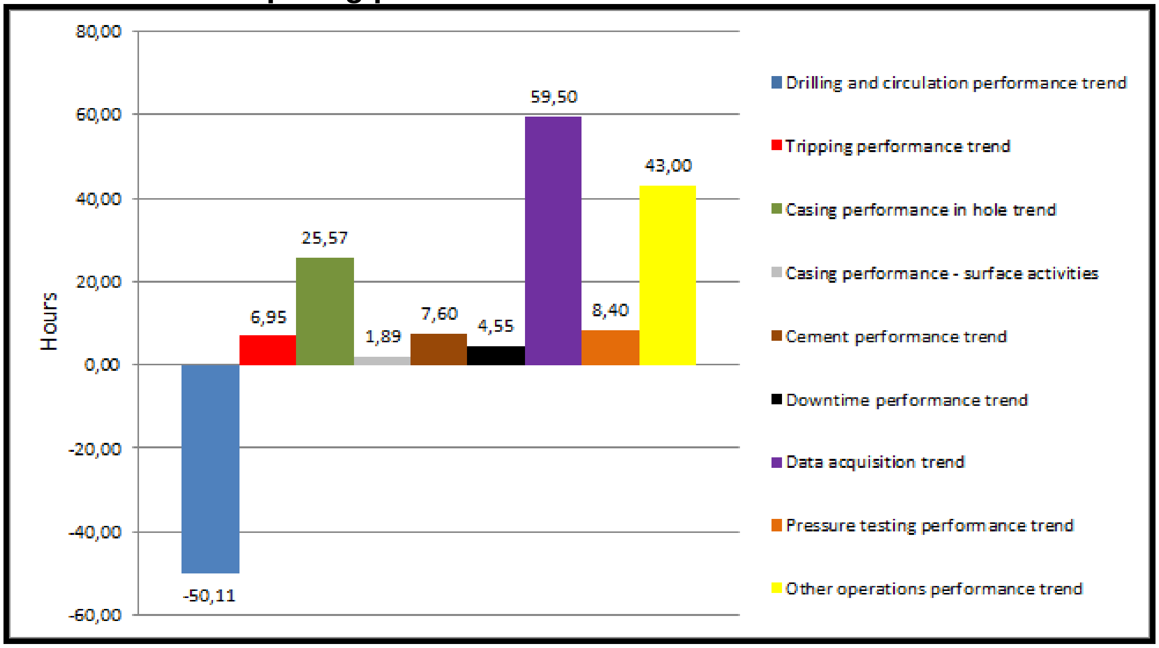

Figure 36 - Trend line performance for end points of Interval 1 and 2

'Figure 36 - Trend line performance for end points of Interval 1 and 2' is set up by using the end points of the trend lines for the two periods. The value in the end of Interval 2 is subtracted from the value in the end of Interval 1.

Drilling and circulation performance trend	-50,11	hrs
Tripping performance trend	6,95	hrs
Casing performance in hole trend	25,57	hrs
Casing performance - surface activities	1,89	hrs
Cement performance trend	7,60	hrs
Downtime performance trend	4,55	hrs
Data acquisition trend	59,50	hrs
Pressure testing performance trend	8,40	hrs
Other operations performance trend	43,00	hrs
Sum	107,36	hrs

Table 18 - Overview of hours for end points of trend graphs for the two Intervals

As seen from 'Table 18 - Overview of hours for end points of trend graphs for the two Intervals' all of the operations, except the drilling and circulation performance, are trending towards taking more time in the end of Interval 2 compared to the end of Interval 1. This development is pointing in a negative direction with a trend towards 107,36 hours more spent on each section.

4.3.2.3. Effect of the drilling stop

The plot shows the effect of the drilling stop by displaying the gap between the value in the end of Interval 1 compared to the start of Interval 2:

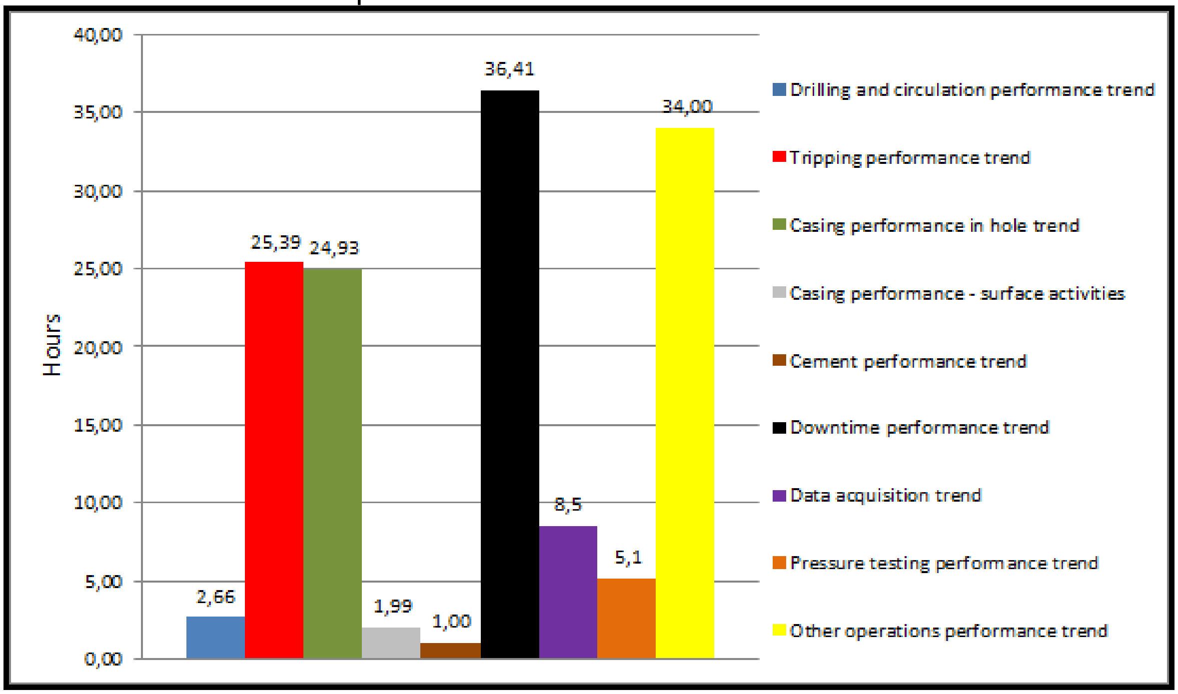

Figure 37 - Trend line gap between Interval 1 and 2

'Figure 37 - Trend line gap between Interval 1 and 2' is set up by subtracting the value of the start point of the trend line in Interval 2 from the end point of the trend line in Interval 1.

Drilling and circulation performance trend	2,66	hrs
Tripping performance trend	25,39	hrs
Casing performance in hole trend	24,93	hrs
Casing performance - surface activities	1,99	hrs
Cement performance trend	1,00	hrs
Downtime performance	36,41	hrs
Data acquisition trend	8,5	hrs
Pressure testing performance trend	5,1	hrs
Other operations performance trend	34,00	hrs
Sum	139,98	hrs

Table 19 - Overview of gap in trend line between interval 1 and 2.

The performance in the end of Interval 1 was at a much higher level for all of the operations than in the beginning of Interval 2. Not a single operation started off at a better level in Interval 2. The end of Interval 2 was a great period with high performance, and it is evident that this trend was lost after the two year drilling stop and when the operation was resumed again. The contributors with greatest impact with regards to lower performance in the start of Interval 2 is the downtime performance trend, the other operations performance trend, the tripping performance trend and the casing performance in hole.

4.3.2.4. Learning and batch drilling effects in Interval 1

From the previous chapter '4.3.2.3 – 55Effect of the drilling stop' we observed that the end of the first interval was having a much better performance than in the start of Interval 2. In the following graph we will have a closer look at the development within the interval to see if there has been any internal development within the time period.

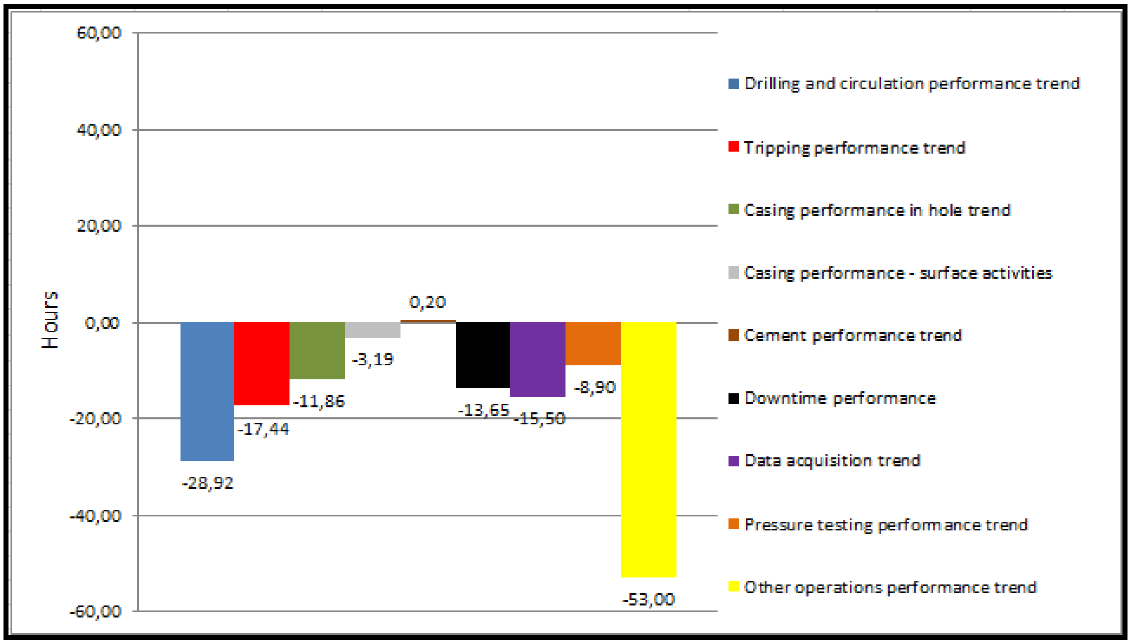

Figure 38 - Batch effects and learnings in Interval 1

Drilling and circulation performance trend	-28,92	hrs
Tripping performance trend	-17,44	hrs
Casing performance in hole trend	-11,86	hrs
Casing performance - surface activities	-3,19	hrs
Cement performance trend	0,20	hrs
Downtime performance	-13,65	hrs
Data acquisition trend	-15,50	hrs
Pressure testing performance trend	-8,90	hrs
Other operations performance trend	-53,00	hrs
Sum	-152,26	hrs

