RISK LEVEL IN THE PETROLEUM ACTIVITY

# Risk of acute discharges Norwegian continental shelf 2001-09

PETROLEUM SAFETY AUTHORITY NORWAY

Preventor
Risk management research and development

# Risk level in the petroleum activity

# Project report – Acute discharges

# Norwegian continental shelf

# 2001–09

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PETROLEUM SAFETY AUTHORITY NORWAY

# Report

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| Summary<br><br>A method has been developed for extending the trends in risk level in the petroleum activity (RNNP) process to include the risk of acute discharges in the Norwegian petroleum sector. This method is presented in a separate report (Ref 2), while this report presents the results for the 2001-09 period. | |
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# Foreword

Through its RNNP process, the Petroleum Safety Authority Norway (PSA) has given a high priority since 2000 to securing an overview of trends in risk level in the petroleum activity. A good collaboration has been established with players in the petroleum sector, the unions and relevant specialists to create the necessary entrenchment of and confidence in the RNNP results.

An important element in the RNNP process since 2000 has concerned the monitoring of factors which are significant for major accident risk. The results presented in this report exploit existing data to produce information about the risk of acute discharges to the sea on the Norwegian continental shelf (NCS). That thereby increases the utility of data reported to the authorities and does not burden the companies with the need to gather additional information.

This report provides an important basis for assessing environmental and social risk associated with the petroleum activity, and represents an important contribution to the work of integrated ecosystem management for the sea areas off Norway.

Preventing accidents is important for workers, the natural environment, the value creation goals set by the players, and society as a whole. Access to new acreage depends increasingly on the players creating confidence that they are able to avoid accidents and that they work continuously to keep the risk of accidents as low as is reasonably practicable. An overview of risk developments is essential for managing accident risk. Positive trends demonstrate that improvement processes make a difference, while negative ones show where improvements are required.

An overview of the risk for acute discharges expands the target group for information about accident risk in the petroleum sector. This offers a potential for a more integrated approach to accident prevention and enhanced safety for people, the natural environment and material assets.

Those of us who work with safety on a daily basis know that the risk of accidents can never be eliminated, but that it can be managed to ensure accidents are avoided. We know that low risk is not a condition, but something constantly created and recreated in each activity. These realities are difficult to communicate because the subject is so serious. We have placed great emphasis on openness and integrity in our risk communication because we are convinced that knowledge about risk is crucial for preventing accidents, while under-informing, overdramatising or playing down accident risk does not serve the cause of safety.

Stavanger, 18.11.2010

Øyvind Tuntland

Director of professional development

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*Contents*



[Chapters 1–7 are only available in Norwegian]

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# 0. Summary and conclusions

## *0.1 Background and purpose*

The project on trends in risk levels on the NCS was initiated in 2000 to monitor changes in the level of risk in the petroleum activity, contribute to a more integrated picture of this development among companies and unions, and identify negative trends at an early stage to thereby improve the prioritisation of accident prevention efforts by government and players.

Separate annual reports on trends in risk level in the petroleum activity (RNNP) are issued by the PSA for offshore operations and land-based plants respectively. The RNNP covers the PSA's area of jurisdiction for safety and the working environment (Ref 1), and embraces major accidents, work accidents, the working environment and health.

Attention in the RNNP has been concentrated so far on the risk to people. However, the safety concept covers the prevention of all undesirable incidents, whether they lead to a loss of human life or cause harm to personnel, the natural environment and/or material assets. The PSA has given priority to preventing undesirable incidents with a major accident potential in the petroleum industry, and has in recent years been increasingly involved in work on integrated management plans for sea areas and other efforts to reach national environmental goals. The need to unify safety and working environment considerations with concern for the natural environment occupies a key place in this work. Preliminary work was accordingly initiated in the autumn of 2009 on extending the RNNP process to provide better monitoring of risk trends associated with undesirable incidents which could lead to acute pollution in the petroleum activity. This is confined to the probability for acute discharges, without any assessment of the impact which such spills could have on the natural environment. Nor does it cover regular operating discharges governed by discharge permits.

The activity in the autumn of 2009 was a pilot project to develop a method for evaluating the probability of acute discharges, which was tested with data from 2005-08 only (Ref 2). This work has continued in 2010 with information for a longer period so that trends can be identified.

The goal of the RNNP acute discharges project is to be able to supplement the PSA's annual publications on trends for personnel risk with annual reports about developments in the probability of acute discharges in the petroleum sector. In that context, monitoring of risk trends will provide information about improvements and deteriorations over time for factors affecting risk which are significant in equipping the government and the companies to:

- reduce opportunities for incidents which could cause acute pollution
- reduce the volume of acute pollution should an accident nevertheless occur
- reduce uncertainty related to accident mechanisms through a purposeful commitment to improvement projects, research and development, surveys, monitoring and so forth.

Risk trends are monitored for acute discharges from petroleum operations, both in general and regionally, in relation to the areas covered by integrated management plans for the NCS.

Extensive data from the RNNP and Environment Web (EW) covering incidents, near misses (or precursors), causes and barriers form the basis for work on the RNNP acute discharges study. The present report includes information from 2001-09, presented as annual values in the case of actual spills. Material from the RNNP includes data for 1999-2009, presented as three-year rolling average values for 2001-09 in order to be able to identify trends more easily and draw conclusions about risk levels in line with experience from many years of methodological development with the RNNP process.

Risk deals with the future, and is accordingly about much more than historical safety performances. An important lesson from major accidents is that information on accident trends does not provide a sufficient basis for saying anything about the risk of an incident. Data from the RNNP acute discharges study must accordingly be assessed in conjunction with other information about health, safety and environmental (HSE) performance in order to acquire an adequate picture of risk trends in the petroleum activity. General developments must also be assessed with the necessary reservations, in part because substantial variations in risk trends exist between different installations and because general developments can be influenced by isolated serious incidents and thereby "under-communicate" a positive trend among the majority of players.

Monitoring risk is essential for picking up negative trends sufficiently early to respond proactively and purposefully, and thereby avoid undesirable incidents. It is equally important that reduced risk does not undermine the attention paid to the need for continued measures in order to remain at that level. Low risk is not a condition, but something constantly created and re-created in each activity. It requires a fundamental recognition of the uncertainty, complexity and dynamics in the activity, and a permanently critical approach to the defences established for accident prevention.

This report is restricted to information from the RNNP and EW as well as the common drilling reporting system (CDRS) and the PSA's incident database. Proposals for expanding the project are given in the section on knowledge gaps. The report presents results from the project for the 2001-09 period. Detailed results are presented in chapters 4, 5 and 6, while chapter 7 presents a discussion of results and trends. A summary of the most important findings and trends is presented in the present chapter.

## *0.2 Restrictions, base data, methodology and uncertainty*

A number of restrictions apply to this project. It is confined to the PSA's area of jurisdiction and accordingly covers only acute discharges. No assessments have been made of the impact of such spills on the natural environment, and regular operating discharges are excluded.

