PETROLEUMSTILSYNET

Investigation report

Report	
Report title Investigation of the unintentional disconnection of the LMRP on *West Mira*	Activity number 404010004

Security grading		
☒ Public	☐ Restricted	☐ Strictly confidential
☐ Not publicly available	☐ Confidential	

Involved	
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Abbreviations

ADS	Automatic disconnect system
ADSL	Assistant drilling section leader
AoC	Acknowledgement of compliance,
ATSL	Assistant technical section leader

Autoshear	Final section of the EDS sequence designed to automatically shut in the well if the LMRP unintentionally disconnects
AW	Anchor winch
BHA	Bottom hole assembly
BOP	Blowout preventer
BSR	Blind shear ram
CET	Central European time
CSR	Casing shear ram
DG	Diesel generator
DNV GL	Classification society
DP	Dynamic positioning
DPM	Dynamic positioning mooring
DPO	Dynamic positioning operator
DSL	Drilling section leader
EDS	Emergency disconnect sequence
Flexjoint	Flexible joint in the riser system
Glonas	Global navigation satellite system
GPS	Global positioning system
Hipap	High precision acoustic positioning
Hs	Significant wave height
HSE	Health, safety and the environment
HTO	Human, technology and organisation
IMO	International Maritime Organisation
LFJ	Lower flexjoint
LMRP	Lower marine riser package
MOC	Management of change
MRU	Motion reference unit
MSL	Marine section leader
MSL	Mean sea level
NCS	Norwegian continental shelf
NMA	Norwegian Maritime Authority
OIM	Offshore installation manager
PL	Production licence
Posmoor ATA	Position mooring system
PSA	Petroleum Safety Authority Norway
ROV	Remotely operated vehicle
Secondary barrier	BOP
Riser margin	Safety margin in drilling fluid weight
AoC	Acknowledgement of compliance
TSL	Technical section leader
Tz	Zero up-crossing wave period
UFJ	Upper flexjoint
UTC	Coordinated universal time
VCG	Vertical centre of gravity
WCSF	Worst-case single failure. See DNVGL-ST-0111, July 2016
WOW	Waiting on weather
WSOG	Well-specific operating guidelines

1 Summary

At 12.00 on 14 March 2020, the lower marine riser package (LMRP) on Seadrill's *West Mira* facility was unintentionally disconnected as the crew prepared to pull out the 12 ¼-inch drill string. Wintershall Dea is operator for well 6407/3-H-3 AH on the Maria field, which lies on the Halten Bank in the Norwegian Sea. Water depth at the location is 303m.

This incident occurred while circulating to clean well after drilling had been halted by deteriorating wave and wind conditions. Unintentional disconnection occurred when the facility lost position because of the weather. That triggered the automatic disconnect system (ADS), which in turn activated automatic disconnection of the LMRP. Most of the oil-based drilling fluid from the riser drained to the sea.

It was quickly verified that the blind shear ram (BSR) had cut the drill string. Subsequent observations showed that the well had been isolated by the BOP's BSR. The weight of the drilling fluid included the riser margin for the section, and the barriers were thereby intact. No drilling had occurred in hydrocarbon-bearing zones of the well. No threat existed of discharges from the reservoir to the environment.

The Petroleum Safety Authority Norway (PSA) decided on 17 March 2020 to investigate the incident. The mandate for the investigation team included clarifying the course of events and assessing the direct and underlying causes, with the emphasis on human, technical, organisational (HTO) and operational conditions from a barrier perspective. This mandate covered conditions up to the time of the incident.

As a result of the incident, some 50m^3 of oil-based drilling fluid was discharged from the riser to the sea.

The direct cause of the incident comprised a combination of several factors which led to activation of the ADS and disconnection of the LMRP. The incident arose after dynamic weather forces resulted in loss of position. Weather conditions deteriorated in the hours before the incident. Compensatory measures defined in the procedures were initiated and implemented at too late a stage to avert the incident.

The investigation has identified four nonconformities. These relate to

- nonconformity: procedures and compliance with procedures
- nonconformity: deficiencies in meeting the operator's see-to-it responsibility
- nonconformity: risk understanding and prioritisation of risk-reduction solutions
- nonconformity: learning lessons from incidents and preventing recurrences.

2 Background information

On the day of the incident, *West Mira* was drilling for Wintershall Dea in well 6407/3-H-3 AH (H-3 AH) on the Maria field, which lies on the Halten Bank in the Norwegian Sea.

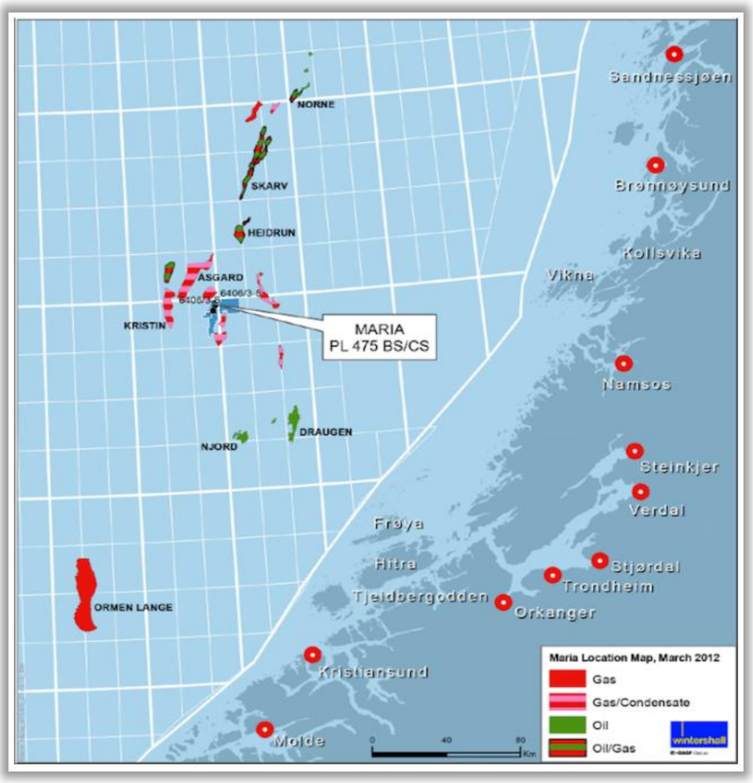


Figure 1: Location and overview map from the consent application for Maria.

Licence organisation for Maria, PLs 475BS and 475CS.

Company	Interest
Wintershall Norge AS (operator)	50%
Petoro AS	30%
Spirit Energy (Norge) AS	20%

This operation was intended to improve production through modifying the water injection pattern by drilling a sidetrack from the 13 3/8-inch casing in the H-3H well on the H template. The well would be a water injector.

The well has the following casing profile: 36- x 30-inch conductor, 20-inch surface casing, 14- x 13 3/8-inch intermediate casing, 10 3/4- x 9 5/8-inch production casing and 4 ½-inch injection casing. Plans called for oil-based drilling fluid to be used in the 12 ¼- and 8 ½-inch section. The water depth at the location is 303m mean sea level (MSL) and, when the consent application was submitted, plans called for using both dynamic positioning (DP) and thruster-assisted mooring. The latter was chosen as the final solution for the Maria location.

2.1 Description of facility and organisation

West Mira is a sixth-generation semi-submersible DP 3 drilling facility based on the Moss Maritime CS60 design. It is configured to operate under tough weather conditions and in water depths down to 3000m. It is also equipped with a conventional mooring system for working in water depths between 80 and 600m.

Built at Korea’s Hyundai yard in 2012-15, *West Mira* was laid up there until Seadrill took it over in 2017. From April-August 2019, it was at the CCB base for testing and commissioning of its own equipment and installation of third-party hardware. The PSA issued an acknowledgement of compliance (AoC) for the facility in October 2019.

The facility is owned by West Mira Inc and operated by Seadrill Europe Management AS (the ISM/DOC holder is Seadrill Management Ltd). Day-to-day operation is managed from Stavanger. Parts of the company’s support structure for technical and subsea disciplines are located in Dubai and Houston.

West Mira flies the Norwegian flag and has DNV GL class certificates. Wintershall Dea received consent to use it for production drilling and completion of the Maria wells in November 2019. The well was the first on the field and the second drilled by *West Mira*.

Figure 2: The West Mira *semi-submersible drilling facility, from the consent application.*

2.2 Seadrill operations organisation on *West Mira*

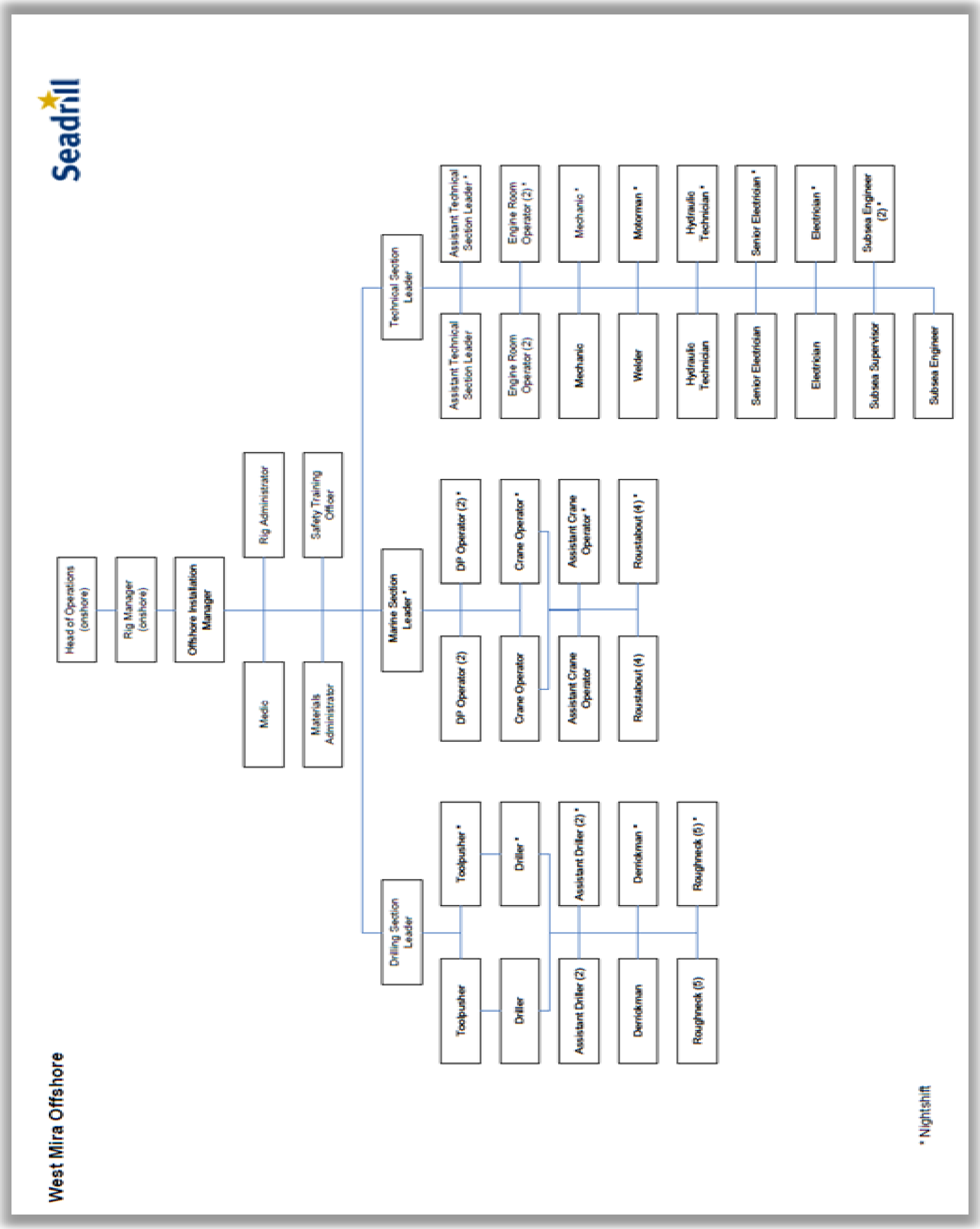
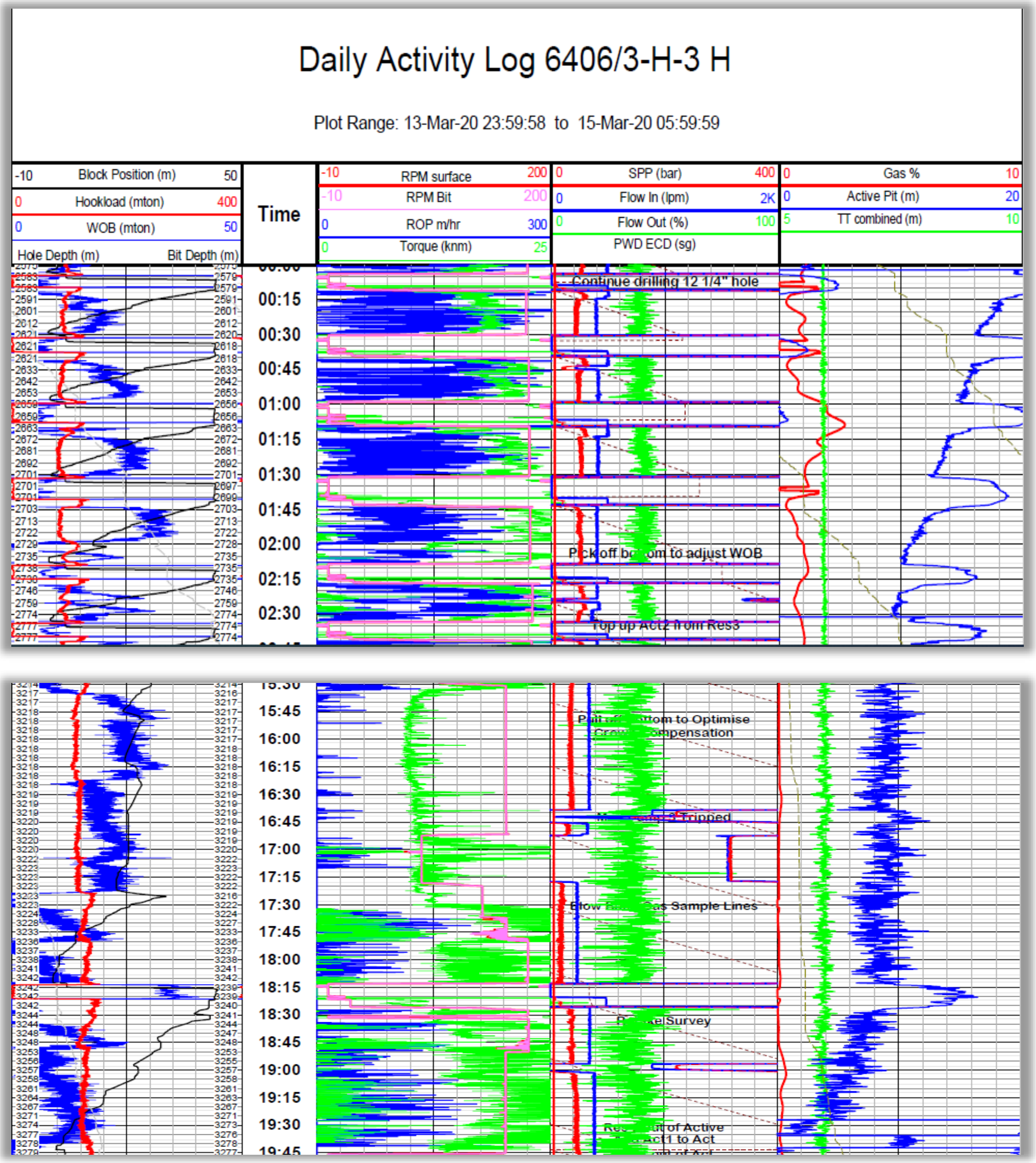


