Havtil
Havindustritilsynet

Investigation report

Report	
Report title Investigation of incident on 31 January 2024 involving a cabin window on Åsgard A being forced in by green water	Activity number 001094054

Classification	
☒ Unclassified	☐ Exempt from publication

Parties involved	
Team A-1	Approved by / date Elin S. Witsø / 28 May 2025
Investigation team participants [redacted]	Investigation leader [redacted]

Contents

1 Summary

During Storm Ingunn on 31 January 2024, a wave hit Åsgard A, causing green water[1] from the starboard side to strike the window and associated frame in cabin 812, forcing them into the cabin. On 8 February 2024, the Norwegian Ocean Industry Authority decided to investigate the incident.

The pressure from the green water exceeded the load resistance of the window of cabin 812. The window and its frame were forced into the cabin.
The most likely sequence of events is that the window frame and window came loose at the bottom and were pushed up through the ceiling by the water that was forced into the cabin. The window frame and window then fell and landed on the cabin floor. The glass most likely broke due to stresses in the frame as the window was forced in.

No one was injured as a result of the incident. Cabin 812 suffered material damage and large quantities of seawater and glass fragments were swept into the living quarter corridors and down the stairwell and elevator shaft on deck 7. Seawater ended up behind the ceiling panel in the cabin and flowed from there into adjacent cabins. Seawater penetrated down to deck 7 and the ceiling of the medical facility. External cable trays and lighting fixtures were damaged during the incident. The fire-protection box on the front deck came loose and parts of the fire-protection box and fire hose were found inside cabin 812.

Had anyone been inside the cabin, the window and the frame as well as seawater would probably have hit them and caused a serious injury or fatality.

The design of the cabin window and frame fixing resulted in vulnerabilities. The inner and outer frames were secured to each other using bolts, but no nuts. The holes in the outer frame had to be drilled out and threaded at the construction yard, and were the only arrangement for withstanding external forces on the window connections to the frame. It would have been difficult to get the positioning correct when attaching the inner frame to the outer frame. The installation method that was chosen was difficult and the margins for adjusting the windows at the construction site would have been small, which resulted in the bolt holes generally having a small edge distance. In the case of the broken window, two bolt holes did not have a full circumference. Examination of the windows in the neighbouring cabins revealed both

[1] Whole waves that wash over the deck of a ship are often referred to as “green water”

loose bolts and over-tightened bolts. The same weaknesses are also assumed to have been present in the window of cabin 812.
The way in which the window was secured to the wall made it difficult to check that the attachment was correct once the window had been fitted. Removing the frame to check that it had been installed correctly would lead to a risk of over-tightening the bolts.
Errors such as using a large drill diameter, poor (incomplete) threading and corrosion of the threaded section of the bolt holes, as well as short engagement length, are likely to have significantly reduced the actual strength of the bolted joint compared with the theoretical capacity of the bolt hole threads.
The load resistance of the window was therefore reduced and ended up being less than the force exerted by the green water that hit the window of cabin 812. The window of cabin 812 is positioned at an angle close to an emergency evacuation shaft, which may have resulted in the green water hitting the window with a greater force.

The construction specification for Åsgard A stipulates requirements for the design of the front cabin windows on deck 8 with removable covers for weather protection. There are also recommendations in experiential documentation to cover the front cabin windows on decks 8 and 9 during the winter season. Neither the design involving removable covers nor the recommendations for covering the windows during the winter season have been implemented. No documentation is available concerning the reasons behind the decision to deviate from the construction specification and recommendations.

No separate model tests were conducted during the design process or thereafter to assess green water on Åsgard A. The model tests on Norne FPSO were used to assess the risks and consequences of green water on Åsgard A, which the incident shows were based on flawed assumptions.

An audit was conducted in 2020 targeted at the integrity of structures and maritime systems on Åsgard A and B. As a result of this audit, Equinor identified an improvement point relating to carrying out assessments of original green water results on Åsgard A against applicable metrological and oceanographic specifications. Equinor’s investigation team has not found any evidence that this has been done.

The investigation identified non-conformities relating to:

- Inadequate assessments for green water
- Lack of compliance with internal requirements for covering cabin windows and inadequate use of experiential knowledge
- Weakened load resistance of cabin windows

Improvement points have been identified relating to wave measurements and meteorological observations.

2 Background information

2.1 Description of facility and organisation

Åsgard A is a floating production, storage and offloading vessel (FPSO) located at Haltenbanken in the Norwegian Sea. The plan for the development and operation of the Åsgard field was submitted to the authorities in December 1995. The facility was built at Hitachi Zosen yard in Japan and completed at Aker Stord yard in 1999. It was installed in the field and production commenced in 1999. Åsgard A produces oil and gas from connected subsea wells. Stabilised oil is stored in separate tanks on board and offloaded to tankers via stern loading. Åsgard A produces and supplies power to Åsgard's subsea gas compression system. The 100-bed living quarters are located at the front. A total of 70 people were on board on 31 January.

Figure 1: Åsgard A (Source: Equinor)

Organisationally, Åsgard A is affiliated to Exploration and Production Norway (EPN EPN). The organisational structure is shown below.

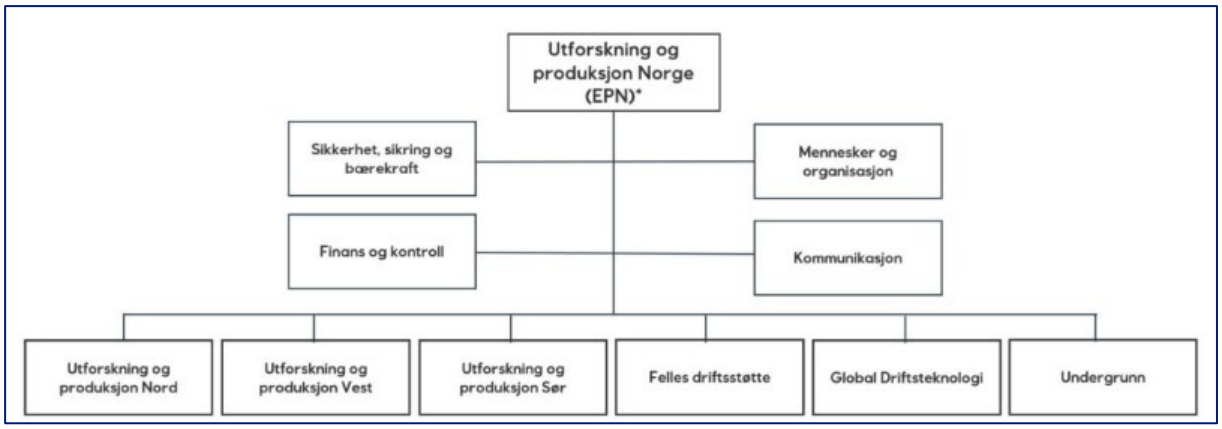


Figure 2: Organisation chart Exploration and Production Norway (EPN) (Source: Equinor)

