# PRELIMINARY ACTION PLAN FOR THE RETRIEVAL ACTIVITIES ON THE FRANKEN SHIPWRECK

MARE

INSTYTUT MORSKI W GDAŃSKU

Project Coordinator

The MARE Foundation
Al. KEN 19/27
02-797 Warsaw, Poland

Project Partner

The Maritime Institute in Gdańsk
Długi Targ St. 41/42
80-830 Gdańsk, Poland

# PRELIMINARY ACTION PLAN FOR THE RETRIEVAL ACTIVITIES ON THE FRANKEN SHIPWRECK

Report from the research expedition carried out on the Franken shipwreck on 23rd-28th April 2018 in the framework of the project "Reduction of the negative impact of oil spills from the Franken shipwreck"

Author:

Benedykt Hac, Ph.D. Eng. Pomiary Morskie / Benisławskiego St. 22A/8, 81-173 Gdynia

Analysis of bottom sediments: Grażyna Dembska, Ph.D.

Typesettings:
Agencja Wydawnicza Ekopress
Andrzej Poskrobko

Cover photo:
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Translation:
Ewa Milewska

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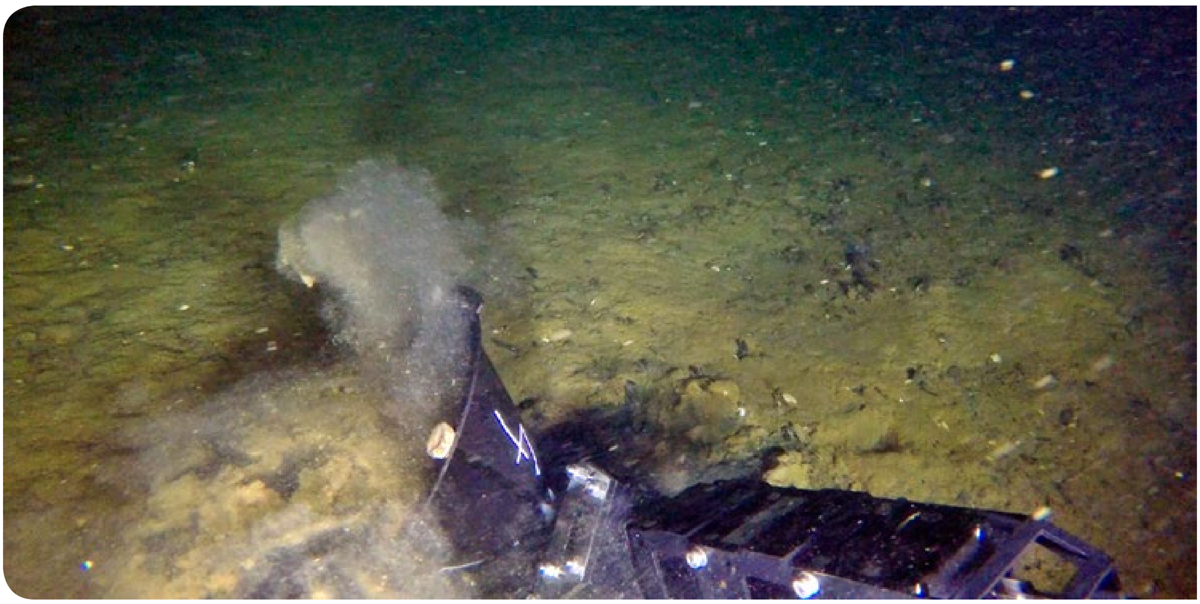

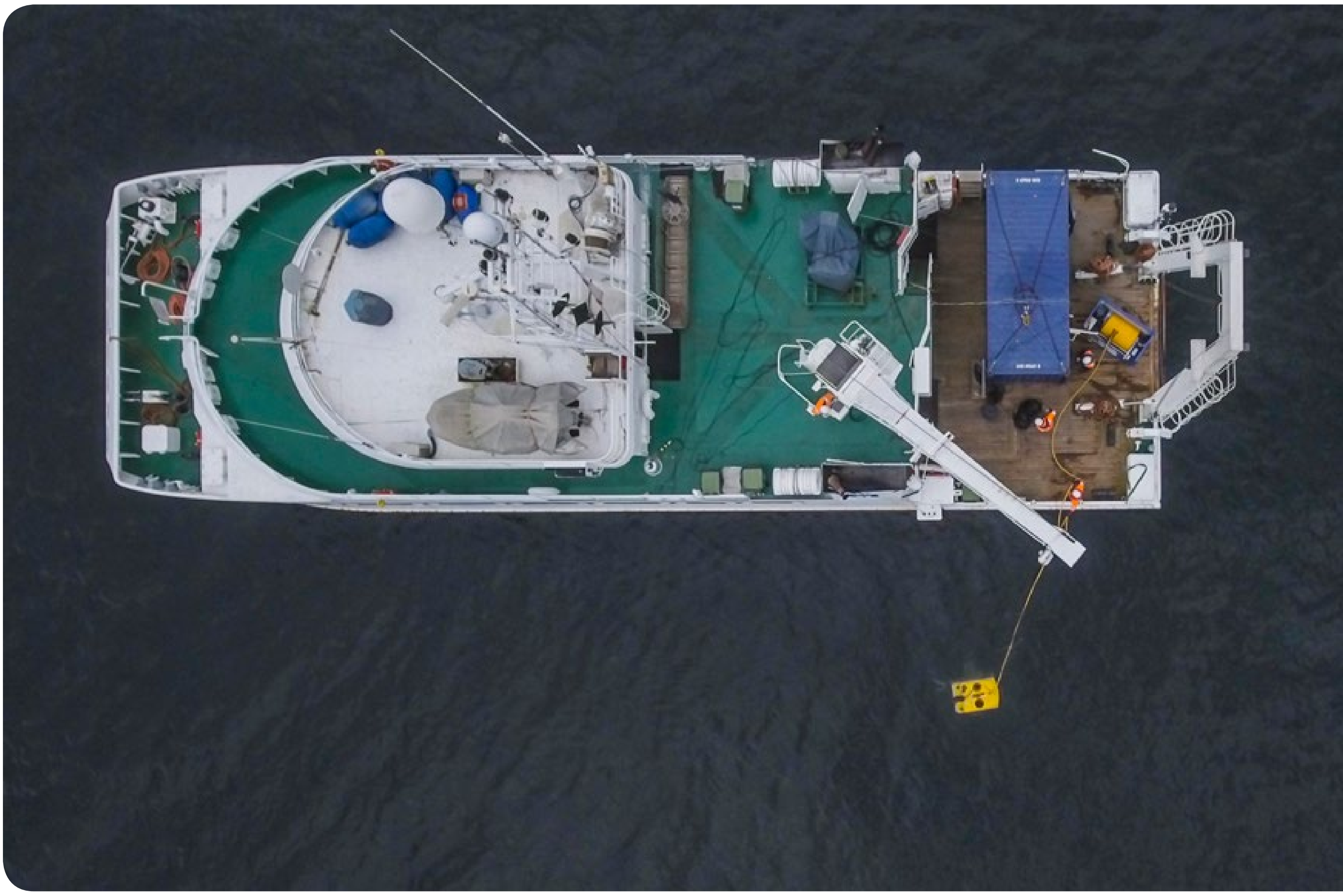


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# INTRODUCTION

On 23rd-28th April 2018, in the framework of project ”Reduction of the negative impact of oil spills from the Franken shipwreck”, financed by the Baltic Sea Conservation Foundation (baltcf), an expedition was carried out to the German tanker FRANKEN, located in the central part of the Gdańsk Bay. The purpose of this expedition was to gather as many photos, videos and information as possible, which after processing could be used to produce a coherent, technical description of the wreck.

The main purpose of the report is to present the outcome of the expedition. This outcome is a compilation of the measurement data, the photographic material as well as the samples collected at the sea bottom, next to the Franken wreck, according to the objective set in the project. The analysis of the activities carried out and the research results are intended to contribute to achieving the two main objectives of the project:

1) to reduce the possibility of ecological disaster in the Gdańsk Bay **through the development and preparation of the best technical and environmentally safe recovery plan of the oil remaining in the Franken shipwreck** and,
2) to mobilise the political will of the maritime administration in the region, where the wreck is located as well as political decision-makers (the Parliament, the Ministry of Environment, the Voivode and Marshal of the Pomeranian Voivodeship) to take over the responsibility for securing the wreck and to undertake actions mitigating the risk of a large oil spill in the Gdańsk Bay. The preparation of the Action Plan for cleaning of the shipwreck will help to show the decision-makers the scale of this undertaking, possible solutions together with an estimation of preliminary costs of such operation.

# 1 DESCRIPTION OF THE FRANKEN SHIP

## 1.1 Position of the shipwreck

On the 8th of April 1945, south of the roadstead of the Hel port, the Russian attack aircrafts Ił, supported by the Douglas A-20 and Pe, sank a German logistic support ship FRANKEN (a supply vessel – *Troßschiff*). The approximate position of the wreck was known to the hydrographers since it had sunk. It was also known to the fishermen, who lost their fishing gears on this wreck. However, for many years, there were no technical means for determining precisely the position of the wreck. The exact position of the wreck (Figure 1) was first determined in the 1980s.

The wreck is identified under the name WK-0140 (Figure 1) in the wreck database of the Hydrographic Office of the Polish Navy (BHMW), it has an *active/public* status and the category obstacle. The wreck was included in the list of wrecks available for diving. The position of the wreck in the BHMW database is:

$\varphi$ = 54° 32’ 19,452” N      $\lambda$ = 18° 57’ 57,024” E

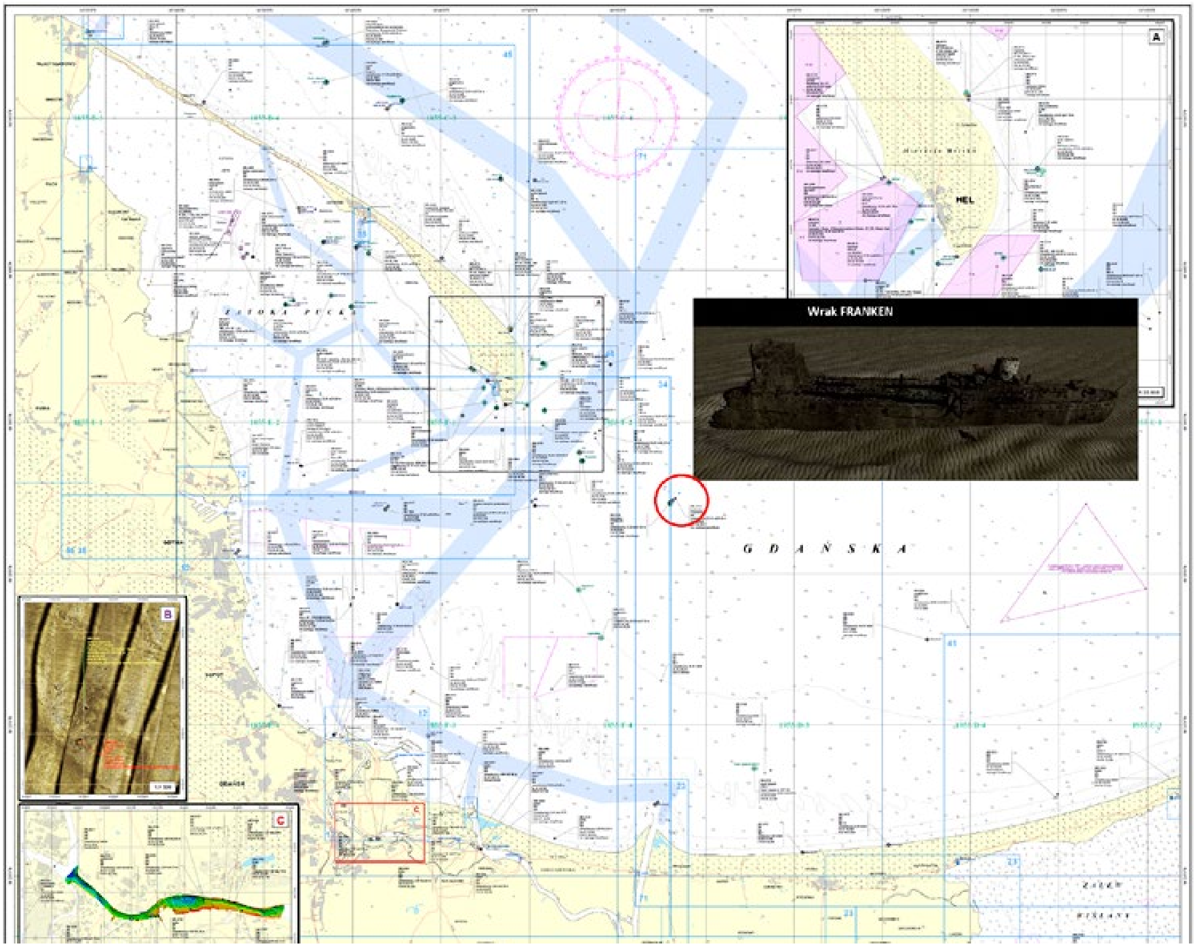
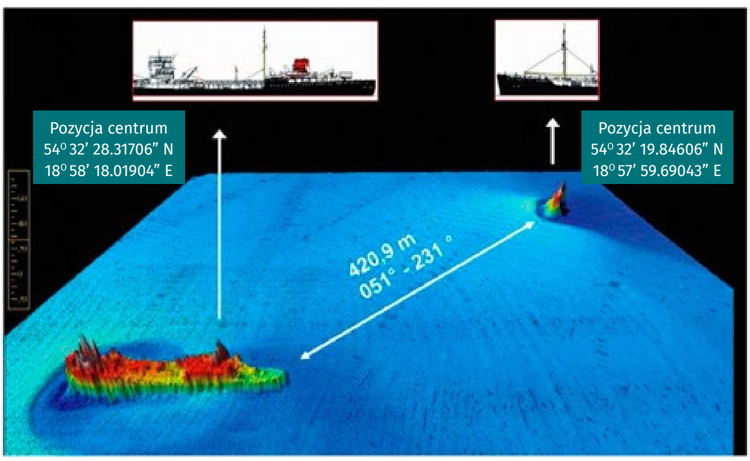



**Figure 1.** Position of the Franken shipwreck in the Gdańsk Bay (source: BHMW Nawigacyjna Mapa Wraków ESC_OP-W001 ak1ed4)

Sonar and bathymetric surveys indicated the existence of two sections of the wreck. This was confirmed by the testimony of the witnesses of the ship sinking, who had informed that the ship broke in two sections minutes after the attack (around 12:00). The bow sank very quickly. The stern drifted, burning for about 20 minutes. The ship sank at 12:22, taking down killed sailors, oil contained in the tanks, ammunition and armament. The main part of the wreck, including the stern and the amidships (where the oil tanks were located), together with the forecastle, approximately 130 metres in length is approximately 420 metres away from the bow, which is 50 metres in length (Figure 2).