Figure 3: The Seadrill operations organisation on West Mira.

2.3 Position before the incident

The main activity on 14 March was drilling the 12 ¼-inch well section. From midnight until minutes before the incident, the facility had drilled about 700m.



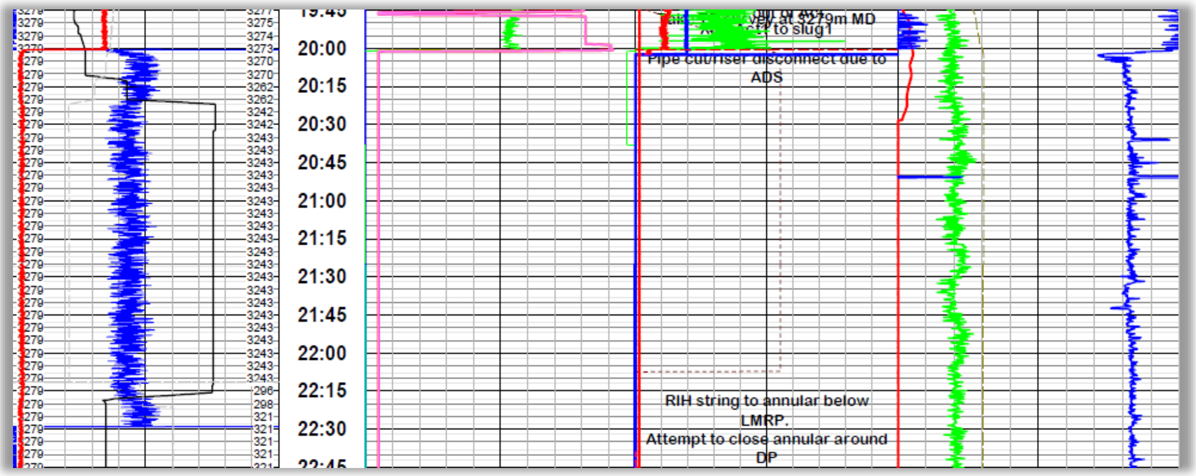


Figure 4: Extracts from the activity log on 14 March 2020 and up to the time of the incident.

While conditions were relatively calm in the early morning, *West Mira*'s weather log shows rising wind speed and wave heights as the day progressed.

Weather Log West Mira

		Air temp	Baro (QNH)	Wind speed (kn) DP	Wind Dir. DP	Gusts (kn)	Wave Hs (m)	Wave max (m)	Wave Period	Swell HS	Swell max	Wave dir.	Current speed DP	Current dir. DP	Heave (double amp)	Pitch (singel)	Roll (Singel)
12.03.2020	4:00	5	974	15	229	25	3.3	4.7	7.1			254			2.2	2	1.5
	8:00	3	974	21	043	27	1,9	2,7	7.2			264			1,8	2,6	1,3
	12:00	2	980	39	019	46	6,1	8,9	9,0			356			3,1	5,3	3,0
	16:00	2	986	27	011	33	[illegible] 5,1	7,4	7,6			001			2,9	[illegible] 2,1	2,2
	20:00	0	991	29	350	34	3.8	5,5	7,0			004			1,8	4,2	2,3
	23:59	1	995	30	325	35	4,0	5,8	7.1			359			1,3	3	2,4
13.03.2020	4:00	0	994	32	337	37	4.5	6.5	8			350			1,4	3,2	2.1
	8:00	-3	1005	26	355	31	5,2	7,8	8			359			3,4	[illegible] 3,3	2.4
	12:00	-1	1008	15	357	18	5,3	7,6	8			008			2,6	2,3	1,8
	16:00	-3	1011	16	319	22	4,3	6,2 [illegible]	7,7			012			2	2,3	1,6
	20:00	-1,5	1012	13	324	18	3,7	5,4	7,2			010			0,9	1,7	1,7
	23:59	-1	1013	8	304	13	3,6	5,1	7,1			006			0,6	2,5	1,1
14.03.2020	4:00	0	1012	13	180	17	3.6	5.2	7.3			357			1,4	2.0	1.0
	8:00	2	1008	29	179	35	3,1	4,5	6,1			357			1,0	1,5	1,2
	12:00	5	1004	41	185	47	3,9	5,6	6,9			221			1,5	3,1	2,7
	16:00	5	1001	50	187	56	6,9	9,9	8,6			227			3,2	5	3,6
	20:00																
	23:59																
	4:00																

Figure 5: Weather log on West Mira *during the days before the incident.*

At 11.14 on 14 March 2020, the first "advisory status" e-mail was sent to all the sections involved on *West Mira*. This covered a wind speed of over 20m per second.

A second advisory status warning was sent at 13.15 the by the dynamic positioning operator (DPO). This time it was the significant wave height (Hs) and pitch which exceeded the limits in the well-specific operating guidelines (WSOG), but they were still within the "white condition" (see the description in section 2.5.3.1).

At about 18.10, while drilling the 12 ¼-inch well section, it was decided to adjust ballast in order to reach survival draught in response to the weather. *West Mira* was at this draught from 19.00.

Immediately before the incident, at about 19.40, the crew decided to cease drilling the 12 ¼-inch section and pull the drill string out of the open hole. The purpose of this operation was to pull the string into the last casing section set in order to prepare for hanging off the string in the BOP because of the weather. While being pulled out, the string was rotating and drilling mud was being circulated through it.

2.4 Equipment and systems involved

The section provides a brief and general description of the systems and equipment which were significant for the incident.

2.4.1 ADS and emergency shutdown system/sequence (EDS)

The ADS is included in this facility's standard equipment package. It was developed by Smedvig and Future in 2002 at the request of Norsk Hydro on the Troll field. Seadrill has patented the ADS, which serves as an extra and independent system installed on the lower flexjoint (LFJ) above the BOP. It is intended to signal activation of LMRP disconnection if the angle of flexjoint exceeds a preset value. On *West Mira*, that was five degrees. This is described in the WSOG as corresponding to 28.4m from the well centre. The activation signal is sent to the EDS.

Figure 6: The ADS installed on the flexjoint.

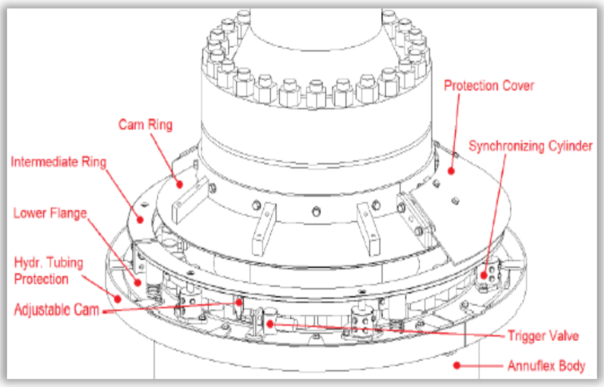


Figure 7: Diagram of the ADS with all its components.

The EDS makes it possible to disconnect the LMRP while simultaneously securing the borehole. This is done by closing the BSR in cases where a dynamically positioned facility is driven off location. A preset sequence ensures that the LMRP is disconnected from the BOP after the EDS has been activated.

When LMRP disconnection occurs, the BSR closes automatically.

