Danish Maritime Accident Investigation Board

MARINE ACCIDENT REPORT
December 2016

AMBER II and SEA WORKER
Loss of tow on 27 January 2016

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Front page: Capsized SEA WORKER. Source: A2SEA

The marine accident report is available from the website of the Danish Maritime Accident Investigation Board (www.dmaib.com).

The Danish Maritime Accident Investigation Board

The Danish Maritime Accident Investigation Board is an independent unit under the Ministry of Business and Growth. It carries out investigations as an impartial unit that is, organizationally and legally, independent of other parties. The board investigates maritime accidents and occupational accidents on Danish and Greenland merchant and fishing ships, as well as accidents on foreign merchant ships in Danish and Greenland waters.

The Danish Maritime Accident Investigation Board investigates about 140 accidents annually. In case of very serious accidents, such as deaths and losses, or in case of other special circumstances, either a marine accident report or a summary report is published, depending on the extent and complexity of the events.

The investigations

The investigations are carried out separately from the criminal investigation, without having used legal evidence procedures and with no other basic aim than learning about accidents with the purpose of gaining and promoting an understanding of safety. Consequently, any use of this report for other purposes may lead to erroneous or misleading interpretations.

CONTENT

1. ABSTRACT

The Maltese tug AMBER II departed Frederikshavn on 24 January 2016 with its tow, the Danish manned installation jack-up platform SEA WORKER. The towage was bound for Esbjerg with an estimated time of arrival 26 January in the morning. The towing line between AMBER II and SEA WORKER broke on 27 January 2016, two and a half days after departure, while the towage was located in the North Sea, 6 nm off the west coast of Jutland and was facing difficulties making speed due to wind, waves and current. When the towing connection was lost, the tug did not succeed in reconnecting by means of the emergency towing equipment. As the platform was drifting uncontrollably towards shore, it was evacuated, because it was deemed dangerous for the crew to stay on board during the grounding.

In the DMAIB's investigation report, it is established that though the breaking of the tow constitutes the main accident event, the investigation cannot be isolated to this single event. The breaking of the tow is instead regarded as a result of an accumulation of several coinciding events and circumstances. Therefore, the investigation report covers the period from when the towing operation was initiated on 22 January until the evacuation of the platform. The investigation report focuses on the questions of how the situation arose that resulted in the towing arrangement failing. To answer these questions, the investigation report focuses on the specifications of the towing arrangement, the weather forecasts, the decision to seek port of refuge and the organisational relationship between the shore organisation and the towage.

The DMAIB concludes that no single cause could explain why the tow was lost, but that the accident happened as a result of organisational factors, which had an effect on how this particular towage operation was planned and carried out. SEA WORKER was operated with a project-driven strategy which entailed an ad hoc problem solving approach to work and a mind-set that all problems that arose could be resolved ad hoc one way or another. On this voyage, it was not until the organisation ran out of solutions to seemingly isolated problems that the involved persons realized that the towage operation had changed from a manageable operational situation into an emergency. This realization did not occur simultaneously throughout the organisation, just as the perception of the criticality of the situation varied among the involved persons. These differences in perception were enhanced by an organisational fragmentation which occurred as the situation grew in complexity. This caused critical information to be dispersed throughout the organisation. When the emergency was evident to all involved, the ship was too close to shore, which meant that the response time for help exceeded the expected time for when the platform would drift aground. In other words, the opportunity for ad hoc problem solving had narrowed in time and distance and the only solution left was to abandon the platform.

The owner of SEA WORKER has informed the DMAIB of the preventive measures taken in order to, inter alia, enhance the robustness of the organisations marine operations.

2. FACTUAL INFORMATION

2.1 Photos of the vessels

Figure 1: AMBER II
Source: Polskie Ratownictwo Okrętowe

Figure 2: SEA WORKER
Source: A2SEA

2.2 Ship particulars

AMBER II

Type of vessel:	Anchor handling tug/Supply vessel
Nationality/flag:	Malta
Port of registry:	Valletta
IMO number:	9425423
Call sign:	9HLD9
DOC company:	Polskie Ratownictwo
IMO company no. (DOC):	0102681
Year built:	2007
Shipyard/yard number:	Guangdong Jiangmen Shipyard Co Ltd/GMG0514
Classification society:	DNV
Length overall:	48.00 m
Breadth overall:	13.20 m
Gross tonnage:	975
Deadweight:	760 t
Draught max.:	4.50 m
Engine rating:	3840 kW
Service speed:	11 knots
Hull material:	Steel
Hull design:	Single hull
Bollard pull:	65 t

SEA WORKER

Type of vessel:	Self-elevating platform (jack-up platform)
Nationality/flag:	Danish
Port of registry:	Fredericia
IMO number:	8769705
Call sign:	OYRN2
DOC company:	A2SEA
IMO company no. (DOC):	5082412
Year built:	2008
Shipyard/yard number:	PT Nanindah Mutia Shipyard/592
Classification society:	DNV-GL
Length overall:	55.50 m
Breadth overall:	33.00 m
Gross tonnage:	3776
Deadweight:	1814 t
Draught max.:	3.60 m
Hull material:	Steel
Hull design:	Single hull

2.3 Voyage particulars

Port of departure:	Frederikshavn, Denmark
Port of call:	Esbjerg, Denmark
Type of voyage:	Coastal
Manning, AMBER II	12
Manning, SEAWORKER:	15
Pilot on board:	No
Number of passengers:	None

2.4 Weather data

Wind – direction and speed:	Southwest/16 $^{m}/_{s}$
Wave height:	3.5 m (significant wave height)
Visibility:	Good
Light/dark:	Dark
Current:	Northeast/1 knot

2.5 Marine casualty or incident information

Type of marine casualty/incident:	Loss of tow
IMO classification:	Very serious
Date, time:	0030 LT on 27 January 2016
Location:	Off Nymindegab, Denmark
Position:	50° 50.95’ N – 008° 08.17’ E
Ship’s operation, voyage segment:	Towing
Human factor data:	Yes
Consequences:	SEA WORKER grounded and was declared a total loss.

2.6 Shore authority involvement and emergency response

Involved parties:	Danish Joint Rescue Coordination Centre (JRCC) Danish coast radio station, Lyngby Radio (LYRA)
Resources used:	Rescue boat EMILE ROBIN, Danish Coastal Rescue Service Rescue helicopter RES519
Actions taken and results achieved:	15 crewmembers from SEA WORKER were evacuated by EMILIE ROBIN and brought to shore.

2.7 Relevant crew

AMBER II

Master:	57 years old and from Poland. Had more than 20 years of experience at sea. Had served with the company for 16 years and two years as master on AMBER II.

SEA WORKER

Master:	42 years old and from the Netherlands. Had 22 years of experience at sea and had served with the company for 5 years. The master had previously served as chief officer on SEA WORKER. This was his first voyage as barge master on SEA WORKER. The master usually served on a similar type of jack-up barge in the company.
Chief officer:	38 years old and from Denmark. Had 15 years of seagoing experience and had served with the company for 2.5 years as chief officer and ashore. Had not previously served on SEA WORKER.

2.8 Scene of the accident

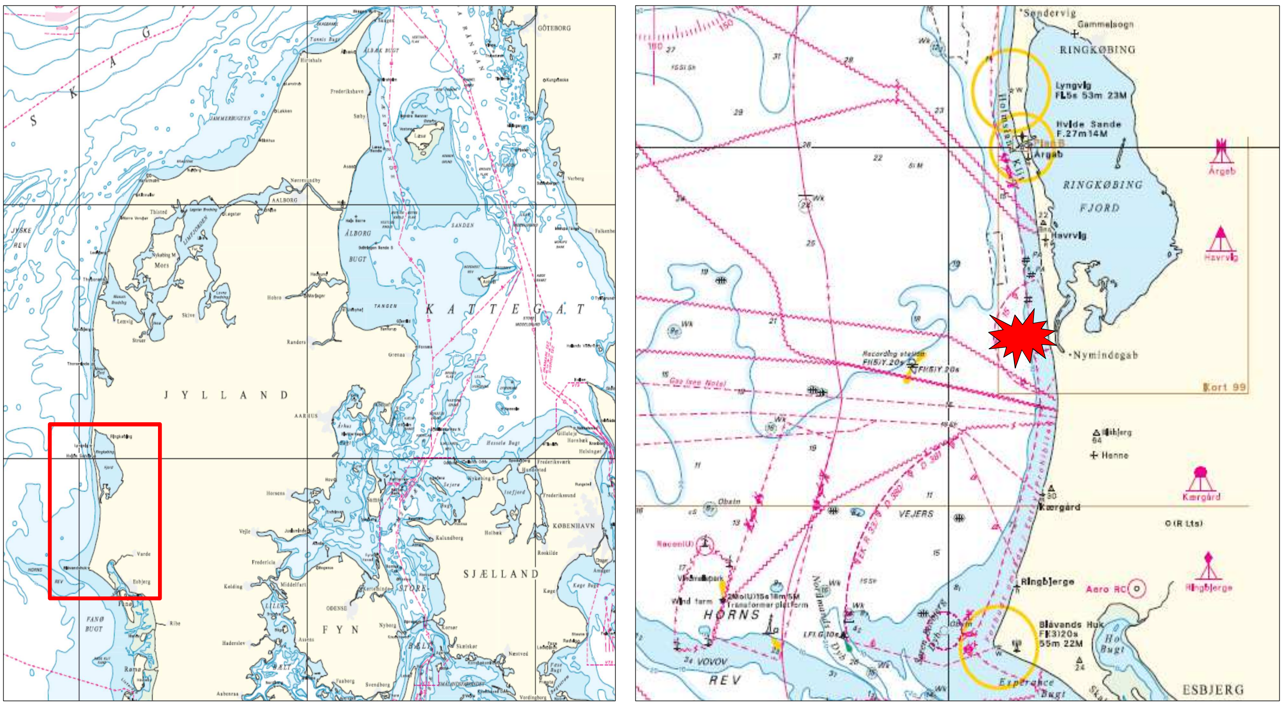

Figure 3: Approximate position of the accident
Source: Danish Geodata Agency, chart C and excerpt of chart 93

3. NARRATIVE ABOUT THE ACCIDENT

3.1 Background

AMBER II was owned and operated by the Polish company Polskie Ratownictwo and was an oceangoing anchor handling tug engaged in towing and offshore supply operations worldwide. The tug was manned with 11 Polish crewmembers and one Maltese crewmember. On 23 January 2016, AMBER II was hired through a Danish shipping agency to tow the self-elevating installation platform SEA WORKER from Frederikshavn to Esbjerg in Denmark (figure 4).

SEA WORKER was owned and operated by the Danish company A2SEA. The platform was equipped with a crane and four legs for jack-up, and it was used for installing foundations and turbines in the offshore wind sector. The platform was not self-propelled and without any propulsion positioning systems. The platform had been taken out of service, and in October 2015 it was manned down. SEA WORKER was berthed in Frederikshavn next to one of the company's other installation platforms, SEA JACK, and the crew on SEA JACK attended to both platforms.

SEA WORKER was to be moved from Frederikshavn to Esbjerg, where it was to undergo some minor repairs, before it was potentially to be chartered and put in service as a hotel platform at a wind farm.

For the voyage, a crew for SEA WORKER was assigned at short notice by reassigning some of the crew members from SEA JACK to SEA WORKER and engaging crew members from other vessels in the company. SEA WORKER was manned by 15 crew members of different nationalities using English as the working language. The barge master did not have any previous experience as a master on SEA WORKER, and had therefore insisted that SEA WORKER's previous master joined the crew as an advisor. This crew member will be referred to as 'the second master'. The assigned barge master was in command during the entire operation. Prior to and during the operation, the barge master on SEA WORKER was supported by an assistant project manager ashore who, during this period of time, referred directly to the company's chief operating officer (COO).

The voyage was to be commenced within a short time frame. SEA WORKER needed to complete some crucial repairs before departure from Frederikshavn, but had to depart on the morning of 24 January in order to arrive in Esbjerg on 26 January at 2000 at the latest. It was forecasted that weather conditions in the area of the North Sea exceeding SEA WORKER's operational limit would occur by that time.

Figure 4: Sketch of the planned route from Frederikshavn to Esbjerg
Source: © Made Smart Group BV 2016, C-Map data © Jeppessen AS 2016

3.2 Sequence of events

The sequence of events aims to describe how the persons involved perceived the events to unfold and what knowledge they possessed at different stages in the course of events. The description of the events collects and merges the multiple view points of the crew on SEA WORKER, the crew on AMBER II, the shore-side personnel, pilots and shipping agents.

The narrative of the sequence of events covers a period of two and a half days, from the morning of 24 January until just past midnight on 27 January. Times given in the report are the ship's local time (UTC+1).

3.2.1 Departure from Frederikshavn

AMBER II arrived in Frederikshavn on 23 January around 1800, and was on standby until SEA WORKER was ready to connect prior to departure. Prior to AMBER II's arrival, the crew on SEA WORKER had discovered a hole in one of the platform's ballast tanks, which had to be repaired before departure.

Besides the repairs and other preparations, the tug, according to SEA WORKER's company procedures, was to be inspected prior to departure because the tug did not hold an IMCA[1]-certification. Usually, a warranty surveyor hired by the platform charterer carried out an inspection of the towage, but as SEA WORKER was not in charter and as no accredited IMCA vessel inspector[2] was available, it was decided to carry out the inspection of the tug internally. No personnel from the company's office capable of carrying out the inspection was available on that day, and as the master on SEA WORKER had tug experience, it was deemed convenient to have him inspect the tug.

