Summary report

DEEPWATER HORIZON

Lessons learned and follow-up

A Norwegian Oil Industry Association (OLF) report with contributions from the Norwegian Clean Seas Association for Operating Companies (NOFO) and the Norwegian Shipowners' Association (NSA)

Contents

1 Main conclusions

The project team has concluded that the NCS is characterised by robust legislation and safe operations. Even so, the Macondo accident and its follow-up have demonstrated that opportunities exist for further improvements in prevention, intervention and response.

The most important priority has been major accident prevention in the areas of well design, planning and execution, cementing and well control, which were identified as the root causes of the accident identified in the BP investigation. Other areas of prevention include management systems, culture, leadership, roles and responsibilities in addition to the design of mobile offshore drilling units (MODUs).

Improvements to intervention and response have also been important, including the areas of capping and containment, unified command (UC), oil spill preparedness and response, working environment and chemical exposure, and environmental impact.

Approach

The OLF Deepwater Horizon project has reviewed the major investigation reports and assessed their implications for Norwegian offshore activities.

A number of international initiatives have been pursued in response to Macondo, including those from International Association of Oil and Gas Producer (OGP), Oil and Gas UK and American Petroleum Institute (API). OLF's recommendations also build on these.

Major accident prevention

The majority of the prevention recommendations will be implemented through changes to the Norwegian drilling standards, Norsok D-001 (drilling facilities) and D-010 (well integrity in drilling and well operations). These include operational issues such as critical cement jobs, lockdown requirements for tubing and casing hangers, negative pressure testing and fluid displacement requirements, enhanced well control exercises, diverter line-up, improved blowout preventer (BOP) back-up control systems and enhanced BOP testing requirements. Important proposed improvements to management systems include management of change, well management systems, process safety, and enhancements of rig-site teamwork and communication.

The report's recommendations cover the assessment of internal verification processes and the well management system (WMS). Combined with improved management of change processes, this should ensure that well design and onshore support teams hold risks to levels as low as reasonably practicable (ALARP) throughout the well lifecycle.

Drill crew expertise is being addressed internationally through OGP, and OLF is discussing crew resource management in the OGP committees to improve well-site teamwork and communication.

The project has determined that the Norwegian regulations for MODUs already comply with the technical recommendations on rig design made by the US Coast Guard.

Intervention and response

Macondo has also been a source of lessons in the areas of well capping and oil spill response. Solutions for well capping and containment are being addressed through the joint industry subsea well response project (SWRP). This initiative provides solutions for both the NCS and international waters.

The Macondo unified command system proved to be an efficient way of managing a large and prolonged incident. This approach is now considered best practice for major incidents, and OLF will work closely with the Norwegian Coastal Administration (NCA) to make a case for implementing the unified command principles in Norway. Through NOFO, the Norwegian oil industry is well prepared to handle a potential oil spill. NOFO's capacity will be further upgraded via its new preparedness strategy, which incorporates lessons learned from Macondo.

The project has also assessed the lessons learned concerning chemical exposure, which indicate that responders need to be provided with the necessary protection equipment and knowledge during and after any oil spill response.

An important conclusion from the project is that environmental studies conducted after the spill show its effects to be smaller than predicted. The rate of natural degradation of oil components by micro-organisms was much higher than expected, and the use of in-situ burning and underwater dispersants appears to have had a beneficial effect on the Macondo oil. OLF will encourage work on the underwater use of dispersants, and will continue monitoring scientific literature on the environment impacts of the Macondo blowout.

Recommendations to the Norwegian oil industry

The project team has 45 specific recommendations to the Norwegian oil industry. The objective is that, wherever possible, these recommendations will be incorporated into industry practice and standards.

The Norsok revision work has been on-going since spring 2011 and draft revisions for comments are planned for end of Q2 2012.

OLF considers it the responsibility of each individual operator and drilling contractor to review, evaluate and, if necessary, revise its internal management system and steering documentation to take account of these recommendations.

International cooperation

OLF has, to the extent possible, developed the recommendations in line with international initiatives and discussions. The objective of this approach has been to gain a broad consensus on all key issues, promote the development of new industry standards, and to facilitate acceptance and implementation across country and company boundaries.

The Deepwater Horizon accident

On 20 April 2010, a blowout occurred on the BP-operated Macondo well. 11 people died and the *Deepwater Horizon* rig sank. The well flowed oil into the Gulf of Mexico for 87 days before it could be controlled.

At the time of the incident, *Deepwater Horizon* was drilling an exploratory well in a water depth of about 5 000 feet (roughly 1 500 metres) on the Macondo prospect. This well is located in Mississippi Canyon block 252 in the US Gulf of Mexico.

Control of the well was lost on the evening of 20 April, allowing hydrocarbons to enter the drilling riser and reach *Deepwater Horizon*, causing explosions and subsequent fires. The latter continued to burn for about 36 hours. The rig sank on 22 April 2010.

From shortly before the explosions until 20 May 2010, when all remotely operated vehicle (ROV) intervention ceased, several efforts were made to seal the well. A sealing cap was finally installed and the well shut in on 15 July 2010. The well was then killed and later cemented on 3 August 2010. A relief well intersection on 16 September confirmed the well to be dead.

