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Concluding report on its follow-up of the **Deepwater Horizon accident (2014)**

The Petroleum Safety Authority Norway's concluding report on its follow-up of the *Deepwater Horizon* accident

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Report and project information

Summary

On the basis of a revised mandate from Øyvind Tuntland, director of professional competence at the Petroleum Safety Authority Norway (PSA), the project team responsible for following up the *Deepwater Horizon* accident (P-DwH) has prepared a concluding report for the project.

This report presents the follow-up of the DwH accident in 2010 by the PSA and the industry, including measures initiated by the industry in response to its own recommendations and those of the PSA. It also illustrates as far as possible some effects of the various recommendations and measures implemented both nationally and internationally. Based on this summing up, the report makes proposals on areas which should still be given emphasis in order to secure lasting effects from post-DwH follow-up work.

Key words

Major accident risk, risk management, barrier management, safety culture, organisation and management, blowout preventer (BOP), capping and containment

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SUMMARY

Both the PSA and the industry itself have taken a number of initiatives under the three headings of risk management, barrier management, and organisation and management, which were conveyed as particularly important for following up after the DwH accident, as well as in other areas such as well control equipment. A number of recommendations – both from the PSA and the Norwegian Oil and Gas Association – have been followed up and have yielded visible results. Updates to drilling and well standards are one example, equipment for capping another. However, follow-up work has gone more slowly in certain areas, in part because some measures require a longer time frame to develop good solutions. Measures which require research and development belong in this category.

Despite the efforts of the industry and the expert groups, a substantial unmet requirement persists for revising industry standards in relation to the principle of one revision every five years. The sector board for petroleum standardisation at Standards Norway has concluded that *the industry's commitment must be substantially increased if the maintenance backlog is to be eliminated within an acceptable time frame* (one to three years).

The PSA concluded in 2011 that the DwH accident demonstrated the need for improved risk management and processes which lead to more robust solutions.[1] The impression is that awareness of major accident risk and robust solutions has increased, but that *the industry still has some way to go with regard to a more proactive approach to managing this risk.* That includes work on developing reliable indicators for managing major accident risk and distinguishing better between indicators for personal injuries and major accidents.

It is not necessarily the case that new methods and tools are the only answer. Today's use of methods, given their strengths and weaknesses, has a clear improvement potential. In the PSA's view, a need exists for *the purpose of the risk management process to be clarified*, a better balance between generic and specific risk assessments, the industry *taking greater account of uncertainty and the level of knowledge in risk assessments*, and results being relevant to and useful for those who are to use them.

Research and development are under way in the industry and at research institutes to improve existing analysis methods and tools. Results from such work are by their nature more long-term, and it will take time to assess the benefit and value of the research results and possibly to implement them. The PSA expects *the industry to contribute actively in terms of commitment to and involvement in carrying this work forward at both industry and company level*.

The industry is familiar with the PSA note on barrier management, and initiatives to improve barrier management can be seen at both company and industry level. However, grounds exist for emphasising the significance of maintaining the industry's commitment, including *clarifying and strengthening understanding of the connection between risk management and barrier management*. Work by the players to *establish and follow up barrier strategies* represents an important contribution and must cover the development of new areas, mature fields, new structures and existing facilities. Subjects which still call for special attention in the future are well integrity, prevention of gas leaks and maritime incidents, and aging installations and plants.

An important condition for developing a good HSE culture is clear and continuous prioritisation of safety by managers at all levels, including involvement by company directors and licensees. Results from the PSA's work on the significance of operating parameters for major accident risk demonstrate that the companies still need *to give emphasis to HSE consequences related to such aspects as contracts, contractual relations, incentives, key performance indicators (KPIs) and securing expertise*. The PSA's impression is that improvement efforts and measures are initiated after incidents, and that

[1] "Robust solutions" are ones with built-in safety margins – something in hand – which equip the enterprise to tolerate human and technical errors, operational interruptions, unforeseen circumstances, pressing conditions and so forth. Robust solutions also contribute to the identification and effective handling of hazards and to adequate time being available to bring a hazardous position under control.

most companies in the Norwegian sector have established systems to follow this up. However, it still sees a need for the industry *to get better at picking up signals of deficiencies at a sufficiently early stage*, and to conduct *overall assessments and evaluations to identify the results and effects actually achieved by the companies* from follow-up efforts.

It is time for a speedier and result-oriented follow-up of the reliability of BOP systems. The PSA expects the current assignment being pursued by *the International Association of Oil & Gas Producers (OGP) and the International Association of Drilling Contractors (IADC) on behalf of the International Regulators' Forum (IRF) to be given priority* – also by the individual companies where required – and to see *results* from this work during 2014.

Capping equipment is available, and the PSA expects the industry to follow up the need to *develop and maintain the expertise needed for operating this*. It is also important that the companies *include capping in their risk assessments* when planning drilling and well operations, and that *exercises are conducted in mobilising and using the equipment*. In this context, the industry should consider conducting a full-scale test of the equipment on the NCS. *Solutions should also be developed for jack-up rigs and wellhead platforms*, and for handling blowouts in shallow waters. Similar follow-up of containment equipment will also be needed once this is available.

A number of the recommendations made in 2011 were intended to focus attention on the challenges which had to be assessed and dealt with regularly. They cannot be signed off, but must be incorporated in a continuous effort to identify the processes, activities and products where improvement is required. *These measures must be followed up and evaluated so that they can form the basis for new initiatives.* In that way, lasting effects can be secured from post-DwH follow-up work.

1 INTRODUCTION

A blowout, explosions and fire occurred on the mobile *Deepwater Horizon* (DwH) unit on the Macondo field in the Gulf of Mexico on 20 April 2010. Eleven people died, a number were seriously injured and the unit sank after two days. More than four million barrels of oil escaped from the well before the uncontrolled flow was halted 87 days later.

Eight months earlier, on 21 August 2009, a blowout occurred on the Montara field in the Timor Sea about 250 kilometres off Australia's north-western coast. This lasted for about 10 weeks and was halted with the aid of a relief well.

The Petroleum Safety Authority Norway (PSA) set up a cross-disciplinary internal project team in May 2010 to follow up work in the wake of the DwH accident and prepare the best possible basis for the authority's supervision and other measures which can improve health, safety and the environment (HSE) on the NCS. The PSA published its report on *The* Deepwater Horizon *accident – assessments and recommendations for the Norwegian petroleum industry* in June 2011.[2] Its findings built on the investigation reports published up to that point and a number of assessments of the accident from various specialist bodies and processes, both national and international. Lessons from Montara (2009) and the incidents on Snorre A (2004) and Gullfaks C (2010) were also taken into account.

An overall conclusion was that the DwH accident could not be confined to something which only concerned BP, Transocean or Halliburton, deepwater drilling, blowouts, the US Gulf and so forth. It raised issues affecting a whole industry, national regulators and international processes, and of relevance for preventing major accidents in general. It was also to be seen as a wake-up call for the Norwegian petroleum industry, and lessons from this and other major accidents were to be used to improve the management of major accident risk in order to contribute to more robust solutions in Norway as well.

The report's recommendations were organised under several main headings. An assessment was also made of issues which the PSA believed should be given particular priority by the government and/or the industry. In an identical letter,[3] the three main headings of risk management, barrier management and organisation and management were conveyed to the industry. BOPs, capping and containment, and updating standards were also named in the letter on the basis of existing measures. The Norwegian Oil Industry Association (OLF)[4] and the Norwegian Shipowners Association (NR) were identified as important contributors to the improvement work, but the importance of all petroleum industry players being committed to and included in further follow-up was emphasised. Consultation on the letter and follow-up work were entrenched in the Safety Forum.[5]

2 BACKGROUND

Several investigations on the DwH accident had not reported when the PSA published its findings in 2011, including the final report from the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), specified as volume II of the joint investigation with the US Coast Guard (USCG),[6] and the report from the US Chemical Safety Board (CSB).[7]

BOEMRE published its report on 14 September 2011, and this was reviewed by the PSA's project team soon afterwards. The conclusion was that the report did not describe unknown causal mechanisms or

[2] PSA: http://www.ptil.no/getfile.php/PDF/Hovedrapport%2013.6.2011.pdf [downloaded 20 Oct 2013]

[3] PSA: http://www.ptil.no/getfile.php/Presentasjoner/Sikkerhetsforum/referat%2001-2012/Notat%20-%20DWH%20tiltak%20i%20n%C3%A6ringen-2%2012%202011.pdf [downloaded 20 Oct 2013]

[4] The OLF changed its name to the Norwegian Oil and Gas Association in September 2012.