Shortly after AMBER II's arrival, the master came on board the tug to commence the inspection and arrange the voyage planning. AMBER II's bollard pull of 65 t exceeded the working load limit (WLL) of 50 t for SEA WORKER's bridle[3]. As AMBER II did not have a tension meter, the two masters agreed that AMBER II would not exceed 75 % power in order to stay within the main tow bridle's limit. During the inspection of the tug, the barge master discovered that the tug did not carry a stretcher[4] for the towing arrangement. The barge master was used to having a stretcher fitted in the towing arrangement and perceived it as a mandatory piece of equipment. Therefore, he contacted the assistant project manager to order a stretcher. As it was not possible to procure a stretcher at short notice in Frederikshavn during the weekend, the assistant project manager inquired the technical department whether the stretcher was mandatory. The technical department reverted that it was not mandatory. Though the master was not comfortable being towed without the stretcher, he did not have any weighty arguments for turning down the tug.

[1] International Marine Contractors Association. It is not mandatory to be certified by IMCA.
[2] The IMCA vessel inspector typically inspect only the tug. A warranty surveyor would typically inspect the entire towage and be assigned to monitor the towage operation.
[3] A description of the towing arrangement is presented in section 4.2.1.
[4] A synthetic fibre rope pennant fitted with the purpose of shock-absorption.

Before the voyage planning, the master contacted the assistant project manager to check if they agreed on the wave limit for SEA WORKER. The wave limit was usually laid out by the charterer, but as the platform was moved outside the scope of the contract, the crew had difficulties finding information on the platform's general wave limit. The barge master knew that the limit was 2.5 m on SEA JACK. Therefore the barge master asked the assistant project manager, who had previously served on SEA WORKER, if a significant wave height of 2.5 m was the correct limit. The assistant project manager did not know the limit, but replied that the limit when loaded was usually 2.0 m, so it did not sound far off with 2.5 m when unloaded. The assistant project manager advised the master to check the operations manual. The barge master consulted the second master instead, who also suggested a 2.5 m limit.

On AMBER II, the barge master provided weather reports to the tug, as the platform crew had access to more specified forecasts than the tug. The barge master presented a two-day weather window for the tug master and they agreed that, with an estimated average speed of 5 knots and a wave limit of 2.5 m, it was possible to reach Esbjerg within the weather window. The barge master required a detailed passage plan to be carried out by the bridge crew on AMBER II. It turned out that AMBER II did not have any sea charts for the route and the barge master provided AMBER II with charts for the coastal voyage. The charts for the port of Esbjerg could be provided by the pilots.

The barge master returned to SEA WORKER and the bridge team on AMBER II prepared a voyage plan. The voyage plan was handed over to the bridge team on SEA WORKER the next morning, and the bridge team on SEA WORKER concluded that it was not sufficiently detailed to comply with the company procedures. Although AMBER II's voyage planning was not satisfying, it did not present a reason to delay the operation, especially because it was important to depart Frederikshavn at the scheduled time due to the narrow weather window.

AMBER II connected with SEA WORKER and the towage departed Frederikshavn at 0840. During the departure the chief officer prepared a more detailed voyage plan and added, inter alia, potential ports of refuge, Hanstholm and Hvide Sande, along the West coast of Jutland. The amended voyage plan was not presented to AMBER II for familiarisation.

3.2.2 Loss of speed

AMBER II and SEA WORKER passed the Skaw in the afternoon of 24 January and continued south along the west coast of Jutland. The towage had until then been sheltered by land from wind and waves. As the Skaw was passed and the course was altered to a south-westerly direction, the navigational officer on AMBER II assessed that the wind force had increased from force 1 to 4 (Beaufort Scale) with the vessel's heading up against wind and current. At the same time as the towage left the sheltered waters and changed its course, the speed dropped and varied from 2.5 to 3.5 knots.

The bridge teams communicated with each other about the speed loss, but did not discuss the reason for it. On both vessels, it was speculated what the cause for the speed reduction might be. On AM-

BER II, it was believed that the crew on SEA WORKER might have lowered the legs a bit to stabilize the platform from rolling and pitching. On SEA WORKER, it was assumed that the tug had slowed down to save fuel. The barge master called the assistant project manager and informed about the decreased speed and shared the crew's thoughts on the reason for the lowered speed. The assistant project manager asked the tug's agent if the reason for the speed reduction was fuel saving. The agent contacted the tug and reverted with the answer that the tug was using 75% of its engine power as agreed with the barge master prior to departure. The towage proceeded at reduced speed, unable to solve the problem. At 2000, the towing wire was extended from 420 m to 475 m, because the current caused too much load on the towing wire.

During the evening, the barge master informed the tug master that it might not be possible to reach Esbjerg within the weather window due to the slow speed, and that he was considering the possibility of returning to Frederikshavn if the speed did not improve.

The next day, 25 January 2016, the speed had not improved. The assistant project manager was continuously kept up to date on the situation by the crew on SEA WORKER. The barge master was in doubt whether it would be possible to reach Esbjerg. He called the assistant project manager and asked if it would be possible to enter the port of Hvide Sande the next day if the speed or weather did not improve. The assistant project manager confirmed that Hvide Sande was a possible port of shelter. Other and larger vessels from the company had been able to enter before. The barge master and the assistant project manager agreed that the assistant project manager would contact the port administration in Hvide Sande and order a tug to assist AMBER II and SEA WORKER during arrival. The tug master was informed that the towage might take shelter in Hvide Sande the following day.

At approx. 1530, the assistant project manager contacted the harbour administration in Hvide Sande, which confirmed that the port was able to receive them. The assistant project manager enquired whether a tug was available in Hvide Sande, or if he should arrange one from Esbjerg. The harbour administration informed that a rescue boat and the local shipyard's working boat, which each could provide 7 t bollard pull, were at their disposal. The assistant project manager did not believe that these vessels would be strong enough to hold SEA WORKER and contacted the company's agent to inquire if there were any tugs available to assist AMBER II and SEA WORKER when entering the port of Hvide Sande. The agent informed that there was a suitable tug available in Esbjerg. The assistant project manager accepted the tug over the phone, but no formal paperwork confirming the order was done. The assistant project manager understood the oral agreement as being valid, and confirmed to the master that tug assistance was available at Hvide Sande.

The barge master had decided that he would return to the port of Frederikshavn if tug assistance in Hvide Sande could not be fully confirmed the same evening. At this point, it was evident that it was impossible to reach Esbjerg within the weather window. There was, however, sufficient time to seek shelter in Hvide Sande, which was considered the only option if they continued. During the night they would pass a point of no return to Frederikshavn, as the barge master was well aware that the weather would overtake the towage before reaching Frederikshavn. In the evening, when tug assistance was confirmed by the assistant project manager, the barge master confirmed his decision to approach Hvide Sande. However, the master wrote to the assistant project manager that he would reassess the situation the next morning and proceed to Esbjerg, if the weather improved.

3.2.3 Seeking port in Hvide Sande

The next morning on 26 January at 0700, the barge master reviewed the latest forecasts, which did not show any improvement in the weather conditions. He called the assistant project manager and re-confirmed that they had no other option than to seek port in Hvide Sande, and that they would alter the course accordingly. The assistant project manager agreed and called their agent in Esbjerg, and asked them to send the tug from Esbjerg. AMBER II and SEA WORKER were expected to arrive at Hvide Sande at 1500. The passage time for the tug from Esbjerg to Hvide Sande was estimated to 4-5 hours. The agent confirmed the arrangement, but shortly after reverted with the message that the tug was assigned to another job and was not available.

The assistant project manager was surprised by this message, as he thought that agreement had been reached. He delivered the news to the barge master, who was frustrated as he had continued to Hvide Sande only because of the confirmed tug. Another tug had to be found so the crew on SEA WORKER, the agent, and the assistant project manager sought for tugs having a suitable bollard pull and draught and capable of reaching Hvide Sande before 1500. No such tug seemed to be available in the area, and it was decided to settle with the rescue boat and the work boat in Hvide Sande, though all parties kept looking for other options.

At 1000, the agent contacted the pilot on duty covering the port of Hvide Sande in order to arrange pilotage. The pilot consulted the forecast and received information about SEA WORKER, AMBER II and the two small tugs in Hvide Sande, and he was informed that the ETA was 1700[5]. With this information in hand together with his knowledge of the port, the pilot was concerned that the two small tugs would not be able to hold SEA WORKER in the wind and current. The towage would pass the breakwater at high tide which was unfavourable, because the increased impact of swell and waves would involve a high risk of grounding or contact with the breakwater. This could cause severe damage to SEA WORKER and the lives of the crew might be at risk. Under those circumstances, he declined taking SEA WORKER into Hvide Sande.

The agent contacted the shipping company Esvagt, specialised in offshore guard ships, in an attempt to hire a ship with towing capabilities. Esvagt informed the agent that the offshore tug ESVAGT CONNECTOR was available and would be able to reach Hvide Sande at 1500. This information was passed on to the assistant project manager and the barge master. The pilot was contacted again and was asked if he could take the towage in with ESVAGT CONNECTOR assisting instead of the two small boats. The pilot did not have any experience with using this type of vessel as a harbour tug and therefore declined again, but advised the agent to contact one of the pilots that had more experience with both the harbour and that type of offshore supply vessel. This pilot, however, was resting and was not to be disturbed until 1130. Meanwhile, the agent received the message that ESVAGT CONNECTOR could not assist SEA WORKER and AMBER II after all. The master on

[5] There is a difference in the perception of ETA in Hvide Sande, which the DMAIB ascribes to miscommunication. It is unclear how and when this miscommunication occurred.

ESVAGT CONNECTOR had declined assisting the towage in Hvide Sande, because he assessed that ESVAGT CONNECTOR's draught was too large to enter the port under the forecasted weather conditions.

The towage had altered its course at approx. 1230 heading east for Hvide Sande and continued on this course, while the assistant project manager, agent, platform crew and pilots tried to find a solution. The plan still was to enter the port of Hvide Sande, and again it was decided to make use of the two small harbour boats. Neither the assistant project manager nor the agent perceived the pilot's warnings as being related to more than structural damage which would be of inconvenience, but not life threatening. Therefore, they were annoyed with the pilot not taking the assignment, because he was obliged to provide pilotage. The crew on AMBER II was not consulted about the possibilities of entering the harbour, but the tug master did not approve of the option of entering with the two small boats as stoppers. He therefore prepared to abort entering the port with SEA WORKER on tow.

At approx. 1230, the pilot, who had been at rest, was contacted by the agent and presented with the assignment. The pilot was informed that two assisting tugs were available in Hvide Sande. The pilot informed that he would take a look at the forecast and revert to the agent. The pilot was puzzled about the information that Hvide Sande had tugs available and called the harbour administration to ask which ships they were, and also to inquire about the present local weather conditions. The pilot was surprised that the two tugs turned out to be the rescue boat and a work boat. Like the first pilot he was informed that the ETA was 1700. At this time the forecast predicted wind speed of 22 $^{m}/_{s}$ and a significant wave height of 3 m. He called the agent and informed that in those weather conditions it would be impossible to get on board the platform or tug and furthermore it would be very unlikely for the two assisting tugs to be able to hold SEAWORKER.

SEA WORKER continued on its course heading for Hvide Sande, while other options were discussed. Ideas from A2SEA's shore-side personnel were passed on to the barge master.

It was suggested reconfiguring so that the two small tugs were in front of SEA WORKER while AMBER II was stopping the tow from drifting. This was deemed impossible, as the two small boats would not be able to provide the sufficient power to tow the platform.

It was also suggested that SEA WORKER could lower its legs so that they could be used as a brake, and it was suggested that SEA WORKER could lower one leg at a time and 'walk' through the breakwater. The barge master did not find any of these options possible.

The pilot had experience with moving platforms like SEA WORKER, and the assistant project manager asked if he could discuss the options with the barge master. The pilot agreed and strongly advised the master not to make use of any of the options above, as the dynamic forces of the swell and waves could tear the platform apart. Instead he advised the barge master to jack the platform up outside the port or seek shelter at a wind farm at Horns Rev north of Esbjerg. The barge master was reluctant to jack the platform up on a sea bottom that had not been mapped, but also doubted that it was possible to reach Horns Rev at their reduced speed. Eventually, he assessed that seeking shelter at Horns Rev was the best option. At approx. 1410, the towage altered its course and headed south, but due to the attempt to go into Hvide Sande, the towage's route was now situated at a distance of approx. 6 nm from the coast.

3.2.4 Loss of tow

As the towage proceeded south along the west coast of Denmark during the afternoon and the evening of 26 January, the weather worsened. In response to the weather conditions, AMBER II reduced power. During the afternoon and evening, the speed decreased to a level where the towage hardly made any progress.

At 1900, on SEA WORKER, the chief officer went to relieve the master on the bridge. At this point, the platform was taking a large amount of water over the bow. This indicated that the limit for the significant wave height was now well exceeded. The master decided to stay on the bridge to assess the situation, and the second master joined them shortly after. They decided to share the duties between them, so that the chief officer would focus on the safety initiatives, the barge master would focus on communication and the second master would focus on the ship's operation.

The bridge team saw that a wave gushed over the deck forward and that boxes with life-saving equipment from one of the platform's two muster stations were torn off the deck into the water. The chief officer assembled a group of crew members to collect the rest of the life-jackets and immersion suits from the muster station at the starboard side aft, to keep them ready inside the accommodation in case they had to evacuate the platform. By this time, the barge master did not feel comfortable with the situation and requested all crew members to be on standby in the mess room.

