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MASTER'S THESIS

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Executive Summary

The Norwegian regulatory and supervisory system is performance based and designed so that the operating companies hold total responsibility for operating in an acceptable manner. The Petroleum Safety Authority (PSA) will often recommend certain practices or ways to solve certain problems, but will not force preferred solutions on the companies. Instead, operators on the Norwegian continental shelf are expected to evaluate, identify and demonstrate the best suitable solutions to a problem. It is thereby the operators own responsibility to demonstrate compliance with the laws and regulations.

Royal Dutch Shell has been operating with an exploration and production department on the Norwegian continental shelf since the mid 1960s. Shell currently operates eight licenses on the Norwegian continental shelf, including the Draugen field and the Ormen Lange gas field, and is partner in an additional 17 licenses.

Through the Norwegian HSE regulations, the Norwegian authorities require that all operators "establish, follow up and further develop a management system designed to ensure compliance with requirements in the health, safety and environment legislation" (PSA 2011a). In Royal Dutch Shell, this is ensured through the application of the group HSSE&SP Control framework.

This thesis provides a comparison and discussion on selected key elements of the Norwegian HSE regulations and the Shell HSSE&SP control framework with a focus on risk, risk management, asset integrity and process safety management. The thesis identifies a total of five areas with potential gaps, and suggests four concrete recommended actions to address these findings. Identified areas include elements of barrier management, general risk theory and principles for risk reduction.

The Shell HSSE&SP control framework is designed as a standardized tool for use in all parts of the Shell group. The fact that Shell is a global company operating in many different countries, with different regulatory regimes has been taken into consideration when recommending actions for ensuring compliance with the Norwegian regulations.

Preface

This master's thesis has been written in cooperation with AS Norske Shell based on an inquiry sent early January 2014. Specializing in offshore safety as well as working in the offshore industry has made the choice of topic a suitable and perhaps a natural conclusion to the study program, and will also provide a good grounding in important aspects of the industry HSSE control frameworks and asset integrity, very much in line with the PSA focus areas for 2013 and 2014.

I would like to thank my company supervisors, Robert Burns and Bjørn Nysted for valuable input and discussion in selecting the topic for this thesis as well as through vital initial stages of the process and with reviewing the various drafts. Also, I would like to thank Øystein Knutsen and Øyvind Raanes who provided valuable insights through telephone interviews/discussions.

Furthermore, I would like to extend a great thanks to Professor Terje Aven for providing valuable insights and references in addition to maintaining motivation through this process. Without this help, this thesis would not have written.

Stavanger, June 15, 2014

Anders Hoem

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Abbreviations

AIPSM	Asset Integrity Process Safety Management
BAT	Best Available Technology
CMMS	Computerized Maintenance Management System
DEM	Design Engineering Manual
FSR	Facility Status Reporting
HEMP	Hazards and Effects Management Process
HSE	Health Safety and Environment
HSSE&SP	Health Safety Security Environment and Social Performance
PSA	Petroleum Safety Authority (Norway)
PS	Performance Standard
PTD	A Permanent Total Disability (PTD) is a work related injury that permanently incapacitates an employee and results in the termination of employment.
PTW	Permit to Work
RAM	Risk Assessment Matrix
SCE	Safety Critical Element
TIV	Technical Integrity Verification

1. Introduction

Since the first wells were drilled on the Norwegian continental shelf in 1966 (Ministry of oil and energy, 2013), there has been a tremendous development in the industry both with regards to technology, organization and not the least within HSSE and Risk management. With the Alexander Kielland accident in March 1980 (SNL, 2013a), and the Piper Alpha incident in the British sector, July 1988 (SNL 2013b) there was a fundamental shift in the way we manage risk and HSSE in the entire industry.

All companies operating on the Norwegian continental shelf are required to follow the rules and regulations provided by the authorities known as the HSE regulations, in addition to a number of laws and acts under the PSA area of authority. Within these regulations, proper Risk management is recognized as a key maintaining a high level of safety.

One of the core elements of the Norwegian HSE regime is the principle of internal control. As explained by the PSA, this term entails that the responsibility of ensuring compliance with the authority regulations lies with the industry. The thought behind this is that is building on the view that "a regulator cannot "inspect" quality into the Norwegian petroleum sector" (PSA 2011b).

Throughout the last few years the PSA has indicated an increasing trend in events with major accident potential in the Norwegian offshore industry (PSA 2012b), as shown in Figure 1.

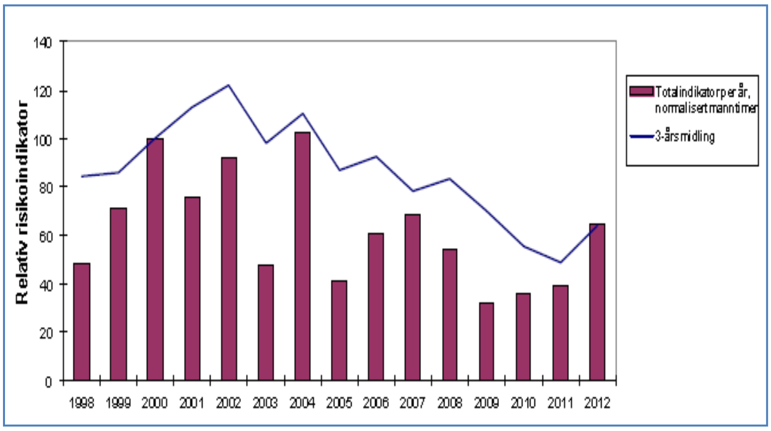

Figure 1 - Development in events with major accident potential, offshore production facilities (PSA 2012b)

The gas leaks at Snorre A in 2004, Visund in 2006, Gullfaks C in 2010 and at Heimdal in 2012 shows that there is still a need to maintain a high focus on HSSE and risk management. Perhaps especially since several of the operating assets on the Norwegian continental shelf are closing in on their design life time and the fact that several of the companies operating on the Norwegian continental shelf are currently seeking license to develop new prospects or in the process of applying for life time extensions for assets closing in on the design life time. One of these companies is A/S Norske Shell, currently operating the Draugen platform at Haltenbanken.

A/S Norske Shell is a part of The Royal Dutch Shell, currently one of the largest oil companies in the world. As a global oil and gas company, Shell has adapted a policy for global standardization, meaning that the same governing documents, guidelines and control framework apply regardless of where in the world one might be.

1.1. Purpose

The objective of this thesis is to compare the Shell global HSSE Control Framework and the Norwegian HSE Regulations in order to identify potential differences between the frameworks and underlying local processes with the purpose of providing recommendations for how to address potential gaps.

1.2. Scope of work

As boundaries to ensure feasibility for the assignment within the given time frame, the scope of work has been limited to considering the control framework for asset integrity, process safety and barrier management and general principles for risk and risk management.

This is done by providing a side by side comparison of the different frameworks based on review of the regulatory documents available from the regulator webpage and the Shell intranet. Where found necessary, specific mandatory Shell internal guidelines, codes of practice and standards have been included in the comparison in order to provide an as thorough as possible overview.

The comparison has been limited to the frameworks concerning the offshore petroleum industry, thus specific requirements for onshore facilities have not been included.

Specific detailed requirements stated in the facilities regulations chapter 5 – Physical barriers have been compared against high level barrier definitions as described in the guidelines associated with the Shell HSSE&SP control framework. Detailed comparisons of the stated functional requirements have not been made as the control framework does not include such level of details.

1.3. Terminology

ALARP

The ALARP (As Low As Reasonable Practicable) principle express that the risk level has been reduced (and documented) to a level where no further measures for risk reduction may be identified, except for those where the cost is grossly disproportionate to the benefits.

Barrier

Technical, operational and organisational elements which are intended individually or collectively to reduce possibility/ for a specific error, hazard or accident to occur, or which limit its harm/disadvantages (PSA 2013a).

Black Swan event

A black swan event can be defined as:

- Events that were completely unknown to the scientific environment (unknown unknowns)
- Events that were not on the list of known events from the perspective of those who carried out a risk analysis (or another stakeholder) (unknown known's)
- Events on the list of known events in the risk analysis but judged to have negligible probability of occurrence (Aven and Krohn 2014).

Bow tie diagram

A bow tie diagram is a simple graphic display of the relationship between hazards with associated potential consequences and initiating events and the barrier functions put in place to either stop the event from happening or to mitigate the consequences.

Major accident

A major accident can be defined as an incident, for instance a large spill, a fire or an explosion as result of an uncontrolled cause of events that causes imminent serious danger to people, environment or material value within or outside of the enterprise, in connection with an activity performed by an enterprise that falls under these regulations and where dangerous chemicals are involved (Storulykkeforskriften, 2005).

Performance Criteria

Auditable requirements for barrier element attributes designed to ensure that barrier is robust and effective. Performance criteria may include requirements related to functionality, effectiveness, integrity, reliability and availability as well as robustness and ability to withstand loads and load effects and competence etc (PSA, 2013b).

Performance Standard

A statement, expressed in qualitative or quantitative terms, of the performance required of a system or item of equipment, which is used as the basis for managing high risk Hazards and Events (Shell, 2011b).

RAM (Shell)

The Risk Assessment Matrix (RAM) is a matrix of the severity of a risk vs. its likelihood that is used by Shell to establish a consistent process for assessing HSSE risks. See chapter 2.2 for more details.2.2

Risk

Risk can be described as the combination of possible future incidents, their consequences and associated uncertainty.

Safety Critical Element / HSE critical element

An item of equipment or structure whose failure could lead to the release of a Major Hazard or whose purpose is to prevent or limit the consequences of a major incident, excluding business loss (Shell 2009).

1.4. Structure

This thesis is built up in five main sections.

- Chapter one provides as short introduction and description of the purpose and problem behind the thesis as well as limitations, methodology, abbreviations and key terminology used throughout the thesis.
- Chapter two gives a simple overall overview of the Norwegian regulations and the Shell HSSE&SP control framework used as basis for the further comparisons and discussions.
- Chapter three provides a general comparison of key subjects of the selected frameworks.
- Chapter four provides a in depth discussion of key subjects identified in chapter 3
- Chapter five concludes the thesis and provides my recommendations to Shell based on the presented findings.

I have deliberately chosen not to include a specific chapter for presentation of relevant theory as this is presented where found applicable in the respective chapters. Also, by doing so I believe the general flow of the thesis is easier to follow whilst still maintaining the relevant level of information.

1.5. Methodology

As the base problem behind the thesis was a gap analysis and as the subject requires a basic understanding of both established terminology and concepts in risk management and insights in the fundamentals of the oil and gas industry, and given the limited experience of the author a thorough literature study was required.

The purpose of the literature study was to establish a basic understanding and insight in the frameworks and regulations used as a basis for this thesis as well a deeper insight in the key concepts of risk management in the offshore industry. Essentially, I have used the information available on the PSA web pages together with the Shell intranet.

As a means to provide background for further discussions in my analysis, I have utilized literature used through the study program, the university library database and articles found through Science direct. Keywords used for data collecting has been “Risk acceptance criteria”, “Major accident risk”, “barrier management”, “process safety” and “technical / asset integrity” as well as specific literature as suggested by the supervisors.

In addition, I have executed telephone interviews with key personnel within Shell and PSA audit reports available on the PSA web pages in order to gain a deeper understanding of the presented topics and how they are applied within the company.

Figure 2 shows a general flowchart of the above described methodology.

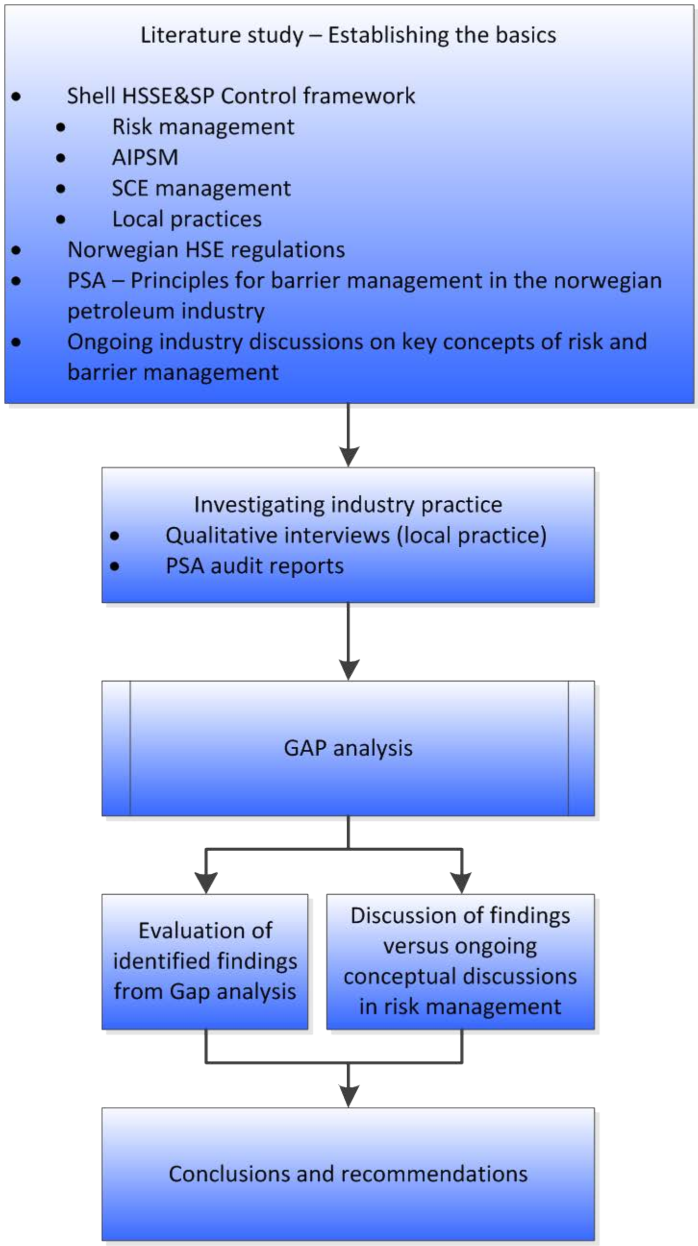

Figure 2 - Methodology flow chart

2. Shell Global AIPSM and the Norwegian HSE regulations

2.1. The Norwegian HSE regulations

The petroleum industry on the Norwegian continental shelf is controlled by Norwegian authorities through the implementation of the Norwegian HSE regulations. These regulations are built up by five sections:

- The Framework Regulations
- The Management Regulations
- The Facilities Regulations
- The Activities regulations
- Technical and operational regulations (for onshore facilities.)

2.1.1. Regulatory approach

The Norwegian regulations are largely risk based and emphasize the importance of principles for risk reduction in relation to health, safety and the environment. (PSA 2011a, PSA 2012a) As described by the Petroleum Safety Authorities (PSA), these regulations provide "a framework for comprehensive and prudent activities". Compliance to these regulations is mandatory for all petroleum activities on the Norwegian continental shelf and is monitored and controlled by the PSA.

However, the regulatory and supervisory system is performance based and is designed so that the operating companies hold total responsibility for operating in an acceptable manner. This is referred to as the principle of internal control, which in the words of the PSA builds on the view that "a regulator cannot "inspect" quality into the Norwegian petroleum sector." (PSA 2014c). Therefore the PSA does not force preferred solutions on the companies, but expect the companies themselves to evaluate and identify the best suitable solutions to a problem. As guidance and recommendations to ensure compliance, a series of standards and guidelines have been made available through NORSOK, OLF and DNV. Compliance to these standards is recommended by the PSA, but is not mandatory by law.

Each company has through the regulations an obligation to inform the authorities of hazards and accident situations (PSA 2012a) as well as plans for high risk activities. Certain activities also require consent from the PSA in order for the activities to commence (PSA 2012a). Furthermore, the PSA will perform risk based inspections, audits, and verifications to ensure that the operators internal management systems and systems for inspection and control (PSA 2014b).

The authorities are also monitoring general development in the petroleum industry through projects like "Trends in risk level in the petroleum industry" often referred to as RNNP. Through this project, the PSA issues an annual report outlining trends and development areas etc. (PSA 2012b). These trends are also communicated through publications like "Dialogue" and "Safety status and signals".

The PSA have also issued a guidance document on the principles of barrier management to the industry (PSA 2013a).

Figure 3 - PSA publications

2.2. The Shell Global HSSE&SP Control framework

The Shell HSSE&SP Control framework was introduced in the Shell group January 1, 2010, replacing the previous HSSE standards and guides. The framework has been implemented across the business as a single source for Shell requirements covering Health, Safety, Security, the environment and social performance.

Through the Shell framework all Shell companies commit to, amongst others, have "a systematic approach to HSSE&SP management designed to ensure compliance with the law and to achieve continuous performance improvement" (Shell 2013a). Employees in specific roles are defined as accountable for implementing and following up requirements stated in the underlying standards of the HSSE&SP control framework.

The framework includes mandatory standards, manuals, specifications, glossary terms as well as non mandatory guidelines and assurance protocols. The implementation is based on risk and priorities and is underpinned by a defined commitment to:

- Pursue the goal of no harm to people;
- Protect the environment;
- Use material and energy efficiently to provide our products and services;
- Respect our neighbours and contribute to the societies in which we operate;
- Develop energy resources, products and services consistent with these aims;
- Publicly report on our performance;
- Play a leading role in promoting best practice in our industries;
- Manage HSSE&SP matters as any other critical business activity; and
- Promote a culture in which all Shell employees share this commitment.