The project is based on existing data from the RNNP and EW as well as the common drilling reporting system (CDRS) and the PSA's incident database. It accordingly covers both actual acute emissions and near misses which could have led to such spills if several barriers had failed.

Only acute discharges from Norwegian offshore petroleum operations and the potential for such spills are covered. Acute discharges to the sea from petroleum installations on land have not been included at this stage.

All types of acute discharges to the sea contained in EW are included. No lower limit has been set for the size of spills registered in EW, so that the base data include all acute discharges. The main emphasis is on acute spills of crude oil to the sea, but similar discharges of other oil types and chemicals are included.

Crude oil quantities are given in tonnes to permit a comparison between the petroleum and maritime industries, since the latter traditionally uses this unit. Volumes of other oils and chemicals are given in cubic metres, since a conversion to tonnes would be too resource-intensive. Categories used for actual discharges are 0-10, 10-100, 100-1 000 and more than 1 000 tonnes. See figure 1.

Undesirable discharges from cuttings injection wells and other injectors are treated separately (see sections 0.3.2 and 4.4) on the basis of an investigation of these incidents by the Norwegian Climate and Pollution Agency (Klif) and the PSA. This solution has been adopted in part because such incidents are not all registered in EW and because the volumes discharged may be recorded collectively in one year even though the discharges have extended in reality over a longer period.

According to the site, the quality of reporting in EW is good for the period after 2003. The level of detail in its information on incidents is limited, and no resources have been allocated in this project to cross-check data with other sources. Substantial uncertainty also exists about the scope of acute discharges from cuttings injection wells and the like. Studies of this issue are still under way. See section 0.3.2. Detecting underwater leaks has been a challenge over time. Account must accordingly be taken of a degree of uncertainty from possible under-reporting of subsea leaks in terms of both number and volume.

Results from the project are presented as risk indicators. These are observations considered to say *something*, but *not necessarily everything* about risk trends. To obtain a more holistic picture, a number of indicators must normally be treated together. Risk indicators are presented both for acute discharges and for near misses which could have led to acute crude oil spills to the sea.

In addition to actual acute discharges registered in EW, extensive data have been utilised from the RNNP on near misses (precursors) which could have led to acute discharges if several established barriers had failed. Such precursors are among the incidents designated by the RNNP as defined situations of hazard and accident (DSHAs). The following DSHAs are regarded as relevant to the probability for acute discharges, and are accordingly included in the analysis. See also other DSHAs in section 2.5.2.

- DSHA1: Non-ignited process leaks
- DSHA3: Well control incidents
- DSHA5: Passing vessels on a collision course
- DSHA6: Drifting objects/vessels on a collision course
- DSHA7: Collisions with field-related vessels/installations/shuttle tankers
- DSHA8: Damage to a support structure
- DSHA9: Leaks from and damage to subsea production installations/pipelines/risers/flowlines/-loading buoys/loading hoses

DSHAs regarded as relevant fall under three types of scenarios, which are explained in more detail in section 2.5.3:

a) blowouts (DSHA3)
b) fires and explosions caused by the uncontrolled escape of hydrocarbons (DSHAs 1 and 9), which could lead as a secondary effect to acute discharges and/or blowouts if many barriers fail
c) major structural damage (DSHAs 5-8), which could also cause acute discharges and/or blowouts as a secondary effect with the failure of barriers.

DSHA2 (ignited process leaks) has not occurred on the NCS after 1996. DSHA4 (other fires) and DSHAs 11-21 are considered to have a negligible probability of causing acute discharges, and have accordingly been excluded from the analysis. Since no ignited process leaks occurred during the period under consideration, the term “process leaks” is confined in this report to DSHA1 (non-ignited process leaks).

The project also addresses the probability for acute discharges associated with activities generated by petroleum operations on the NCS, including all transport of crude oil from offshore installations to land. Incidents related to Russian tankers in Norwegian waters (see moreover section 0.3.4) are not included in the analysis. Nor are exports of petroleum (including crude oil) from petroleum plants on land (Mongstad, Kårstø, Sture and so forth).

For each DSHA, a probability has been calculated of a near miss actually resulting in an acute discharge. These probabilities are based on fixed weights for the precursors which have occurred, and are described in detail in a separate methodology report (Ref 3). The weights are determined by the specific circumstances for the relevant type of incident and installation, and express the potential of the relevant incident to cause an acute discharge. Distributions are applied which express the range of variation for the acute discharges, given the circumstances in the scenarios involving such spills.

The data utilised in this part of the report are extensive and drawn from information collected by the RNNP process in 1999-2009, with considerable work devoted to quality assurance of the material. Uncertainty in the reported data is accordingly regarded as limited. The potential for the various near misses has been analysed and assessed on the basis of information about the incidents.

Most of the risk indicators used are normalised in relation to a level of activity – per installation year, for instance. The normalisation data used are largely the number of drilled wells and the number of installation years, including production and exploration activity. Where acute crude oil spills are concerned, the installation year is restricted to installations producing oil or condensate and to all exploration operations.

Actual incidents are expressed as the number per year, while indicators for most of the near misses are based on rolling three-year averages for the 2001-09 period. The value in 2001 is accordingly the average for 1999-2001, in 2002 for 2000-02 and so forth. This method of calculation is utilised for near misses to avoid a limited number of incidents having arbitrary effects from year to year. Using a three-year rolling average makes it easier to identify trends. The exception is precursors in the Barents Sea. Only two of these occurred during the period, so that a three-year average would have no significance. The average for the whole period is accordingly used for the Barents Sea to indicate a level. Trends are in any event impossible to specify on the basis of two incidents.

Risk indicators for near misses with the potential to cause acute discharges are also expressed on a relative scale, in the same way as Norway’s consumer price index. This is done by converting the values for all years after setting the value for 2005 equal to one on the whole NCS (all sea areas taken together). This “normalisation” (or relativisation) aims to focus attention on trends, with the absolute values of no particular interest.

Risk trends are monitored for acute discharges from petroleum operations, both in general and regionally, on the basis of the areas covered by integrated management plans for the NCS (the North, Norwegian and Barents Seas). Data naturally vary from one planning area to another. This presents a challenge in comparing risk and risk trends between these areas. Information from the Barents Sea is so limited that data on the risk of acute discharges in these waters are unsuitable for comparing with comparable risks in the North and Norwegian Sea. Assessing the probability of acute discharges in the Barents Sea must be based to a great extent on probability information from other petroleum operations on the NCS, since activities in these far northern waters will in practice involve the same players, experience, knowledge and technology. The probability of an acute discharge in the Barents Sea must accordingly be evaluated for the time being as a reflection of the probability in other parts of the NCS.