2 Introduction

After the *Deepwater Horizon* accident, OLF – working jointly with the Norwegian Clean Seas Association for Operating Companies (NOFO) – took a number of initiatives to

- gather available facts concerning the incident
- compare relevant regulations in Norway and the USA
- recommend changes and improvements on behalf of the Norwegian oil and gas industry to ensure that similar accidents do not happen on the NCS.

As a first step to improve understanding of the investigation reports which were to come, OLF and NOFO commissioned DNV to compare relevant regulations in Norway with those in the USA

A project was then formed in August 2010. The project comprised representatives from OLF, NOFO and the OLF member companies. The Norwegian Shipowners' Association (NSA) has also contributed to the project. The objective defined for the project was to assess the need for new methods and standards in Norway, both to prevent similar accidents in the future and to stop and limit the consequences of a subsea blowout should one ever occur.

The *Deepwater Horizon* accident has had a significant impact on the global offshore oil industry. Regulators, operators, and drilling and specialist contractors have found it necessary to review their operating and management practices.

OLF *Deepwater Horizon* project has reviewed the major investigation reports and assessed their implications for Norwegian offshore activities. A number of international initiatives have been pursued in response to Macondo, including those from the OGP, Oil and Gas UK and the API, and the OLF's recommendations also build on these.

OLF´s sources of information and data analysis

- **BP:** Deepwater Horizon Accident Investigation Report, September 2010
- **National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling:** Deepwater. Report to the President, January 2011; Chief Counsel's Report 2011, Macondo the Gulf Oil Disaster, February 2011
  US Coast Guard: Report of Investigation into the Circumstances
  Surrounding the Explosion, Fire, Sinking and Loss of Eleven Crew Members
  Aboard the Mobile Offshore Drilling Unit Deepwater Horizon, April 2011
- **SINTEF report:** Deepwater Horizon Accident May 2011
- **Petroleum Safety Authority Norway:** Deepwater Horizon-ulykken- vurdering og anbefalinger for norsk petroleumsvirksomhet [The Deepwater Horizon accident – assessments and recommendations for the Norwegian petroleum industry], June 2011
- **BOEMRE:** Report Regarding the Causes of the April 20, 2010 Macondo Well Blowout, September 2011
- **OGP:** Deepwater Wells, and Oil Spill Response, global industry response group recommendations, May 2011
- **National Academy of Engineering:** Macondo Well Deepwater Horizon Blowout. Dec 2011

While the report has targeted improvements to practices on subsea wells, several of the recommendations are equally applicable to platform wells.

Comparison of Norwegian and US offshore drilling regulations

To provide a baseline for the Deepwater Horizon project, OLF commissioned a study to review and compare the offshore drilling regulatory regimes in Norway and the US Gulf of Mexico. This study was completed by DNV in September 2010 and identified similarities, but also noted fundamental differences between the two regimes in place at the time of the incident in April 2010. The review concluded that the Norwegian legislation is robust.

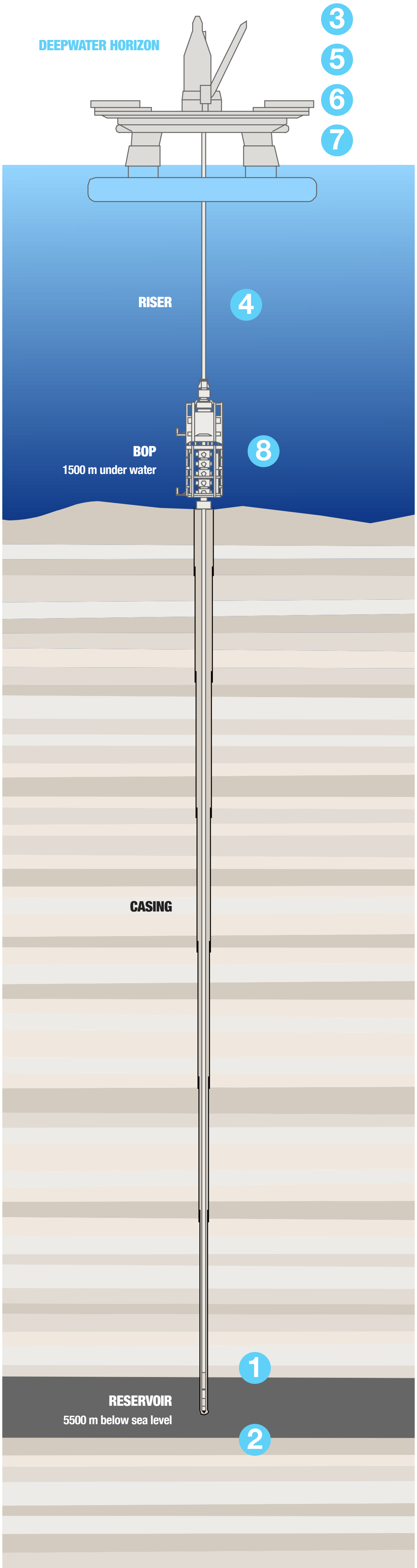
In Norway, offshore regulations are primarily performance-based and supplemented by prescriptive requirements through established norms and standards, whereas US regulations are generally prescriptive and do not require the application of systematic risk management. To implement this requirement, Norwegian regulations specify the performance or acceptable level of risk to be attained and maintained by the industry.

