Chapter 5
Lessons from Macondo Accident

5.1 The Deepwater Horizon and Macondo Well

In March 2008, BP Exploration and Production Inc. (BP) leased the Mississippi Canyon Block 252 for oil and gas exploration and designated it the Macondo Prospect. BP sold interests in the prospect to Anadarko (25 %) and MOEX (10 %) but remained the operator and majority owner (65 %). BP, as the operator, was responsible for all aspects of the design and development of the Macondo well.

BP's application for permit to drill was submitted to the Minerals Management Service (MMS) on 13th May 2009, and was approved on 22nd May 2009. The plan specified using the Transocean Marianas mobile unit to drill a well about 50 miles off the coast of Louisiana, southeast of New Orleans, in just over 1,500 m water depth. The total depth of the well was planned to be 6,100 m.

During the planning phase BP designed the well in accordance with the geological conditions of the prospect. During this process, BP engineers and geologists determined the type and strength of the well casing, cement, well head, and other equipment, in order to ensure well integrity and prevent its failure during drilling. This is crucial for well safety. Thereafter, selected contractors performed specific procedures such as drilling, cementing, well monitoring, vessel support services, and other well-related tasks.

At Macondo, BP began exploration on 6th October 2009, using the Transocean Marianas rig. Hurricane Ida damaged the Marianas on 9 November 2009, and drilling on Macondo was suspended following the installation and cementing of the well casing. The Marianas was demobilised to a shipyard for repairs, and BP applied to the MMS for permission to use the Transocean Deepwater Horizon rig to continue drilling. MMS approved this change on 14th January 2010.

The Deepwater Horizon, a fifth-generation, dynamically positioned, semi-submersible MODU, was capable of working in water up to 3,000 m. In 2009, the Deepwater Horizon crew drilled the deepest oil and gas well in the world, which had a vertical depth of more than 10.5 km.

The Deepwater Horizon entered service in April 2001 and went to work for BP in the Gulf of Mexico in September. With the exception of one well drilled for

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BHP Billiton in 2005, the rig worked exclusively for BP. The Deepwater Horizon crew drilled more than 30 wells on the US OCS during the course of the rig's career, in water depths between 700 m and 2,900 m, and maintained an excellent performance and safety record. BP extended its drilling contract on the Deepwater Horizon to September 2013 in September 2009.

The Deepwater Horizon arrived at Macondo on 31st January 2010. The crew performed maintenance work on the BOP stack, including function and pressure testing, before lowering it onto the wellhead on 8th February 2010. The crew then performed another successful pressure test of the BOP stack after it was attached to the wellhead. Drilling operations resumed on 11th February 2010.

The drilling of the Macondo well was performed as an overbalanced operation, which uses a mud column to prevent the influx of formation fluids into the well. The pressure of the mud column has to exceed the formation pore pressures encountered in the well. In overbalanced operations, the mud column is the primary well barrier, which has to exert a pressure greater than the pore pressure, but lower than the fracture gradient. The secondary well barrier in overbalanced operations is the well containment envelope consisting of selected components of the BOP. The Macondo was planned to be abandoned and left underbalanced by replacing drilling mud with seawater, and with two cement barriers in place.

Many deepwater reservoirs have such narrow drilling windows between the pore pressure and fraction gradient, that resolving one problem often creates another, and the resolution of that problem creates another, and so on until the cycle is broken with hydraulic balance or the well is abandoned. The operational drilling problems most associated with non-productive time include lost circulation, stuck pipes, wellbore instability and a loss of well control.

BP encountered a number of obstacles while drilling the Macondo well. Two cement repair operations, or squeezes, were required because of weak formations and possible problems with cement. On several occasions, fluid losses into the formation necessitated the use of lost-circulation material to stop the escape of fluids. On 8th March 2010, a 35 bbls influx of hydrocarbons, or "kick," occurred, sticking a section of drill pipe in the well. The drill crew had to plug the affected section of the well with cement and drill a side-track in order to continue. In early April, additional fluid losses to the formation prompted BP engineers to change the total planned depth of the well from 6,100 m to about 5,550 m to maintain its integrity.