[5] PSA: http://www.ptil.no/om-sikkerhetsforum/category1083.html [downloaded 2 Oct 2013]

[6] BSEE: http://www.bsee.gov/BSEE-Newsroom/Publications-Library/Joint-Investigation-Team-Report.aspx [downloaded 3 Nov 2013]

[7] CSB: http://www.csb.gov/macondo-blowout-and-explosion/ [downloaded 3 Nov 2013]

causes, but supported the findings discussed in the other investigation reports and the information reviewed, including the report of the presidential commission.[8] However, it had a clearer technological slant than the other reports and covered some of the technical conditions which contributed to the accident in more detail. The CSB report has still not been completed.

3 GOALS AND LIMITATIONS

The report's goal is to account for the way the PSA has followed up post-DwH improvement work and what measures the industry has implemented to meet the regulator's (and its own) recommendations. It is also intended to illustrate as far as possible some effects of the various recommendations and measures implemented both nationally and internationally. On that basis, it will highlight areas which should still be followed up, and make proposals for further work by the PSA and the industry on HSE in the Norwegian petroleum sector.

Certain projects which have provided substantial synergies with the work of meeting the PSA's 2011 recommendations are covered in the report.

The report's information base is largely confined to measures and relevant activities in the Norwegian petroleum industry related to the three main headings, with the exception of international initiatives which clearly influence the PSA's follow-up, such as the Subsea Well Response Project.[9] Key contributors to the follow-up work internationally mentioned here are the IRF,[10] the North Sea Offshore Authorities' Forum (NSOAF)[11] and the OGP.[12] Selected activities and projects related to government follow-up, risk-based supervision, and regulations and standards are also covered.

4 GOVERNMENT FOLLOW-UP

The PSA concluded in 2011 that a continued need existed to prioritise research and development (R&D) activities which can improve the required understanding of what constitutes robust regulation and key assumptions, expectations and restrictions for this. It noted that a clarification of "how far the assumptions for a functional regulatory regime are present in the Norwegian petroleum industry, so that the PSA can acquire a good basis for developing regulations and is able to adopt the necessary measures" could be relevant.

White Paper no 29 (2010-2011)[13] recommended a broad review of HSE regulation in the petroleum industry to increase knowledge of how current follow-up by the regulator is adapted to the challenges faced today and in the future. On that basis, the Ministry of Labour appointed an expert committee on 31 October 2012 to assess new requirements faced by the authorities and the HSE regime from such developments on the NCS as changes in the player picture, certain serious incidents and accidents, a high level of activity, and pressure on tripartite collaboration between companies, unions and government. The report from this Engen committee, entitled *Supervisory strategy and HSE regulation in the Norwegian petroleum industry* was submitted to the ministry on 27 August 2013. It concluded that the HSE regulations by and large function well and should therefore be maintained.[14] The report is now under consideration by the ministry, and comments on its contents will accordingly be confined here to a few observations related to risk management in chapter 7.

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[8] US Government Printing Office: http://www.gpo.gov/fdsys/pkg/GPO-OILCOMMISSION/pdf/GPO-OILCOMMISSION.pdf [downloaded 7 Nov 2013]

[9] Subsea Well Response Project: http://subseawellresponse.com/about-swrp/approach/ [downloaded 3 Nov 2013]

[10] IRF: http://irfoffshoresafety.com/ [downloaded 5 Nov 2013]

[11] NSOAF: http://www.ptil.no/nsoaf/category806.html [downloaded 5 Nov 2013]

[12] OGP: http://www.ogp.org.uk/about-ogp/ [downloaded 5 Nov 2013]

[13] Ministry of Labour: http://www.regjeringen.no/nb/dep/ad/dok/regpubl/stmeld/2010-2011/meld-st-29-20102011.html?id=653071 [downloaded 7 Nov 2013]

[14] Norwegian government: http://www.regjeringen.no/nb/dokumentarkiv/stoltenberg-ii/ad/Nyheter-og-pressemeldinger/pressemeldinger/2013/anbefaler-at-hms-regelverket-i-petroleum.html?id=734387# [downloaded 7 Nov 13]

The 2012 book *Risiko og tilsyn – Risikostyring og rettslig regulering* (Risk and regulation – risk management and legal regulation) is also relevant to the subject of regulatory follow-up in the light of the DwH accident.[15] One result of a long-term collaboration between the Centre for Risk Management and Societal Safety (Seros) at the University of Stavanger and several Norwegian regulators, including the PSA, this volume is directed at everyone concerned with the organisation and exercise of supervision, be they civil servants at various levels, government relations personnel, managers or others in industries involved with official regulators.

In its report, the presidential commission recommended an inter-government collaboration to establish a robust foundation for managing Arctic regions. Both R&D activities and standardisation work were planned in this context. The PSA pointed in 2011 to the importance of participation by Norwegian safety regulators in these efforts, not least in order to benefit from and ensure consistency in development work under way on management plans and in the Barents 2020 project. A new main priority for the far north has been set by the PSA, which will monitor far-northern activities closely.

Bilateral collaboration has also been established by the PSA with the safety and working environment regulators in those countries with current or future offshore petroleum operations in Arctic or sub-Arctic waters, such as the USA, Canada, Russia, Greenland and Iceland. This relates mainly to knowledge development, experience transfer and work related to regulations and standardisation.

The DwH report noted the importance of following up the companies' own incentives for preventing major accidents (concern for their own goals and strategies, financial reporting, business continuity, reputation, commercial opportunities, access to acreage and so forth). Seeking government-managed incentives which could influence and motivate the companies to invest more in safety and safety-enhancing R&D was also identified as relevant.

An audit activity on managing the risk of major accidents in a governance perspective[16] looked in part at issues related to company self-interest in preventing major accidents. According to the companies, a major accident would have serious consequences for their ability to achieve their goals and strategies. That was particularly the case if a major accident occurred where a company is the operator, but would also hold true were it to happen in activities where it was not the operator. A number of companies also reported that the concentration on major accidents by industry and government in recent years had helped to increase the attention given to the underlying causes of such incidents.

The PSA's follow-up of the DwH accident has naturally involved extensive information acquisition, contact and collaboration with specialist teams and other regulators, nationally and internationally – through collaborative bodies such as the NSOAF and the IRF, for example.

5 REGULATIONS AND STANDARDS

The 2011 report noted that the DwH accident was not considered to challenge the central principles in the PSA's regulations, such as the division of responsibility for regulatory compliance and requirements for systematic and risk-based compliance with functional requirements. Nor was the accident considered to challenge a risk-based regulatory regime. However, the report noted "the need for the PSA to continue evaluating and improving on a continuous basis how it seeks to influence safety in the Norwegian petroleum industry, and the effect of such influence". This will be handled in part through the RNNP measurement tool[17], the PSA's annual main priorities and the supervision activities listed in chapter 6.

[15] University of Stavanger: http://www.uis.no/om-uis/nyheter-og-presserom/ny-bok-om-risiko-og-tilsyn-article61950-8108.html [downloaded 7 Nov 13]

[16] PSA: http://www.ptil.no/getfile.php/Tilsyn%20p%C3%A5%20nettet/tilsynrapporter%20pdf/2008_568_rapport%20virksomhetsstyring%20og%20storulykkesrisiko.pdf [downloaded 7 Nov 2013]

[17] PSA: http://www.ptil.no/rnnp/category700.html [downloaded 7 Nov 2013]

The 2011 report noted that the need to clarify certain requirements at the level of regulations and in guidelines or interpretations should be assessed. That included the following:

- requirements for managing major accident risk, so that differences from managing the risk of occupational accidents are made clearer
- requirements for managing major accident more clearly consistent with the safety concept, so that they cover concern for people, the environment and material assets
- requirements for the players to demonstrate that technology, operations, organisation and the like are tailored to such considerations as regional factors affecting risk – activities in deep water, for example, or in Arctic areas.