The prescriptive regulations in the USA define specific technical requirements for structures, technical equipment and operations to prevent accidents and mitigate hazards. And while these are in some respects simpler to review, implement and assess, they are generic and not linked to any level of risk. They also require frequent updating – when new technology is introduced, for instance.

Another major difference between the regulations on well design and operation is the Norwegian requirement for the systematic application of two independent and tested well barriers.

A mandatory requirement exists in Norway for the recertification of well control equipment every fifth year and drilling and well control equipment must be subject to independent review by a classification society. An alternative (back up) BOP control system is also required on all mobile rigs operating on the NCS.

In the course of the work, the project has concluded that the Norwegian regulatory regime and industry standards are robust and fit for purpose. Over the years, this has led to progressive improvements in safety performance and it is hoped that the experience drawn from the Macondo accident will facilitate further improvement.



Main technical causes

Well integrity was not established or failed

1 Annulus cement barrier did not isolate hydrocarbons

2 Shoe track barriers did not isolate hydrocarbons

Hydrocarbons entered the well undetected and well control was lost

3 Negative pressure test was accepted although well integrity had not been established

4 Influx was not recognized until hydrocarbons were in riser

5 Well control response actions failed to regain control of well

Hydrocarbons ignited on the Deepwater Horizon

6 Diversion to mud gas separator resulted in gas venting onto rig

7 Fire and gas system did not prevent hydrocarbon ignition

Blowout preventer did not seal the well

8 Blowout preventer (BOP) emergency mode did not seal well

3 Prevention

The investigation reports made it clear that prevention of future accidents should be the main focus of the project, so most of the OLF technical recommendations are targeted at the main causes of the accident, which were identified in the BP investigation report.

The first cause was the failure of the cement to isolate hydrocarbons behind the casing. To ensure cement quality in the hydrocarbon zone, OLF has proposed that provisions are included in Norsok D-010 identifying "critical" cement jobs, and a requirement for operators to secure independent verification of critical cement designs and placement plans.

Secondly, the accident was initiated by the undetected flow of hydrocarbons into the well. Under Norwegian rules, putting a well in an unbalanced condition prior to establishing well integrity is not accepted. Barrier verification should have taken place before circulating the well to an underbalanced condition. To further reduce risks, more explicit requirements are to be included in Norsok D-010 for conducting negative pressure (inflow) tests. As an urgent and easily implemented measure, OLF proposes that in well control drills, more emphasis be placed on pipe space out, simulated pipe shearing and diverter line up. Emergency drills should also cover high potential, low frequency events to ensure the entire well site crew are ready for any eventuality. OLF has also recommended that well control bridging documents are developed jointly by Operators and Drilling Contractors to identify relevant well control configurations, shut-in procedures and the roles and responsibilities of all involved in well control activities.

The third cause reflects the rig itself, where a gas cloud enveloped the *Deepwater Horizon* and exploded. In Norway, explosion risks are already significantly reduced by the Norwegian Maritime Directorate (NMD) requirement for automatic closure of air intakes and automatic shutdown of non-explosion (non-Ex) equipment upon gas detection. There are also NMD requirements in-place for fully independent power supplies for fire-fighting and dynamic positioning (DP). To reduce the risk of a gas cloud over the rig, Norsok D-001 will specify that the mud gas separator (MGS) should no longer be connected directly to the diverter system. The diverter system itself should be upgraded to a "safety system" designed to divert any gas in the riser to the overboard lines and safely away from the rig.

The fourth and very significant concern was the failure of the blowout preventer (BOP) to shut-in the well. This has been subject to extensive review. Many reports including that from DNV, identified deficiencies in control systems, maintenance requirements and failure of the shear rams. Norwegian regulations require five year overhaul and recertification of all BOP components, a back-up control system and regular testing. Further improvements will be made in Norsok D-010 to strengthen testing procedures of the BOP, its control and emergency back-up systems. Regarding the failure of shear rams to seal, the current revision of American Petroleum Institute (API) Standard 53 "Blowout Prevention Equipment Systems for Drilling Wells" proposes the use of dual shear rams as a base case for subsea BOPs. However OLF considers that this may not always be the safest option. Due to the variability of rig and drilling environments in the NCS, all ram configurations should, as part of well planning, be subject to comprehensive well specific risk and engineering analysis, using the latest BOP reliability and performance data.

Technical recommendations

Prevention of future accidents has been the main focus of the project. This review of the recommendations from the major reports has enabled the project to identify a number of improvements to reduce blowout risks on the NCS even further. These typically relate to drilling standards, operator and contractor management systems, well control exercises, steering documentation and emergency equipment.

Further improvements will continue to be made over time as international standards evolve from groups such as the OGP's WEC, in which OLF participates, API and the International Association of Drilling Contractors (IADC).