Table 20 - Overview of batch effects and learnings in Interval 1

The performance in the end of Interval 1 was improved greatly from the start. All of the operations, except the cement performance, were trending towards a better performance and spending much less time than in the beginning of the period. This demonstrates clearly, as the numbers are quite high, that the drilling and circulation, other operations, tripping, data acquisition and the downtime performance was at a very high level in the end of this period.

In the first time period the wells were drilled rapidly after each other, with no major stop in the drilling. This is facilitating a learning culture and environment, and it is a common belief that being able to repeat a task will lead to better execution the next time. [xv]

4.4. Performance of the rigs drilling on the fields in Interval 1 and 2

Interval 1: The following rigs were present on the fields in this time period:

	Interval 1	Meters per day	OPS(f) [%]	Number of 12 1/4"
1	TRANSOCEAN WINNER	147,1	91	24
2	TRANSOCEAN SEARCHER	132,6	80	10
3	TRANSOCEAN ARCTIC	118,7	87,8	9
			Total	43

Figure 39 - Rigs present in Interval 1

From the 'Figure 39 - Rigs present in Interval 1' we see that there were three rigs on the field drilling 43 of the 12 ¼'' sections. A simple observation is that Transocean Winner has drilled more than double the amount of wells than the next rigs. The performance, both with regards to the operational factor (OPS(f)) and meters per day seem to follow the amount of wells drilled. This suggests that experience and hand-on knowledge gives an advantage with regards to performance.

Interval 2: The following rigs were present on the fields in this time period:

	Interval 2	Rushmore [m/day]	OPS(f) [%]	Number of 12 1/4"
1	OCEAN VANGUARD	164,0	91,8	1
2	AKER SPITSBERGEN	131,0	87,2	1
3	STENA DON	116,0	78,3	2
4	TRANSOCEAN SEARCHER	113,9	80,9	6
5	DEEPSEA BERGEN	110,0	94,5	4
6	SCARABEO 5	101,1	94,5	1
			Total	15

Figure 40 - Rigs present in Interval 2

From the figure 'Figure 40 - Rigs present in Interval 2' we see that there were six rigs on the field drilling 15 of the 12 ¼'' sections. Here we observe that many of the rigs has only drilled one well, and the overall performance with regards to meters per day is at a lower rate than in Interval 1.

Another observation is that Transocean Searcher was drilling both in Interval 1 and 2, but the performance is at a lower level after the period of drilling stop.

5. Discussion

5.1. Introduction

In the following chapter the main findings from chapter 4 in each of the different ways of analyzing the data will be discussed.

5.1.1. Discussion of chapter 4.2. and 4.3.1 – Average time.

The total average time spent on drilling a 12 ¼'' section has increased by 39,09 hours from 437,19 hours in Interval 1 to 476,28 hours in Interval 2. The average time distribution for the operations in the two intervals has changed. As shown in 'Table 13 - Change in distribution for Interval 1 and 2' the major changes in distribution are the following:

1. **Drilling and circulation performance** (16,21% less time in Interval 2)
   - The percentage of time spent on drilling has developed quite drastically in positive direction. This is very positive and may be due to the following reasons:
     - The technology used for drilling the wells is rapidly developing. Upgraded bit technology and other BHA equipment has been launched to the marked. The operators are spending both resources and capital to try to get a technological advantage. Statoil has several research and development departments to speed the process of maturing technologies to introduce them to the operations. In addition the different operations are encouraged to use new technology by adding it as a goal in the company's 'Ambition to Action' plan.
     - Over the years there is a learning effect. Statoil has drilled many wells on Smørbukk and Smørbukk Sør, and the experiences from the operations are all added to DBR for later use. The planning engineers will base the planning and the risk assessment of new wells on earlier experiences.
     - The incentives and KPI's has been adjusted and concretized. In the whole time span of the Smørbukk and Smørbukk Sør fields the drilling performance KPI has been in focus in Statoil. The meters drilled per day are displayed both at each operational department's internal 'MIS page' and on the 'MIS page' for the leader teams. The KPI is considered important for being able to improve. The performance target provides a measurable and very visible goal for success and at the same time it gives a signal of what is most important. [xxviii]

2. **Data acquisition performance** (4,84 % more time in Interval 2)
   - The percentage of time spent on data acquisition has developed in negative direction, towards spending 4,84 % more time on that operation in Interval 2. This may be due to the following reasons[xxix]:
     - Extra logging runs done in the later years due to changes in requirement in internal technical guidelines (ARIS) and NORSOK. New

requirements have been implemented requiring logging in more situations than what was necessary earlier.
    - For cement logging: There has been a development from utilizing normal CBL/VDL logging tools to more advanced logging tools like CBL/VDL plus Ultrasonic combinations the later years. These tools require a lower logging speed and will lead to a lower performance of logging.
    - There has been more use of synthetic OBM's (including higher densities) in the later years. This leads to a requirement for a higher torque to rotate the logging tools. So a new gearbox was required and this meant lower logging speeds in some situations.
    - The rigs/platforms require an answer regarding the barrier status almost immediately in the later years. There is a need to confirm barriers before drilling the next section. This results in the interpretation of the log needs to be done immediately and this can add time to data acquisition performance as the logs often must be reprocessed during the operation to be able to give the answer.

3. **Downtime performance related to hole problems** (4,26 % more time in Interval 2)
    - In Interval 1 three of the wells had more than 90 hours downtime related to downhole problems. The dataset is large, so the average impact on the rest of the wells is not very significant (Average 11,40 hours). Two of the wells in Interval 2 had major downtime related to downhole problems. As the dataset in Interval 2 is quite small (15 wells) this has a greater impact on the average time spent on downtime for each well. (Average 33,03 hours). The two wells with major downhole problems were both related to the cement job:
        - Well NO 6506/12-Q-4 H in year 2006 due to a failed foam cement job and a great number of logging hours spent.
        - Well NO 6506/12-I-1 AH in year 2008 where a gas kick was taken when drilling out the 9 5/8'' casing shoe. This was most likely due to poor cement and work was done to kill the well, run USIT/CBL logs, squeeze cementing and performing an in-flow test.

      It is not possible from the analysis performed in this thesis to conclude why there were two major incidents related to the cement job in Interval 2 and why the average time spent on downtime is increasing.

4. **Casing performance in hole** (2,73 % more time in Interval 2).
    - As seen in 'Figure 15 - Running casing – meters per hour in Interval 1 and 2' the running casing performance had a positive trend in Interval 1 that stopped in Interval 2. There is no obvious explanation to as of why this is the case, but it can be due to the following:
        - The later wells in Interval 2 having a higher inclination than the wells Interval 1. A higher inclination in a well can introduce challenges related to for example hole cleaning and to run the casing in the hole successfully. xxx

- A change in internal practice with regards to running casing. This is suggested because the trend in Interval 2 is showing a very straight line with no particular positive or negative development. None of the wells in this interval came up on the same level as for Interval 1.

5.1.2. Discussion of chapter 4.3.2

The four different plots showing the trend lines by using different methods gives a good overall picture of how the drilling performance is developing. As the plots are built up to get different perspective of the data a separate paragraph presenting the results from each curve is needed.

5.1.2.1. Discussion of chapter 4.3.2.1

The plot changes in trend for the total period is shown in 'Figure 35 – Long time performance development' and the overall picture demonstrates that we are going in the direction of spending more time on the different operations. The trend development is towards spending 20,23 hours more on each 12 ¼'' section. This is not much when compared to the increased average time spent in Interval 2 at 39,09 hours. In other words the trend values are not showing a picture as negative as when the average values are used.

The contributor to increased performance in the trend line for total time period:

1. **Drilling and circulation performance**. (76,94 hours less in the end of the period)
   - The trend is contributing positively towards better performance with a reduction at 76,94 hours spent on the operation in the end of the period compared to the start. From 'Figure 9 - Drilling operation performance (meters / hour)' it is evident that the trend is developing in positive direction. Possible reasons for the improvement are the following:
     - Better technology available. Automated drilling processes.
     - Established KPI's, management focus and stretch goals based on technical limits for operation.
     - Learning and knowledge transfer.