The framework consists of 11 manuals of which compliance is mandatory for all Shell operated assets and all projects over which Shell has overall control (Shell, 2013a).
As described in chapter 1.2, this thesis will focus largely on the specific manuals from the HSSE&SP control framework focusing on general requirements for risk management and asset integrity process safety management.

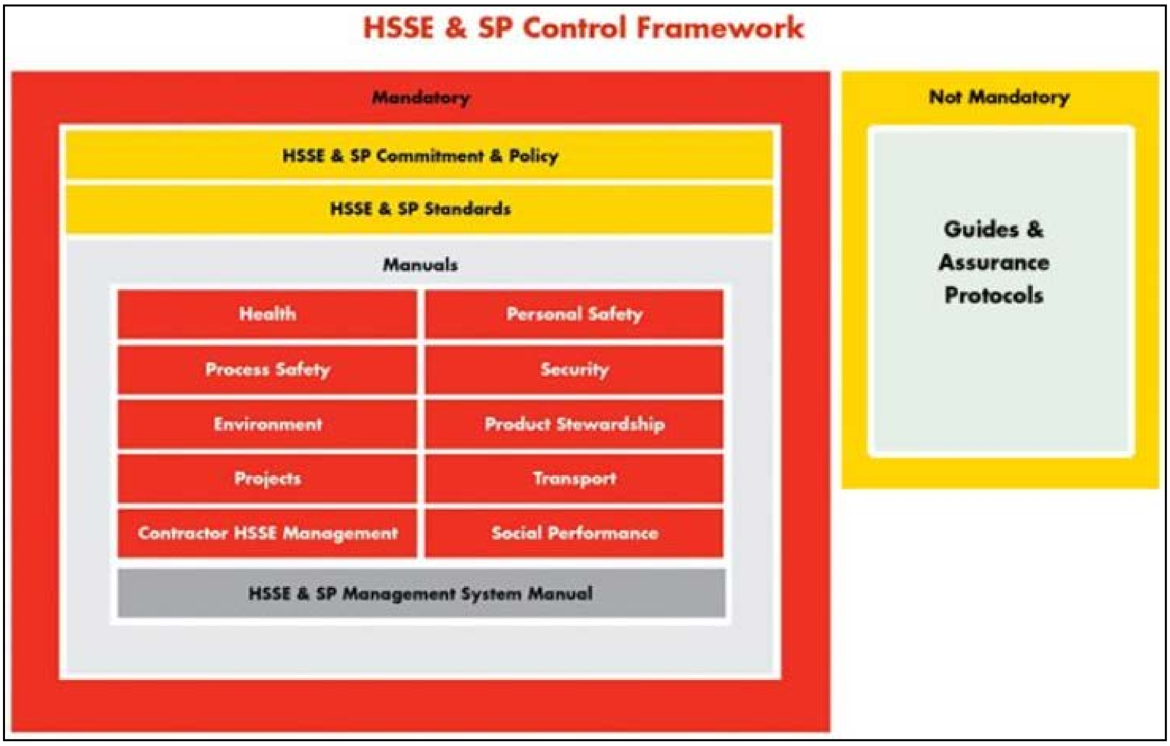

Figure 4 - Shell HSSE&SP Control framework (Shell 2013a)

3. Establishing context and comparing frameworks

In this chapter I will present selected key areas from a comparison of key aspects of the Norwegian HSE regulations against the global Shell HSSE&SP Control framework. The presented comparisons have been made by examining the different frameworks and have in certain cases been extended to include underlying standards and procedures as well as defined guidelines to interpretation. Certain key concepts and definitions as used by the PSA, but not necessarily defined and included in the regulations have also been considered where found applicable.

3.1. Risk definition

There is no commonly accepted and agreed definition of what risk is. Different interpretation of the term has been discussed in various scientific articles, textbooks, standards and regulations etc, and seems to vary significantly based on different disciplines and traditions.

The Shell Global HSSE&SP control framework defines risk as “A combination of the probability of an event and its consequences” (Shell, 2013a). This definition is very much in line with the classical risk perspective and is used in various forms in risk management standards and frameworks. Up until recently, this definition was also used by the Norwegian PSA. The Norwegian HSE regulations do currently not provide a formal definition of the risk concept.

Nevertheless, in an article published by the PSA, it is argued that they in many contexts see oversimplifications of the risk picture, where uncertainties and lack of knowledge are not sufficiently accounted for in order to comply with the regulations (PSA 2014f).

The HSE regulations require risk assessments to be carried out through all phases of the petroleum activities (PSA 2011a), with the intention that these analyses should provide a vital contribution to decision taking in the industry. As described in chapter 2.1, the Norwegian regulations are largely risk based and emphasize the importance of risk reduction. The interpretation and use of the risk concept is thereby vital as background to any risk assessment and to risk management in general. As a result of this, the risk definition adopted by the PSA sees risk as “the combination of possible future incidents and their consequences, and associated uncertainty” (PSA 2014a).

With this in mind, it may be that the Shell definition of risk, may lead to non-compliance with the intentions of the regulations set by the PSA. As an example, risk assessments that do not sufficiently include the uncertainty dimension might exclude potential events with enormous consequences, simply because they were not identified (due to lack of knowledge concerning a specific type of event) or disregarded due to low perceived probability.

Implications of the difference in definitions applied by the Norwegian PSA and in the Shell HSSE&SP Control framework and thereby potential differenced in understanding of the requirements in the HSE regulations are discussed in chapter 0.

3.1.1. Risk Acceptance Criteria

The Norwegian management regulations, section 9 states that “The operator shall set acceptance criteria for major accident risk and environmental risk. Acceptance criteria shall be set for:

a) the personnel on the offshore or onshore facility as a whole, and for personnel groups exposed to particular risk,
b) loss of main safety functions as mentioned in Section 7 of the Facilities Regulations for offshore petroleum activities,
c) acute pollution from the offshore or onshore facility,
d) damage to third party.

The acceptance criteria shall be used when assessing results from risk analyses, cf. Section 17. Cf. also Section 11 of the Framework Regulations.” Furthermore, the guidelines following the framework states that these acceptance criteria “shall express and represent an upper limit for what is considered an acceptable risk level for the various categories mentioned in literals a to d. Additional risk reduction shall always be considered, even if the results of risk analyses or risk assessments indicate a level of risk that is within the acceptance criteria, cf. Section 11 of the Framework.”

The Shell HSSE&SP Control framework defines high level requirements for ALARP demonstration but does not provide specific and defined risk acceptance criteria. Specific risk acceptance criteria are being used, but are defined in asset or country/region specific governing documents. As an example; In A/S Norske Shell, specific risk acceptance criteria for the Draugen field is given in the Draugen HSE case. Table 1 shows field specific risk acceptance criteria for acute oil and condensate spill to sea (for year with maximum risk).

Table 1 - Field specific RAC for acute oil and condensate spill to sea. (Shell 2012)

MIRA Consequences Categories	Recovery Time	Intolerable probability per year	ALARP probability per year	Negligible probability per year
Minor	1 month – 1yr	2×10^{-2}	$2 \times 10^{-2} - 2 \times 10^{-3}$	2×10^{-3}
Moderate	1-3 yrs	5×10^{-3}	$5 \times 10^{-3} - 5 \times 10^{-4}$	5×10^{-4}
Significant	3-10 yrs	2×10^{-3}	$2 \times 10^{-3} - 2 \times 10^{-4}$	2×10^{-4}
Serious	>10 yrs	5×10^{-4}	$5 \times 10^{-4} - 5 \times 10^{-5}$	5×10^{-5}

Similarly, the overall Norske Shell Risk acceptance criteria for major offshore spills are defined below with reference to the Shell Risk assessment matrix. These criteria are based on the NORSOK Z-013 standard and are considered to be compliant with the Norwegian HSE regulations.

Table 2 . AS Norske Shell Risk acceptance criteria for major offshore spills (Shell, 1997)

Consequence categories	**Recovery time**	**Field specific**	**Installation specific**	**Operation specific**
C2 – Minor damage	1 month – 1 year	2.0×10^{-2}	1.0×10^{-2}	1.0×10^{-3}
C3 – Moderate damage	1-3 years	5.0×10^{-3}	2.5×10^{-3}	2.5×10^{-4}
C4 – Considerable damage	3-10 years	2.0×10^{-3}	1.0×10^{-3}	1.0×10^{-4}
C5 – Serious damage	>10 years	5.0×10^{-4}	2.5×10^{-4}	2.5×10^{-5}

In internal ALARP evaluations, risk is classified as “Intolerable” if above these border values. If the risk is in the region 50-100% of the border values, the risk is classified as ALARP A, and if the risk is between 10-50% it is classified as ALARP B. Below this the risk is “Negligible”. (Ref. Figure 5)

In both regions of the ALARP zone incentives are in place for implementing technical, organizational and operational measures to reduce the risk levels.

3.1.2. Risk reduction principles

A key element in risk management as depicted in the Norwegian HSE regulations is principles for risk reduction.

> "Harm or danger of harm to people, the environment or material assets shall be prevented or limited in accordance with the health, safety and environment legislation, including internal requirements and acceptance criteria that are of significance for complying with requirements in this legislation. In addition, the risk shall be further reduced to the extent possible.
>
> In reducing the risk, the responsible party shall choose the technical, operational or organisational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved." (PSA 2011)

The first subsection of the above requirements of the framework regulations necessitates that risk is reduced beyond the stated minimum levels as given in the regulations, whereas this risk reduction shall follow the principle outlined in the second subsection. This is largely in line with the ALARP principle as applied in the Shell HSSE&SP Control framework.

In general, the ALARP concept is based on "reversed burden of proof", which means that an identified measure should be implemented unless it cannot be documented that there is an unreasonable disparity ("gross disproportion") between cost/disadvantages and benefits. (Aven, 2009b) The Shell HSSE&SP Control framework provides a suite of eight high-level mandatory requirements that in short stipulates a step by step process for how to manage HSSE hazards and risks to an ALARP level.

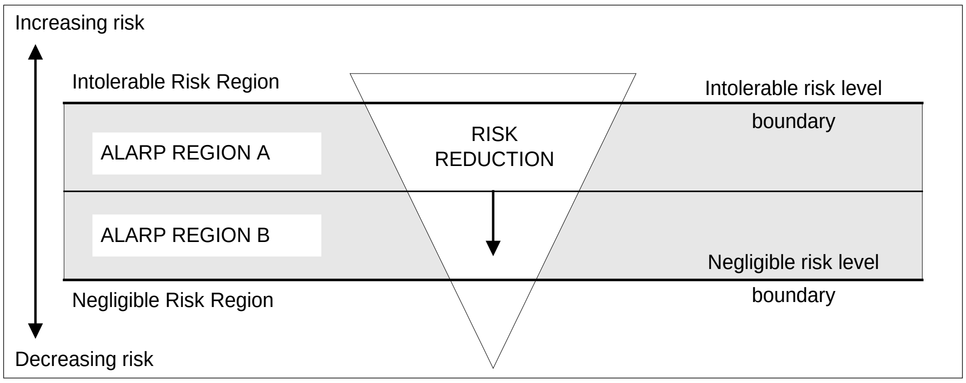

Figure 5 – ALARP (Shell, 1997)

As in the Norwegian HSE regulations, risks are identified, assessed for likelihood and consequences in relation to people, environment, assets and reputation. Each individual risk is then rated in a risk assessment matrix (Figure 6). The four areas of the RAM describe the level of control required to manage risk:

- Light Blue: Manage for continuous improvement, although may set lower priority for further Risk reduction.
- Dark Blue: Manage for continuous improvement through the effective implementation of the HSSE Management System.
- Yellow: Identify and implement controls and recovery measures to reduce risk to ALARP.
- Red: Identify and implement controls and recovery measures to reduce the risk to ALARP and provide a documented demonstration of ALARP by a Bow-Tie or equivalent methodology.

SEVERITY	CONSEQUENCES				INCREASING LIKELIHOOD				
	People	Assets	Environment	Reputation	A Never heard of in the Industry	B Heard of in the Industry	C Has happened in the Organisation or more than once per year in the Industry	D Has happened at the Location or more than once per year in the Organisation	E Has happened more than once per year at the Location
0	No injury or health effect	No damage	No effect	No impact					
1	Slight injury or health effect	Slight damage	Slight effect	Slight impact					
2	Minor injury or health effect	Minor damage	Minor effect	Minor impact					
3	Major injury or health effect	Moderate damage	Moderate effect	Moderate impact					
4	PTD or up to 3 fatalities	Major damage	Major effect	Major impact					
5	More than 3 fatalities	Massive damage	Massive effect	Massive impact					

Figure 6 - Shell Risk assessment matrix

The above section from the framework regulations also refers to the principle of best available technology (the BAT principle). Through this principle, the party responsible for the activities is required to use the technology and methods that provide the best and most effective results as a basis for its planning and operations. This principle is not used within the Shell HSSE&SP control framework. Here the Shell framework simply ALARP principle, meaning that where reasonably practicably, measures will be implemented to reduce risk to as low as possible. Which technology, and what solutions or measures that are to be used, is not part of this equation.

Table 3 below shows a side by side comparison of the requirements related to risk reduction in the HSE regulations versus the HSSE&SP control framework.

Table 3 - Risk reduction Principles

Regulatory topic	Framework regulations	Management regulations	Shell HSSE&SP Control framework
Risk reduction	**Section 11 – Risk reduction principles**	**Section 4 – Risk reduction**	**Chapter 01 – Risk management, Section 04 - Managing Risk**
	• Harm or danger of harm to people, the environment or material assets shall be prevented or limited in accordance with the health, safety and environment legislation, including internal requirements and acceptance criteria that are of significance for complying with requirements in this legislation. In addition, the risk shall be further reduced to the extent possible. • In reducing the risk, the responsible party shall choose the technical, operational or organisational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved. • If there is insufficient knowledge concerning the effects that the use of technical, operational or organisational solutions can have on health, safety or the environment, solutions that will reduce this uncertainty, shall be chosen	• The responsible party shall select technical, operational and organisational solutions that reduce the probability that harm, errors and hazard and accident situations occur. • Furthermore, barriers as mentioned in Section 5 shall be established. • The solutions and barriers that have the greatest risk-reducing effect shall be chosen based on an individual as well as an overall evaluation. Collective protective measures shall be preferred over protective measures aimed at individuals.	Establish a process to identify HSSE Hazards and to reduce the Risks to As Low As Reasonably Practicable (ALARP). • Identify HSSE Hazards in the Business and document their effects on people, Assets, environment and reputation in a Hazards and Effects Register. • Assess the Risk of identified Hazards for Worst-Case Credible Scenarios using the RAM • Manage Hazards having Risks in the dark and light blue areas of the RAM through the effective implementation of the HSSE&SP management system. • Identify and implement Controls and Recovery Measures for Hazards in the yellow area of the RAM to reduce Risk to ALARP. • Identify and implement Controls and Recovery Measures for Hazards in the red and yellow 5A and 5B areas of the RAM as stated in requirement 6 (above) and in addition by a Bow-Tie or equivalent methodology
	• Factors that could cause harm or disadvantage to people, the environment or material assets in the petroleum activities, shall be replaced by factors that, in an overall assessment, have less potential for harm or disadvantage.		• Where Reasonably Practicable, eliminate Hazards or substitute Hazards that have Risk in the yellow and red area of the RAM with ones having lower Risk.
	• Assessments as mentioned in this section shall be carried out during all phases of the petroleum activities.		• The Shell risk management manual applies to Managing HSSE Risks in Assets, facilities, operations, projects and activities where the Shell HSSE & SP Control Framework applies. *

* Reference is made to chapter 2.2

3.1.3. Analyses

"The responsible party shall carry out risk analyses that provide a balanced and most comprehensive possible picture of the risk associated with the activities.

The analyses shall be appropriate as regards providing support for decisions related to the upcoming processes, operations or phases. Risk analyses shall be carried out to identify and assess contributions to, amongst others, major accident and environmental risk, as well as ascertain the effects various processes, operations and modifications will have on major accident and environmental risk (...)" (PSA 2012a).

The Shell process for providing such balanced and comprehensive risk pictures is shown in the below visualisation of requirements from the HSSE&SP control framework. Here, risk is first identified, assessed for worst case credible scenarios and rated using a standardized risk assessment matrix. Further analyses are then performed based on the assessed risk rating.

Risk assessments are carried out at all phases of a project and throughout the operating life of an asset and form the basis for documentation of design and operate phase ALARP demonstration. As an example, the AIPSM specifies a requirement to "Identify and document Hazards with RAM red and yellow 5A and 5B Process Safety Risks for existing and new assets." Furthermore section 19 and 20 of the same document requires process safety risks to be reviewed at least annually (Shell, 2011a).

As can be seen from Figure 7 and Table 4 below, the intent of such analyses is aligned between the two frameworks. Risk analyses and emergency preparedness analyses follow the same general approach in both frameworks. This process is outlined in both the Shell HSSE&SP control framework and the management regulations as a process for identifying hazards and associated initiating incidents, assessing different scenarios and consequences and thereby using this data in order to indentify and implement barriers or selecting emergency preparedness measures. (Shell uses the term controls and recovery measures)

Furthermore, the Shell framework specifies use of bow-tie or equivalent methodology, which in addition to the RAM assessment itself would pass as recognised and suitable models/methods for conducting and updating analyses. Reference is made to §16 of the management regulations.