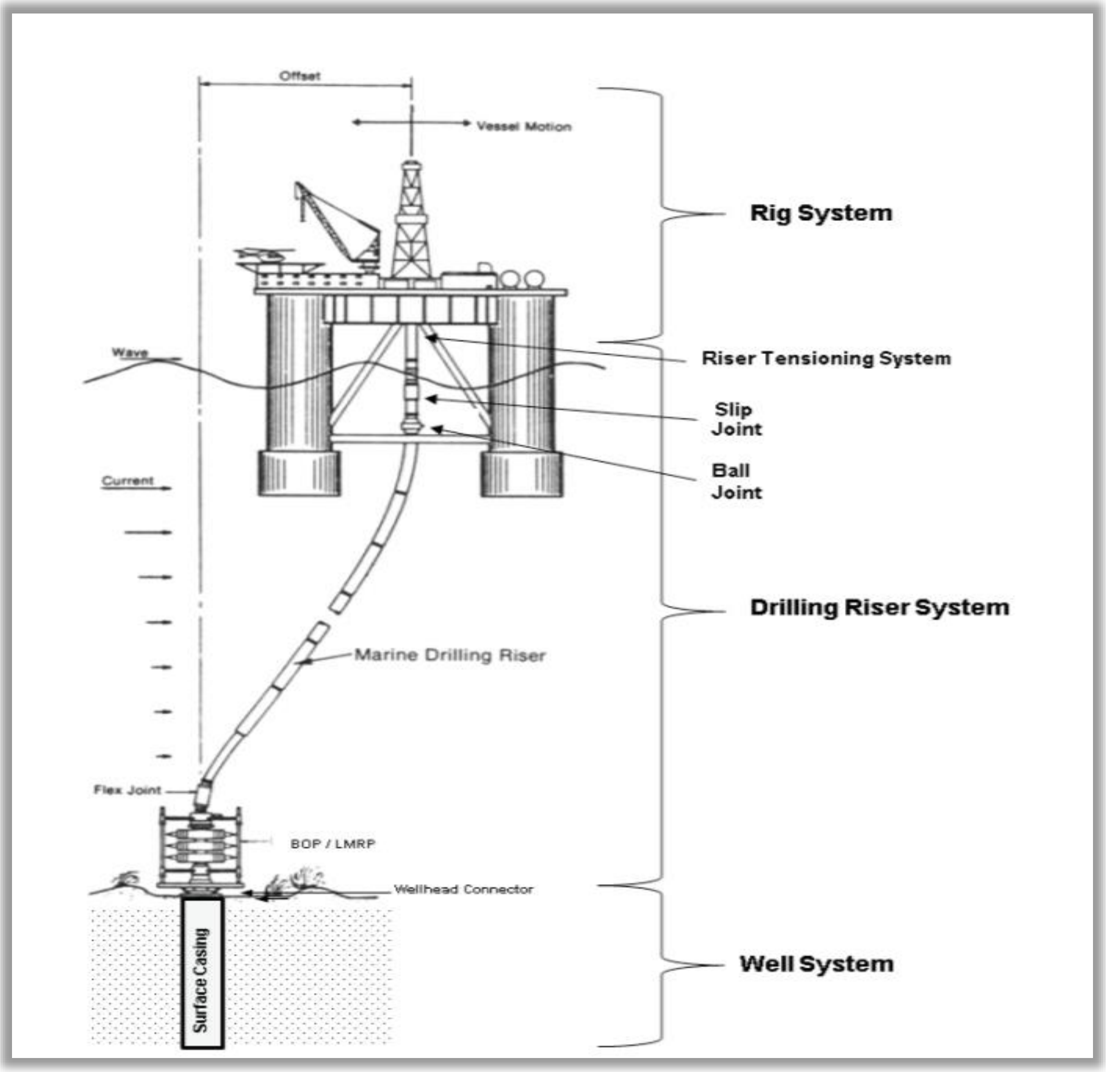


Figure 8: A typical riser system and subsea BOP, LMRP, wellhead and well.

According to the riser analysis, the disconnection sequence takes 14 seconds if triggered by the ADS. When disconnection occurs because the EDS on the facility is activated, the sequence takes about 35 seconds to complete.

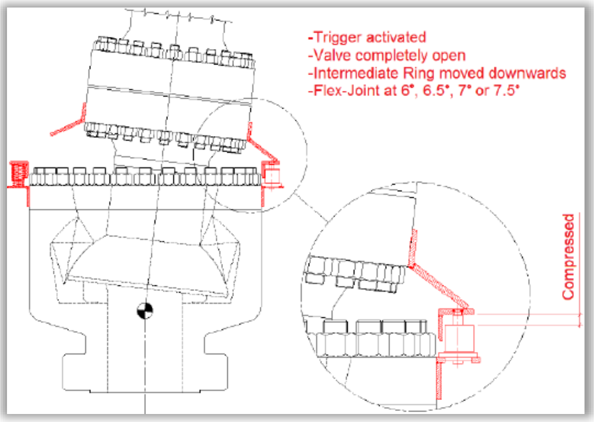


Figure 9: ADS activation of the release mechanism.

2.4.2 Dynamic positioning (DP)

This solution allows a floating facility or vessel to use its propulsion machinery (engine, propellers, thrusters and so forth) to maintain position. In practice, the system for DP operation involves the whole vessel – hull, propulsion machinery, control equipment, water- and fire-tight sectioning and so on. Requirements for redundancy involve doubling and sectioning the individual components so that certain elements can drop out without affecting system function. Propulsion machinery on *West Mira* is divided between four engine rooms with two diesel generators in each. The facility has eight thrusters – in other words, propellers which can be rotated to counter external forces from weather, wind, waves and currents. The DP system uses reference systems which are either global (such as GPS or Glonas) or local (such as Hipap or TW). Drawing on measurements of wind, motion, draught and so forth, the DP control system utilises a computer model to calculate optimal use of thruster power and direction to maintain position. The system can be switched between various modes, depending on the accuracy/speed of the response required.

- "Hi gain", with a fast and strong response in reacting to changes and maintaining position.
- "Medium gain" and "low gain" settings with more moderate responses.

The system can also be set to prioritise steady motions using various damping functions.

DP systems are primarily used in deep waters where mooring is not possible, but also for short-term operations in shallower waters.

Positioning is essential for the facility to pursue drilling activities. The system has a built-in function for evaluating redundancy and capacity, with a consequence analysis conducted continuously to evaluate whether a worst-case single failure (WCSF) would mean excessive deviation from position. This analysis generates both warnings and alarms, depending on the size of the drift-off estimated for the WCSF. The system works with a set point which defines the optimal position. Deviation from this point involves several levels visualised as circles.

- The innermost "watch" circle to be monitored is indicated in green and shows where normal operation can be conducted without restrictions.
    - Outside the green circle is the "advisory" circle. This is a condition which requires extra attention to and caution with deviations which are either actual or predicted by the consequence analysis.
- "Warning" is delineated by a yellow circle.
- "Alarm" is delineated by a red circle.

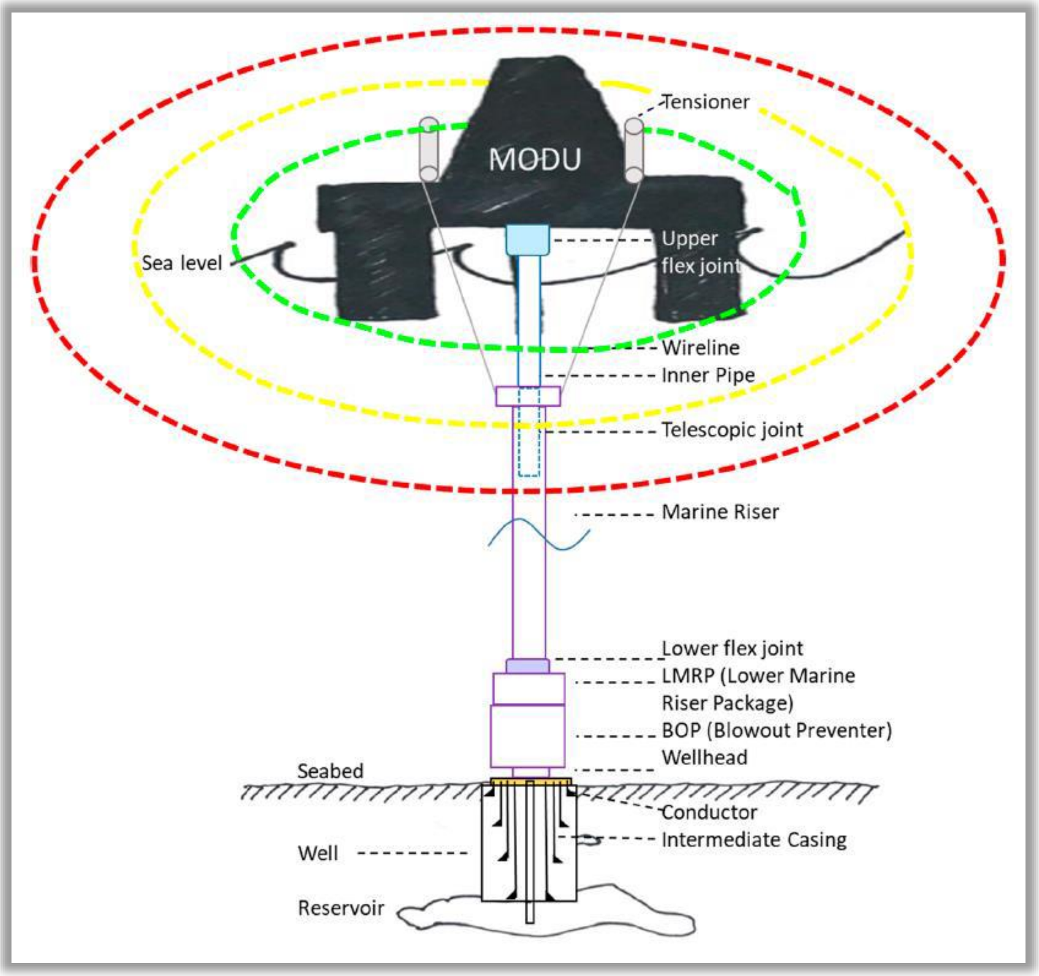


Figure 10 The green circle in the diagram shows the safe working area, while yellow shows where the EDS initiates disconnection.

Power supply to the thrusters from the four engine rooms can be used in two ways.

- Four-split sharing where each corner is independent of the others. The WCSF is then the loss of one-quarter of the power.
- Two-split sharing, where the power supplies are connected together diagonally. The WCSF is then the loss of half the power.

The DP system on *West Mira* has been delivered by Kongsberg and is designated the K-Pos DPM control system. It logs measured values, consequences and so forth, and Kongsberg has produced a report in the wake the incident which considers the available data from this event.

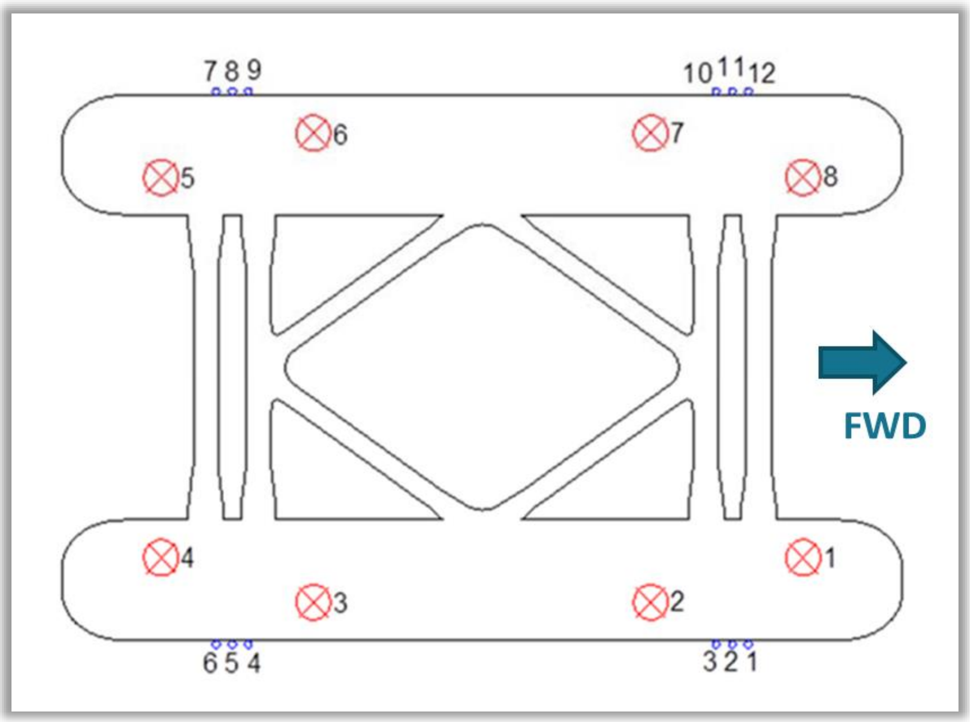


Figure 11: Positioning and numbering of thrusters (red) and mooring lines/fairleads (blue). Forward is to the right and starboard at the bottom of the diagram, which is taken from the mooring analysis [see 4275-MM-JR-435-002, rev 03].

2.4.3 Combined mooring (Posmoor ATA)

The facility can be positioned with anchors, with DP or with a combination of anchors and DP known as "position mooring, automatic thruster assisted" (Posmoor ATA). *West Mira* is able to deploy up to 12 mooring lines, as illustrated in figure 11. Posmoor ATA was utilised at the Maria H location with eight mooring lines, deployed in an asymmetric pattern because of the need to avoid pipelines.

Passive mooring alone is used to maintain position, with the DP system compensating for variations in and changes to weather. In addition, the system can be set to reduce (moderate) motion. For the Posmoor ATA to function optimally in different weather conditions, the length of the mooring lines must be adjusted regularly. Such adjustments aim to place the facility so that the passive lines maintain a median position close to the DP system's set point. That minimises the amount of power required by the DP system to compensate for dynamic forces.