**Figure 2.** T/S FRANKEN, current state, hydrographic survey (source: BHMW) "Hydrographic survey of the Franken shipwreck" by Artur Grządziel, www.dzh.mw.mil.pl/zasoby/archiwum/upload/badania.pdf



The location of the wreck is very suitable for divers performing deep dives with departure from ports of the Gdańsk Bay (Gdynia, Gdańsk, Hel, Jastarnia). At the same time, its location in the centre of the Gdańsk Bay is extremely unfavourable in terms of ecological risks. A potential oil leakage from the wreck is a threat to the existence of protected areas and can very seriously damage the ecosystem of the Gdańsk Bay and pollute the beaches from Piaski through the Vistula Spit, to Władysławowo (the sea coast). The reserves, protected areas and Natura 2000 sites are very seriously threatened (Figure 3). Oil spills from the wreck will negatively impact tourism in the entire region. Closures and cleaning of the beaches of the total length of 80 km during the tourist season will have a negative impact on the tourist industry (hotels, pension houses, restaurants, cafes, pubs, cultural centres and other tourist attractions) are threatened by losses counted in hundreds of millions zlotys (it is estimated that the loss of one season means approx. 500 million loss for the Pomeranian voivodeship).

## 1.2 Technical parameters of the Franken shipwreck

The Franken is one of the five twin supply ships of the German Kriegsmarine. It was originally built at the Deutsche Werke A.G. in Kiel. It was launched on June 8$^{th}$, 1939. However, after the outbreak of the Second World War, its construction was suspended due to more important orders. In 1942 the ship was redirected to the shipyard Burmeister & Wain's Maskin & Skibsbyggeri - B&W shipyard in Copenhagen. During its construction it was named a *„supply ship C – Troßschiff C“*, Dithmarschen class. It was equipped with diesel engines (MAN, similarly to Altmark). It was commissioned to the Navy on 17$^{th}$ March 1943, two year before the sinking.

Table 1. **Technical parameters of the Franken ship**

| | |
|---|---|
| **Gross tonnage** | 11 115 BRT<br>(other sources: 10 850 BRT) |
| **Displacement** | 22 850 t |
| **Length** | 178,25 m |
| **Width** | 22,1 m |
| **Immersion** | 10,2 m |
| **Crew** | 94 to 208 |
| **Propeller** | 4 engines 9 cylinder diesel engines MAN |
| **Speed** | 21 knots |
| **Power** | 24 000 KM |
| **Armament** | 3 guns, cal. 15 cm L/48<br>8 machine guns<br>16 anti-aircraft guns cal. 2 cm<br>6 anti-aircraft guns cal. 3.7 cm |
| | Space for an aircraft on board under a tent just behind the bridge, with a crane. Such aircraft was never transported on board the Franken ship |
| **Loading** | 11 810 tonnes of liquid oil and oils<br>3 937 tonnes of food and ammunition (calibres from 20 mm to 280 mm)<br>2 214 tonnes of water |

Source: *„Die deutschen Kriegsschiffe“* (Part 7: ISBN 37882202678); I. Tomica, P. Karaś: „Franken – the last days of the Kriegsmarine ship in the Gulf of Gdansk” (2018).

Commanders:

KK **Kempf Heinrich**: December 1942 – March 1943 (born 13.04.1896 in Brünn)

KL **Schwarze Friedrich**: March 1943 – September 1943

KK d.Res. **Krapohl Franz:** September 1943 – April 1945 (born 12.03.1878), he died on the day the ship sank

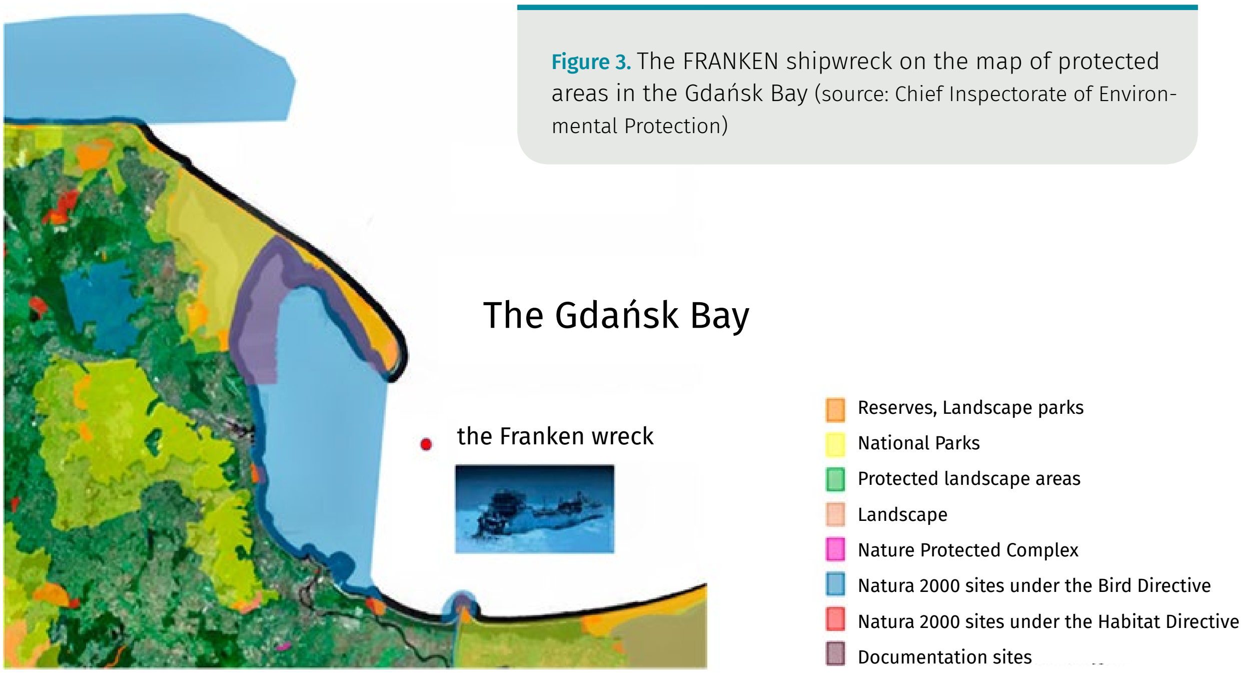
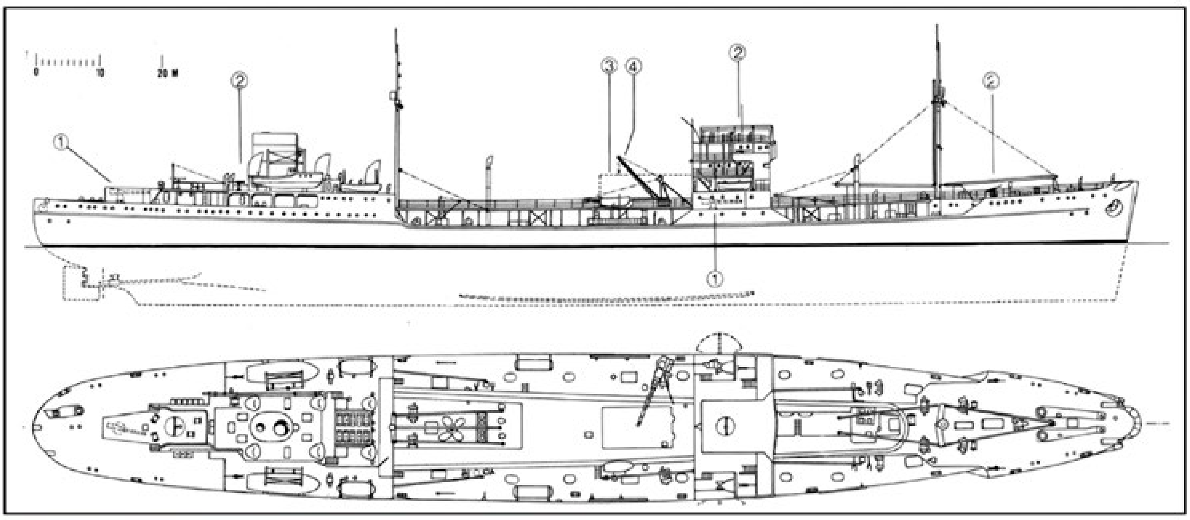



**Figure 3.** The FRANKEN shipwreck on the map of protected areas in the Gdańsk Bay (source: Chief Inspectorate of Environmental Protection)



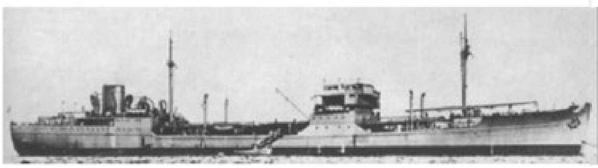


**Figure 4.** A drawing of a Dithmarschen class ship (source: „Die deutschen Kriegsschiffe", Part 7: ISBN 37882202678)

**Photo 1.** The Franken model based on the plans (source: http://www.arbeitskreis-historischer schiffbau.de/e328/e443/e6952/e6954/media_photoHires) • **Photo 2.** T/S FRANKEN (archives)

## 1.3 Last days of the ship, the history of sinking

In the last phase of the war, the Franken ship was stationed in the Gdańsk Bay, in the port of Gdynia or Hel, as part of the Thiele battle group. Intensive battles and partial seizure of the ports in Gdynia and Gdańsk by Russian troops prevented supplies for the battleships Lutzow and Admiral Scheer, as well as the Prinz Eugen cruiser. The role of the supply ship Franken had increased to the point, that after its sinking on 8th April 1945, all battleships and the cruiser were sent from the Gdańsk Bay to the western Baltic, where they took part in the battle of Kołobrzeg. In the last phase of the battles in the Tricity and the East Prussia region (until 8th April 1945) Franken supplied the ships of two naval groups, which included the Prinz Eugen cruiser, torpedo boats Panther, T1, T5, T12, T35, minehunters M15, M18, M29, tankers Breitgrund, GÖ15 and the patrol ship V1706.

The sinking of the Franken coincided with the end of the Hannibal Operation in the Gdańsk Bay, the biggest military evacuation of the population in the naval history, during which Franken supplied many other smaller vessels. On 21$^{st}$ January 1945, Karl Dönitz, the commander of Kriegsmarine gave the order to a big evacuation of troops, service supporting the military and naval activities, as well as civilians. The activities of Franken in its last days, as well as the military situation in the Gdańsk Bay and the Hel Peninsula region is illustrated in detail in the KTB (*Kriegstagebuch*), the war diary of the gunboat Z-43, which protected Franken during its last days. The role of the supply ship Franken had increased to the point, that after its sinking on 8$^{th}$ April 1945, all battleships and the cruiser were sent from the Gdańsk Bay to the western Baltic, where they took part in the battle of Kołobrzeg. The sinking of Franken coincided with the end of the Hannibal operation in the Gdańsk Bay (the operation lasted until May 1945, when 180 thousand German soldiers were evacuated from Courland).

**Figure 5.** T/S FRANKEN – View of the Długi Targ in Gdańsk, projection of the decks (below T/S FRANKEN on the square in Długi Targ in Gdańsk (B. Hac/Google Earth)

## 8th April 1945, the Gdańsk Bay, roadstead in Hel (according to the KTB Z-43)

*On 8th April Franken at the roadstead in Hel, at anchorage G.*

*In the morning several dozen Soviet aircrafts Boston, Il and Pe-2 start a massive attack, which turns out to be tragic for Franken, which is only protected by a weakly armed destroyer Z-43. Around 11:38 the ship gets a lot of bombs and probably torpedoes in the bow, which cause serious damages and a huge fire of the bow and forecastle. There are many ammunition explosions under the deck.*

*The ship starts to burn, it quickly bends to the bow and starts to sink. The fire reaches the stern and a black smoke covers the deck. A few minutes after the bombardment, the ship breaks in front of the forecastle (where ammunition is stored and oil tanks are located). The entire crew of the bridge and the bow guns is killed. The order to leave the ship is quickly released. Those crew members, who survived evacuate to the rescue boats on the starboard, the state of larboard prevents the use of rescue boats.*

*Most of the rescued 200 crew members are taken over, together with the injured by the S-boots and anti-submarine warfare (ASW) boats and transported to the destroyer Z-43. Z-43 remains in place until the sinking of Franken. The intensified raid of Soviet aircrafts makes the ship go down to the sea bottom at 12:22, approx. 40 minutes after the attack. 48 crew members die on Franken and in the surrounding waters.*

Source: KTB (Kriegstagebuch) Z-43, translation by IWONA TOMICA, PIOTR KARAŚ 2018
"Franken – ostatnie dni okrętu Kriegsmarine na wodach Zatoki Gdańskiej".