The contributors to decreased performance in the trend line for total time period:

1. **Data acquisition performance.** (44,0 hours more in the end of the period)
   - The trend is towards spending 44 hours more on the data acquisition in the end of the total period than in the start. The possible reasons for this are already described in chapter 5.1.1.
2. **Casing performance in hole.** (25,21 hours more in the end of the period)
   - As seen in 'Figure 14 - Running casing – meters per hour total' the trend is towards spending more hours more on the casing running in hole in the end of the total period than in the start. The reason for this development is not possible to extract directly from the data in this thesis, but in addition to the possible reasons provided in chapter 5.1.1. the following is a likely explanation:

    - We were not able to keep up the motion and learning effect that was evident in Interval 1 in 'Figure 15 - Running casing – meters per hour in Interval 1 and 2' due to the two-year drilling stop.
3. **Downtime performance**. (11,38 hours more in the end of the period)
    - From the 'Figure 20 - Total downtime percentage' we observe that the total percentage of downtime hours has increased from the start of the period to the end. This increase is at 11,38 hours. It is not possible from the analysis performed in this thesis to conclude why the downtime percentage has increased over the years, but the following are likely explanations:
        - There is an increased focus on reporting downtime as currently the contracts set up with the service companies are widely focused on the operation being a success. If there is downtime related to a particular type of equipment or operation that a service company is performing it is important to connect the downtime to the company in question in order to be able to reduce the compensation for that company. In addition there is a wide focus in Statoil on analyzing data to be able to choose the correct provider for equipment and services, something that leads to an increased focus on correct reporting when it comes to wasted time.
        - There is possibly a more advanced well design. When we are doing a slot recovery an old well is plugged and kicked off from. This leads to a well design that must be adjusted and adapted to the already existing well, and that is possibly not the optimum design. In addition it has been suggested that the inclination of the wells has been necessary to increase the later years in order to be able to achieve the objective and reach the reservoir in the correct position.
        - In addition one has used more advanced and sensitive equipment in the later years. The steerable BHA's as an example have restrictions with regards to RPM and how much heat it can withstand. [xxxi]
4. **Cement performance**. (7,6 hours more in the end of the period)
    - From the' Figure 18 - Cement job total hours' we observe that the total trend for hours spent on the cement job is increasing. It is not possible from the analysis performed in this thesis to conclude why the hours spent on the cement job has increased, but it can be speculated in if the procedures for the cementer with regards to how to perform the cement job has been revised.
5. **Tripping performance**. (5,78 hours more in the end of the period)
    - From the 'Figure 12 - Tripping hours total' the total trend for time spent on tripping is increasing. It has increased a total of 5,78 hours. This is not a very significant increase. Likely reasons for this increase in spent hours can be the following:
        - More trips in and out of the hole. This performance factor does not take into consideration whether or not several trips were performed, so if there are many hours spent on this operation it can be due to several trips done.
        - Possible changes in procedures for how fast the tripping should be performed in open hole and cased hole.
6. **Other operational hours performance**. (4 hours more in the end of the period)

From ‘Figure 29 - Other operations hours total’ we see that the overall trend is towards spending more time on other operational activities. This has increased by 4 hours and is not a significant increase. As this is a quite random performance factor (containing both normal waiting and waiting on weather) there is no definite explanation as to why this has increased a little trend wise.

The negligible changes in trend for total time period:

1. **Casing performance – surface activities**. (2 hours less in the end of the period)
   - Displayed in ‘Figure 16 - Casing performance – surface activities – total hours’ and has decreased trend wise with 2 hours.
2. **Pressure testing performance.** (1,20 hours more in the end of the period)
   - Displayed in ‘Figure 27 - Total pressure testing hours and has increased trend wise with 1,20 hours.

5.1.2.2. Discussion of chapter 4.3.2.2

The purpose of creating the ‘Figure 36 - Trend line performance for end points of Interval 1 and 2’ is to verify if the performance in the end of Interval 1 is better or worse than the performance in the end of Interval 2. The figure clearly demonstrates that all of the operations, except the drilling and circulation performance, are trending towards taking more time in Interval 2. The overall development is pointing in a negative direction.

The contributor to better performance in the end of Interval 2 is the following:

1. **Drilling and circulation performance.** (50,11 hours less in the end of Interval 2)
   - The trend is going towards spending 50,11 hours less on drilling and circulation in the end of Interval 2 compared to the end of Interval 1. The possible reasons for this have already been discussed in chapter 5.1.1 and 5.1.2.1.

     For Interval 2 in ‘Figure 10 - Drilling operation performance (meters / hour) in Interval 1 and 2’ an observation is that the displacement between the curve for ‘Average ROP per hour’ and ‘Average ROP and circulation per hour’ is increasing; indicating that more time is spent on circulation activities outside of the drilling phase. Still we are drilling with higher efficiency with regards to average ROP per hour.

The contributors to decreased performance in the end of Interval 2 are the following:

1. **Data acquisition performance.** (59,50 hours more in the end of Interval 2)
   - The trend is going towards spending 59,50 hours more on data acquisition in the end of Interval 2. The possible reasons for that have been discussed in chapter 5.1.1.
2. **Other operations performance.** (43 hours more in the end of Interval 2)
   - The trend is that time on these operations has increased by 43 hours. In the end of Interval 1 there were very few hours spent on these operations, but in

the end of Interval 2 that has changed. There is not a specific reason for why this is the case, since the hours include both normal waiting hours and waiting on weather this performance is partly random. The time spent on the following operations has increased in Interval 2:
  - M/U and L/D equipment
  - The pre-job meetings and washing on drill floor
  - Waiting on weather.
3. **Running casing performance**. (25,57 hours more in the end of Interval 2)
   - The trend is going towards spending 25,57 hours more on running casing in Interval 2. The likely reason for that is provided in chapter 5.1.2.1.

5.1.2.3. Discussion of chapter 4.3.2.3.

This purpose of the 'Figure 37 - Trend line gap between Interval 1 and 2' is to verify if there has been a change in the direction of the development in performance between Interval 1 and Interval 2.

The major gaps in performance between the end of Interval 2 and the start of Interval 1 are the following:

1. **Downtime performance.** (36,41 hours more in the start of Interval 2)
   - Interval 1 had an improving trend towards fewer hours used on downtime. In the end of the Interval we were at a low percentage of downtime. In the start of Interval 2 there were some trouble wells with high downtime percentage, and the trend line started at a higher point. The trend line in Interval 2 is also having a positive development towards fewer hours spent on downtime.
2. **Other operations performance.** (34,0 hours more in the start of Interval 2)
   - Interval 1 had a very positive development towards spending fewer hours on 'other operations'. When we started up the operation after the drilling stop the trend was to spend more hours in this respect, so the gap here is quite large.
3. **Tripping performance.** (25,39 hours more in the start of Interval 2)
   - Interval 1 had an improving trend towards fewer hours spent on tripping. Interval 2 also had an improving trend, but the trend line started at a higher point than what the trend ended on in Interval 1.
4. **Casing performance in hole.** (24,93 hours more in the start of Interval 2)
   - Interval 1 has a significant improvement in the casing performance in hole. In the end of the interval we were at a quite constant high level. In the start of Interval 2 the trend was at a much lower level performance wise and never came up to the same performance as in Interval 1 again.

The 'Figure 37 - Trend line gap between Interval 1 and 2' and the results from above clearly demonstrate that all of the operations are taking more time in the start of Interval 2 than in the end of Interval 1. This is a strong indicator of that the two year drilling stop has had a major impact on the drilling performance at Smørbukk and Smørbukk Sør.

5.1.2.4. Discussion of chapter 4.3.2.4.

When taking the end point of all the trend lines and subtracting it by the start point in the interval we get an impression of which direction the development is going and if there has been any learning effects within the interval.

The result is promising for Interval 1. In total the trend is going towards spending 152,26 hours less on each 12 ¼'' section in the end of the Interval compared to the beginning. From 'Figure 38 - Batch effects and learnings in Interval 1' we observe that basically all of the operations are performed at a better level, except the cement job which is at a nearly constant level in the interval.

The contributors to increased performance in Interval 1 are the following:

1. **Other operational hours performance.** (53,0 hours less in the end of the interval)
    - The hours included in this operation are described in chapter '3.5.8 - Other operations'. This is the operation contributing the most to increased performance in the end of this interval, with 53,0 hours less spent. This can be related to:
        - There were two wells in the start of the interval with extraordinarily many hours spent on this operation. See 'Figure 30 - Other operations hours total in Interval 1 and 2'. This is skewing the trend development in very positive direction as we do not have any wells with the same amount of hours on this operation in the end of the interval. The two wells were the following:
            - Well NO 6506/12-R-1 H in year 1997 with (among other operational hours) 149 hours spent waiting on weather.
            - Well NO 6506/11-G-3 H in year 1997 with (among other operational hours) 177,5 hours spent on fishing.
2. **Drilling and circulation performance.** (28,92 hours less in the end of the interval)
    - The reason behind this can be due to the following:
        - As previously mentioned the wells were drilled with a much higher frequency in the first interval than in the last. There was no major break in the drilling, the operation was continuous. As there were so many wells drilled it is natural that the wells in the end of the interval had a better performance based on the learning curve and had much of the same, experienced personnel onboard.
        - Three rigs were present on the field in this interval, drilling continuously. This nurtures a competitive and learning environment.
        - As observed in **'**Figure 10 - Drilling operation performance (meters / hour) in Interval 1 and 2**'** the displacement between the 'drilling hours per meter' and the 'circulation hours per meter' is decreasing. This implicates that the time spent on circulating outside of the drilling phase (time spent on washing, reaming, other circulation) is reduced.
3. **Tripping performance.** (17,44 hours less in the end of the interval)

- The details can be found in 'Figure 13 - Tripping hours in Interval 1 and 2'. This can be due to the following:
    - More trips in and out of the hole in the beginning of the interval. As previously mentioned this performance factor does not take into consideration whether or not several trips were performed, so if the meters tripped per hour is low it can be due to several trips done.
    - Learning effect both with regards to the equipment on the rig and the technical limit it is possible to work towards.