## 0.3 Acute crude oil discharges – status and trends

This section presents overall conclusions relating to the status and trends for the risk of acute oil discharges on the NCS. The quality of data in EW is reportedly good for the period after 2003. As mentioned above, the level of detail in the information about each incident in EW is limited, and this project has not had the resources to cross-check it against other sources. A more detailed discussion of the results can be found in section 4.1 and chapter 5.

### 0.3.1 Actual acute crude oil discharges to the sea

Actual discharges have been normalised against the number of installation years.[1] Figure 1 shows the development in acute crude oil discharges to the sea for the whole NCS per year and normalised per installation year. A clear reduction has occurred, from just under 90 incidents per annum to 40, or from a little over one acute discharge per installation year to 0.5. This low value has been constant throughout the 2004-09 period. As a sensitivity check, figure 1 was also produced with a lower limit of 0.05 cubic metres. The number of incidents was roughly halved, but the shape of the curve remained almost the same with the exception of 2001, which shows that the reporting rate was virtually unchanged throughout the period.

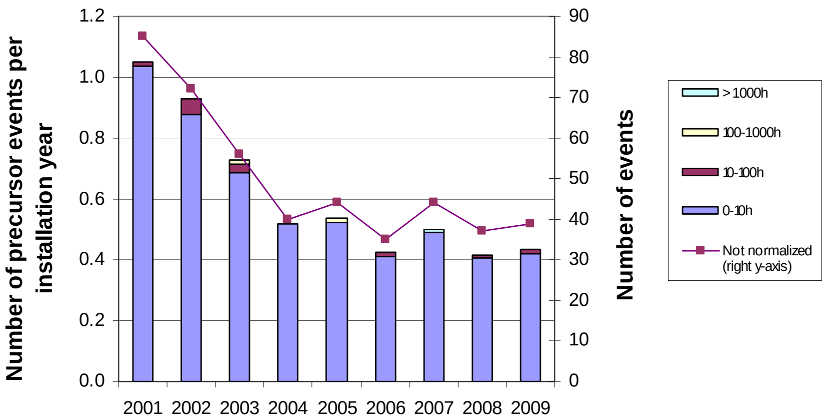



**Figure 1 Actual acute discharges of crude oil to the sea, per installation year and in total, for the whole NCS in 2001-2009**

A significant decline in crude oil spills per annum occurred in the North Sea, from just over 60 in 2001 to just over 20 in 2009 (figure 2). Reductions were at their highest up to 2003, and have been more limited over the past six years. Their frequency declined in the North Sea from 0.91 per installation year in 2001 to 0.43 in 2009. See figure 2. The North Sea experienced a clear reduction in frequency during the period, and this decline was statistically significant for 2009 when compared with the average for the preceding period.

The Norwegian Sea experienced an increase in such spills during the years immediately after 2000, then a substantial reduction and finally a stable level from 2004. See figure 3. There were 0.44 acute crude oil discharges per installation year in this part of the NCS during 2006, which had risen to 0.94 in 2009. Thirteen acute crude oil discharges occurred on Norwegian Sea installations during the latter year. An acute discharge of crude oil during production testing of a well in 2001 is the only incident of this kind reported from the Barents Sea.

1 Installation years for all oil discharges are limited to oil production installations and drilling units.

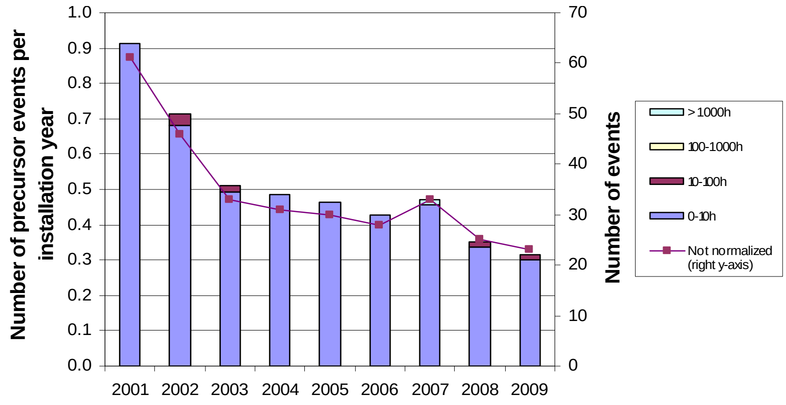



**Figure 2** **Actual acute discharges of crude oil to the sea, per installation year and in total, for the North Sea in 2001-2009**

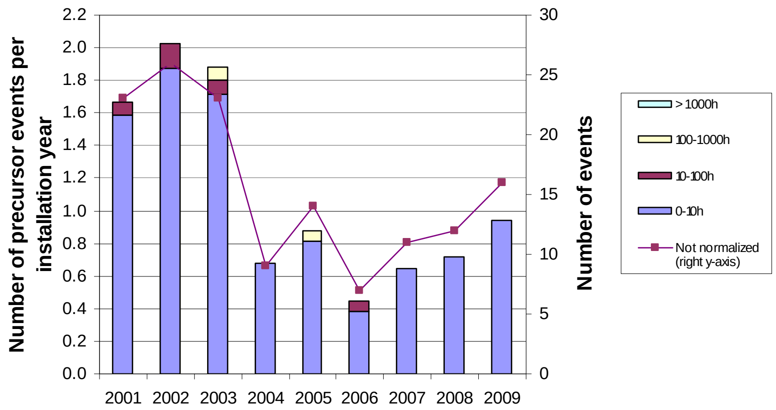



**Figure 3** **Actual acute discharges of crude oil to the sea, per installation year and in total, for the Norwegian Sea in 2001-2009**

Acute discharges per installation year in the Norwegian Sea were significantly fewer in the final six years of the period than in 2001-03. See figure 3. Registered acute spills were two per installation year in 2002, and 0.94 in 2009. The frequency of acute crude oil discharges per installation year was lower in the North Sea than in the Norwegian Sea throughout the period. The average frequency was almost 104 per cent higher in Norwegian Sea than in the North Sea. Only one acute crude oil spill was registered in the Barents Sea during the period. As mentioned above, data for these waters are so limited that its normalised result is unsuitable for comparison with corresponding figures for the North and Norwegian Seas. Given that activities in the Barents Sea will involve the same players, experience, knowledge and technology as the other areas of the NCS, results for the latter should be regarded for the time being as applicable to the former.

Of 310 actual acute discharges in the North Sea, 304 were smaller than 10 tonnes (0.36 tonnes per spill on average). Five of the incidents were in the 10-100 tonnes category (averaging 33 tonnes per spill), while one was above 1 000 tonnes (roughly 3 700 tonnes). See figure 2 for the details. The total volume per year has varied sharply, depending on large individual spills. The average volume released to the sea from acute discharges during the period was about 441 tonnes per annum in the North Sea and roughly 123 tonnes per annum in the Norwegian Sea. Excluding the year when the biggest discharge was registered in each area from the calculation illustrates how this average is influenced by individual spills. The average quantity of crude oil spilt per installation year during the period then falls to 31 and 34 tonnes for the North and Norwegian Seas respectively. That follows the exclusion of 2007 with 3 713 tonnes of crude oil discharged in the North Sea, and 2003 with 660 tonnes spilt in the Norwegian Sea.