In connection with the continuous regulatory development process and the annual amendments to the HSE regulations, the proposals circulated for consultation in 2013 included suggested changes related to the maritime system, risk management, barriers, emergency preparedness and drilling relief wells. Changes which had not attracted significant comments during the consultation process were approved on 23 December 2013.[18] The other proposed amendments will be revised during the spring of 2014. No comments are made on the changes in this report.

The PSA's DwH report emphasised the need for regular updating of standards. Company involvement in standardisation work is regarded by the PSA as a specific way for them to demonstrate their collective responsibility for a high level of safety, work actively on incorporating established best practice and support national standardisation strategy. A new five-year work programme includes identifying standards which require updating now and which of these can be handled as international standards. This has been given priority by the petroleum standardisation board at Standards Norway.

Great attention has been paid by the sector board for petroleum standardisation at Standards Norway to maintaining the Norsok standards. Despite the efforts of the industry and the expert committees (EGenes), a substantial requirement remains to meet the principle of a revision every five years. The sector board has concluded that the industry's commitment must be substantially increased if the maintenance backlog is to be eliminated with in an acceptable time frame (one-three years). Sixteen Norsok standards must be revised every year to satisfy the five-year revision rule. Both the industry and the PSA have made expertise and financial support available to Standards Norway to clear the backlog for updating Norsok standards.

As part of the PSA's post-DwH follow-up, all the standards referenced in its regulations were reviewed. This identified certain standards which particularly needed updating. Examples include Norsok D-001 on drilling facilities and D-010 on well integrity in drilling and well operations.[19] These two standards had not been updated for many years, but could incorporate important lessons from the incident in the Gulf of Mexico as well as those on Montara, Snorre A and Gullfaks C.

The report from the OLF on *Deepwater Horizon – lessons learned and follow-up*[20] addressed a number of recommendations related to well workovers, planning and execution, as well as cementing and well control. A total of 14 recommendations in the OLF report were specific proposals for updating Norsok D-001 and D-010. These two standards have been revised and published. During 2013, Standards Norway also revised and published D002 *Well intervention equipment* and D007 *Well testing system*. Another relevant standard for drilling facilities currently undergoing revision is DNV-OS-E101 (Drilling Plant – DNV Offshore Standards).

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[18] PSA: http://www.ptil.no/vedtatte-endringer-i-regelverket/aarlige-endringer-i-hms-forskriftene-article10292-1111.html [downloaded 3 Jan 2014]

[19] Standards Norway: http://www.standard.no/no/Fagomrader/Petroleum/NORSOK-Standard-Categories/D-Drilling/ [downloaded 6 Nov 2013]

[20] Norwegian Oil and Gas: http://www.norskoljeoggass.no/no/Publikasjoner/Handboker/Deepwater-Horizon---lessons-learned-and-follow-up/ [downloaded 6 Nov 2013]

6 RISK-BASED SUPERVISION

6.1 Main priorities

The PSA adopts a set of main priorities every year which indicate safety challenges it considers important in the Norwegian petroleum industry. In connection with its post-DwH follow-up, the three main subjects of risk management, barrier management and organisation and management – see chapter 1 – served as input to the main priorities for 2012 and 2013.[21]

6.2 RNNP

The report from the presidential commission highlighted the importance of securing the development and application of major accident indicators. During the debate on develop robust risk indicators, the companies and regulators involved – both post-DwH and in the investigation of other accidents (such as the Texas City Refinery) – were criticised for paying greater attention to performance figures for personal injuries than for major accidents.

Since 2000, and in cooperation with companies and unions in the industry, the PSA has built up an extensive database on various activities, incidents, barriers, maintenance and so forth. It issues an annual assessment of trends in risk level in the petroleum activity (RNNP).[22] This includes indicators related to major accident risk. That helps in part to unite companies, unions and government on improvement processes at an industry level, prioritise regulatory supervision and ensure transparency with the level of risk in the sector. Work is now under way on further development of the RNNP to improve communication of development features, use the database to identify underlying relationships and increase knowledge about risks.

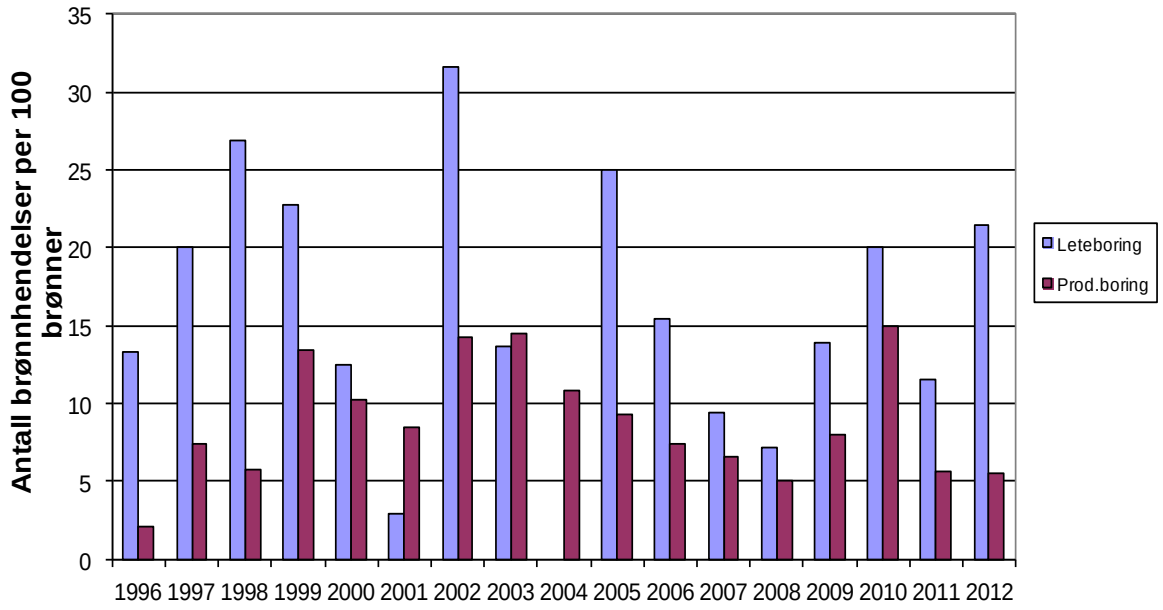

Figure 1: Well incidents on the NCS 1996-2012.
Key: Well incidents per 100 wells; Exploration drilling; Production drilling

One example from the RNNP is the indicator for well control incidents on the NCS. Figure 1 shows the trend for reported well control incidents from 1996 to 2012, normalised per 100 wells drilled.

[21] PSA: http://www.ptil.no/nyheter/ptils-hovedprioriteringer-2013-article8980-702.html [downloaded 7 Nov 2013]

[22] PSA: http://www.ptil.no/rnnp/category700.html [downloaded 6 Nov 2013]

The PSA published a qualitative study in 2011 on causes of well control incidents on the NCS[23] in response to a negative trend for reported incidents in 2008-10 and experience from the DwH accident.

Four main challenges were identified in the study:
- the need for a stronger commitment to technical measures to improve safety
- a bigger commitment to planning, barrier management and better-adapted risk analyses
- paying greater attention to major accident risk – more investigation of incidents
- creating operational parameters for good collaboration in the operator/supplier hierarchy.

The current CSB investigation has assessed the use of indicators by various regulatory regimes and the industry. It staged a public hearing[24] on 24 July 2012 about using indicators which cover both petrochemical plants on land and offshore petroleum operations. The PSA contributed a presentation of the RNNP with examples of its well-control indicators. With reference to the RNNP and others, the CSB recommended at the hearing that industry, government and employees join forces to develop more effective process-safety and indicator programmes[25] for operations on the US continental shelf.

Together with other regulators, the PSA has participated in an IRF project to develop joint criteria for certain incident data in order to measure and compare the level of risk on different continental shelves.[26] Most well control incidents and hydrocarbon leaks reported to the RNNP fall outside the IRF's categorisation because several member countries have set a higher threshold for potential and actual consequences when reporting. Such data are therefore not comparable today.