The combination of mooring and DP can either

- increase the safety of a DP operation
- expand the watch circle (operating space) without reducing safety.

Posmoor ATA is the most complicated positioning solution of the three. In addition to the DP system's normal components, mooring-line tension and length/geometry must be included in the DP analysis. Loss of a mooring line is a possible WCSF included in the consequence analysis. The latter calculates deviation from the set point every fifth minute, and gives a warning or an alarm if system redundancy is threatened by the loss of a mooring line, a switchboard failure or the like.

Two DPOs per shift are required for both DP and Posmoor ATA operation.

2.4.4 Loading conditions (draughts) for floating facilities

Floating semi-submersible drilling facilities have several draughts for various purposes.

- Normal operating condition (operating draught), where normal operation (drilling) can be pursued within specified operational limits for the drilling equipment and the facility. In this condition, the facility lies low in the water in order to be as stable as possible.
- Safety condition (survival draught), where the facility is deballasted to lie higher in the water and increase the air gap from wave crests to superstructure. Since this draught is shallower and is used in bad weather, the facility's motions are greater than in operating condition. Normal operations must thereby cease – as the name indicates, the facility must survive the weather (storm).
- Normal transit condition (transit draught) is used for long moves. Such transits require shallow draught in order to minimise hull resistance. Since the facility lies very high in the water, strict weather limits apply for redeployment. Figure 2 shows *West Mira* in transit draught.

West Mira is designed with operating and survival draughts of 23.5m and 21.5m respectively.

The facility can also conduct normal operations at a draught of 21.5m with specified limits on its vertical centre of gravity (VCG), as described in the DNV GL approval of stability analyses. Operations at both normal operating (23.5m) and reduced (21.5m) draught can only be conducted until design criteria for wind speed and sea state reach the limit values. Design wind speeds and sea-state limits are specified in the appendix to the class certificate (see the sea-state limits reproduced in figure 18). When the weather deteriorates beyond the design limits for normal operation, Norwegian Maritime Authority (NMA) regulations call for the riser to be disconnected and all activity not necessary for riding out the storm to cease.

When the facility is changing draught, it is in a temporary condition. Section 13.2 of the NMA's stability regulations specify that only operations required for ballasting/ deballasting the facility can be conducted during a temporary condition. This means that drilling operations cannot be pursued when the facility is changing draught.

2.4.5 Power supply on *West Mira*

In addition to the above-mentioned four- or two-split distribution of power to the thrusters, the engine rooms supply electricity to the whole facility – including the drilling operation in particular. "Optimisation" means the length of the mooring lines is adjusted to ensure that the facility lies as well as possible with a minimum of thruster power. This calls for a power supply to the mooring winches. Power capacity and supply on *West Mira* are designed so that drilling and winch operation cannot take place simultaneously – power must be shared between two systems:

- mooring winches, used to adjust the mooring lines
- drilling equipment, including fluid pumps and the drilling machinery.

That means drilling must be suspended when adjusting/optimising the mooring lines. The distribution is controlled by a switchboard, which must be reset when swapping between the two operations.

2.5 Requirements, assumptions and procedures for operation

When a mobile facility pursues petroleum operations on the Norwegian continental shelf (NCS), it is subject to Norway's petroleum regulations in addition to the requirements set by its flag state and classification society. The PSA is the highest authority for oil and gas activities. The HSE regulations make reference to the NMA's regulations concerning maritime conditions. Since *West Mira* is registered in the Norwegian International Ship Register (NIS), the NMA has an independent responsibility to follow up the maritime requirements. The facility must also comply with its relevant class certificates. Recommendations and guidelines from the classification society may also be relevant for technical conditions.

2.5.1 Facility-specific requirements

2.5.1.1 Norway's HSE regulations for petroleum operations

Section 3 of the framework HSE regulations opens for the use of maritime regulations for a number of technical requirements on mobile facilities. Seadrill has opted to apply this section to *West Mira*. In that context, it is relevant to refer to the letter of 20 September 2016 from the PSA to all vessel owners engaged in Norway's petroleum industry. This deals with analysis methods for wave slamming on the topside box developed after the *COSLInnovator* incident of 2015. These methods and requirements for temporary and permanent reinforcement have been developed by DNV GL and described in its offshore technology guidelines (DNVGL-OTG-13 and DNVGL-OTG-14). Similar letters were sent by the NMA (29 September 2016) and DNV GL (22 September 2016 with extension of 1 November 2017). Subsequent letters have also provided guidance on the level of safety in operating condition. See the identical letter from the PSA of 17 October 2019.

Key Norwegian maritime regulations are:

- Construction of mobile offshore units (no 0856)
- Stability regulations (no 0878)
- Ballast regulations (no 67)
- Anchoring regulations (no 0998)
- Regulations for mobile offshore units (no 0123).

Section 17 of the stability regulations on loading conditions (see draughts as described in section 2.4.4 above) is reproduced in figure 12. Note sub-section 2 on survival condition, which assumes that the riser is disconnected.

§ 17. *Lastetilstander*

Følgende tilstander skal beregnes og inngå i operasjonsmanualen:

1. Vanlig operasjonstilstand ved største dypgående, der maksimal dekkslast og utstyr er plassert i den ugunstigste posisjon som kan komme til anvendelse.
2. Sikkerhetstilstand ved maksimum sikkerhetsdypgående idet en benytter den samme vektfordeling som i nr. 1 unntatt for nødvendige endringer av ballast og eventuell dumping av flytende boreslam. For boreinnretninger forutsettes at stigerøret er frakoplet, og at et representativt antall borerør står i boretårnet.
3. Vanlig forflytningstilstand med maksimal dekkslast. For oppjekkbare innretninger skal forflytningstilstanden kontrolleres både med leggene stående i sin høyeste posisjon og dersom det er aktuelt, leggene nedlagt for havslep.
4. Sikkerhetstilstanden ved maksimum sikkerhetsdypgående idet en benytter den samme vektfordeling som i nr. 3 unntatt for nødvendige endringer av ballast, og eventuelt dumpet flytende boreslam. I beregningene forutsettes at innretningens ankere er om bord.

Figure 12: Section 17 of the stability regulations.

Definitions of operating and survival condition from section 2 of the stability regulations are reproduced in the extract in figure 13.

10. *Operasjonstilstand:* Tilstanden når innretningen utfører sine normale arbeidsoppgaver, f.eks. boring, og er innenfor de operasjonsbegrensninger som er gitt for tilstanden.
11. *Rederiet:* Definisjonen av rederiet i skipssikkerhetsloven § 4 gjelder tilsvarende.
12. *Sikkerhetstilstand:* Tilstanden når operasjonsbegrensningene (maks. tillatt vindhastighet) for aktuell operasjons- eller forflytningstilstand er overskredet, og/eller når nødvendige tiltak for tilstanden er iverksatt.

Figure 13: Extract from the definitions in section 2 of the stability regulations.

2.5.1.2 Classification society rules, standards and definitions

West Mira is classed by DNV GL. It has DNV GL ID number 32795 and IMO number 9662344. The facility has the following class notation:

> 1A1 Column-stabilised Drilling unit(N) Battery (Power) Crane-offshore(N) DRILL(N) DYNPOS(AUTRO) E0 HELDK (S, H, CAA-N) POSMOOR(ATAR)

The appendix to the class certificate occupies a key place in classification documents because it describes the design assumptions. The appendix to *West Mira*'s certificate includes the graph reproduced in figure 18, which shows limits imposed on the use of operating draught in order to comply with the guidance in DNV GL-OTG-13 and -14 for air gap and slamming loads, based on the letters issued in 2016, 2017 and 2019. The graph has two criteria for using *West Mira* at operating draught. Where long waves are concerned, the limit is based solely on Hs, but depends for steep waves on a combination of Hs and the zero up-crossing wave period (Tz) for the wave condition. The following requirements must be met for using *West Mira* at operating draught:

- $Hs \leq 8.0m$, $Tz \geq 11$ seconds
- $Hs \leq 2/3 \cdot (Tz + 1)$, $5\ s \leq Tz < 11\ s$ (Hs [m], Tz [s])

Where low waves are concerned, the steepness criterion from DNV GL is the limiting curve. This criterion is an approximation of the physical limit for how steep waves can become in nature. Limits do not normally need to be specified for wave periods of Tz < 5 seconds.

When wave conditions exceed the above-mentioned limits, the facility must be deballasted to survival draught and meet the assumptions for survival condition pursuant to the ballast regulations. Analysis of the *West Mira* design indicates that it can withstand wave loads in accordance with DNVGL-OTG-14. This means that both columns and topside can be expected to receive slamming which conveys considerable energy, but that the structure is strong enough to withstand the loads defined in the technology guideline without incurring substantial damage or loss of human life.

2.5.2 Location-specific analyses

2.5.2.1 Riser analysis

The riser analysis was prepared by Stress Engineering Services Inc for using *West Mira* to drill at the Maria H location. This referred to calculations of maximum drift-off of the facility over the sea surface with regards to limitations in the upper and lower flexjoint (UFJ/LFJ). The summary of the analysis describes the required ADS setting to ensure timely disconnection before the upper limit is exceeded (90 per cent of contact). The analysis includes the influence of the time taken to activate the ADS and thereby the margin required to initiate timely disconnection in the event of an excursion away from the DP set point. To ensure disconnection within a 27m excursion (corresponding to 90 per cent of the angle for collision), the analysis concludes that the offset for ADS initiation is 14.7m and that the angle required is less than six degrees if considering a fast drift-off.

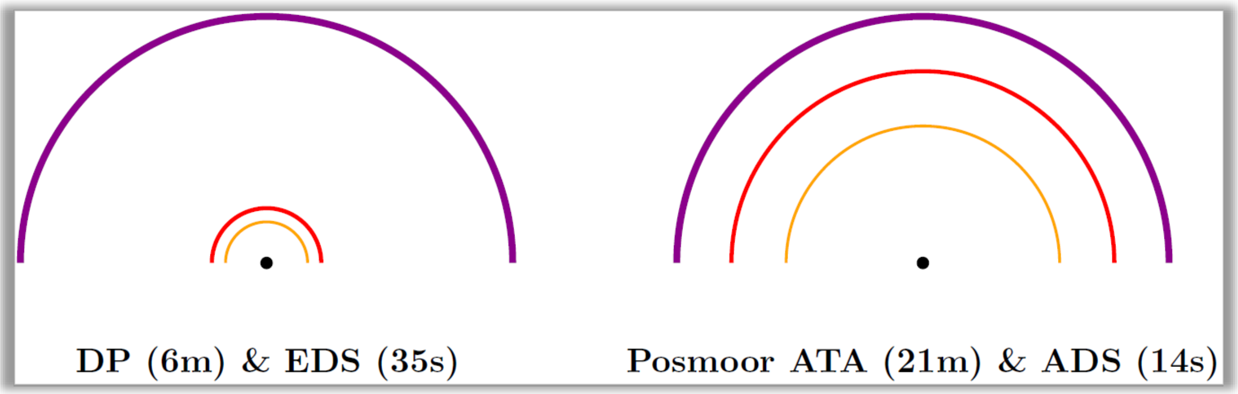


Figure 14: Summary of the riser analysis (disconnection completed at 27m shown as the outermost purple semicircle).
Two possible circumstances are shown. Left: with DP and EDS function at 35 seconds action time, which gives a radius of about 6m for the red "watch" circle where disconnection must start. Right: Posmoor ATA and ADS with 14 seconds action time, giving a red "watch" circle of about 21m.

2.5.2.2 Mooring analysis

The mooring analysis (prepared by *West Mira* design office Moss Maritime for Seadrill Norway Operations Ltd) provides the basis for the mooring part of the Posmoor ATA operation at the Maria H location. It assumes that the mooring lines will be slackened when *West Mira* changes from operating to survival draught. Figure 15 gives the specific lengths for each of the eight mooring lines.

- When entering survival condition:
  - Line 1, 10 and 12 must be slacked by 15 m
  - Line 3, 6 and 9 must be slacked by 20 m
  - Line 4 and 7 must be slacked by 25 m

Figure 15: Extract from the summary of the mooring analysis (section 1.3, p 7).