4. **Data acquisition performance**. (15,50 hours less in the end of the interval)
    - The detailed distribution can be found in 'Figure 26 - Data acquisition hours in Interval 1 and 2'. From the figure we can easily observe that the frequency and amount of hours spent on data acquisition is larger in the beginning of the interval. This can be related to the following:
        - Smørbukk and Smørbukk Sør was relatively new and unfamiliar territory in the beginning of this interval. The first wells were drilled as exploration wells before they were changed to be production wells later on. Naturally exploration wells will have a higher focus and spend more time on data acquisition to get to know the formation and the reservoir characteristics.
5. **Downtime performance.** (13,65 hours less in the end of the interval)
    - The details can be found in 'Figure 21 - Total downtime percentage in Interval 1 and 2'.
        - It is not possible from the data set in this thesis to pinpoint why we are able to perform the operation with fewer hours wasted on downtime in the end of the interval, but one can speculate in learning effects and experienced personnel is playing an important role in this regard.
6. **Casing in hole performance**. (11,86 hours less in the end of the interval)
    - In 'Figure 15 - Running casing – meters per hour in Interval 1 and 2' we observe the following:
        - The performance of the wells in the interval is fairly consistent and the trend line is slowly increasing. This is something that indicates that we are having a period with consistency and are able to follow the planned target time that has been set for completing the operations. Again this is most likely due to having experienced personnel, knowledge transfer and frequent casing running operations.
7. **Pressure testing performance.** (8,90 hours less in the end of the interval)
    - As seen in 'Figure 28 - Pressure testing in Interval 1 and 2' there was a period in year 1997 - 1999 where it was common to spend nearly 15 hours per well on pressure testing. In the end of this interval there are no wells with this many hours spent on this operation. It is not possible from the data set to find the reason for why fewer hours are spent on pressure testing in the end of the interval.
8. **Casing performance – surface activities.** (3,19 hours less in the end of the interval)
    - The trend is towards spending 3,19 hours less on activities related to surface activities for running casing. This is fairly constant and the reduction in time

usage is most likely due to experienced personnel that knows which operations can be run in parallel and in depth knowledge of the equipment,

5.1.2.5. Discussion of chapter 4.4.

In the first interval the wells were drilled continuously with no major breaks in operation. The performance were at a high level, and especially for Transocean Winner with an average of 147,1 meters drilled per day and 24 of the 12 ¼'' sections drilled. The performance, both with regards to OPS(f) and meters per day seem to follow the amount of wells drilled. This shows a strong correlation to experience and hand-on knowledge giving an advantage with regards to performance.

In the second interval there were six rigs on the field drilling 15 of the 12 ¼'' sections. Half of the rigs has only drilled only one well, and the overall performance with regards to meters per day is at a lower rate than in Interval 1. There is not a rig that has drilled continuously during this interval, and it can suggest that there is limited possibility to gain field specific knowledge and experience by only drilling one or a few wells.

The change in performance between the rigs in the two intervals is pointing towards batch effects from drilling several wells and to build up knowledge about the specific field and challenges is important. The internal competition between the rigs in Interval 1 could also have contributed positively to an improved performance. When one rig has performed an operation faster than the other it is customary to call in for an information exchange meeting for the other rig to learn and be able to perform the operation in the same manner.

6. Conclusion

The drilling performance has been studied by using the daily reported data on the wells at Smørbukk and Smørbukk Sør. The reports have been manually examined and categorized in the different operations required to drill a 12 ¼'' section. Because the results obtained in this study are limited to the 12 ¼'' drilling section on these two fields the conclusions drawn may not apply for other drilling sections and other fields.

Due to a drilling stop for two years between year 2002 and 2004 the wells has been divided into two intervals; Interval 1 for the period from year 1996 to 2002 and Interval 2 for the period from year 2002 – 2014.

The development of the drilling performance has been investigated and visualized utilizing several different approaches;

- Displaying the average percentage time distribution on operations in both Interval 1 and Interval 2 by use of pie charts
- Quantify the average change in the time distribution between the two intervals
- Showing the change in the trend of the long time performance development for the total time period
- Comparing the performance in the end of both intervals
- Showing the learning and batch drilling effects in Interval 1
- Outline of the performance of the rigs working on the fields in Interval 1 and 2

On average all operations are taking longer time except the drilling and circulation operation. The total trend is going towards spending more time on the 12 ¼'' section, meaning all the other operations are both consuming the hours saved on the drilling operations and in addition more hours are spent on these operations.

The key findings related to the drilling performance are as follows:

1. The fraction of time spent on the 12 ¼'' drilling section is somewhat above one third of the total time spent on all of the drilling sections. A higher efficiency in this drilling section will have a high impact on the cost effectiveness and the ability to deliver a well faster.

2. The average time spent on the 12 ¼'' section in Interval 2 has increased by 39,09 hours. The meters drilled per hours were higher in Interval 1.

3. The drilling and circulation performance has improved over the years and in addition the fraction of time spent on this operation has decreased 16,21 % from Interval 1 to Interval 2. The other operations are both consuming the hours saved on this operation and in addition more hours are spent in total.

4. In average, the time spent on data acquisition, downhole problems and running casing are the operations that have increased most from Interval 1 to Interval 2. Possible reasons for this have been discussed in details in chapter 5.1.1.

5. Interval 1 was a period of steady improvement and positive development. In the end of the period the performance was at an all-time high.

6. Interval 2 started off at a lower point with regards to performance. The good performance gained from learning effects, knowledge transfer and frequently drilled wells were lost when operations resumed in Interval 2.

7. The largest gaps in drilling performance between end of Interval 1 and start of Interval 2 was due to the increased downtime, more hours spent on ‘other operations’, tripping performance and the running casing performance. The performance in the end of Interval 1 was at a much higher level for all of the operations than in the beginning of Interval 2. Not a single operation started off at a better level in Interval 2. It is evident that the drilling stop resulted in a major negative impact on the drilling performance.

8. Average downtime percentage has increased from 8,8 % in the first interval to 13,6 % in the latter.

9. To assure improved drilling performance in the future the effect of batch drilling and continuous operation should not be underestimated. If there is a possibility for having more than one rig drilling at the same time this can provide a competitive environment and synergies with regards to knowledge transfer.

According to Petoro in the referenced article [vii] the time spent on drilling on the Norwegian Continental Shelf has doubled the last 20 years. For the 12 ¼’’ section on Smørbukk and Smørbukk Sør this is not the case. The performance is still at a reasonable level with the average time spent in Interval 1 at 437,19 hours, and 476,28 hours in Interval 2. We are spending at average 39,09 hours more in Interval 2 and that results in an percentage increase of nearly 9 % on this section. This is a negative development, but nowhere near a doubling in time usage.

7. Future work

The focus on drilling efficiency and to deliver wells faster and cheaper has been high the last years. This thesis studies the drilling efficiency of the 12 ¼'' drilling section on Smørbukk and Smørbukk Sør. It would be interesting to follow the same approach for investigating other 12 ¼'' drilling sections to see if the results in this thesis is also valid for them. It would also be interesting to use this method for investigating other drilling sections than the 12 ¼'' section to see if other sections are contributing more to the declining drilling performance on the NCS.

The approach used in this study could also be used as basis for finding out which wells have the best performance on the different operations to form a “perfect well”. This well could be used as the offset for setting the technical limit when planning a new well. The log of the operation both with regards to equipment use, detailed operational procedures and sequence of the operations are to be found in (or linked to) DBR. The approaches utilized in this study have however been a challenging manual job, so some kind of automation of the process would be beneficial.

Finally the data quality is extremely important in regards to performing an analysis on the drilling performance. The reporting software could be adjusted to facilitate quality reporting even further by adding validity checks on some of the important input fields and in addition force the user to add key information before being able to save the reporting. Data quality is important and quality reporting should be high on the agenda.