6.3 Audit activities

The three main subjects of risk management, barrier management and organisation and management, see chapter 2, were also incorporated in the PSA's main priorities before the Montara and Macondo accidents. As mentioned above, however, these incidents have provided an important basis for extending the main priorities and prioritising audits.

Audit activities with a direct background in the DwH accident include:
- a multinational audit series under the NSOAF's auspices on the subject of organisation and human factors in well control [27] and national audits by the PSA with a corresponding method
- an audit series on maritime systems related to stability, buoyancy and ballasting.[28]

Furthermore, a number of audits have been conducted on the basis of the above-mentioned main subjects, including ones for barrier management within various subjects. See chapter 8.

Findings from the audits confirm the conclusions drawn in chapters 7-10.

7 RISK MANAGEMENT

Post-DwH reports have exposed a number of deficiencies in risk management, including handling of uncertainty in different phases, understanding barrier management and status, change management, interpreting danger signals, and handling and understanding risk at complex interfaces.

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[23] PSA: http://www.ptil.no/getfile.php/PDF/RNNP%202011/RNNP2011_Hovedrapport.pdf#nameddest=kapittel00 [downloaded 7 Nov 2013]

[24] US Chemical Safety Board: http://www.csb.gov/events/csb-public-hearing-safety-performance-indicators/ downloaded 7 Nov 2013]

[25] Process safety here in the sense "major accident".

[26] IRF: http://irfoffshoresafety.com/country/performance/ [downloaded 7 Nov 2013]

[27] PSA: http://www.ptil.no/getfile.php/Presentasjoner/Sikkerhetsforum/Referater%202012/NSOAF%20felles%20tilsyn060612.pdf [downloaded 7 Nov 2013]

[28] The audits were conducted on Veslefrikk B, Heidrun, *Petrojarl Knarr* and *Ocean Vanguard*, and the reports are published at http://www.ptil.no/tilsynsrapporter/category713.html

The PSA's 2011 DwH report addressed a need both in the industry and at the regulators to review the tools currently used for risk management with the aim of identifying required changes and possibly to assess requirements for developing new instruments. Special mention was made of risk management related to changes. The term "tools" was not confined to any specific solutions, but could cover all aids which are or should be available for managing major accident risk. As part of this review, assessments were found to be needed for the strengths and weaknesses of existing tools, the kind of decision support they provide, and in which circumstances and decision levels or phases. Barrier management should form a key part of the parameters for this work. The PSA also urged the industry to help initiate and conduct research in this area. The post-DwH investigations and hearings have also pointed to a need for suitable and reliable indicators (both proactive and reactive) for managing major accident risk. See chapter 6.

This chapter should be read in conjunction with chapters 8 on barrier management and 9 on safety culture, organisation and management.

7.1 Follow-up by the PSA

The main post-DwH message from the PSA to the industry was directed both at reassessing current principles and methods related to risk management *and* at the way these are practised. In that context, the PSA has been particularly concerned about how a better basis than current practice provides can be created for systematically identifying, describing and taking account of uncertainty, unexpected incidents and context. In that context, insight into and understanding of uncertainty and the significance of knowledge gaps represent key topics in the PSA's main priorities and its follow-up of the industry.

Existing tools and principles for risk management have their limitations, and understanding of these and their possible consequences for managing risk is inadequate. Handling of risk assessments, for example, in light of the precautionary principle – where uncertainty exists – is deficient. Although the whole regulatory regime is built up around this principle, it is not properly understood in the industry. Greater attention to the precautionary principle in the industry could prompt a focus on built-in safety margins and extra barriers, robust design so that errors which might arise can be handled, better preparations for identifying and dealing with the unexpected, applying BAT and Alarp thinking, increased knowledge development or the avoidance of certain activities.

The PSA has also noted the importance of clarifying the purpose of the risk management process. Risk assessments are important, but not an end in themselves. Operating parameters varying between different types of personnel in different types of companies. The trends are towards expectations of a greater flexibility by employees, complicated management systems and organisational models which facilitate periodic rotation of personnel, and activity-managed staffing. Personnel rotation occurs both between facilities and between offshore and land. This challenges the relationship between facility-specific expertise and the individual's understanding of the risk they are exposed to and must handle. The evaluation and use of risk assessments must therefore be appropriate, and the assumptions on which the analyses and assessments are based must be operationalisable, useful and relevant for those who are to utilise them – at all levels and in every phase.

The PSA concluded in 2011 that assessing the need to clarify some requirements at the level of regulations and in guidelines or interpretations was timely. This included requirements for managing major accident risk so that the differences between managing occupational accident and personal injury risk were more clearly specified, and for managing major accident risk which are more clearly consistent with the safety concept so that they cover concern for people, the environment and material assets. Proposals for regulatory amendments were included on that basis.

The Engen report (see chapter 4) made a number of recommendations which deal in part with risk management and major accident risk. These tend towards strengthening the PSA's opportunities to

conduct more efficient supervision of the industry's management of major accident risk, but also address the need for new tools and methods.

This report also notes that the earliest design phases for facilities offer the biggest potential for risk reduction without disproportionate cost. The Norwegian Petroleum Directorate's evaluation of projects implemented on the NCS[29] also notes that "thorough, high quality work in the early phase is crucial for the rest of the project implementation to succeed". The PSA has recently worked to strengthen follow-up of projects in the early phase.

7.2 Follow-up by the industry

Key R&D projects now under way could contribute to dealing with the risk management challenges mentioned above. These also include contributions from industry players. The industry's follow-up must also be viewed in connection with the next chapter, which deals with barrier management.

The Petromaks 2 programme pursued by the Research Council of Norway[30] recently launched two relevant projects focused on the petroleum sector. "Improved risk assessments – to better reflect the knowledge dimension and surprises"[31] is a four-year project at the University of Stavanger, which aims primarily to develop a practical new framework for understanding risk and uncertainty by taking the necessary account of the knowledge dimension and surprises. "Modelling instantaneous risk for major accident prevention"[32] is a three-year project at the Norwegian University of Science and Technology (NTNU) to research "living risk analyses" which can provide a more updated and specific risk picture. These can give an immediate snapshot, unlike the generic picture usually provided by traditional risk analyses in the petroleum sector.

Norwegian Oil and Gas has furthermore taken the initiative on a project called "A new perspective on how to understand, assess and manage risk and the unforeseen"[33] in cooperation with the University of Stavanger and the International Research Institute of Stavanger (Iris). It aims to explain and describe the new way of thinking about risk and to identify what the industry accordingly can and should do to improve risk and safety work The project will support Norwegian Oil and Gas and its member companies in their efforts to avoid major accidents. Attention will focus on how to ensure good decisions, an informative and solid decision base, experience transfer and expertise development.

The Research Council of Norway has an agreement with the EU's Joint Research Centre (JRC), including the SAF€RA project, on collaboration with Norwegian universities and research centres working on safety in such areas as:

- assessment of reliability and performance needs for critical safety systems and barriers – especially in sensitive and harsh environments, such as Arctic and sub-Arctic regions
- human and organisational factors
- management of risks, especially the less well-known or atypical ones ("black swans")
- learning from past accidents, near-misses and successful operations.

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[29] NPD: http://www.npd.no/no/publikasjoner/rapporter/vurdering-av-gjennomforte-prosjekter-pa-norsk-sokkel/ [downloaded 11 Jan 2014]

[30] Research Council: http://www.forskningsradet.no/prognett-petromaks2/HMS_i_PETROMAKS_2/1253981958856 [downloaded 13 Nov 2013]

[31] Research Council: http://www.forskningsradet.no/servlet/Satellite?c=Prosjekt&cid=1253987332188&pagename=ForskningsradetNorsk/Hovedsidemal&p=1181730334233 [downloaded 11 Jan 2014]

[32] Research Council: http://www.forskningsradet.no/servlet/Satellite?c=Prosjekt&cid=1253987332179&pagename=ForskningsradetNorsk/Hovedsidemal&p=1181730334233 [downloaded 11 Jan 2014]

[33] ScienceDirect: http://www.sciencedirect.com/science/article/pii/S0951832013002159 [downloaded 14 Jan 2014]

7.3 Conclusions

The DwH accident demonstrates a need for better risk management and processes which lead to more robust solutions and operations. The impression is that awareness of major accident risk and robust solutions/operations has increased, but that the industry still has some way to go in adopting a more proactive approach to managing risk. That includes developing reliable indicators for managing major accident risk and distinguishing better between personal injury and major accident indicators.