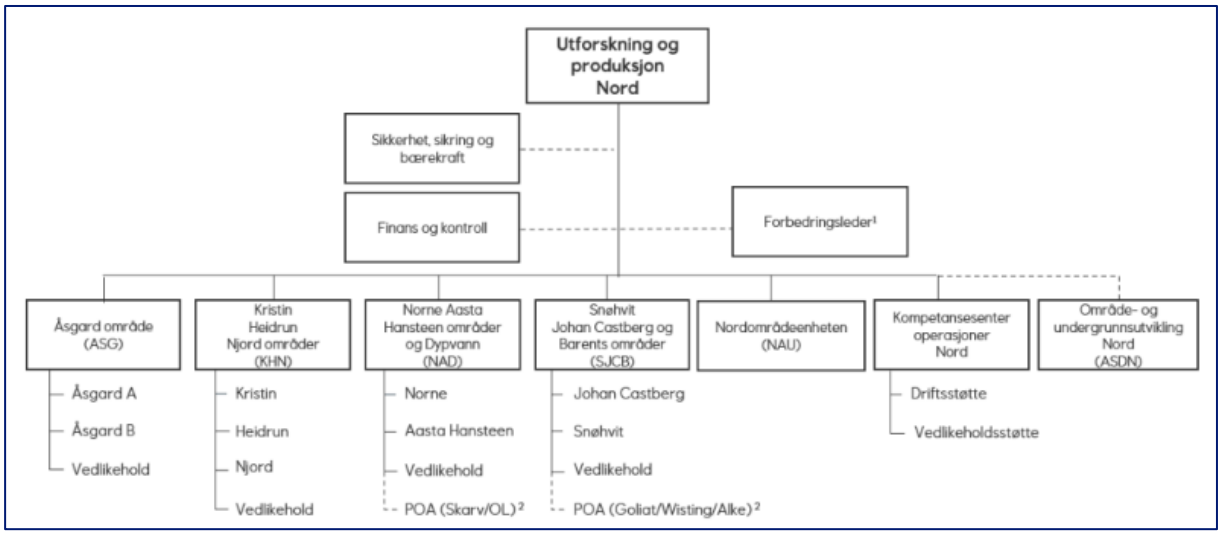


Figure 3: Organisation chart Exploration and Production Norway (EPN EPN) (Source: Equinor)

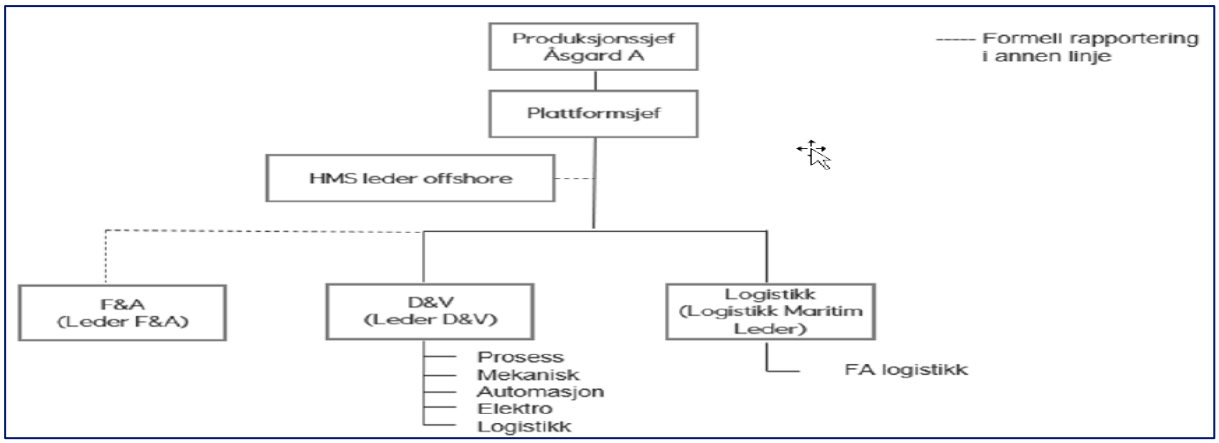


Figure 4: Organisation chart Åsgard A (EPN EPN ASG) (Source: Equinor)

3 Situation before the incident

3.1 Green water modifications on Åsgard A

Åsgard A was under construction and was installed after Norne FPSO had been positioned in the field and become operational. Norne FPSO had already experienced

incidents involving green water. Model tests and calculations were therefore carried out on Norne FPSO. These green water events and model tests led to the bow of Åsgard A being raised by 4.7 metres compared with Norne FPSO during construction. Sheltering walls were later retrofitted to the tank deck and exposed equipment was protected, relocated or modified.

On Norne FPSO, winter operations condition was introduced with limited draught combined with aft trim to ensure equivalent protection against green water. The windows at the front of deck 8 were permanently covered as recommended in the model test report (1999). After the green water incident in 2019, the windows at the front of deck 9 were covered and operational restrictions introduced concerning the use of front cabins during harsh weather.

3.2 Description of Åsgard A bow and living quarters

Deck 8 at the foreship consists of weather decks (in front of and on both sides of the living quarters) and storage areas at the back of the living quarters. An emergency evacuation shaft is positioned at an angle to the window of cabin 812.

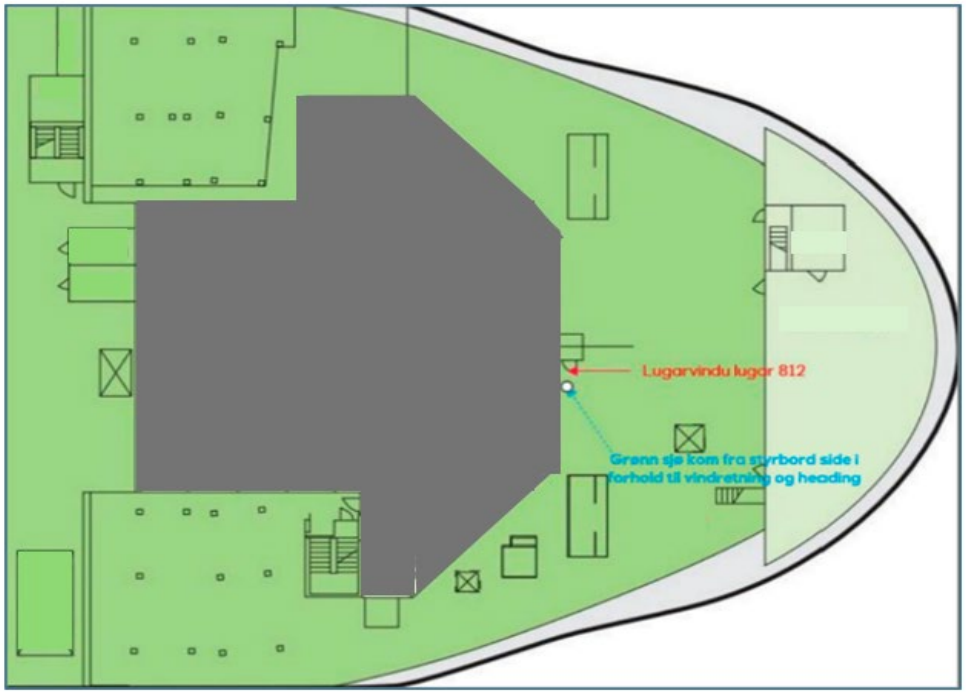


Figure 5: Living quarters, weather decks and outdoor areas on deck 8 (Source: Equinor)

Equinor states that the construction specification (Main Specification) imposed requirements on the design of windows in the living quarters, stipulating that it must be possible to carry out maintenance and replacement from the inside: *The design of the windows shall be such that all maintenance and repair, including replacement of inner and outer glass, can be carried out from the inside.*

The window of cabin 812 is of type W1, as shown in Figure 6 Window plan, with A60 fire resistance and a 670x1050mm glass area (W x H). The external dimensions of the window including the frame are 735x1110mm. The glazing consists of tempered outer glass, a gas layer and laminated tempered glass consisting of two glass panels and a flexible polymer panel with fire-resistant properties.

The type W1 windows are mounted using 8mm bolts screwed into threaded holes through the outer frame. The outer frame is a prefabricated, 4mm-thick profile made of 37-2 grade steel with a yield strength of 235 MPa and a tensile strength of approx. 370 MPa. The frame itself is welded using a 3.5mm fillet weld on the outside and inside of the bulkhead.
Equinor's investigation report shows that 26 bolts are used to secure the window, based on the photographs taken after the incident. However, 22 bolts are shown on drawing C055-HX-C-XF-7550-07. It is uncertain whether this difference is due to a typographical error or later revision of the drawing.