8. Appendices

Appendix A - Full well list (including meters / day) for all wells analyzed

Well	Section start	Section end	Drilling performance m/day
NO 6506/11-4 S	06.03.1996	31.03.1996	42,00
NO 6506/12-11 S	02.07.1996	16.07.1996	179,25
NO 6506/11-5 S	19.09.1996	29.09.1996	210,68
NO 6506/12-R-1 H	16.02.1997	15.03.1997	79,53
NO 6506/12-L-1 H	27.04.1997	17.05.1997	126,55
NO 6506/11-G-3 H	07.05.1997	07.06.1997	81,18
NO 6506/12-L-2 H	11.07.1997	25.07.1997	174,12
NO 6506/12-K-3 H	12.07.1997	31.07.1997	104,03
NO 6506/12-P-3 H	29.08.1997	05.10.1997	77,86
NO 6506/12-K-2 H	13.09.1997	06.10.1997	119,76
NO 6506/12-S-1 H	23.11.1997	16.12.1997	107,83
NO 6506/12-S-1 AH	03.01.1998	02.02.1998	69,00
NO 6506/12-R-4 H	11.01.1998	31.01.1998	96,24
NO 6506/12-P-2 H	11.03.1998	01.04.1998	100,01
NO 6506/12-I-1 H	23.04.1998	16.05.1998	170,60
NO 6506/12-S-2 H	02.05.1998	22.05.1998	108,25
NO 6506/12-I-3 H	31.05.1998	19.06.1998	146,57
NO 6506/12-R-2 H	01.07.1998	15.07.1998	160,12
NO 6506/12-L-3 H	22.07.1998	02.08.1998	217,69
NO 6506/12-K-1 H	06.08.1998	20.08.1998	180,45
NO 6506/12-S-3 H	03.09.1998	27.09.1998	114,97
NO 6506/11-G-4 HT2	02.11.1998	16.11.1998	193,69
NO 6506/12-P-1 H	03.11.1998	17.11.1998	166,53
NO 6506/12-L-4 H	25.01.1999	12.02.1999	133,73
NO 6506/12-L-2 AH	02.03.1999	24.03.1999	145,17
NO 6506/12-I-2 H	19.04.1999	03.05.1999	174,76
NO 6506/11-F-2 H	19.06.1999	11.07.1999	111,88
NO 6506/12-J-2 H	02.09.1999	13.09.1999	180,30
NO 6506/12-J-3 H	29.09.1999	18.10.1999	135,49
NO 6506/12-M-3 HT2	09.05.2000	30.05.2000	161,72
NO 6506/12-N-4 H	20.05.2000	17.06.2000	122,39

Table is continued on next page.

Well	Section start	Section end	Drilling performance m/day
NO 6506/11-E-3 H	01.08.2000	14.08.2000	199,56
NO 6506/12-H-3 H	29.09.2000	15.10.2000	143,64
NO 6506/12-H-1 H	03.11.2000	17.11.2000	196,54
NO 6506/12-J-4 H	20.12.2000	03.01.2001	186,59
NO 6506/12-M-1 H	27.01.2001	07.02.2001	197,72
NO 6506/12-S-4 H	07.03.2001	24.03.2001	146,29
NO 6506/12-N-3 H	10.05.2001	27.05.2001	143,57
NO 6506/12-H-4 H	05.08.2001	12.08.2001	323,51
NO 6506/12-P-4 H	01.09.2001	09.09.2001	228,80
NO 6506/12-N-2 H	03.09.2001	26.09.2001	156,15
NO 6506/12-M-2 H	26.09.2001	08.10.2001	219,65
NO 6506/12-M-4 H	23.03.2002	12.04.2002	172,91
NO 6506/12-N-1 H	06.02.2004	24.02.2004	133,55
NO 6506/12-Q-2 H	10.05.2004	24.05.2004	183,09
NO 6506/12-Q-3 H	11.09.2005	02.10.2005	117,26
NO 6506/12-M-2 AH	03.02.2006	25.02.2006	125,61
NO 6506/12-Q-1 H	13.06.2006	30.06.2006	124,55
NO 6506/12-Q-4 H	21.11.2006	20.12.2006	70,61
NO 6506/12-J-1 H	12.05.2007	24.05.2007	164,24
NO 6506/12-R-3 Y1H	21.07.2007	04.08.2007	134,92
NO 6506/12-I-1 AH	20.06.2008	26.07.2008	99,43
NO 6506/12-Q-5 Y1H	10.09.2009	02.10.2009	101,13
NO 6506/12-K-4 H	03.05.2011	21.05.2011	134,14
NO 6506/12-P-1 AH	20.07.2011	17.08.2011	78,72
NO 6506/11-F-3 H	21.07.2012	24.07.2012	141,46
NO 6506/12-H-2 HT2	20.08.2013	03.09.2013	157,44
NO 6506/12-Q-3 BH	17.02.2014	05.03.2014	132,01

Wells are listed in chronological order.

Appendix B - Breakdown of operations of all wells analyzed

1	Well	6506/11-4 S	NO 6506/12-11 S	6506/11-5 S	NO 6506/12-R-1 H	NO 6506/12-L-1 H
2	Section start	06.03.1996	02.07.1996	19.09.1996	16.02.1997	27.04.1997
3	Section end	31.03.1996	16.07.1996	29.09.1996	15.03.1997	17.05.1997
4	Section start depth	2828	2242,00	2140,00	2028,00	2170,00
5	Section end depth	4530	4759,00	4238,00	4205,00	4788,00
6	Section length	1702,00	2517,00	2098,00	2177,00	2618,00
7	MU PU all drilling equipment	12	10,5	9,5	22,5	13,5
8	Drilling	150,5	141	99	214,5	171,5
9	Flowcheck and circulate open hole	13	9	23,5	30,5	22,5
10	Flowcheck and circulate cased hole / displace mud	2		2		2,8
11	RIH	12	14,5	15,5	44	36,2
12	POOH	16,5	19	13,5	48	29,5
13	Cut and slip drill-line	4	0,5	2	2	3,5
14	Ream and wash	11,5	4	1,5	9,5	6
15	L/D all equipment	8,5		5	9,5	8
16	Pre job meeting, drills, infomeetings and washing on drillfloor	2	0,5	2	0,5	1
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	15,5	15	15	6,5	10
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	29,5	30	23,5	38,5	32
19	Cement job	10	7	9	8,5	10
20	Pressure test seal assembly and POOH		3		1,5	
21	Pressure test / function test BOP	1	2,5	4,5	14,5	5
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)	5	2,5	3		2,5
23	RU, perform and LD coring					
24	Fishing (waiting on equipment and all time spent)					16,5
25	FIT		1	1	1	
26	Other	1	1,5	2,5	5	3,5
27	Incidents w/downtime - hole problems	496,5	7,5	2	8,5	
28	Incidents w/downtime - Equipment problems and other problems	41,5	38,5	5	15	94,5
29	Cement logging (rigging up, logging, rigging down)					
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)	108,5	29,5		28	28
31	Waiting on weather	32			149	
32	Other waiting					
33	Operational hours	972,5	337	239	657	496,5

1	Well	NO 6506/11-G-3 H	NO 6506/12-L-2 H	NO 6506/12-K-3 H	NO 6506/12-P-3 H	NO 6506/12-K-2 H
2	Section start	07.05.1997	11.07.1997	12.07.1997	29.08.1997	13.09.1997
3	Section end	07.06.1997	25.07.1997	31.07.1997	05.10.1997	06.10.1997
4	Section start depth	2278	2190	2155	2569	2802
5	Section end depth	4798	4479	4099	5450	5524
6	Section length	2520,00	2289,00	1944,00	2881,00	2722,00
7	MU PU all drilling equipment	18	8,5	18,5	19	15,5
8	Drilling	229	147	120,5	463,5	261,5
9	Flowcheck and circulate open hole	7	8	9,5	16	26
10	Flowcheck and circulate cased hole / displace mud	4	4			
11	RIH	15,5	19,5	26,5	57,5	36
12	POOH	24	26,5	22	35	34
13	Cut and slip drill-line	1,5	2,5	1,5	2,5	3,5
14	Ream and wash	3	0,5	2	25	9,5
15	L/D all equipment	5	9	5	14	10,5
16	Pre job meeting, drills, infomeetings and washing on drillfloor	0,5	0,5	0,5	2	2,5
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	11,5	5,5	13,5	12,5	12
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	50	32	40	57	55,5
19	Cement job	8	7	9,5	9,5	13
20	Pressure test seal assembly and POOH	1				0,5
21	Pressure test / function test BOP	4	5	4,5	11,5	7,5
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)			2	5,5	0,5
23	RU, perform and LD coring					
24	Fishing (waiting on equipment and all time spent)	177,5				
25	FIT	0,5				
26	Other	5,5		5	0,5	18
27	Incidents w/downtime - hole problems	101,5	15,5		6,5	2,5
28	Incidents w/downtime - Equipment problems and other problems	78	15,5	145	129,5	13,5
29	Cement logging (rigging up, logging, rigging down)					
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)		9	23	4	9
31	Waiting on weather				17	14,5
32	Other waiting					
33	Operational hours	**745**	**315,5**	**448,5**	**888**	**545,5**

1	Well	NO 6506/12-S-1 H	NO 6506/12-S-1 AH	NO 6506/12-R-4 H	NO 6506/12-P-2 H	NO 6506/12-I-1 H
2	Section start	23.11.1997	03.01.1998	11.01.1998	11.03.1998	23.04.1998
3	Section end	16.12.1997	02.02.1998	31.01.1998	01.04.1998	16.05.1998
4	Section start depth	2221	2240	2150	2120	2110,00
5	Section end depth	4600	4353	4131	4191	4310,00
6	Section length	2379,00	2113,00	1981,00	2071,00	2200,00
7	MU PU all drilling equipment	23,5	16	20,5	18,5	8,5
8	Drilling	298,5	371,5	223	264,5	184,5
9	Flowcheck and circulate open hole	7,5	14	17,5	11	8
10	Flowcheck and circulate cased hole / displace mud	1	4		6	
11	RIH	36	35,5	11	28	15
12	POOH	36	32	10	30	10,5
13	Cut and slip drill-line	3	3,5	2	2	1
14	Ream and wash	5,5	4	5	0,5	1,5
15	L/D all equipment	10	9,5	3,5	9,5	6
16	Pre job meeting, drills, infomeetings and washing on drillfloor	5	3,5	1,5	1	1
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	13,5	13,5	7	10	7,5
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	34	45	44	47,5	34
19	Cement job	12,5	7,5	8	12	12
20	Pressure test seal assembly and POOH	1	1,5	1		1
21	Pressure test / function test BOP	10	15,5	16	10	5
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)	4,5	2,5	1,5	2,5	1,5
23	RU, perform and LD coring					
24	Fishing (waiting on equipment and all time spent)					
25	FIT					
26	Other	2,5	3,5	2	10	3
27	Incidents w/downtime - hole problems					
28	Incidents w/downtime - Equipment problems and other problems	17,5	73,5	25	8,5	9,5
29	Cement logging (rigging up, logging, rigging down)					
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)	8	10,5	54,5	11,5	
31	Waiting on weather		68,5	41	14	
32	Other waiting					
33	Operational hours	**529,5**	**735**	**494**	**497**	**309,5**