Recommendation no 1

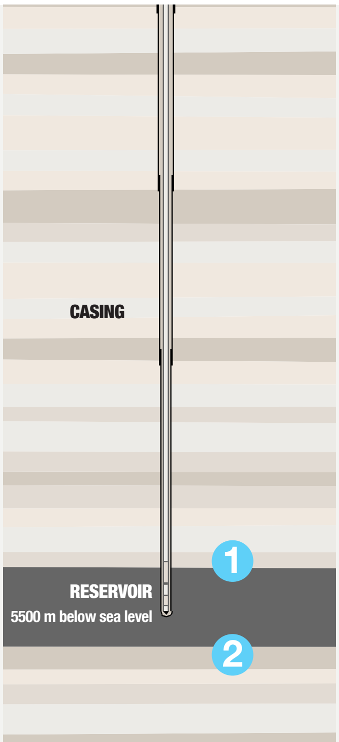
Norsok D-010 should be updated to include the term "critical cement job". A requirement for independent design verification of "critical cement jobs" should also be introduced. This verification can be performed by either an independent in-house department or an external third party.

Recommendation no 2

Norsok D-010 should furthermore require that cement and casing design for slurries placed across hydrocarbon zones be verified in cementing company labs prior to use. For critical slurry designs, such as those containing foam cement or gas block additives, the slurry design, slurry properties, waiting on cement times and cementing plan should be independently verified. This verification can be performed by either an independent in-house department or an external third party.

Recommendation no 3

a) Norsok D-010 should be updated to define the requirements related to inflow (negative) pressure testing clearly.
b) Well programmes should provide a detailed procedure and acceptance criteria for all inflow tests. Inflow tests should be conducted in a controlled manner with detailed procedures which have been approved by an authorised person, and accompanied by a demonstrated risk analysis. This should be covered in Norsok D-010.



Well integrity was not established or failed

1 Annulus cement barrier did not isolate hydrocarbons

Existing Norwegian Requirement:
- a) Dual tested barrier requirement in-place for Norway (D010)

New OLF Recommendations:
- b) Introduction and definition of "Critical Cement Jobs" (D010)
- c) Independent design and placement verification required for critical cement jobs (D010)

2 Shoe track barriers did not isolate hydrocarbons

Existing Norwegian Requirements:
- a) Casing flapper valves not considered well barriers (D010)
- b) Explicit requirements for barrier testing incuding shoe tracks (D010)
- c) All well barriers must be monitored and in the event of failure a secondary barrier activated as soon as possible (D010)

Hydrocarbons entered the well undetected and well control was lost

3 Negative pressure test was accepted although well integrity had not been established

New OLF Recommendations:

a) Expanded negative pressure test procedures and rig-up (D010)

b) Test requirements, applications and acceptance criteria to be detaied in well programs (D010)

4 Influx was not recognized until hydrocarbons were in riser

Existing Norwegian Requirement:

a) Fluid not to be changed out until downhole barriers tested (D010)

New OLF Recommendations:

b) Change out of primary fluid barrier to be via closed BOP (D010)

c) Common definition of well losses (full/partial/seepage) (D010)

R&D Proposal:

d) Industry R&D into well control automation (already underway)

5 Well control response actions failed to regain control of well

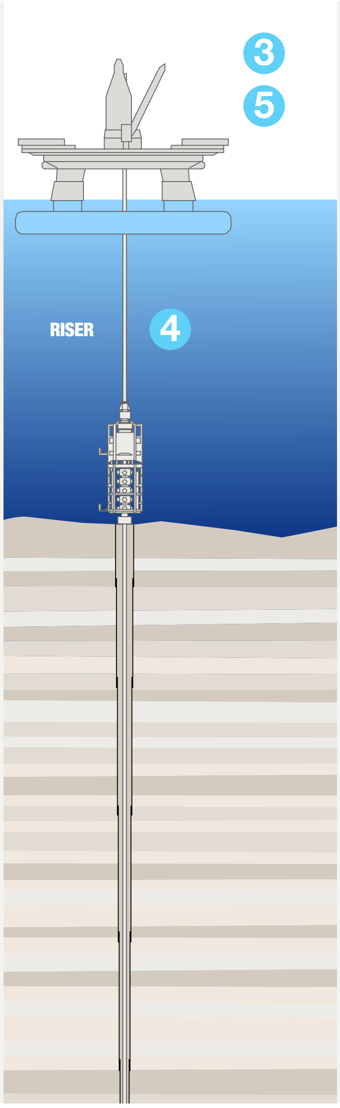
New OLF Recommendations:

a) Well control actions and drills include need to centralize pipe (D010)

b) Well control bridging document to be in place defining:

- Shut-in procedure
- Well control roles and responsibilities during the operation (D010)

c) Crew Resource Management (behavioral) training to be included in well control training



Recommendation no 4

Norsok D-010 should be further clarified to state that, when changing out the fluid barrier element while the remaining barrier consists of untested cement or mechanical plugs, all displacement to a lighter underbalanced fluid should be done with a closed BOP and through the choke and kill lines.

Recommendation no 5

Norsok D-010 should be updated to include descriptive values for full/partial/seepage and static/dynamic fluid losses so that deviations in return flow can be reported using a common frame of reference. Such data can be used to generate acceptable downhole loss rates for specific fields.

Recommendation no 6

OLF recommends that operators and contractors develop simple solutions for well control automation which are reliable and driller-friendly.