Of 141 actual acute discharges in the Norwegian Sea, 134 were smaller than 10 tonnes (0.25 tonnes per spill on average), five fell into the 10-100 tonnes category (averaging 30 tonnes per spill) and two were in the 100-1 000 tonnes range. See figure 3 for details.

When the sizes of discharges per installation year are compared, the five largest acute spills in the period dominate.

- Norwegian Sea
  - 2003: Draugen – 659 tonnes
  - 2005: Norne – 286 tonnes
  - 2006: Draugen – 82 tonnes
- North Sea
  - 2007: Statfjord A – 3 696 tonnes
  - 2009: Statfjord C – 80 tonnes

A large discharge associated with cuttings injection also occurred in 2008. As mentioned above, however, undesirable discharges from cuttings injection wells are treated separately. See section 0.3.2.

Because the volumes discharged in the five incidents listed above are so much larger than the great majority of acute discharges, they have been excluded from figure 4 to make it possible to explore trends for the majority of actual acute discharges to the sea. See also section 4.1.2.

Figure 4 provides an overview of quantity per installation year after excluding the five large acute spills listed above. It shows that, although the number of discharges was higher per installation year in the Norwegian Sea, the average annual volume was marginally lower there than in the North Sea when the final six years of the period are viewed as a whole. The Barents Sea experienced a small acute discharge of crude oil in 2001 (0.02 tonnes) but has been excluded from the figure because the paucity of data means no trend can be given for these waters.

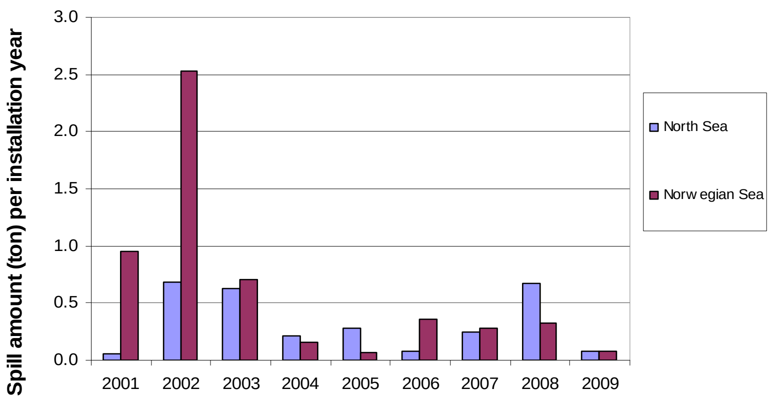



**Figure 4 Mass of crude oil spilt to the sea per installation year through actual acute discharges in the North and Norwegian Sea planning areas when the five larges incidents are excluded**

### 0.3.2 Acute discharges from injection wells

A number of incidents involving undesirable discharges from cuttings injection wells have occurred over more than a decade. The most recent leak was discovered on the Veslefrikk field in November 2009, and had probably been under way since 1997.

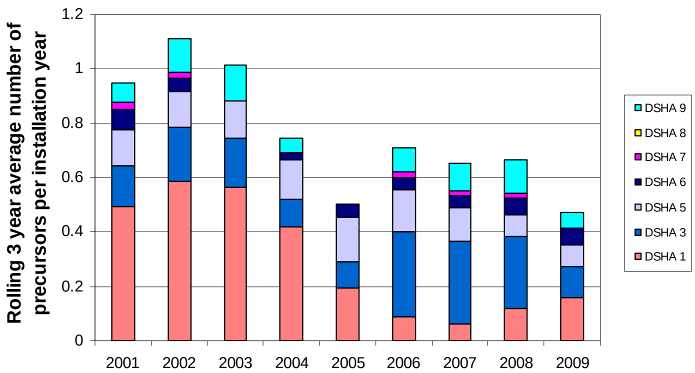
Undesirable discharges from injection wells are treated separately because these incidents are not all registered in EW and because discharged volumes may be measured collectively for a single year although the discharge could in reality have occurred over a longer period. Such discharges have therefore been excluded from the other presentations of actual acute spills (see section 0.3.1) and collected in a separate table in section 4.4. An overall picture of actual acute discharges in the petroleum industry can thereby be obtained by looking at the collective results for actual acute discharges and undesirable discharges from injection wells.

After the Veslefrikk leak was discovered in November 2009, the PSA and Klif have collaborated on gathering information from the companies, and a status report was issued by Klif in May 2010 (Ref 4). Information from that document has been used as input for section 4.4.

### 0.3.3 Near misses which could have led to acute discharges

This analysis has drawn on comprehensive data from the RNNP on near misses (precursors) which could have led to acute discharges to the sea if a number of established barriers failed. Had such failures occurred, the course of events could have involved fires, explosions and/or extensive structural damage which might have far-reaching consequences for personnel as well as a potential for acute discharges of oil to the sea. Each near miss is weighted on the basis of its potential to cause an acute spill. The reporting quality for these RNNP data is generally good.

Figure 5 shows that the trend for near misses in the RNNP with the potential to cause an acute discharge (see the list in section 0.2) on the NCS was declining throughout the period, and that the 2009 value of 0.47 precursors per installation year was the lowest in the series. The values in figure 5 are shown as three-year rolling averages, as discussed in section 0.2. It emerges clearly that hydrocarbon leaks declined sharply until 2007, and then rose a good deal in 2008 and 2009. A substantial variation in well control incidents also shows up clearly, making the biggest contribution per installation year in 2006-08. The other incidents have lower levels and less variation.




DSHA9: Leaks from and damage to subsea production installations/pipelines/risers/flowlines/-loading buoys and hoses

DSHA8: Damage to support structures

DSHA7: Collision with field-related vessels/installations/shuttle tankers

DSHA6: Drifting objects/vessels on a collision course

DSHA5: Passing ships on a collision course

DSHA3: Well control incidents

DSHA1: Process leaks

**Figure 5 Rolling three-year averages for registered near misses in the RNNP with the potential to cause an acute crude oil spill on the NCS, normalised by the number of installation years**

About 90 near misses which could potentially have led to an acute discharge of crude oil in the North Sea occurred in 2002, compared with 38 in 2009. In the Norwegian Sea, such incidents varied between 19 in 2006 and four in 2007. The 2009 figure was 11, which is also the average for the period. Two such near misses (well control incidents) occurred in the Barents Sea in 2000 and 2008 respectively. No near misses occurred in these waters in other years. Developments in the North and Norwegian Seas are shown in figure 6 as three-year rolling averages for near misses per sea area normalised over the number of installation years.