After the completion of drilling operations on 9th April 2010, Schlumberger conducted a detailed analysis of the well's geological formations, or well logging, for BP over a period of approximately four-and-a-half days. The logging data from the new depth indicated that the well had reached a sizable reservoir of hydrocarbons. BP began planning for the next phase of the development, in which the Deepwater Horizon would run casing and prepare the well for temporary abandonment. On 16th April 2010, BP submitted its proposed temporary abandonment plan to the MMS and received approval the same day.

Upon reaching final well depth five days were spent logging the well in order to evaluate the reservoir intervals. After logging was complete, a cleanout trip was conducted to condition the wellbore and verify that the open hole section was in good condition. This procedure included circulating ‘bottoms up’ to verify that no gas was entrained in the mud. Upon achieving bottoms up, no appreciable volumes of gas were recorded, indicating that the well was stable.

On 16th April 2010 the MMS approved the procedure for the temporary abandonment of the well. At the time of the accident the 9 $^7/_8'' \times 7''$ production casing had been run and cemented in place at 5,527 m, and pressure testing had been completed. The rig crew was preparing for the final activities associated with temporary well abandonment when the accident occurred.

5.2 Organisations Involved

The well drilling project involves as noted above a number of contractors and subcontractors for specific tasks. The following is an overview of the involved in drilling the Macondo well:

BP	BP personnel in Houston, Texas, managed the development and operation of the Macondo well, and provided management and support to their personnel onboard the Deepwater Horizon. These onshore personnel consisted of three engineers, an engineer team leader, an operations team leader, and a manager. BP offshore personnel consisted of two well site leaders, a well site trainee, and three subsea personnel. Well site leaders exercised BP’s authority on the rig, directed and supervised operations, coordinated the activities of contractors, and reported to BP’s shore-based team.
Transocean	Contracted to provide the Deepwater Horizon drilling rig and the personnel to operate it. The Transocean team included the drilling, marine, and maintenance crews. The senior Transocean personnel involved in day-to-day operations were the offshore installation manager (OIM) and captain. The OIM was the senior Transocean manager onboard who coordinated rig operations with BP’s well site leaders and generally managed the Transocean crew. The captain was responsible for all marine operations and was the ultimate command authority during an emergency and when the rig was underway from one location to another. The Transocean drilling crew was led by a senior toolpusher, who supervised two toolpushers responsible for coordinating round-the-clock drilling operations. These toolpushers supervised the drillers and assistant drillers, who operated the drilling machinery and monitored the rig instruments. At the time of the accident, there were 79 Transocean personnel onboard the Deepwater Horizon, of which nine lost their lives.
Halliburton	Contracted to provide specialist cementing services and expertise and to support the BP teams both onshore and on the Deepwater Horizon. At the time of the accident, two Halliburton cementing specialists were onboard the Deepwater Horizon.
Sperry Sun	Contracted to install and operate a sophisticated well monitoring system on the Deepwater Horizon. Sperry deployed trained personnel, or mud loggers, to monitor the system, interpret the data it generated, and detect influxes of

	hydrocarbons, or kicks. At the time of the accident, there were two Sperry Sun mud loggers onboard the Deepwater Horizon.
M-I SWACO	Contracted to provide specialised drilling mud and mud engineering services on the Deepwater Horizon, which included mud material, equipment, and personnel. At the time of the accident, there were five M-I SWACO personnel onboard the Deepwater Horizon, including two who lost their lives.
Schlumberger	Contracted to provide specialised well and cement logging services on the Deepwater Horizon, which included equipment and personnel. At the time of the accident, no Schlumberger personnel were onboard the Deepwater Horizon.
Weatherford	Contracted to provide casing accessories, including centralisers, the float collar, and the shoe track on the Deepwater Horizon. Weatherford also provided specialist personnel to advise BP and the drill crew on the installation and operation of their equipment. At the time of the accident, two Weatherford personnel were onboard the Deepwater Horizon.
Tidewater Marine	Contracted to provide the offshore supply vessel the Damon B. Bankston. The Bankston carried supplies (such as drilling equipment, drilling chemicals, food, fuel oil, and water) to and from the Deepwater Horizon. At the time of the incident, the Bankston was alongside the Deepwater Horizon and provided emergency assistance. Other personnel onboard the Deepwater Horizon included 14 catering staff, two BP executives, and 14 BP subcontractors for a total of 126 personnel onboard.