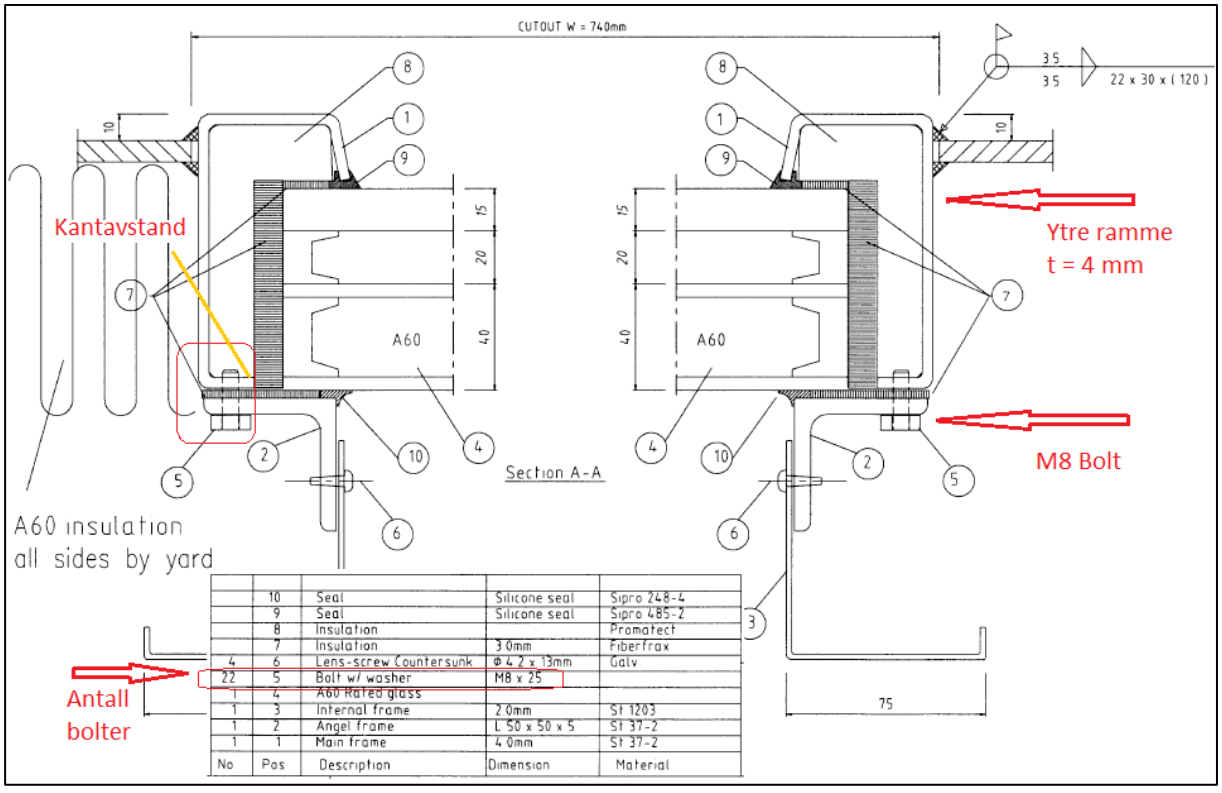


Figure 6: Extract from drawing C055-HX-C-XF-7550-07, rev. 01F (source: Equinor)

It is assumed that the windows are installed by drilling and threading the outer frame at the construction site. The part of the outer frame used for attachment is measured on the drawing above as being 20mm, including a plate thickness of 4mm. Edge distances for the window's bolted connection were measured and are shown in Table 4-2 of Equinor's investigation report. Edge distances ranged from 2.2mm to 7.6mm, which is significantly less than the value of 1.2 times the bolt hole diameter specified in the NS 3472 standard dating from 1984.

As the chosen attachment method was difficult and the margins for adjusting the windows in situ were small, this resulted in bolt holes generally having small edge distances and, in the case of the broken window, two bolt holes which did not have a full circumference.

The way in which the window was installed to the wall made it difficult to check that the attachment was correct once the window had been fitted. Removing the frame to check that it had been attached correctly would lead to a risk of over-tightening the bolts.

Equinor's investigations following the incident have shown that some of the bolts on the windows of neighbouring cabins were loose and some were over-tightened. Errors such as using a large drill diameter, poor (incomplete) threading and corrosion of the threaded section of the bolt holes, as well as short engagement length, are likely to have significantly reduced the actual capacity of the bolted connection compared with the theoretical capacity of the bolt hole threads.

In its review, Equinor found no documentation concerning strength calculations for windows in living quarters and cabins. Equinor states that the specification for the living quarters has probably been shredded in accordance with its archiving period requirements.

Current requirements applicable during the construction period of Åsgard A do not provide specific details on the design of cabin windows in living quarters, including *Regulations relating to systematic supervision of the working environment in the petroleum industry* published in August 1995. NORSOK standard C-CR-002 rev. 1 Architectural components and equipment published in May 1996, Chapter 3, Windows and glazed surfaces, Subchapter 3.5.1 state that *All window frames shall be continuously welded to the outside surface of the external bulkheads or prefabricated walls. Bolted windows may be used, if approved by the project*. And further: *The design of the windows shall be such that all maintenance, repair and replacement of glass can be carried out from the inside*.

This indicates that the construction specification for Åsgard A cabin windows used the applicable design practice.

3.3 Operational condition and heading

Equinor's investigation report describes Åsgards A's movements prior to and during the incident. Data for its analysis has been taken directly from the DP system, and we have no reason to question this data.

The data indicates that Åsgard A's heading was within the normal 10 degrees towards the weather. As a result of the wave event, the ship was pushed approx. 25m east and approx.18m north. The heading changed by approx. 5 degrees, but remained within the normal 10 degrees towards the weather.

According to Equinor's investigation report, at the time of the incident, Åsgard A had a draught measured amidships of 18,455m with an aft trim of 3,493m (0.7758 degrees). This gives a freeboard above still water level of 22.8m on the forward perpendicular (FP), and 18.9m at the bulkhead towards the bow (front wall of living quarters). This means that, during the incident, Åsgard A had approximately 0.5m less freeboard above still water level at the living quarters than Norne FPSO is able to operate with when in winter condition. Equinor also states that the freeboard on the FP was 3.2m higher on Åsgard A than the minimum for Norne FPSO in winter condition.

Within the operating criteria for Åsgard A, the freeboard in line with the living quarters may be less than the equivalent on Norne FPSO. This is because, during the winter months, Norne FPSO has introduced loading condition with a higher freeboard.

Equinor considers it likely that this incident was caused by a wave coming from the starboard side rather than over the bow. We have no reason to doubt this conclusion.