In terms of maintaining documentation, the management regulations require a "comprehensive overview of the analyses that have been carried out and are underway. The Shell framework is much more specified and require documentation of ALARP evaluations with associated bow-ties (or equivalent), controls and recovery mechanisms with associated performance criteria and monitoring method etc. Reference is made to requirement 7 and corresponding sub-sections as shown in Figure 7 below.

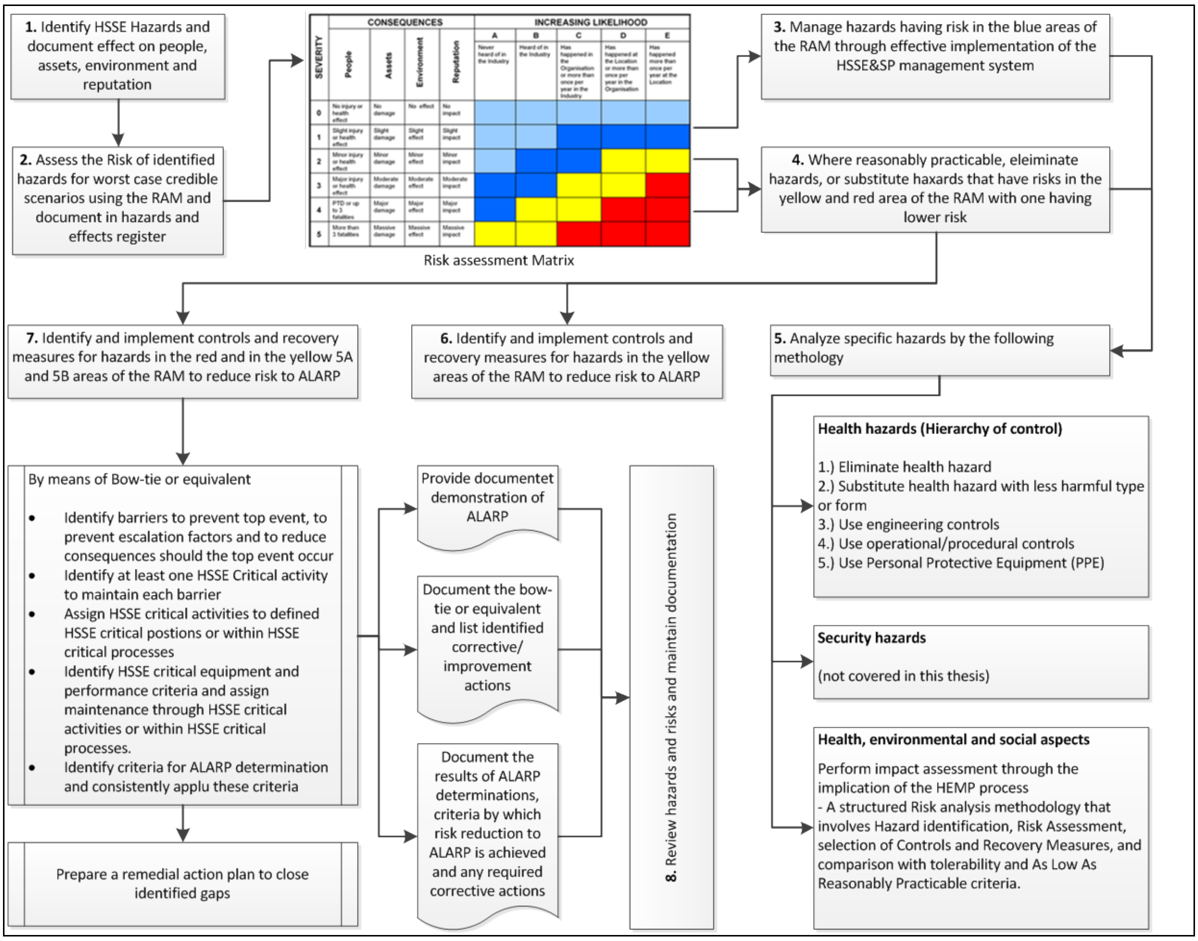

Figure 7 - Risk management in the Shell HSSE&SP control framework

Table 4 - Requirements for risk analyses

Regulatory topic	Management regulations		Management regulations
Analyses	**Section 16 – General requirements for risk analyses**	**Section 17 – Risk analyses and emergency preparedness analyses**	**Chapter 01 – Risk management** **Section 04 - Managing Risk**
	• The responsible party shall ensure that analyses are carried out that provide the necessary basis for making decisions to safeguard health, safety and the environment. • Recognised and suitable models, methods and data shall be used when conducting and updating the analyses. • The purpose of each risk analysis shall be clear, as well as the conditions, premises and limitations that form its basis. • The individual analysis shall be presented such that the target groups receive a balanced and comprehensive presentation of the analysis and the results. • Criteria shall be set for carrying out new analyses and/or updating existing analyses as regards changes in conditions, assumptions, knowledge and definitions that, individually or collectively, influence the risk associated with the activities. • The operator or the party responsible for operating an offshore or onshore facility shall maintain a comprehensive overview of the analyses that have been carried out and are underway. Necessary consistency shall be ensured between analyses that complement or expand upon each other.	...The risk analysis shall • identify hazard and accident situations, • identify initiating incidents and ascertain the causes of such incidents, • analyse accident sequences and potential consequences, and • Identify and analyse risk-reducing measures. Risk analyses shall be carried out and form part of the basis for making decisions when e.g.: • identifying the need for and function of necessary barriers, cf. Sections 4 and 5, • identifying specific performance requirements of barrier functions and barrier elements, including which accident loads are to be used as a basis for designing and operating the installation/facility, systems and/or equipment, cf. Section 5, • designing and positioning areas, cf. Section 5 of the Facilities Regulations, • classifying systems and equipment, cf. Section 46 of the Activities Regulations, • demonstrating that the main safety functions are safeguarded , stipulating operational conditions and restrictions, • selecting defined hazard and accident situations. Emergency preparedness analyses shall be carried out and be part of the basis for making decisions when e.g. • defining hazard and accident situations, • stipulating performance requirements for the emergency preparedness, selecting and dimensioning emergency preparedness measures.	Establish a process to identify HSSE Hazards and to reduce the Risks to As Low As Reasonably Practicable (ALARP). • Identify HSSE Hazards in the Business and document their effects on people, Assets, environment and reputation in a Hazards and Effects Register. • Assess the Risk of identified Hazards for Worst-Case Credible Scenarios using the RAM • Manage Hazards having Risks in the dark and light blue areas of the RAM through the effective implementation of the HSSE&SP management system. • Where Reasonably Practicable, eliminate Hazards or substitute Hazards that have Risk in the yellow and red area of the RAM with ones having lower Risk. • Identify and implement Controls and Recovery Measures for Hazards in the yellow area of the RAM to reduce Risk to ALARP. • Identify and implement Controls and Recovery Measures for Hazards in the red and yellow 5A and 5B areas of the RAM as stated in requirement 6 (above) and in addition by a Bow-Tie or equivalent methodology. " Review hazards and risks and maintain documentation

3.2. Barriers, barrier management and (main) safety functions

As stated in Principles for barrier management in the petroleum industry (PSA, 2013a), the main purpose of barrier management is to establish and maintain barriers so that risk faced at any time can be handled by preventing an undesirable event from occurring by limiting the consequences should such an incident occur.

> The management regulations §5 specifies as follows;
>
> "Barriers shall be established that:
>
> a) reduce the probability of failures and hazard and accident situations developing,
>
> b) limit possible harm and disadvantages.
>
> Where more than one barrier is necessary, there shall be sufficient independence between barriers..."

The Shell equivalent to this requirement can be seen from Table 5 below, and states a requirement to "Identify Barriers to prevent a Top Event, to prevent Escalation Factors and to reduce the Consequences should the Top Event occur.

The PSA specifies that the term barrier does not refer to specific systems, equipment or personnel. These are barrier elements. In order to for a barrier to be effective, performance requirements must be defined for all such barrier elements (technical, operational and organizational). (PSA 2013a)

In Shell, Operational and organizational barrier elements are defined as HSSE critical positions and HSSE critical procedures with specific requirements defined through the AIPSM manual. Technical barrier elements are defined as HSSE critical equipment or Safety Critical elements and are identified and broken down into eight high-level groupings defined as Hardware barriers for Major Hazards. Each of these Safety Critical Elements requires a dedicated performance standard containing specific functional requirements and defined assurance and verification activities (Shell 2009).

Risks with RAM-rating of 5 or in the red sections of the Shell Risk Assessment Matrix are defined as major accident hazards (Shell 2009). By combining the definitions of such risks in light of risk to people, asset, the environment and reputation, the Shell definition of a major accident becomes an incident which may cause multiple (more than 3) fatalities (or PTD) and/or major environmental damage and/or major damage to/loss of assets and/or major impact to reputation.

The Norwegian PSA defines a major incident as; “An acute incident, such as a major discharge/emission or a fire/explosion, which immediately or subsequently causes several serious injuries and/or loss of human life, serious harm to the environment and/or loss of substantial material assets” (PSA 2014d).

As can be seen from the above the PSA definition of major accidents does not quantify fatalities in their definition of major accidents. This difference in definition has an effect on the principles of barrier management as stated in the different frameworks. As an example, In Shell, establishment of maintenance procedures is only mandatory for HSSE critical equipment or Safety Critical Elements, which again is defined as “An item of equipment or structure, or a system (including software logic), that acts as a barrier to prevent the uncontrolled release of a Hazardous Substance or release of energy leading to worst case credible scenario with RAM red, yellow 5A or yellow 5B Risk, or acts as a barrier to control or mitigate the effects of such a release. HSSE critical equipment is also known as Safety Critical Equipment or SCE” (Shell, 2011a).

As a comparison, the activities regulations require that “fault modes that constitute a health, safety or environment risk shall be systematically prevented through a maintenance program” (Activities regulations §47). The definition of a health, safety and environment risk would in this context include all risk levels and thereby not be limited to the major accident hazards.

Similar applies to ensuring availability of operating procedures and critical documentation. See Table 5 for details. Implications of the above are discussed more in detail in chapter 4.

Table 5 - Risk management and establishment of barriers

Management regulations Chapter II – Risk management	Shell HSSE&SP Control framework Section 01 HSSE SP – Pt. 4 Risk management	Comments
Section 5 – Barriers Barriers shall be established that: a) reduce the probability of failures and hazard and accident situations developing, b) limit possible harm and disadvantages.	**Managing risk pt 6-8:** • Identify and implement Controls and Recovery Measures for Hazards in the yellow area of the RAM to reduce Risk to ALARP. • Identify and implement Controls and Recovery Measures for Hazards in the red and yellow 5A and 5B areas of the RAM • Identify Barriers to prevent a Top Event, to prevent Escalation Factors and to reduce the Consequences should the Top Event occur. Review the content of the Documented Demonstration of ALARP (for Risks in the red area of the RAM) and Hazards And Effects Register (for Risks in the red or yellow areas of the RAM) when existing operations/activities are changed in a way that would change the Hazards or reduce the effectiveness of Controls and Recovery Measures.	See text above
	DSM-2500003-RP-01 - Hazards and Effects Management Process (HEMP) recommended practice	**Comments**
"…Where more than one barrier is necessary, there shall be sufficient independence between barriers..."	"A Valid Barrier is: **effective**, **independent** and **auditable**: a. **Effective** – The Barrier prevents the Consequence when it functions as designed (i.e. big enough, fast enough, strong enough). An effective Barrier has the following three elements: i. A detector - detects the condition that requires action, ii. A logic solver – decides action is to be taken, and iii. An actuator – action taken to address the condition. b. **Independent** – The Barrier is independent of the Initiating Event (Threat) and the components of any other Barrier already validated for the same condition. The Barriers cannot be considered independent from one another if there is a Common Cause Failure. c. **Auditable** – The Barrier can be evaluated to assure that it can operate correctly when it is called upon. i. A Critical Activity maintains the Barrier. This links to accountability, responsibility and competence assurance. ii. The Barrier reduces the Risks by a factor of at least 10, i.e. the Probability of Failure on Demand (PFD) is maintained at no greater than 10%. This links to requirements for maintenance and inspection in the maintenance system (SAP). "	There is no clear requirement for independence between these barriers in the HSSE&SP control framework. However, the guidelines for risk management sections (Shell 2011d) reference rules for barrier validity provided in recommended practice for the Hazards and effects management process (Shell 2011c).

Management regulations **Chapter II – Risk management**	**Shell HSSE&SP Control framework** **Chapter 03 – Process Safety – Asset Integrity Process Safety Management**		**SCE management process (step 1-5)**
Section 5 – Barriers contd.. The operator or the party responsible for operation of an offshore or onshore facility shall stipulate the strategies and principles that form the basis for design, use and maintenance of barriers, so that the barriers' function is safeguarded throughout the offshore or onshore facility's life.	14. Establish and Maintain Procedures to operate HSSE Critical Equipment within its Operating Limits. 14.1. Set Operating Limits for HSSE Critical Equipment which are accessible to staff in HSSE Critical Positions involved in operating, maintaining, inspecting and managing the Assets. 14.2. Establish and Maintain operating Procedures, including for start-up, normal operation, shutdown, emergency shutdown, isolation and making the HSSE Critical Equipment safe for maintenance activities. 14.3. Establish and Maintain procedures for monitoring the process conditions in HSSE Critical Equipment.	15. Establish and Maintain procedures to inspect the technical integrity of HSSE critical equipment 15.1. Maintain, in an accessible system, a register of items of HSSE critical equipment and their minimum Performance Criteria. 15.1.1. Include in the register any long-term effects that may degrade technical integrity, and the expected rate of degradation of static equipment. 15.2. Inspect and verify the performance of HSSE critical equipment. 15.2.1. Set inspection intervals to confirm that minimum Performance Criteria are met based on the expected rate of degradation and the actual condition when last inspected. 15.4 Inspect and re-verify the technical integrity of HSSE critical equipment if an Equipment Constraint is exceeded beyond predefined values. 15.5 Keep inspection records	• Identify major hazards, barriers and SCE groups • Identify SCEs in asset register • Define operate phase performance standards • Upload SCE information into the CMMS • Align maintenance strategy with assurance tasks • Prepare performance assurance tasks • Upload to the CMMS • Set up FSR (monitoring of barrier status and performance) • Prepare and execute work • Record and analyse results • Identify SCE performance assurance task backlog • Perform risk assessment • Identify and execute mitigating actions • Review and approve deviation • Status reporting Review and improve status

Comments
• The Shell requirements are mandatory for all projects where Shell is operator. • The requirement for establishing strategies and forming basis for design, operation and maintenance are shown in section 14 of the AIPSM as well as in the SCE management process.

Management regulations Chapter II – Risk management	Shell HSSE&SP Control framework Chapter 03 – Process Safety – Asset Integrity Process Safety Management	Comment
Section 5 – Barriers contd.. Personnel shall be aware of what barriers have been established and which function they are intended to fulfil, as well as what performance requirements have been defined in respect of the technical, operational or organisational elements necessary for the individual barrier to be effective.	***Asset managers, project/wells managers are accountable for:*** 21. Know what Hazards the Asset has with RAM red and yellow 5A and 5B Process Safety Risks, and know how these Risks are managed to ALARP. 22.2. Set expectations and accountabilities for the Process Safety management of the Asset. 22.3. Communicate on a frequent basis face-to-face with staff about Process Safety. 22.4. Encourage reporting of Process Safety Incidents, including near misses, investigate and review Incidents, set corrective action, and communicate learning. 22.5. Track and communicate closure of actions arising from Process Safety Incident investigations and Process Safety reviews. 15.1. Maintain, in an accessible system, a register of items of HSSE critical equipment and their minimum Performance Criteria.	Awareness of established barriers and their functional requirements is required through section 21 though 22 It is the duty of the asset manager / project/wells manager to ensure that project personnel and/or operators are aware of the established barriers and their performance criteria.
Personnel shall be aware of which barriers are not functioning or have been impaired.	*14.3. Establish and Maintain procedures for monitoring the process conditions in HSSE Critical Equipment.* *14.7 Establish and Maintain procedures for handover communication within and between shifts.*	Status of active safety functions is monitored through FSR and is monitored from the CCR. Barrier status is also maintained through the PTW system (Ref Appendix 1.5) and through routines for handovers between shifts.

Management regulations Chapter II – Risk management	Shell HSSE&SP Control framework Chapter 03 – Process Safety – Asset Integrity Process Safety Management	Comment
Section 5 – Barriers contd.. The responsible party shall implement the necessary measures to remedy or compensate for missing or impaired barriers.	16. Establish and Maintain to maintain HSSE Critical Equipment. 16.1. Repair or replace within a defined period any item of if its performance deviates from the agreed minimum Performance Criteria (see also 14.1). 16.2. Specify corrective and preventive maintenance processes for . 16.2.1. Establish and Maintain controls to meet the specified minimum criteria for spare parts. 16.2.2. Establish controls for deviating from agreed maintenance intervals. 16.3. Establish and Maintain work instructions, including job and checklists for the maintenance of . 16.4. Verify that the maintenance work has been executed correctly and that meets the specified minimum Performance Criteria (see also 14.1). 16.5. Keep maintenance records for .	Requirement 16 of the AIPSM upholds the intention of the requirement as stated in the management regulations.