Given the petroleum industry's complexity, this makes extensive demands on risk assessments and not least on the suitability of such assessments. It is not necessarily the case that new methods and tools are the only answer. Today's use of methods, given their strengths and weaknesses, has a clear improvement potential. In the PSA's view, a need exists for the purpose of the risk management process to be clarified, a better balance between generic and specific risk assessments, the industry to take greater account of uncertainty and the level of knowledge in risk assessments, and results to be relevant and useful for those who are going to use them.

Research and development are under way in the industry and at research institutes to improve existing analysis methods and tools. Results from such work are by their nature more long-term, and it will take time to assess the benefit and value of the research results and possibly implement them.

The PSA expects the industry to contribute actively in terms of commitment to and involvement in carrying this work forward at both industry and company level.

8 BARRIER MANAGEMENT

The PSA's previous post-DwH report addressed a number of issues and challenges related to barrier management for the Norwegian petroleum industry, both at an overall level and in relation to the need for better and more specific performance requirements for technical, organisational and operational barrier elements. Both the report and audit experience confirmed a continued need to give a high priority to the industry's work on putting better barrier management in place. The report also pointed to work on better barrier management in relation to the need to improve maintenance of safety-critical equipment and to develop the level of safety in the petroleum industry.

8.1 Follow-up by the PSA

As mentioned above, barrier management was followed up via one of the PSA's main priorities even before the DwH accident. A number of its post-DwH activities related to this area have accordingly involved projects which were not initiated directly as a result of the accident, but which have provided substantial synergies with the follow-up work.

One outcome of the PSA's work on barriers over a number of years has been the identification of a need to clarify for the industry the requirements and expectations which relate to barrier management pursuant to the regulations. A need has also been identified to develop a more coherent and standardised approach to barrier management in the petroleum sector, which complies to a greater extent than today with the regulatory requirements on barriers. Furthermore, a strengthened understanding of the interaction between technical, organisational and operational elements required to take care of barrier functions is seen to be required. The PSA has accordingly published a note on *Principles for barrier management in the petroleum industry*, last updated in January 2013, which outlines its expectations for good barrier management.[34] This document does not include new barrier management requirements, but outlines how the PSA, for its part, determines requirements in the regulations and guidelines in relation to the content of relevant standards. However, it does not form part of the formal petroleum regulations.

[34] PSA: http://www.ptil.no/getfile.php/PDF/Prinsipper%20for%20barrierestyring%20i%20petroleumsvirksomheten.pdf [downloaded 7 Nov 2013]

Also relevant, and with synergies for post-DwH follow-up work, is a causal study of hydrocarbon leaks on the NCS conducted for the 2010 RNNP process. This work followed an increase in the number of gas escapes reported in the RNNP's major accident indicator for hydrocarbon leaks.[35] Findings from the study have been communicated to individual companies and industry bodies, and have been applied in the PSA's audits of companies. Like the post-DwH findings, it concluded that the industry must ensure the establishment of barrier strategies and principles which underpin the design, use and maintenance of barriers with specified performance requirements for the technical, organisational and operational barrier elements (figure 2). A need was also identified for better understanding of the interaction between technical, organisational and operational barrier elements. At the same time, it is important to strengthen understanding of the relationship between risk and barrier management. As mentioned in chapter 6, a corresponding causal study of well control incidents was conducted in 2011.

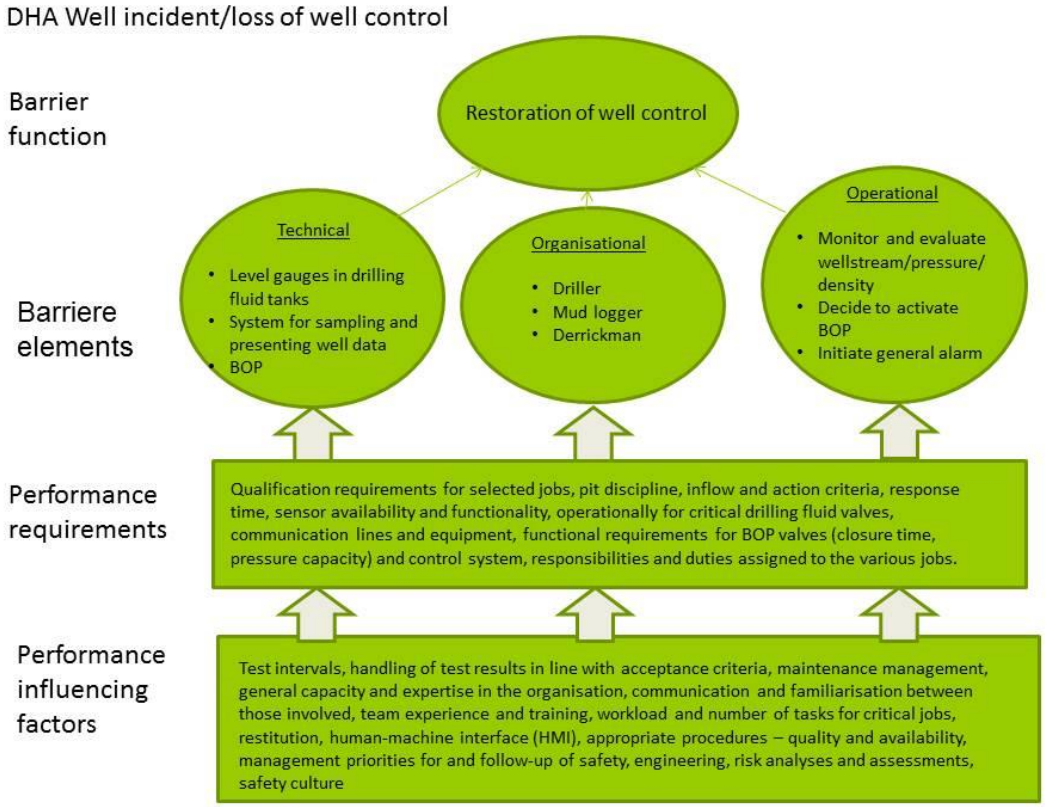

Figure 2: Relationship between technical, organisational and operational barrier elements for well control.

The PSA has also conducted a large number of barrier management audits under its main priority for barriers since 2009[36]. Audits in 2013 covered a number of issues, such as establishing barrier strategies, technical safety, electrical facilities, instrumented safety systems, managed pressure drilling, maintenance management, design and construction of drilling and production facilities, analyses and analysis tools, well control, well emergency preparedness, operational preparedness, control rooms on land, logistics, helidecks, structural integrity, maritime systems, coiled tubing drilling and so forth.

[35] PSA: http://www.ptil.no/getfile.php/PDF/RNNP%202010/RNNP_2010_Arsaksforhold_og_tiltak_knyttet_til_hydrokarbonlekkasjer_norsk_sokkel.pdf [downloaded 7 Nov 2013]

[36] PSA: http://www.ptil.no/tilsynsrapporter/category713.html [downloaded 2 Jan 2014]

Also relevant is follow-up of barrier management within various disciplines through the PSA's consideration of applications for consent, early-phase projects, plans for development and operation (PDOs), applications for acknowledgements of compliance (AoCs), and incidents. Examples include robust design of a well for its whole operational life, including plugging and abandonment, maintaining barriers on aging facilities, producing life extension and emergency preparedness in the far north.

8.2 Follow-up by the industry

As noted in chapter 1, an identical letter to the industry observed that a more coherent and uniform approach to barrier management needed to be developed in the petroleum industry and that the industry – under the auspices of the OLF, the NR and other key players – should accept responsibility for implementing such a commitment. The PSA took the view that the industry should establish an arena with the aim of developing a common and more coherent approach to barrier management.