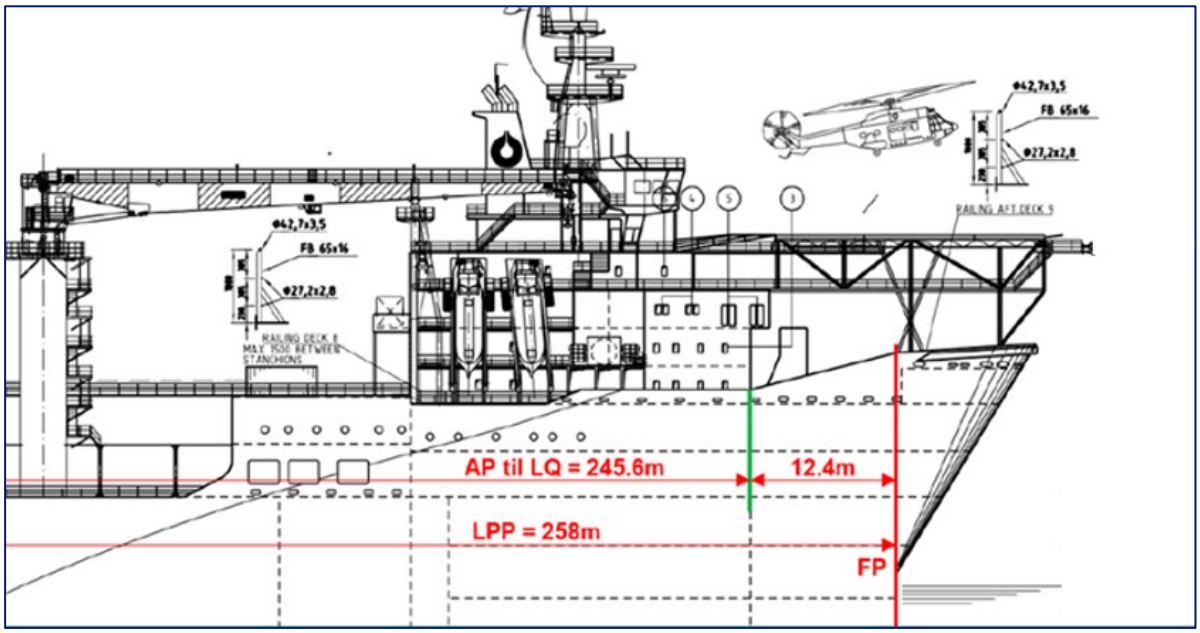


Figure 7: Deck elevations for description of freeboard above still water level to LQ and FP. Illustration for Åsgard A. (Source: Equinor)

3.3.1 Documents on preparatory measures for bad weather

Document "GL0639 - Local guidelines for operational measures in relation to weather preparation – Åsgard A" describes preparatory measures for bad weather. It states

that production should be suspended and recommends depressurising the processing plant when weather involving significant wave heights in excess of 14m is forecast. In case of a weather forecast involving significant wave heights in excess of 12m, the weather must be monitored and reported at increased frequency.

The guidelines do not describe any specific operational measures such as trim and draught of Åsgard A in relation to green water in bad weather.

The separate procedure that follows from "WR 1156 Supplement to: Emergency preparedness on the Norwegian continental shelf – Åsgard A, App B Procedures for extreme weather (B.5, B.6 and B.7)" must be followed and includes measures such as:

- Sea fastening and checking of sea fastening,
- Closure of the tank deck and traffic to/from the turret,
- Verifying operation of the thrusters,
- Assessing ballast, anchor tension and storage situation.

Interviews indicate that the guidelines and procedure were implemented prior to the incident.

4 The Norwegian Ocean Industry Authority's investigation

The Norwegian Ocean Industry Authority (Havtil) was notified of the incident by Equinor on 1 February at 19.03. On 6 February, a meeting was held with Equinor for updates on the incident, and on 8 February, Havtil decided to launch an investigation.

4.1 Mandate and composition of the investigation team

The following mandate was approved for the investigation team:

a. Determine the scope and course of the incident (using a systematic review that typically describes timeline and events).
b. Assess the actual and potential consequences for
    1. Harm sustained by people, property and the environment.
    2. The incident's potential for harm to people, property and the environment.
c. Assess direct and underlying causes.
d. Identify regulatory non-conformities and improvements relating to regulations (and internal requirements).
e. Discuss and describe any uncertainties/unclear issues.
f. Consider barriers that did function. (i.e. barriers that helped to prevent a hazard from developing into an accident, or barriers that mitigated the consequences of an accident.)
g. Assess the company's own investigation report.
h. Prepare a report and cover letter (potentially including suggestions for use of enforcement powers) according to the template.

i. Recommend – and normally contribute to – further follow-up.

It was decided that the investigation team would not travel on board to Åsgard A.

The investigation team consisted of:

[redacted]

4.2 Methodology

The investigation work consisted of collecting and reviewing necessary documents. Interviews have been conducted with personnel from Åsgard A, including the offshore installation manager, logistics maritime manager, incident commander for emergency teams and the main safety delegate, as well as the specialist responsible for constructions and marine systems. Equinor's own investigation report was received on 5 July and formed the basis for our work.

The investigation was based on investigating conditions during the period from 31 January at 16.54 until conclusion of the muster on board Åsgard A at 00.30 on 1 February. The immediate preparations for the reported weather situation were also investigated. Regarding matters relating to the design, construction and modifications of Åsgard A which are considered to be contributory causes behind the incident and the extent of the damage, we have used Equinor's investigation report and associated technical investigations and assessments. A number of underlying causal factors are attributed to choices made a long time ago regarding the design, execution of construction works, recommendations and assessments of green water measures, among other things. We have not specifically investigated these factors, and we used Equinor's own investigation report as a basis.

On 26 September 2024, we held a meeting with Equinor regarding their handling and further follow-up of the recommendations from their own investigation report.

5 Sequence of events

5.1 Meteorological conditions at Haltenbanken on 31 January

In the investigation report, Equinor reports the meteorological conditions as shown in Table 1. The Norwegian Ocean Industry Authority has also received NORA3 data from the Norwegian Meteorological Institute, which is also included in Table 1.

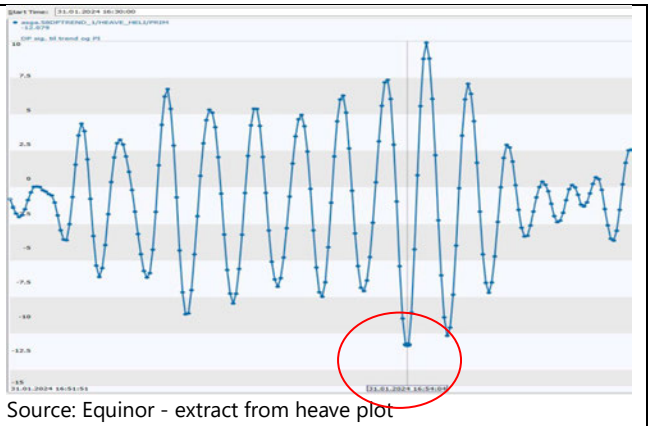
	Equinor (2024)	NORA 3 – DNMI (UTC time 16.00)
Total sea waves	Hs=10.8m Tp=14.3s Dir=214 degrees	Hs=12.9m Tp=14.86s
Wind-driven waves	Hs=10.3m Tp=11.4s Dir=210 degrees	Hs=12.88m Tp=14.86
Swell	Hs=2.8m Tp=13.1s Dir=270 degrees	Hs=0.54m Tp=16.35 (directional deviation of approximately 60 degrees from wind-driven and total sea waves)

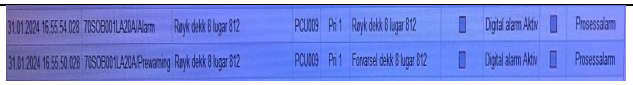
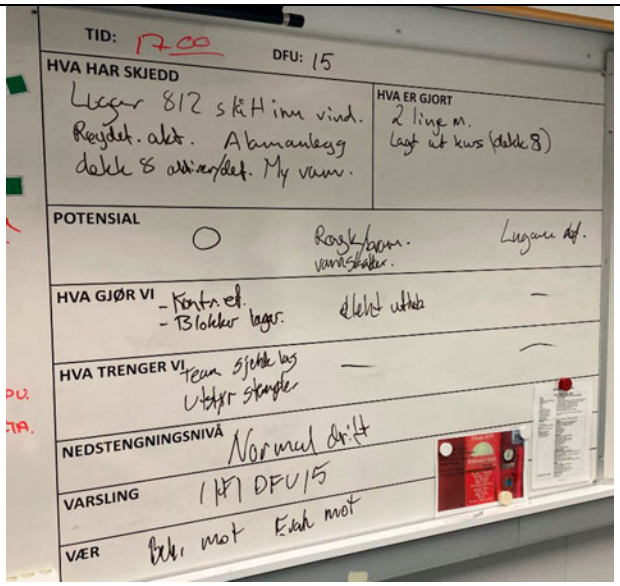
Table 1 Weather situation

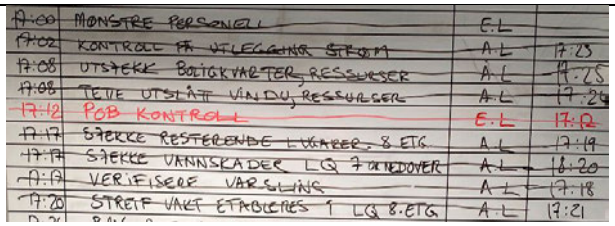
Equinor uses actual measurements, among other things, while the data from the Norwegian Meteorological Institute is based on a hindcast model. The deviations are slightly greater than expected and may indicate that the estimates from Equinor are slightly on the low side. However, in practice it is more serious if such an incident could occur in the sea state described by Equinor.