Maximum and minimum line tensions are specified by the analysis. High tension could pull the anchor free from the seabed, while low tension (on the leeward side of the facility) could put the lines too close to pipelines they cross. Mooring line capacity is determined by 100-year design loads pursuant to the Metocean specification for the Maria location. The anchors must be tested on deployment to their maximum intact loading.

The mooring analysis uses approximate values for maximum acceptable horizontal offset (excursion on the surface), based on a maximum LFJ angle of 8.6 degrees and water depth at the location. These values are used to compare the mooring system's tensions and the analysed displacements under various weather conditions.

Assumptions in the mooring analysis are specified as text, including:

- "4-split ATA system used for operation and survival condition." (page 8)

- "The riser is assumed to be disconnected from the BOP and all drilling activities have stopped. The rig should be in survival loading condition, hence increasing the still water air gap height."

West Mira was operated with two-split power distribution from the engine rooms at the time of the incident, and the riser was not disconnected. The above-mentioned assumptions could be relevant for how the DP system and consequence analyses were configured ahead of the incident.

2.5.3 Operating procedures and manuals

The *West Mira* operations organisation has established documents to deal with regulatory requirements and design assumptions for the facility in general. These are the DP Posmoor ATA and the operations in severe weather procedures.

2.5.3.1 Well-specific operating guidelines (WSOG)

The practice for drilling operations is to use the WSOG when in DP mode. These guidelines are intended to combine the facility's operating limits with conditions at the specific drilling location. They are summarised in an overview with a list of parameters which affect the drilling operation and the facility's ability to maintain the correct position, including

- thruster load and possible warnings and alarms from the DP system
- angles of the LFJ and UFJ on the riser
- position/reference systems (well reference, GPS and so forth)
- the facility's motions (roll, pitch and heave).

Each parameter in the WSOG has four status levels:

- normal – normal drilling operation – marked in green
- advisory – alertness/attentiveness – marked in white/blue
- yellow – warning with drilling shutdown – marked in yellow
- red – alarm with immediate drilling shutdown – marked in red

Clear limit values are set for green, yellow and red. In advisory, white/blue, involved/ relevant personnel must be advised and the position discussed with a view to continued operation. This status forms the basis for assessing condition and its interpretation is more position-dependent in the interval between normal (green) and warning (yellow) levels. Requirements described for parameters in advisory status are

- "Notify: Advise OIM/MSL, TSL/ATSL Driller, DSL/Toolpusher, Client"
- "Action: **Discusses** situation with all parties on continuation of operation".

The intention with the advisory condition is to provide an early pre-warning of any failure or changes which may lead to a heading or positioning problem.

The advisory condition is used to give the supervisory staff the possibility to assess, at an early stage, any failure or loss of performance against current and planned operations in order to make prudent changes to ongoing or planned operations.

Figure 16: Extracts from the Seadrill DP operations directive (DIR-37-0283, version 1).

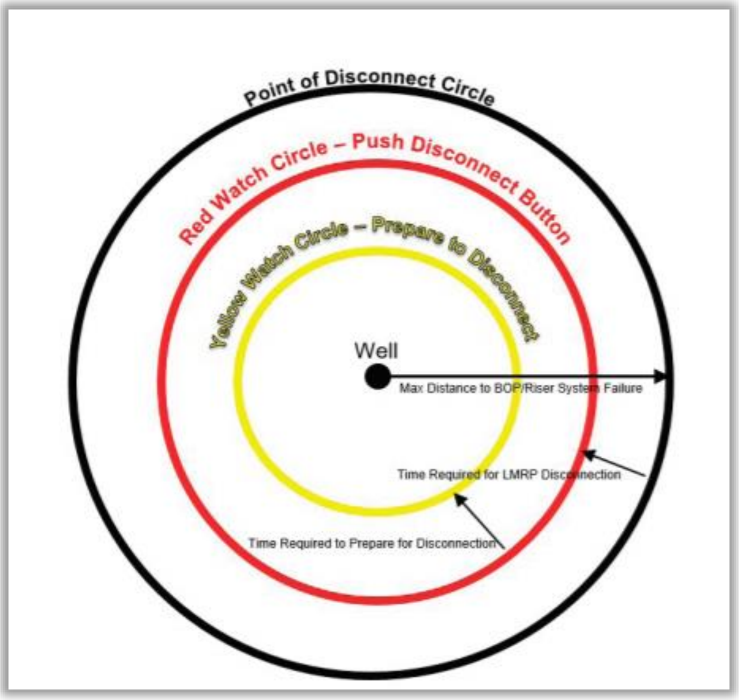


Figure 17: The various WSOG colour levels for the "watch" circle.
The reference point (centre) is the well location and the outermost perimeter is disconnection, where the ADS function should ideally coincide with the black circle. In normal DP operation, the facility's set point in the drilling centre will be positioned over the well centre, so that DP-alarm and watch-circle radii coincide.

3 The PSA investigation

The PSA was notified of the *West Mira* incident on 14 March 2020, and decided on 17 March 2020 to launch an investigation.

Composition of the investigation team, with discipline area

- Amir Gergerechi drilling and well technology (investigation leader)
- Eigil Sørensen drilling and well technology
- Fredrik Dørum drilling and well technology
- Linn Iren V Bergh occupational health and safety
- Terje L Andersen structural integrity.

The investigation has been pursued from land in the form of meetings, interviews and document reviews, without an inspection on *West Mira*. Thanks to the Covid-19 pandemic, meetings and interviews were conducted with Skype and Teams. Personnel from Seadrill and Wintershall were interviewed, with observers from Seadrill. Fifteen interviews were carried out with a number of participants.

The investigation team has compiled its report on the basis of meetings, interviews, presentations and a document review to understand/clarify the direct and underlying causes of the incident.

4 Course of events

Weather on the Halten Bank was relatively calm in the early morning of 14 March, with waves from a northerly direction. The wind had shifted from north-west to south during the night, and the weather forecast showed a similar change for the waves. It also showed that the sea state would deteriorate through the day.

Drilling was conducted on *West Mira* during the day. Despite relatively calm weather, an undesirable amount of power was used to drive the thrusters in order to remain in position. According to the log for 13 March, optimisation was required but this was not prioritised. It was first undertaken from 07.50 to 08.19 on 14 March.

Figure 18 presents the air gap limits for the facility. This graph also shows how the two weather reports from StormGeo at 12.34 and 17.41 predicted developments. The 12.34 forecast shows a predicted trend with very steep waves and rapidly rising Hs, with the latter increasing from about 4m before 12.00 to more than 7m by the end of the day. The updated forecast at 17.41 showed a rise in expected maximum Hs to 7.5m at about 22.00. Furthermore, Hs of 7m was expected from 17.00. As can be seen from figure 18, where the weather forecast is plotted by hourly points, the limiting sea state curve was expected to be exceeded between 13.00-14.00 on 14 March. This curve indicates the boundary between conditions with positive and negative air gap at operating draught. A negative air gap means that waves can be expected to hit the base of the topsides (box bottom) on the facility.

Log entries for registered weather on *West Mira* are also plotted in figure 18. The log is updated every four hours and shows developments from 04.00 until the incident. These data give the impression that observed sea states had a wave period about one second longer than the forecast condition. There are also signs that *West Mira*'s limiting sea state was exceeded a little later in the day. According to the logged data, the transition to sea states with a negative air gap occurred between 12.00 and 16.00, and possibly closer to 16.00. In addition to weather recordings every four hours, the times 19.00.00/30 are specified – and then with a very long wave period.

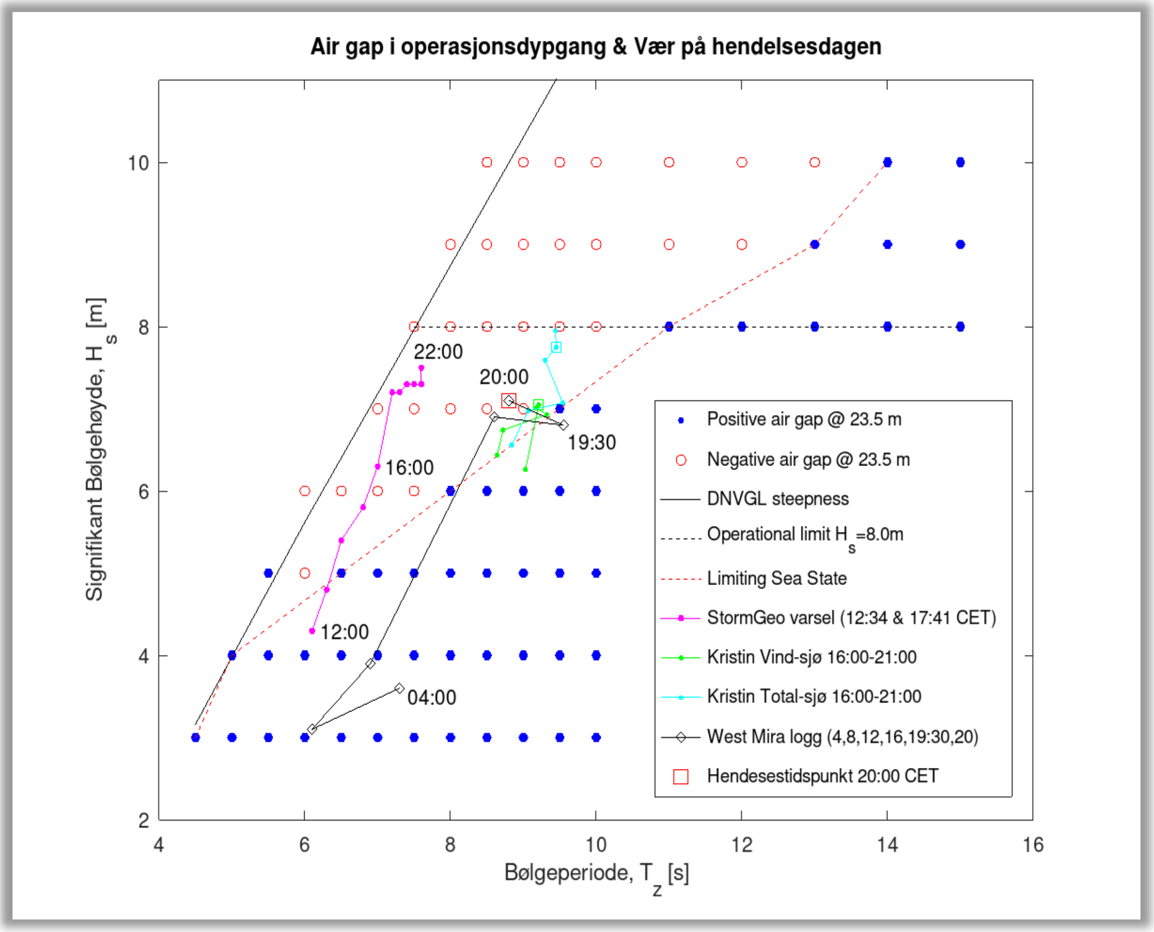


Figure 18: Graph from the appendix to the West Mira *class certificate showing the limit values for a positive air gap at operating draught. Weather forecasts from StormGeo, log registrations from* West Mira *and weather measurements from the Kristin field have been plotted. (Source: PSA) Key: Significant wave height; Wave period.*

From interviews and the logbook on the bridge, it is clear that the weather was a topic during the day. Descriptions by interviewees show that conditions were noticeable but not a problem. Three thrusters and two diesel generators were taken out of service early in the day and then restarted to contribute power for maintaining position. At 11.15, the wind speed exceeded 40 knots (about 20m per second) – a limit in the WSOG matrix. This meant that, in accordance with the WSOG, positioning was in advisory white/blue status. In other words, conditions were no longer within the normal or green condition. Hs exceeded 4.5m at 13.05, which represented yet another parameter in the advisory status. At 13.15, dynamic motions on the facility were so large that the third parameter entered advisory status – pitch exceeded four degrees (see figure 19 for a description of the degrees of freedom for a floating facility).