Recommendation no 7

OLF recommends that well control bridging documents be prepared for all future drilling operations. (OLF issued this recommendation to Norwegian operators and contractors in January 2011. It has also been referred to the Norsok D-010 revision committee.)

Recommendation no 8

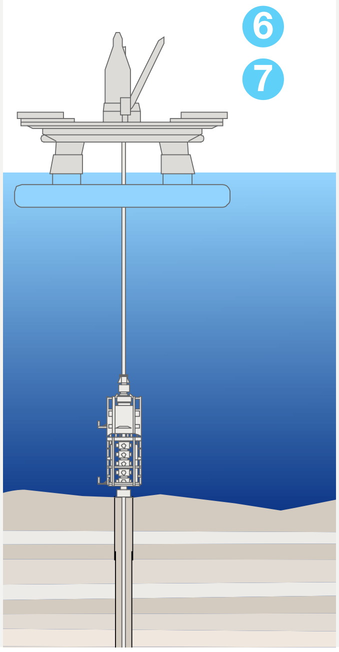
a) Norsok D-001 should be updated to identify the diverter system as a safety system designed to handle gas in the riser above the BOP, and to eliminate the possibility of a gas cloud being released over the rig. The use of the diverter in such circumstances should ensure that all explosive hydrocarbons are released in a safe area to the side and ideally downwind of the rig.

b) To eliminate the possibility of overloading the mud gas separator (MGS), Norsok D-001 should be updated to prevent any connection between the diverter system and the MGS. However, a connection from the downstream end of the choke manifold to the MGS is permitted.

Recommendation no 9

The need for more practice with well control emergencies is recognised. Norsok D-010 should be updated to include requirements for routine well control exercises, specifically in the areas of:

- spacing out and centralising pipe prior to shearing and disconnecting
- diverter line-up to overboard lines
- well control exercises to be conducted (scope, frequency, acceptance, etc).



Hydrocarbons ignited on the Deepwater Horizon

6 Diversion to mud gas separator resulted in gas venting onto rig

New OLF Recommendations:

a) Classify and manage the diverter as a safety system (D001)
b) MGS only connected to choke manifold and not diverter (D001)
c) Diverter line-up drills to be conducted

7 Fire and gas system did not prevent hydrocarbon ignition

Existing Norwegian Requirements:

a) ESD-1 (on gas detection) shuts down all Non-Ex equipment (NMD)
b) Automated air intakes and engine shut down on local gas detection (NMD)
c) Emergency power built into DP3 design requirement (NMD)

Recommendation no 10

Norsok D-010 should specify and require periodic testing of emergency subsea well control activation systems, with due regard to operational activities.

Recommendation no 11

Norsok D-001 and D-010 should include more explicit requirements for primary and back-up BOP control systems, their ability to perform in emergencies and testing of them.

Recommendation no 12

Norsok D-001 should contain a requirement for activating BOP functions via ROV intervention. This will facilitate external activation of BOP elements or release functions should all other systems fail. It is recognised that a BOP ram may not be closed fast enough by an ROV to seal off a flowing well.

Recommendation no 13

Operators should conduct a risk assessment to determine the optimum BOP configuration for each well, utilising the latest BOP reliability, performance and assessment data, the design of the well to be drilled, and the rig in use. The findings should be recorded in the well control bridging document.

Recommendation no 14

OLF recommends that the industry supports further work on BOP reliability to be coordinated by the WEC, where OLF is represented.

Blowout preventer did not seal the well

8 **Blowout preventer (BOP) emergency mode did not seal well**

Existing Norwegian Requirements:

a) BOP overhaul and recertification required every five years

b) Alternative BOP control system required on all floating rigs (D001)

New OLF Recommendations:

c) Well action drills described in D010 should include:

- Procedures for centering pipe prior to shearing
- Diverter line-up
- Frequency, type and scope of well control drills

d) Well Control Bridging Document required to clarify R&Rs and well control configuration for each well activity (D010)

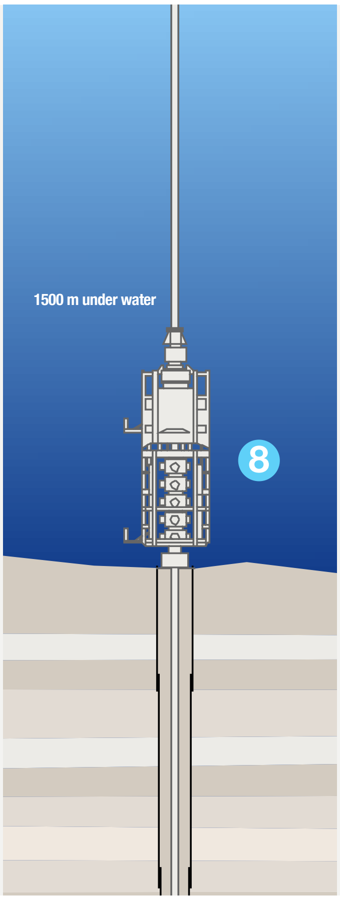
e) Specifications for periodic testing of emergency subsea well control activation systems (D010)

f) Requirements for primary and back up BOP control systems including testing of systems (D001)

g) Recommended practice for preparing BOPs for ROV activation (D001)

h) Risk analyses required to determine optimum BOP configuration (D010)

i) Further work on BOP reliability should continue under the WEC



Recommendation no 15

Norsok D-001 should be updated to ensure that subsea wellhead casing/tubing hangers are locked down on all strings in contact with hydrocarbon-bearing zones.