1	Well	NO 6506/12-S-2 H	NO 6506/12-I-3 H	NO 6506/12-R-2 H	NO 6506/12-L-3 H	NO 6506/12-K-1 H
2	Section start	02.05.1998	31.05.1998	01.07.1998	22.07.1998	06.08.1998
3	Section end	22.05.1998	19.06.1998	15.07.1998	02.08.1998	20.08.1998
4	Section start depth	2312,00	2516,00	2122,00	2261,00	2342,00
5	Section end depth	4407,00	5310,00	4347,00	4583,00	4733,00
6	Section length	2095,00	2794,00	2225,00	2322,00	2391,00
7	MU PU all drilling equipment	15	12,5	3,5	6,5	22,5
8	Drilling	254,5	282,5	201,5	135,5	148,5
9	Flowcheck and circulate open hole	15	21	2	7,5	16
10	Flowcheck and circulate cased hole / displace mud	4,5				
11	RIH	23	18,5	6,5	13,5	19
12	POOH	18	8	10,5	11,5	19,5
13	Cut and slip drill-line	5		2	1	1
14	Ream and wash	7,5	8,5	0,5	0,5	2
15	L/D all equipment	9,5	9	4	4	13
16	Pre job meeting, drills, infomeetings and washing on drillfloor	2	2,5	1	1,5	1,5
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	11	4,5	11	10	7
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	47	44,5	35,5	37	37
19	Cement job	7,5	11	6,5	7,5	9,5
20	Pressure test seal assembly and POOH			0,5	0,5	
21	Pressure test / function test BOP	4	11	4,5	3	2,5
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)	1,5	4	2	2	2,5
23	RU, perform and LD coring					
24	Fishing (waiting on equipment and all time spent)					
25	FIT					
26	Other	8		3	1,5	0,5
27	Incidents w/downtime - hole problems		1,5	27,5		
28	Incidents w/downtime - Equipment problems and other problems	22	2	4	1,5	11
29	Cement logging (rigging up, logging, rigging down)					
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)	9,5	16,5	7,5	11,5	5
31	Waiting on weather					
32	Other waiting					
33	Operational hours	**464,5**	**457,5**	**333,5**	**256**	**318**

1	Well	NO 6506/12-S-3 H	NO 6506/11-G-4 HT2	NO 6506/12-P-1 H	NO 6506/12-L-4 H	NO 6506/12-L-2 AH
2	Section start	03.09.1998	02.11.1998	03.11.1998	25.01.1999	02.03.1999
3	Section end	27.09.1998	16.11.1998	17.11.1998	12.02.1999	24.03.1999
4	Section start depth	2652,00	2932,00	2174,00	2315,00	2200,00
5	Section end depth	5555,00	5797,00	4502,00	4736,00	5303,00
6	Section length	2903,00	2865,00	2328,00	2421,00	3103,00
7	MU PU all drilling equipment	26	6	5,5	8,5	8,5
8	Drilling	330	158,5	178	217,5	251
9	Flowcheck and circulate open hole	44	19	2,5	11,5	15
10	Flowcheck and circulate cased hole / displace mud		3,5	2,5	1	2
11	RIH	32	25,75	15	14	43,5
12	POOH	16	18,75	11	11	27,5
13	Cut and slip drill-line	2,5	1,5	1	2	5,5
14	Ream and wash	5	5			12
15	L/D all equipment	13,5	9,5	5	7	11,5
16	Pre job meeting, drills, infomeetings and washing on drillfloor	2	2	2	2,5	2
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	8,5	12,5	8,5	6	27
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	56,5	45	35,5	39	23,5
19	Cement job	7	8	5	9	7
20	Pressure test seal assembly and POOH	1	0,5	1	1	1
21	Pressure test / function test BOP	10,5	5,5	2,5	4,5	10
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)	4,5	4	1		1,5
23	RU, perform and LD coring					
24	Fishing (waiting on equipment and all time spent)					
25	FIT					0,5
26	Other	0,5		1		
27	Incidents w/downtime - hole problems					
28	Incidents w/downtime - Equipment problems and other problems	39,5	1	47	11	48,5
29	Cement logging (rigging up, logging, rigging down)					
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)	7	9	8,5	8	2
31	Waiting on weather			3	81	13,5
32	Other waiting					
33	Operational hours	**606**	**335**	**335,5**	**434,5**	**513**

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1	Well	NO 6506/12-I-2 H	NO 6506/11-F-2 H	NO 6506/12-J-2 H	NO 6506/12-J-3 H	NO 6506/12-M-3 HT2
2	Section start	19.04.1999	19.06.1999	02.09.1999	29.09.1999	09.05.2000
3	Section end	03.05.1999	11.07.1999	13.09.1999	18.10.1999	30.05.2000
4	Section start depth	2226,00	2210	2090	2072	2884
5	Section end depth	4578,00	4669	4047	4525	6260
6	Section length	2352,00	2459,00	1957,00	2453,00	3376,00
7	MU PU all drilling equipment	15	11,5	13	16	12
8	Drilling	184,5	315,5	141	231	250,25
9	Flowcheck and circulate open hole	8	25	6	12	43,5
10	Flowcheck and circulate cased hole / displace mud	2,5	6,5	2	0,5	3
11	RIH	20	29,5	9,5	17	31,5
12	POOH	17	27	17	16,5	12,5
13	Cut and slip drill-line	1	2	1	3	3
14	Ream and wash	0,5	9	1		57,25
15	L/D all equipment	11,5	10,5	0,5	12,5	10
16	Pre job meeting, drills, infomeetings and washing on drillfloor	1,5	6	2,5	4	0,5
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	7,5	1	13	10,5	11,5
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	31	32	27	43,5	41
19	Cement job	11,5	9	6,5	6	7
20	Pressure test seal assembly and POOH					1
21	Pressure test / function test BOP	3	7,5	3	3,5	2,5
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)	1,5	3,5		2	1
23	RU, perform and LD coring					
24	Fishing (waiting on equipment and all time spent)					
25	FIT					
26	Other	1		1		0,5
27	Incidents w/downtime - hole problems				54	3
28	Incidents w/downtime - Equipment problems and other problems	5	10	16,5	1,5	9
29	Cement logging (rigging up, logging, rigging down)					
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)	1	13,5		1	
31	Waiting on weather		0,5			
32	Other waiting		8			1
33	Operational hours	**323**	**527,5**	**260,5**	**434,5**	**501**

1	Well	NO 6506/12-N-4 H	NO 6506/11-E-3 H	NO 6506/12-H-3 H	NO 6506/12-H-1 H	NO 6506/12-J-4 H
2	Section start	20.05.2000	01.08.2000	29.09.2000	03.11.2000	20.12.2000
3	Section end	17.06.2000	14.08.2000	15.10.2000	17.11.2000	03.01.2001
4	Section start depth	2332	2308	2110	2152	2220
5	Section end depth	5476	5002	4504	4834	4805
6	Section length	3144,00	2694,00	2394,00	2682,00	2585,00
7	MU PU all drilling equipment	8,5	14,5	7	11,5	10
8	Drilling	362,5	188	186	200	185,5
9	Flowcheck and circulate open hole	13,5	7,5	6,5	9	29
10	Flowcheck and circulate cased hole / displace mud	4			1	
11	RIH	25,5	21	17,5	17	22,5
12	POOH	52,5	20,5	12	16,5	15
13	Cut and slip drill-line	2,5	2	3	1,5	2
14	Ream and wash	3	5	1	2,5	0,5
15	L/D all equipment	2	11,5	7	5,5	5,5
16	Pre job meeting, drills, infomeetings and washing on drillfloor	0,5	1,5	2	2,5	1
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	6,5	2,5	10	11	7,5
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	51	25,5	30	28,5	31
19	Cement job	22	8	5,5	6,5	5
20	Pressure test seal assembly and POOH		1,5	0,5	0,5	0,5
21	Pressure test / function test BOP		3	3,5	2,5	2,5
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)			3	2	
23	RU, perform and LD coring					
24	Fishing (waiting on equipment and all time spent)					
25	FIT					
26	Other			0,5	1,5	1,5
27	Incidents w/downtime - hole problems			94		1
28	Incidents w/downtime - Equipment problems and other problems	46	10	11	3	1,5
29	Cement logging (rigging up, logging, rigging down)					
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)		2		3,5	11
31	Waiting on weather	16,5				
32	Other waiting				1,5	
33	Operational hours	616,5	324	400	327,5	332,5