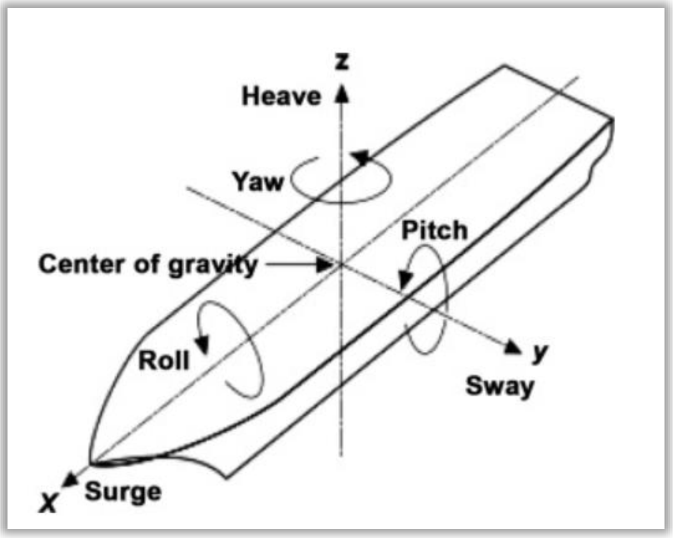


Figure 19: Terms for the motion of a floating facility: Three translational directions: surge back and forth, sway side to side, and heave up and down. Three rotation: roll around the longitudinal axis, pitch around the transverse axis and yaw around a perpendicular axis.

An advisory meeting on the bridge at 15.10-15.50 covered the weather among other topics, and involved the management team – the OIM, the MSL, the drilling supervisor, the DSL and the toolpusher as well as the DPOs on watch. The log does not list any conclusions from this meeting.

On the day of the incident, the mooring lines were not adjusted when the wave direction changed and the weather deteriorated. This meant the lines were not appropriately adjusted for optimal distribution of loads between the eight anchors. One diesel generator (DG3) was also shut down for maintenance. According to the log, thruster 3 was readied but not allocated power up to the incident

A footnote to the WSOG states: "Any reduction of performance or availability of DPM related Equipment due to maintenance will trigger advisory status". The log shows that advisory status was used with earlier maintenance work.

In short, the position on the facility around 16.00 on the incident day, when the advisory meeting has been held without clear conclusions or action, was as follows.

- In advisory status because of equipment maintenance (DG3/4)
- In advisory status because of winds exceeding 40 knots (20 m/s)
- In advisory status because of Hs above 4.5m
- In advisory status because of more than four degrees of pitch
- At operating draught with negative air gap (nonconformity with design assumptions in the class certificate appendix and operating procedure[1])

[1] *Operations in severe weather*, PRO-37-1801, version 2.02, section 2.2: "The rig shall always maintain positive airgap when at operational draught."

- Drilling operation under way

The drilling operation continued after the advisory meeting. According to the log, the facility was moved 3m off centre at 17.30 to reduce the thruster load. This operation is described in interviews as an alternative to optimising the mooring lines. It is unclear when and in what forum the decision was taken to move the facility by 3m.

Moving the DP system's set point away from the location over the well centre meant that alarm limits defined in the DP system could not be compared directly with the WSOG limits for the position. The DP information and alarms described below use the DP set point as their reference. In addition comes the deviation of about 3m from the well location, since the facility was moved in the same direction as the weather forces.

Deballasting began at 18.10 and survival draught was reached at 19.00. According to the log, the facility had then been at operating draught for more than three hours (from before 16.00) in sea states which gave a negative air gap. The log does not show that the mooring lines were optimised after the change of draught (which would tauten all the lines). The mooring analysis assumes that an adjustment will be made when changing draught. According to the drilling log, the drilling operation continued during the period when the facility was deballasted. Pursuant to section 13.2 of the NMA's stability regulations, operations which are not necessary for deballasting the facility, and which might represent a threat of damage, cannot be conducted simultaneously with deballasting.

Figure 20 shows position-related warnings and alarms from the DP system between about 18.00 and 20.30. Many position warnings reported that the 3m limit was being exceeded. Since the DP set point had been manually moved by 3m, the real distance from the well location was closer to 6m at the times when the DP system was warning of 3m drift-off.

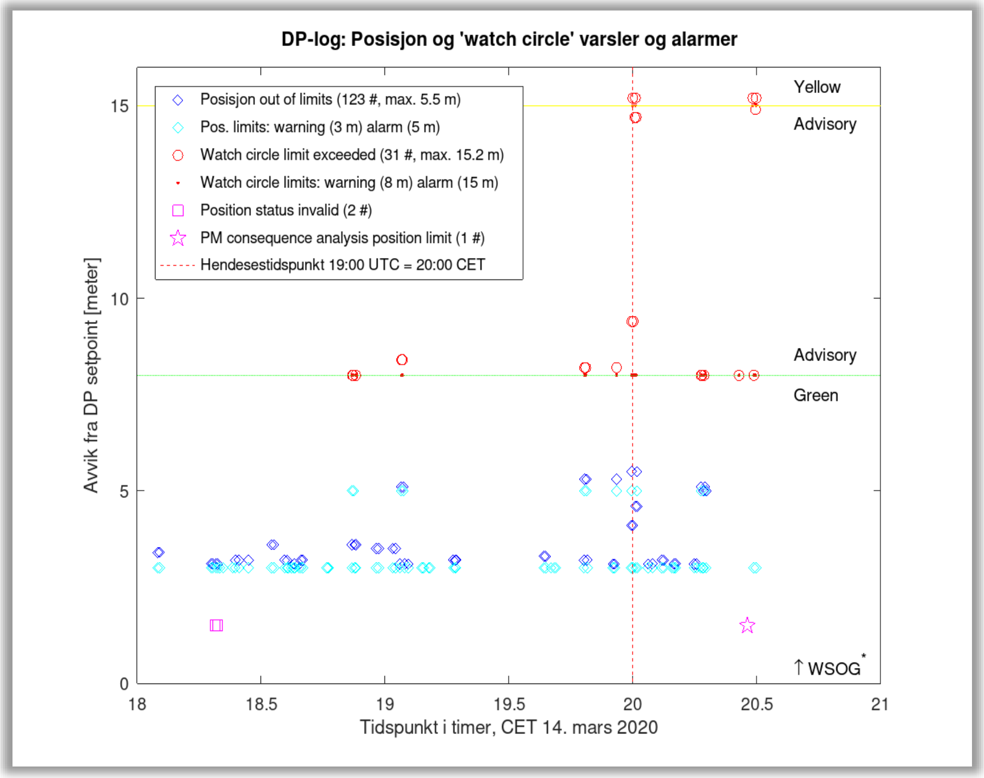


Figure 20: Graph of position-related warnings and alarms from the DP system's data log.
Note that points on the right of the graph above WSOG show the WSOG limits which would normally coincide with the distance from the DP set point. During the hours shown in the graph (post-17.30), the latter had been manually set to 3m from the well centre in the direction of the waves (produced by the PSA). Key: Deviation from DP set point (m); Time in hours.*

The 8m limit in the WSOG matrix was twice exceeded around 19.00, which meant another parameter – position offset from wellhead – entered advisory status. In reality, this deviation was closer to 8+3=11m, corresponding to almost 40 per cent within the white/blue advisory circle. No advisory WSOG status was logged on the bridge, and there are no indications in the investigation findings that advisory e-mails about position deviation were sent around 19.00 on 14 March. Shift change and handover for the various positions occurred at around that time.

Drilling was halted around 19.45 and the string pulled up a few metres. The string was still rotating with drilling mud being circulated.

Figure 20 shows that warnings were also issued at 19.48 and 19.56 that the yellow watch circle had been passed. Several yellow WSOGs accordingly occurred before the incident. None of these excursions were logged. The incident developed at 19.59 with several warnings/alarms.

- 19.59.41 Position, warning 5.5m
- 19.59.43 Motion, warning Pitch 5.3 degrees
- 19.59.48 Mooring line tension too low on leeward side
- 19.59.57 Position, alarm 15.2m
- 20.00.35 Position, alarm 15.2m

Descriptions in interviews and the data presented above accord with *West Mira* being struck by a large single wave or train of waves at 20.00 on 14 March 2020.

- According to the Kongsberg report, the maximum drift-off from the set point was 16.8m. This was registered in the DP system at 20.00.05 (Kongsberg doc no 5248178, revision D).
- Kongsberg also concludes that unfiltered measurements from the MRU on board give more accurate figures for maximum drift-off. They show a drift-off of about 21m from the DP set point.

The maximum drift-off totalled about 24m. That includes the three metres when the facility was moved from the well centre.

In addition, the facility experienced a pitch of roughly 5.3 degrees at the same time as the incident. This motion could have affected the riser and had an effect on the angle of the LFJ, where the ADS mechanism was triggered.

Figure 21 illustrates motion warnings and alarms graphically. Note that a shift occurs in the limit value for pitch, which indicates that a (manual) adjustment was made to the value in the DP system from four degrees (in accordance with the WSOG) to five degrees. Carried out between 19.34.24 and 19.49.43, this was not logged and has not been mentioned in interviews during the investigation.

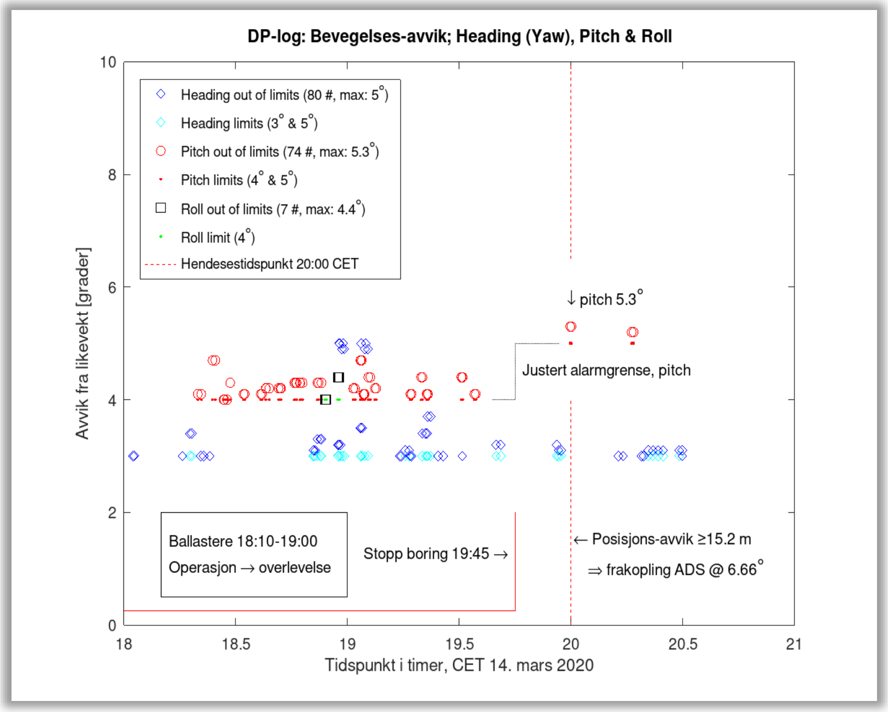


Figure 21: Graph of alarms from the DP system for dynamic motions of the West Mira *facility (produced by the PSA on the basis of the alarm log in the DPM system). Key: Deviation from equilibrium [degrees]; Time in hours.*

In addition to those shown in figures 20 and 21, many more warnings and alarms were generated by the DP system ahead of the incident. These included warnings of inadequate thruster power, and that thruster capacity was somewhat reduced at the time of the incident because diesel generator 3 and thruster 3 were not in normal operation. The Kongsberg report estimates that the power requirement at the actual moment of the incident was twice as large as the amount available, so that the one thruster has probably reduced the excursion but not prevented the incident. Figure 22 presents an image of the DP console after the incident with some sections highlighted. The trace from the excursion of about 17m from the DP set point and a further 3m from the well centre is shown on the left. The energy graph at top right shows that available power is lower on the right-hand side. Weather loads from waves and currents (about 230t) appear at lower right. Thruster loads to withstand wind, waves and current were about 374t when the image was captured.