Facilities regulations **Chapter II – General provisions**	**AS/Norske Shell** **Draugen Safety Case**	**Comment**
Section 7 – Main Safety functions "The main safety functions shall be defined in a clear manner for each individual facility so that personnel safety is ensured and pollution is limited For permanently manned facilities, the following main safety functions shall be maintained in the event of an accident situation: a) preventing escalation of accident situations so that personnel outside the immediate accident area are not injured, b) maintaining the capacity of load-bearing structures until the facility has been evacuated, c) protecting rooms of significance to combating accidents so that they remain operative until the facility has been evacuated, d) protecting the facility's secure areas so that they remain intact until the facility has been evacuated, e) Maintaining at least one escape route from every area where personnel are found until evacuation to the facility's safe areas and rescue of personnel have been completed."	"The primary physical measures which reduce the probability of a situation of hazard and accident occurring, or which limit the consequences of an accident. With regard to permanently manned facilities the following are defined: • Preventing escalation of accident situations so that personnel outside the immediate vicinity of the scene of accident are not injured • Maintaining the main load carrying capacity in load bearing structures until the facility has been evacuated • Protecting rooms of significance to harm limitation of accidental events, so that they are operative until the facility has been evacuated, • Protecting the facility's safe areas so that they remain intact until the facility has been evacuated • Maintaining at least one evacuation route from every area where personnel may be staying until evacuation to the facility's safe areas and rescue of personnel has been completed." (Shell 2012b)	The requirements for Main safety functions as per the facilities regulations are not mentioned in the HSSE&SP control framework. In A/S Norske Shell, these requirements are maintained by local processes and have been implemented in the HSE Case for specific assets. The example used in this table has been taken from the HSE case from the Draugen platform, and is a direct implementation of the requirements from the facilities regulations
Facilities regulations, Chapter II – General provisions	**Shell HSSE&SP Control framework Chapter 03 – AIPSM**	**Comment**
Section 8 – Safety functions "Facilities shall be equipped with necessary safety functions that can at all times a) detect abnormal conditions, b) prevent abnormal conditions from developing into hazard and accident situations, c) Limit the damage caused by accidents. Requirements shall be stipulated for the performance of safety functions. The status of active safety functions shall be available in the central control room."	***Operations, inspection and maintenance*** *14.4. Identify and establish controls for handling Abnormal Situations.* *14.5. Establish and Maintain controls for the management of overrides of Process Safeguarding systems and Process Safety Alarms.* *14.6. Define any specific HSSE Critical Equipment, which, if impaired, would require immediate shutdown of equipment.* *14.7 Establish and Maintain procedures for handover communication within and between shifts.*	Requirements for performance of safety functions is referred to in the comparison against the management regulations §5 (above) and encompasses the requirement from facilities regulations section 8. Status of active safety functions is monitored through FSR as required in AIPSM section 14 and in the SCE management process. These sections are shown in the comparison against paragraph 3 of the management regulations §5

<table>
<tr>
<th>Activities regulations
Chapter VI – Operational prerequisites for start-up and use</th>
<th>Activities regulations
Chapter IV – Preliminary surveys and installations</th>
<th>SHELL HSSE&SP Control framework
Section 03 Process Safety – 1. AIPSM</th>
</tr>
<tr>
<td rowspan="3">Section 20 – Start-up and operation of facilities

Before facilities and parts of these are started up for the first time or after technical modifications, the commissioning as mentioned in Section 16 shall be carried out.

During start-up as mentioned in the first subsection, and during operation,
• The management system with associated processes, resources and operations organisation shall be established,
• Governing documents, including technical operations documents, shall be available in an updated version and the operations personnel shall be familiar with them,
• Systems for employee participation shall be established, cf. Section 13 of the Framework Regulations,
• The health service shall be in accordance with Section 8 and
• The occupational health service shall be in accordance with Section 5.</td>
<td>Section 16 – installation and commissioning

During installation of facilities and parts of these, it shall be ensured that the loads they are exposed to, do not exceed the loads mentioned in Section 11 of the Facilities Regulations.

Upon completion of facilities, it shall be ensured that they fulfil the requirements in the Facilities Regulations, cf. also Section 23 of the Framework Regulations and Section 5 of the Management Regulations. The technical condition of facilities, systems and equipment shall be maintained until the facilities, systems and equipment are put into service.</td>
<td rowspan="3">Requirement #7

Develop a Statement of Fitness before commissioning a new Asset or a Modification to an existing Asset and confirm in the Statement of Fitness that:
• Employees or Contractors executing HSSE Critical Activities are competent and fit to work;
• HSSE Critical Equipment meets its Technical Integrity requirements, and modifications are complete and have been authorised as specified in Management of Change;
• the design and construction of new Assets and modifications to existing Assets meet design and engineering requirements;
• Procedures are in place to operate HSSE Critical Equipment within its Operating Limits.

Requirement #10

Create, make available and maintain the documentation for HSSE Critical Equipment, including data and drawings that are critical to managing Process Safety. As a minimum documentation includes:
• the Design Basis;
• Process Engineering Flow Schemes / Process And Instrumentation Diagrams;
• Process Safeguarding documentation including a Cause and Effects Diagram to show the basis for Process Safeguarding, and Process Safety Alarms documentation including a Variable Table or equivalent to show the basis for Process Safety Alarms;
• Plot Plans; and Classified Areas documentation.</td>
</tr>
<tr>
<td>Activities regulations
Chapter VI – Operational prerequisites for start-up and use</td>
</tr>
<tr>
<td>Section 24 – Procedures

The responsible party shall set criteria for when procedures shall be used to prevent faults and hazard and accident situations.

It shall be ensured that procedures are established and used in such a way as to fulfil their intended functions.</td>
</tr>
<tr>
<td colspan="3">Comments:</td>
</tr>
<tr>
<td colspan="3">The Norwegian HSE regulations do not differentiate between different risk ratings in determining requirements for documentation, procedures and maintenance programs.</td>
</tr>
</table>

3.3. Performance criteria for barriers and barrier elements

The PSA defines performance requirements as auditable requirements for barrier element ability to secure barrier effectiveness. Such performance criteria can include requirements related to capacity, effectiveness, reliability, availability, integrity, load resistance and robustness, etc. (PSA, 2013a)

As shown in chapter 3.4, both the HSE regulations and the HSSE&SP control framework specify requirements for establishment of such performance criteria for barrier elements. However, the Facilities regulations also provide a suite of defined performance requirements for specific physical barriers. Such detail requirements are not incorporated into the Shell HSSE&SP control framework. Instead, The Shell framework mandates through requirement 14 and 15 of the AIPSM that each asset is required to establish performance standards for each SCE group, and provides a compilation of global standard templates for both design and operating phase performance standards.

The figure below shows an overview of how performance criteria for technical barrier elements (SCEs) categorized in Shell internal guidelines against the HSE regulations and NORSOK / ISO3370.

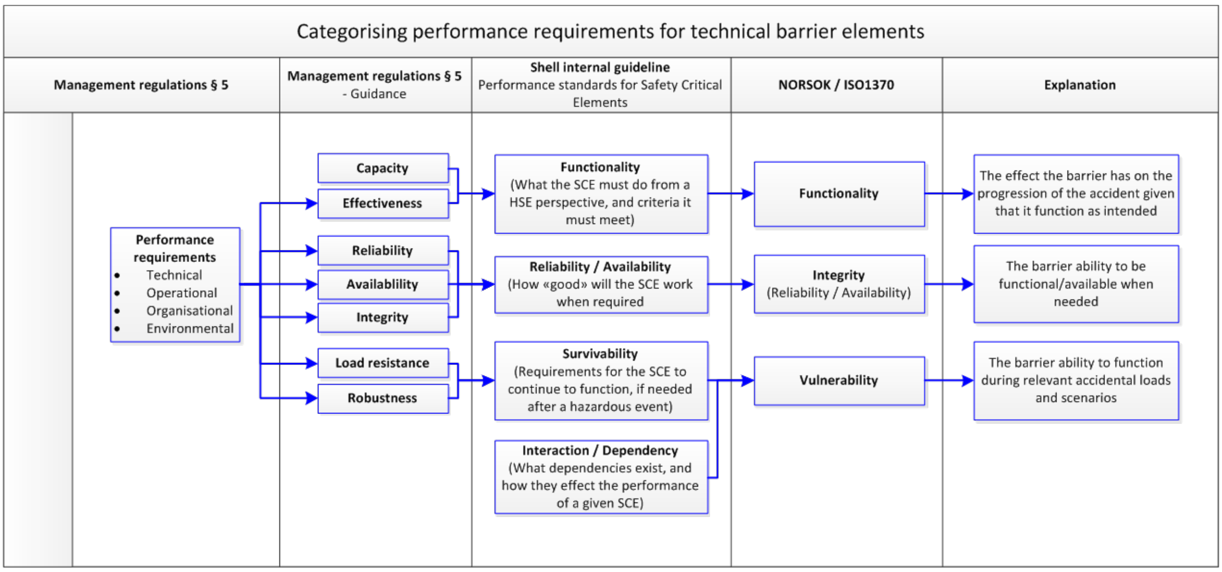

Figure 8 - Categorization of performance criteria for technical barrier elements, based on PSA 2013a

Table 6 shows a selection of elements from a comparison between defined requirements for physical barriers in the HSE regulations versus the requirements provided in the defined global standard templates for performance standards. A further comparison between functional requirements for selected physical barriers defined in the facilities regulations can be found in appendix 1.2.

Table 6 - Performance criteria comparison - Load bearing structures

HSE regulations			Shell HSSE&SP Control	
Facilities regulations Section 56 – Load bearing structures and maritime systems	**Facilities regulations Section 11 – Loads / actions, load/action effects and resistance**	**Facilities regulations Section 7 – Main Safety functions**	**SI001 – Structures Subsea / Vessel hull / GBS / Foundation structures**	**SI002 – Topside structures**
• Load-bearing structures shall maintain satisfactory safety in use, failure, fatigue and accident limit states. They shall be able to withstand the loads/actions they are exposed to, including loads/actions with an annual probability of 10-2 in the failure limit state and the loads/actions that follow from Section 11, in the accident limit state. • Load-bearing structures shall be sufficiently robust to ensure that local damage or failure will not result in unacceptable consequences. • Maritime systems shall be sufficiently robust to ensure that local damage or individual technical or operational faults do not result in unacceptable consequences. • The analyses shall be verified by an organizationally independent party.	• The loads/actions that can affect facilities or parts of facilities, shall be determined. Accidental loads/actions and environmental loads/actions with an annual probability greater than or equal to $1x10^{-4}$, shall not result in loss of a main safety function, cf. Section 7. • When stipulating loads/actions, the effects of seabed subsidence over, or in connection with the reservoir, shall be considered. • Functional and environmental loads/actions shall be combined in the most unfavourable manner. • Facilities or parts of facilities shall be able to withstand the design loads/actions and probable combinations of these loads/actions at all times.	• For permanently manned facilities, the following main safety functions shall be maintained in the event of an accident situation: • b) maintaining the capacity of load-bearing structures until the facility has been evacuated	**Purpose:** To provide and maintain structural integrity under all expected actions through service life. Provide sufficient robustness to maintain availability of critical systems during a major accident hazard **Functional criteria:** 1. Primary and secondary steel structures shall be suitable for continued operation. 2. Appurtenances shall be suitable for continued operation 3. Subsea structures shall be suitable for continued operation 4. Handrails, Gratings, Stair Treads & Deck Plating from all areas of the platform to be structurally sound and complete. 5. Seawater Drawdown • System of gravity based structures operates within set limits to maintain the concrete structure in compression at all times during oil storage and transfer • Ballasting systems maintains floating structures at appropriate draft and trim.	**Purpose:** To provide and maintain structural integrity under all expected actions through service life, and to provide sufficient robustness to maintain availability of critical systems during a major incident **Functional criteria:** • Topside structures shall be suitable for continued operation. • Topside structures inspection shall be suitable for continued operation • Topside structure fabric shall be suitable for continued operation • Maintain temporary refuge support for defined load cases and suitability for continued operation • Personnel access structures shall be suitable for continued operation.

As can be seen from the above, the functional criteria given in the Shell global performance standards are very generic and do not provide any specific measurable requirements. Local performance standards exist, but as can be seen below, the functional criteria are based on the same high level requirements. For simplicity, only the topside structures performance standards have been used in the comparison below.

Table 7 - Functional criteria - Topside structures

Facilities regulations **§56 – Load bearing structures and maritime systems**	**SI002 – Topside structures** **Global standard templates** **Operational Performance standard**	**SI002 – Topside structures** **Draugen Asset** **Operational Performance standard**
Load-bearing structures shall maintain satisfactory safety in use, failure, fatigue and accident limit states. They shall be able to withstand the loads/actions they are exposed to, including loads/actions with an annual probability of 10-2 in the failure limit state and the loads/actions that follow from Section 11, in the accident limit state. Load-bearing structures shall be sufficiently robust to ensure that local damage or failure will not result in unacceptable consequences. Maritime systems shall be sufficiently robust to ensure that local damage or individual technical or operational faults do not result in unacceptable consequences. The analyses shall be verified by an organizationally independent party.	**Purpose:** To provide and maintain structural integrity under all expected actions through service life, and to provide sufficient robustness to maintain availability of critical systems during a major incident **Functional criteria:** • Topside structures shall be suitable for continued operation. • Topside structures inspection shall be suitable for continued operation • Topside structure fabric shall be suitable for continued operation • Maintain temporary refuge support for defined load cases and suitability for continued operation • Personnel access structures shall be suitable for continued operation.	**Purpose:** To provide and maintain structural integrity under all expected actions through service life, and to provide sufficient robustness to maintain availability of critical systems during a major incident **Functional criteria:** • Topside structures shall be suitable for continued operation. • Topside structures inspection shall be suitable for continued operation • Topside structure fabric shall be suitable for continued operation • Maintain temporary refuge support for defined load cases and suitability for continued operation • Personnel access structures shall be suitable for continued operation.

Asset specific HSE Cases do to some extent provide more specific performance criteria. As an example, the Draugen HSE Case describes the following: "The Platform is also designed to withstand earthquake loadings for a return period of 100 years. The strongest earthquake registered in Norway in the last 100 years is 5.4 on the Richter scale. This is the dominating load condition for the main support areas including the main footings.

The passive fire protection is designed to withstand hydrocarbon fires for timing as shown below:

• Critical structures: 4 hours
• Main structures: 2 hours
• Shelter area: 2 hours
• Main escape ways: 1 hour
• Local escape ways: 1 hour
• Selected pressure vessels 0.5 hours"

Furthermore, the HSE case provides a specific evaluation of impairment frequencies of load bearing structures from process fires and explosions relative to the 10-4 criterion as given in the facilities regulations.

Table 8 - Impairment frequencies of load bearing structures from process fires and explosions (Shell, 2012)

Areas where process accidents initiate:	Accidental load strain	
	Process fires	Process explosions
CMU60	0.075	0.099
CMU50	0.013	0.005
CMU42	0.200	0.030
C43	0.100	0.025
M3343&U43	0.200	0.015
W5060/S61	0	0
W40	0.032	0.026
W20/30	0	0
Top deck (Hasselmus)	0	0
Sum	**0.62**	**0.20**

These criteria can be said to be slightly more specific and more in line with the intention in the HSE regulation than what was seen from the global Performance Standard templates. Although, most of these specifications are more relevant to passive fire protection as a barrier element than it is to load bearing structures. Also, the HSE case only describe such detail for selected barrier elements as opposed to the general and all encompassing requirement as of Management regulations §5 (PSA 2012a).

3.3.1. Verification and follow-up

A key function in managing risk is to ensure that the measures put in place are robust and effective. This is often referred to as assurance and verification activities. As stated in the Norwegian HSE regulations: "The responsible party shall determine the need for and scope of verifications, as well as the verification method and its degree of independence, to document compliance with requirements in the health, safety and environment legislation. When verifications are deemed necessary, they shall be carried out according to a comprehensive and unambiguous verification programme and verification basis.

The operator shall establish the verification basis for the overall activities after assessing the scope, method and degree of independence of the verification. The operator shall also carry out an overall assessment of the results of the verifications that have been carried out”
(PSA 2012a).

The Shell HSSE&SP control framework does not provide a dedicated section for verification and follow-up. Instead, requirements for such activities are defined in relation to specific topics.

However, the AIPSM-manual does specify requirements for inspection and verification of performance or HSSE critical equipment during design and construction as well as similar inspections and re-verifications of technical integrity if an equipment constraint is exceeded beyond predefined values.

Similarly, local procedures and governing documents do specify requirements for verification and are intended to suit the requirement of the Framework regulations.. As an example the Draugen HSE Case specifies the following:

“A yearly program of audits and verifications is put in place to independently review and verify the effectives of systems and processes for managing integrity. The audit findings and corrective actions are managed using FOUNTAIN or Omnisafe (level 3 audits)” (Shell 2012).

Moreover, the Shell design engineering manuals used in projects include provisions stating requirements specifically directed at assurance and verification activities.

However, as there is no overall overview of these requirements within the HSSE&SP control framework, it is difficult to assess compliance between the HSSE&SP control framework and the HSE regulations. Degree of compliance will thereby have to be assessed in each individual case. Table 9 below shows an overview of the requirements from the framework regulations as compared to identified requirements stated in the AIPSM and in the above referenced Shell DEP.