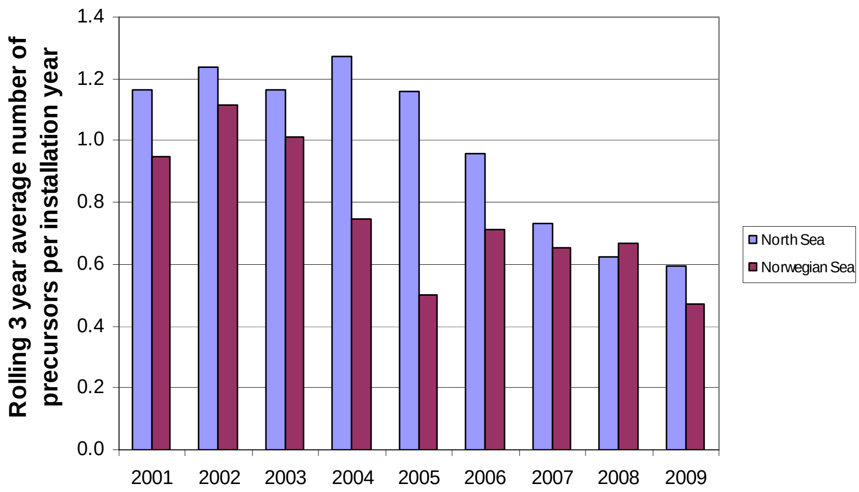



**Figure 6 Rolling three-year avearges for registered near misses in the RNNP with the potential to cause an acute crude oi spill in the North and Norwegian Seas, normalised over the number of installation years**

When normalised over the number of installation years, near misses with the potential to cause acute discharges declined over time in both North and Norwegian Seas.

The average frequency per installation year over the whole period was 0.95 and 0.75 for the North and Norwegian Seas respectively. As mentioned above, two incidents occurred in the Barents Sea in 2000 and 2008. Data for these waters are so limited that normalised results for this area would be unsuitable for comparison with corresponding results in the North and Norwegian Seas. Results for the Barents Sea should be considered for the time being to be the equivalent of figures for the other areas of the NCS.

Contributions from the various types of precursor incidents on the NCS in 1999-2009 are:

- hydrocarbon leaks 31%
- well control incidents 16%
- structural incidents 53%

Most categories of precursors recorded on the NCS have primarily had the potential to cause acute oil spills of up to 1 000 tonnes. The exception is the well control category, which has had a higher probability of leading to acute oil spills larger than 1 000 tonnes.

Figure 7 shows an overview of relative risk indicators for potential acute discharges in 2001-09 on the NCS, normalised over the number of installation years and broken down by spill volume category.

These figures are normalised by setting the total risk indicator for acute discharges on the whole NCS at one for 2005. See the explanation in section 2.6. Rolling three-year averages are presented.

According to figure 7, the level was stable throughout the period, with 2005 as the year with the lowest value. Substantial variations exist between values in the individual years, despite the use of three-year rolling averages. Well control incidents made a large contribution in 2006-08, which meant that relative indicator values were fairly high in these years.

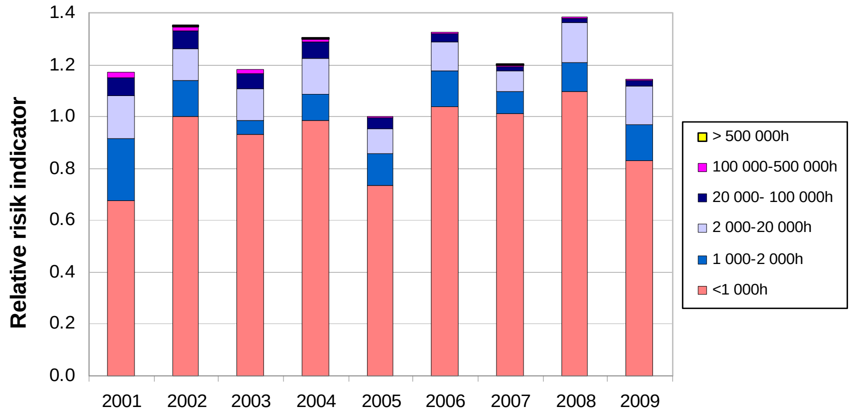



**Figure 7 Relative risk indicators for potential acute crude oil discharges on the NCS, three-year rolling averages normalised over the number of installation years, with 2005 set as 1.0 for the whole area**

Figure 7 shows, for example, that the probability of a potential acute crude oil spill to the sea ending up in a specific size category in 2009, as a three-year average, was 72 per cent for below 1 000 tonnes, 13 per cent for 2-20 000 tonnes, 1.8 for 20-100 000 tonnes, 0.4 per cent for 100-500 000 tonnes and 0.05 per cent for above 500 000 tonnes. Note that these probabilities are conditional on an acute discharge occurring on the NCS in 2009 as the result of extensive barrier failure in the near misses recorded for that year. From that perspective, these are hypothetical values in that no such discharge occurred in 2009, and the barriers functioned in the relevant near misses to prevent an escalation of these incidents. Despite their hypothetical character, however, they express a potential for acute discharges which it is important to take into account.

The values in figure 8 show "statistically expected"[2] spill volumes related to acute discharges per installation year in the North and Norwegian Seas during the period. This identifies a clearly declining trend for the Norwegian Sea, and a certain reduction over time in the North Sea. As mentioned above, the Barents Sea experienced only two incidents. The average value for the North Sea over the whole period was 0.38 on the relative scale, while the corresponding average value for the Norwegian Sea came to 0.94. The average value for figure 8 moreover shows that, on a relative scale, the expected discharge volume per installation year for the Norwegian Sea was higher than for the North Sea in every year except 2001.

[2] Note that "statistically expected" is a mathematical concept, and does not express any actual expectation of what will happen.

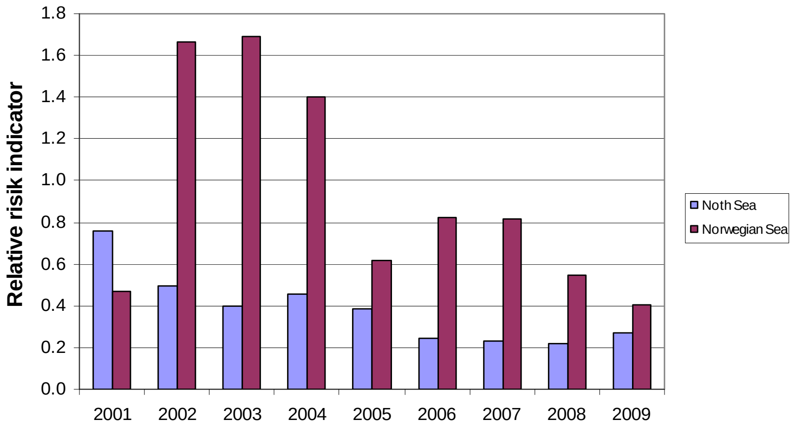



**Figure 8 Relative risk indicators for potential acute crude oil discharges on the NCS, three-year rolling averages normalised over the number of installation years, with 2005 set as 1.0 for the whole area**

### 0.3.4 Transport by shuttle tanker and maritime operations

Results for acute discharges to the sea from installations in sections 0.3.1 and 0.3.2 include pipeline transport of oil to land and oil storage on installations for export by shuttle tanker. Oil export by shuttle tanker to land is also included in this report to cover all transport of produced crude from the NCS.