Recommendation no 16

OLF recommends that NCS operators and drilling contractors review and utilise the OLF well integrity guidelines for all aspects of well planning and execution.

Management recommendations, prevention

Management failures have been identified as a major contributor to the Macondo accident in several investigation reports. In order to structure the recommendations, the following diagram, sourced from OGP, has been used This presents the multiple causes of a failed leadership and safety culture addressed along a time line both before and after a possible well incident. The changing influence of organisational and human factors is identified along the top axis.

Evidence of a broken or ineffective safety culture is often provided by the reaction that "this can't happen here" or by the tendency of employees to pass only good news up to management.

Recommendation no 17

OLF will assess the OGP's work on process safety and key performance indicators related to asset integrity and major accident risk.

Recommendation no 18

OLF recommends that the findings from the PSA assessment [Ref 8] should be reviewed by NCS operators and drilling contractors.

Recommendation no 19

A recommendation on management of change (MOC) should be implemented in Norsok D-010 as follows:

a) An MOC procedure covering the well life cycle should be included in the operator's management system steering documentation. The MOC procedure should describe the processes used to assess risk and to mitigate, authorise and document material changes to previously approved information or procedures. Material changes subject to an MOC process include, but are not limited to, the following:
   - changes in surface and downhole well control equipment
   - changes that impact well barriers
   - change in well type (eg, producer to injector)
   - changes in procedures
   - changes in rig or contractor well control equipment while on hire to an operator
   -changes of key personnel.

b) An MOC procedure covering the following elements of rig systems and key personnel should be included in the drilling contractor's management system steering documentation. The MOC procedure should describe the processes used to manage, maintain, modify, risk analyse, authorise and document material changes to rig systems and procedures. Elements subject to an MOC process include, but are not limited to, the following:
   - safety critical systems
   - changes of key personnel
   - changes in procedures
   - changes in the contractor's well control equipment while on hire to an operator

Recommendation no 20

OLF recommends that operators and contractors review their well management system (WMS) to the relevant extent in order to ensure that well design and planning will reduce operational risks to ALARP.

Recommendation no 21

OLF recommends that operators on the NCS should exchange experiences related to operational barriers.

Recommendation no 22

OLF recommends the inclusion of a requirement in Norsok D-010 for setting either pass/fail criteria or assessment KPIs for all key well control and safety exercises.

Recommendation no 23

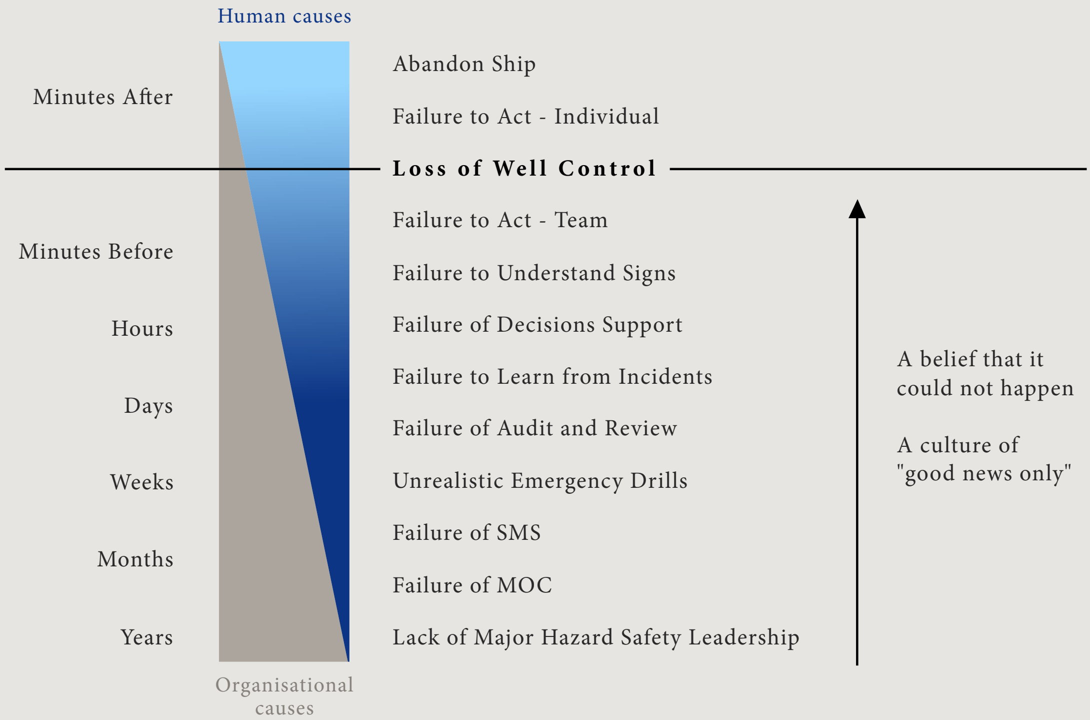
OLF recommends that operators consider the use of independent verification for high-risk areas, through the identification of critical well design elements or activities. The requirements for independent verification should be described in the well management system, and can be performed by either an independent in-house department or an external third party.