Equinor states that Åsgard A receives wave data from a local wave radar. Equinor's investigation report further states that errors have been reported on this radar.

5.2 Description of the incident during the period from 16.54 on 31.1 to 00.30 on 1.2

Time 16.54 The heave movement indicates that Åsgard A is situated deep in one of the waves.	 Source: Equinor - extract from heave plot
Alarm indicating loop fault, loops A and B, on the fire and gas alarm system.	 Source: Equinor - extract from alarm log

Time 16.55 Smoke alarm on deck 8 from smoke detector in cabin 812. PA notification of smoke detector alarm in cabin 812. Orders given for *searches and reports*. Alarm with muster at alternative muster location, deck 10.	 Source: Equinor - extract from alarm log  Source: Equinor - extract from GA log
Time 16.55 - 17.00 Offshore installation manager in position in the central control room (SKR) – first meeting in emergency preparedness room. Alerts second line, but second line does not muster. Emergency response vessels requested to sail from Heidrun to Åsgard A. Search and rescue teams in position in living quarters at the damage site cabin 812. Smoke observed emerging from emergency light switch and burning smell from cabin 812's electrical system, window observed to be broken. Large quantities of water reported in cabins, corridors and adjacent cabins on deck 8. Message given to check other cabins for windows/damage. Lead electrician arrives and establishes circuits on deck 8, stops smoke generation from the emergency light switch, and reports a ground fault in the fire alarm system, loop deck 8.	 Source: Equinor - extract from whiteboard in emergency room

Report by radio of sighting of loose objects out on deck. Search and rescue teams clear and secure loose items on deck.	
Time 17.05 Other windows checked. Damage to neighbouring cabin 811 from water that has come through the ceiling.	
Time 17.12 POB check, no one injured.	 Source: Equinor - extract from whiteboard in emergency preparedness room
Time 17.20 Patrol watch established on deck 8.	
Time 17.24 Resources in place to prepare cabin window cover.	
Time 17.25 Check-out of living quarters under deck 8 started.	
Time approx. 17.40 Preparations underway to find a solution to cover the cabin window with a steel plate.	
Time 18.12	

Overview of water damage on deck 7 established.	
Time approx. 19.30 Cover plate installation plan approved. No attempt was made to install the cover plate with personnel located inside and outside due to the weather conditions. Cover plate modified to enable installation from the inside.	
Time approx. 20.30 Steel plate installed to cover the cabin window opening. Work team muster on deck 10.	 Source: Equinor - extract from Synergi Report #3039984
Time 21.00 Towards gradual normalisation. Troubleshooting of the fire and gas warning system, deck 8. All personnel remain on deck 10.	
Time approx. 22.30 Short debrief for personnel on deck 10.	
Time approx. 00.30 Muster on deck 10 concluded. Patrol watch every half an hour overnight on deck 8. Parts of the fire and gas	

warning system operational on deck 8.	

5.3 Cabin window forced in by green water

Equinor's investigation report assumes that the most likely sequence of events is that the window frame and window came loose at the bottom and were pushed up through the ceiling by the water that was forced into the cabin and then landed on the floor. The glass most likely broke due to stresses in the frame as the window was forced in. Equinor has used an external party to assess the likely sequence of events.

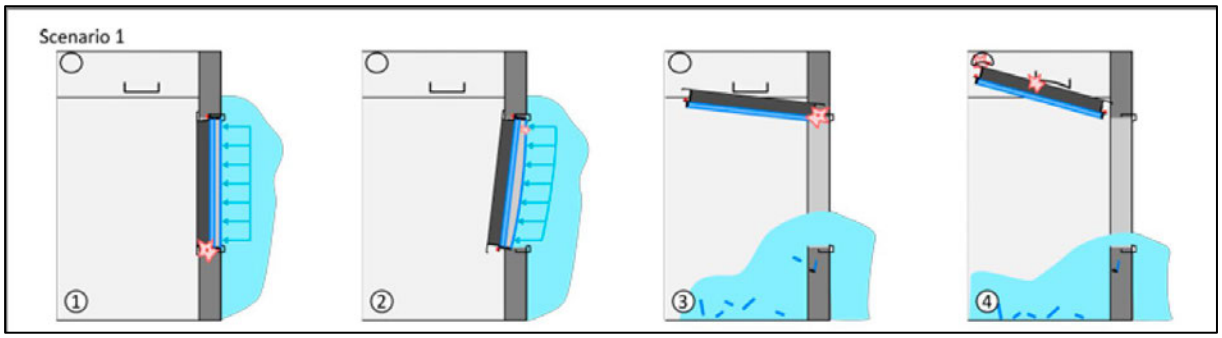


Figure 8: Most likely sequence of events (Source: Equinor)

The bolts along the top edge of the window were the last to become detached and acted as hinges before being wrenched out of their fixings. Finally, the window and frame landed on the floor.

We see no reason to doubt this description of the sequence of events.

6 Potential of the incident

Actual consequences

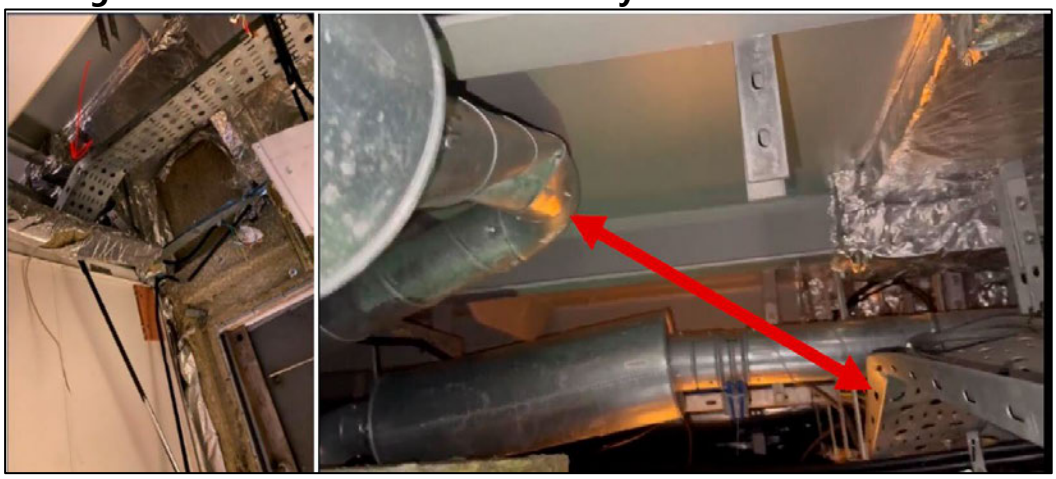
No one was harmed during the incident. There were no one in cabin 812 or in the corridors on deck 8, but personnel from the night shift were using other cabins on deck 8.