The last moments of the Franken tanker in pictures taken by Russian aviators at the moment of the attack of *Ił* aircrafts and shortly after.

**Figure 6.** The Franken ship during the attack, 8th April 1945, the explosion of ammunition storage and oil tanks (source: www.pwm.org.pl)

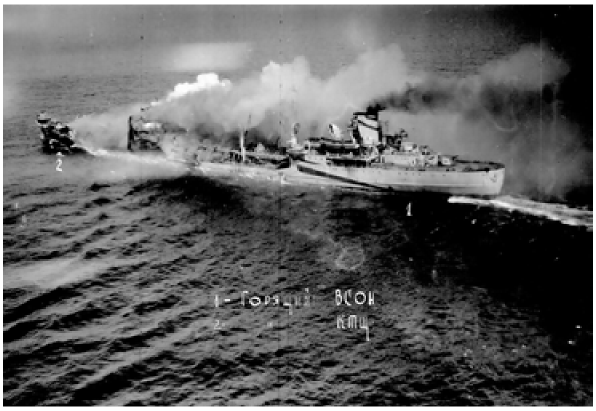


**Figure 7.** The Franken ship during the attack, 8th April 1945, during sinking, visible damage to the bow just before breaking (source: www.pwm.org.pl)

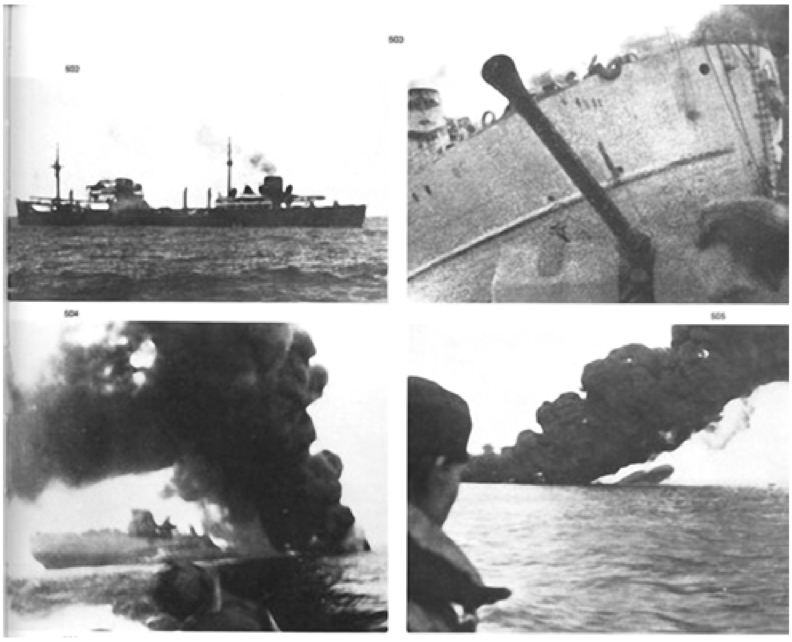


**Figure 8.** T/S FRANKEN during the bomb attack of Ił aircrafts, 8th April 1945, 12:00 hours. "Die Tragödie der Flüchtlingsschiffe: Gesunken in der Ostsee 1944/45" (author Heinz Schön) – "Lufttorpedos versenken TMS Franken"

The history of the Franken ship is described based on historical materials collected and quoted in earlier publications: „Franken – the last days of the Kriegsmarine ship in the Gulf of Gdansk" by Iwona Tomica and Piotr Karaś (2018) and „Monitoring of seabed contamination in shipwreck areas – FRANKEN shipwreck" by Benedykt Hac and others (2016).

# 2 THE FRANKEN SHIPWRECK

The wreck of the Franken has been identified by the Maritime Institute in Gdańsk in the framework of a programme investigating the negative impact of motor shipwrecks on the environment and ecosystems of the southern Baltic as a wreck posing potential serious threat to the marine environment. The historical documents such as loading plans (plans of the hold) copies of the Kriegsmarine commands related to the tasks of the Franken in April 1945, testimonies of witnesses and historical photos of the ship made during the attack, as well as today's photos made by the divers, who often visit the wreck were used to investigate the current status of the wreck and the possible risks it could pose.

On the basis of the collected documents, it was assumed with an absolute degree of certainty that at the moment of sinking, the Franken's tanks were filled in with 2700 tonnes of oil, not including the oil for the ship engine (approx. 300 tonnes). Ten days before the sinking, the Franken ship delivered supplies for the battle group Thiele in the Gdańsk Bay. The British Secret Service had captured the German radio signals, which indicated that the ship was supplied with 2066 $m^3$ of oil from the Thalatta tanker. On 29th March 1945 the total load of oil of the Franken ship amounted to 3136 $m^3$, which is an equivalent of approximately 2700 tonnes, depending on the oil type.

Below on the loading plans it is indicated where the ship broke in two. After summing up, the capacity of the 7 remaining tanks, which (potentially) showed little or no damage, amounts to as much as 5772 tonnes. This means that there is a lot of free space in the undamaged tanks and after considering the principles of oil distributions on tankers, the amount of potential oil could be estimated at approx. 2000 tonnes. This estimation had been made before the start of the expedition in April 2018 and without taking into account the knowledge that was obtained later.

The current state of the loading of the Franken wreck is unknown. During the expedition, it was not possible to identify clearly which tanks are filled with oil, but it was possible to determine, which tanks are empty due to unsealing.

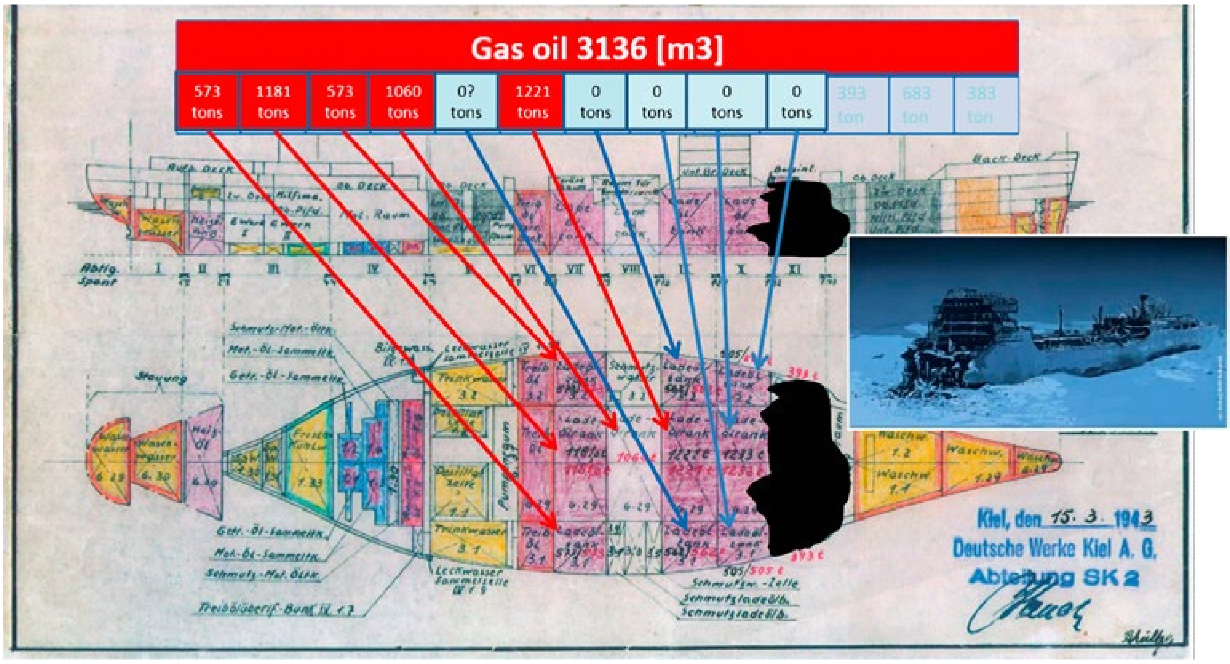



Figure 9. T/S FRANKEN – the undamaged tanks can accommodate approx. 4 thousand tonnes of oil. On the basis of the data from the reports, the amount of oil was estimated at maximum 3 thousand tonnes, and most probably much less, that is 2 thousand tonnes (source: historical plans, own description)

The documentation collected during the expedition (photos, films, measurements) indicates that 5 tanks which look sealed could contain 4608 tonnes of different oils. We know, that at the time of the sinking the ship was carrying a lot of load, including oil in the amount of 2.7 thousand tonnes (3136 $m^3$), not including the oil for the ship engine. The photos taken during and after the attack show light oil leaking from destroyed tanks remaining at the water surface. The type of oil in different tanks has not been identified. It could be aviation oil (on the deck, in front of the forecastle, these tanks do not exist), light diesel marine oils (MDO), medium marine diesel oil (DMB), heavy marine diesel oils, or the heaviest heating oils used for supply turbines. There is no documentation on the basis of which such assessment could be carried out. According to the general rules, during transportation each type of oil must be stored in separate tanks. That means that the oil was transported in several tanks. Almost half of the tanks are still closed (5 out of 13), without access, therefore they can still contain oil. Sealed tanks have a capacity of 573 tonnes up to 1221 tonnes. Oil from even one unsealed tank could contaminate the water and shores of the Gdańsk Bay. Heavy oil from the tanks could only cause local contamination of the sea bottom.

We do not know all scenarios of such a spill (Figure 10), although on the basis of the identified surface current flow patterns (Figure 11) we can accurately model the scope and distribution of the contaminations (Figure 12). Since the wreck is located in a region which is particularly sensitive to contamination, and the currents in this region will cause the dispersion of the spill in the direction of the shores, located from 10 to 25 km away from the wreck position, the environmental losses will be enormous. Very intensive contamination of the entire Gdańsk Bay area, in particular the shore (beaches) from Piaski to the port of Hel could be expected. Fortunately, the analysis of the directions and speed of the surface currents around the wreck performed on a yearly basis indicates that the current directions and speed are favourable during 40% of the year, whereas during another 40% of the year the currents would move the oil to the Vistula Spit (included the protected area in the Vistula river cone) and the Russian part of the Gdańsk Bay. During 20% of the year all oil would be moved to the central part of the Gdańsk Bay, posing a real threat to the protected areas and the beaches of the Tricity and Hel.

The estimates of the quantities of petroleum products should include other products (oils, lubricants, fuel oils, bilge water) in the amount of approx. one thousand tonnes that were located in the undamaged part of the shipwreck.

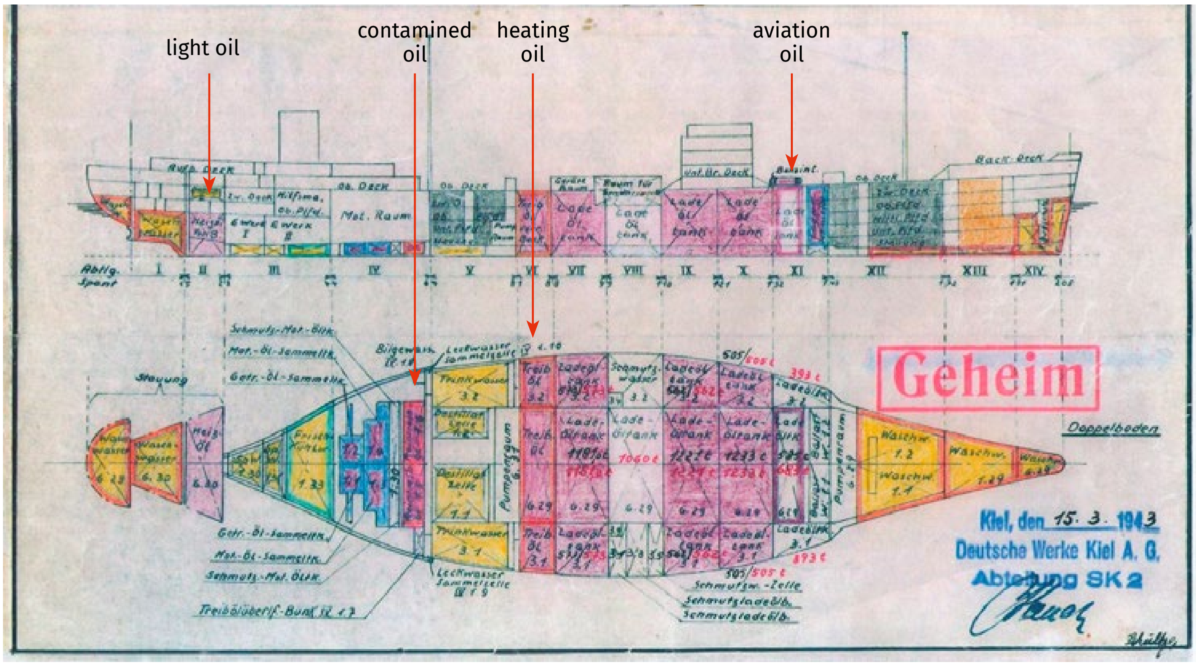



**Figure 10.** T/S FRANKEN – could have about one thousand tonnes of other petroleum products in its tanks (source: historical plans, own description)

The exposure of the steel from which the ship was built to salt water causes its rapid degradation, thus very seriously affecting the structural strength. Due to the corrosion of the ship's hull, every year the ship's plating is decreased by approx. 0,1 millimetres (a value typical for this area of the Baltic Sea) and thus, 70 years after sinking, the overall corrosive loss is estimated at approx. 7 mm. This means that the shipwreck is at the verge of collapse under its own weight (the photos show serious losses in the ship structure). **This will soon cause a violent collapse of the wreck and thus uncontrolled spill of fuel, oils and other substances, which will pollute the environment.**