Generally speaking, other maritime operations are not covered by the project – with one exception. Maritime activities represent a threat to installations on the NCS should a collision occur between vessels engaged in external and/or internal (offshore-related) operations and the installations which these units are normally required to stay at a safe distance from. The installations have contingency plans for such emergencies, with the primary focus on saving life and health – in other words, evacuation of all personnel in good time. A sufficiently powerful collision could cause the total loss of the installation and yield secondary effects such as acute discharges from storage tanks or cells, broken pipelines/risers or wells affected by barrier failures.

Possible collisions with passing merchant vessels, drifting objects and field-related vessels are included in relation to the threat they pose of an acute crude oil spill. The same incidents are included as near misses in the RNNP. Contributions to the figures in section 0.3.3 include near misses from passing merchant vessels or drifting objects on a collision course and possible collisions with field-related vessels. The same category also embraces structural failures which arise without external input – in other words, extensive structural damage as a result of design or construction errors or extreme natural loads. When all structural damage is treated as a separate category, it becomes one of the three largest.

To cover the risk associated with shipping crude oil to land in shuttle tankers, an activity index has been established which illustrates the trend for such transport from fields on the NCS to land-based refineries and terminals. The trend for acute oil spills from shipment by shuttle tanker is declining in both North and Norwegian Seas because the volume of oil exported by ship is falling. This project report takes no account of other variables apart from the level of activity which could influence a change in risk for acute oil spills from shipment to land by shuttle tankers.

### 0.3.5 Significant barrier data for preventing acute discharges

Data about significant barriers for preventing acute discharges relate to the near misses which could cause an escape of hydrocarbons to the sea. These include hydrocarbon leaks from process systems, risers/subsea production installations, pipelines, flowlines, loading hoses and buoys, and well control incidents. Insufficient data have been available in the RNNP on barriers against acute discharges from risers, pipelines, flowlines, loading hoses and buoys and subsea production systems, which are accordingly excluded. The other near misses are incidents which could lead to structural failure and cause secondary escapes of hydrocarbons through the total loss of an installation. Barriers relevant to avoiding major accidents in general are included in the RNNP. See section 2.4 and chapter 6 for further details.

Relevant barrier functions for process leaks relate to detection, isolation, pressure blowdown and spill collection on the installation. Both automated and manual interventions have been assessed. For well control incidents, these functions relate to detection, shut-down, well killing and diversion of drilling fluids. Barrier information in the RNNP rests on periodic testing of barrier components. Such data of significance for preventing acute discharges are based on information about barrier functioning in actual near misses which could have caused discharges to the sea.

Detection and shut-down rank as readily available barrier functions. Blowdown is a barrier function with a little lower availability, while so few incidents provide additional information about spill collection on the installation that no conclusions can be drawn about the efficiency of this barrier function on the basis of RNNP data alone. Where barriers for well control incidents are concerned, no failure of the functions analysed have been registered in those instances where such functions were relevant. Barriers functioned as intended in most cases of near misses which could develop into a blowout. The exception was the gas blowout on Snorre A in 2004, and 14 cases of shallow gas blowouts in 1999-2009. The barriers available in the early stages of a well are not the same as those deployed when drilling into a reservoir formations. It should be noted that barrier data in the RNNP cover both gas and oil production installations.

### 0.3.6 Significant trends from the RNNP

As mentioned above, the RNNP reports published annually since 2001 provide an overview of risk trends in the petroleum industry with the emphasis on risk to people. These reports cover such issues as the development of major accident risk on offshore installations, and thereby embrace a number of findings which are also significant for establishing a picture of the probability for acute crude oil discharges to the sea. Only those sections of the RNNP are referred to here.

Generally speaking, indicators related to major accidents have shown a positive trend in recent years. The industry has focused much attention on reducing the number of hydrocarbon leaks. These are primarily gas escapes which could cause fires and explosions. Should many barrier functions fail, they could lead to acute oil spills. Clear reduction targets have been established in several stages – first a maximum of 20 leaks larger than 0.1 kilograms per second (kg/s) in 2005, then 10 leaks in 2008 and thereafter a 10 per cent annual cut. The first of these goals was reached in 2005, with 10 such leaks registered in 2007, 14 in 2008 and 15 in 2009. A comparison of leak frequencies on the NCS and the UK continental shelf (UKCS) indicates that a reduction potential exists in the Norwegian industry. In other words, the targets for cutting hydrocarbon leaks were not achieved in 2008 and 2009. As can be seen, the trend points in the other direction. The significance of this development is primarily that possible precursors for fires and explosions, and thereby the probability of acute oil discharges, are on the increase. Such scenarios occur only if a number of barriers fail, so that an uncontrolled fire breaks out with the possibility of total loss of the installation.

Indicators related to well control incidents have also displayed a generally positive trend in recent years, but again showed an increase in frequency during 2009 for both exploration and production drilling. Weighted in relation to the potential contribution of this type of incident to loss of life, such incidents were at a median level for the whole period in 2009. This indicator has a corresponding effect on the probability of acute oil spills to the sea and, viewed from that perspective, the likelihood of acute spills being caused by well control incidents has also increased. The industry's well integrity project is described in the main RNNP report for 2009 (section 6.3.1.4).

Generally speaking, indicators for structural incidents – including ships and drifting objects on a collision course and collisions with field-related traffic – show stable levels for production installations but have declined slightly for mobile units. Discharges from risers and pipelines also remained stable with regard to personnel risk.

Data on the availability of barriers intended to prevent near misses from developing into major accidents show stable levels, but with big differences from one installation to another. Some of the latter have substantially lower availability than the average for the industry. This could mean that a near miss might develop into a major accident with substantial consequences for personnel and considerable acute discharges.

The RNNP report for 2009 was the first to provide an overview of maintenance status, one of the most important requirements for sustaining an acceptable technical condition. While reported data are subject to great uncertainty, they show that big differences may exist in the extent of tagging and classification for systems and equipment, lags in preventive maintenance and outstanding corrective measures. That also applies to safety-critical systems and equipment.

Viewed overall, near misses with a major accident potential showed a slight rise in 2008-09 compared with earlier years. When combining frequency and potential for loss of life related to the same incidents, the 2009 value was lower than in previous years. Moreover, values for 2007-09 were lower than for any other three-year period over the past decade and a half. This also means that reducing the probability of acute oil spills is under consideration.