Meanwhile, the bridge team observed that the towing wire was suddenly crossing the rail on AMBER II and became worried that the tug might be about to capsize. The bridge team called AMBER II over the VHF to inquire about the situation, but received no information on what was going on at the tug. The AMBER II bridge team had momentarily lost control of the tug while using auto-helm and was busy regaining it by switching to manual steering and activating the thrusters to help control the heading. The situation was recovered and AMBER II continued holding itself and SEA WORKER up against the weather.

AMBER II's loss of control, in addition to the towage's difficulties of making speed, caused the crew on SEA WORKER to lose confidence in the tug. The barge master contacted the assistant project manager and requested that a tug was sent from Esbjerg to assist AMBER II. The need for the extra tug was emphasized by informing the assistant project manager that if the request was not granted, the barge master would request tug assistance himself, under the terms of Lloyds Open Form[6]. Furthermore, he requested to communicate directly with A2SEA's COO about the situation from then on, as the COO had greater authority to take decisions. Both requests were granted. Until then, the COO had been under the impression that the towage was situated 20 nm from the coast, and he was surprised to hear that the actual distance was only 6 nm. This caused his perception of

[6] A standard legal document for a marine salvage operation. The amount paid for the salvage will be determined later by arbitration.

the situation to change from being an operational disruption to being a critical situation, and he therefore decided to assemble the company's emergency team.

At 2100, the assistant project manager contacted the agent and requested ESVAGT CONNECTOR to head out for SEA WORKER and assist AMBER II. It was expected that ESVAGT CONNECTOR would be able to reach the towage within approx. 6 hours. The crew on ESVAGT CONNECTOR, however, expressed doubt about their possibilities of providing assistance for the towage, as the weather was too rough for them to be able to connect with SEA WORKER. The assistant project manager informed ESVAGT CONNECTOR that it did not matter. There were different views on the usefulness of requesting the assistance of ESVAGT CONNECTOR. The assistant project manager thought that ESVAGT CONNECTOR could at least provide lee; the COO thought there might be a chance to connect anyway, as the weather would improve briefly after midnight; the master thought that having ESVAGT CONNECTOR in the immediate proximity of SEA WORKER would be reassuring if the need for evacuation of the platform should arise. The towage still made zero speed and aimed only at keeping the position and not moving backwards, while waiting for ESVAGT CONNECTOR to arrive. The weather was considered too rough to anchor.

The master on board SEA WORKER informed the COO of A2SEA that he did not trust AMBER II to be able to hold the platform and that the crew prepared for evacuating the platform. The crew donned their immersion suits, and a life raft was prepared at starboard side aft. The impact of the waves gushing over the platform tore the life raft off and into the water, and containers had begun to slide back and forth as their lashings had broken. The COO advised the crew to stay on board.

At approx. 0030, the crew on AMBER II noticed that the towing wire suddenly became slack and the crew on SEA WORKER felt the platform making some irregular movements, and the crews on both ships established that the tow wire had broken. All crew members had donned their immersion suits at this point and the chief officer issued MAYDAY. The bridge team reconfigured so that the chief officer overtook the communication with the rescue services in Danish, the barge master communicated with the company, and the second master directed the operation of anchors and the jack-up legs. The rescue boat from Hvide Sande headed out for SEA WORKER and a rescue helicopter was also commissioned.

When the towing connection was lost, SEA WORKER started to drift towards the coast at a speed of 3 knots. The crew immediately lowered the stern starboard anchor and deployed the platform's emergency towing arrangement from the starboard forward corner. The speed of the drift reduced to 1.5 knots, which gave them two hours before reaching the coast. It was not possible to deploy the platform's second anchor as it had to be operated by the auxiliary crane, which was impossible due to the adverse weather conditions.

Meanwhile, AMBER II attempted to approach SEA WORKER in order to pick up the emergency towing arrangement's buoy and reconnect. Due to the anchor having been lowered, the platform turned into the wind, which got the emergency towing gear caught alongside SEA WORKER. The master on AMBER II asked the crew on SEA WORKER to retrieve the towing gear and deploy it once again. On SEA WORKER, the bridge team were concerned about the risk of collision if AM-

BER II approached SEA WORKER to pick up the emergency towing wire. The barge master on SEA WORKER requested AMBER II to abort the attempt and keep distance. AMBER II distanced itself from SEA WORKER and was on stand-by.

The master on SEA WORKER decided to lower the platform's four legs ten metres. It was assessed that the legs were the strongest part of the platform, and that it would cause least damage if SEA WORKER drifted aground having lowered the legs. Furthermore, it was assessed that going aground further from shore would enhance the possibility of reconnecting with a tug.

The crew on SEA WORKER informed that they would evacuate the platform before grounding, as they were concerned with the risk of the platform capsizing on impact with the seabed. The company's emergency team expressed that they found it safer to stay on the platform, and the rescue service advised them to stay on the platform until the helicopter was on scene, in case of a man over board situation. The crew on SEA WORKER acted accordingly. While waiting for the helicopter to arrive, the crew collected and packed their certificates and log books.

3.2.5 Evacuation

The crew on SEA WORKER prepared a life raft. While working on deck with preparing the life raft, the crew members had trouble operating the equipment due to the integral mittens of the immersion suits. Therefore, they had to take off the upper part of the immersion suit, thus having the upper body exposed to wind and waves. When the helicopter was on scene and the rescue boat approx. 10 minutes away, the crew began entering the raft hanging in the davit. The raft proved difficult to enter, as it was not balanced. The chief officer was in charge of the preparation of the evacuation and the launch of the raft, and was the first person to enter. As he was about to lower the raft, he realised that the red and green handles for releasing the raft could not be distinguished from one another in the dark. The green handle would release the raft in a free fall manner, which could be fatal in this situation, while the red handle would initiate a controlled release when the raft was in the water. The chief officer did not want to risk a free fall, and did not pull any of the handles before lowering the raft.

As the raft was lowered down the side of the platform, it got caught by an edge on the platform's hull and started to tilt. The chief officer climbed out of the raft and up on top of it, where he managed to free the raft from the edge while holding the raft's wire with his hand and pushing with his feet on the ship's side. The chief officer climbed inside the raft and lowered the raft on to the water. Once in the water, the chief officer had to climb out of the raft to manually operate the release hook, which succeeded after a couple of attempts. The raft drifted alongside the platform. At each corner of the platform, anchor racks protruded (figure 5), and due to the motions of the sea these were constantly moving up and down several metres. As the raft drifted very close to the platform's side, the chief officer was worried that the raft could get caught underneath one of these racks, but as it passed the rack, the raft steered clear of the platform.

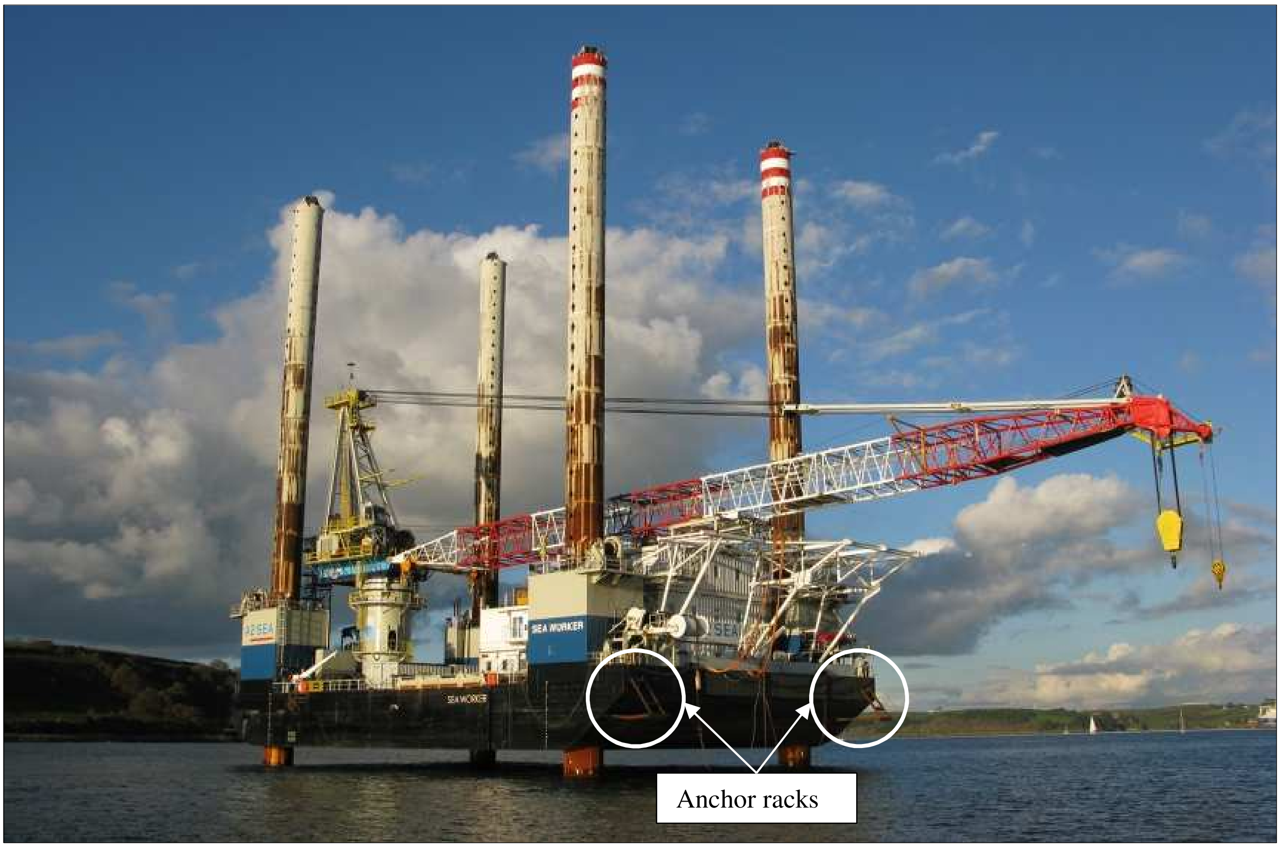

Figure 5: Anchor racks on SEA WORKER
Source: A2SEA

The rescue boat EMILE ROBIN was on scene when the life raft drifted away from SEA WORKER, and approached the raft. All crew members from the raft were transferred to the rescue boat and were then transported back to Hvide Sande, where the company had arranged for transport, hotel rooms and debriefing.

4. INVESTIGATION DATA

4.1 The accident

The towing line between AMBER II and SEA WORKER broke on 27 January 2016, three days after departure, while the towage was situated in the North Sea, 6 nm off the west coast of Jutland and was facing difficulties making speed due to wind, waves and current. When the towing connection was lost, the towage did not succeed in reconnecting by means of the emergency towing equipment. As the platform was uncontrollably drifting towards shore, it was evacuated, because it was deemed dangerous for the crew to stay on board during grounding.

Though the breaking of the tow constitutes the main accident event, the investigation cannot be isolated to this single event. The breaking of the tow will instead be regarded as a result of an accumulation of several coinciding events and circumstances laid out prior to the accident. Hence, the investigation will cover the period from when the towing operation was initiated on 22 January until the evacuation of the platform.

The investigation will focus on the questions of what caused the towing arrangement to fail and how the situation arose. To answer these questions, the investigation will focus on the specifications of the towing arrangement, weather forecasts, Hvide Sande as a port of refuge and the organisational relationships.

4.2 Towing equipment

4.2.1 Towing arrangement on SEA WORKER

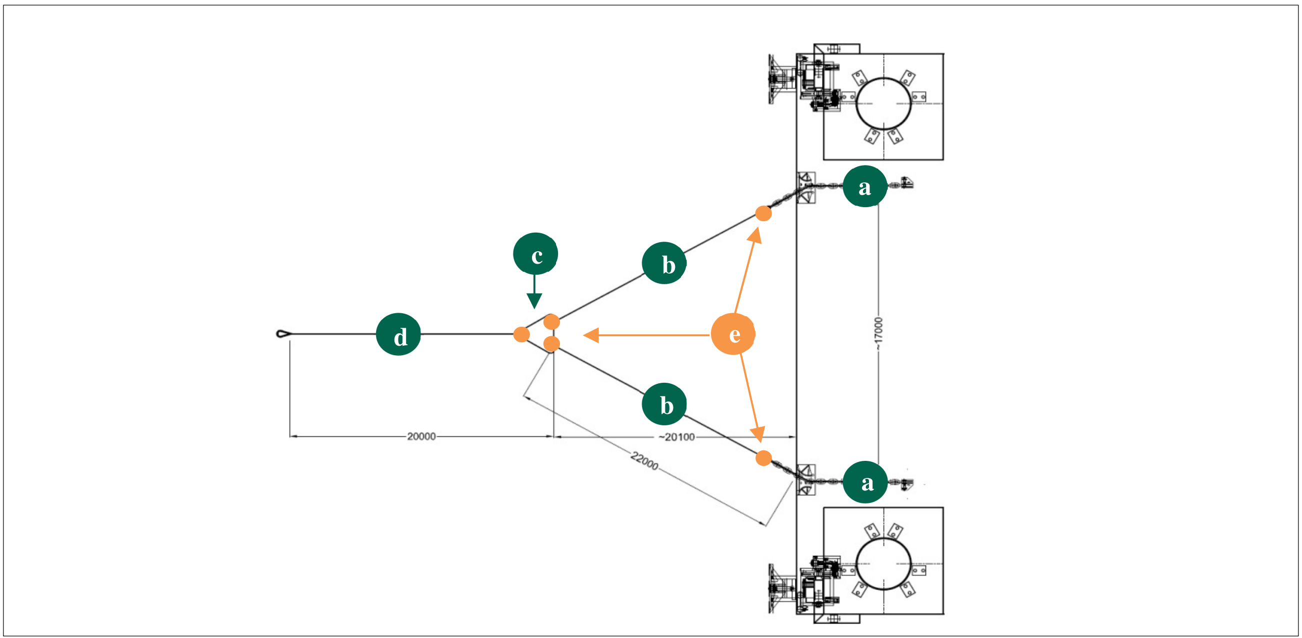

Figure 6: SEA WORKER's towing arrangement
Source: DMAIB

The towing arrangement on SEA WORKER is depicted in figure 6 above and consisted of the following components:

a) Chafing chains: Two stud link chains were fastened at the bow in Smitt brackets on deck, and were led over the side through fairleads. Chains were installed with the purpose of hindering chafing on the towing wires at the fairlead. Furthermore, the chains added weight to the towing bridle to obtain a desired catenary. Each stud link chain had a diameter of 54 mm and a safe working load (SWL) of 55 t according to the certificates.