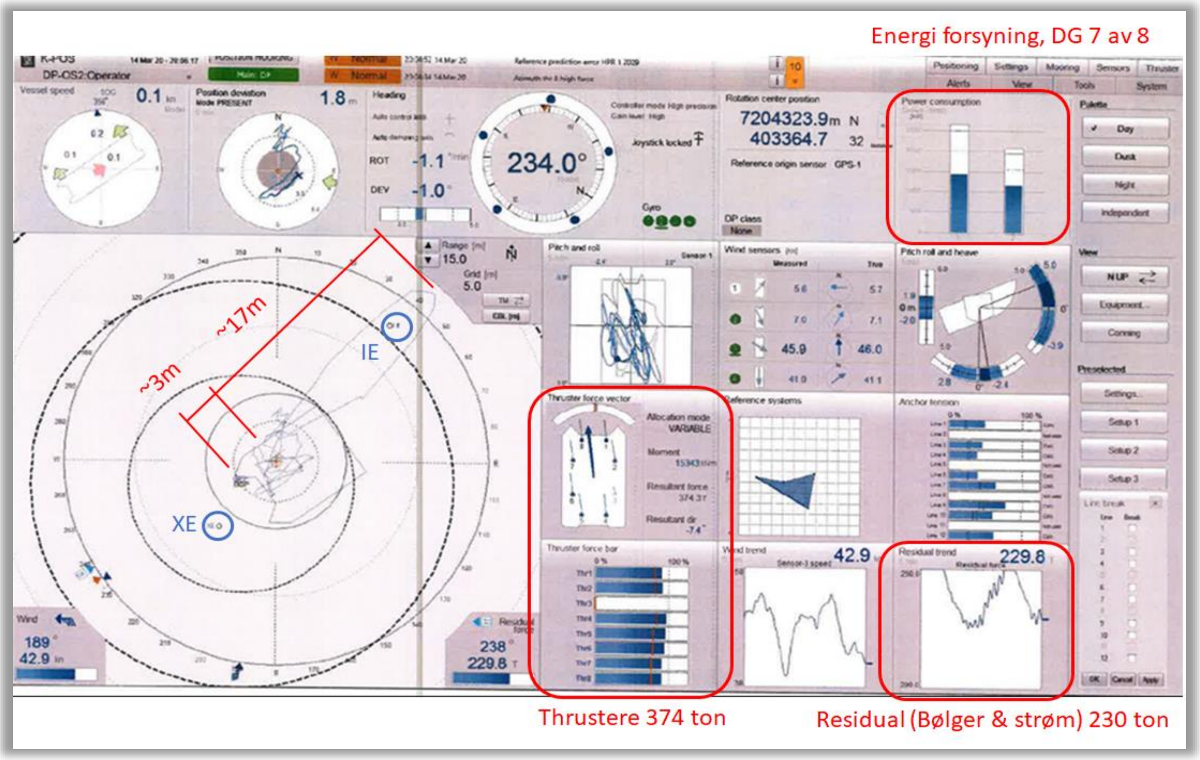


Figure 22: The DP console immediately after the incident on 14 March at about 20.00 CET (local time), 19.00 UTC. The excursion trace is shown to the left, where the silhouette of West Mira *can also be seen. The DP set point below the drilling centre is marked in orange as the target, and the well centre is forward of the starboard pontoon. Two marked points can also be seen, one forward of* West Mira *(XE below left), which is where the facility would locate itself with active mooring and thrusters if all weather forces disappeared. The IE point more than a vessel's length aft of* West Mira *is the one which the facility would move around if all thruster power disappeared and the mooring system alone was left to withstand the natural forces.*

At 20.00, the string was about 6m from the bottom of the well when the crew observed a sharp reduction in hook load and also confirmed observations from the moonpool that the riser was disconnected.

5 Potential of the incident

5.1 Actual consequences

The incident caused the discharge of 49.9m^3 of drilling fluid from the riser to the sea/ natural environment. The drill string was cut and had to be fished out of the well. The drilling operation was delayed for about three days.

No personal injuries were caused by the incident.

5.2 Potential consequences

Based on documents received and information from interviews, the investigation team concludes that the probability of losing well control while drilling in the reservoir section was low. Plans called for the well to be drilled with a fluid able to balance pressure in the formation if the mud column in the riser was lost. In the event of an unintentional disconnection, the BOP would cut the string and shut in the well.

The incident could have caused material damage to the facility and its equipment.

6 Direct and underlying causes

6.1 Direct causes

The direct cause of the incident is a combination of several factors. It occurred when the facility lost position because of dynamic weather forces. The drilling contractor concluded that the drift-off activated the ADS. A combination of sub-optimal mooring lines and extensive use of thruster capacity to maintain position meant thruster power was insufficient to withstand the dynamic forces at the time of the incident. The disconnection signal was given after the ADS exceeded the five-degree activation point, which in turn automatically cut the string and shut in the well.

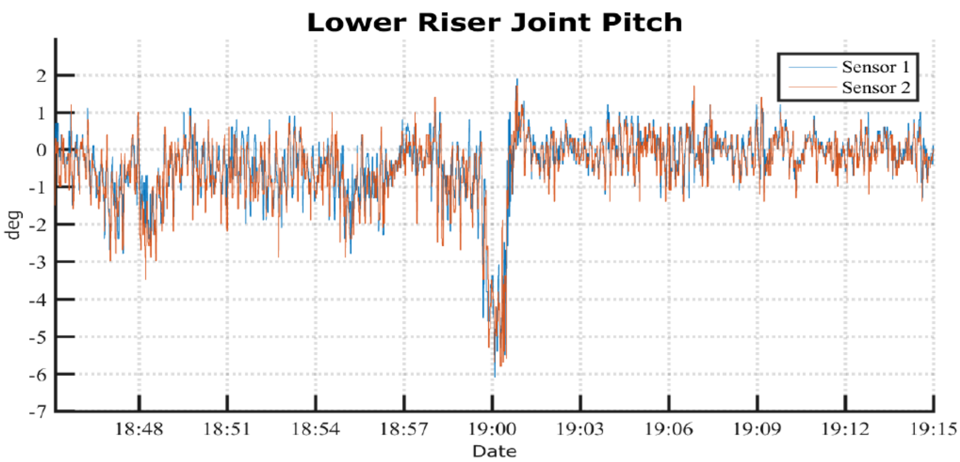


Figure 23: The angle attained by the LFJ at the time of the incident.

6.2 Underlying causes

The investigation has identified several underlying causes for the *West Mira* incident. These relate primarily to:

- reduced situational awareness and assessment of risk
- procedures and compliance with these
- use of analyses
- management of change (MOC)
- design of the facility
- cost cuts and concentration on efficiency.

6.2.1 Reduced situational awareness and assessment of risk

The incident on *West Mira* arose as a result of weather loads. The facility was hit by one or more waves while it was at survival draught with the riser connected. At the time of the incident, the mooring system had not been optimised over the previous 12 hours although the weather had changed considerably.

An advisory meeting held at 15.10-15.50 with relevant crew included the weather position. It took place as an action after several parameters had exceeded advisory status during the day. The log records no conclusions from the meeting. Those involved have explained in interviews that the weather was a topic, but little information exists on what specific actions were discussed and decided on.

Weather forecasts and measured sea states on Kristin and the Maria H location showed a trend which called for action pursuant to the procedure for Posmoor ATA operation.

Crew received many warnings and alarms during the day which should have led to

- optimising the mooring lines
- halting drilling
- changing draught.

Despite developments over time, with many warnings and alarms from deteriorating weather, nothing was done to comply with the operating procedures. On the other hand, action was taken at 17.30 by moving the facility 3m. Changing from operating to survival draught first began about two hours after the crew had logged weather conditions which exceeded the limiting sea state (see section 2.5.1.2).

Grounds therefore exist for saying that the crew underestimated the risk associated with the earlier signals from the DP system and the weather forecasts/measurements.

The investigation team considers that the most likely reason for responding late and erroneously to the earlier warnings is that crew understanding of risk was reduced. That had further significance for assessing and following up risk.

Several aspects related to HTO conditions have been significant in explaining why situational awareness was reduced on *West Mira*. These include the following.

- The significance of new equipment and a new crew composition, which has influenced communication on board and understanding of the facility's operational requirements. Interviews made it clear that the challenges related to power sharing were not sufficiently familiar to all relevant personnel.
- Communication and logging of decisions between drilling and maritime crew with regard to prioritising optimisation. The investigation has revealed a failure to log conclusions from the advisory meeting, and varying explanations by personnel involved over what was discussed and decided there. That may have made it more difficult for personnel to pick up important signals on risk.
- Understanding the priorities for optimising the mooring system between energy consumption and position. While energy optimisation was described as central in interviews, the procedures give priority to position.
- Crew were aware of several warnings and alarms from the positioning system during the day, but did not receive alarms from the consequence analysis. That indicates an unfortunate lack of response to early warnings and possibly a "glut" of alarms, where crew have become accustomed to constant alarms and their seriousness is not sufficiently understood.
- Differing perceptions in the organisation over how far optimisation has led to a reduced rate. This affected decisions taken and priorities set on *West Mira*.
- Inadequate procedures helped to give the crew an unrealistic impression of the robustness of the operating assumptions for the facility.

Several conditions ahead of the incident should have prompted a halt and a new risk assessment. Many opportunities existed to prevent the accident, but failures occurred at several levels. Reduced situational awareness could have led in this case to inadequate interpretation of signals, consequent poor decisions and risk assessments, and an undesirable incident.

6.2.2 Procedures and compliance with these

The investigation has shown that several procedures have not been followed or are deficient. Examples include the following.

a) The DP Posmoor ATA procedure (PRO-37-1448 rev 1) specifies that the mooring system should be optimised when the weather changes or if thrusters are used to carry more than 40 per cent of environmental loads in moderate weather.

b) The mooring analysis (4275-MM-JR-435-002, rev 03, section 5.1), clearly specifies specific requirements for mooring optimisation when changing to survival draught. The analysis assumptions were not applied on the day of the incident.
c) The DP Posmoor ATA procedure (PRO-37-1448 rev 1) does not refer to the assumptions specified in the mooring analysis.
d) According to the operations manual, *West Mira* must always have a positive air gap at operating draught. The facility was not deballasted to survival draught until several hours later. See *Operations in severe weather*, PRO-37-1801.
e) Drilling continued after deballasting to survival draught, contrary to section 17 of the ballast regulations from the NMA and the assumptions in the mooring analysis (4275-MM-JR-435-002, rev 03, section 3.2).
f) Moving the facility away from the well centre to reduce thruster load is not described in the positioning procedure. The move was made as an alternative to mooring optimisation. This decision was not dealt with in accordance with the requirements for temporary orders, and was thereby not adequately documented or risk assessed.
g) According to the WSOG (figure 24), the position after a status warning (Notify) must also be discussed with relevant departments on board. No documentation has been presented to show that such meetings took place when the warnings were issued. Relevant departments were not called to a meeting until the third advisory warning.

Seadrill	**Well Specific Operating Guidelines (WSOG)** **West Mira, Operator: Wintershall** **Well: Maria H template Posmoor ATA** **6406/3-H**	**Date: 06.02.20** **Revision: 02**

Condition	Green	Advisory	Yellow	Red
Notify	Normal status	Advise OIM/MSL, TSL/ATSL Driller, DSL/Toolpusher, Client	Advise OIM/MSL, TSL/ATSL Driller, DSL/Toolpusher, Client	Advise Driller immediately, OIM/MSL, TSL/ATSL, DSL/Toolpusher, Client
Action	None required	Discuses situation with all parties on continuation of operation	DPO initiate DP yellow alert. Driller follows relevant procedure and prepare for disconnect	Issue alarm and Follow procedures

Figure 24: Extract from the WSOG.

h) The investigation shows that decisions taken in the advisory meeting at 15.10, including their basis, were not documented/logged. Interviewees also expressed differing perceptions of what was decided.
i) The procedures do not adequately describe the design assumptions related to power distribution/sharing on the facility.
j) Information in the WSOG has several deficiencies. See section 6.2.3.

A key place is occupied by the WSOG document as the link between facility-specific procedures for *West Mira* and the specific operation at the Maria H location.

The investigation shows that the point concerning ADS was given great weight in the risk assessments conducted by the crew. According to the WSOG, the trigger angle was set at five degrees. This was supposed to correspond to 28.4m drift-off, and interviewees expressed great surprise that the ADS was triggered before the specified limit. The crew had thereby acquired an unrealistic perception of the robustness of the operating assumptions for the facility.

To sum up, inadequate procedures and compliance are seen to have contributed to the incident.

6.2.3 Use of analyses

The investigation shows that calculations and recommendations used in preparing the WSOG's operational assumptions contain deficiencies and weaknesses. Some examples are as follows.