The OLF submitted its comments in March 2012 both on the identical letter, as noted in chapter 2, and on the *Principles for barrier management in the petroleum industry* document. It proposed to the PSA that the following areas could be addressed at industry level:

- clarification of concepts: such as operational and organisational barrier elements, and so forth
- study: can performance requirements be related to operational and organisational conditions?
- develop proactive major accident indicators
- experience transfer and exploration.

According to the latest update received by the PSA from Norwegian Oil and Gas on follow-up with barrier management, the following has been done:

- Norwegian Oil and Gas has organised working meetings and workshops on key issues related to barrier management, with follow-up of various issues set to continue under its auspices
- work on and follow-up of barrier management is entrenched in the Norwegian Oil and Gas Operations Committee, which has nominated participants for working meetings and workshops
- contact has been established between Norwegian Oil and Gas and the NR, and these organisations will look at closer collaboration, experience transfer and learning in the area.

The industry is pursuing processes to change the way barrier management is followed up. Statoil, for example, has initiated a pilot project – on the basis of the PSA's audits related to the topic – to develop a strategy for barrier management. The company has now resolved to implement the results. Its work, and the experience based on this, are likely to yield proposals for the industry's continued efforts with barrier management. The PSA is also aware that the NR has initiated its own work to contribute to a common approach to barrier management.

Inadequate maintenance was a contributory factor in the DwH accident, primarily related to the BOP (follow-up related to this equipment is otherwise covered in chapter 11). A number of the critical components required to operate the BOP had not been maintained in line with the manufacturer's recommendations. The PSA's 2011 report noted that an evaluation of maintenance systems was relevant for drilling contractors and suppliers of equipment used in drilling and well operations in order to assure themselves that facilities and equipment they are responsible for can perform their functions. The NR has established an Asset Integrity Forum to work with maintenance challenges on mobile units. It has begun a study of requirements for maintenance management on such facilities.

Well integrity is another area which has attracted much post-DwH attention.[37] The OLF's own report and associated recommendations in the wake of the accident emphasise this. As mentioned in chapter 5, the OLF has made several proposals for updating Norsok standard D-010 on well integrity in drilling and well operations, which specifies performance requirements for well barriers. Activities

[37] Lack/failure of well integrity was a principal technical cause of the DwH accident

pursued by the Norwegian Oil and Gas Well Integrity Forum[38] (WIF) and the Plug and Abandonment Forum (PAF)[39] can also be mentioned since their work involves important synergies for follow-up efforts.

8.3 Conclusion

The industry is familiar with the PSA note on barrier management, and initiatives to improve barrier management can be seen at both company and industry level. However, grounds exist for emphasising the significance of maintaining the industry's commitment, including clarifying and strengthening understanding of the connection between risk management and barrier management. Failures and deterioration of barriers are a recurring causal factor in undesirable incidents. The risk picture must be utilised in barrier management both to establish specific barrier strategies and to specify the properties barriers must possess. Technical, organisational and operational barrier elements must be highlighted as part of risk assessments. Work by the players to establish and follow up barrier strategies represents an important contribution and must cover the development of new areas, mature fields, new structures and existing facilities.

Subjects which still call for special attention in the future are well integrity, prevention of gas leaks and maritime incidents, and aging installations and plants.

9 SAFETY CULTURE, ORGANISATION AND MANAGEMENT

"The immediate causes of the Macondo well blowout can be traced to a series of identifiable mistakes made by BP, Halliburton and Transocean that reveal such systematic failures in risk management that they place in doubt the safety culture of the entire industry"

(Presidential commission's report, page vii)

The presidential commission report and other post-DwH studies identified challenges related to safety culture, organisation and management as key underlying causes. As such, this indicates that major accidents often arise from long-term organisational decay – in other words, errors develop over time in a system of interlocked, to some extent interdependent, players and processes.

Features of the DwH accident show similarities with other major accidents, which underlines the importance of being open to the unknown, paying serious attention to signals of vulnerabilities and taking account of uncertainty. Where learning is concerned, the accident also demonstrates a need to ask why important insights and experience from earlier incidents appear to have been lost. Learning is not something which only occurs after incidents or accidents. It goes on all the time. Steps must be taken to ensure that organisations have sufficient capacity and expertise, and that key safety-critical knowledge is understood. Furthermore, learning must be secured at the interface between players from several companies. Safety-critical conditions must be monitored continuously, and signals of weaknesses must be treated seriously and assigned sufficient significance.

Post-DwH work on learning by the PSA and the industry has addressed aspects related to safety culture in various ways – both generally in the industry and specifically in the companies. The PSA's DwH report noted that development of a good safety culture calls for involvement and commitment by the companies, the unions, the government and other relevant players.

Key issues in the post-DwH follow-up have primarily related to the companies' own follow-up, management's role, capacity and expertise, crew resource management (CRM) and training, change management, roles and responsibilities, employee participation and involvement, information, culture and learning systems, and the significance of operational parameters for managing major accident risk.

[38] The WIF was established in 2007 on the basis of the PSA's survey of well integrity on the NCS in the spring of 2006.

[39] The PAF was established in 2009 to promote the development of robust and cost-effective solutions to current and future P&A challenges.

9.1 Follow-up by the PSA

Through its main priority on management and major accident risk, the PSA has addressed over time company management and licensee work on such risk. According to the players themselves, these activities have contributed to increased awareness of major accident risk at various management levels. The role of company management in managing such risk and learning from incidents has also been addressed through audits (see chapter 6). As an overall result, the companies say that the DwH accident has increased the attention they pay to safety culture, leadership, compliance, having the necessary expertise in place, and the importance of risk-assessing and managing both operational and organisational changes.

The PSA has also addressed the work done by on licensees on major accident risk in the licence over time. As a consequence of this work, some companies have initiated a joint project to establish better processes for licensee follow-up of such risk.

Through R&D projects and audits, the PSA has contributed to knowledge development and directed attention to the significance of operating parameters for managing working environment and major accident risk. Results from these activities point to contracts, incentives, KPIs, expertise management, information and communication, and the division of roles and responsibilities as among the key operating parameters and considerations in managing working environment and major accident risk.

The rising level of activity and a larger number of rigs heading for the NCS put pressure on the supply of sufficiently qualified personnel. The PSA established a project in 2013 to identify possible safety and working environment challenges related to this trend.

The "Culture and system for learning" project was pursued in 2012-13 on the basis of experience from DwH and other incidents as well as challenges for safety culture and organisational learning in the Norwegian petroleum industry. It has produced a summary of available knowledge on organisational learning and safety[40] and a pamphlet on learning.[41] The project team held regular discussions with the HSE authorities in the UK on this issue, and its results have been incorporated in audit activities.

On the basis of findings that the industry's safety culture lacks robustness, both the government and the industry have conducted a number of studies and issued recommendations on this subject. The IRF has prepared a series of documents on behalf of offshore safety regulators in several countries to 1) review the safety culture concept, 2) provide guidance to regulators on how safety culture can be audited and 3) provide a system for company self-assessment of safety-culture performance.[42] The US Bureau of Safety and Environmental Enforcement (BSEE) announced a new safety-culture strategy on the basis of the post-DwH findings,[43] while the OGP at industry level has produced a report to clarify concepts on safety culture and management[44]. The PSA has reviewed the studies and recommendations on safety culture produced by the IRF and the BSEE. It has also assessed them in relation to the way an HSE culture is addressed in the PSA's regulations and follow-up of the industry. This concludes that the PSA's follow-up of the requirements in section 15 of the framework regulations on a sound HSE culture and its clarification of the concept in the *HSE and culture*[45]

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[40] Rosness, R, Nesheim, T and Tinmannsvik, R. Sintef rapport (A24120): *Kultur og systemer for læring. En kunnskapsoversikt om organisatorisk læring og sikkerhet*. http://www.ptil.no/rapporter-og-seminarer/ny-sintef-rapport-kultur-og-systemer-for-laering-article9261-1048.html [downloaded 7 Nov 2013]

[41] PSA: http://www.ptil.no/en-bok-om-laering/category1117.html [downloaded 5 Feb 2014]

[42] IRF: http://www.irfoffshoresafety.com/conferences/2011Summit/presentations/Presentation-MarkFleming-Safetycultureandleadership.pdf og http://www.irfoffshoresafety.com/conferences/2010conference/presentations/930%20Mark%20fleming%20International%20regulators.pdf [downloaded 13 Nov .2013]

[43] BSEE: http://www.bsee.gov/BSEE-Newsroom/BSEE-News-Briefs/2012/BSEE-Announces-Safety-Culture-Policy.aspx [downloaded 7.11.2013]

[44] OGP: *Shaping safety culture through safety leadership*. http://www.ogp.org.uk/pubs/452.pdf [downloaded 7 Nov 2013]

[45] PSA: http://www.ptil.no/getfile.php/z%20Konvertert/Produkter%20Og%20Tjenester/Publikasjoner/Dokumenter/hmskulturnorsk.pdf [downloaded 7 Nov 2013]

publication take account of the knowledge developed in the wake of the DwH accident, and that its approach to the regulations is tailored to the Norwegian regulatory regime.