b) Bridle legs: The bridle legs consisted of two 22 m long steel wire ropes with a diameter of 44 mm and a minimum breaking load (MBL) of 138 t. The working load limit for the wire ropes was established by a safety factor of a 5:1 ratio to the MBL according to the certificates. The bridle legs were connected to the chafing chains (a) with the towing plate (c) and were fastened at each end with shackles (e).

c) Towing plate: The towing plate connected the two bridle legs and the towing pennant. The purpose of the towing pennant was to prevent the wires from coiling up and ensuring a steady towing connection. The towing plate had a safe working load of 55 t according to the certificates.

d) Towing pennant: The towing pennant was a 20 m long steel wire with a diameter of 44 mm and was fitted with thimbles at both ends. The minimum breaking load of the wire was stated as 138 t and the safe working load as 25 t. The ratio between the minimum breaking load and the safe working load was 5:1 according to the certificates.

e) Shackles: The shackles connected all the components above and had a safe working load of 55 t.

In SEA WORKER's general towing arrangement, information on the different components was stated, e.g. dimension, safe working load and minimum breaking load (figure 7). However, the different types of components were described by different sets of information. In the figure below, it should be noted that a safe working load was given for shackles, stud link chains and the towing plate, but not for the steel wires.

Item	Description	Dim.	SWL (t)	MBL (kN)
A:	Bow Shackles	-	55 t	-
B:	Tow Wire MBL With Thimble	44 mm	-	1380 kN
C:	Towing triangle / Link Plate	-	3 x 55 t	-
D:	Tow Wire MBL	44 mm	-	1380 kN
E:	Stud link Chain	Max. 54 mm	2 x 55 t	-
F:	Smit Bracket	Max. 54 mm	100 t	-

Figure 7: Excerpt from SEA WORKER's general towing arrangement
Source: DMAIB

On SEA WORKER, the safe working load for the towing arrangement was considered to be 50 t, and the bollard pull provided by the tug therefore ought not to exceed 50 t. AMBER II provided a bollard pull of 65 t. As the tug was not equipped with a tension meter, the masters agreed not to exceed 75 % of AMBER II's propulsion power.

It is an industry standardised practice that the safe working load for steel wires for towing is established by a 1:2.5 or 1:3 ratio of the minimum breaking load. A safe working load of 1:5 is most commonly used on lifting wires. For steel wires of a 44 m diameter and a minimum breaking load of 138 t, the safe working load is therefore most often related to a safe working load between 45-55 t in for towing. Towing with a load of 50 t on this type of wire is therefore not controversial, though it exceeded the safe working load stated in the steel wires' certificates.

4.2.2 Breakage of tow

The tow broke at SEA WORKER's towing pennant, just behind the aluminium clamp of the pennant's thimble eye (figures 8, 9, 10). The fractured wire has been examined by FORCE Technology with the purpose of establishing the condition of the wire and a cause for the fracture.

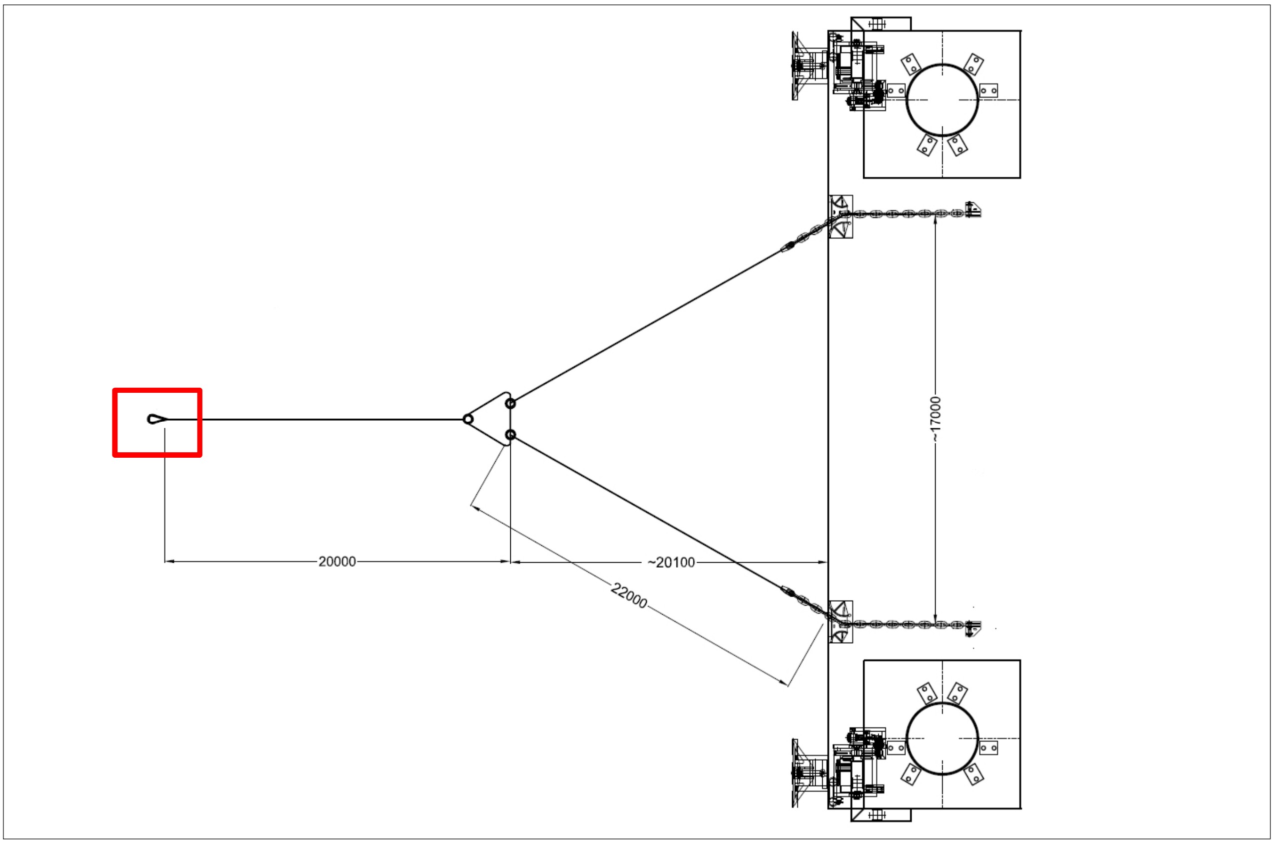

Figure 8: Location of the wire fracture
Source: DMAIB

Figure 9: The fractured steel wire
Source: FORCE Technology

The FORCE report concludes that the wire showed no signs of material defects or manufacturing imperfections. The wire appeared with slight surface corrosion as expected due to normal wear and tear, which might cause the tensile strength of the individual wire strands to be slightly below the required value. The Talurite clamp appeared severely corroded. However, the FORCE report does not ascribe these results as significant factors for the fracture. Instead, FORCE suggests that, based on the location of the fracture, the angle of the individual wire strands' fractures and contractions at the fracture surfaces: *"the cause for the fracture is a sudden overload at an unfortunate angle for the wire rope end"* (figure 10).

Figure 10: Close-up of the wire fracture
Source: FORCE Technology

Based on the FORCE report and the facts provided on the weather conditions at the time the wire broke, the DMAIB has found it likely that the towing pennant broke due to overload. The strain on the wire, caused by heading up against strong winds and current, the impact and movements of towing in high waves with short roll periods, and the tug pulling at a constant engine power, exceeded the wire's minimum breaking point, causing the wire to break at its weakest and least flexible point, the aluminium clamp.

4.2.3 *Emergency towing equipment*

SEA WORKER was equipped with an emergency towing wire fastened and stowed on deck at the bow. The emergency towing wire consisted of a single steel wire fastened on deck with a Smitt bracket and with a buoy mounted at the end of the towing wire (figure 11). The emergency towing wire was not fitted with a bridle, which meant that the ability for the tug to keep the platform within a desired angle was reduced. Therefore the emergency towing line was intended for the limited purpose of bringing the towage into sheltered water or a port of refuge, in case of emergency. The towing wire's safe working load was 20 t.

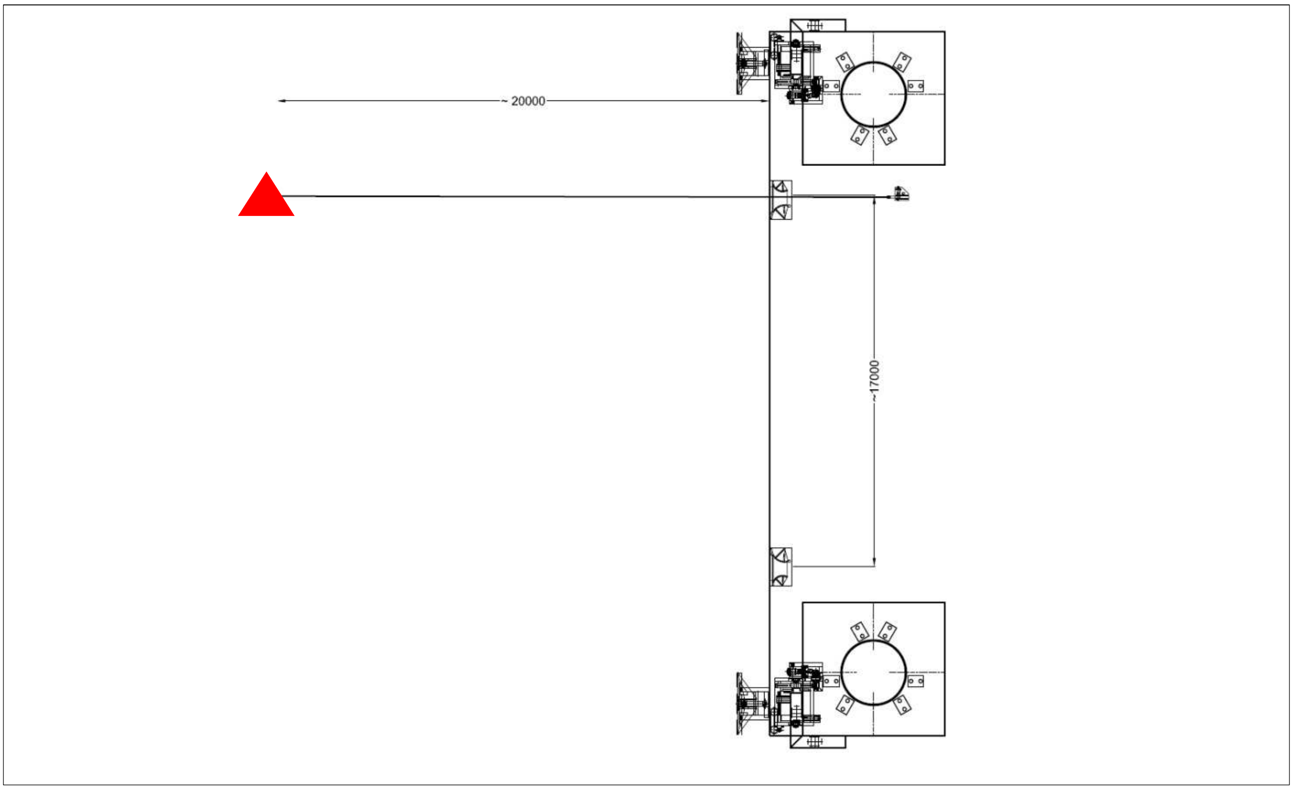

Figure 11: Excerpt of SEA WORKER's general arrangement
Source: DMAIB

No procedure described how the emergency towing equipment was to be used, but the general principle of the emergency towing arrangement on SEA WORKER was that the equipment was to be deployed in case the main towing wire failed, and that the equipment then would drift alongside the platform and fall behind the platform, clear for the tug to pick up. During the release of the emergency towing line following the failed main towing connection on 27 January 2016, the buoy was caught alongside SEA WORKER making it impossible to pick up for AMBER II.

On AMBER II, the crew expected and was accustomed to a practice of deploying the emergency towing equipment before departure, so that the buoy would drift behind the platform during the entire towing operation, ready for pick up. Usually, the tug crew would rig and deploy the emergency towing gear. However, in case the towing object was manned by a crew, the tug crew was of the perception that the platform crew attended to the towing equipment provided by the platform.