### *0.4 Acute discharges of other oils and chemicals – status and trends*

In addition to acute crude oil spills to the sea, the project has assessed data on acute discharges of other oils and chemicals. Total acute discharges for the sea areas, normalised against installation years,[3] are presented in figure 9 for other oils and figure 10 for chemicals. Chemicals and other oils are specified by volume (cubic metres), since insufficient information is available in EW for converting these values to mass (tonnes). It should again be noted that undesirable discharges from injection wells are treated separately. See section 0.3.2.

[3] Where chemicals are concerned, installation years have been calculated for all types of installation.

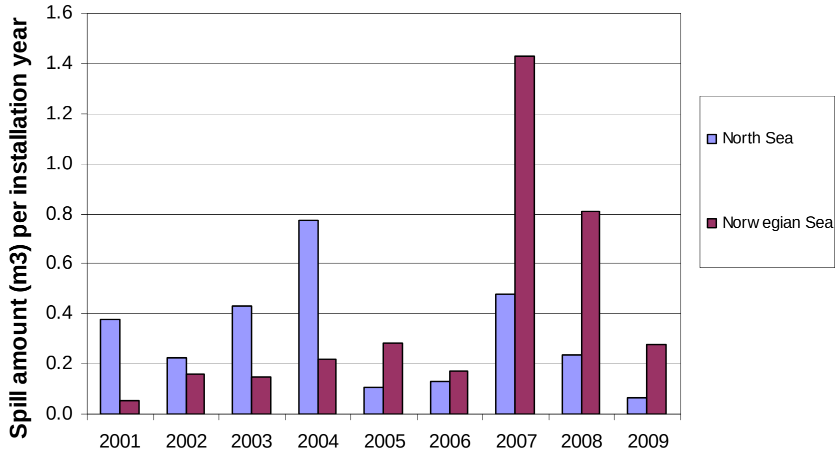



**Figure 9** **Volume of acute discharges of other oils on the NCS in the North and Norwegian Seas by installation year in 2001-2009**

Figure 9 shows that the largest volume discharged was in the North Sea up to 2004, but that this trend appears to have reversed from 2005. During 2005-09, the volume of acute discharges per installation year was larger in the Norwegian Sea than in the North Sea. Three large acute discharges of diesel oil were experienced in the Norwegian Sea in 2007 and 2008. Base data for the volume of other oil discharges in the Barents Sea are too few for trends to be detectable during the period. These waters are accordingly excluded from figure 9. The Barents Sea experienced acute discharges of other oils in 2005 (two incidents), 2006 (two) and 2009 (one). Those in 2005 and 2006 were smaller than 0.05 cubic metres. As mentioned above, data for the Barents Sea are so limited that normalised results for this area are unsuitable for comparison with corresponding values in the North and Norwegian Seas. Results from the Barents Sea should be regarded for the time being as corresponding with values for the other areas of the NCS.

Stable levels for acute discharges of chemicals per installation year in the North and Norwegian Seas are shown in figure 10, with substantial variations from year to year. The average volume of acute chemical spills per installation year over the whole period was largest in the Norwegian Sea.

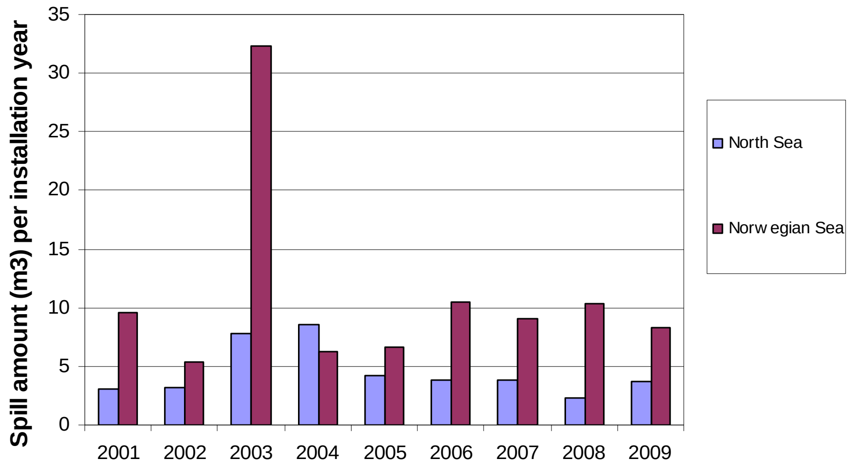



**Figure 10** **Volume of acute chemical discharges per installation year on the NCS in the North and Norwegian Seas in 2001-2009**

### *0.5 Overall assessment – acute discharges to the sea*

Actual acute crude oil discharges declined in 2001-09 for the NCS as a whole. No clear trend emerges for the quantities discharged in such incidents. Quantity was dominated to a great extent by a few individual spills. When these are excluded, values were generally lower in the second half of the period than in the first half. Four of the five largest discharges occurred in 2005-09.

Undesirable discharges related to cuttings injection are treated separately, but must be viewed together with other information about actual incidents to secure an overall view of trends for actual acute discharges in the petroleum industry.

Actual acute crude oil spills declined in 2001-09 for the North and Norwegian Sea planning areas. The frequency calculated per installation year was almost 104 per cent higher in the Norwegian Sea than the North Sea.

Annual quantities were higher in the Norwegian Sea than the North Sea when calculated per installation year in the early part of the period. In more recent years, virtual parity prevailed on this measure between the two areas. This means that acute crude oil discharges were smaller on average in the Norwegian Sea than in the North Sea.

One acute crude oil spill occurred in the Barents Sea, in 2001. A low level of activity in these waters indicates that it will take a long time before such a large volume of data is available that the probability of acute discharges can be based solely on information from this area. It will accordingly be necessary to utilise data from the North and Norwegian Seas to draw conclusions about the probability of acute discharges in the Barents Sea. The industry's ability to limit the number and scope of acute discharges in the North and Norwegian Seas can also be expected to indicate its corresponding ability in the Barents Sea.

The frequency per installation year of near misses which could cause crude oil spills if barriers fail declined on the NCS viewed as a whole. In addition, the potential quantity of crude oil spilt in such incidents fell during the period for the whole NCS. Most of such potential acute discharges (70 per cent or more) will be smaller than 1 000 tonnes.

Near misses which could cause crude oil spills if barriers fail also declined in frequency per installation year in both North and Norwegian Seas. In addition, the potential quantity of crude oil spill in such incidents fell during the period, more in the Norwegian Sea than in the North Sea. As an average for 1999-2009, the statistically expected[4] quantity of such potential discharges owing to near misses was roughly twice as high in the Norwegian Sea than in the North Sea. This means that near misses on Norwegian Sea installations had a greater potential for causing acute crude oil spills than similar incidents on North Sea installations.

The Barents Sea had two near misses with the potential to cause crude oil discharges during 1999-2009.