5.3 Sequence of Events

Twice, prior to the blowout on 20th April, the Macondo well experienced a "kick". The well kicked at 2,798 m. The rig crew detected the kick and shut in the well. They were able to resolve the situation by raising the mud weight and circulating the kick out of the wellbore. The well kicked again, at 4,018 m. The crew once again detected the kick and shut in the well, but this time, the pipe was stuck in the wellbore. BP severed the pipe and sidetracked the well. In total, BP lost approximately 16,000 barrels of mud while drilling the well, which cost the company more than $13 million in rig time and materials. The kicks, ballooning and lost circulation events at Macondo occurred in part because Macondo was a "well with limited offset well information and the preplanning pressure data [were] different than the expected case" (Bartli et al. 2011).

The crew started on 20th April at around 20:00 replacing mud with seawater. Around 21:00 the drill string pressure started to increase, despite the pump rate being constant. Over the next 40 min there were several signs that they had problems, but nobody reacted to these signals in an appropriate manner. Between 21:40 and 21:43 mud started to spew out on the drill floor, and the driller realised apparently for the first time, that they had a kick.

The crew took immediate action, routing the flow coming from the riser into the mud-gas separator rather than overboard into the sea. Second, they closed one of the annular preventers on the BOP to shut in the well. Their efforts were futile. By the time the rig crew acted, gas was already above the BOP, rocketing up the riser, and expanding rapidly. The flow from the well quickly overwhelmed the mud-gas separator system. Ignition and explosion were all but inevitable. The first explosion occurred at approximately 21:49. On the drilling floor, the Macondo disaster claimed its first victims.

The sudden occurrence and impact of the explosion made it difficult for members on the bridge to assess the situation immediately following the incident. In addition, various alarms were sounding and lights were flashing, making it difficult for the crew to acknowledge what was going on.

Typically as part of the evacuation procedure, once crew members reach the designated muster stations, they register their names so that a proper head count can be conducted and missing members can be accounted for. Based on the testimonies provided, there were efforts to prepare such a headcount, however there were difficulties when trying to accurately account for all members.

While crew members on the bridge were trying to assess the situation, others were already mustering near the lifeboats. Some were urging for the lifeboats to be launched despite them being only partially full. The Deepwater Horizon did have a split command depending on the status of the rig; latched up, underway, or in an emergency situation. The decision to evacuate the rig rested on the captain when the rig was in an emergency situation, but from the testimonies it seems to be unclear who was in charge due to missing procedures of handover and interpretation if the rig was latched up, underway or in an emergency situation (DHJIT 2010).

Nevertheless, all persons who were not victims of the explosions and fires in the first few minutes were able to evacuate the installation, mainly by lifeboats, but also by liferafts, and a handful of persons jumping overboard.

The rig sank 36 h later. From then on the focus was on killing the blowout and fighting the pollution. The blowout was stopped by temporary measures, when a capping stack was installed and successfully stopped the flow on 15th July 2010, after 87 days. On 4th August BP reported that a final static condition in the well had been achieved by filling the well with mud. The total amount of oil spilled was evaluated to have been 650,000 tons.

5.4 Investigations

Several investigations have been conducted by various stake holders and official organisations. In 2012 court proceedings started, but this is outside the scope of the present discussion. The best known investigations are the following:

- BP investigation, September 2010 (BP 2010).
- National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, Report to the President, January 2011 (Commission 2011).
- Deepwater Horizon Study Group (DHSG; author member of this group) Final Report on the Investigation of the Macondo Well Blowout (DHSG 2011).

- Transocean investigation, June 2011 (Transocean 2011).
- US Chemical Safety and Hazard Investigation Board, report not yet published (end of 2012).