4.2.4 Bollard pull requirement

A bollard pull calculation for SEA WORKER was carried out by Global Maritime Consultancy Ltd in 2013. The bollard pull requirements were calculated for two different conditions: *short coastal towage* and *long ocean towage*. The bollard pull requirement was calculated to correspond with the tow line pull required to hold the platform at zero forward speed in a fully developed gale in a fully loaded condition.

In the calculation for *long ocean towage,* the weather criteria for the calculation of the required tow line pull was a significant wave height of 5 m, a wind speed of 20 $^{m}/_{s}$ and current velocity of 0.5 $^{m}/_{s}$, acting simultaneously. Based on this calculation, a total bollard pull of 104.64 t was required for making zero speed. To account for 75 % tug efficiency, a tug with a rated bollard pull of 139.50 t or above was recommended.

For *short coastal towages* the criteria could be reduced to a significant wave height of 2 m, a wind speed of 15 $^{m}/_{s}$ and a current velocity of 0.5 $^{m}/_{s}$. Based on this calculation, a total bollard pull of 38.63 t was required for making zero speed. To account for 80 % tug efficiency, a tug with a rated BP of 48.30 t or above was recommended.

SEA WORKER’s ISM manual considered all operations within or between Northern European ports as *short coastal tow.*

SEA WORKER’s class approved Operations Manual required the platform to be moved by means of two tugs unless the underwriter had approved another setup. In the ISM manual’s appendix for Tug Specifications, it is however concluded by the company that this requirement was only relevant for in-field moves and that one tug was sufficient for moves outside of project operations.

4.2.5 Load on the tow

AMBER II was not fitted with a tension meter on the towing winch. The knowledge of the actual load on the wire between AMBER II and SEA WORKER was therefore based on an assumption.

The load on a towing arrangement is determined by a set of interrelating factors, which all affect the force needed to tow an object:

Load on wire <=> environmental factor <=> speed <=> propulsion

The environmental factor reflects the resulting force of the effects of wind, waves and current on the towed object. The stronger these forces are, the more power is needed to tow the object at a certain speed.

When planning a towing operation, focus can be on either maintaining a constant load on the towing wire, or on maintaining a constant speed.

Keeping the load on the wire constant means that, if the environmental factor increases (i.e. stronger wind, higher waves, stronger current), the propulsion power and thus speed of the tug must be reduced.

If, on the other hand, the speed is to be maintained constant, any increase in the environmental factors will also increase the load on the towing wire.

During the voyage from Frederikshavn to Esbjerg, both the tug master and the platform master were focused on maintaining a speed of 5 knots and keeping the propulsion close to 75% of AMBER II's capacity in order to stay below 50 t load on the wire.

The impact of the increased wind speed, current velocity and wave height and the fact that the towage was not able to maintain speed though keeping propulsion at 75% indicates that the load on the wire exceeded 50 t.

Figures 13 and 14 below show two different towing situations[7]. The top figure pictures how the towing wire ideally should be hanging between the two vessels in a curve. The underwater curve adds flexibility to the tow, so that it is less likely to break.

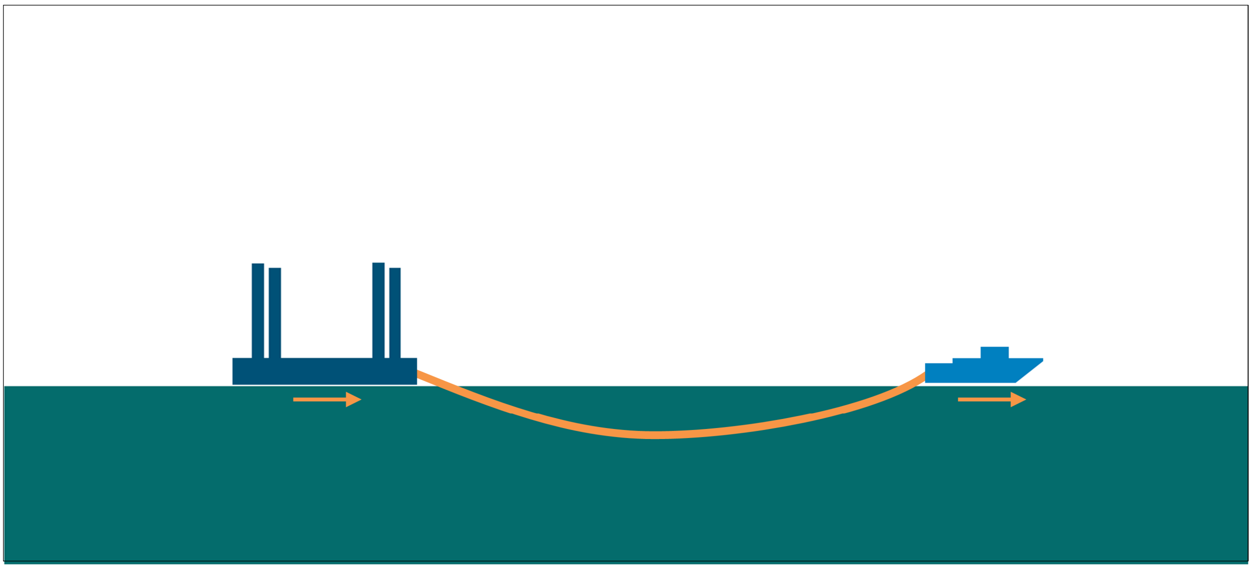

Figure 13: Towing situation with a great amount of catenary
Source: DMAIB

[7] The figures is not a realistic representation, but an illustration of the phenomenon described.

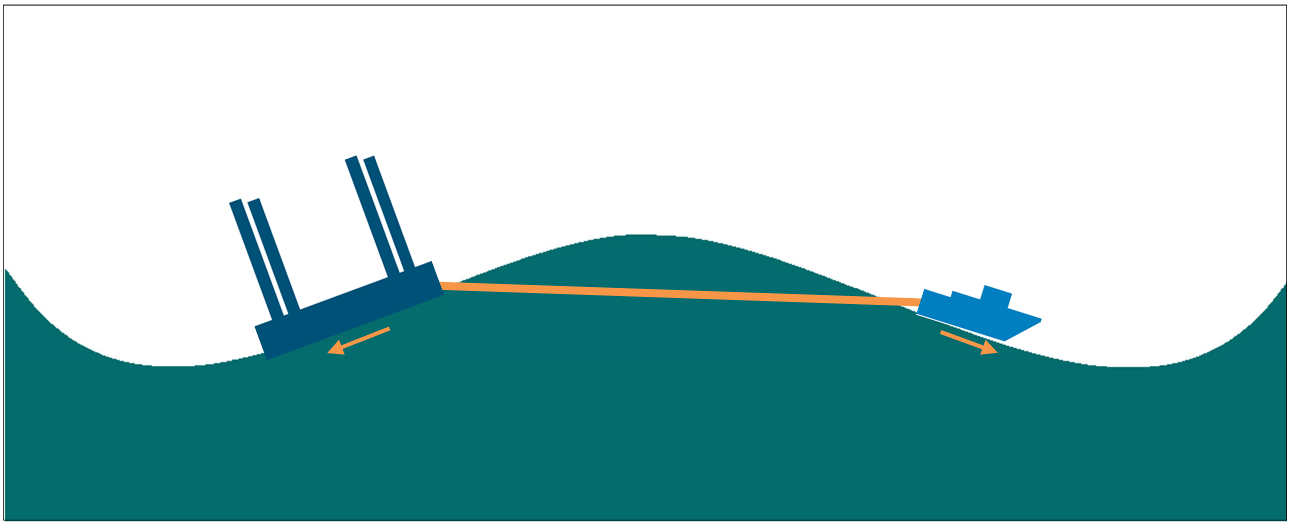

Figure 14: Towing situation with a tightening towing wire due to waves
Source: DMAIB

The bottom figure shows an undesirable situation where the towing vessel and the towed object are situated on each side of a wave. In this situation the towing vessel will pull forward, while the towed and often heavier object pulls in the opposite direction, causing substantial extra load on the towing line. Thereby, the towing wire is tightened, and the elasticity is lost. This can cause the wires or the joints of the tow to fail. When this situation occurs, the only way of reducing the strain on the towing wires is for the tug to idle or even reverse its engines, in order to let itself being pulled in the towed object's direction.

Close to shore, the wave period decreases and the wave height increases. This means that the situation in the bottom figure is more likely to happen at a higher frequency, straining the towing wire immensely. It is likely that AMBER II and SEA WORKER encountered this situation during the voyage, especially when passing close to shore. As focus on both ships was on gaining speed to reach shelter, it is likely that the towing wire was tightened repeatedly.

4.3 Weather

4.3.1 Operational weather criteria for SEA WORKER

The Danish Maritime Authority had issued a trading permit for SEA WORKER stating the weather criteria for its towage: *"As manned towage the platform may only be moved with a significant wave height of maximum 2.0 m"*. This operational limit was provided to the Danish Maritime Authority by the owner. It has not been possible to establish what this criterion is based on, and it is not repeated elsewhere in the ship's documentation.

On SEA WORKER, the trading permit was perceived as part of the platform's formal certification documentation and was not used on board in operational situations. Therefore, it did not occur to the crew to consult the trading permit before determining the weather criteria ahead of departure from Frederikshavn.

When doubt occurred about the wave height limit for SEA WORKER, the master was referred to the platform's class approved operations manual by the assistant project manager. In the operations manual's section on weather criteria it is stated that:

"Maximum design weather criteria for the floating condition are to be found in the unit's Statutory Operations Manual".

The reference does not point to an exact section in the operations manual, and it is hence unclear where to retrieve the information. The DMAIB has searched the document and its thirteen appendixes and found the following weather limitations for the platform in floating condition:

Appendix 3, Designers Manual – 1.6.3. Limitations for the floating/towing conditions:
"The wind velocity in the stability analysis for severe storm/survival condition is 51.5 m/sec (100 knots.)

And,

"The legs and supporting structures have been designed to withstand a roll or pitch motion of 15 degrees each side of the vertical in a 10 second full cycle period, when legs are fully retracted."

The second criterion is also stated in the operations manual's ***Appendix 2, Basic specification of a self-elevating pontoon – 2.3 Towing conditions.***

The crew on board SEA WORKER did not consult the operations manual before or during the towage from Frederikshavn to Esbjerg. However, the operations manual did not contain any clear operational weather criteria besides the wind speed limit for operation of the crane. The limits of the roll and pitch period and angle concerned what the barge was designed to endure, however, this did not translate into an operational criterion that could be used during voyage planning. Wave height was not mentioned for SEA WORKER in floating/towing condition. Considering the size of the operations manual, the information stated in it and the structure of the information, the crew on SEA WORKER had limited preconditions for determining the operational weather criteria by means of the manual.

Usually, criteria for operation were established by the charterers and, hence, the operations manual was rarely used. The operations manual was last revised in 2013. This supports the indication that the manual was not used actively, neither on SEA WORKER nor at the back office.

4.3.2 Weather at the time of the accident

At the time of the accident, the wind speed was 16 $^{m}/_{s}$ coming from southwest. The significant wave height was approximately 3.5 m, with maximum waves of approximately 5-6 m. The current velocity was approximately 1 knot in a north-easterly direction.

4.3.3 Forecasts and passage planning

SEA WORKER received weather forecasts from the Danish Meteorological Institute every six hours. The weather data were modelled to fit six specific geographical locations along the coast of Jutland. The quality of the data of each forecast could vary considerably and hence each forecast needed to be compared to the prior or/and the following forecasts in order to verify the quality. This meant that the forecasts and their quality needed to be assessed continuously during the voyage, and this assessment was compared to observations of the actual weather conditions that the ship was currently facing. Furthermore, the accuracy of the forecasts improved as the time span of the forecast decreased.

In order to apply forecasts to voyage planning, it was necessary to estimate where the towage would be situated at a given time. Before departure, the expected average speed for the towage was estimated to 5 knots. At this speed, the towage had an estimated time of arrival in Esbjerg on 26 January at 0800. The bridge team entered 2 m significant wave height as a limit in the software presenting the forecast. Prior to departure, the forecast had consistently showed that this limit would not be exceeded on the planned route until 27 January.

During 25 January, it became evident that the towage was unable to reach Esbjerg before the weather would deteriorate. The towage was not able to keep the expected average speed, meaning that the towage would meet weather that exceeded the acceptable significant wave height earlier than expected. Therefore, the towage decided to seek port in Hvide Sande, which it would according to the forecast be possible to reach at a low speed before the undesired weather was encountered.

4.3.4 Wave height

The weather criteria stated in the trading permit concerned the significant wave height. The crew on board SEA WORKER had also defined their limits for acceptable weather based on the significant wave height.

Below is an excerpt from the American National Weather Service defining significant wave height[8]:

> *"Significant wave height is an average measurement of the largest 33% of waves. We measure it because in many applications of wave data, larger waves are more "significant"*

[8] Source: The National Weather Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

(important) than smaller waves. For example, the larger waves in a storm cause the most erosion on a beach.

Significant wave height measured by a wave buoy corresponds well to visual estimates of wave height. Most human observers tend to overestimate the real height of waves. As the significant wave height is an average of the largest waves over a recording period it should be noted that some individual waves might be much larger than this.

On average, about 15% of waves will equal or exceed the significant wave height. The highest 10% of waves could be 25-30% higher than the significant wave height. And on occasion (about one per hour) one can expect to see a wave nearly twice the significant wave height."

Therefore, it is probable that the wave heights encountered by AMBER II and SEA WORKER, over a period of time would vary substantially from the wave height values given in the weather forecast.