- The calculation of the relationship between the defined ADS trigger angle and displacement over the surface is based on a straight line between the two flexjoints on the riser. This simplification excludes, for example:
  - wellhead deviation from the vertical
  - deflections in the riser from the facility's motion (pitch/roll)
  - deflection of the riser from the vertical (catenary curve):
    - because of the specific weight of riser and mud
    - because of currents in the sea.

  At the same time, the calculation assumes that the DP set point is optimally positioned over the well centre. That contributed to the ADS being triggered earlier than the crew expected. This expectation was based on the values specified in the WSOG, which fail to take account of the above-mentioned points.
- The summary from the riser analysis specifies the following:
  - "Minimum riser limit identified is at mean offset 27.0m (UFJ limit at 90% of clashing)"
  - "Reaction time for ADS is 14 seconds"
  - "Angle required is less than 6 degrees if considering a fast drift"
  - "This requires the ADS to engage at 20.8m offset (approx 5.7 degrees on LFJ)".

Values in the WSOG therefore do not correspond with the riser analysis results.

Seadrill	Well Specific Operating Guidelines (WSOG) West Mira, Operator: Wintershall Well: Maria H template Posmoor ATA 6406/3-H	Date: 06.02.20 Revision: 02

Location - Maria H Template (PWL) 6406/3-H / UTM Northing: 7 204 316m / Easting 403 362m / Zone 32N / Datum ED50 N62 /
- Water Depth: 303m / Heading: 235˚ / Mean tension approx. 115 tons

Condition	Green	Advisory	Yellow	Red
Position offset from WH (Input consequence analysis) Water depth 303m ADS 5° (28.4m)	< 8m	<15m	>15m	No later than **24 m** or immediately, if confirmed that situation cannot be controlled

Figure 25: Extract from the WSOG showing the various levels for "position offset from WH".

Deficiencies and weaknesses in the calculations and recommendations applied in producing the operating assumptions have led to consequential errors. Input to the consequence analysis in the Kongsberg system, for example, was based on imprecise limit values in the WSOG. That meant the systems involved failed to give alarms and weakened situational awareness by personnel involved.

6.2.4 Management of change (MOC)

According to information which emerged during the investigation, the decision to use Posmoor ATA as the final positioning solution was only taken about a couple of weeks before operations began. Interviews and document reviews reveal inadequate assessments of changes related to this choice. That includes:

- the combination of ADS and Posmoor ATA positioning in shallow water was not adequately risk-assessed
- recommendations from the riser analysis were not included when calculating critical values in the WSOG
- assessment of possible HTO limitations related to power distribution between drilling and mooring winches.

Interviews have indicated that the operator was not sufficiently well informed about issues related to power distribution which proved to pose operational problems with the chosen positioning solution. The investigation team thereby believes that Wintershall failed to take risk-informed decisions related to the choice of positioning.

6.2.5 Design of the facility

As described above, *West Mira* is designed so that power supplies have to be split between the mooring winches and drilling. This represents an important operational assumption and is significant for organising and managing work. The distribution of power between drilling equipment and mooring winches is a significant design assumption which affected the course of events and choices on the incident day. Descriptions from interviews and logs related to optimisation on 13 March show that the maritime section failed to receive the power required to adjust the mooring lines. No entries on mooring optimisation appear in the log for the following day. This indicates that the anchors were not used optimally up to the morning of 14 March.

The investigation shows that both management and executing personnel were insufficiently aware of potential problems related to power sharing before the decision was taken to use Posmoor ATA. Important design and operating assumptions were insufficiently integrated in operational procedures and practice. This means that the investigation team could not see that Seadrill had adequately reviewed the operating concept for *West Mira* so that safety considerations and operational requirements were compared with management parameters. Interviews and documentation show that this issue was not adequately assessed and considered in risk assessments prior to the operations.

No conclusions have been reached by the investigation about how far the decision base in the design phase contained adequate assessments of power distribution between technical systems, and about how human and organisational factors were taken into account. The investigation shows that challenges associated with sharing power during operations justify asking whether the decision base in the design phase was inadequate.

Insufficient attention paid to challenges related to technology and physical configuration as well as human and organisational factors in designing the facility could have contributed to insufficiently robust organisational and operational factors which promote human performance.

6.2.6 Cost cuts and concentration on efficiency

Drilling must cease to optimise the mooring lines on *West Mira*. The same switchboard distributes power to the mooring winches and to drilling, which means the latter must reduce electricity consumption for the winches to function. Findings by the investigation indicate that drilling has been prioritised on *West Mira* ahead of optimising the mooring lines. Contractual terms are an important parameter, which can potentially affect decisions and priorities. Interviews have revealed that views differed about whether optimisation led to a rate reduction, and that this influenced decisions taken and priorities set on *West Mira*. Several interviewees believed that optimisation involved downtime.

Mooring optimisation was mentioned several times in interviews as important for reducing fuel consumption by the thrusters, while the overall purpose of positioning was not a central issue when describing why such optimisation was necessary. Interviewees reported that the need for optimisation had been expressed earlier, during the night of 13 March, but that the marine department was not allocated power for it because of the drilling work.

On 14 March, the attention of personnel was concentrated on completing the drilling operation. They opted for an alternative solution by moving the facility 3m off centre in order to reduce the load on the thrusters. The investigation found differing views about when and in which forum the decision to move 3m off centre was taken.

Information from the DP log shows that the question of optimising the mooring lines had already (13 March) been a challenge during the same drilling operation. This observation is also supported by feedback from interviews during the investigation.

Seadrill has been through a number of organisational changes in recent years, both offshore and on land. These include moving and reorganising the head office and technical support several times. The company has had facilities laid up, and personnel have been laid off. Interviews revealed that a number of employees have felt under pressure to deliver efficient operation. The investigation also learnt that a good deal of additional work not completed in the project phase had to be done while commissioning *West Mira*. It was told that the organisation received extra resources, but clearing the backlog from the project period came on top of ordinary work.

An excessive concentration on efficiency and costs could thereby have contributed to weakening Seadrill's ability to ensure prudent planning and execution of necessary work in its organisation.

Ongoing operational plans are reviewed and assessed by the land and offshore teams in several arenas. Weather conditions are a key element in this planning. The investigation shows that the operator has failed adequately to follow up risk assessments or drilling operations where weather is concerned. It could not see that any documentation is available which shows that the operator sought to halt the operation, even though weather conditions indicated that optimisation was required.

7 Observations

The PSA's observations fall generally into two categories.

- Nonconformities: this category embraces observations which the PSA believes to be a breach of the regulations.
- Improvement points: these relate to observations where deficiencies are seen, but insufficient information is available to establish a breach of the regulations.

7.1 Nonconformity: procedures and compliance with procedures

Inadequate configuration of and compliance with procedures in connection with planning and execution of the operation.

Grounds
The investigation shows that several procedures have not been observed or are deficient. For examples, see section 6.2.2 Procedures and compliance with these.

Requirement
Section 24 of the activities regulations on procedures.

7.2 Nonconformity: deficiencies in meeting the operator's see-to-it responsibility

Wintershall Dea has failed to ensure that Seadrill complies the requirements specified in the HSE regulations.

Grounds

- Wintershall Dea failed to follow up sufficiently how far the facility was in safe condition with regard to weather conditions and drift limitations.
  Ongoing operational plans are reviewed and assessed by Wintershall Dea's land and offshore teams in several arenas. Weather conditions are a key element in this planning. The investigation shows that the operator has failed adequately to follow up risk assessments or drilling operations where weather is concerned. It could not see that any documentation is available which shows that the operator sought to halt the operation, even though weather conditions indicated that optimisation was required.
- Wintershall Dea has not ensured that management of HSE is followed up and improved in order to take account of lessons learnt from earlier incidents (the lifeboat incident of 11 January 2020) and thereby to prevent recurrence.

Requirements

Sections 7 and 18 of the framework regulations on responsibilities pursuant to these regulations and on qualification and follow-up of other participants.

7.3 Nonconformity: risk understanding and prioritisation of risk-reduction solutions

Risk assessment in planning and operation has inadequately identified and assessed contributions to such areas as major accident and environmental risks related to acute pollution. Technical, operational and organisational solutions which would have reduced the probability of harm, errors and hazards/accidents were given a lower priority.

Grounds

- The investigation shows that both management and executing personnel were insufficiently aware of potential issues related to power sharing before the decision was taken to use Posmoor ATA. Important design and operating assumptions were inadequately integrated in operational procedures and practice. See section 6.2.5 Design of the facility.
- Interviews and document reviews showed a failure to assess changes related to the choice of Posmoor ATA. Deficiencies were found, for instance, related to assessing possible organisational and human constraints related to sharing power between drilling and mooring winches. See section 6.2.4 Management of change (MoC)

- Interviews and document reviews showed inadequate understanding, assessment and follow-up of signals from the DP system as well as weather forecasts and measurements on the day of the incident. See 6.2.1 Reduced situational awareness and assessment of risk.
- Findings from the investigation show that the drilling operation on *West Mira* was given priority over optimising the mooring lines. The company did not apply principles for good intrinsic HSE properties in operations on board. See section 6.2.6 Cost cuts and concentration on efficiency.
- Findings from the investigation show that personnel opted to move the facility 3m off centre rather than halt drilling and optimise. Moving the DP system's set point from over the well centre meant that alarm limits defined in the system were not directly comparable with WSOG limits for position. The additional distance from the well location was about 3m, since the facility was shifted in the same direction as weather loads.

Requirements
Section 17 of the management regulations on risk analyses and emergency preparedness assessments
Section 12 of the management regulations on planning
Section 4 of the management regulations on risk reduction

7.4 Nonconformity: learning lessons from incidents and preventing recurrences

Seadrill has failed to ensure that HSE management was corrected, followed up and improved in order to apply lessons learnt from earlier incidents and to prevent recurrences.

Grounds
Seadrill and Wintershall DEA investigated the incident of 11 January 2020 on *West Mira*, when the facility was hit by a wave, suffered structural damage to the topsides and lost a lifeboat. This investigation revealed that the facility was operated in a sea state with Hs of 8m and a Tz of 9.5 seconds. It was at operational draught (23.5m) and operated outside the limit curves specified in the appendix to the class certificate.

Investigation of the 14 March incident shows that *West Mira* was again operated outside the limit curves for negative air gap, and thereby breached the design assumptions and flag-state requirements. The facility was deballasted to survival depth about three hours after the limit curve had been exceeded, although the procedure requires deballasting at least 100 minutes before the curve is exceeded. The NMA requires the riser to be disconnected when the limit curve for negative air gap is exceeded. The drilling operation nevertheless continued for about 45 minutes after the change in draught, or a total of 3¾ hours after *West Mira* should have been in safety condition. The riser was still connected when the facility was hit by the wave train which caused disconnection, about four hours after exceeding the limit curve.

Similarities between the two incidents can be summarised as follows.

- Direct causes:
    - slamming
    - using the facility in breach of the flag-state requirements and classification society assumptions.

The recurrence and the long period with weather forecasting and developments in the latest incident show that Seadrill has not ensured sufficient learning from earlier events.

Requirements
Section 21 of the management regulations on follow-up
Section 23 of the management regulations on continuous improvement

8 Barriers which have functioned

Technical barrier elements which have functioned as intended are as follows.

- The ADS was triggered after the riser reached the trigger angle (five degrees).
- The LMRP was disconnected.
- Automatic lifting of the riser and the LMRP.
- Automatic cutting of the string and shut-in of the well.

The investigation has assessed technical, operational and organisational barrier elements up to the point when the string was cut and the well secured.

9 Assessment of the player's investigation report

Wintershall Dea investigated the incident with Seadrill's participation, with its report completed on 30 April 2020. This finds that the disconnection of the LMRP was triggered by the ADS. That in turn was triggered by the facility's drift-off, which is estimated at 24m from the well centre. The drift-off is attributed to environmental forces from the prevailing weather conditions, which became too large for the non-optimised mooring system and the thrusters working at maximum available power. The size of the drift-off reflected the failure to observe procedures.

The investigation report lists several specific proposals for further follow-up in order to avoid the recurrence of similar incidents. In the PSA's view, this report by and large presents the same observations as its own investigation report, but devotes less attention to important underlying causes related to operating parameters as well as human and organisational factors.

10 Appendices

A: Overview of personnel interviewed
B: List of documents utilised in the investigation
C: Root cause analysis