Recommendation no 24

OLF recommends that a system for the verification and documentation of safety critical points in the well is developed. OLF will work with the WEC to establish a common industry practice with efficient workflow management.

Recommendation no 25

OLF will progress alignment of well incident reporting with future WEC recommendations.



Source: OGP

Recommendation no 26

OLF recommends that operational tools (eg, well barrier schematics) should be developed by NCS operators to provide the various well-site crew members with simple visual aids, including descriptions of monitoring methods for each defined barrier element.

Recommendation no 27

OLF recommends that formal risk assessments should be implemented by operators and drilling contractors when Simops are planned, and where one activity could affect the safety barriers intended to prevent incidents in the other activity.

Recommendation no 28

OLF will follow up further development of expertise guidelines for well personnel through the OGP WEC HF (Human factors) task force. This will require careful study and adjustment to accommodate Norwegian vocational education and training systems in delivering the best solution for Norway.

Recommendation no 29

OLF recommends that the industry gives consideration to introducing CRM or similar scenario-based team behaviour training for well-site and support personnel.

Recommendation no 30

OLF recommends that training and emergency exercises should involve the wider rig-site crew and also, where appropriate back-up staff and management on land. Operators should ensure exercises are based both on common accidents and on higher-impact, low-probability events.

4 Intervention

The *Deepwater Horizon* accident illustrates that, following BOP failure and an uncontrolled subsea blowout, at least three intervention actions should be considered: the initiation of a relief well (or wells), the deployment of equipment to cap and control the flowing well and the use of a containment system to minimise hydrocarbon escape to the environment.

The Macondo well was finally sealed with a subsea capping device. The Subsea Well Response Project is a not-for-profit joint initiative. Its project team consists of technical experts and management personnel selected from the nine major oil companies involved (BG Group, BP, Chevron, ConocoPhillips, ExxonMobil, Petrobras, Shell, Statoil and Total). As well as managing the selection and design of capping stacks and associated equipment which can enhance the industry's ability to respond to well control incidents, the project will recommend a model for international storage, maintenance and deployment of the equipment.

Enhancing international well incident intervention capabilities is an opportunity for – and dependent on – international cooperation. This is central to the SWRP's approach. The project team is actively engaging with national and international regulators and working closely with other organisations to ensure that its efforts build on and complement existing practices.

System requirement will be included in Norsok D-010. The SWRP team is also studying design options for subsea well containment.

Recommendation no 31

OLF recommends on-going support for the SWRP as planned.

Recommendation no 32

OLF supports the development of options for containment.

Recommendation no 33

OLF supports opportunities for non-participants to gain access to the equipment

Recommendation no 34

OLF recommends that Norsok D-010 should require an outline plan and procedure for capping and shut-in of a flowing subsea well, in which the operator demonstrates how to access and install equipment to shut in the well within a reasonable time.

5 Incident response

This section covers four main topics:

- Lessons learned from the management of the incident following the blowout
- Issues to be addressed in Norway regarding oil spill response
- An assessment of the spill's environmental impact and its relevance to Norway
- A study of working environment issues for personnel engaged in the clean-up.

In the event that hydrocarbons are released to the environment, the Norwegian industry is well prepared using the capability of the Norwegian Clean Seas Organisation for Operating Companies (NOFO). However, the Macondo accident has also provided new learning, for example the success of subsea injection of dispersants and in-situ burning. These, and other experiences, are being implemented within the new NOFO Preparedness Strategy for 2012-2016 which will also take account of new technological developments and additional capacity requirements for northern Norway.

NOFO also plans to share best practices with other international responders. To address concerns reported by oil spill response personnel in the Gulf of Mexico, OLF has developed and published a number of best practices and recommendations to improve the working environment for clean-up crews.

Recommendation no 35

OLF will continue working closely with the Norwegian Coastal Administration to make a case for implementing the principles of unified command for incidents of national significance on the NCS.

Recommendation no 36

Implement a new strategy with measures to strengthen the capability and robustness of oil spill response.

Recommendation no 37

The development of cooperative agreements on oil spill response between North Sea oil producing countries is being pursued via the Operators' Cooperative Emergency Services (OCES)

Recommendation no 38

NOFO should join the global response network.

Recommendation no 39

NOFO should continue to facilitate expanded/increased use of dispersants in the operators' emergency preparedness plans and in conjunction with the subsea well response project.

Recommendation no 40

NOFO should support the Norwegian Coastal Administration in taking the lead on evaluating in-situ oil burning as a supplementary clean-up method.

Recommendation no 41

NOFO should support the Norwegian Coastal Administration in taking the lead on evaluating in-situ oil burning as a supplementary clean-up method.

The working environment and chemical exposure

The *Deepwater Horizon* accident showed that many of the personnel involved in clean-up and capping were inadequately protected and could have been exposed to hydrocarbons and various chemicals used in mitigating the incident. Several of these chemicals can have unfortunate health effects.