4.4 Seeking port in Hvide Sande

4.4.1 Description of Port of Hvide Sande

Hvide Sande is a fishing port in Denmark that has in recent years developed into a commercial port, providing service for the offshore wind sector.

The port is located on the west coast of Jutland with the approach facing the North Sea directly. The approach is protected by two breakwaters constructed of water building stone. A strong north-going current runs across the entrance of the breakwaters. The water depth of the approach is 7 m, and the tidal range is 0.7 m. South-westerly winds can increase the water level up to 3.5 m in the port.

The width of the fairway between the outer pier heads is approx. 100 m and 75 m between the inner pier heads. The port can accommodate vessels with a length of 140 m, a breadth of 50 m and a draught of 5.5 m.

A work boat and a rescue boat were available to provide towage assistance during departure and arrival and each had a bollard pull of 7 t. Pilot service was ordered from the pilot station in Esbjerg.

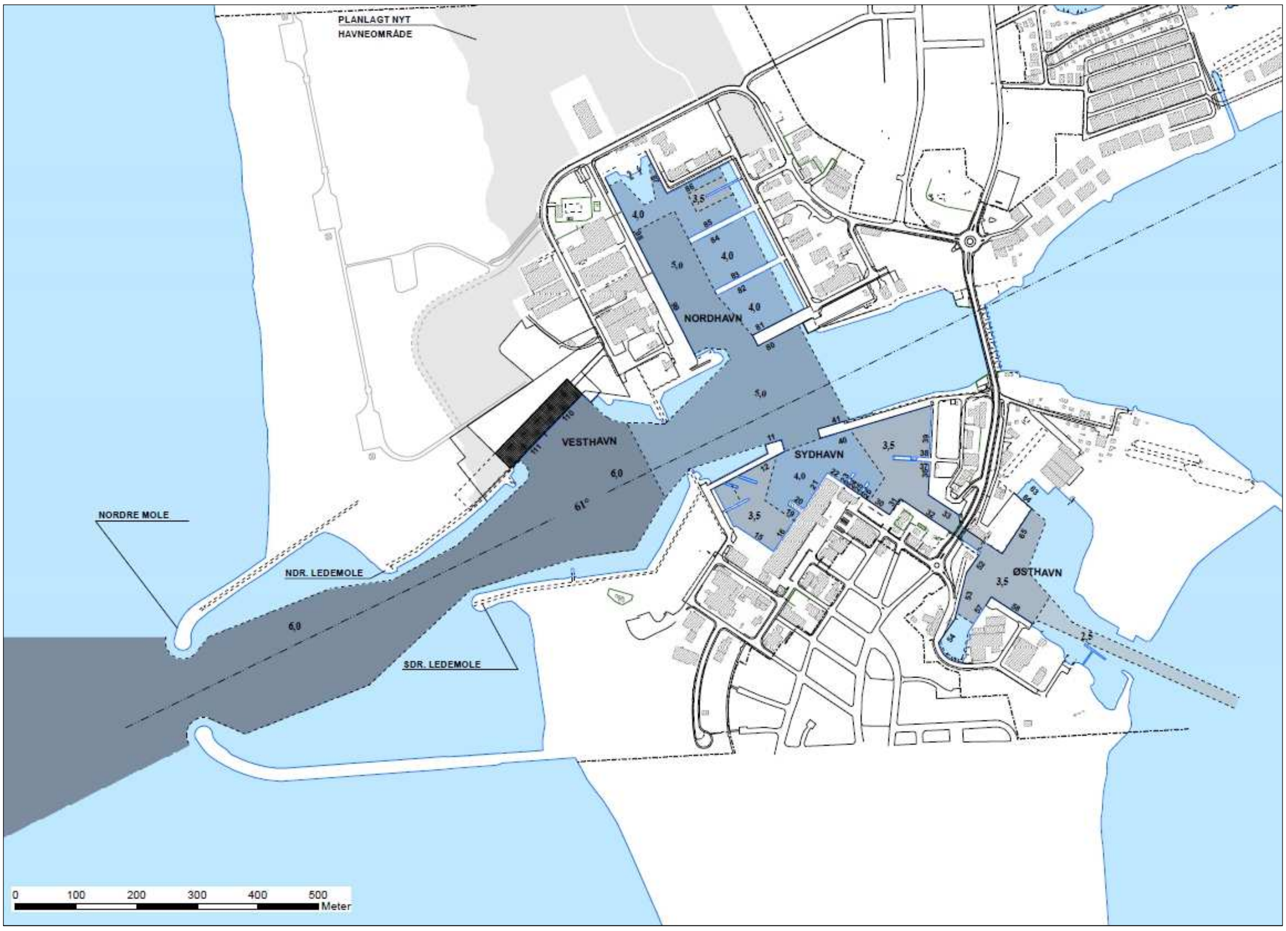

Figure 13: Map of port of Hvide Sande
Source: Port of Hvide Sande

4.4.2 Choosing Hvide Sande as port of refuge

Hvide Sande was identified as a possible port of refuge in the voyage plan by the crew on SEA WORKER shortly after departure. The decision made on 25 January to go to Hvide Sande instead of proceeding directly to Esbjerg was based on mainly three facts: 1) The company's largest self-propelled jack-up vessel SEA INSTALLER had entered the port before, and it was therefore considered unproblematic to enter the port with the smaller platform SEA WORKER. 2) Forecasts showed that there was an acceptable weather window for the towage to reach Hvide Sande. Between the two options of entering Hvide Sande and returning to Frederikshavn, Hvide Sande was the closest in distance. Furthermore, Hvide Sande would render it possible to continue the voyage to Esbjerg. 3) The port staff considered it unproblematic for the towage to enter the port on 26 January and held their resources available.

The crew on board did not consider Hvide Sande a port of refuge when finally deciding to head for Hvide Sande, because the arrival was planned a day ahead, but used the term 'shelter port'. However, it was emphasized to the office that going into Hvide Sande was the last possibility for seeking shelter for the towage. The back office personnel perceived Hvide Sande as a port of convenience rather than a port of refuge, as they were of the perception that the crew wanted to avoid unpleasant weather – not an emergency situation.

Although identifying Hvide Sande as a potential port of refuge, the crew of SEA WORKER did not consider it optimal for the purpose. Due to the port's location on the west coast facing the North Sea directly, they knew that a second tug was crucial for entering the port, even in calm weather. Therefore, the bridge team established an abort position – the point of no return. SEA WORKER would not pass this point, but return to Fredrikshavn, unless a tug for Hvide Sande was confirmed.

4.4.3 Pilot's concerns of the towage entering port of Hvide Sande

Two pilots were consulted concerning entering port of Hvide Sande with AMBER II and SEA WORKER. The first pilot had previous experience with entering the port with A2SEA's largest vessel SEA INSTALLER. The second pilot had previous experience with pilotage of SEA WORKER in Esbjerg, and had more experience with pilotage at the port of Hvide Sande as well as with large offshore installation vessels. Independently, both pilots assessed the risk of entering the port with the towage, based on weather forecasts for the towage's estimated time of arrival, the availability of assisting tugs, and the nature of the port's approach.

Both pilots had been informed that the towage had an estimated time of arrival in Hvide Sande at 1700. At that point in time, the tide would be at its highest, the waves were forecasted to exceed 3 m and the wind to reach 22 $^{m}/_{s}$. These weather conditions caused the pilots to point out several critical risks:

- *Swell and draught:* When approaching Hvide Sande, the water depth decreases, which means that swell and waves are building up fast. The sea state can seem calm at a 200 m distance from the shore, but at the port's entrance, waves and swell can be quite different. The water depth at the port's entrance was estimated to 6-7 m, and the swell was forecasted to reach 2 m at the estimated time of arrival. AMBER II's draught was 4.4 m and both ESVAGT CONNECTOR and the originally planned tug's draught was more than 5 m. With the vessel's expected movements in the water in 2.5 m swell, the risk of grounding for all three ships was deemed substantial, with or without assistance from ESVAGT CONNECTOR.

- *Waves and length of the towing wire:* The wire length between AMBER II and SEA WORKER would need to be reduced to approximately 10 m while entering the port. When towing, it is desirable to keep the towing wire long when facing high waves, in order to prevent the dynamic forces from straining the towing wire. At the estimated time of arrival, the wave height was forecasted to reach 3 m. Towage in 3 m waves with a very short towing line would cause a significant load on the towing wire, and therefore the risk of the towing line breaking and subsequent grounding or contact with the jetty was deemed substantial.

- *Current, wind and the lack of an adequate stopper*: The strong north-going current was at the estimated arrival forecasted to be accompanied by a south-westerly gale. As SEA WORKER's wind area was large, both pilots considered it difficult to hold SEA WORKER in place when approaching the port entrance. Even in calm weather, an assisting tug with substantial bollard pull would be required to keep the platform from drifting. The second pilot collected information himself on the proximity of an adequate, available tug, and found it to be located in Fredericia, Denmark, 24 hours away. The second pilot was presented with the suggestion of using the platform's legs as brakes by SEA WORKER's back office. Both the pilot and the barge master rejected this suggestion, as the impact and movements of the waves along with the speed of the towage would break the legs and cause significant damage to the hull.

- *Nature of the break water:* The breakwater at the port's entrance consisted of rows of piled large, edged stones (figure 14). The construction broadened from the top down, which meant that the stone breakwater would extend considerably under the water. Both pilots perceived contact with the breakwater as a serious event and even life-threatening, because the stones could tear up the ship's hull.

- *Waves and possibility to board AMBER II or SEA WORKER:* In Hvide Sande, the rescue boat serves as a pilot boat. The rescue boat has an operational limit of 3 m wave height for this service. This means that the port effectively closes for pilotage at this wave height. At the estimated time of arrival, it was forecasted that the limit would be exceeded.

Figure 14: Breakwater, port of Hvide Sande
Source: DMAIB

All the concerns listed above caused both pilots to strongly recommend the towage not to enter the port. Pilots are required to provide pilotage, but can refuse to go on board if they consider the operation life threatening.

The narrow port entrance, the strong current and the relatively low water depth at the entrance with waves building up at the shore, altogether made the pilots consider Hvide Sande a relatively weather sensitive port.

SEA WORKER was ready to approach Hvide Sande at 1500, before high tide. It is unclear how the miscommunication concerning the ETA came about. It does, however, not change the fact that neither pilot found it acceptable to enter Hvide Sande without the assistance of a tug of an adequate size and bollard pull. The pilots communicated only with the agent and the project assistant until 1540 on 26 January, when the second pilot was put in direct contact with the master on SEA WORKER. At this point, the towage had passed Hvide Sande.

According to the pilotage company's guidelines, a request for pilotage to port should be given 24 hours in advance. Pilotage was not ordered until 1000 on 26 January. However, this was not considered a problem by the pilots, as they could be in Hvide Sande within two hours.

4.5 Decision Support System – Loss of tow

In addition to SEA WORKER's safety management system, a decision support system for emergencies was in place. A decision support system has the purpose of helping the crew with the decision-making through an emergency situation as it is happening. SEA WORKER's decision support system contained a guideline for loss of tow.

The guideline identifies three different scenarios for the loss of tow: broken wire, loss of power or steering of tug, and complete loss of tug. The guidance for actions to be taken in the case of a broken wire consisted of two pieces of advice:

> *"[1] In case of a wire break, the tug must immediately inform the barge, and all safe actions should be taken to reconnect the tug. [2] Prior to departure, the weak point of the towage arrangement must be identified and all parties should have a clear agreement on what to do, in case this does break."*

Neither of these offered practical decision making guidance during the emergency situation. Advice number one refers to the tug, and not the crew on board SEA WORKER. Furthermore, the advice of taking *all safe actions* is underspecified as it does not offer any guidance of what these safe actions consisted of. Advice number two referred to actions which should take place prior to departure, which means that it was not relevant for the emergency situation in progress.

In case reconnection of the tow turns out to be impossible, the document advises that:

"[…], the Master of the barge must consider other solutions to keep the barge safe. This should include calling for outside assistance, either from other vessels in the area or dedicated rescue tugs, if available. Before any new rescue tugs are connected the Company must be notified and a contractual agreement must be agreed prior to the rescue tugs are connected. If the situation develops and the safety of the crew and barge is jeopardized the Master may agree on any kind of rescue operations."

The excerpt from the decision support document presents a sequence of actions. External assistance is to be engaged when both the tow and the emergency tow have failed. Furthermore, it describes the line of authority during the loss of tow situation, as it is laid down that the master is not authorized to request external assistance without intervention from the back office until the emergency situation is evident.

The document also mentioned the possibility of deploying anchors and contained procedures for who should be contacted and what documents to be filled in. Lastly, the document referred to a "blackout and loss of manoeuvrability memory list".

Because the document mainly presented underspecified guidelines for action taking, apportion of authority and referred to actions to be taken prior to departure, it appeared to be a formal procedure, rather than offering practical decision support guidance for a developing emergency situation.

4.6 Regulatory and practical relationship between tug and platform

4.6.1 Overall regulatory framework for SEA WORKER

SEA WORKER was registered under the Danish flag in 2011. The regulatory basis under the Danish flag was Technical Regulation on barges' construction and equipment, etc. (Order No 9186 of April 2003). According to the Technical Regulation barges shall be approved according to the provisions for a cargo or passenger ship of a similar size and use. Therefore, SEA WORKER was approved according to various regulatory instruments, including the SPS[9] Code and Notice B from the Danish Maritime Authority[10]. In practical terms the implication was that the platform was to be equipped with life-saving equipment as if it was a cargo ship above 500 GT and it was issued with various certificates according to SPS, SOLAS, MARPOL and STCW. In addition, several other requirements had to be met in relation to e.g. the crane, the jack-up system, occupational health and CE marking of equipment.