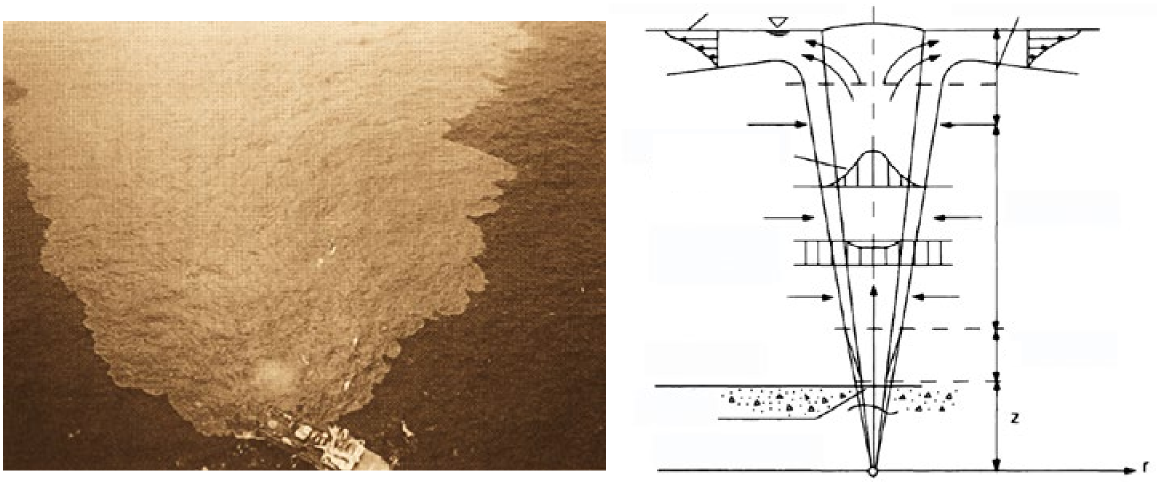
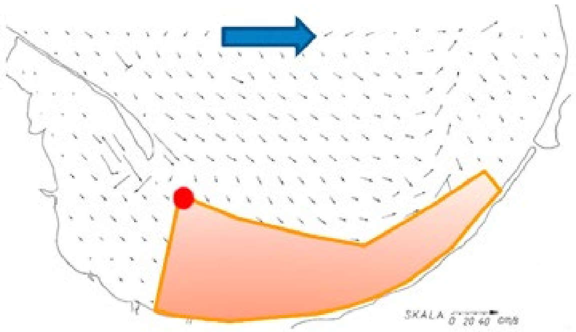
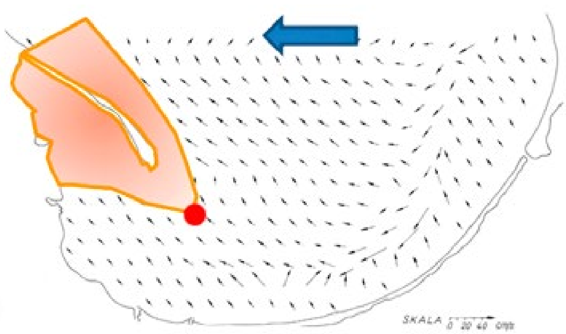


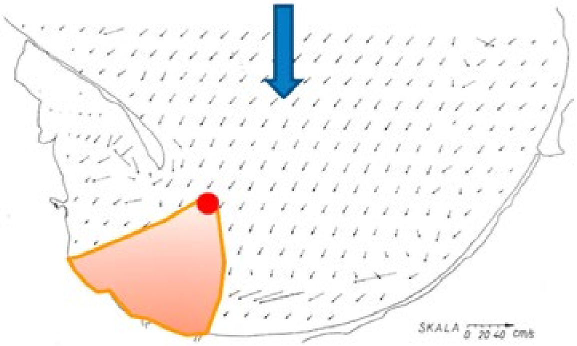

**Figure 11.** Distribution of oil spills from the wreck



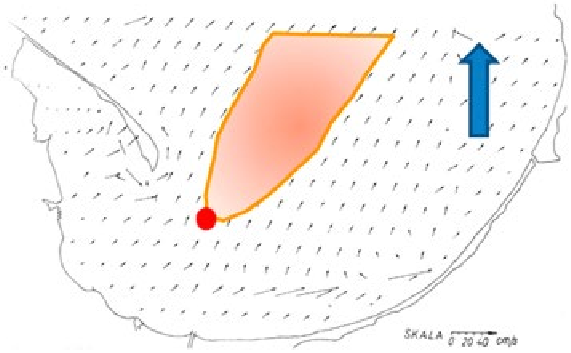

Direction of surface currents - west wind 10 m/s




Direction of surface currents - east wind 10 m/s




Direction of surface currents - north wind 10 m/s




Direction of surface currents - south wind 10 m/s

**Figure 12.** Distribution of the Surface currents in the site of the Franken wreck, caused by winds from different directions, together with an illustration of the direction of the oil from the wreck (source: GIOŚ)

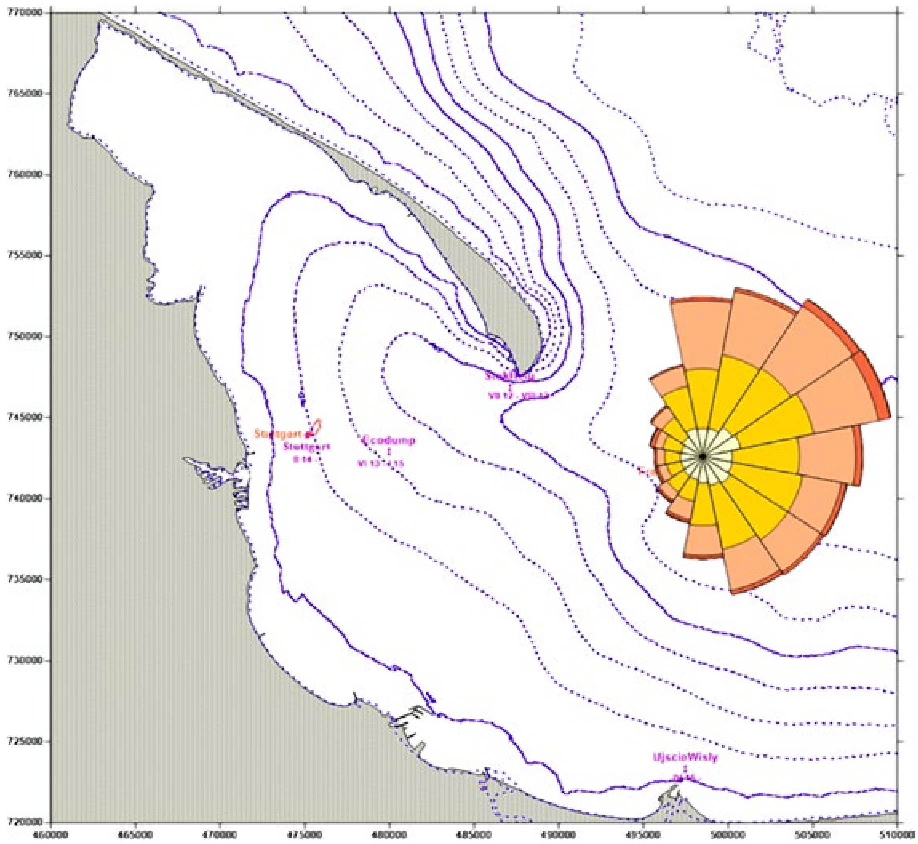



**Figure 13.** Distribution of surface currents in the site of the Franken shipwreck (data from a model, own elaboration)

# 3 THE RESULTS OF ACOUSTIC SURVEYS

## 3.1 A sonar image of the sea bottom at wreck site

According to the vast experience of the employees of the Maritime Institute in Gdańsk (Gajewski et al. 2002) it was decided that the penetration of the sea bottom leading to a discovery of objects at the sea bottom should begin with a sonar survey. An image of the sea bottom relief in the research area is obtained on the basis of the analysis of the signal reflected from the sea bottom. The reflections from the objects protruding above the bottom and the information on the type of surface sediments provide the basic information on the size of the object lying at the sea bottom, its structure, permitting to make an initial identification, as well as information needed to plan further measurement and research activities. Measurements also provide additional knowledge on the size, shape and condition of other elements or objects lying in the vicinity of the main object.

A towed side-scan sonar EdgeTech 4125 was used to investigate the Franken shipwreck. The registration of return sonar signals from four channels (frequency 600 and 1600 kHz) was done using a digital data acquisition system CODA DA 2000.

It is most advantageous to collect data in such a way as to allow a development of a sonar map of the sea bottom, called a mosaics on the basis of sonar observations. It differs from a raw sonar image, because each of the map raster pixels has assigned coordinates after geometric signal correction and navigation file verification. International standards covering hydrological surveys assume that the positioning error of the pixel centre should not exceed 6 metres.

Currently, underwater positioning with the towed sonar applies the acoustic system of positioning with the so-called ultrashort base line (USBL). In such a case, the towfish of the sonar is continuously positioned with an accuracy lower than 0.5 metres, which significantly improves the quality of the sonar mosaics. However, it is not always necessary. If it is possible to visualise the main object and other objects in its vicinity on one sonar image obtained from one sonar survey, thus optimising the effort, it is advisable to skip the stage aimed at creating the sea bottom mosaics.

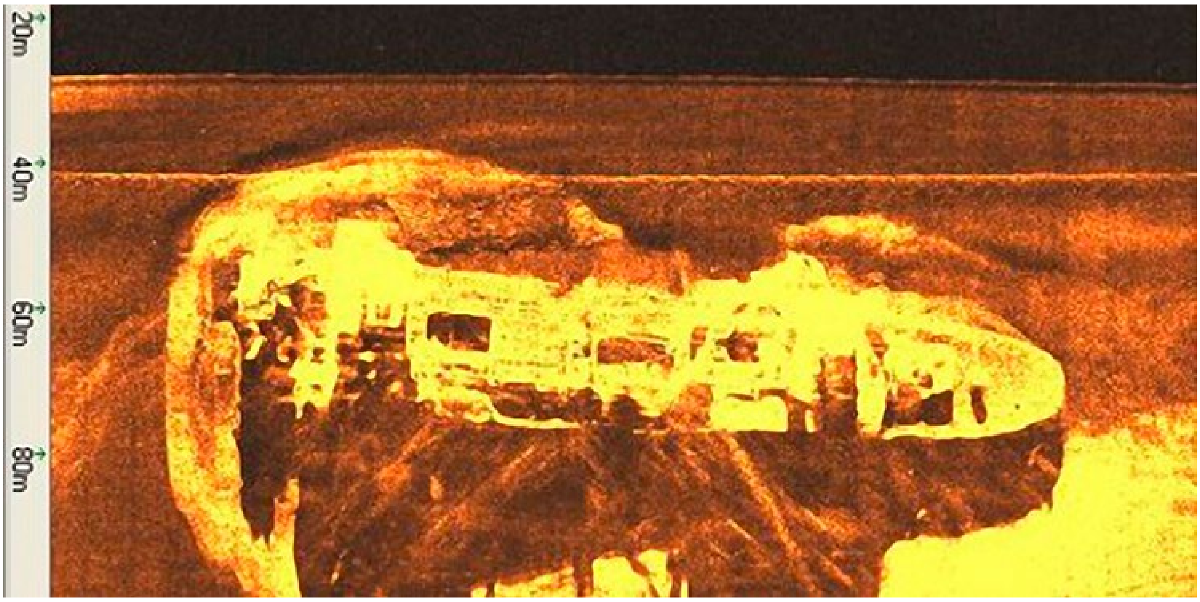



**Figure 14.** Sonar image of the sea bottom around the stern of the Franken shipwreck (data: Maritime Authority in Gdynia)

In this project a complete mosaic of the sea bottom around the wreck was not preformed. There was no such need, as the area had been previously scanned with a sonar. One survey along the broadside was enough to find out how the wreck looks at the moment of the research expedition (Figure 14). At the same time the wreck and its vicinity are well explored with the use of a multibeam echosounder. It was confirmed that 100% of the area within 500 meters from the wreck had been measured. This is a unique situation due to a previously carried out project aimed at surveying the sea bottom in this area.

The FRANKEN shipwreck is broken near the forecastle. The ship broke in two sections after the bombardment by a Russian IŁ aircraft and an explosion of the load (aircraft oil and ammunition), which were located in the bow. The bow section is located 420 meters in the direction 051° (north-east) (Figure 2). The stern presented on the echogram (Figure 14 and Figure 16) is in one piece and no elements around the wreck could be spotted. The ship lies on the keel, the bow and stern superstructures, as well as the deck with oil tanks, are all heavily built-up.

All wrecks are subject to decomposition. Usually, wrecks are decomposed according to a well-known scenario, due to the processes that occur on the sea bottom around a particular wreck. The usual scenario of the wreck decomposition does not apply in the case of this particular wreck (it usually refers to wrecks which are not broken), because the Franken was broken in two parts (the bow and the stern) after the bomb and oil explosions at the moment of sinking. The two sections of the wreck drifted away from each other by approx. 420 meters. However, the stern (the main section of the wreck), lying in an area of very strong bottom currents, which carry a lot of sediments, is subject to decomposition according to the scenario illustrated below (Figure 15). This means that in the near future this section of the wreck will completely decompose. Taking into account the progressive decomposition of the hull due to corrosion of the steel elements exposed to salt water, the hull will probably disintegrate in its central part and the forecastle, 10-12 meters high, will collapse (Figure 15).