1	Well	NO 6506/12-M-1 H	NO 6506/12-S-4 H	NO 6506/12-N-3 H	NO 6506/12-H-4 H	NO 6506/12-P-4 H
2	Section start	27.01.2001	07.03.2001	10.05.2001	05.08.2001	01.09.2001
3	Section end	07.02.2001	24.03.2001	27.05.2001	12.08.2001	09.09.2001
4	Section start depth	2274	2053	2100	2092	2080
5	Section end depth	4556	4549	4463	4242	3858
6	Section length	2282,00	2496,00	2363,00	2150,00	1778,00
7	MU PU all drilling equipment	9	16,5	7	7,5	3,5
8	Drilling	148	219,5	208,5	84	99,5
9	Flowcheck and circulate open hole	10,5	17,5	8	3,5	4,5
10	Flowcheck and circulate cased hole / displace mud				1,5	0,5
11	RIH	13,5	28,5	21,5	10,5	11
12	POOH	10,5	19	21	6	11,5
13	Cut and slip drill-line	1	2	3	1	1,5
14	Ream and wash	0,5	7,5	11		0,5
15	L/D all equipment	5	15	4	4	3
16	Pre job meeting, drills, infomeetings and washing on drillfloor	1	2,5	2,5	1	3
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	14	7	9	2,5	8,5
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	27	29,5	30	26	20,5
19	Cement job	10	8,5	6,5	6	7
20	Pressure test seal assembly and POOH	1,5				
21	Pressure test / function test BOP	3,5	2	2,5	1	
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)	2,5	3,5	1	1,5	
23	RU, perform and LD coring					
24	Fishing (waiting on equipment and all time spent)					
25	FIT					0,5
26	Other	0,5		3,5	0,5	0,5
27	Incidents w/downtime - hole problems		11			
28	Incidents w/downtime - Equipment problems and other problems	8,5	18	2,5		4
29	Cement logging (rigging up, logging, rigging down)					
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)	10,5	2	53,5		7
31	Waiting on weather					
32	Other waiting				3	
33	Operational hours	**277**	**409,5**	**395**	**159,5**	**186,5**

		NO 6506/12-N-2 H	NO 6506/12-M-2 H	NO 6506/12-M-4 H	NO 6506/12-N-1 H	NO 6506/12-Q-2 H
1	Well	NO 6506/12-N-2 H	NO 6506/12-M-2 H	NO 6506/12-M-4 H	NO 6506/12-N-1 H	NO 6506/12-Q-2 H
2	Section start	03.09.2001	26.09.2001	23.03.2002	06.02.2004	10.05.2004
3	Section end	26.09.2001	08.10.2001	12.04.2002	24.02.2004	24.05.2004
4	Section start depth	2260	2078	2434	2158	2167
5	Section end depth	5845	4636	5867	4662	4316
6	Section length	3585,00	2558,00	3433,00	2504,00	2149,00
7	MU PU all drilling equipment	11,5	3	9	17	7,3
8	Drilling	216,5	158,5	220	196,5	120,4
9	Flowcheck and circulate open hole	18,5	2	20	8,5	13
10	Flowcheck and circulate cased hole / displace mud					
11	RIH	19	5,5	45	35	27,8
12	POOH	24	6,5	26,5	36	15,6
13	Cut and slip drill-line	2	2	3,5		1
14	Ream and wash	17		6	1,5	1,5
15	L/D all equipment	8,5	3,5	27,5	9	5,3
16	Pre job meeting, drills, infomeetings and washing on drillfloor	0,5	1,5	3,5	3	1
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	9	10	7,5	7,5	8,8
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	49,5	29	45	49	48,8
19	Cement job	21,5	4,5	9,5	10	13,6
20	Pressure test seal assembly and POOH					1,5
21	Pressure test / function test BOP	4,5	5	2	12	
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)	2	2	1,5	3	
23	RU, perform and LD coring					
24	Fishing (waiting on equipment and all time spent)					
25	FIT					
26	Other	1,5		2	1,5	1,6
27	Incidents w/downtime - hole problems	131,5				
28	Incidents w/downtime - Equipment problems and other problems	14	46,5	22,5	35,5	4
29	Cement logging (rigging up, logging, rigging down)					
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)				18	10,5
31	Waiting on weather			24,5	7	
32	Other waiting			1		
33	Operational hours	**551**	**279,5**	**476,5**	**450**	**281,7**

1	Well	NO 6506/12-Q-3 H	NO 6506/12-M-2 AH	NO 6506/12-Q-1 H	NO 6506/12-Q-4 H	NO 6506/12-J-1 H
2	Section start	11.09.2005	03.02.2006	13.06.2006	21.11.2006	12.05.2007
3	Section end	02.10.2005	25.02.2006	30.06.2006	20.12.2006	24.05.2007
4	Section start depth	2269	2095	2137	2133	2018
5	Section end depth	4704	4896	4288	4195	4095
6	Section length	2435,00	2801,00	2151,00	2062,00	2077,00
7	MU PU all drilling equipment	15,2	13,3	7,8	11,5	4,5
8	Drilling	209,4	204,3	156,6	146,9	81
9	Flowcheck and circulate open hole	28,8	11,7	4,2	9,3	11,5
10	Flowcheck and circulate cased hole / displace mud	10,6	4,5	2,8	9,6	1,5
11	RIH	40,6	24,2	19,9	20,1	6,5
12	POOH	39,8	34,3	11,4	10,3	17,5
13	Cut and slip drill-line	2,3	1,5	1,5	1,3	1,5
14	Ream and wash	8,9	3,1		1,3	0,5
15	L/D all equipment	3,8	9,8	1,8	3,5	2
16	Pre job meeting, drills, infomeetings and washing on drillfloor	4,3	3,6	4,6	2,9	2
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	11,8	10,6	10,7	10,9	6
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	53,9	64	47,5	50,5	50
19	Cement job	13,5	15,8	16,2	8,2	5,5
20	Pressure test seal assembly and POOH			0,8	1,8	
21	Pressure test / function test BOP	6,4	4,8		6,1	1
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)	2	5,3	8,6		
23	RU, perform and LD coring					70,5
24	Fishing (waiting on equipment and all time spent)					
25	FIT					
26	Other	2,5	5,6	1,5	2,3	1,5
27	Incidents w/downtime - hole problems			34,3	207,9	
28	Incidents w/downtime - Equipment problems and other problems	12,6	61,2	84,3	20,8	25
29	Cement logging (rigging up, logging, rigging down)					
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)	11,1	18		9,4	15,5
31	Waiting on weather	20,9	39,6		166,3	
32	Other waiting					
33	Operational hours	**498,4**	**535,2**	**414,5**	**700,9**	**303,5**

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1	Well	NO 6506/12-R-3 Y1H	NO 6506/12-I-1 AH	NO 6506/12-Q-5 Y1H	NO 6506/12-K-4 H	NO 6506/12-P-1 AH
2	Section start	21.07.2007	20.06.2008	10.09.2009	03.05.2011	20.07.2011
3	Section end	04.08.2007	26.07.2008	02.10.2009	21.05.2011	17.08.2011
4	Section start depth	2138	2103	2228,00	2312,00	2120,00
5	Section end depth	4114	5681	4436,00	4707,00	4396,00
6	Section length	1976,00	3578,00	2208,00	2395,00	2276,00
7	MU PU all drilling equipment	13,1	21,5	15,5	6,3	34,6
8	Drilling	167,3	199,8	253	150,8	147,2
9	Flowcheck and circulate open hole	14,6	19	6,5	19,7	30,1
10	Flowcheck and circulate cased hole / displace mud	4,5	16	22	11,4	14,4
11	RIH	18,8	43	30	10,3	61,2
12	POOH	31,4	46	28,5	11,9	54,5
13	Cut and slip drill-line			3,5		2
14	Ream and wash		9,5	4,5	4,3	7,2
15	L/D all equipment	2,5	8	9		22,9
16	Pre job meeting, drills, infomeetings and washing on drillfloor	3,8	4	8	6,4	15,8
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	8,5	18,5	14,5	6,7	14,1
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	50	82,5	54	55,7	47,2
19	Cement job	9	10,5	8,5	12	14,5
20	Pressure test seal assembly and POOH		0,5		1	
21	Pressure test / function test BOP		20,5	4,5	7,9	16,3
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)		10	2,5	2	4,3
23	RU, perform and LD coring					
24	Fishing (waiting on equipment and all time spent)					
25	FIT				1,5	
26	Other	2	7,5	7	15,1	16,8
27	Incidents w/downtime - hole problems		250,8			2,5
28	Incidents w/downtime - Equipment problems and other problems	10	64	29	50,5	41,6
29	Cement logging (rigging up, logging, rigging down)				34,6	45,7
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)	16	32	23,5	15,5	101
31	Waiting on weather					
32	Other waiting				4,9	
33	Operational hours	**351,5**	**863,6**	**524**	**428,5**	**693,9**