Table 9 - Verifications

Regulatory topic	Framework regulations	Shell HSSE&SP Control framework		Shell Design Engineering Practices
Verification, and follow-up	**Section 19 - Verifications**	**Chapter 03 – Process safety Section 01 - AIPSM**	**Chapter 07 – Contractor HSSE management**	**Shell DEP 82.00.10.10-Gen Project quality assurance**
	• "The responsible party shall determine the need for and scope of verifications, as well as the verification method and its degree of independence, to document compliance with requirements in the health, safety and environment legislation. When verifications are deemed necessary, they shall be carried out according to a comprehensive and unambiguous verification programme and verification basis. • The operator shall establish the verification basis for the overall activities after assessing the scope, method and degree of independence of the verification. The operator shall also carry out an overall assessment of the results of the verifications that have been carried out."	5. Verify that contract holders monitor the HSSE requirements of the contract that are relevant to competence and fitness to work of contractor staff 12.2.3 Verify the documented demonstration of ALARP 15.2 Inspect and verify the performance of HSSE Critical equipment 15.4 Inspect and re-verify the technical integrity of HSSE critical equipment if an equipment constraint is exceeded beyond predefined values 16.4 Verify that the maintenance work has been executed correctly and that HSSE critical equipment meets the specified minimum performance criteria. (See also 14.1)	• Verify that the Contractor company and its personnel have been informed of the HSSE requirements of the contract. • Verify that the Contractor company manages the HSSE requirements of the contract and review and approve the Contract HSSE Plan when it is required • Verify that Contractor personnel are given an HSSE induction on the HSSE Risks of the contracted activities, the controls to manage those Risks, and applicable HSSE requirements.	• A Technical Integrity Verification (TIV) program shall be implemented for all Safety Critical Items under a Scope of Work through all phases of the work, including work carried out by the Subcontractors. • The TIV is the Principal's process that ensures technical integrity from concept through design and construction and that the knowledge (systems, people, tools) required to maintain integrity during operation is delivered. • The purpose of the TIV process is to provide assurance and verification to ensure that the systems defined as critical to the safety of the facility are suitable, i.e. appropriate for their intended purpose, dependable and effective when required to perform their intended function. • The TIV applies to components that the Principal designates as Safety Critical Elements (SCEs). Each SCE has a Performance Standard that describes the performance requirements of each SCE as well as how these requirements are to be verified. • The performance standards include information that shall be used in the creation of Inspection and Test Plans, equipment requirement/specification documents, preservation and maintenance requirements.

4. Discussion

The main purpose behind this thesis was to identify potential gaps between the Norwegian HSE regulations and the Shell global HSSE&SP control framework and where gaps where found, to assess which of these were covered through local procedures. In this chapter, identified gaps and problem areas are further evaluated in light of the comparisons above, audit findings by the PSA, interviews with key personnel within A/S Norske Shell, and previous work on related subjects.

4.1. Understanding and assessing risk and uncertainties

Both the Norwegian regulatory regime and the Shell control framework demands that activities are controlled through a risk based perspective. In the comparison shown in chapter 3, I described a difference in one of the key concepts in understanding and assessing risks, the definition of risk itself.

Although as stated in chapter 3, the Norwegian HSE regulations does not include such a definition, the regulating body, the PSA, does. In order to assess whether the different frameworks are in coherence, it is therefore imperative to understand how the regulator perceives and interprets the key concepts behind the regulations. Furthermore, the PSA has also stated a concern that the risk picture they are presented in many contexts does not sufficiently account for uncertainties and lack of knowledge and thereby becomes too simplified to comply with the regulations.

The risk perspective adapted by the PSA is based on the thought that the degree of uncertainty behind any risk assessment, if measured through probability, cannot sufficiently reflect the strength of knowledge that the probabilities are based upon, and that surprises may occur relative to the knowledge of the persons conducting the assessments. (Aven, 2013a)

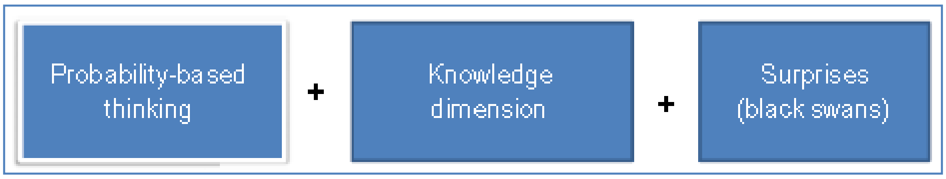

Figure 9 - New risk perspective (Aven, 2013a)

The risk definition used as basis in the Shell HSSE&SP control frame does not contain any reference to associated uncertainties in relation to either the probability- or the knowledge dimension. Thus, it would seem that it automatically falls under the area of concern as per the PSA. Does this mean that risk assessments performed using the methodology prescribed in Shell is inherent insufficient by definition? After all, it could be argued that the establishment of balanced and comprehensive risk picture is largely dependent on the understanding of what risk is.

The Shell approach to risk analyses as explained in chapter 3.3 is largely based on the use of a standardized risk assessment matrix. The starting point of such assessments is the identification of potential events. Probabilities of the identified events are then assigned along with expected consequences. Probability distributions are mainly gathered based on experience and historical data, and would thereby be based on the assumption that such historical data would be representative for future events.

The danger here is that, by basing risk assessments on perceived probabilities and consequences alone, there may be a whole range of possible events that are not considered as the possibility of these event occurring is regarded as extremely low by the experts and analysts involved in the risk assessment, e.g. they are surprises compared to the established risk picture. The event may also be a “unknown unknown”, meaning the possibility of the event occurring, and its consequences is not known to the scientific community. There is also a chance that events are not considered in the overall risk assessment as they are not known in the relevant industry, although they might be well known elsewhere (so called “unknown known’s”). All of the above types of events can be defined as so-called “black swans”. (Aven 2013b).

The Shell HSSE&SP control framework does attempt to a certain degree to include events where historical data is insufficient or not available by including a column for events classified as “never heard of in the industry” in the risk assessment matrix. However, chances are that the consequences will be underrated or the events will simply be disregarded due to the assessed low probability.

The above assumption is supported by the fact that there is no guidance or examples available in the Shell guidance procedure for the risk assessment matrix covering incidents in this column.

The above mentioned “unknown known” and “unknown unknown” types of events are not captured by the Shell risk assessment methodology. “Unknown unknowns” are for understandable reasons not easy to incorporate in risk analyses. The “unknown knowns” should however be possible to handle. These events are typically disregarded either because of failure to look wide enough or simply because it is not known within the team / organisation or industry etc.

As pointed out by Aven (2013b), “the key is knowledge building, transfer of experience and learning”. Such processes are already baked into the Shell HSSE&SP control framework trough requirements for continuous improvement, incident investigations and recording lessons learned. These principles are already applied between different operators, but could perhaps be used more specifically towards addressing these difficult and rare types of events. In addition, they way risk assessments are performed will need to be improved. One possibility for doing so, could be utilizing a “red teaming” methodology. As explained by Masys (2012), such methodologies are for example used by the military to anticipate enemy courses of actions. This is done by first performing risk assessments in the traditional sense, and then bringing in an independent analysis team to challenge the assumptions and mental models made by the initial assessors. Specifically how to improve these assessments is however not part of this thesis.

4.2. Risk reduction, ALARP and acceptance criteria

As presented in chapter 3.4, the Shell framework application of the ALARP principle is largely in line with the framework regulation description of the risk reduction principle with the exception of the lack of incorporation of the BAT principle.

Shell is committed to utilizing the ALARP principle in all risk assessment. However, utilizing this principle in combination with predefined risk acceptance criteria may reduce the validity of such evaluations. The challenge here is to ensure that the focus does not deteriorate to meeting predefined criteria as opposed to reducing risk to as low as reasonably practicable/possible.

Aven and Abrahamsen (2012) suggest that theoretically speaking, it cannot be expected that oil companies have common interests with societal priorities in determining risk acceptance criteria. As pointed out by Engen et al. (2013) the lack of development in established risk acceptance criteria throughout the last 20 years can be seen as a confirmation of this. This is however part of a much bigger discussion which will not be discussed in more detail in this thesis.

However, if risk acceptance criteria are set by the operator, as in the current situation, and the ALARP evaluations are limited towards reaching these criteria, then indeed such a situation would not only be contradiction to the ALARP principle itself, but also constitute non-compliance with the defined requirement for risk reduction as stated in the Norwegian HSE regulations.

This is often taken as one of the reasons behind the predefined overall risk acceptance criteria for major accident set by the authorities within the HSE regulations, the so called like 10^{-4} criteria, to ensure a minimum level of safety. It should however be noted that by establishing such overall acceptance criteria the authorities may contradict the principle of internal control (Aven and Abrahamsen, 2012).

Implications of not including the BAT principle into the Shell HSSE&SP Control framework have not been fully investigated through this thesis, it could however be that effective and cost efficient measures used elsewhere and which could have been implemented to reduce a given risk are overlooked due to lack of considerations of applicability of technology used in other areas or industries.

4.3. Barriers, barrier management and major accident risk

Barriers, Barrier and risk management and major accident risks are rated as the main focus areas for the Norwegian PSA. HSE management in the eyes of the PSA involves management, controlling and handling all aspects of HSE in the petroleum industry, with a focus on major accident hazards (PSA 2013).

As seen in chapter 3.2, there does not appear to be any large differences between the general framework descriptions of barrier management strategies. Both the Shell framework and the Norwegian HSE regulations require barriers to de identified and implemented to reduce the probability of failures and hazard and accident situations developing and to limit possible harm and disadvantages.

Both frameworks also require performance criteria to be established for each barrier element to ensure that the barriers are maintained and effective. Although the Shell HSSE&SP control framework does not specify how to implement these performance criteria, or provide any guidance to this process, as seen in chapter 3.3, the application of these requirements though the available guidance documents and local interpretations may have been approached in a slightly different way than what was intended by the Norwegian authorities. The Shell global templates for performance standards are very generic and do not contain any specific functional requirements for ensuring barrier robustness.

This view in enhanced by the findings of an audit report released by the PSA where the practical application of these principles in certain aspects was found to be in non-compliance with the regulatory requirements. Table 10 shows an overview of findings from the referenced PSA audit.

Table 10 - Identified deviations (PSA, 2013d)

#	Description	Relevant requirements
1	• Relationship between risk analysis, barrier strategy and specific performance requirements for barrier elements are lacking. • Hazard maps and bow ties described as generic and partially non applicable to Draugen • No specific performance criteria for load bearing structures could be demonstrated.	Management regulations §5 - Barriers
2	• Inadequate barrier management and maintenance. • As a result of lacking specific performance requirements, maintenance routines and requirements for the above mentioned barrier elements could be documented and verified as sufficiently adequate.	Management regulations §5 – Barriers, paragraph 3 – Barrier Maintenance Activities regulations §45 - Maintenance
3	• No established adequate measurement parameters, indicators and procedures for monitoring barrier performance for construction • Shell was unable to document specific and quantitative measurement parameters in relation to the performance standards of structures. Also, it was unclear whether deviations from applied standards were fully identified.	Management regulations § 10 - measurement parameters and indicators Management regulations § 19 – Collection, use and processing of data
4	• Inadequate procedures for emergency related to construction incidents. Criteria for the construction incidents and injuries that may result in an emergency situation is not adequately described	Activities regulations § 73 – Establishment of emergency preparedness Activities regulations § 76 – Emergency preparedness plans
5	• Lack of quality assurance and verification of worker process for safeguarding structural Integrity • Verifications of work processes for maintaining the structural integrity in operational state could not be documented	Framework regulations § 19 – Verifications Management regulations § 21 – Follow-up NORSOK N-001, chapter 5.2 and 4.2

Reviewing the referenced performance standards used in operations at Draugen reveals that the functional criteria are copied directly from the global performance standard templates. A comparison between the functional requirements given in the facilities regulation and the performance standards from the global template and the Draugen asset are shown below.

For simplicity, only the topside structures performance standards have been used in the comparison below. A separate standard exist for foundation structures. However, the functional criteria are based on the same high level requirements.

Table 11 - Functional criteria - Topside structures

Facilities regulations §56 – Load bearing structures and maritime systems	SI002 – Topside structures Global standard templates Operational Performance standard	SI002 – Topside structures Draugen Asset Operational Performance standard
Load-bearing structures shall maintain satisfactory safety in use, failure, fatigue and accident limit states. They shall be able to withstand the loads/actions they are exposed to, including loads/actions with an annual probability of 10-2 in the failure limit state and the loads/actions that follow from Section 11, in the accident limit state. Load-bearing structures shall be sufficiently robust to ensure that local damage or failure will not result in unacceptable consequences. Maritime systems shall be sufficiently robust to ensure that local damage or individual technical or operational faults do not result in unacceptable consequences. The analyses shall be verified by an organizationally independent party.	**Purpose:** To provide and maintain structural integrity under all expected actions through service life, and to provide sufficient robustness to maintain availability of critical systems during a major incident **Functional criteria:** • Topside structures shall be suitable for continued operation. • Topside structures inspection shall be suitable for continued operation • Topside structure fabric shall be suitable for continued operation • Maintain temporary refuge support for defined load cases and suitability for continued operation • Personnel access structures shall be suitable for continued operation.	**Purpose:** To provide and maintain structural integrity under all expected actions through service life, and to provide sufficient robustness to maintain availability of critical systems during a major incident **Functional criteria:** • Topside structures shall be suitable for continued operation. • Topside structures inspection shall be suitable for continued operation • Topside structure fabric shall be suitable for continued operation • Maintain temporary refuge support for defined load cases and suitability for continued operation • Personnel access structures shall be suitable for continued operation.

In this specific example, it should be noted that the Shell framework differentiate between performance criteria set during design, construction and commissioning and those defined for operations. Technical integrity is established during design and construction and then safeguarded and maintained during operation.

The operational performance standards will thereby typically not include performance criteria set as basis during the design, construct and commissioning phase. Typical functional requirements used during design can be seen in Table 12.

Table 12 - Typical performance standard criteria as defined in engineering

SCE goals		To provide and maintain structural integrity under all expected actions through service life, and to provide sufficient robustness to maintain availability of critical systems during a major incident
Documentation		Norwegian regulations: The Facilities Regulations, Chapter 2, Section 7 Main safety functions Chapter 10, Section 56 Load bearing structures and maritime systems Fire and Explosion Hazard Management Philosophy
Functionality		
Ref.	**Function**	**Performance criteria and basis**
F0.1	Load bearing structures shall withstand all load conditions under normal operation and also ensure structural integrity during DAL (Dimensional Accidental Loads)	• Load-bearing structures shall be able to withstand the loads they are exposed to, including loads with an annual probability of 10-2 in the ultimate limit state and the loads that follow from accidental limit state. The analyses shall be verified by an organisationally independent party • Load bearing structures shall be sufficiently robust to ensure that local damage or failure will not result in unacceptable consequences.
F0.2	Topside structures inspection shall be suitable for continued operation	All bolted and welded connections to be easily accessible for future inspection
Reliability / Availability		
Ref.	**System / Sub-system**	**Performance criteria and basis**
R0.1	Topside structures	To retain integrity throughout design life.
Survivability		
Ref.	**Hazardous event**	**Performance criteria and basis**
S.0.1	Fire	NORSOK S-001-Section 6.5 -Structure Survivability Requirements The design shall ensure sufficient structural integrity during DALs(Dimensional Accidental Loads. This applies to all main structures as well as other structures. The main load carrying capacity shall be maintained until the facility has been evacuated. The DALs shall be combined with other functional and environmental loads according to NORSOK N-003 NORSOK S-001 Section 19.4.2 -Load Bearing Structures Fire Protection Requirements Load bearing structures/important elements shall have adequate fire resistance to maintain required integrity during a dimensioning fire. No account shall be taken from possible cooling effect from fire fighting equipment. Coat back (integrity protection) may be required on unprotected structural elements in order to maintain load bearing capacity during dimensional accidental loads. This may be necessary in order to avoid excessive and unacceptable heat conduction into fire proofed structural elements. In General the following shall apply: • Coat back is required for structural elements with a contact area equal or larger than 1 000 mm2 per m2 of fireproofed structural elements; • Coat back distance shall be 450 mm, unless documented otherwise.

Here, performance criteria reference applicable standards and guidelines as well as providing specific requirements for maintaining barrier integrity. Some of which are gathered from the above referenced criteria in the facilities regulations.

Design performance standards are however usually only used within projects and there is therefore no guarantee that operational personnel have access to performance standards used in the basis of the design. This could potentially be in conflict with the §5 of the management regulations and might very well be one of the causes behind the finding made by the PSA:
"(...) Personnel shall be aware of what barriers have been established and which function they are intended to fulfil, as well as what performance requirements have been defined in respect of the technical, operational or organisational elements necessary for the individual barrier to be effective (...)" (PSA 2012a).

However, as shown in chapter 3.5, the requirement for establishment of defined performance criteria is maintained within the HSSE&SP control framework through the implementation of the AIPSM. It seems the issue at hand is more in the lack of a sufficiently robust guideline or procedure for how this should be implemented in practice

Some of these criteria are indeed maintained through other procedures as for example through establishment of asset specific HSE case with associated bow-ties. But due to the nature of the HSE case also being a relatively high level document it does not sufficiently record performance criteria on the detail level required by the Norwegian regulations. Also, as pointed out by the PSA, the bow-ties currently included in the HSE case are to a large degree generic and in certain cases not applicable to the relevant asset.

Furthermore, as reflected in the comparison made in chapter 3.6 the different definitions of what constitutes a major accident or major accident hazard could cause a slight mismatch between the Shell HSSE&SP control framework and the intentions behind the HSE regulations. As an example, by limiting requirements for establishment of maintenance programs, operating procedures and critical documentation, etc to HSSE critical equipment only, the Shell framework finds itself in a state of non compliance. This view is also enhanced by the findings in the PSA audit as referenced above.