The PSA's 2011 report called for the development of tools and data required to cost the consequences of accidents from a social perspective. That would contribute to improved assessment of the companies' financial responsibility for post-accident clear-up and normalising, and to a greater emphasis on safety concerns in competition with other considerations. This would influence such aspects as:

- perspectives on the valuation of safety
- pricing of accident risk
- decision processes which do not explicitly address safety-related issues but which determine key operating parameters for safety (cost cuts, reorganisations, contractual incentives, remuneration systems and the like).

The PSA has carried out a study of the way company managements view and emphasise the issues. It will also continue efforts to place a value on safety, both through its own work and in a possible collaboration with other regulators and research institutions nationally and internationally.

9.2 Follow-up by the industry

The PSA's identical letter, see chapter 2, asked the industry to assess the need to review i) processes related to management and audit functions, to see whether these provide the information required on major accident risk in the enterprise and how they support a culture of responsibility, ii) practice related to the type of contract (content, structure, relationships and incentives) and whether sufficient account is taken of managing major accident risk, iii) processes and criteria for qualifying equipment suppliers and service providers, and whether sufficient account is taken of managing major accident risk, iv) continuous development and maintenance of a good safety culture, and v) key operating parameters which influence management's freedom of action and decisions on major accident risk.

Norwegian Oil and Gas, with contributions from the NR, pointed as part of its post-DwH follow-up to measures related to safety culture, organisation and management. It lists such specific initiatives as:

- updating standards
- industry-level collaboration
- the OGP's work on guidelines addressing process safety and KPIs related to field integrity and major accident risk
- criteria and KPIs for evaluating well control (Norsok D-010)
- change management related to the well's life cycle (Norsok D-010)
- review of well management systems at operators and contractors
- preparation of guidelines on the qualifications of well personnel
- studies and recommendations to the industry on the use of CRM.[46]

Several of these items have been covered in other chapters of this report.

A study carried out by the University of Aberdeen on behalf of the UK Health and Safety Executive in 2003 is relevant for CRM.[47] Post-DwH, the same team was asked by the OGP to conduct a new review with associated recommendations. This work has yet to be completed. In 2012, the OGP also published a report on *Cognitive issues associated with process safety and environmental incidents*,[48] which includes CRM, and another on *Recommendations for enhancements to well control training, examination and certification*[49] with contributions from the International Well Control Forum (IWCF)

[46] CRM refers to a joint training programme which has attracted greater attention after the DwH and Montara accidents. Derived from safety training in the aviation industry, it is also utilised in a number of other sectors. CRM training will typically embrace work to strengthen the understanding of conditions by different players, decision-making, management, collaboration and stress management in pressing conditions.

[47] UK HSE: http://www.hse.gov.uk/research/rrpdf/rr061.pdf [downloaded 11 Nov 2013]

[48] OGP: http://www.ogp.org.uk/pubs/460.pdf [downloaded 11 Nov 2013]

[49] OGP: http://www.ogp.org.uk/pubs/476.pdf [downloaded 11 Nov 2013]

and the IADC. The OGP's Human Factors Task Force under the Wells Expert Committee (WEC) will also draw up a standard for well operations crew resource management (WOCRM).

The Drilling Managers' Forum (DMF) at Norwegian Oil and Gas took an initiative in 2010 to establish a work group together with drilling contractor representatives through the NR which aims to help reduce the number and risk potential of well control incidents on the NCS.[50] Referred to as "better through sharing knowledge", this work has resulted in a series of presentations, exchanges of experience and recommendations to learn from recent well control incidents.

9.3 Conclusion

The PSA considers that it remains important for both government and players in the petroleum industry to work on creating and maintaining robust safety cultures. It also regards it as positive that clarifications, operationalisations and guidelines have been drawn up for key concepts which are useful for players in the industry. An important condition for developing a good HSE culture will continue to be clear and continuous prioritisation of safety by managers at all levels, including involvement by company directors and licensees.

Operating parameters provide key guidance for the freedom of action available to different players and their opportunities to influence and reduce major accident risk. The PSA sees a need for the companies themselves to assess continuously how various operating parameters influence HSE and major accident risk.

The PSA's impression is that improvement efforts and measures are initiated after incidents, and that most companies in the Norwegian sector have established systems to follow this up. However, it still sees a need for the industry to get better at picking up signals of deficiencies at a sufficiently early stage, and to conduct overall assessments and evaluations to identify the results and effects actually achieved by the companies from their follow-up efforts.

10 WELL CONTROL EQUIPMENT

Much attention was focused post-DwH on the BOP and equipment for capping and containment. The PSA's identical letter, see chapter 2, noted that the OGP and the IADC had started work on behalf of the IRF on following up the reliability, integrity and vulnerability of BOPs, and that the PSA was awaiting the outcome of this work. Furthermore, it expected the industry to be working to develop effective solutions for halting and/or diverting the wellstream in the event of a subsea blowout.

10.1 Blowout preventer (BOP)

The current requirement[51] calls for the control system of a drilling BOP to undergo an integrity analysis to ensure that it meets a specified minimum safety integrity level (SIL). In light of the DwH accident and the fact that a blowout can also occur during operations other than drilling, the PSA has noted that an analysis with a specified minimum SIL should apply to all types of BOPs – including ones for well intervention.

One of four priority areas defined by the OGP for well incident prevention was an assessment of the BOP system's reliability and potential improvements to this equipment. The OGP's WEC has initiated a study to establish a consistent method for calculating BOP integrity in order to be able to conduct comparable analyses. This work includes close collaboration with regulators globally to develop clear definitions and a common method of evaluating system integrity. It has yet to be completed, but the results will help to assess the cost/benefit of possible technical development.

[50] Norwegian Oil and Gas: http://www.norskoljeoggass.no/no/Nyhetsarkiv/HMS-og-drift/Deler-kunnskap-for-a-redusere-antall-bronnhendelser/ [downloaded 10 Nov 2013]

[51] See Norwegian Oil and Gas guidelines 070.

A study of BOP system integrity initiated by the OGP on the basis of historical data shows that a BOP including the control system but not the wellhead connection will typically have a SIL of 3, which falls to 2 when the wellhead connection is included. This analysis indicates that the control system and wellhead connection are the most critical components in the system, and that maintaining a specified SIL over the BOP's lifetime poses a challenge. Moreover, the integrity of the individual components, such as the ability of the shear rams to close in various conditions, is not covered in the analysis.[52]

The PSA believes that lessons from the DwH accident must not be confined to the well control system used on that rig, but must cover all types. In its view, it goes without saying that today's barrier philosophy must form the basis for further development of standards, guidelines and requirements for following up and maintaining BOPs with their control systems. The PSA will consider a clarification of reliability requirements for BOPs, including units for intervention, if this is not taken care of by updating standards referenced in the regulations.

According to the *Journal of Petroleum Technology*, the BSEE has four expectations for BOP:[53]
- that shear rams have the capacity to cut the equipment being run into the well through the BOP
- that the BOP is maintained as a critical safety system
- that real-time condition monitoring is established by instrumenting the BOP
- that requirements are developed for the competence of BOP maintenance personnel.