5.4.1 Technical Aspects

According to the Commission, the root technical cause of the blowout was that the cement BP and Halliburton had pumped to the bottom of the well did not seal off the hydrocarbons in the formation. The exact reason why the cement failed may never be known, but several factors increased the risk of cement failure at Macondo. These included (Bartli et al. 2011):

- Drilling complications forced engineers to plan a 'finesse' cement job that called for, among other things, a low overall volume of cement;
- The cement slurry itself was poorly designed, some of Halliburton's own internal tests showed that the design was unstable, and subsequent testing by the Chief Counsel's team raised further concerns;
- BP's temporary abandonment procedures, only finalised at the last minute, called for rig personnel to severely 'underbalance' the well before installing any additional barriers to back up the cement job.

According to the Commission (Graham et al. 2011), BP's management process did not adequately identify or address the Risk Influencing Factors (RIFs) created by late changes to the well design and procedures. BP did not have adequate controls in place to ensure that key decisions in the months leading up to the blowout were safe or sound from an engineering perspective. While initial well design decisions undergo a rigorous peer-review process, and changes to well design are subsequently subject to a management of change (MOC) process, changes to drilling procedures in the weeks and days before implementation are typically not subject to any processes. At Macondo, such decisions seem to have been made by the BP Macondo team in an ad hoc fashion without any formal risk analysis or internal expert review (Graham et al. 2011).

According to the Chief Counsel's Report (Bartli et al. 2011), several of BP's decisions, such as not using drill collars, not using a mechanical plug, setting the plug in seawater and, setting the lockdown sleeve last, may have been made in isolation. However, the decisions also created RIFs, individually and especially in combination with the rest of the temporary abandonment operation. For instance, BP originally planned to install the lockdown sleeve at the beginning of the temporary abandonment. BP's decision to change plans and set the lockdown sleeve last triggered a cascade of other decisions that led it to severely underbalancing the well while leaving the bottom hole cement as the lone physical barrier in place during the displacement of the riser. There is no evidence that BP conducted any formal risk analysis before making these changes, or even after the procedure as a whole (Bartli et al. 2011). BP's own investigative report agrees that they did not undertake a risk analysis to consider the consequences of its decision. BP's management system did not prevent such ad hoc decision-making. BP required relatively robust risk analysis and mitigation during the planning phase of the well but not during the execution phase (Bartli et al. 2011). Further, Transocean's crew seems never to have undertaken any risk analysis nor to have established mitigation plans regarding its performance of simultaneous operations after the cement barrier was judged to be safe (Bartli et al. 2011).

5.4.2 *Organisational Aspects*

The following is a summary of the conclusions on the organisational aspects of the DHSG Macondo report (DHSG 2011) ('Looking back—Organizational factors'):

"The organizational causes of this disaster are deeply rooted in the histories and cultures of the offshore oil and gas industry and the governance provided by the associated public regulatory agencies. While this particular disaster involves a particular group of organizations, the roots of the disaster transcend this group of organizations. This disaster involves an international industry and its governance.

This disaster was preventable if existing progressive guidelines and practices been followed—the Best Available and Safest Technology. BP's organizations and operating teams did not possess a functional Safety Culture. Their system was not propelled toward the goal of maximum safety in all of its manifestations but was rather geared toward a trip-and-fall compliance mentality rather than being focused on the Big-Picture. It has been observed that BP's system "forgot to be afraid." The system was not reflective of one having well-informed, reporting, or just cultures. The system showed little evidence of being a high-reliability organization possessing a rapid learning culture that had the willingness and competence to draw the right conclusions from the system's safety signals. The Macondo well disaster was an organizational accident whose roots were deeply embedded in gross imbalances between the system's provisions for production and those for protection.

The multiple failures (to contain, control, mitigate, plan, and clean-up) that unfolded and ultimately drove this disaster appear to be deeply rooted in a multi-decade history of organizational malfunctions and shortsightedness. There were multiple opportunities to properly assess the likelihoods and consequences of organizational decisions (i.e., Risk Assessment and Management) that were ostenibly driven by BP management's desire to "close the competitive gap" and improve bottom-line performance. Consequently, although there were multiple chances to do the right things in the right ways at the right times, management's perspective failed to recognize and accept its own fallibilities despite a record of recent accidents in the US and a series of promises to change BP's safety culture.