It should however be stated, as also mentioned earlier, that one of the core intentions behind the framework is to ensure compliance with local regulations and laws and thereby where applicable support introduction of local procedures to support the framework where gaps exist. The fact that Shell is a global company and different countries and regions having very different laws and regulations makes it difficult to encompass all needs in one single standardized framework.

The issue at hand may therefore be more appropriately directed towards underlying procedures for project to asset handover, establishment of maintenance routines and verification processes in general. This could be done on both local and global levels in the organization.

Some of the existing local procedures do to some extent outline requirements that are more in line with the Norwegian regulations (Shell 2013b, 2014a). Nevertheless, the PSA audit findings reveal a need to review both global and local procedures in order to ensure that sufficient procedures are established, that critical documentation is in place and that assurance and verification activities are defined and executed so as to sufficiently safeguard barrier performance.

5. Conclusions and recommendations

In this thesis I have identified potential gaps and improvement areas in the following areas (listed in random order):

- Risk definition and understanding as basis for risk management
- ALARP evaluations if focused against achieving predefined risk acceptance criteria
- Lack of incorporation of the BAT principle.
- Establishment of performance criteria/performance standards for barrier elements
- Definition of major accident hazards and thereby management of risks with lower probability and consequence rating. Including establishment of procedures, work processes, assurance and verification.

5.1. Risk definition and addressing uncertainties

As shown in chapter 0 and further discussed in chapter 4.1, risk management in general is dependent on the definition and understanding of the risk concept. There is no commonly accepted definition of this terminology, thus different industries, companies and persons utilize different definitions as deemed best fit for its purpose.

In the petroleum industry, risk and risk management have been highly incorporated in legal requirements as well as company specific frameworks, perhaps especially in the years following the Piper Alpha incident in 1988. Still, in 2010, BP experienced the Macondo incident. This shows that even though there has been a tremendous development in these areas, there is still work to be done.

As referenced in chapter 4.1 research performed on this topic throughout the last few decades have introduced theories including addressing uncertainties in relation to risk assessments (black swans etc). The theoretic framework that has been adapted by the PSA in the last few years is an example of this.

Since all risk evaluations will by definition be dependent on the underlying adaptation and understanding of the risk concept, alignment between the authorities and companies is imperative in order to achieve total compliance and also in order to fully implement the ALARP principles.

I do realize that Shell being a global company and the HSSE&SP control framework is intended as a standardized overarching system to be used regardless of which country one operates in, and that requirements vary from country to country. Any changes to the global and overarching systems will therefore be time consuming and will not be done over night.

Still, my recommendation would be for Shell, if so only on country level, to evaluate how to incorporate uncertainty into its risk definition in a way that encompasses both the extremely low probability but high consequence types of events in addition to so called "unknown known's". Efforts should also be made in terms of understanding the possibility of occurrence of what we do not know that we do not know. This would however be a more long term action as research on this topic is still far from concluded.

5.2. ALARP evaluations, risk acceptance criteria and the BAT principle

As described in chapter 4.2, focusing ALARP evaluations against pre defined risk acceptance criteria could constitute non-compliance with the Norwegian HSE regulations and the stated principles for risk reduction as well as contradicting the ALARP principle itself.

Although the work performed in this thesis has not identified any clear examples of such practice, the examples shown in chapter 3.1.1 does indicate that occurrence of such practice is not totally impossible. Especially when considering time constraints and economic incentives to progress a project.

In this respect, my recommendation would be to establish clear procedures for how ALARP demonstrations should be performed, specifying that risk acceptance criteria should be used only to indicate the absolute minimum levels of effort required if all elements have been evaluated.

I would also suggest that the BAT principle is introduced as a tool to further enhance ALARP evaluations.

5.3. Establishment of performance criteria for barrier elements

As per 3.3 and 0, the Shell processes for establishment of defined performance criteria do not meet the requirements of the Norwegian HSE regulations. The Shell design engineering manuals as well as both national and international standards like NORSOK do contain a large quantity of such requirement, but there is currently no proper established procedure for translating these specifications as used in design of facilities into clear and concise functional requirements for individual or groups of barrier elements.

As the purpose of the HSSE&SP control framework is to provide overall guidance and requirements, I would not recommend implementing detailed functional requirements directly into this framework, this because the document would lose its functionality and become too detailed to serve its purpose.

I would thereby recommend that Shell implements a mandatory procedure, with reference to the applicable sections of the AIPSM (as previously referenced) where it is explicitly described which level of detail is required and how these criteria should be incorporated into the performance standards. This could very well be linked towards asset specific bow-ties to ensure applicability to each relevant asset.

I would also recommend that Shell implements such above referenced asset specific bow-ties as a means to meet the requirements of the management regulations §5.

Requirements for independence between barriers as referenced in 3.2 and shown in Table 5 should also be incorporated into the HSSE&SP control framework in the relevant subsections for establishing barriers.

5.4. Major accident hazards and risks with lower probability and consequence

In chapter 3.2 I described how the definition of what constitutes a major accident hazard and subsequent what is defined as safety critical elements affects compliance with specific sections of the Norwegian HSE regulations. Specifically, requirements for establishment of operational procedures and ensuring operational prerequisites for start-up and use are in place.

As discussed in chapter 0, the issue is not so much about the HSSE&SP control framework using this definition, but perhaps more a question of to which degree underlying procedures simply refer to the requirements of the control framework or whether they specify general requirements for equipment regardless or risk rating, to be specially ensured for HSE critical elements /SCE's.

The current situation seems to be that procedures for project to asset handover etc, define requirements to be in line with the HSSE&SP control framework without consideration of the effect this has on the applicability of said procedures for barrier elements not covered by the somewhat narrow definition of HSE critical.

My recommendation is therefore to revise underlying procedures for project to asset handover etc, either on a global or a national level, to maintain the requirements stated in the Norwegian HSE regulations as referenced in chapter 3.2 and in Table 5.

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Appendices

1. Comparison of the Shell HSSE&SP Control Framework and the Norwegian HSE regulations

Regulatory topic	Framework regulations	Management regulations	Management regulations	Management regulations	Shell HSSE&SP Control framework	Shell HSSE&SP Control framework
Management of the petroleum activities	**Section 17 – Duty to establish and further develop a management system**	**Section 6 – Management of health, safety and the environment**	**Section 7 – Objectives and strategies**	**Section 8 – Internal requirements**	**Chapter 00 – Commitment and policy**	**Chapter 01 – HSSE SO Management system Section 3 – Organization, responsibilities and resources**
	• The responsible party shall establish, follow up and further develop a management system designed to ensure compliance with requirements in the health, safety and environment legislation	• The responsible party shall ensure that the management of health, safety and the environment comprises the activities, resources, processes and organisation necessary to ensure prudent activities and continuous improvement, cf. Section 17 of the Framework Regulations.	• The responsible party shall stipulate and further develop objectives and strategies to improve health, safety and the environment.	• The responsible party shall set internal requirements that put regulatory requirements in concrete terms, and that contribute to achieving the objectives for health, safety and the environment, cf. Section 7 regarding objectives and strategies.	**Every Shell Company:** • Has a systematic approach to HSSE&SP management designed to ensure compliance with the law and to achieve continuous performance improvement;	3. Define roles, responsibilities and authorities to implement the Shell HSSE&SP control framework and comply with regulations and laws including: • Shell HSSE&SP control framework requirements that are applicable to the asset • Regulatory requirements and laws that are applicable to the asset • Inclusion of roles and responsibilities in plans, procedures, job descriptions, individual tasks and targets
		• Responsibility and authority shall be unambiguously defined and coordinated at all times. • The necessary governing documents shall be prepared, and the necessary reporting	• The operator shall ensure agreement between short-term and long-term objectives in various areas, at various levels and between various participants in the activities. • The objectives shall be expressed so that	• If the internal requirements are expressed as functional requirements, achievement criteria shall be set.	**Every Shell Company:** • Sets targets for improvement and measures, appraises and reports performance;	1. Establish a governance structure for HSSE&SP in the group to show who is responsible for: • Monitoring HSSE/SP performance • Leading HSSE&SP continuous improvement plans • Managing the HSSE&SP skillpool

		lines shall be established.	the degree of achievement can be assessed			• Approving the Shell HSSE&SP control framework 4. Establish and maintain the resources (people, equipment, materials, information and time) needed to implement the Shell HSSE&SP Control framework and comply with regulatory requirements and laws 5. Maintain the requirements of 3 and 4 throughout organizational change in line with management of change

<table>
<tr><th>Regulatory topic</th><th>Framework regulations</th><th>Management regulations</th><th colspan="2">Shell HSSE&SP Control framework</th></tr>
<tr><td rowspan="2">Contractor risk management</td><td>Section 18 – Qualifications and follow up of other participants</td><td>Section 8 – Internal requirements</td><td>Chapter 00 – Commitment and policy</td><td>Chapter 07 – Contractor HSSE management</td></tr>
<tr><td>• When entering into a contract, the responsible party shall ensure that the contractors and suppliers are qualified to fulfil the regulatory requirements relating to health, safety and the environment. Furthermore, the responsible party shall follow up to ensure that the participants comply with the requirements while performing the assignment in the activities covered by these regulations.

• The operator shall ensure that any deficiencies in other participants' management of health, safety and the environment are corrected, and that the necessary adjustments are made with respect to its own and other participants' management systems, to ensure the necessary uniformity.</td><td>• The operator shall ensure agreement between its own requirements and between its own and other participants' requirements</td><td>Every Shell Company:
• Requires contractors to manage HSSE&SP in line with this policy;
• Requires joint ventures under its operational control to apply this policy, and uses its influence to promote it in its other ventures;</td><td>Pre-Award HSSE Requirements
Requirements
1. Appoint a competent Contract Owner for each contract.
2. Identify the HSSE associated with the contracted activities and define how to manage the Risks.
3. During the bid evaluation, assess whether the Contractor company has the capability and resources to manage the HSSE risks.
4. Before contract award, confirm that the contractor company meets requirements above. Use an approval process for exceptions and record the outcome.
5. The contract shall contain HSSE requirements (clauses) and possible consequences for non-compliance.
6. Define the level of Company monitoring based on the capability of the Contractor company and the Contract HSSE Risk.
7. Before the contractor company awards a subcontract, check that the Contractor has assessed the subcontractor's ability to meet requirements above.

Post-Award HSSE Requirements
Requirements
8. Verify that the Contractor company and its personnel have been informed of the HSSE requirements of the contract.
9. Verify that the Contractor company manages the HSSE requirements of the contract and review and approve the Contract HSSE Plan when it is required
10. Verify that Contractor personnel are given an HSSE induction on the HSSE Risks of the contracted activities, the controls to manage those Risks, and applicable HSSE requirements
11. Monitor and regularly assess the HSSE performance of the Contractor company.
12. For locations under the control of a Shell management system, control the entry and exit of contractor personnel in accordance with Security.
13. Regularly review the management of HSSE risks in contracted activities. When necessary, define and document actions for continuous improvement</td></tr>
</table>

Regulatory topic	Framework regulations	Management regulations	Shell HSSE&SP Control framework
Risk reduction	**Section 11 – Risk reduction principles**	**Section 4 – Risk reduction**	**Chapter 01 – Risk management** **Section 04 - Managing Risk**
	• Harm or danger of harm to people, the environment or material assets shall be prevented or limited in accordance with the health, safety and environment legislation, including internal requirements and acceptance criteria that are of significance for complying with requirements in this legislation. In addition, the risk shall be further reduced to the extent possible. • In reducing the risk, the responsible party shall choose the technical, operational or organisational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved. • If there is insufficient knowledge concerning the effects that the use of technical, operational or organisational solutions can have on health, safety or the environment, solutions that will reduce this uncertainty, shall be chosen	• The responsible party shall select technical, operational and organisational solutions that reduce the probability that harm, errors and hazard and accident situations occur. • Furthermore, barriers as mentioned in Section 5 shall be established. • The solutions and barriers that have the greatest risk-reducing effect shall be chosen based on an individual as well as an overall evaluation. Collective protective measures shall be preferred over protective measures aimed at individuals.	Establish a process to identify HSSE Hazards and to reduce the Risks to As Low As Reasonably Practicable (ALARP). • Identify HSSE Hazards in the Business and document their effects on people, Assets, environment and reputation in a Hazards and Effects Register. • Assess the Risk of identified Hazards for Worst-Case Credible Scenarios using the RAM • Manage Hazards having Risks in the dark and light blue areas of the RAM through the effective implementation of the HSSE&SP management system. • Identify and implement Controls and Recovery Measures for Hazards in the yellow area of the RAM to reduce Risk to ALARP. • Identify and implement Controls and Recovery Measures for Hazards in the red and yellow 5A and 5B areas of the RAM as stated in requirement 6 (above) and in addition by a Bow-Tie or equivalent methodology
	• Factors that could cause harm or disadvantage to people, the environment or material assets in the petroleum activities, shall be replaced by factors that, in an overall assessment, have less potential for harm or disadvantage.		• Where Reasonably Practicable, eliminate Hazards or substitute Hazards that have Risk in the yellow and red area of the RAM with ones having lower Risk.
	• Assessments as mentioned in this section shall be carried out during all phases of the petroleum activities.		*

* Reference is made to chapter 3.1.2

Regulatory topic	Framework regulations	Shell HSSE&SP Control framework		Shell Design Engineering Practices
Verification, and follow-up	**Section 19 - Verifications**	**Chapter 03 – Process safety** **Section 01 - AIPSM**	**Chapter 07 – Contractor HSSE management**	**Shell DEP 82.00.10.10-Gen** **Project quality assurance**
	• "The responsible party shall determine the need for and scope of verifications, as well as the verification method and its degree of independence, to document compliance with requirements in the health, safety and environment legislation. When verifications are deemed necessary, they shall be carried out according to a comprehensive and unambiguous verification programme and verification basis. • The operator shall establish the verification basis for the overall activities after assessing the scope, method and degree of independence of the verification. The operator shall also carry out an overall assessment of the results of the verifications that have been carried out."	5. Verify that contract holders monitor the HSSE requirements of the contract that are relevant to competence and fitness to work of contractor staff 12.2.3 Verify the documented demonstration of ALARP 15.2 Inspect and verify the performance of HSSE Critical equipment 15.4 Inspect and re-verify the technical integrity of HSSE critical equipment if an equipment constraint is exceeded beyond predefined values 16.4 Verify that the maintenance work has been executed correctly and that HSSE critical equipment meets the specified minimum performance criteria. (See also 14.1)	• Verify that the Contractor company and its personnel have been informed of the HSSE requirements of the contract. • Verify that the Contractor company manages the HSSE requirements of the contract and review and approve the Contract HSSE Plan when it is required • Verify that Contractor personnel are given an HSSE induction on the HSSE Risks of the contracted activities, the controls to manage those Risks, and applicable HSSE requirements.	• A Technical Integrity Verification (TIV) program shall be implemented for all Safety Critical Items under a Scope of Work through all phases of the work, including work carried out by the Subcontractors. • The TIV is the Principal's process that ensures technical integrity from concept through design and construction and that the knowledge (systems, people, tools) required to maintain integrity during operation is delivered. • The purpose of the TIV process is to provide assurance and verification to ensure that the systems defined as critical to the safety of the facility are suitable, i.e. appropriate for their intended purpose, dependable and effective when required to perform their intended function. • The TIV applies to components that the Principal designates as Safety Critical Elements (SCEs). Each SCE has a Performance Standard that describes the performance requirements of each SCE as well as how these requirements are to be verified. • The performance standards include information that shall be used in the creation of Inspection and Test Plans, equipment requirement/specification documents, preservation and maintenance requirements.

<table>
<tr><th>Regulatory topic</th><th>Management regulations</th><th>Management regulations</th><th>Shell HSSE&SP Control framework</th></tr>
<tr><td>Analyses</td><td>Section 16 – General requirements for risk analyses</td><td>Section 17 – Risk analyses and emergency preparedness analyses</td><td>Chapter 01 – Risk management
Section 04 - Managing Risk</td></tr>
<tr><td></td><td>

The responsible party shall ensure that analyses are carried out that provide the necessary basis for making decisions to safeguard health, safety and the environment.
Recognised and suitable models, methods and data shall be used when conducting and updating the analyses.
The purpose of each risk analysis shall be clear, as well as the conditions, premises and limitations that form its basis.
The individual analysis shall be presented such that the target groups receive a balanced and comprehensive presentation of the analysis and the results.
Criteria shall be set for carrying out new analyses and/or updating existing analyses as regards changes in conditions, assumptions, knowledge and definitions that, individually or collectively, influence the risk associated with the activities.
The operator or the party responsible for operating an offshore or onshore facility shall maintain a comprehensive overview of the analyses that have been carried out and are underway. Necessary consistency shall be ensured between analyses that complement or expand upon each other.

</td><td>
...The risk analysis shall

identify hazard and accident situations,
identify initiating incidents and ascertain the causes of such incidents,
analyse accident sequences and potential consequences, and
Identify and analyse risk-reducing measures.

Risk analyses shall be carried out and form part of the basis for making decisions when e.g.:

identifying the need for and function of necessary barriers, cf. Sections 4 and 5,
identifying specific performance requirements of barrier functions and barrier elements, including which accident loads are to be used as a basis for designing and operating the installation/facility, systems and/or equipment, cf. Section 5,
designing and positioning areas, cf. Section 5 of the Facilities Regulations,
classifying systems and equipment, cf. Section 46 of the Activities Regulations,
demonstrating that the main safety functions are safeguarded , stipulating operational conditions and restrictions,
selecting defined hazard and accident situations.