In 2011, SEA WORKER was surveyed by the Danish Maritime Authority and the classification society and, subsequently, issued with a trading permit for manned tow in GMDSS areas A1 and

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[9] IMO Resolution MSC.266(84) – Code of Safety for Special Purpose Ships, 2008.

[10] Notice B from the Danish Maritime Authority, Technical Regulation on the Construction and Equipment, etc. of ships, dated 10 May 2010.

A2 in northwest European waters within a significant wave height of maximum 2 metres. The trading permit did not state any limitations for the unmanned towage of SEA WORKER.

SEA WORKER had a minimum safe manning certificate stating that the platform was to be manned with a minimum of nine crew members: Master, chief mate, mate, chief engineer, second engineer and four able seamen. SEA WORKER was manned in compliance with the minimum manning requirements.

4.6.2 Legal relationship between AMBER II and SEA WORKER

AMBER II and SEA WORKER were each manned with a master who had authority over his own vessel. As the vessels were connected by a towing wire, they were mutually dependent on each other to ensure the safe passage from Frederikshavn to Esbjerg. SEA WORKER depended on AMBER II to provide towage, and AMBER II depended on SEA WORKER to provide details about the planning of the voyage and the operational limits of the platform. The Danish maritime legislation and guidance did not contain specific provisions about the relationship between the ships in towage operations. From a regulatory perspective, it was therefore unclear how the authority and responsibility between AMBER II and SEA WORKER was to be managed and which master was in overall command of the towing operation. However, if SEA WORKER was unmanned, then the tug master would be in overall command of the towing operation.

The legal relationship between AMBER II and SEA WORKER was governed by a BIMCO TOWCON charter agreement, which the owner of SEA WORKER and a broker had agreed upon via email. Besides the standard TOWCON agreement, the email correspondence contained information about the time of arrival in Esbjerg and the average speed that the tow was to keep in order to reach Esbjerg in due time. It was agreed that, if the weather window would close, then AMBER II could adjust its speed in order to reach Esbjerg in due time on the basis of an additional cost. The TOWCON agreement did not contain clauses about the relationship between the tug and a manned tow, but seemingly had the underlying premise that the tow was unmanned. Thereby, the interrelationship between AMBER II and SEA WORKER was governed by the operational practices that the involved parties had developed over time.

4.6.3 The practical relationship between AMBER II and SEA WORKER

SEA WORKER was manned and operated as a conventional ship, but had no propulsion or propulsion positioning systems. This meant that the speed and manoeuvring changes were executed by AMBER II by orders from the barge master on SEA WORKER. There was an understanding among the parties involved in the towing operation that the master on SEA WORKER was in command and had authority over the master on AMBER II. This understanding was common practise within the towing company and the company which operated SEA WORKER.

On AMBER II, it was perceived as standard procedure for towing a manned barge that the barge master was in command and responsible for the operation as well as the barge’s own towing arrangement though the TOWCON agreement stated that the tug master had the task of ensuring that the towing equipment was in good working order. The crew on AMBER II did not examine SEA

WORKER’s towing gear as this was usually done by a warranty surveyor. However, the warranty surveyor was replaced by the SEA WORKER’s master in Frederikshavn.

The navigational crew on SEA WORKER expected AMBER II to provide navigational services such as, inter alia, a voyage plan and the responsibility for safe navigation. However, the barge's procedures and practice called for the crew to monitor the performance and navigation of AMBER II, and the company held the bridge team on SEA WORKER responsible for the safe navigation and towing operation.

The result was that SEA WORKER was, in many respects, operated as if it was a ship with propulsion with the exception that the manoeuvrability was outsourced to an assisting vessel. It had the implication that the bridge crew on SEA WORKER had a limited overview or knowledge of the performance and situations concerning the maintaining of speed to reach Esbjerg in due time and, more importantly, within the weather window.

Before SEA WORKER was taken out of service, the platform had been paired with the same tugs for years during operations. Therefore, the bridge team on SEA WORKER was used to work in close collaboration with the tug’s bridge team. AMBER II had not been engaged in towing SEA WORKER and there was little time for the two bridge teams to familiarise prior to departure. Therefore AMBER II’s involvement in the decision-making and the communication between tug and barge was sparse.

4.7 Organizational set-up for sea-going operations at A2SEA

A2SEA was specialised in transport and installation services for the offshore wind industry. The transport and installation and other offshore services, e.g. providing accommodation, together constituted a project. Each project was requested by and carried out on behalf of a charterer.

Operations could be carried out in two different modes: *in project* and *out of project*. *In project* operations was the primarily mode, whereas *out of project* operations were rare.

In project meant that the operation was carried out for a charterer. The charterer would prepare a set of operational criteria to be met by A2SEA. In A2SEA a project manager acted as a central person as he was the liaison between the charterer and the platform master executing the operation and facilitated consultancy from the company’s relevant divisions. An external warranty surveyor hired by the charterer also had a significant role in the organisational setup as he verified compliance with the standard set by the charterer.

SEA WORKER was moved from Frederikshavn to Esbjerg *out of project*. This meant that the charterer was not involved in the move. Hence, the company needed to comply only with its own standards. This meant that an external surveyor was deemed dispensable prior to departure. As SEA WORKER was rarely moved *out of project*, the crew and back office personnel were used to receive operational criteria stated by the charterer.

5. ANALYSIS

On 27 January 2016, the tow between the tug AMBER II and the manned installation platform SEA WORKER broke as the towage was heading for Horns Rev to seek shelter from adverse weather conditions in the North Sea along the coast of Jutland. An earlier attempt to seek shelter in the port of Hvide Sande had been cancelled due to the unavailability of an assisting tug with adequate bollard pull and pilots' recommendations to abort the approach. When the towing pennant broke, the platform went adrift towards the coast, and the platform was evacuated without any injured persons.

The investigation aimed to examine how and why the loss of tow occurred and to clarify the circumstances of the event leading to the evacuation of SEA WORKER. The analysis presents a likely explanation of how and why the pennant broke. Though loss of tow can be perceived as a local equipment failure, the DMAIB's investigation has shown that the failure of the towing pennant was the result of the organisation of the towing operation. Therefore, the analysis will address the technical and operational circumstances resulting in the breakage of the towing equipment and explain how and why the accident was a result of organisational factors.

5.1 Loss of tow

5.1.1 Breakage of towing pennant

An examination of the wire carried out by FORCE Technology concluded that the fractured steel wire showed signs of wear and tear as expected for a wire that had been exposed to sea water in normal service, and that it showed no sign of manufactural defects. However, the corrosion found on the wire was not linked directly to the parting of the wire. Instead, the report concluded that the nature of the fracture indicated that the wire broke due to overload.

The fractured towing pennant was the weakest link on the towing bridle and was certified for a safe working load of 25 t and a minimum breaking load of 138 t. The crew on SEA WORKER was of the perception that the working load limit for the towing bridle and, hence, the weakest link was 50 t. The configuration of the towing arrangement was based on an industry standardised practice which was considered safe and normally unproblematic, even though the use of the towing arrangement did not adhere to the equipment's certified standards. The certified safe working loads for the wires were based on criteria for lifting and not towing.

The broken towing pennant did not show signs of material malfunction. Therefore, the parting of the wire happened because the breaking load was exceeded. The breaking of tow occurred as the towage was exposed to strong head winds and current and waves with a significant height and short frequency due to the close proximity to the shore. Global Maritime's calculations of the required bollard pull for SEA WORKER showed that a 50 t bollard pull was needed in order to maintain zero speed during a combination of 15 $^{m}/_{s}$ wind speed, 0.5 knots current velocity and 2 m wave height. As the weather conditions exceeded all of these parameters while the towage periodically still made speed, it is evident that the load on the wire exceeded 50 t. Furthermore, facing waves of a significant height and frequency while maintaining speed or position most likely imposed situations where the tug and the platform were situated on each side of a wave. This caused the tug and the platform to pull in opposite directions on the wire, significantly increasing the load on the wire, and causing the wire to tighten up and lose its flexibility while being exposed to significant movements. As the towing pennant fractured at its least flexible point at the clamp, the heavy load, frequency and movement of waves coming between the tug and platform most likely contributed to the parting of the wire.

There was no tension meter on AMBER II and the load of the wire was therefore estimated by setting a limit of 75 % engine power on AMBER II and observing how the towing bridle acted in the water. Thereby the estimated tension on the towing bridle was based on individual judgement and experience on both AMBER II and SEA WORKER, which became increasingly difficult as the weather conditions worsened.

It should be noted that the issues related to the towing arrangement were only a couple of several weather related concerns that had to be addressed, e.g. seeking shelter, loss of speed and risk of drifting aground. The bridge team on SEA WORKER was well aware that the situation was critical, but had no possibility of mitigating the risk of the wire breaking. The main concern of the crew on SEA WORKER was that AMBER II was not able to hold the platform and the subsequent risks of the tug capsizing or the platform grounding. Therefore, focus was primarily on moving forward and, later, on keeping the position until assistance arrived.

5.1.2 Operational limitation of SEA WORKER

SEA WORKER's operational limit of 2 m significant wave height was stated in the trading permit. This operational limit was provided to the Danish Maritime Authority by the owner. It is uncertain how this limit was determined, and it was not stated in the operational manual. The information in the operational manual was based on criteria other than wave height, e.g. roll period.

The strength of the towing gear determined how much bollard pull SEA WORKER could be towed with. The crew established that the safe working load for the towing bridle was 50 t and expected a 5 knots average speed within the established weather criteria with a maximum significant wave height of 2 m. The barge master expected that the mounted towing arrangement was adequate for towing SEA WORKER.

The calculations for the bollard pull requirement for *short coastal tows* with SEA WORKER were carried out by Global Maritime Consultancy which established it to be 50 t. The bollard pull requirement was established by calculating the force needed to maintain zero speed in weather conditions of 15 $^{m}/_{s}$ wind speed, 0.5 knots current and 2 m wave height. However, the DMAIB concludes that the general towing arrangement was undersized for this operation, both in theory and in practice, if the speed was to be maintained.

The crew estimated the operational limit to be 2.5 m significant wave height. To allow for a buffer, the crew applied a significant wave height of 2 m for determining the weather window. This was done independent of the information provided in the Trading Permit and the bollard pull calculations.

The wave height limits of the weather window and the Trading Permit, respectively, were both limits for what was considered acceptable and safe by the crew, the owner and the authority. The wave height in the calculations was a limit for the possibility to make speed, meaning an absolute minimum requirement. This means that, if the towage was operating in conditions at the margins of the weather window, a 50 t bollard pull would ensure little or no forward speed. This explains AMBER II's and SEA WORKER's difficulties with making speed from the time they passed the Skaw and turned directly into stronger wind and current in the North Sea, even though they were within the margins of the weather criteria.

5.2 Recovery of tow

The emergency towing line was stowed on deck until the tow was lost. The crew on SEA WORKER deployed the emergency towing gear immediately after the towing line parted, but the Norwegian buoy with the recovery line was caught on the side of SEA WORKER rendering it impossible for AMBER II to recover the tow. This type of emergency towing gear is generally deployed at departure, in order for the pick-up line to float free of the platform. However, during the investigation no instructions of how to use the emergency towing gear could be found in the safety management system. The tug master on AMBER II was used to having the emergency towing gear deployed on the towed object, but did not intervene in the practices used on SEA WORKER, as he perceived the barge master to be in command of the towing operation.

The emergency towing line consisted of a single wire with a SWL of 20 t connected to a Smitt bracket on the forward deck. Towing with a wire fastened to a single point would decrease AMBER II's ability to manoeuvre SEA WORKER. As the main tow line most likely parted due to the impact of the adverse weather conditions, it is not likely that the recovery of the emergency tow would have improved the possibilities of reaching shelter or maintaining SEA WORKER's position, as the emergency gear had less strength.

The installation platform was manned as a ship, but was entirely dependent on external assistance. When the tug and towline failed, it was evident to the crew that the platform would drift aground and capsize and/or break apart. Therefore, the crew had no other option than to evacuate the platform.

According to the decision support system, it was possible to order an assisting tug if the tow had failed and could not be recovered. The response time for a tug would, however, impose significant delay on the recovery of an emergency situation. On this voyage, the barge master on SEA WORKER requested an assisting tug *before* the tow failed, as he had already prior to the parting of the wire deemed the situation unacceptable, due to the tug's loss of control. The company accepted the request, but the assisting tug did not reach AMBER II and SEA WORKER before the risk of grounding was deemed too great, and the crew was evacuated. Furthermore, the master on the assisting tug doubted whether they could connect with the platform under the given weather conditions. The response time for assistance from other ships proved too long, even though the master on SEA WORKER demanded assistance at an earlier stage than called for in the procedure.

Due to the long response time, external assistance is not a very effective resource to rely on in an emergency situation. Requesting an assisting tug in case it should become relevant is not a good option for a master, as this would most often turn out to be an unnecessary expense. It is inherently difficult to predict if and when an emergency situation will occur that will necessitate an assisting tug. Emergency situations are often preceded by events that are typically characterised as operational disturbances which are manageable. Only when no options are left for normalising the situation, is the situation perceived as an emergency.