Analysis of the available evidence indicates that when given the opportunity to save time and money—and make money—poor decision making played a key role in accident causation. The tradeoffs that were made were perceived as safe in a normalized framework of business-as-usual. Conscious recognition of possible failure consequences seemingly never surfaced as the needle on the real-time risk-meter continued to climb. There was not any effective industry or regulatory checks and balances in place to counteract the increasingly deteriorating and dangerous situation on Deepwater Horizon. Thus, as a result of a cascade of deeply flawed failure and signal analysis, decision-making, communication, and organizational-managerial processes, safety was compromised to the point that the blowout occurred with catastrophic effects.

In many ways, this disaster closely replicates other major disasters that have been experienced by the offshore oil and gas industry. Eight months before the Macondo well blowout, the blowout of the Montara well offshore Australia in the Timor Sea developed in almost the same way—with very similar downstream effects. The Occidental Petroleum North Sea Piper Alpha platform explosions and fires (1988) and the Petrobras P-36 production platform sinking offshore Brazil (2005) followed roadmaps to disaster that are very similar to that developed during and after the Macondo well blowout. These were major system failures involving a sequence of unanticipated compounding malfunctions and breakdowns—a hallmark of system disasters.

This disaster also has eerie similarities to the BP Texas City refinery disaster. These similarities include: (a) multiple system operator malfunctions during a critical period in operations, (b) not following required or accepted operations guidelines ("casual compliance"), (c) neglected maintenance, (d) instrumentation that either did not work properly or whose data interpretation gave false positives, (e) inappropriate assessment and management of operations risks, (f) multiple operations conducted at critical times with unanticipated interactions, (g) inadequate communications between members of the operations groups, (h) unawareness of risks, (i) diversion of attention at critical times, (j) a culture with incentives that provided increases in productivity without commensurate increases in protection, (k) inappropriate cost and corner cutting, (l) lack of appropriate selection and training of personnel, and (m) improper management of change.

In both cases—the BP Texas City and the BP Macondo well disasters—meetings were held with operations personnel at the same time and place the initial failures were developing. These meetings were intended to congratulate the operating crews and organizations for their excellent records for worker safety. Both of these disasters have served—as many others have served—to clearly show there are important differences between worker safety and system safety. One does not assure the other.

In all of these disasters, risks were not properly assessed in hazardous natural and industrial-governance-management environments. The industrial-governance-management environments unwittingly acted to facilitate progressive degradation and destruction of the barriers provided to prevent the failures. An industrial environment of inappropriate cost and corner cutting was evident in all of these cases as was a lack of appropriate and effective governance—by either the industry or the public governmental agencies. As a result, the system's barriers were degraded and destroyed to the point where the natural environmental elements (e.g., high-pressure, flammable fluids and gases) overcame and destroyed the system. Compounding failures that followed the triggering failures allowed the triggering failures to develop into a major disaster—catastrophe."

5.5 Findings

The following is a summary of the findings of the DHSG Macondo report (DHSG 2011) ('Looking forward' and 'Findings'):

"Short-term measures have been initiated and are being developed by the Department of Interior's Bureau of Offshore Energy Management, Regulation and Enforcement (BOEMRE). The previous Minerals Management Service (MMS) has been reorganized into three organizations, each of which is responsible for different aspects of offshore oil and gas developments (leasing, revenues, and regulation). These measures have addressed both technical and organizational aspects. In some cases, the BOEMRE has proposed long-term technical and organizational measures associated with drilling and production operations in ultra-deepwater (5,000 ft or more) depths.

In addition, the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling has addressed both short-term and long-term government regulatory technical and organizational reforms associated with drilling and production operations in high hazard environments—including those of ultra-deep water and in the arctic. US industrial companies and trade organizations (e.g., American Petroleum Institute, International Association of Drilling Contractors) also have responded with suggestions for a wide variety of technical and organizational reforms that will be considered for implementation in its future operations. Many international governmental regulatory agencies have and are responding in a similar fashion. There is no shortage of suggested technical and organizational reforms.