The PSA is aware that work is under way nationally and internationally within the four expectations presented by the BSEE. With the exception of the requirement for more powerful shear rams, they are also included in the PSA's recommendations. Equipment suppliers are developing technology and new models for shear rams which can cut more substantial components, such as tool joints. Furthermore, initiatives are to be found for strengthening maintenance of equipment included in drilling and well operations. These include the NR's Asset Integrity Forum. Instrumentation for continuous condition monitoring of BOPs has been developed and presented to the PSA by a supplier, but it does not know how extensively this system has been applied. Maintenance of safety-critical equipment, including condition monitoring, is a key issue in the PSA's audits. Both the IWCF and the IADC have taken initiatives on competence and training, but these do not appear to be coordinated.

10.2 Capping and containment

The DwH accident highlighted the significance of players in the petroleum industry having effective plans for capping wells and halting a blowout if necessary. The PSA's 2011 report pointed out that equipment, resources, procedures, plans, collaboration agreements and the like must be in place in any activity where a blowout is possible. It also noted the importance of tailoring these resources to the relevant conditions expected in each case (reservoir, regional and so forth).

As a direct result of the DwH accident and the OGP's Global Industry Response Group (Girg),[54] the Subsea Well Response Project (SWRP)[55] was established as a consortium involving a number of oil and gas companies. This international collaboration designed and built an integrated subsea well intervention system (Swis), which was ready for use at the beginning of 2013.

Oil Spill Response Limited (OSRL)[56] now operates Swis, including a total of four capping stacks suited for international use and two tool sets for equipment removal, BOP intervention and use of dispersants around seabed wellheads. The system can be used on most known subsea wells in waters up to 3 000 metres deep.[57] Swis equipment is now stockpiled at three international locations –

[52] IRF: http://irfconference2013.com.au/cms/wp-content/uploads/Update-on-progress-of-collaborative-efforts-.pdf [downloaded 4 Nov 13]

[53] *Journal of Petroleum Technology*: http://www.mydigitalpublication.com/publication/?i=119413 [downloaded 4 Nov 13]

[54] OGP: http://www.ogp.org.uk/index.php/download_file/view/64/378/ [downloaded 4 Nov 2013]

[55] Subsea Well Response Project: http://subseawellresponse.com/about-swrp/timeline/ [downloaded 5 Nov 2013]

[56] Oil Spill Response Limited: http://www.oilspillresponse.com/ [downloaded 3 Nov 2013]

[57] Subsea Well Response Project: http://us4.campaign-archive2.com/?u=34975835703afbeff730de1e4&id=ebdd6e1d74 [downloaded 3 Nov 2013]

Stavanger, Singapore and Saldanha Bay in South Africa – and is being readied for a fourth site in Brazil. It will be maintained in a way which permits immediate mobilisation by sea or air freight.

Several suppliers have also developed and can offer equipment and services for well capping, including Wild Well Control.[58]

As a result of experience from the DwH accident and of the intervention equipment developed and available for use, the PSA has proposed a new regulatory requirement that an agreement must in place before drilling begins on the availability of equipment for sealing the well should control be lost. This was communicated in an identical letter sent to the industry in March 2013.[59] The PSA has also clarified the need to secure access to the expertise required to operate the equipment, see section 21 of the activities regulations. The letter stated that, from the date of its despatch, the PSA would "set as a condition for consenting to activities which involve drilling of, completion of or intervention in subsea wells that an agreement has been entered into before drilling begins on the availability of equipment and expertise required to be able to halt a blowout from a subsea well with equipment for sealing, pursuant to section 10-18 of the Petroleum Act".

As noted in chapter 6, a new revision of Norsok standard D-010[60] was published in 2013. This standard has been updated with a recommendation that an overall plan for capping and containment of a subsea well blowout should be in place, and what this plan should cover.

Equipment suited for operations from jack-up facilities and wellhead platforms remains to be developed. Capping equipment can also be tailored for direct use in kill operations. These options are under discussion at an international level.

A global containment solution is under development to supplement the intervention system. According to the SWRP, this will be ready for use by the end of 2014.

10.3 Conclusion

Existing regulations specify requirements for the reliability of safety systems, including BOPs. The PSA sees that their integrity is not sufficiently clarified in applicable standards, and that a need accordingly exists to strengthen its follow-up for ensuring that the integrity of BOPs is documented.

A continued need for improvements to BOP integrity was one of several subjects underlined at the IRF conference in Australia during October 2013.[61] The summing up from this meeting identified a continued need to develop technology based on "out-of-the-box" thinking and as an alternative to traditional BOPs. The initiatives which have been taken look like demanding a more long-term perspective, which underlines the need for a result-oriented follow-up of the traditional BOP systems. The PSA has an expectation that the current assignment being pursued by the OGP and the IADC on behalf of the IRF will be given priority (also in the individual companies where required), and that results of this work will be seen during 2014.

Capping equipment is ready for use, and the PSA expects the industry to follow up the need to develop and maintain the expertise required to operate this. It is also important that the companies include capping in their risk assessments when planning drilling and well operations, and that exercises are conducted in mobilising and using the equipment. In this context, the industry should consider conducting a full-scale test of the equipment on the NCS. Solutions should also be developed for jack-

[58] Wild Well Control: http://wildwell.com/wellContained/index.html [downloaded 11 Jan 2014]

[59] PSA: http://www.ptil.no/getfile.php/Tilsyn%20p%C3%A5%20nettet/Samtykker/2013_406%20BREV.pdf [downloaded 5 Nov 2013]

[60] Standards Norway: http://www.standard.no/PageFiles/29619/D-010u4_2013_en_02.pdf [downloaded 5 Nov 2013]

[61] IRF: http://irfoffshoresafety.com/conferences/2013conference/Summary-IRF-2013-Offshore-Safety-Conference.pdf [downloaded 11 Nov 2014]

up rigs and wellhead platforms, and for handling blowouts in shallow waters. Similar follow-up of containment equipment will also be needed once this is available.

DEFINITIONS AND ABBREVIATIONS

Definitions
The most relevant concepts can be explained as follows:

Barriers	A barrier can be regarded as a function which prevents a specific course of events from occurring or which influences it in an intended direction by limiting damage or loss. "Function" means the job or role of the barrier. Examples of typical barrier functions include leak prevention, limiting leak volumes and preventing ignition. Technical, operational and organisational barrier elements must be in place to realise a barrier function. Their sum is crucial if the barrier is to function and remain effective at all times. Barrier elements are personnel, equipment or systems who/which execute or help to maintain a barrier function
Major accident	A major accident is an acute incident, such as a large discharge/emission, a fire or an explosion, which immediately or later causes a number of serious personal injuries and/or loss of human life, serious harm to the environment and/or loss of substantial material assets.
Performance (of barriers)	Integrity (reliability, availability), efficiency (capacity, time) and vulnerability (the opposite of robustness).

Abbreviations

Alarp	As low as reasonably practical
AoC	Acknowledgement of compliance
BAT	Best available technology
BSEE	Bureau of Safety and Environmental Enforcement
BOP	Blowout preventer
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
CRM	Crew resource management
CSB	Chemical Safety Board
DNV	Det Norske Veritas
DMF	Drilling Managers' Forum
DwH	*Deepwater Horizon*
Girg	Global Industry Response Group
GoM	Gulf of Mexico
HSE	Health, safety and the environment
IADC	International Associaton of Drilling Contractors
IRF	International Regulators' Forum
JRC	Joint Research Centre
KPI	Key performance indicator
NCS	Norwegian continental shelf
NR	Norwegian Shipowners Association
NSOAF	North Sea Offshore Authorities' Forum
NTNU	Norwegian university of science and technology
OLF	Norwegian Oil Industry Association
OGP	International Association of Oil & Gas Producers (previously the E&P Forum)
OSRL	Oil Spill Response Ltd
PAF	Plug and Abandonment Forum
PDO	Plan for development and operation
PSA	Petroleum Safety Authority Norway
R&D	Research and development
RNNP	Trends in risk level in the petroleum activity
SIL	Safety integrity level
Swis	Subsea well intervention system
SWRP	Subsea Well Response Project
WEC	Well Experts Committee
WOCRM	Well Operations Crew Resource Management