The incident caused material damage where the window and frame of cabin 812 were broken. The window's outer and inner glass layers were smashed into lots of small round fragments. Seawater was washed into the living quarters on deck 8 and down the elevator shaft and stairs to the stairway on deck 7. Water got under the cabin's ceiling panel and flowed from there into the adjacent cabins 810, 811 and 813. Water penetrated deck 7 and the ceiling of the medical facility. Ventilation pipes and cable trays in the ceiling of cabin 812 were damaged. External cable trays and lighting fixtures were damaged during the incident. The fire-protection box on the front deck came loose and parts of the box and fire hose were found inside cabin 812.

Damage to cabin 812

Source: Equinor – still image from mobile recording

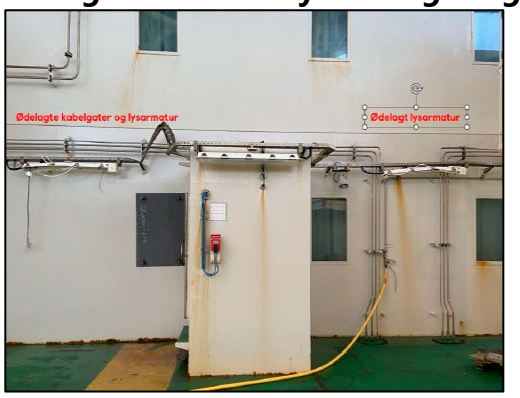
Damage to ventilation duct and cable trays in cabin 812



Source: Equinor

Fire-protection box attachment torn-off

Damage to cable trays and lighting fixtures



Source: Equinor - extract from Synergi report #3039984

There were no discharges in connection with the incident. The incident did not result in a production shutdown.

Potential consequences

Cabin 812 was used by personnel on the day shift, but the cabin is available for use during working hours. The cabin is also available for cleaning staff. Had the incident occurred when people were in the cabin, the window and the frame as well as seawater would probably have hit them and caused a serious injury or fatality.

7 Direct and underlying causes

7.1 Direct causes

Green water event

A wave hit Åsgard A, which led to green water entering from the starboard side of the foreship. The pressure from the green water exceeded the load resistance of the window in cabin 812. The window and its frame were forced into the cabin.

7.2 Underlying causes

Location of emergency escape shaft

The window of cabin 812 is positioned at an angle close to an emergency escape shaft, which may have resulted in the green water hitting the window with a greater pressure.

Design and execution of the window connections

The fixing design resulted in vulnerabilities. The inner and outer frames were secured to each other using bolts, but no nuts. The holes in the outer frame had to be drilled out and threaded at the construction site, and were the only arrangement for withstanding external forces on the window fixing. It would have been difficult to get the positioning correct when attaching the inner frame to the outer frame. Other factors also made mounting difficult, such as the use of low strength and thin (4mm-thick) steel, which both made it easy to over-tighten the bolts and impossible to see

how the threaded holes meet the outer frame, as the inner frame obscures them. It would have been easy to use the wrong diameter when drilling and threading holes at the construction site. There was a vulnerability in that a worn threading tap could have caused the threads to be ripped out, rather than cut out. Torque on the M8 bolt would have caused over-tightening, as the tensile strength of the outer frame is 370 MPa compared with the bolt which has a tensile strength of 800 MPa.
Threaded holes were the only source of load resistance, as the installation was designed without the use of nuts on the bolts.

The window fixing in the wall made it difficult to check that the attachment was correct once the window had been installed. Removing the frame to check that it had been attached correctly would lead to a risk of over-tightening the bolts.

Equinor's investigations of windows in the neighbouring cabins (cabins 811 and 813) showed loose bolts and over-tightened bolts. Equivalent weaknesses were also assumed to be present in the window of cabin 812. The installation of the window in cabin 812 also involved two holes which did not have a full circumference, and the window was mounted crooked, too low and too far towards the port side, with the result that most of the bolts in this window had a reduced edge distance.

The window's load resistance was reduced and less than the pressure exerted by the green water hitting cabin window 812.

Inadequate protection of cabin windows
Equinor's review of available documents, including both the construction specification and experiential documentation, revealed requirements and recommendations for the covering of cabin windows.

Among other things, the contract for the design of Åsgard A (Main Specification) stipulated requirements for removable weather protectors over the windows at the front of deck 8: *"In addition all windows in the accommodation on deck 8 facing forward shall be equipped with outside removable scuttles (weather protectors)."*

During the period 1999-2002, operational experience with the FPSOs indicated recommendations relating to green water and specifically for Åsgard A:

- *"Windows facing forward on the two first floors of the living quarters should be sheltered during winter season*." (1999: Statoil, Norne FPSO Assessment of Green Water on Deck, Chapter 8 Åsgard A issues)
- "*The front windows on the two lowest decks should be protected during the winter*." (2000: Green Water, meeting at NPD, Conclusions for Åsgard A)
- "*Front windows on the lowest decks should be sheltered during the winter season*." (2002: Statoil, Presentation: FPSO and Green Water, Recommendations for FPSO Åsgard A)

Equinor has not found any documentation which explains why the recommendations to protect the cabin windows on decks 8 and 9 were not implemented. In addition, no documentation has been found concerning these recommendations in Equinor's established system for extracting lessons/implementing recommendations. The specification regarding the ability to cover cabin windows was apparently not implemented/delivered from the shipyard, and no documentation has been found of assessments or decisions explaining why this did not happen.

Equinor argues that a belief that green water did not pose risk to the facility or personnel on board may have contributed to the failure to implement physical or operational measures on Åsgard A. The bow of Åsgard A was raised 4.7 metres relative to the bow of Norne FPSO, sheltering walls were retrofitted to the tank deck, and exposed equipment was protected, relocated or modified.

Lack of green water model tests

The issue of green water as a challenge on FPSOs was largely overlooked when the first FPSOs were introduced on the Norwegian continental shelf, but the industry gradually became more aware of the issue during the 1990s. It became clear from model tests that FPSOs could be subjected to substantial loads, both in the bow area and on tank decks.

Model tests were therefore conducted for Norne FPSO which identified severe green water events. Measures were implemented in Norne as a result of these tests (including an aft trim in winter that raised the bow by 5m and permanent covering of windows in living quarters on deck 8).

No separate model tests were conducted either during or after the design stage to assess green water on Åsgard A. The model tests on Norne FPSO were used to assess the hazards and consequences of green water on Åsgard A with, according to Equinor's investigation, flawed assumptions relating to a higher freeboard in line with the living quarters and without implementing corresponding operational measures.

Despite the lack of facility-specific model tests, measures were also recommended for Åsgard A, including raising the bow by 4.7 m and covering the front windows in the living quarters on deck 8 during the winter season. The covering of windows in the living quarters was not implemented, possibly due to the lack of model tests highlighting the need for these measures.

The lack of model tests may also have contributed to the risk of green water in the bow area from perpendicular waves (rough sea) not being sufficiently assessed.

Lack of follow-up of observations
An audit was conducted in 2020 targeted at the integrity of structures and maritime systems on Åsgard A and B. As a result of this audit, Equinor identified an improvement point relating to carrying out assessments of original green water results on Åsgard A against current metrological and oceanographic specifications. Equinor's investigation team has not found any evidence that this has been carried out.

If another review had been carried out, this could have triggered a model test and better mapping of hazards and consequences relating to green water. This could have led to a decision to protect the windows in the living quarters on deck 8.

8 Emergency preparedness

When the smoke detector alarm in cabin 812 was activated, it was reported that a window had been broken and that there were large quantities of water in cabin 812, the corridor and the adjacent cabins on deck 8.

The management team was preparing for the evening meeting, right next to the central control room when it was informed about the incident. The first-line emergency preparedness management was then mobilised, and the second line was notified. A general alarm was issued and personnel without any emergency tasks were asked to muster at an alternative muster station.
It was decided that the emergency response vessel should head to Åsgard A, but at a slow speed as the weather was bad and it was not an emergency. The emergency response vessel was at Heidrun at the time.