Finding 1—The oil and gas industry has embarked on an important next generation series of high hazard exploration and production operations in the ultra-deep waters of the northern Gulf of Mexico. These operations pose risks (likelihoods [sic] and consequences of major system failures) much greater than generally recognized. The significant increases in risks are due to: (1) complexities of hardware and human systems and emergent technologies used in these operations, (2) increased hazards posed by the ultra-deep water marine environment (geologic, oceanographic), (3) increased hazards posed by the hydrocarbon reservoirs (very high potential productivities, pressures, temperatures, gas-oil ratios, and low strength formations), and (4) the sensitivity of the marine environment to introduction of very large quantities of hydrocarbons.

Finding 2—The Macondo well project failures demonstrated that the consequences of major offshore oil and gas system failures can be several orders of magnitude greater than associated with previous generations of these activities. If the risks of major system failures are to be ALARP, the likelihoods of major failures (e.g., uncontrolled blowouts, production operations explosions and fires) must be orders of magnitude lower than in the BP Macondo well project and that may prevail in other similar projects planned or underway. In addition, major developments are needed to address the consequences of major failures; reliable systems are needed to enable effective and reliable containment and recovery of large releases of hydrocarbons in the marine environment.

Finding 3—The Macondo well project failures provide important opportunities to re-examine the strategies and timing for development of important non-renewable product and energy resource. This final frontier in the ultra-deep waters of the northern Gulf of Mexico and other similar areas provides access to an important public resource that has significant implications for the future generations and energy security of the United States. These social, economic, and national security Deepwater Horizon Study Group Investigation of the Macondo Well Blowout Disaster interests, as well as safety and environmental considerations, dictate a measured pace of development consistent with sustainable supplies and development and application of the Best Available and Safest Technology (BAST).

Finding 4—Major step change improvements that consistently utilize the BAST are required by industry and government to enable high hazard offshore exploration and production operations to develop acceptable risks and benefits. Future development of these important public resources require an advanced high-competency, collaborative, industrial-governmental-institutional enterprise based on use of high reliability technical, organization, management, governance, and institutional systems."

5.6 Lessons Learned

5.6.1 Lessons Learned for Risk Management in Association with Well Drilling

Section 5.4.2 discussed the organisational factors that failed in the case of Macondo. These aspects provide important lessons for the improvement of the safety of well drilling, especially the drilling of ultra deep wells.

Other studies have shown that two high level aspects are crucial for the safety of well drilling, namely the well planning ahead of commencement of operations, and the management of change (or continuous risk assessment) during the execution of well drilling operations. These findings tie in well with the findings cited above.

5.6.2 Lessons Learned for Emergency Management

This section addresses the lessons that may be concluded from Macondo with respect to escape, evacuation and rescue (EER) as well as technical and organisational aspects. The text is mainly based on (Skogdalen et al. 2012).

Explosions, fire and smoke were life-threatening hazards during the EER from the Deepwater Horizon. On offshore installations, the crew is familiar with the facility and escape routes. They also participate in regular muster and lifeboat drills. To determine which measures would reduce the time to make decisions, and which steps would lead to people choosing the right egress routes, information is needed regarding human and organisational factors. Of special interest are the perceptions, intentions and motives of the personnel when faced with such situations.

However, is noteworthy that it seems that all of those who were not seriously injured during the initial explosion, and even a few of those who were seriously injured during the first stages, were able to escape to lifeboats and were rescued.

One of the important roles of the master of the vessel is to take charge during a crisis, and to give the order to abandon ship if necessary. The master should assess the severity of the situation properly, and if the decision to abandon is made, the master would then give the order to launch the lifeboats and evacuate the installation. Lowering the lifeboats at the right time is critically important for an effective evacuation, because there are a limited number of lifeboats on an installation. If proper communication is not achieved lifeboats can be launched only partially filled up, resulting in personnel being left behind. By contrast, if members wait too long to launch the lifeboats, they risk being harmed by explosions, fire, smoke, and falling objects.