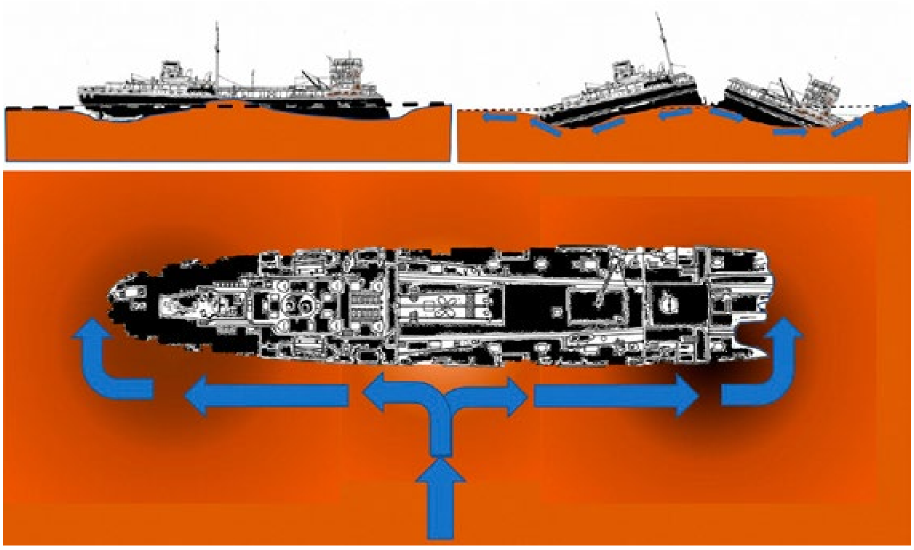


**Figure 15.** An example of how the wreck is destroyed by strong currents washing out the hull (source: own information)

Breaking of the hull in the place where the two main oil tanks are located will cause an uncontrolled leakage of their content. A similar effect will occur if the bow superstructure, weighing over one thousand tonnes collapses on the oil deck. If the bow superstructure falls to the opposite side, the hull will break and the tanks will leak. Even such scenario is dangerous for the Gdańsk Bay.

## 3.2 Analysis of wreck decomposition processes on the basis of sonograms and echograms from a multibeam echosounder

The analysis of wreck sonograms indicates that its present state is bad. The stern is heavily destroyed and is slowly sinking into the bottom, as a result of it being covered by underwater dunes created by water currents around the underwater objects found at the sea bottom in this part of the Gdańsk Bay. Wrecks are most often destroyed by long-term stay at the sea bottom in the area of strong bottom currents, which cause very strong movements of bottom sediments, composed of sand and small gravel, that wash out around the hull. In consequence, natural decomposition of the wreck is caused by collapsing and covering by sand. The process of natural decomposition of wrecks at the sea bottom is shown on the photographs (Figure 15 and Figure 16).

The sediments washed away from the bow section of considerable weight (the weight of the Franken might amount to approx. 8 thousand tonnes) cause very strong tensions causing a breakage of the hull. Further washing away of the bottom below the stern section creates tensions leading to further breaks in the hull and a total collapse of the wreck.

**The dimensions of the wreck are as follows: length of the bow approx. 40 metres, stern and central section approx. 130 metres, width approx. 22 m, height 22 m. The main section of the wreck sticks above the sea bottom by approx. 10 to 22 m. The depth around the wreck was estimated at 67.4 – 60.0 m, in the bow section the minimum depth was estimated at 47.4 m, and a maximum depth at 67.4 m. The minimum depth in the stern section was estimated at 55.3 m and maximum depth at 60.8 m. The bottom around the wreck is sandy. The wreck is heavily covered by sand.**

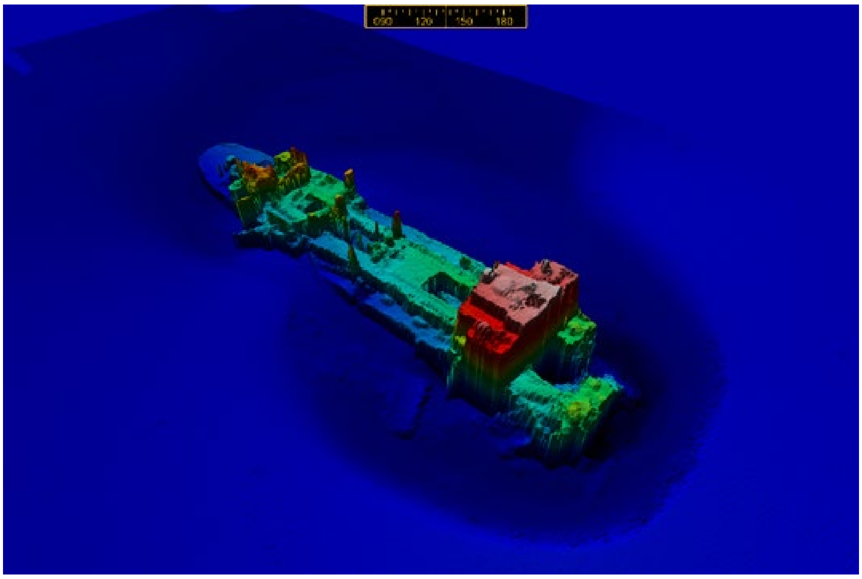



**Figure 16.** The distribution of the depth around the Franken wreck, visualisation of data obtained by MBES (source: own information)

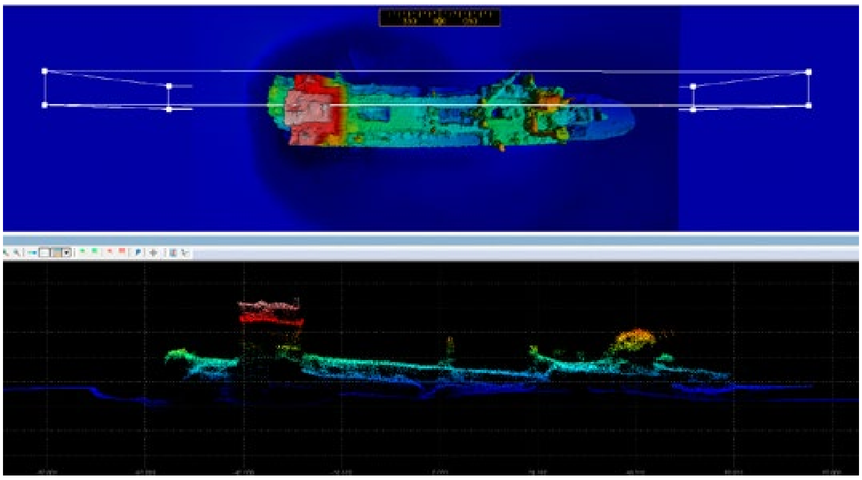


**Figure 17.** Bathymetric mapping of the bottom, longitudinal section along the starboard of the wreck, shows the washed out bottom in the forecastle section and a high shaft in the central section, closer to the stern, causing strong tension in this part (source: own information)

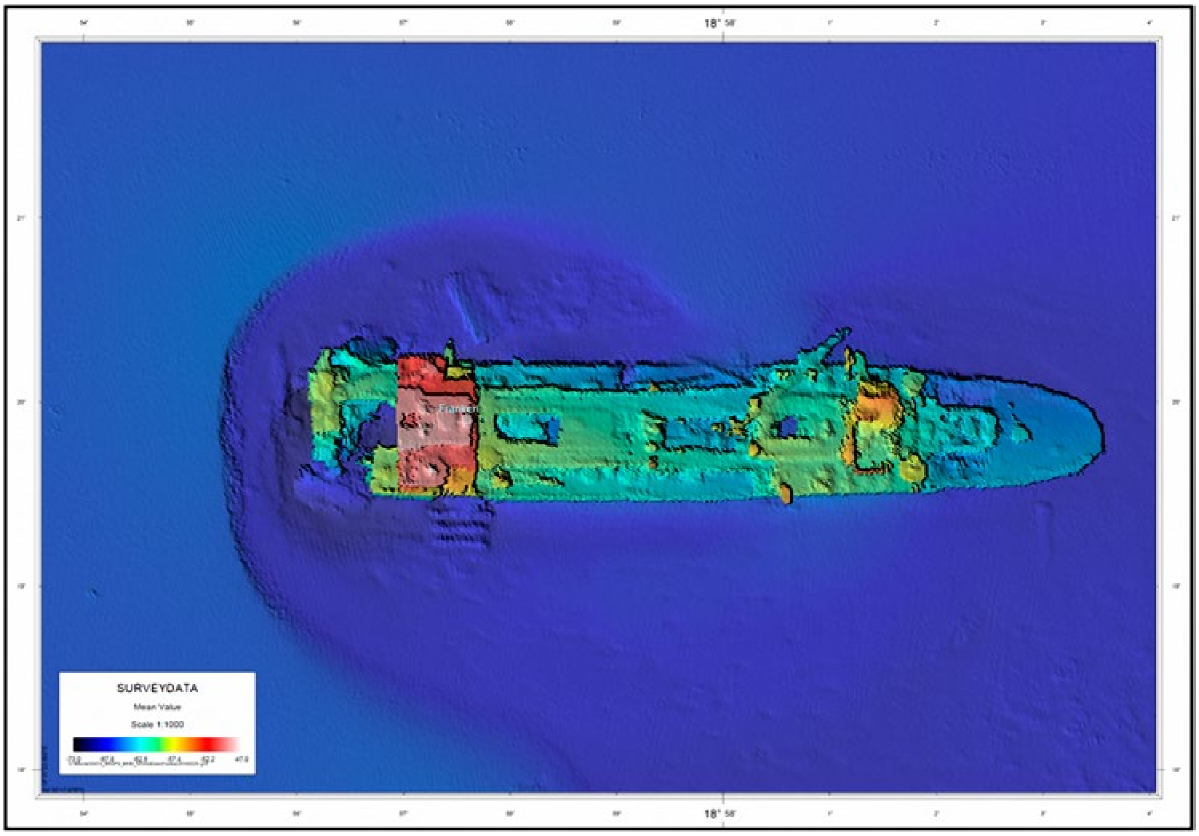



**Figure 18.** Bathymetric mapping of the bottom in the central section of the wreck

The analysis of depth distribution around the wreck (Figure 15), (Figure 16), (Figure 17) clearly indicates that submarine dunes, characteristic for this part of the Southern Baltic, are formed around underwater objects (obstructions), suggesting that there are strong bottom currents, characteristic for this area.

In the case of the Franken wreck, a full scale scenario of the wreck decomposition by sea currents is underway, as described on Figure 14. In this situation, a complete collapse of the wreck is only a matter of time.

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# 4 MEASUREMENT TOOLS USED AT FRANKEN SHIPWRECK

## 4.1 Measurement methodology

All hydrographic works (surveys, taking samples using vibrocorer and water and sediment sampling) were carried out in the Coordinate System 1992. All sensors and converters of measurement devices on board the IMOR research vessel (Figure 19) were positioned in real time mode using the GPS RTK satellite system.

The accuracy of the positioning, determined by the positioning systems, was higher than 0.5 m. The positioning system was connected to the sensors via the QINSy v.8.1 integrated navigation system. It allows a digital measurement and registration of all parameters of the system, as well as visualisation of the position, enabling navigation according to a given measurement profile, which has a significant impact on the wreck survey. It is important to maintain the position during the survey, which is essential for safe operation of the remotely operated vehicle (ROV).

## 4.2 Research vessel and measurement tools

The research vessel of the Maritime Institute in Gdańsk, r/v IMOR was used in this project to conduct a survey of the Franken wreck. This vessel is 32.5 m long, 10.5 wide, its immersion is 2.5 m and displacement of 370 tonnes.

During this survey, the vessel was equipped with:

- Two high accuracy professional satellite positioning systems **RTK Trimble SPS 851 GPS** – the positioning systems were connected to measuring sensors through the integrated QINSy navigation system. The system was also in the calibration of measurement systems. The system provides information on geographic coordinates, which are needed to determine the measurement positioning. In parallel, **POS MV™ v5 WaveMaster** system provided positioning in bad measurement conditions.
- **Two parallel measurement systems,** which deliver very precise data on the current position, orientation and velocity, that is POS MV™ v5 WaveMaster by Applanix and HYDRINS (inertial navigation system) by iXsea.
- **Mulitbeam echosounder SeaBat 7125** produced by Reson, which is the basic measurement system used to produce bathymetric picture of the sea bottom around the wreck. The data from the echosounder is gathered and registered in real time using the QINSy v.8.1. software.
- **Underwater Scout positioning system** produced by Sonardyne permits to position the surveyed object (e.g. ROV, divers) in relation to any chosen point of the research vessel. In addition to the visualisation of the object, it permits to determine its digital position and send it to the QINSy system to integrate it into the remaining parts of the measurement system. Scout uses an acoustic positioning method USBL (Ultra-Short Baseline). The heart of the USBL system is a transceiver with acoustic converters, which permit to measure phase shifts of the received acoustic signals.
- **Acoustic camera ARIS 1800** produces an acoustic analogous to an image from an optical camera. The received acoustic image shows the shape, dimensions and movement of the object under the conditions of zero visibility in water. The image is presented on a screen, in real time, and at the same time recorded to permit a playback on any computer. The camera is used during inspections of ship hulls and search of submerged objects in turbid water or in the absence of light.

- **Ultrasonic sensor for measuring thickness of the hull plating** of the CYGNUS Dive wreck. This sensor is worn on a wrist, easy to handle, water-resistant ultrasonic meter for measuring the thickness of metal plating under water. Usually used by divers. It can also be used to measure objects with the ROV.
- **2× HMI 1200 W lights.** Special HMI 1200 W lights, used in water at depths up to 300 m. The lights were used to take pictures and make the film footage.
- **The ROV – Seaeye Cougar-XTi underwater vehicle,** equipped with a lighting kit consisting of strong LED lights, 2 cameras, heavy duty hydraulic arm and a sector sonar to operate in the water column. The vehicle was the main tool for inspecting the hull (film footage with GoPro cameras, ROV cameras, and an acoustic ARIS camera). It was used for sampling the sea bottom around the wreck. It supported the divers in making the photographic documentation and provided the divers, who made the wreck survey with the possibility to contact the project management centre in real-time mode.
- **Different samplers for sampling the sea bottom, oil, water**.