Recommendation no 42

OLF recommends that all operators and contractors which may require emergency response offshore should ensure that the following are implemented as part of their emergency preparedness planning process.

Clear responsibilities in emergency response plans
The emergency response plans should clearly indicate who is responsible for occupational health measurements, risk assessment, health examinations and health follow-up. This must be implemented for accidents where directly employed personnel, other active personnel or third parties are exposed to chemicals with potential health hazards. Operators must also develop uniform systems for measurements, health examinations and follow up.

Access to the right expertise
Provide access to qualified personnel who can implement occupational hygiene measurements, risk assessments and health examinations, where relevant. Ensure also that necessary measurement equipment is available.

Relevant education and training
Personnel who take part in oil spill response activities or accidents which lead to chemical exposure must be educated about potential health hazards, and how to protect themselves against hazards. Information packages should be prepared for use as HSE awareness topics on the facilities.

Access to adequate protective equipment
Emphasis in the various exposure scenarios is placed on identifying adequate PPE, including respiratory protection, skin protection and any other gear. This equipment must be readily available for use during campaigns.

Recommendation no 43

OLF recommends that the following be implemented or provided during an incident as an integral part of emergency response plans.

Implement exposure measurements and risk assessment
Exposure measurements must be made quickly and preferably continuously, by qualified personnel, so that necessary risk assessment can be carried out and personnel can be equipped with adequate protective gear. This will form the foundation for providing affected parties with rapid and precise information. An evaluation should also be made of whether biological exposure data should be obtained.

Provide access to adequate protective equipment
Based on plans and risk assessments, ensure that correct protective equipment is used. For vessels used in oil spill response, it is recommended that active coal filters are available and used in the fresh air intake for ventilation air.

Ensure rapid and precise information
Rapid and precise communication of information about potential chemical exposure and any ensuing health effects. This is important both for the personnel involved, and in relation to other affected parties. Reliable scientific information should be emphasised. Information will reduce uncertainty and can help prevent stress reactions.

Recommendation no 44

OLF recommends that the following actions should be implemented after an incident for follow-up of involved personnel:

Ensure that the exposure is documented
It is important that all information about possible exposure is retained with an eye to possible delayed effects, and for learning and research purposes.

Ensure necessary monitoring and follow-up of health
Emphasis is placed on systematic gathering and subsequent evaluation of necessary health information, where this is considered appropriate. In the event of major accidents involving the exposure of many people, it is recommended that a systematic health monitoring and follow-up programme be implemented by qualified professionals over an extended period.

6 Environmental Impact

In order to better understand the environmental impact of the DWH accident, OLF commissioned a desk study of officially published reports in 2011 to review the incident and its impact. A report on the marine environmental impacts of the oil spill was published in December 2011. Environmental monitoring and research carried out during, and after, the blow-out has indicated that the rate of natural degradation of oil components by micro-organisms was much higher than expected. At approximately 1000 meters water depth in the vicinity to the well head, where a high concentration of hydrocarbons had been found, the majority of the natural degradation took place at a temperature (around 4º C) and ambient conditions comparable to the NCS.

Further, the research shows that the planktonic community exhibits an encouraging level of resilience. There was evidence that oil carbon was incorporated into the planktonic food web, but negative impacts of this are yet to be documented. The fisheries in the GOM were closed after the accident due to risk of contamination of sea food. While this closure had large economic consequences, the 2010 cohorts of commercial fish species were not negatively affected by the accident, and no impacts on the commercial fish stocks were observed approximately one year later.

Due to generally stronger winds and higher waves in Norwegian waters compared to GOM, oil would be expected to dissolve and naturally disperse faster in normal NCS conditions. At present in Norway, the general recovery approach is to use mechanical systems as close to the source as possible. However, the positive results from chemical dispersion observed during and after the Macondo incident will likely accelerate the inclusion of dispersion in contingency plans for fields on the NCS. This experience and other data are being addressed by OLF and NOFO.

Recommendation no 45

OLF will continue to follow up the results of relevant research programmes, including work packages by the API with SINTEF as one of the contributors.

7 HSE Impact Assessment

The project has assessed the Health, Safety and Environment benefits of each the recommendations made in this report to ensure they are both effective and that operational and cost impacts are generally aligned with those imposed on other regions.

The analysis concluded that the three most cost effective recommendations for blowout prevention are; the implementation of enhanced well control drills, independent verification of critical well cementation and an improved regime of Management of Change. Further, the introduction of Crew Resource Management (CRM) teamwork training, implementation of an effective Well management system, compliance with OLF's revised well integrity guidelines and tighter procedures for negative pressure testing are all highly effective. Significant environmental impact and risk reduction should be achieved by full implementation of the NOFO 2012-2016 preparedness strategy and provision of well capping systems.

For a typical exploration well, full implementation of the report's recommendations could in worst case, increase well costs in the range of 2 %, with blowout risk reduction costs accounting for major part of this. This includes approximately 0.5% additional costs for improving oil spill preparedness including capping equipment and response preparations, which have largely been developed from Macondo experience.

Many of the recommendations made in this report are likely to improve operational practices in other aspects of the well, resulting in cost or efficiency savings, so reducing the net cost of implementation.

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