According to the RNNP, the frequency of certain near misses (well control incidents and hydrocarbon leaks) increased somewhat over the past couple of years, so that the positive trend which had persisted for several years was reversed. Over the past couple of years, however, these two types of precursors

[4] Note that "statistically expected" is a mathematical concept, and does not express any actual expectation of what will happen.

were not as serious as in the 2004-06 period. Nevertheless, the fact that near misses in the RNNP for hydrocarbon discharges (primarily gas leaks) and well control incidents were those which increased in 2009 was a clearly negative feature of the overall picture. These two types of incidents are the most significant for the probability for acute discharges.

The availability of the barriers intended to prevent major accidents has been stable at a generally high level for the NCS as a whole. However, reported data show that substantial variations exist between installations when safety systems are tested. Some have a considerably poorer standard than the average for the industry. Clear indications have also been seen that the installations tested most frequently had fewer faults. In addition, some installations are lagging seriously behind in carrying out maintenance – including work on safety-critical equipment. An extensive analysis has been conducted on possible relationships between the development of barrier condition and the trend for DSHAs (Ref 5). It has not been possible to establish statistically significant connections of this kind, although substantial quantities of data are available. The same is also expected to apply for barrier elements of significance for preventing acute discharges to the sea.

The Macondo blowout in the Gulf of Mexico has demonstrated the potential for long-lasting blowouts with large acute discharges. This also represents a relevant risk for the NCS. See sections 5.1.2 and 5.2.2. It is reflected in the models incorporated in the study. The highest category for the quantity of crude spilt to the sea was increased during the work from more than 100 000 tonnes to over 500 000 tonnes in order to reflect the largest discharges in a more refined way. See moreover section 7.6.

As a result of the Macondo incident, a more detailed investigation, broken down by water depth, has also been carried out into incidents which occurred with subsea wells from 1999 to 2009. Relatively few incidents are recorded annually with such wells. None of these has developed into an acute discharge. Viewed overall, the frequency of incidents involving deepwater wells (water depths beyond 600 metres) is clearly above average and in most cases higher in statistically significant terms than for wells in shallower waters. More detailed investigations of near misses connected with deep-water operations have so far failed to identify that the water depth as such can explain this excess frequency.

Comparing the NCS with the US outer continental shelf (USOCS) for the relationship between the quantity of crude oil and condensate produced and the quantity of crude oil discharged (all discharges above 50 barrels, about 6.7 tonnes) shows that little difference existed between these two areas in 2001-09, but that the USOCS performed a little better than the NCS as a whole. Nor does much difference exist on the NCS between the North Sea and the Norwegian Sea where the relationship between quantities produced and discharged is concerned.

Trends are both positive and negative for acute discharges of other oils and chemicals to the sea. The North Sea had the highest values in some contexts, while the Norwegian Sea came top in other areas.

To sum up, it can be noted that a number of indicators developed positively in 2001-09, a number were stable, while a few – particularly in the RNNP – showed a negative trend. Although differences exist between the North and Norwegian Sea planning areas, they did not point uniformly in any specific direction. No basis therefore exists for claiming that historical performance has been better in the Norwegian Sea than in the North Sea where the probability of acute discharges is concerned.

To secure a more holistic picture of the accident risk in the petroleum industry, the RNNP acute discharges study must be assessed together with the main RNNP report for 2009. The latter also provides more information on important processes for reducing accident risk in the petroleum business.

### *0.6 Knowledge gaps and further work*

This project needs to be continued in order to achieve improved monitoring of developments in the risk of undesirable incidents in the petroleum activity leading to acute discharges. A continuation of the project must be regarded as an integrated part of the further development of the RNNP.

The RNNP acute discharges report has been developed on the basis of existing data in the RNNP and EW. That has considerably enhanced the value of existing information, and the players have not been burdened by added reporting requirements. It is proposed to continue increasing the value of existing information before a possible expansion in data capture. In that context, a priority commitment is proposed to enhance information on actual acute discharges – particularly by relating discharged volumes better to individual incidents and by improving the specification of location when acute spills occur on mobile units. Other proposed priority commitments include improved utilisation of synergies between the main RNNP report and the RNNP acute discharges study in terms of both data handling and dissemination of information.

An overview of risk trends from the RNNP acute discharges study aims to supplement the overall picture of the development in personnel risk from the RNNP and to promote a more integrated approach to accident prevention which will strengthen protection for people, the natural environment and material assets. The RNNP acute discharges report expands the target audience for information about the development of accident risk in the petroleum sector. That calls for a particular commitment to risk communication in order to avoid misunderstanding and misuse of results from the RNNP and the RNNP acute discharges reports.

A long-term upgrading of risk indicators for acute spills from shipping crude oil to land by shuttle tanker is recommended.

The RNNP process combines qualitative risk studies with quantitative indicators. In the longer terms, consideration needs to be given to the question of whether qualitative studies in the RNNP can be utilised or supplemented for following up the risk of acute discharges.

In the longer term, the framework of the project should be expanded to exploit available data for petroleum plants on land.

Monitoring developments in the probability of acute discharges by the petroleum industry represents an important contribution to the technical work on management plans for the various sea areas. This is a matter of producing relevant information in order to be able to respond proactively to negative trends, and thereby avoid undesirable incidents in the future. Historical acute discharges and near misses provide valuable information about the past safety performance of the players, but are inadequate as indicators of the robustness of participants for preventing incidents in the future. Risk is influenced in each case by a number of factors which are very specific to the activity and the player(s). Generalising across players and activities must therefore be done with caution. It is accordingly necessary to assess results from the RNNP acute discharges study in conjunction with other information on the development of a number of indicators over time. These include the following.

- Development of actual acute discharges.
- Development of actual near misses which could have caused acute discharges to the sea.

- Development of factors influencing risk in the planning areas, such as the type of activity, scope, level, geographic location, installation age, technological advances, operational developments, specialist expertise, climate changes and so forth.
- Developments for actual acute discharges and near misses which could have led to acute discharges elsewhere on the NCS, given that risk trends in a planning area may be affected by factors which apply regardless of location, and be associated with challenges related to risk management which should be viewed in an industry perspective. This could involve, for example, players, technology, operations, management systems, knowledge, capacity and access to competent resources, the company's adaptation to cyclical economic changes and so forth.
- Information on developments in the efficiency of existing barriers, based on audits, investigations, data gathering and so forth.
- Information on developments in data quality as well as in the theoretical, empirical and methodological basis (including understanding of phenomena) which can explain conclusions on risk trends.
- Information on the development of frame conditions which can influence risk trends, such as licence award criteria, development of standards, and new environmental requirements influencing technology/operations/players.
- The use of social science methods already applied in the RNNP process could produce supplementary information related to the development of quantitative indicators for acute discharges, such as:
  - maintenance of the technical condition of significant barriers for preventing acute discharges
  - development of the player picture and possible consequences for preventing acute discharges
  - development of frame conditions which are significant for prevention of acute discharges by the players.

Given the limited information available for the Barents Sea, great caution must be exercised over the conclusions which can be drawn from this base data. Results from other areas will continue to provide the most relevant basis for risk management of activities in the Barents Sea.

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