**Figure 19.** R/v IMOR research vessel with equipment used during the measurements (described above)

# 5 MEASUREMENT AND RESEARCH WORK CARRIED OUT ON THE FRANKEN SHIPWRECK

**The following two teams took part in the research expedition**:

- **the team conducting technical activities** on the r/v IMOR vessel,
- **the team of divers (photographers)** making a photographic documentation and a survey directly on the wreck.

In order to achieve the objectives, the expedition tasks were realised according to the procedure established for all projects carried out by the Maritime Institute in Gdańsk. According to this procedure, all activities start with a tool box for all persons engaged in the project. The project manager divided all the tasks. The objectives of the project, use of the equipment and security measures were discussed. One of the important elements of these briefings is to precisely identify the human resources, diving schedule (sequence and composition of diving teams), the equipment needed for film making, measurement or sampling of oil. This was extremely important, because two teams of divers worked together, carrying out different tasks at the same time, supported by an underwater vehicle Cougar XTi.

After completing the diving operations, further briefings took place onboard the IMOR ship to discuss the objectives, present film and photographic material obtained during previous operations. Tasks for the next day were given.

## 5.1 Diving activities, the LITORAL ship

From 23rd to 26th April 2018, the crew of the LITORAL ship and 4-5 divers (the composition of the divers team was subject to a change) carried out the project tasks. In total, the divers spent 60 hours underwater, including 13 hours on the wreck.

**The group performed the following tasks:**

1. Executing photographic documentation for the film.
2. Executing photographic documentation for a documentary mosaic.
3. Inspecting the part of the wreck with tanks.
4. Placing containers for oil sampling.
5. Searching for places where oil is visible.
6. Selecting and preparing spots to measure the plating thickness.
7. Measuring the plating.
8. Collecting containers for oil sampling.

## 5.2 Measurements, the IMOR ship

From 23rd to 27th April 2018, the crew of the ship, the measurement team and the communication team, in total 14-16 persons performed the following tasks:

1. Placing the lights on the wreck position.
2. Executing photographic documentation using the ROV camera.
3. Executing photographs for a mosaic.
4. Measuring the plating.
5. Measuring the plating with an acoustic camera.
6. Assessing the technical condition of the wreck.
7. Sampling the sea bottom around the wreck.

n total, the ROV spent approx. 30 hours under water, including the inspection of the entire wreck during 10 hours and approx. 20 hours executing other tasks.

## 5.3 Selected tasks executed by diving teams

The divers played a very important role in investigative operations on the wreck, because of their autonomy, lack of restrictions resulting from the cable connection to the ship and the possibility to enter space with limited access. This space is often inaccessible for underwater vehicles of a size used in the project.

### 5.3.1 Executing photographic documentation for the film and photographs for the PR team (communication purposes) and technical photographs

The photographs were taken using two methods:

- **For the purpose of the film promoting the project** according to general principles of film making, the divers concentrated on the main part of the wreck and interesting views showing the size of the wreck, curiosities, divers.
- **For the purpose of VR (3D) photographs**. These photographs were used for the scenes in augmented reality. The VR technology consists of imposing virtual 3D objects, generated in real-time onto the image of the real world, using image processing devices (e.g. glasses, cameras, smartphones, tablets etc.). The augmented reality permits to move in three dimensions. The virtual objects adapt their appearance in the same way as the objects do in the real world. The user can see, how a given object fits into the surroundings, in which it would be placed. The augmented reality allows to create interactive materials, books, catalogues, leaflets, which become alive when watched with dedicated apps. The technique of taking pictures in this technology is shown on the Figure below (Figure 20).

**Photographs for communication and technical purposes**

Hundreds of photographs were made, showing the size of the wreck, divers, and curiosities. The photographs show a detailed overview of the places, which should be documented for the assessment of the wreck condition.

Despite the search, it was not possible to find places, where oil spills could be filmed. Cracks and other critical spots on the wreck, indicating "an imminent disaster" were filmed. The photographs show the scope of damages of the hull, its elements and tank covers.

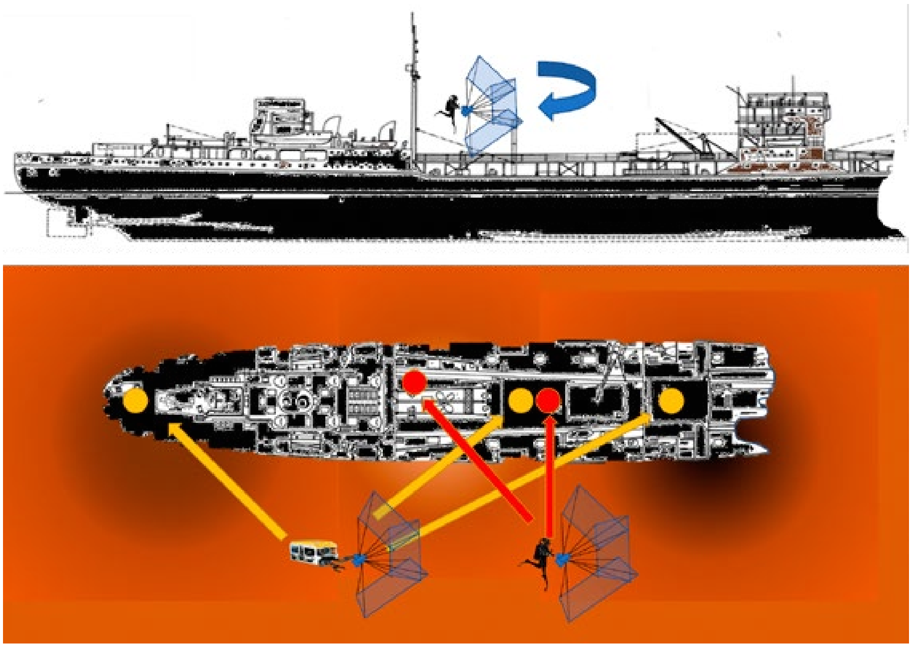


**Figure 20.** Executing photographs for the film using VR system. The picture is showing the spots, from which the film was made

### 5.3.2 Executing photographic documentation for a documentary mosaic

A few hundred photographs were made to execute a documentary mosaic used to create a 3D photogrammetric image of the deck and broadsides of the Franken in the place where the oil tanks are located. The photographs show a section of the deck and subsequent images were taken as to overlap each other. This is necessary for the software used for processing the photographs to have common points on subsequent photographs or strips. The technique of taking pictures in this technology is shown on the Figure below (Figure 21).

Despite training and arrangements, the material received from the divers is not suitable for the processing and creating a mosaic, but can be used a wreck documentation used to analyse the damages.

There is a possibility to execute a mosaic from film frames made according to a specified procedure (for a mosaic). The frames will be used to make a mosaic of the port side and a section of the deck.

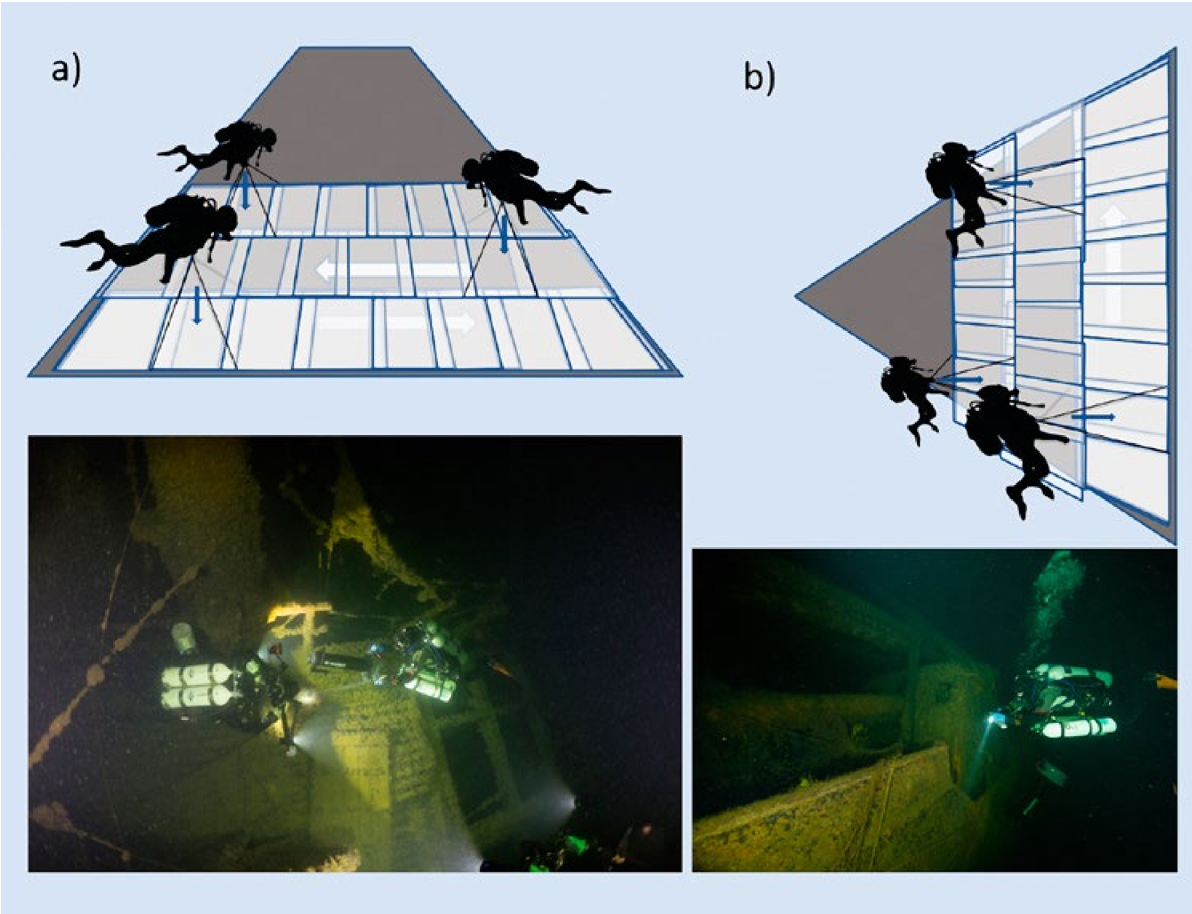



**Figure 21.** A scheme for taking pictures for the mosaic of the main deck. The photographer should move along the profiles, so that the subsequent strips overlap (source: 2018 expedition)

### 5.3.3 Inspecting the part of the wreck with tanks

One of the main tasks of the expedition was to acquire samples of oil leaking through the cracks and rusty spots of the tanks. On the basis of the historical documentation of the ship we know the location of the tanks with different oil. Oil spills from the tanks should be visible in this area.

Oil tanks are located on the main deck, from frame No. 81 to the forecastle and on the boards from the frame No. 81 to 119 (roughly in the middle of the forecastle) (this area is marked in light brown on Figure 21). A characteristic spot on the main deck, beyond which the tanks are located is marked with a red circle. These are three hatches with covers, located in one line, between the sterncastle (oval-shaped structures with covers fixed with screws) used as entrances to freshwater tanks (Figure 22). Small, red, oval-shaped objects marked with green arrows are covers of hatches of oil tanks. These spots are the most interesting and were very thoroughly checked. The surface of the deck was checked for cracks and leakages. The decks are often covered with a thick layer of sediments, sand and silt (Photo 5).