Before the first meeting, they verified that deck 8 had been rendered electrically dead. Immediately after the emergency preparedness management had held its first meeting, they conducted a POB check.

The emergency preparedness management decided to keep personnel at the alternative muster location until they had secured the window and gained control over the situation.

The emergency preparedness management decided to order patrol watches every half an hour throughout the night, as only parts of the fire and gas plant were operational.

In our assessment, the emergency preparedness on board worked well.

9 Observations

Havtil's observations are generally divided into two categories:

Non-conformity: Observations where we *prove* the existence of a breach/non-compliance with respect to the regulations.

Improvement point: Observations where we *believe we have seen a* breach/non-compliance with respect to the regulations, but do not have sufficient information to be able to prove it.

9.1 Non-conformity: Inadequate assessments of green water

Equinor has not ensured that analyses and assessments for decisions concerning green water are based on appropriate models, methods and data.

Rationale
No adequate assessments of green water with associated model tests were performed on Åsgard A during the design and fabrication phase or thereafter. The model tests on Norne FPSO were used to assess the hazards and consequences of green water on Åsgard A based on assumptions which, according to Equinor's investigation, were flawed.

Model tests on Norne FPSO and calculations relating to green water events led to the bow of Åsgard A being raised by 4.7 metres during construction compared to Norne FPSO. Winter operations condition was introduced on Norne FPSO in 1999, with limited draught combined with aft trim to ensure equivalent safety levels with regard to green water. During the incident, Åsgard A had around 0.5m less freeboard above still water level at the living quarters than Norne FPSO is able to operate with when in winter operations condition. There were no special operational measures such as specific draught and trim on Åsgard A in relation to green water in bad weather. After the green water incident in 2019 with Norne FPSO, the windows on the front of deck 9 were covered, and operational restrictions introduced concerning the use of cabins at the front during bad weather.

The need to carry out assessments of original green water results on Åsgard A with respect to applicable meteorological and oceanographic specifications has previously been identified. Equinor's investigation report states that no documentation has been found which indicates that corrective measures have been taken.

The incident shows that the adopted technical solution of raising the bow does not sufficiently reduce the likelihood of damage, faults and hazard and accident situations occurring. The incident further shows that models, methods and data have not been sufficient.

Requirements
The Management Regulations, Section 4 concerning risk reduction, first paragraph
The Management Regulations, Section 16 concerning general requirements for analyses, first paragraph

9.2 Non-conformity: Lack of compliance with internal requirements for covering cabin windows and inadequate utilisation of experiential knowledge

Equinor has not corrected non-conformities with respect to internal requirements concerning provision to cover cabin windows at the front of deck 8 on Åsgard A with weather protectors. Experience from its own operations has not been sufficiently utilised in the improvement work.

Rationale
The construction specification's design requirement for removable weather protectors and repeated recommendations during the period 1999 – 2002 concerning the covering of front cabin windows on decks 8 and 9 during the winter season have not been followed by Equinor.

The contract for the construction of Åsgard A included a requirement for removable weather protectors for the cabin windows at the front of deck 8. The specification regarding provision to cover cabin windows was apparently not implemented/delivered from the shipyard. No documentation of assessments or decisions explaining why this was not implemented/delivered has been found.

During the period 1999-2002, operational experience linked to green water with FPSOs and specifically with Åsgard A indicates repeated recommendations concerning the covering of front cabin windows on decks 8 and 9 during the winter season. No documentation has been found as to why the recommendations on protecting the cabin windows on decks 8 and 9 were not implemented. In addition, no documentation has been found concerning these recommendations in Equinor's established system for extracting lessons/implementing recommendations.

Requirements
The Management Regulations, Section 22 on handling of non-conformities, first and second paragraphs
The Management Regulations, Section 23 on continuous improvement, last paragraph

9.3 Non-conformity: Weakened load resistance of cabin windows

The technical solution adopted for mounting the cabin windows did not sufficiently reduce the likelihood of damage, faults and hazard and accident situations. No essential measures were implemented to correct or compensate for this impairment; cf. the green water meeting at the Norwegian Petroleum Directorate in 2000.

Rationale
The type W1 windows are mounted using 8mm bolts screwed into threaded holes through the 4mm-thick outer frame. It is assumed that the windows were installed by drilling and screwing the outer frame at the construction site.

The installation method that was chosen was difficult and the margins for adjusting windows on site were small, which resulted in the bolt holes generally having a small edge distance. In the case of the broken window, two bolt holes did not have a full circumference. The way in which the window was secured to the wall made it difficult to check that the attachment was correct once the window had been fitted. Removing the frame to check that it had been attached correctly would lead to a risk of over-tightening the bolts.

Examination of the window connections in neighbouring cabins showed that some of the bolts were loose and some were over-tightened. Errors such as using a large drill diameter, poor (incomplete) threading and corrosion of the threaded section of the bolt holes, as well as short insertion distance, are likely to have significantly reduced the actual capacity of the bolted connections compared with the theoretical capacity of the bolt hole threads.

The design of the window connections was flawed which enabled installation errors, made it difficult to check the installation and resulted in reduced load resistance.

Requirements
The Management Regulations, Section 4 concerning risk reduction, first paragraph
The Management Regulations, Section 5 concerning barriers, last paragraph

9.4 Improvement point: Wave measurements and meteorological observations

Equinor does not appear to have ensured that meteorological and wave conditions that are of importance for the proper execution of the activities on Åsgard A are monitored and kept under control at all times.

Rationale
The safe operation of FPSOs in bad weather relies on precise, complete and timely information on meteorological and oceanographic conditions to ensure that correct decisions can be made on board the facility.

Equinor states that Åsgard A uses a wave radar installed on Åsgard B to provide information about waves, and that this has a number of known limitations. For example, the wave radar cannot adequately determine what the true storm peak was. Furthermore, Equinor's investigation report states that being "at the mercy of real-time wave information from only one [wave] Radar" hinders good decision-making during events. It is stated that there also used to be wave buoy which ensured that two sources of wave information were available.

According to Equinor's investigation report, searches in SAP show a number of M2 notifications on the radar.

Equinor's investigation report points out that historical data on weather and vessel movements is only available (in Fugro North Star) for about a week. This means that it is not possible to carry out the necessary analyses in order to learn lessons based on historical information.

Requirements:
The Activities Regulations, Section 31 on monitoring and control, first paragraph, cf. the Management Regulations, Section 19 on the collection, processing and use of data

10 Barriers that did function

Prior to the incident, attention on board was directed towards sea fastening. Notification of a general restriction on going out on deck was enforced at approximately 14.00 and the last work permit was deactivated at approximately 16.00 on 31 January. The central control room (SKR) uses a checklist of actions which are to be carried out in the event of poor weather being forecast, and WR1156 defined the actions that should be taken in the event of different criteria being met.

The emergency preparedness organisation mustered and gave notification in accordance with the plan for DSHA 15 for extreme weather conditions.

11 Discussion concerning uncertainties

At the time of the incident, there was no one in either cabin 812 or the corridor on deck 8. There were no eyewitnesses to the sequence of events when seawater forced the window and frame into the cabin. Equinor based its internal investigation on the most likely sequence of events. We have no reason to doubt this sequence of events.

Equinor states that some documents from the construction phase/construction project were not available in the last revision, and that the last available revision was used in their investigation work. The specification for the living quarters was probably

shredded in accordance with its archiving period requirements. We have used the factual information provided in Equinor's investigation report.