1	Well	NO 6506/11-F-3 H	NO 6506/12-H-2 HT2	NO 6506/12-Q-3 BH
2	Section start	21.07.2012	20.08.2013	17.02.2014
3	Section end	24.07.2012	03.09.2013	05.03.2014
4	Section start depth	2264	2156,00	2242,00
5	Section end depth	4584	4351,00	4385,00
6	Section length	2320,00	2195,00	2143,00
7	MU PU all drilling equipment	25	13,4	15,1
8	Drilling	148,1	88,8	103,9
9	Flowcheck and circulate open hole	30,1	22,4	14,7
10	Flowcheck and circulate cased hole / displace mud		16,5	6,4
11	RIH	22,5	24,6	8,8
12	POOH	30,7	17,4	13,5
13	Cut and slip drill-line		1	1,8
14	Ream and wash	4,3	3,3	2,8
15	L/D all equipment	9,2	11	
16	Pre job meeting, drills, infomeetings and washing on drillfloor	6,3	10,4	14,6
17	RU / M/U L/D to run 9 5/8" and 10 3/4" casing and release/set wearbushing and seal assembly	2,3	4,7	16,3
18	Run 9 5/8" casing (inc retrieving wear bushing, pressure testing circulating and other work inbetween)	49,3	49,7	54,8
19	Cement job	20,9	21,7	15,3
20	Pressure test seal assembly and POOH	0,5		2,8
21	Pressure test / function test BOP	4,1	3,5	7,8
22	Pressure test equipment. (Kelly cock,top drive, IBOP, Mud hoses, spare parts etc)		2,6	2,3
23	RU, perform and LD coring			
24	Fishing (waiting on equipment and all time spent)			
25	FIT			1,3
26	Other	1,3	9,4	6,3
27	Incidents w/downtime - hole problems			
28	Incidents w/downtime - Equipment problems and other problems	9,2	7,1	26,3
29	Cement logging (rigging up, logging, rigging down)		12	
30	Logging, surveys or coring inc cluster shot (Rigging up, logging, rigging down)	1,8	15,1	74,8
31	Waiting on weather	28		
32	Other waiting			
33	Operational hours	**393,6**	**334,6**	**389,6**

Appendix C - Overview of time distribution on all drilling sections

	A	B	C	D	E	F	G	H	I	J
1	10	2								
2	time_period	sum_level	u	k	d	w	wow	sum_type	op_type	Title
3	(01.01.1996 - 01.01.2015)	HALTEN/NORDLAND	2097,5942	190,73	396,80792	14,34375	77,2466667	Area	Drilling	Total operation time per Area
4										
5			2776,722537							
6			0,7554	0,0687	0,1429	0,0052	0,0278			

Appendix D - Overview of time distribution on the 12 1/4'' drilling section

	A	B	C	D	E	F	G	H	I	J
1	10	2								
2	time_period	sum_level	u	k	d	w	wow	sum_type	op_type	Title
3	(01.01.1996 - 01.01.2015)	HALTEN/NORDLAND	837,033	83,3646	148,125	3,072916667	29,5417	Area	Drilling	Total operation time per Area
4										
5		Totaltid	1101,137217							
6			0,7602	0,0757	0,1345	0,0028	0,0268			

Appendix E - Overview of time distribution on the 12 1/4'' drilling section in Interval 1

	A	B	C	D	E	F	G	H	I	J
1	10	2								
2	time_period	sum_level	u	k	d	w	wow	sum_type	op_type	Title
3	(01.01.1996 - 01.01.2003)	HALTEN/NORDLAND	580,146	72,354	98,21	2,75	18,21	Area	Drilling	Total operation time per Area
4										
5			771,67							
6			0,7518	0,0938	0,1273	0,0036	0,0236			

Appendix F - Overview of time distribution on the 12 1/4'' drilling section in Interval 2

	A	B	C	D	E	F	G	H	I	J
1	10	1								
2	time_period	sum_level	u	k	d	w	wow	sum_type	op_type	Title
3	(01.01.2003 - 01.01.2014)	HALTEN/NORDLAND	241,9483333	11,01041667	48,82291667	0,322916667	11,33333333	Area	Drilling	Total operation time per Area
4										
5			313,4379167							
6			0,7719	0,0351	0,1558	0,0010	0,0362			

Appendix G - Mapping of operations for chapter 4.3.1 and 4.3.2

			Interval 1	Interval 2	Difference
No	Consist of operation		Average hours	Average hours	Hours
1	2: Drilling		216,14	158,27	-57,9
	3: Flowcheck and circ open hole		14,74	16,27	1,5
	4: Flowcheck and circ cased hole / displace mud		1,4	8,01	6,6
	8: Ream and wash		5,87	3,51	-2,4
2	5: RIH		23,33	26,22	2,9
	6: POOH		20,66	26,59	5,9
3	12: Run 9 5/8" casing		37,43	53,79	16,4
4	11: R/U R/D for casing and seal assy		9,88	10,13	0,3
5	13: Cement job		8,93	13,01	4,1
6	21: Incident Downhole		26,48	32,07	5,6
7	22: Incident equipment and other problems		11,69	33,03	21,3
8	17: Coring		0	4,7	4,7
	23: Cement logging		0	6,15	6,2
	24: Logging, surveys,		9,87	22,95	13,1
9	14: Pressure test seal assy and POOH		0,54	0,59	0,0
	15: Pressure test / function test BOP		5,46	6,33	0,9
	16: Pressure test eq (kelly cock, top drive, iBOP, etc)		1,88	2,84	1,0
10	1: M/U drilling eq		12,57	14,74	2,2
	7: Slip and cut drill line		2,16	1,16	-1,0
	9: L/D drilling eq		8,13	6,52	-1,6
	10: Pre job meetings, drills, info, was DF		1,89	6,05	4,2
	18: Fishing (wait on eq and all time spent fishing)		4,73	0	-4,7
	19: FIT		0,11	0,1	0,0
	20: Other		2,22	5,46	3,2
	25: WOW		10,8	17,45	6,7
	26: Other waiting		0,28	0,33	0,1
	Sum hours		436,91	475,94	39,0

Appendix H - Average values for drilling performance factors

Drilling and circulation performance	Average Interval 1	Average Interval 2
Average hours	238,15	186,07
Average Interval 2 - Average Interval 1	**-52,09**	
Tripping performance	Average Interval 1	Average Interval 2
Average hours	43,99	52,81
Average Interval 2 - Average Interval 1	**8,82**	
Casing performance in hole	Average Interval 1	Average Interval 2
Average hours	37,43	53,79
Average Interval 2 - Average Interval 1	**16,36**	
Casing performance - surface activities	Average Interval 1	Average Interval 2
Hours	9,88	10,13
Average Interval 2 - Average Interval 1	**0,25**	
Cement performance	Average Interval 1	Average Interval 2
Average hours	8,93	13,01
Average Interval 2 - Average Interval 1	**4,08**	
Downtime performance downhole problems	Average Interval 1	Average Interval 2
Average hours	11,69	33,03
Average Interval 2 - Average Interval 1	**21,34**	
Downtime performance equipment problem	Average Interval 1	Average Interval 2
Average hours	26,48	32,07
Average Interval 2 - Average Interval 1	**5,59**	
Data acquisition	Average Interval 1	Average Interval 2
Average hours	9,87	33,8
Average Interval 2 - Average Interval 1	**23,93**	
Pressure testing performance	Average Interval 1	Average Interval 2
Average hours	7,88	9,76
Average Interval 2 - Average Interval 1	**1,88**	
Other operations performance	Average Interval 1	Average Interval 2
Average hours	42,89	51,81
Average Interval 2 - Average Interval 1	**8,92**	

Appendix I - Trend line values for drilling performance factors

	Plot for trend Interval 1		Plot for trend Interval 2		Total plot for trend from 1996 - 2014	
Drilling and circulation performance	Trendline startpoint in 1996	Trendline endpoint in 2002	Trendline startpoint 2004	Trendline endpoint in 2014	Trendline startpoint in 1996	Trendline endpoint in 2014
Meters / hour	11,800	13,700	13,500	19,000	11,60	18,20
Hours per well	208,56	179,64	182,30	129,53	212,16	135,22
Trendline endpoint - trendline startpoint	-28,92		-52,77		-76,94	
Tripping performance						
Tripping meters / hour	102,00	164,00	87	132	138	118
Hours per well	46,13	28,69	54,08	35,64	34,09	39,87
Trendline endpoint - trendline startpoint	-17,44		-18,44		5,78	
Casing performance in hole						
Casing meters / hour	113,00	158	86	85	140	80
Hours per well	41,64	29,78	54,71	55,35	33,61	58,81
Trendline endpoint - trendline startpoint	-11,86		0,64		25,21	
Casing performance - surface activities						
Hours per well	11,3	8,11	10,1	10	10	8
Trendline endpoint - trendline startpoint	-3,19		-0,10		-2,00	
Cement performance						
Hours per well	8,80	9,00	10	16,6	7,7	15,3
Trendline endpoint - trendline startpoint	0,20		6,6		7,6	
Downtime performance						
Percentage of total time	9,2 %	6,2 %	14,2 %	7,2 %	8,0 %	10,5 %
Hours per well	41,87	28,22	64,62	32,77	36,41	47,79
Trendline endpoint - trendline startpoint	-13,65		-31,86		11,38	
Data acquisition performance						
Hours used per well	19,00	3,5	12	63	4	48
Trendline endpoint - trendline startpoint	-15,50		51		44	
Pressure testing performance						
Hours used per well	12	3,1	8,2	11,5	8,00	9,20
Trendline endpoint - trendline startpoint	-8,9		3,3		1,20	
Other operations performance						
Hours used per well	67	14	48	57	44,00	48,00
Trendline endpoint - trendline startpoint	-53		9		4,00	

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