**Photo 3.** The deck on the larboard of the wreck in the midship (source: 2018 expedition, © M. Pocajło)

**Photo 4.** The deck in the area of the sterncastle, on starboard (source: 2018 expedition, © M. Pocajło)

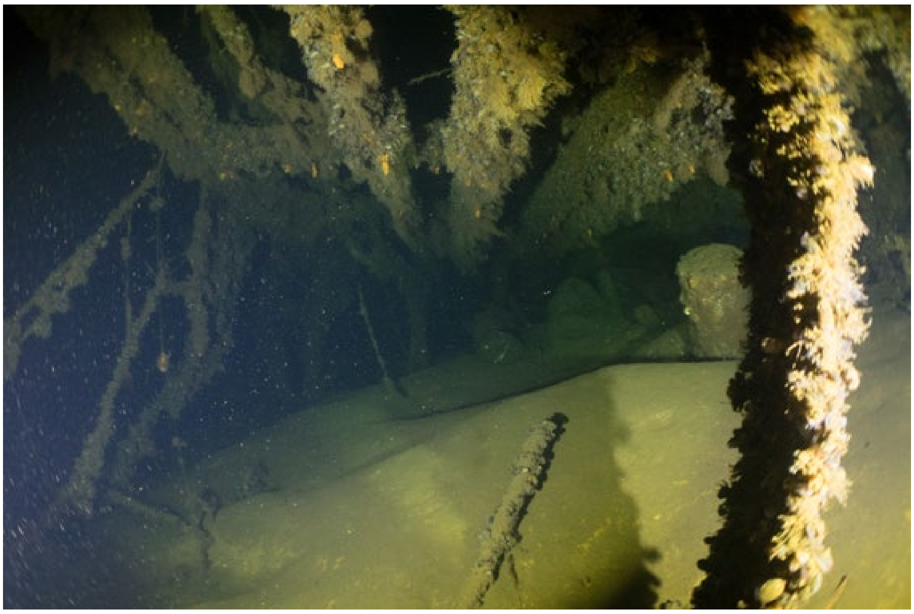


**Photo 5.** The deck covered with a thick layer of sediments (source: 2018 expedition, © M. Czermiński)

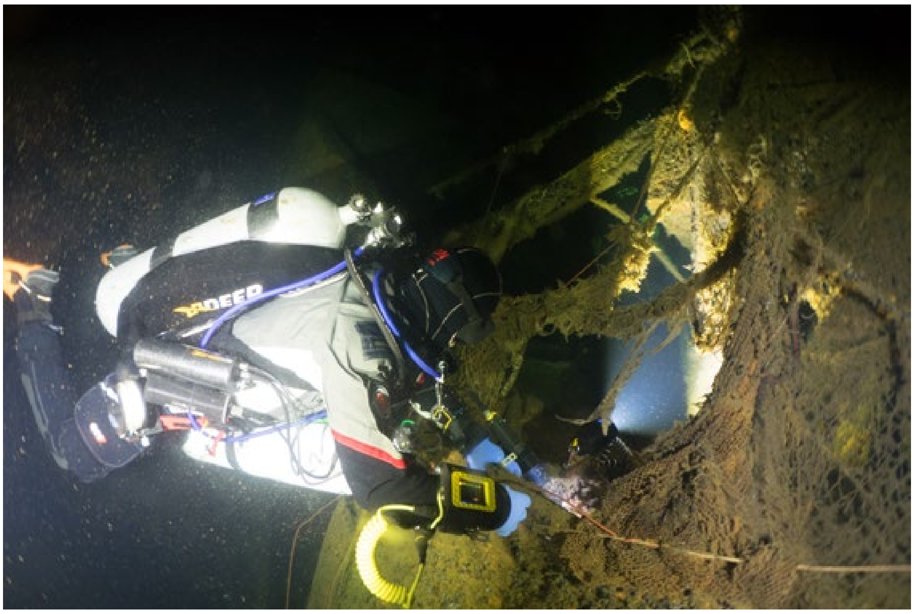




**Photo 6.** Derelict fishing nets hooked on the deck equipment (source: 2018 expedition, © M. Czermiński)

**Photo 7.** Fishing nets covering the deck equipment (source: 2018 expedition, © S. Paćko)

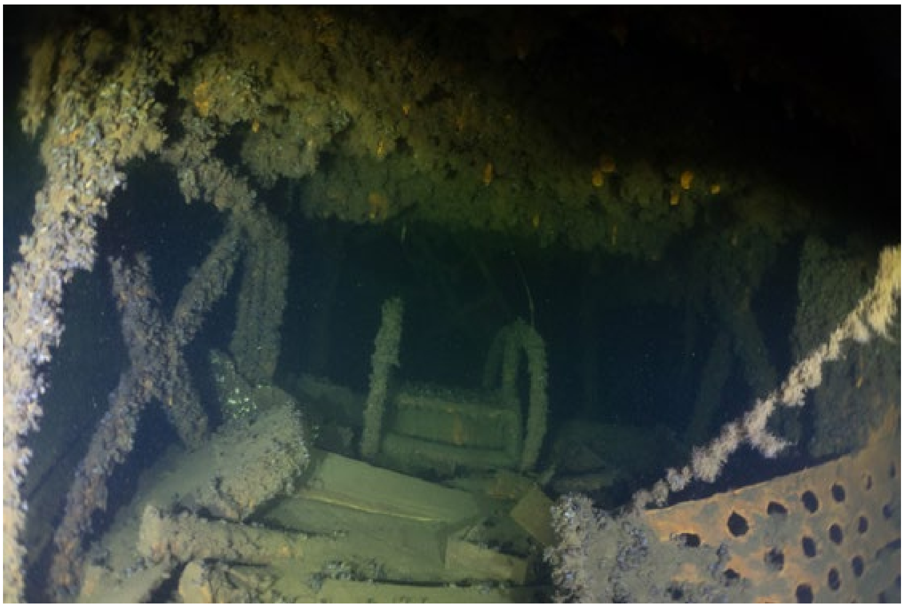


**Photo 8.** Equipment and litter on the main deck (source: 2018 expedition, © T. Trojanowicz)

**Photo 9.** Broken equipment and litter blocking the entrance to the pumping rooms (source: 2018 expedition, © M. Czermiński)

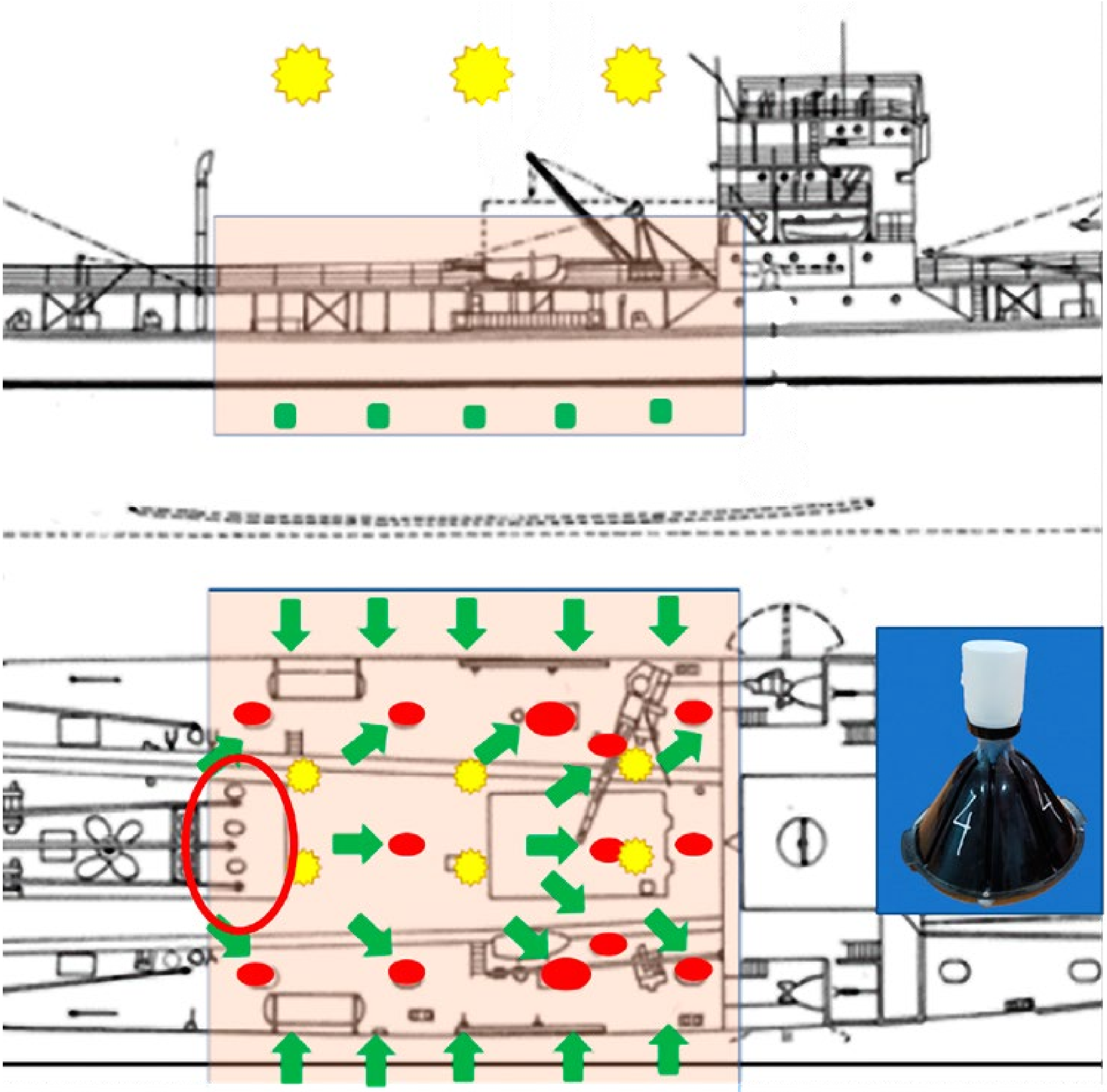


Figure 22. The section of the ship where tanks are located. Hatches to oil tanks are marked with red oval--shaped markings, green arrows indicate the spots which need to be controlled to see whether there are leakages. On the right, an oil sampling container (own source)

In many places the deck is covered by derelict fishing gears, ropes (Photo 6), small equipment displaced from their original place, litter of all kind, formed during and after the sinking of the ship.

Both broadsides were inspected in the places, where tanks are located (partly by divers and more precisely by the ROV. No cracks or leaks were found. The broadsides are significantly damaged in several places (with broken hull plating) (Photo 17), (Photo 18), (Photo 19). These damages occur around the forecastle, where the tanks were destroyed during the hull fracture after the bomb attack.

Oil sampling containers were placed in the locations of leaks. Such sampling device of own construction was placed near one of the hatches to a hold, without visible effects.

**Photo 10.** A hatch to an oil tank on the larboard (source: 2018 expedition, © M. Czermiński)

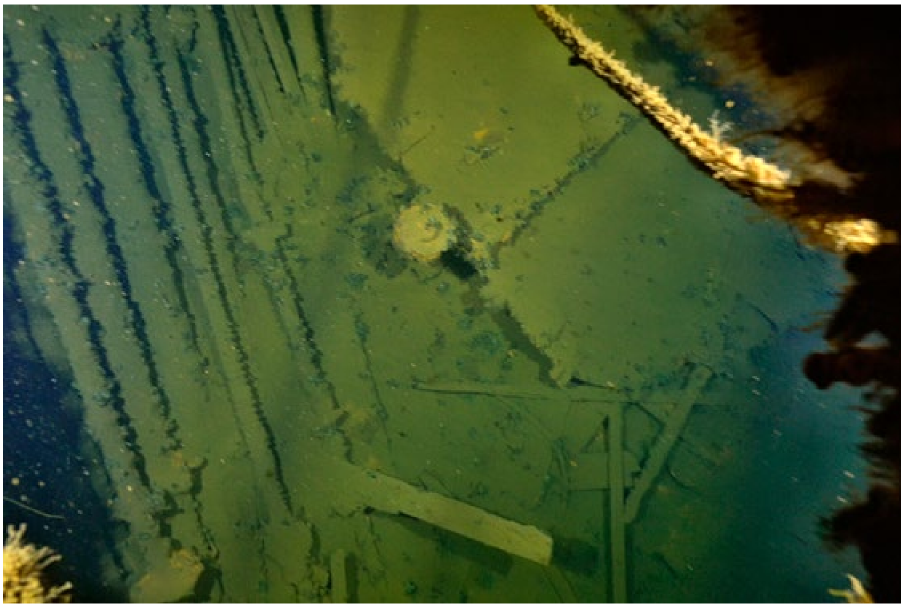


**Photo 11.** A hatch to an oil tank on the starboard (source: 2018 expedition, © S. Paćko)

The divers carefully inspected the covers of the hatches (Photo10 to 16), where there is the highest probability of oil leakages. No leakages were spotted. This means that:

- The covers of the tanks are still tight,
- There is still no perforation on the main deck, exposed to direct impact of salt water,
- The tanks below the deck are filled with oil or some other substance, which protects the steel of the hull from corrosion, therefore the condition of the deck is unexpectedly good.