5.3 Weather window

The platform master and the second master on SEA WORKER had combined experience from SEA WORKER and SEA JACK, which had similar operational characteristics. In the perceived absence of detailed information about SEA WORKER's operational limits, the masters' determination of the weather window was therefore based on the operational limits for SEA JACK and previous experience with towing installation platforms. The operational manual's limitation referred to design limits, concerning roll period, on which it would not have been possible to base a weather window. The actual roll period depends on a combination of multiple varying factors, such as wave patterns and periods, which it is not possible to predict with sufficient accuracy. Roll period as a criterion is a theoretical construct, which has little or no practical use in voyage planning.

The DMAIB has established that the criterion which limited the operation turned out to be the requirement for keeping the tension load on the bridle below 50 t, as the wave height needed to be well below 2 m in order to make the expected speed of 5 knots with this bollard pull. No person on the platform or within the organisation was aware that the provided bollard pull combined with the forecasted weather conditions was not adequate for making the expected speed.

As the expected speed performance was not attained, the towage was not able to reach Esbjerg within the weather window. The realisation of this was delayed due to a set of factors: 1) The loss of speed occurred unexpectedly approx. eight hours after departure. 2) Until 25 January, the bridge crews on AMBER II and SEA WORKER were not aware what caused the slow speed but believed that speed could be regained if the weather improved. 3) The quality of individual weather forecasts could not be determined on their own and had to be compared with later forecasts.

The factors mentioned above show that the prediction of weather during sea operations is not as simple as it may seem in hindsight. Firstly, because the quality of the weather forecasts is variable and weather can change. Secondly, the prediction of the weather is connected to a certain place and time, which means that an unexpected speed reduction can suddenly change the weather conditions and the time when they will be faced.

As the speed could not be maintained and the towage was not able to reach Esbjerg within the weather window, the need for an alternative port arose. Entering the alternative port however depended on tug assistance. On the day of arrival at Hvide Sande, tug assistance turned out not to be available, although it had been confirmed to the bridge team on SEA WORKER. Therefore the towage continued for south for Horns Rev though the weather window had closed.

5.4 Organisational change

5.4.1 Organisational change and drift for the particular project operation

Most of SEA WORKER's project specific operations had been handled *in project*, meaning that a charterer had been involved in working out the operation criteria and that a warranty surveyor continuously verified that the agreed standards were met. The assistant project manager ensured that the standard was met by drawing on consultancy from the other divisions in the company and the master executed the project.

The voyage from Frederikshavn to Esbjerg was handled *out of project*, meaning that a charterer was not involved in the transport of SEA WORKER. *In project*, the management and planning of the operation was centralised and prepared in advance. The voyage from Frederikshavn to Esbjerg had been announced, but neither the ship nor the crew was prepared for the voyage when the project manager and master on Friday 22 January 2016 were informed by a person in the company that an agreement of using SEA WORKER as a hotel platform at a windfarm had been reached, and that SEA WORKER was to be moved to Esbjerg as soon as possible. As there was a weather window at the beginning of the week, it was decided to depart two days later. Meanwhile, tugs and crew needed to be arranged, as SEA WORKER was only partly manned, and the installation platform needed to be prepared for the voyage, which included an unforeseen repair of a hull fracture. Due to the short notice, an accredited IMCA vessel inspector could not be arranged, and it was decided that an external surveyor was not needed, as the platform was not loaded and only needed to be moved. Therefore, the task of inspection of the tug was assigned to SEA WORKER's master. If the tug was not approved, there was no time to wait for another tug because of the weather window, and it was uncertain when a weather window would occur again. This fact, combined with the time pressure and work load concerning the preparation of the platform, is likely to have influenced the master's perception of whether he could reject the tug, even though it meant that the towage departed Frederikshavn with no satisfactory voyage plan in place in order to reach Esbjerg within the weather window. Furthermore, the master inspected only the tug as he was not able to act as an impartial inspector on SEA WORKER.

The description above shows that standards for operations *in project* and *out of project* were not the same. Because the move of the platform was *out of project*, the operation was not to the same degree planned ahead as operations *in project* usually were. An example of this is that the question of SEA WORKER's operational criteria was not raised before the operation was initiated. This difference between the *in project* and *out of project* approach caused what could be characterised as an organisational drift for this specific operation: the centralised project management changed to local ad hoc problem solving. This organisational drift caused the involved persons, the platform master and assistant project manager in particular, to be faced with a room for action that continuously narrowed over time and with problems gradually being more complex and difficult to overcome.

Two essential problematic phenomena can be derived from the organisational drift preceding the loss of tow: *allocation of knowledge* and *allocation of authority*.

Allocation of knowledge means that vital facts were allocated to different stakeholders and that these vital facts were not collected at a central point. Three examples of this follows below:

- *Operational weather criteria:* The determination of the weather criteria for the operation was usually carried out by the charterer. As no charterer took part in SEA WORKER's move, no weather criteria were provided to the company. As SEA WORKER usually received the operational criteria from the charterer, neither the operational manual nor the safety management system or any person (in the organisation) possessed information about the platform's operational criteria.
- *Arrangement of tug for Hvide Sande:* The arrangement of a tug for seeking port in Hvide Sande went through the assistant project manager, who thought he had an oral agreement with the agent for a tug to be on stand-by to assist in Hvide Sande, though no paper work was done. The master, however, thought that the tug was booked and took the decision to proceed for Hvide Sande based on that belief.
- *Towing arrangement:* During the investigation, the DMAIB has not been able to ascertain information about how the towing arrangement for SEA WORKER had been chosen. The technical department referred to a company technician inspecting the lifting and towing equipment, but this person was only guided by what was stated for the technical department's specified towing arrangement and referred back to the technical department.

Allocation of authority means that the authority for action was divided between several stakeholders, but this allocation was neither agreed nor consistent. The master formally had the overall responsibility for the towing operation. However, the master's responsibility and his possibility of knowing and acting on what was happening on the tug did not correspond. Furthermore, a sign of the formal authority of the master as an overruling authority had in practice been reduced, which could be seen in the decision-making document for loss of tow, where it was stated that the master would have to clear the arrangement of assisting tugs with the back office.

As the operations in A2SEA were based on project management, the project manager had become a central person in the operation; he was the connection point between charterers, specialised contractors/companies, and the master on board. As a consequence of this, the master had relinquished some of his authority to the back office, which was reflected by the communication and decision hierarchy. During this specific *out of project* operation, the project management structure was weakened causing organisational fragmentation.

5.4.2 Project-driven approach to problem solving for this voyage

SEA WORKER was normally operated on the basis of a project-driven strategy, where centralised management and external standard verification were combined with a problem solving mentality. This was usually effective for performing operations *in project*. For this voyage the centralised management and the external standard verification were absent, and the move of SEA WORKER had to be carried out within a weather window determined by operational limits rarely present in the North Sea during the winter. However, the forecasted weather window for the voyage rendered the platform move possible, though it was narrow.

Problems prior to departure and work areas usually covered by the charterer and the warranty surveyor were solved and covered ad hoc by the crew and the back office. This imposed an extra work load on the crew, which narrowed the weather window further and meant that some tasks, which should have been carried out prior to departure, were solved while the towage was underway. The main objective for the personnel on board and ashore was to execute the move within this weather window as it was uncertain when another window would open.

While the towage was underway, it became evident that the weather window would close before Esbjerg was reached as the speed could not be maintained. The bridge team on SEA WORKER tried to resolve whether the speed loss was caused by the tug, and when this explanation was excluded, they awaited new forecasts to see if the weather would improve before they reached their established point of no return. At the point of no return, it was decided to continue south. The crew on SEA WORKER was aware that they were dependent on the assisting tug, but all parties preferred the solution of seeking port in Hvide Sande, as this would ease the possibility of finding another and shorter weather window for the remainder of the move.

When AMBER II and SEA WORKER passed the point of no return, and the tug remained absent, the bridge crew on SEA WORKER was aware that they were in a critical situation, as they realised that the last option for a controlled voyage was lost. However, the back office kept on the problem solving approach and trusted that a solution could be found. It was decided to rely on the two small working boats as a back-up solution, while working on finding a better option. Therefore, AMBER II and SEA WORKER continued the approach to Hvide Sande, though it caused the towage to be situated close to shore. The back office suggested using the legs as brakes together with the two small working boats as stoppers. They also suggested using the working boats alone with the risk of colliding with the breakwater, as they perceived that the potential damage of contact would not be dangerous to the crew on board. The pilots rejected both options and strongly recommended aborting the approach as the risk of life-threatening consequences was significant.

When the pilots strongly recommended aborting the approach and rejected to board the towage, the bridge crew on SEA WORKER perceived the situation as an emergency because no solutions were left other than continuing south and facing the adverse weather conditions. The company recognised that control of the situation was lost and collected the designated emergency team. The problem solving approach was maintained at the back office until the crew evacuated the platform as they reckoned that an assisting tug and a weather improvement would render it possible to re-establish the tow, though the assisting tug had proclaimed that they were not able to do so.

6. CONCLUSIONS

On 27 January 2016, a towing pennant on SEA WORKER parted and caused the towing connection to the tug AMBER II to fail during passage in adverse weather conditions. The DMAIB concludes that no single cause of the accident can be found, but that the accident can be seen as a result of organisational drift and fragmentation leading to a continuously narrowing room for options for the involved persons and a loss of overview.

SEA WORKER was perceived and operated as a functioning ship that had allocated its propulsion to another vessel, AMBER II, by means of a towing wire. Both masters agreed that the barge master was in command and was responsible for the overall operation. However, as the propulsion and navigational means were allocated to the tug, he was formally in charge of the navigation and had a limited knowledge of and influence on the towing operation. On the other hand, the tug received critical information, such as weather forecasts, and directions from the towed object. This added complexity to the towing operation. The practical implication was that the master on SEA WORKER had little or no knowledge about and control over the propulsion.

In addition to the complicated overlap of authority between the masters on AMBER II and SEA WORKER, an organisational layer consisting of the project management increased the level of complexity within the organisation, causing the knowledge and authority to be allocated to more stakeholders. The DMAIB has, over a period of time, observed that the traditional idea of the master as a central, overriding authority is in practice contested as the master is faced with balancing the goal conflicts of fulfilling commercial interests and attending to the safe operation of the ship. Both can influence the master's perception of his professionalism and his continued employment.

SEA WORKER was normally operated on the basis of a project-driven strategy which entailed an organisational problem solving approach to work and a mind-set that all problems that arose could be resolved ad hoc one way or another. On this voyage, it was not until the organisation ran out of solutions to seemingly isolated problems that the involved persons realized that the towage operation had changed from a manageable operational situation to an emergency. This realization did not occur simultaneously throughout the organisation, just as the perception of how critical the situation was varied among the involved persons. These differences in perception were enhanced by an organisational fragmentation which occurred as the situation grew in complexity and which caused critical information to be dispersed throughout the organisation. When the emergency was evident to all those involved, the ship was situated close to shore, which meant that the response time for help exceeded the expected time for when the platform would drift aground. In other words, the opportunity for ad hoc problem solving had narrowed in time and distance and the only solution left was to abandon the platform.

The company's project driven strategy usually ensured an effective and successful execution of marine operations. However, AMBER II's loss of tow and the subsequent evacuation and grounding of SEA WORKER occurred as a result of a unique set of tightly coupled coinciding factors for this voyage which the problem solving approach turned out to enhance rather than mitigate.

7. PREVENTIVE MEASURES TAKEN

The DMAIB has received the following information from A2SEA about the preventive measures taken:

- *"To ensure that all marine operations are planned, assessed, executed and monitored to the same standard, the distinction between "in project" and "out of project" has been fully removed from all our operational systems and practices.*

- *To improve (cross) references and operational (planning) support, a detailed review and revision of the operational documentation supporting marine operations has been performed.*

- *As an extra layer of assurance, all weather restricted operations is assessed by an external Marine Warranty Surveyor or an in-house Marine Superintendent.*

- *All our passage planning procedures and templates have been updated, in order to ensure that all relevant factors (including weather restrictions and contingency plans) are addressed and documented, Further, passage plans are now reviewed by both an in-house Marine Superintendent and the Master.*

- *To improve the quality and frequency of weather forecasts a new and enhanced weather routing and monitoring scheme have been agreed with DMI.*

- *All minimum weather window requirements for marine and weather restricted operations have been reassessed, documented and discussed in-depth with our masters.*

- *Procedures for tug assessment, selection and contracting have been reviewed and enhanced and the practice of having the master assess potential tugs by himself has been fully abandoned.*

- *The (emergency) towing arrangements on all vessels have been re-assessed for adequate size and for ease of deployment and connection. Emergency towing drills are conducted every 3 months on all vessels.*

- *Towing of non-propelled barges outside port is only permitted with an additional (safety) tug, to eliminate the potential response time for an assisting tug. Such tug is to have a bollard pull of minimum 75% of the recommended bollard pull of the lead tug.*

- *The handover procedure for senior officers has been reviewed and enhanced in regard to time for familiarisation when joining a new vessel – including mandatory familiarisation with statutory and operational documentation.*

- *To ensure the right balance between marine operations and project operations - and not least to ensure that the Master's "voice" is even better heard and understood in the office - internal roles and responsibilities as well as interfaces and work flows have been mapped, enhanced and documented.*

- *All relevant risk assessments and related control and mitigation measures for marine and weather restricted operations have been re-assessed and enhanced where appropriate.*

- *It has been ensured that all vessels have immersion suits with removable mittens and that all release wires for lifeboats and life rafts are fitted with launch handles that are easily identifiable in the dark.*

- *In order to further reduce the potential risks associated with manned tows, and to eliminate the regulatory grey zones of authority and responsibility between the towed object and the tug(s), the necessity to man any future tows will be carefully evaluated"*