Emergency preparedness analyses shall be carried out and be part of the basis for making decisions when e.g.

defining hazard and accident situations,
stipulating performance requirements for the emergency preparedness,
selecting and dimensioning emergency preparedness measures.

</td><td>
Establish a process to identify HSSE Hazards and to reduce the Risks to As Low As Reasonably Practicable (ALARP).

Identify HSSE Hazards in the Business and document their effects on people, Assets, environment and reputation in a Hazards and Effects Register.
Assess the Risk of identified Hazards for Worst-Case Credible Scenarios using the RAM
Manage Hazards having Risks in the dark and light blue areas of the RAM through the effective implementation of the HSSE&SP management system.
Where Reasonably Practicable, eliminate Hazards or substitute Hazards that have Risk in the yellow and red area of the RAM with ones having lower Risk.
Identify and implement Controls and Recovery Measures for Hazards in the yellow area of the RAM to reduce Risk to ALARP.
Identify and implement Controls and Recovery Measures for Hazards in the red and yellow 5A and 5B areas of the RAM as stated in requirement 6 (above) and in addition by a Bow-Tie or equivalent methodology. “
Review hazards and risks and maintain documentation

</td></tr>
</table>

1.1. Asset integrity

		SHELL HSSE&SP Control framework Section 03 Process Safety – 1. AIPSM
Ref chapter 3.1.2		Identify and document hazards with RAM red and yellow 5A and 5B Process Safety Risks for existing and new Assets.
Ref chapter 3.1.2		Manage identified Risks to As Low As Reasonably Practicable (ALARP) as specified in Managing Risk.
Activities regulations **Chapter VI – Operational prerequisites for start-up and use**	**Management regulations** **Chapter IV – Recourses and processes**	**SHELL HSSE&SP Control framework** **Section 03 Process Safety – 1. AIPSM**
Section 21 - Competence The responsible party shall ensure that the personnel at all times have the competence necessary to carry out the activities in accordance with the health, safety and environment legislation. In addition, the personnel shall be able to handle hazard and accident situations, cf. Section 14 of the Management Regulations and Section 23 of these regulations. Personnel who will carry out bell diving or surface-oriented diving, shall have a valid certificate. The Petroleum Safety Authority Norway appoints suitable enterprises to issue certificates on its behalf. Payment can be charged for issuance of certificates. **Section 23 – Training and drills** The responsible party shall ensure that necessary training and necessary drills are conducted, so that the personnel are always able to handle operational disturbances and hazard and accident situations in an effective manner.	**Section 14 – Manning and competence** The responsible party shall ensure sufficient manning and competence in all phases of the activities; cf. Section 12 of the Framework Regulations. Minimum requirements will be established for manning and competence to safeguard functions a) where mistakes may have serious consequences for health, safety or the environment, b) that reduce the probability of mistakes and hazard and accident situations developing, cf. Sections 4and 13 The manning of the various work tasks shall ensure that the personnel are not assigned incompatible tasks. The assumptions that form the basis for manning and competence shall be followed up. In the event of manning changes, potential consequences for health, safety and the	Manage the competence of employees in HSSE Critical Positions as specified below: • Provide information, instruction, training and supervision so that people are competent to carry out their work safely in their area of responsibility. • Identify and record the HSSE Critical positions in their reporting line. They require Competence Assurance. There are three categories: • Frontline Barrier Management positions; • Technical Authority Level 1 or 2 roles in DCAF (or equivalent); • Leader positions Manage the fitness to work of employees as specified below: • Identify all job tasks requiring evaluation of fitness to work. • Verify that employees identified by requirement 1. Complete fitness to work evaluations. • Review any work restrictions provided by the health professional designated by Shell Health and subsequently approve changes in work assignment

<table>
<tr><td></td><td>environment shall be reviewed.</td><td>or return to work of employees.</td></tr>
<tr><td>Framework regulations
Chapter III – Management of the petroleum activities</td><td>SHELL HSSE&SP Control framework
Section 07 Contractor HSSE management</td><td>SHELL HSSE&SP Control framework
Section 03 Process Safety – 1. AIPSM</td></tr>
<tr><td>Section 18 – Qualification and follow-up of other participants

When entering into a contract, the responsible party shall ensure that the contractors and suppliers are qualified to fulfil the regulatory requirements relating to health, safety and the environment. Furthermore, the responsible party shall follow up to ensure that the participants comply with the requirements while performing the assignment in the activities covered by these regulations.

The operator shall ensure that any deficiencies in other participants' management of health, safety and the environment are corrected, and that the necessary adjustments are made with respect to its own and other participants' management systems, to ensure the necessary uniformity.</td><td rowspan="3">Identify the HSSE Risks associated with the contracted activities and define how to manage the Risks.

During the bid evaluation, assess whether the Contractor company has the capability and resources to manage the HSSE risks.
- The Contractor company must show past and current HSSE performance.
- The contractor company must have a documented process, including Procedures and work instructions, or an HSSE MS, which shows that the Contractor can manage the HSSE Risk.
• Before contract award, confirm that the contractor company meets requirements above. Use an approval process for exceptions and record the outcome.
• Before the contractor company awards a subcontract, check that the Contractor has assessed the subcontractor’s ability to meet requirements above.
• Monitor and regularly assess the HSSE performance of the Contractor company.
• Regularly review the management of HSSE risks in contracted activities. When necessary, define and document actions for continuous improvement.</td><td rowspan="3">• Verify that Contract Holders monitor the HSSE requirements of the contract that are relevant to the competence and fitness to work of contractor staff as specified in Contractor HSSE Management.
• Provide supervision of HSSE Critical Activities appropriate to the complexity of the activity including multiple concurrent tasks, and non-routine and unexpected activities; and the competence of the individuals performing the activity.</td></tr>
<tr><td>Framework regulations
Chapter II – Basic requirements for health, safety and the environment</td></tr>
<tr><td>Section 12 – Organisation and competence

“The responsible party shall ensure that everyone who carries out work on its behalf in activities covered by these regulations has the competence necessary to carry out such work in a prudent manner.”</td></tr>
</table>

1.2. Physical barriers

Table 13 – Examples of physical barriers functional requirements

HSE regulations	Shell HSSE&SP Control	
Facilities regulations **Section 56 – Load bearing structures and maritime systems** Load-bearing structures shall maintain satisfactory safety in use, failure, fatigue and accident limit states. They shall be able to withstand the loads/actions they are exposed to, including loads/actions with an annual probability of 10-2 in the failure limit state and the loads/actions that follow from Section 11, in the accident limit state. Load-bearing structures shall be sufficiently robust to ensure that local damage or failure will not result in unacceptable consequences. Maritime systems shall be sufficiently robust to ensure that local damage or individual technical or operational faults do not result in unacceptable consequences. The analyses shall be verified by an organizationally independent party.	**SI001 – Structures Subsea / Vessel hull / GBS / Foundation structures** **Purpose:** To provide and maintain structural integrity under all expected actions through service life. Provide sufficient robustness to maintain availability of critical systems during a major accident hazard **Functional criteria:** 6. Primary and secondary steel structures shall be suitable for continued operation. 7. Appurtenances shall be suitable for continued operation 8. Subsea structures shall be suitable for continued operation 9. Handrails, Gratings, Stair Treads & Deck Plating from all areas of the platform to be structurally sound and complete. 10. Seawater Drawdown • System of gravity based structures operates within set limits to maintain the concrete structure in compression at all times during oil storage and transfer • Ballasting systems maintains floating structures at appropriate draft and trim.	**SI002 – Topside structures** **Purpose:** To provide and maintain structural integrity under all expected actions through service life, and to provide sufficient robustness to maintain availability of critical systems during a major incident **Functional criteria:** • Topside structures shall be suitable for continued operation. • Topside structures inspection shall be suitable for continued operation • Topside structure fabric shall be suitable for continued operation • Maintain temporary refuge support for defined load cases and suitability for continued operation • Personnel access structures shall be suitable for continued operation.

<table>
<tr><th>HSE regulations
Facilities regulations</th><th colspan="2">Shell SCE management
Global performance standard templates</th></tr>
<tr><td rowspan="2">Section 37 – Fixed fire-fighting systems

Fixed fire-fighting systems shall be installed in explosion-hazard areas and in areas with a major risk of fire. The systems shall also cover equipment containing significant amounts of hydrocarbons. The systems shall be designed such that fire-fighting can be carried out quickly and efficiently at all times.

The systems shall be automatically activated by a signal from the fire detection system. In the event of gas detection, the systems shall be automatically activated if this can result in lower explosion pressure.

In areas where gas is used as an extinguishing medium, notification systems shall be installed that announce the release of gas.

Manual activation of the fire-fighting systems shall activate the facility's general alarm.</td><td>PS001 – Deluge systems

Purpose: To mitigate the consequence of fire and explosion

Functional criteria:
1. To provide firewater via the deluge system to the minimum application rates.
2. Control room operators are to be aware of the operation of the deluge system.
3. Upon demand, the deluge system is to deliver firewater within the specified time.
4. Retain control of deluge valves upon loss of instrument air during a Major Accident Hazard (MAH).</td><td>PS005 – Fire water ring main and other distribution systems

Purpose: To distribute sufficient fire water to all fire water systems

Functional criteria
1. The firewater ring main has the integrity to distribute firewater at the required pressure and flow rates
2. The firewater ring main pressure is to be maintained at the specified level
3. To supply firewater for manual fire fighting
4. To ensure monitors are suitable for manual fire fighting</td></tr>
<tr><td>PS009 – Sprinkler systems

Purpose: To control or extinguish localised fires and to prevent escalation of fires

Functional criteria
1. To provide sufficient water to mitigate the effects of fires in normally manned areas.
2. Control Room to be aware of sprinkler system operation.</td><td>PS008 – Fine water spray systems

Purpose: To mitigate the effects of a fire and to prevent escalation of fires in enclosed areas (e.g. Diesel engine enclosures)

Functional criteria
1. To provide a water mist to extinguish fires</td></tr>
</table>

	PS007 – Gaseous fire protection systems **Purpose:** To mitigate the effects of a fire and to prevent escalation of fires in enclosed areas. **Functional criteria** 1. To mitigate the effects of a fire in a Galley Hood 2. To mitigate the effects of a fire in an enclosed protected area or equipment	**PS011 – Fixed foam systems** **Purpose:** To provide an application of foam to prevent, or mitigate, hydrocarbon pool fuel fires (including aviation fuel). **Functional criteria** 1. To provide an application of foam on the helideck (offshore only) 2. To provide a sufficient quantity and quality of foam at the discharge point To provide an application of foam to specific areas via a deluge ring main and foam branch systems.
Section 29 – Passive fire protection Where passive fire protection is used, this shall be designed such that it provides relevant structures and equipment with sufficient fire resistance as regards load/action capacity, integrity and insulation properties during a design fire load/action. When designing passive fire protection, the cooling effect from fire-fighting equipment shall not be considered.	**PS006 – Passive fire protection** **Purpose:** To limit the effect of a fire on structure, plant, safety systems and personnel. **Functional criteria** To maintain the integrity of the coating or barrier so that it provides adequate thermal protection to the object or area from the identified fire hazards for the required resistance period.	

HSE regulations Facilities regulations	Shell SCE management Global performance standard templates
Section 36 – Firewater supply All facilities with accommodation shall have a sufficient supply of firewater to a) combat fires and b) suppress gas explosions if this can result in lower explosion pressure, with reference to Section 37. Permanently manned facilities shall have firewater supply from fire pumps or other independent supply to ensure sufficient capacity at all times, regardless of whether parts of the supply are out of service. Simpler facilities with accommodation shall have a firewater supply from a fire pump or other equivalently reliable supply. Simpler facilities without accommodation shall have an adequate supply of firewater so that the personnel can be protected from fires that can occur when the facility is manned. The firewater system shall be designed such that a pressure stroke does not make the system or parts of it inoperative. On facilities where firewater is supplied from fire pumps, the pumps shall start up automatically in the event of a pressure drop in the fire main and fire and gas detection. Fire pumps shall also be capable of being manually activated from the central control room and at the propulsion unit. Propulsion units for fire pumps shall be equipped with two independent starting arrangements. Automatic disconnection functions shall be as few as possible. Firewater piping shall be designed and placed such that a sufficient supply of firewater is ensured to any area on the facility.	**PS004 – Fire water pumps** **Purpose:** To provide fire water on demand to extinguish or limit the spread and effects of a fire **Functional criteria** 1. Each fire pump shall operate in accordance with its design characteristic 2. Each fire pump shall start on demand from initiation signals. Each pump shall be capable of running without interruption for the duration of a defined emergency event 3. Control Room Fire & Gas Panel shall indicate Fire Pump status 4. To supply combustion and cooling air to the diesel drivers associated with fire pumps 5. Each pump shall be capable of running without interruption for the duration of a defined emergency event

Facilities regulations **Section 31 – Fire divisions in living quarters**	**Facilities regulations** **Section 30 – Fire divisions**	**PS002 – Fire and explosion protection**
The living quarters shall be protected by fire divisions that, as a minimum, satisfy fire rating a) H-60 for external walls facing a process or drilling area and which may be exposed to fire from these, b) A-60 for other external walls, c) A-0 for external walls on the living quarters that are located on a separate facility at a safe distance from production or drilling facilities, and for external walls on the emergency quarters on simpler facilities with accommodation, if these quarters are separated from the production or wellhead areas with a main fire division that, as a minimum, satisfies fire rating H-0. The internal design of the living quarters shall be such that it limits the spread of fire.	The main areas on facilities shall be separated by fire divisions that, as a minimum, can withstand the design fire and explosion loads/actions and, as a minimum, satisfy fire rating H-0 if they can be exposed to hydrocarbon fires. Rooms with important functions and important equipment, as well as rooms with a high risk of fire, shall be separated from their surroundings with fire divisions with a fire rating corresponding to the fire type and the design fire and explosion loads/actions to which they would be exposed. Penetrations shall not weaken the fire divisions. Doors in fire divisions shall be self-closing.	**Purpose:** To limit the effect of a fire and/or an explosion. **Functional criteria** • To be able to contain the effects of an explosion and/or fire event and avoid escalation • To be able to reduce the effects of an explosion by providing explosion venting • To be able to prevent the migration of hazardous gas and smoke between adjacent areas • Temporary Refuge (TR) Specific Function: To be able to withstand the effects of explosion and/or fire events. (TR Reference to be reviewed to fit local terminology)

<table>
<tr>
<td rowspan="2">Facilities regulations
Section 38 – Emergency power and emergency lighting

Facilities shall have a reliable, robust and simple emergency power system that ensures sufficient supply of power to equipment and systems that shall function in the event of a main power failure.

It shall be ensured that interruptions do not entail operating problems for the emergency power users when switching from main power to emergency power.

The emergency power system shall have as few as possible automatic disconnection functions to ensure continuous operation.

Facilities shall be equipped with emergency lighting that ensures necessary lighting on the facility in the event of main lighting failure.</td>
<td>ER005 – Uninterrupted power supply (UPS)

Purpose:

To provide an uninterrupted power supply to the vital services during a Major Accident Hazard (MAH) when normal power fails

Functional requirement:

To provide an uninterrupted power supply for vital services when normal power fails.</td>
<td>ER007 – Emergency power

Purpose:

To provide an emergency power supply to support essential facilities during an emergency following loss of the normal power supply

Functional requirements:
The Emergency Generator shall start upon demand, and have battery life to support multiple starting attempts
The Emergency Generator shall be capable of supplying its rated voltage and frequency on demand to the Emergency Switchboard</td>
</tr>
<tr>
<td>PS010 – Power management systems

Purpose:

To isolate faulty circuits from the electrical power generation/distribution and maintain the stability of the main power generating system by load sharing and shedding

Functional requirements:
To protect personnel and equipment against electrical system failures
To maintain the power system stability when excessive loads are connected
The power generating system shares load in proportion to the generator capabilities in normal operation</td>
<td>ER003 – Emergency and escape lighting

Purpose:

To provide adequate illumination at emergency response locations and to escape routes in the event of a major hazardous event

Functional requirements:
To provide sufficient illumination to escape along designated emergency escape routes and designated emergency response locations following loss of external power supply.
To provide adequate illumination for managing an incident at the designated emergency response locations following loss of normal power supply</td>
</tr>
</table>

Facilities regulations **Section 75 – Personal protective equipment** Personal protective equipment as defined in the Regulations relating to construction, design and production of personal protective equipment (in Norwegian only) (the PPE regulations) shall be in accordance with the requirements in the PPE regulations, also when such equipment is used in the petroleum activities. One exemption from this provision is Section 49, No. 2 of the Regulations relating to Personal Protective Equipment (in Norwegian only).	**Facilities regulations** **Section 45 – Survival suits and life jackets, etc.** It shall be possible to store personal survival suits in the cabins. In addition, a number of survival suits and life jackets shall be placed easily accessible on the facility, based on the results from the emergency preparedness analysis mentioned in Section 17 of the Management Regulations. It shall be possible to store the survival suits and life jackets without compromising their quality. Life buoys shall be placed so they are easily accessible on the facility.	**Facilities regulations** **Section 46 – Manual fire fighting and fire fighters equipment** Facilities shall be equipped with sufficient manual fire-fighting and firefighter equipment to effectively combat incipient fires and prevent escalation.	**LS001 – Personal Survival equipment** **Purpose:** • To provide all personnel escaping from a major hazard with suitable protective clothing and equipment. • To provide personnel within emergency response roles with suitable protective clothing and equipment **Functional requirements:** • To assist in escaping from specific work places to the Temporary Refuge (TR). • To provide personal safety equipment to enable personnel to evacuate the installation from the Temporary Refuge to a place of safety • Protection of personnel with specific emergency duties whilst carrying out those duties (e.g. to assist in the rescue and recovery of personnel).