12 Assessment of the company's investigation report

Equinor has conducted a corporate investigating at assignment level 2, with the director of Åsgard (EPN EPN ASG) as the client. We received the report on 5 July 2024. The actual consequences of the incident are classified as *Red 1 Critical weakness or barrier failure* on the basis that green water caused structural damage that load-bearing structures (the living quarters) should be designed to withstand. Possible consequences have been classified as *Red 1 Potential fatality under slightly different circumstances*, with the assessment that had someone been inside the cabin, this could have resulted in a fatality. Three people who were out on deck for a short period of time to remove loose objects would have been at risk had more green water struck during this period. While the plate was being fitted over the window, four people were present in cabin 812. If more green water had struck with a similar force while the plate was being fitted, this could have resulted in one or more fatalities.

The investigation report sets out recommendations in nine learning and improvement areas, which have been considered by a separate working group and are included in a learning plan for transfer to Synergi.

The causes of the incident correspond to our assessments of the sequence of events and causal links.

13 Abbreviations

DNMI	Norwegian Meteorological Institute
DSHA	Defined situation of hazard and accident
DP	Dynamic Positioning
FA	Responsible Professional
FPSO	Floating, Production, Storage and Offloading
Hs	Significant wave height
LQ	Living quarters
NORA 3	Norwegian Meteorological Institute hindcast database
PA	Public Announcement
POB	Personnel On Board
SKR	Central Control Room
Tp	Peak wave period (spectral wave period)
UTC	Coordinated Universal Time
WR	Work Requirement

14 Annexes

A: The following documents were used as a basis for the investigation:

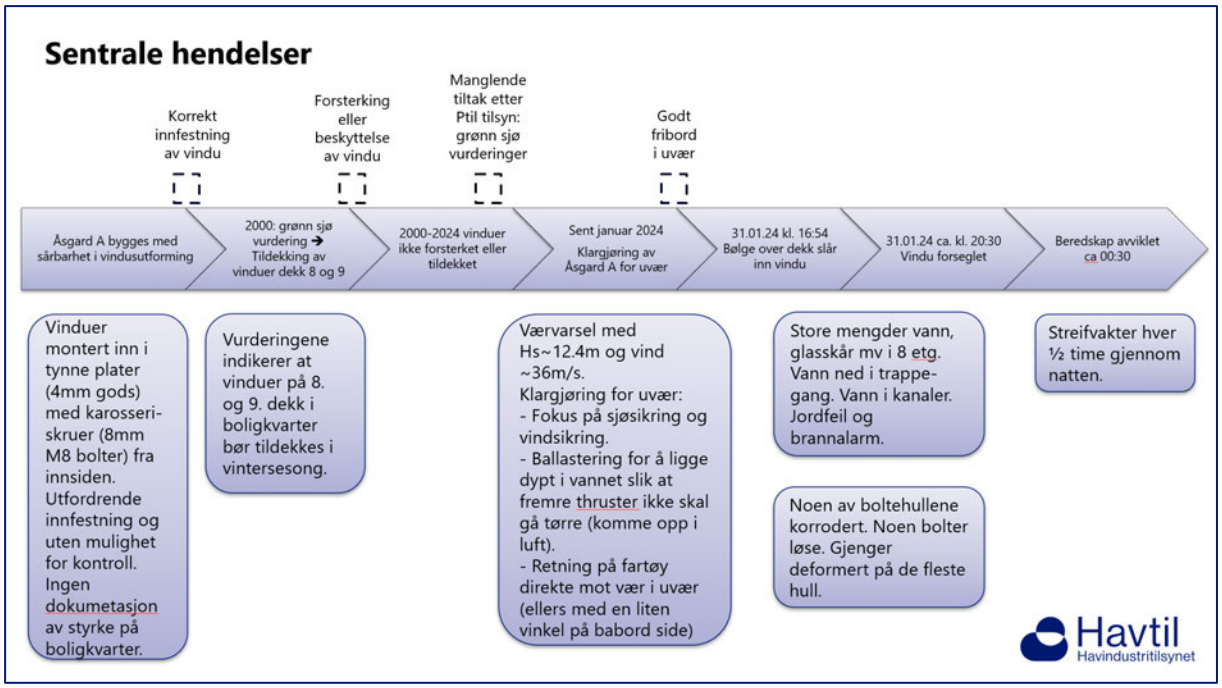
1. Notification of incident – submitted 01.02.2024
2. Synergi report #3039984 (preliminary) - Cabin window forced in by fire-protection box during bad weather
3. Meeting minutes – Information about the incident on Åsgard A 31.1.2024 – window forced into cabin, date 06.02.2024
4. Mandate for Equinor's investigation HSE incident on Åsgard A, signed on 12.02.2024
5. GL0639 Local guidelines for operational measures in relation to weather preparations – Åsgard A, version no.: 1.02, last revised on 16.07.2021
6. App B Extreme weather procedures (from WR1156 annex to: Emergency preparedness on the Norwegian continental shelf – Åsgard A version 18)
7. Åsgard A loading condition, print-out 14.02.2024
8. Overview of wind, thruster power and direction, maximum roll, pitch and heave prior to the event, time interval 31.01.2024 from 15.30 to 16.30
9. Time series Gyro 31.01.2024 with five-minute averaging
10. Time series Gyro 31.01.2024 between 16.30 - 17.30 with one-second averaging
11. As-built drawing W1 A-60 rated offshore window, C055-HX-C-XF-7550-07, rev. 01F
12. Construction drawing Window plan, C055-MT-C-XE-0018-01, rev. 03
13. As-built drawing Plot plan Deck no 8 QB21, C055-HZ-L-XE-0210-01, rev. 03
14. As-built drawing Plot plan Deck no 8 FH20, C055-HZ-L-XE-0210-02, rev. 03
15. Construction drawing Arrangement Accommodation Deck 8 1 of 2, C055-MT-C-XE-0003-01, rev. 03
16. Construction drawing Arrangement Accommodation Deck 8 2 of 2, C055-MT-C-XE-0003-02, rev. 03
17. Photographs of cabin 812
18. Equinor note “Ingunn storm on January 31st – February 1st 2024“, MCM-ME2024-029, date 07.02.2024
19. Equinor Timeline event ASG A, received on 22.02.2024
20. Maritime Operations Manual – Åsgard A – Operating Procedure, SO09401, version no.: 3, last revised on 06.12.2021
21. Equinor Video of water in corridor area on deck 8
22. Images of whiteboards in the emergency preparedness room during the incident on Åsgard A, 31.1.2024
23. Alarm log from the central control room (SKR) - Alarm in cabin 812 at 16.55 and time of initiated GA
24. Heave plot for the time period 16.51.51 – 16.59.55
25. Updated time series for weather and movement on Åsgard A for the time period 16.30 – 17.30 on 31.1.2024
26. Explanation of draught Åsgard A in case of bad weather, email dated 22.3.2024

27. Questions to Equinor concerning protection of front windows on decks 8 and 9 with attachment - Statoil presentation Green water assessments, email dated 18.3.2024
28. Answers to questions about protection of front windows on decks 8 and 9, email dated 5.4.2024
29. Application for consent for extended operation of Åsgard A, AU-ASG-00131, date 06.02.2018
30. Investigation report - Incident involving cabin window and green water on Åsgard A, 31.1.2024, A 2024-2 EPN L2, rev. 03, date 26.06.2026
31. Presentation and minutes from meeting concerning review of recommendations after internal investigation report following incident involving cabin window on Åsgard A, dated 26.9.2024
32. Norwegian Meteorological Institute – NORA3 for the time period 31.1.2024 00:00:00 – 01.02.2024 23.00:00, date 10.10.2024
33. NORSOK C-CR-002:1996 Architectural components and equipment, rev. 1 May 1996
34. NS 3472 Steel Structures, Design Rules, 2nd edition June 1984
35. Petroleum Safety Authority Norway Audit 001094037 – Equinor Åsgard A and B – Integrity of structures and maritime systems, inspection report dated 17.11.2020

B: List of interviewed personnel. Separate attachment.

C: Schematic overview of sequence of events

C1: Key events



C2: Timeline 28.1 – 1.2.2024