The Deepwater Horizon had a split chain of command between the OIM and the captain, which seemed to have caused confusion as the lines of authority and the shift of responsibility in the event of an emergency apparently were unclear to some crew members. A critical question to be considered is how can it be relied upon that the captain of the vessel (or installation) will be in a sufficiently healthy condition to perform critical tasks, such as properly assessing the situation, activating the alarm, and giving the order to muster and abandon ship? Or even to discover that the captain is unable to perform his/her function. This was the problem the crew faced following the explosion on board the Piper Alpha, with fatal consequences. During a crisis, it is possible that situations will occur where bypassing the chain of command is unavoidable and necessary; however, the situation must be properly assessed by individuals such that the result is not detrimental to the safety and success of the operations. This can be accomplished through proper training on the worst case scenarios.

It is expected that in some cases, not all members will be able to evacuate using the primary means of evacuation and therefore rescue means are necessary to ensure the safe evacuation of the personnel left behind or not able to make it to safe refuge. As seen in the case of the Deepwater Horizon, there was a need for secondary means of evacuation. In addition to liferafts, these can be escape chutes and ladders. Personal survival suits with splash protection extend the available rescue time due to increased protection from waves and hydrocarbons in the sea. They also extend time before hypothermia.

Several hazards faced those on the Deepwater Horizon who prepared to jump to the sea. Among those hazards were the height from the platform deck to the surface of the water from which they have to jump, the possible fires on the sea level and smoke inhalation. Ideally, the crew would have to get as close as possible to the water surface before jumping or entering the sea. Under some circumstances jumping into the sea is necessary, and offshore personnel should be trained to do this as safely as possible.

The supply ship Damon Bankston played a vital role in rescuing survivors from the Deepwater Horizon. Given the remote location of deepwater operations, nearby vessels play a critical role in rescuing personnel from offshore installations following major accidents. A fast response is especially important with a high number of personnel in the sea and/or in the case of bad weather. Custom designed third generation rapid response rescue vessels are available. They are specially designed to launch and recover a fast rescue craft or daughter craft from a slipway in the stern. The slipway can also be used to recover a lifeboat from the sea. The sea trials of these vessels are promising and it is generally considered to be possible to operate in sea conditions with significant wave heights of up to $Hs = < 9$ m (Jacobsen 2010).

The distance from shore to the Deepwater Horizon (66 km) meant that it took several hours for rescue boats from shore to arrive. The US Coast Guard scrambled HH-65C Dolphin helicopters when they received the mayday call from the Deepwater Horizon. These helicopters have a limit of rescuing three to four persons. Helicopters did not contribute to the rescue of personnel in the Macondo accident.

The Norwegian system for area based emergency preparedness arrangements (Norwegian Oil and Gas Association 2012) may be a relevant model to consider also for the Gulf of Mexico, in order to quickly and efficiently rescue personnel in emergencies. This system includes use of offshore based Search and Rescue (SAR) helicopters as well as fast rescue crafts, in order to provide rescue capabilities for the relevant number of personnel within 120 min from an emergency.

Training, knowledge, experience, and competence are important throughout all steps of EER operations, and for some steps, it is purely human actions that can ensure the success of the operation. Emergency drills and training have limitations on preparing the crew to deal with real-life emergencies and unanticipated events. However, proper training and knowledge can provide the basic ability to cope with evacuation scenarios (Skogdalen and Vinnem 2012).

5.7 Similarity Between Offshore and Nuclear Accidents

One lesson learned from the Macondo blowout which is somewhat special, is the similarity between this accident and nuclear accidents. If we think about nuclear accidents such as Three Mile Island, Chernobyl, Fukushima they have worldwide effects, it does not matter which country it occurred, there will be worldwide repercussions.

For offshore petroleum it has often been claimed that unless it takes place very close to shore, there is normally no 3rd party personnel risk to consider. Before the Macondo blowout, this could have been said without the "personnel" word in. However, Macondo has demonstrated that the accident has worldwide repercussions, and is "everybody's accident". This is a similarity between nuclear and offshore petroleum, when it comes to accidental pollution. Then one country's accident is everybody's accident.

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