Facilities regulations **Section 44 – Means of evacuation** Personnel on facilities shall be able to evacuate quickly and efficiently to a safe area under all weather conditions, cf. Section 77, litera d of the Activities Regulations. The choice of means of evacuation, their placement and protection shall be based on the defined hazard and accident situations, cf. Section 73 of the Activities Regulations. Free-fall lifeboats, supplemented by rescue chutes and associated life rafts shall be used as means of evacuation for evacuation to sea.	**ER006 – Helicopter facilities** **Purpose:** To facilitate the evacuation of personnel from the installation to the nearest place of safety. **Functional requirement:** • Avoid collision with the installation under any conditions and to facilitate the evacuation of personnel to the nearest place of safety
	LS003 – Lifeboats / totally enclosed propelled survival craft **Purpose:** To facilitate a secondary means of evacuation of personnel, independent of external resources, when the primary means is unavailable. **Functional requirements:** • Lifeboats can be launched safely from the installation to the sea • Lifeboats can move away from the installation and provide a safe environment for personnel onboard • Lifeboats can provide a safe environment for personnel onboard.
	LS004 – Tertiary means of escape (offshore only) **Purpose:** To have a variety of means to facilitate escape to sea of personnel from the installation when primary and secondary means are unavailable. **Functional requirements:** • To provide a means to facilitate escape to sea of personnel from the installation and into the sea when the primary and secondary means of escape are unavailable

1.3. Risk and emergency preparedness analyses

Regulatory topic	Management regulations		Shell HSSE&SP Control framework
Analyses	**Section 16 – General requirements for risk analyses**	**Section 17 – Risk analyses and emergency preparedness analyses**	**Chapter 01 – Risk management** **Section 04 - Managing Risk**
	• The responsible party shall ensure that analyses are carried out that provide the necessary basis for making decisions to safeguard health, safety and the environment. • Recognised and suitable models, methods and data shall be used when conducting and updating the analyses. • The purpose of each risk analysis shall be clear, as well as the conditions, premises and limitations that form its basis. • The individual analysis shall be presented such that the target groups receive a balanced and comprehensive presentation of the analysis and the results. • Criteria shall be set for carrying out new analyses and/or updating existing analyses as regards changes in conditions, assumptions, knowledge and definitions that, individually or collectively, influence the risk associated with the activities. • The operator or the party responsible for operating an offshore or onshore facility shall maintain a comprehensive overview of the analyses that have been carried out and are underway. Necessary consistency shall be ensured between analyses that complement or expand upon each other.	...The risk analysis shall • identify hazard and accident situations, • identify initiating incidents and ascertain the causes of such incidents, • analyse accident sequences and potential consequences, and • Identify and analyse risk-reducing measures. Risk analyses shall be carried out and form part of the basis for making decisions when e.g.: • identifying the need for and function of necessary barriers, cf. Sections 4 and 5, • identifying specific performance requirements of barrier functions and barrier elements, including which accident loads are to be used as a basis for designing and operating the installation/facility, systems and/or equipment, cf. Section 5, • designing and positioning areas, cf. Section 5 of the Facilities Regulations, • classifying systems and equipment, cf. Section 46 of the Activities Regulations, • demonstrating that the main safety functions are safeguarded , stipulating operational conditions and restrictions, • selecting defined hazard and accident situations. Emergency preparedness analyses shall be carried out and be part of the basis for making decisions when e.g. • defining hazard and accident situations, • stipulating performance requirements for the emergency preparedness, • selecting and dimensioning emergency preparedness measures.	Establish a process to identify HSSE Hazards and to reduce the Risks to As Low As Reasonably Practicable (ALARP). • Identify HSSE Hazards in the Business and document their effects on people, Assets, environment and reputation in a Hazards and Effects Register. • Assess the Risk of identified Hazards for Worst-Case Credible Scenarios using the RAM • Manage Hazards having Risks in the dark light blue areas of the RAM through the effective implementation of the HSSE&SP management system. • Where Reasonably Practicable, eliminate Hazards or substitute Hazards that have R in the yellow and red area of the RAM wi ones having lower Risk. • Identify and implement Controls and Recovery Measures for Hazards in the yellow area of the RAM to reduce Risk to ALARP. • Identify and implement Controls and Recovery Measures for Hazards in the red and yellow 5A and 5B areas of the RAM as stated in requirement 6 (above) and in addition by a Bow-Tie or equivalent methodology. " • Review hazards and risks and maintain documentation

1.4. Design Engineering Manual 2 (DEM 2)

The Shell HSSE&SP Control Framework defines 11 basic requirements for process safety with focus on preventing re-occurrence of known process safety incidents by focussing on main causes and key barriers.

Table 14 - DEM 2 Overview

SHELL HSSE&SP Control framework Section 03 Process Safety – 4. DEM2	Major incident in the industry	Comment
PSBR 1 - Safe siting of occupied portable buildings	BP Texas City Isomerisation unit explosion, March 23, 2005	Onshore only Not relevant for this thesis
PSBR 2 - ESD valves on platform risers	Piper Alpha Platform, UK, North Sea, July 6, 1988	Facilities regulations section 33 & 48
PSBR 3 - Temporary refuge	Piper Alpha Platform, UK, North Sea, July 6, 1988	Partially mentioned in Facilities regulations section 58
PSBR 4 - Permit To Work	Piper Alpha Platform, UK, North Sea, July 6, 1988	Activities regulations section 30
PSBR 5 - Management Of Change	Chernobyl, USSR, April 26, 1986	No defined requirement in the HSE regulations
PSBR 6 - Avoid liquid release relief to atmosphere	BP Texas City Isomerisation unit explosion, March 23, 2005	Partially mentioned in Facilities regulations
PSBR 7 - Avoid tank overfill followed by vapour cloud release	Buncefield storage terminal explosion, UK, December 11, 2005	Partially mentioned in Facilities regulations
PSBR 8 - Avoid brittle fracture of metallic materials	Esso Longford Gas plant explosion, Australia, September 25, 1998	No defined requirement in the HSE regulations
PSBR 9 - Alarm management	Esso Longford Gas plant explosion, Australia, September 25, 1998	Not part of the HSE regulations. The PSA has issued a separate document outlining principles for alarm system design. This is however outside the scope of this thesis
PSBR 10 - Sour Gas (H2S)	Chuandongbei gas well blow-out, China, December 23, 2003	No defined requirement in the HSE regulations
PSBR 11 - Deepwater Well Design and Construction	Macondo well blow-out, Gulf of Mexico, April 20, 2010	Facilities regulations section 48 & 49 and Activities regulations section 85

A simple comparison of regulatory requirements for the sections found applicable for this thesis is presented in Table 15 below.

Table 15 - Comparisson DEM2 PSBR's vs HSE regulations

Shell HSSE&SP Control Framework Design & Engineering Manual 2	Facilities regulations	
PSBR 2 - ESD valves on platform risers • For offshore pipelines containing flammable or toxic fluids an ESD valve shall be located at the top of each riser connected to a manned offshore installation. The ESD valve shall be located in a position: o in which it can be safely inspected, maintained and tested; o such that it is above water; o such that its exposure to topside incidents is minimised; and o subject to the above, such that the distance from the ESD valve to the base of the riser is as short as reasonably practicable. • For pipelines containing flammable or toxic fluids1 and connected to a manned offshore installation, an additional subsea isolation valve (such as Subsea Isolation Valve (SSIV), Riser Isolation Valve (RIV), Keel or Pontoon Valve) shall be evaluated as specified in Managing Risks and the results included in the documented demonstration of ALARP. • For pipelines other than those in requirement 2 and for risers the risk of harm to people occupying the offshore installation shall be managed to as specified in and the results included in the documented demonstration of ALARP.	**Section 33 – Emergency shutdown systems** "...Emergency shutdown valves shall be installed that can stop streams of hydrocarbons and chemicals to and from the facility and to and from wells, and which isolate and/or partition the fire areas on the facility."	**Section 48 – Well barriers** Well barriers shall be designed such that well integrity is ensured and the barrier functions are safeguarded during the well's lifetime. Well barriers shall be designed such that unintended well influx and outflow to the external environment is prevented, and such that they do not hinder well activities. When a production well is temporarily abandoned without a completion string, at least two qualified and independent barriers shall be present. When a well is temporarily or permanently abandoned, the barriers shall be designed such that they take into account well integrity for the longest period of time the well is expected to be abandoned. When plugging wells, it shall be possible to cut the casings without harming the surroundings. The well barriers shall be designed such that their performance can be verified.

Shell HSSE&SP Control Framework Design & Engineering Manual 2	Facilities regulations
PSBR 3 - Temporary refuge • Every offshore installation has a temporary refuge (TR). • The main function of the TR is to provide a place where the total personnel on board (POB) can muster without undue Risk and still have access to the communications, monitoring and control equipment necessary to ensure their personal safety, and from where, if necessary, safe and complete evacuation can be effected. • The escape and evacuation routes and the embarkation areas provide1: o secure means of escape to the TR; and secure means for a complete evacuation from the TR	**Section 58 – Living quarters** • The living quarters' furnishings and capacity shall ensure a prudent residential environment and be adapted to the various functions that shall be safeguarded, and the anticipated personnel needs in the various phases of the petroleum activities. • The living quarters shall be equipped and furnished so as to maintain an adequate standard of hygiene. • Emergency quarters on simpler facilities with accommodation possibilities shall be adapted to the greatest personnel need. The same safety and hygiene requirements are set for simpler facilities with accommodation possibilities as for living quarters.

<table>
<tr><th>Shell HSSE&SP Control Framework
Design & Engineering Manual 2</th><th>HSSE&SP Control framework
Chapter 01 – HSSE SP management system
Section 5, pt 3 – Permit to work:</th><th>Activities regulations</th><th>Activities regulations</th></tr>
<tr><td>PSBR 4 - Permit To Work

• Meet the requirements for the Permit To Work systems specified in Permit to Work
• Verify the effectiveness of the Permit To Work system of the Asset using a tiered approach ranging from daily monitoring to less frequent self-assessments.
• Make the effectiveness of the Permit To Work system and the Permit To Work verification process part of each Independent HSSE MS audit</td><td>• Establish and maintain a Permit To Work (PTW) Procedure that meets the following requirements. The PTW Procedure must:
• Identify the types of work that need to be controlled through a PTW
• Specify that all Shell and Contractor personnel at a location must work under a single PTW system, unless specifically approved for work conducted by specialist Contractors using their own PTW system
• Specify the Controls required for the work, based on a Risk Assessment, and the Hierarchy Of Controls.
• Define when a Job Hazard Analysis is required as part of the PTW Procedure
• Specify the operational preparations required before a PTW can be issued, which are:
o isolation of the work area from Hazards including all potential sources of energy, conforming to Safe Isolation - Lock Out Tag Out;
o Specify how permits are issued and closed, including for both ‘complete’ and ‘suspended’ situations, how shift handovers are managed, and the period of validity of permits.
o Make available at least two copies of the permit. One must be at the work site with the Permit Holder and one at the issuing point, so that the status of the permits in any area can be readily assessed.
o Communicate to the members of the Permit Holder’s work party the information on Hazards, precautions, action in the event of emergency and changes to work conditions.
o Specify that permits be retained for a period defined by legislative requirements or the criticality of the permit, and in any case for not less than three months.</td><td>Section 30 – Safety Clearance of activities

• Planned activities shall be cleared as regards safety before they are carried out.
• Which conditions shall be met, shall be evident from the clearance, including which measures shall be implemented before, during and after the work so that those participating in or who may be affected by the activity, are not injured, and so that the probability of mistakes that can lead to hazard and accident situations is reduced.</td><td>Guidelines Re Section 30 – Safety clearance of activities

• In order to fulfill the safety clearance requirement, a work permit system should be used.
• When activities are cleared in accordance with this section, a safe job analysis should be conducted when sub-activities are not covered by procedures, the procedures can conflict with each other, or the activities are new to the personnel involved.
• As regards conducting safe job analyses, Appendix B.4 to the ISO 17776 standard and Chapter 4.4.3 of the NORSOK standard S-002N should be used in the area of health, safety and working environment. With regard to conducting a job safety analysis, see the last paragraph in the above-mentioned Appendix B.4, the party responsible for carrying out the work and the workers who actually carry it out, should participate, possibly also the persons responsible for the system and area.</td></tr>
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<table>
<tr><th>Shell HSSE&SP Control Framework
Design & Engineering Manual 2</th><th>Facilities regulations</th></tr>
<tr><td>PSBR 6 - Avoid liquid release relief to atmosphere

Create for each Asset an inventory of all atmospheric vents that have the potential to release hydrocarbon liquid above its flash point.</td><td rowspan="2">Section 35 – Gas release system

Facilities equipped with or attached to process facilities, shall have a gas release system. The system shall prevent escalation of hazard and accident situations by quickly reducing the pressure in the equipment, and it shall be designed so that the release of gas does not harm personnel or equipment.

It shall be possible to trigger the depressurisation manually from the central control room.

Liquid separators installed in the gas release system shall be secured against overfilling</td></tr>
<tr><td>PSBR 7 - Avoid tank overfill followed by vapour cloud release

• Create for each Asset an inventory of all storage tanks containing fluids that have the potential to overfill resulting in a vapour cloud explosion. Examples of such fluids are finished gasoline, gasoline components, naphtha(s), benzene, methyl ethyl ketone, MTBE, acetone, pentane, special boiling point solvents SBP1 and SBP2, and natural gas liquids (condensates) and crude oils with a Reid Vapour Pressure RVP > 2.5 psi.</td></tr>
<tr><td>PSBR 8 - Avoid brittle fracture of metallic materials

• For each Asset, determine the lower design temperature (LDT) or alternatively the minimum allowable temperature (MAT) for all unfired pressure vessels, heat exchangers, piping, piping components and valves (including control valves) or rotating equipment, containing liquefied gas or compressed flammable low molecular weight hydrocarbon gas.
• Take measures to prevent the equipment being at pressure below the LDT or alternatively ensure the equipment metal temperature is not below the appropriate MAT at any given operating pressure. Consider scenarios in which equipment temperature can drop such as blow-downs, as well as scenarios of subsequent (re-)pressurization of equipment.</td><td>Section 12 – Material

• Materials to be used in or on facilities shall be selected considering
• the load/action requirements mentioned in Section 11,
• manufacturing, joining and construction processes,
• possible use of materials protection,
• fire-resistance properties,
• probable changes in operating conditions,
• the opportunity to reduce future use of chemicals and pollution,
• the opportunity to reduce, reuse and recover waste,
• the employees' health and working environment,
• potential future removal.</td></tr>
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Shell HSSE&SP Control Framework Design & Engineering Manual 2	HSE regulations
PSBR 11 - Deepwater Well Design and Construction **(applies to all deepwater wells – greater than 1000ft water depth)** • During drilling or when hydrocarbon zones are being completed, well barrier elements related to exposed protective and production casing strings shall be designed to enable a cap-and-shut off of anticipated hydrocarbons from the borehole to the surface external environment. • Plans shall be in place to mobilise the capping (shut-off) and containment (collection) equipment. • After surface casing has been installed, if a pressure differential exists that may cause uncontrolled outflow from the borehole or well to the surface2 external environment there shall be two well barriers available during all well construction operations. • Fit-for-purpose dual shear rams shall be installed on all subsea deepwater blow-out preventers.	**Activities regulations** **Section 85 – Well barriers** • During drilling and well activities, there shall be tested well barriers with sufficient independence, cf. also Section 48 of the Facilities Regulations. • If a barrier fails, activities shall not be carried out in the well other than those intended to restore the barrier. • There shall be pumping and fluid capacity available on the facility or on vessels in the event of heavy well intervention. The need for pumping and fluid capacity in the event of light well intervention shall be included in the activity-specific risk assessment. When handing over wells, the barrier status shall be tested, verified and documented. **Facilities regulations** **Section 48 – Well barriers** • Well barriers shall be designed such that well integrity is ensured and the barrier functions are safeguarded during the well's lifetime. • Well barriers shall be designed such that unintended well influx and outflow to the external environment is prevented, and such that they do not hinder well activities. • When a production well is temporarily abandoned without a completion string, at least two qualified and independent barriers shall be present. • When a well is temporarily or permanently abandoned, the barriers shall be designed such that they take into account well integrity for the longest period of time the well is expected to be abandoned. • When plugging wells, it shall be possible to cut the casings without harming the surroundings. • The well barriers shall be designed such that their performance can be verified. **Facilities regulations** **Section 49 – Well control equipment** • Well control equipment shall be designed and capable of activation such that it ensures both barrier integrity and well control. For drilling of top hole sections through risers or conductors, equipment shall be installed with a capacity to divert shallow gas and formation fluids away from the facility until the personnel have been evacuated. • The pressure control equipment used in well interventions shall have remote-controlled valves with mechanical locking mechanisms in the closed position. • Well intervention equipment shall have a remote-controlled shear/blind ram as close to the christmas tree as possible. • Floating facilities shall have an alternative activation system for activating critical functions on the blowout preventer for use in the event of an evacuation. • Floating facilities shall also have the capacity to disconnect the riser package after the shear ram has cut the work string.