**Photo 12.** A hatch to an oil tank in the midship (source: 2018 expedition, © S. Paćko)

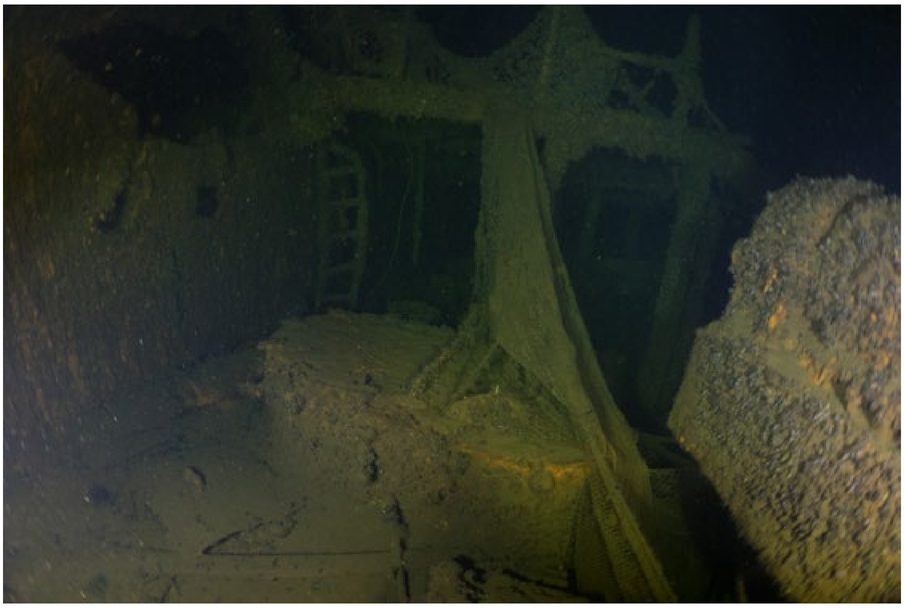


**Photo 13.** A hatch to an oil tank (source: 2018 expedition, © M. Czermiński)

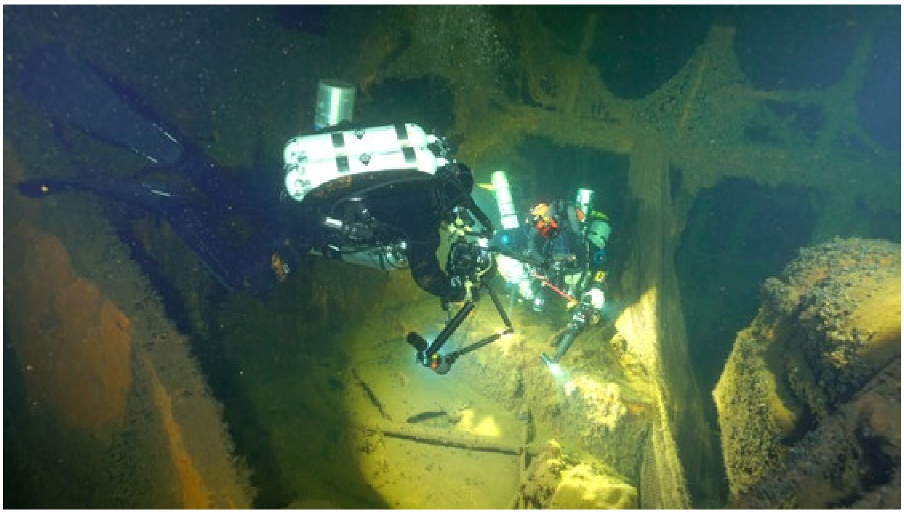


**Photo 14.** A hatch to an oil tank (source: 2018 expedition, © S. Paćko)

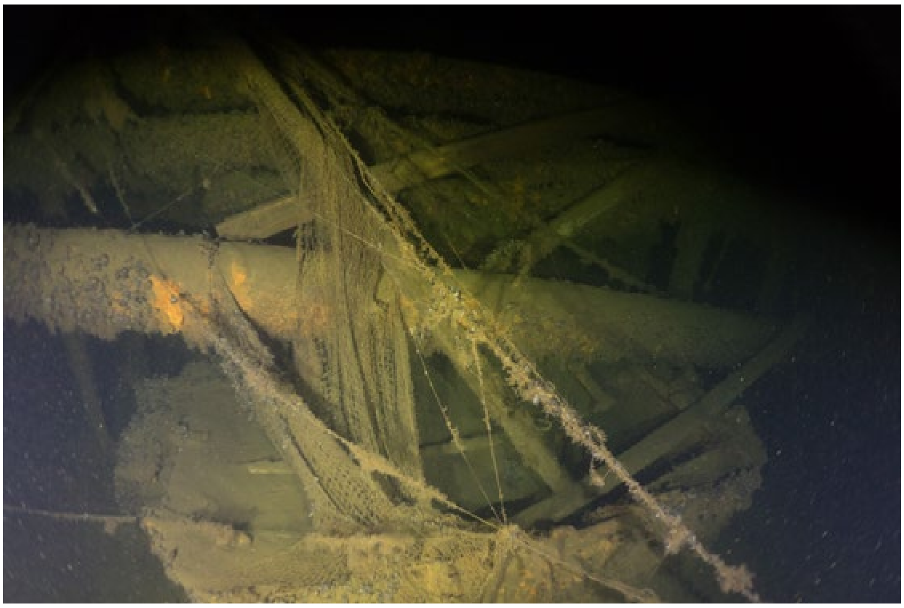


**Photo 15.** A hatch to an oil tank (source: 2018 expedition, © M. Czermiński)

**Photo 16.** A hatch on the larboard in the direction of the stern (source: 2018 expedition, © M. Czermiński)

**Photo 17.** Broken bulkhead between the tanks under the forecastle (source: 2018 expedition, © M. Czermiński)

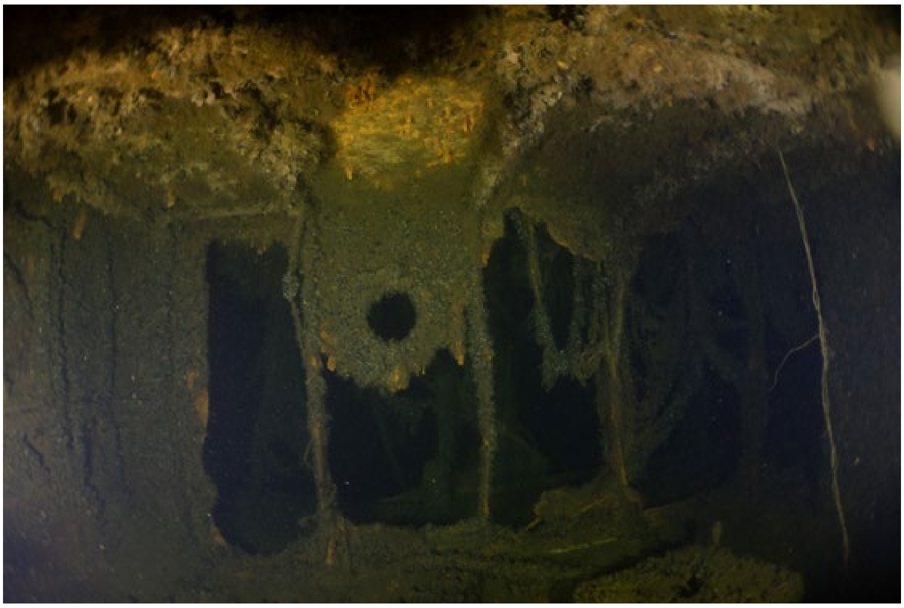


**Photo 18.** Broken bulkhead between the tanks under the forecastle (source: 2018 expedition, © M. Czermiński)

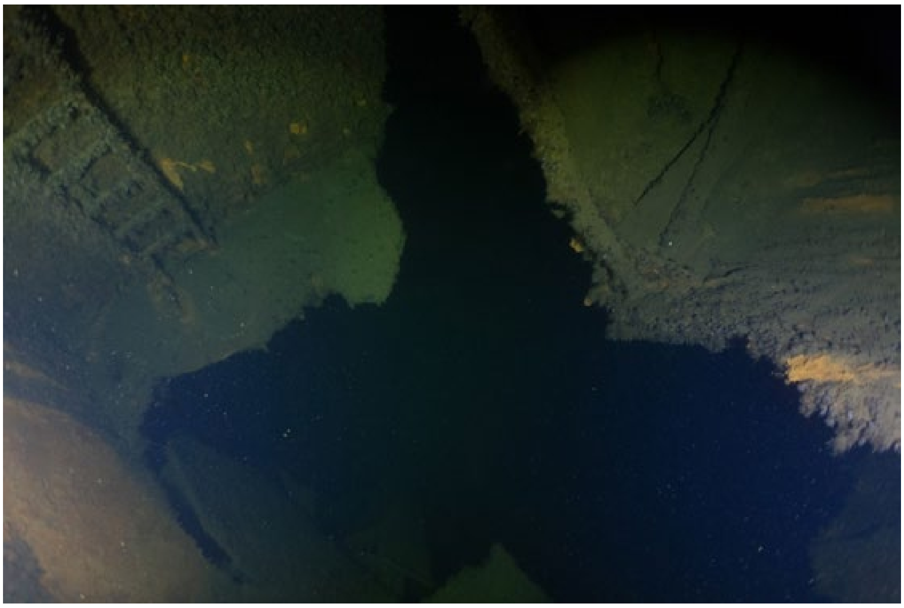


**Photo 19.** Broken hatch to the tank under the forecastle (source: 2018 expedition, © M. Czermiński)

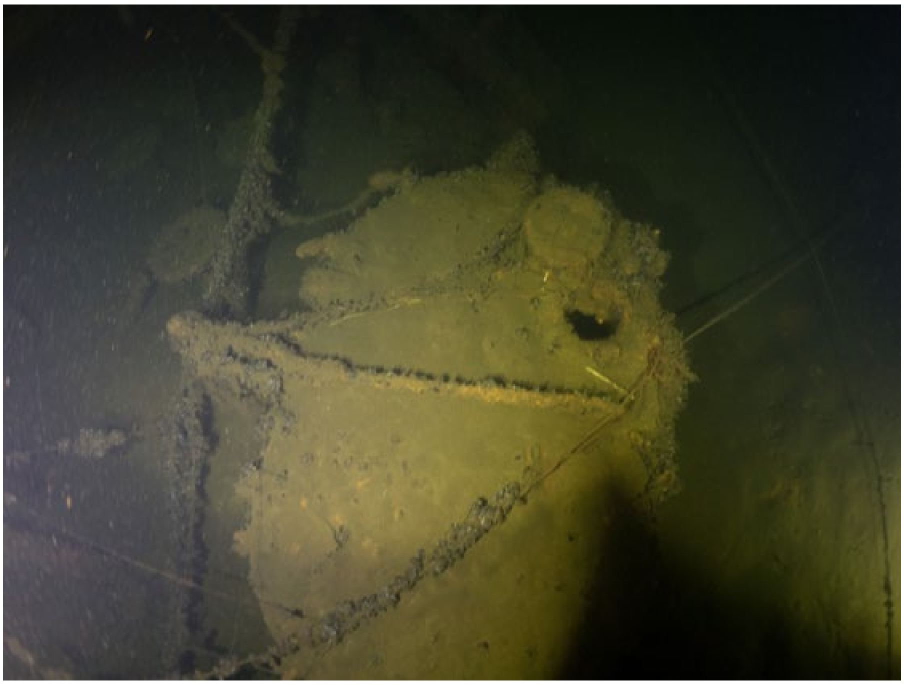


**Photo 20.** The tank hatch on the larboard, next to the forecastle. Visible inspection hatch. If the tank contained light oil, it is already empty, if it contained heavy oil, an inspection inside the tank is needed to confirm whether it is empty or full (source: 2018 expedition, © M. Czermiński)

### 5.3.4 Looking for oil leaks, sample collection

Some tanks were badly damaged during the bomb attack and after sinking (Photos 17 -19). A large part of the board is detached on the larboard, under the forecastle. The tank is probably empty, but there is a great chance that oil is trapped under the deck, in the frames and in some other well-hidden places. Despite the attempts, it was not possible to enter the tank. Therefore, it cannot be excluded that the tank is filled with heavy oil at the bottom, or light oil in its upper part. According to the divers, a similar situation takes place in the forecastle, where remaining oil can be observed in the recesses and niches.

Small screw containers were prepared for oil sampling. The entry of the diver into a deep well to retrieve a sample was considered too risky. A sample of water taken in the upper part of the well did not show any changes apart from an increased content of hydrogen sulphide.

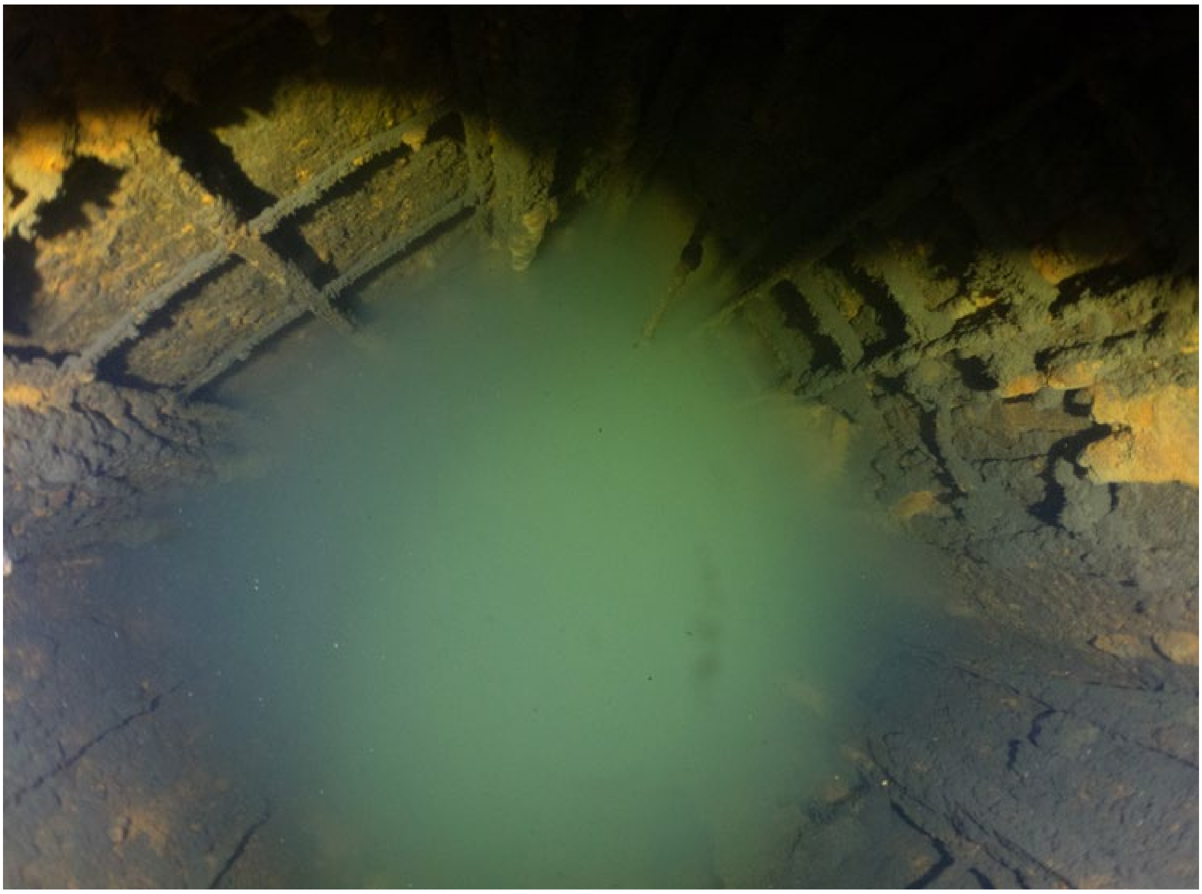


**Photo 21.** The interior of the well, leading to the valves separating the pipelines connecting the tanks. Visible opalescent liquid is probably a mixture of water and petroleum products (source: 2018 expedition, © M. Czermiński)

# 6 TASKS COMPLETED BY THE CREW OF THE IMOR SHIP AND THE GROUP OPERATING UNDERWATER VEHICLES

## 6.1 Placing the lights on the wreck position

Each diver and each underwater vehicle had its own lighting, used for taking pictures and filming. Two 1200 W HMI lamps were used to secure more intensive lighting on the film set.

The IMOR ship assured the transfer of the lamps along the long axis of the wreck to the left and to the right. The on-line mode of the lamps and lighting effects were observed by the crew (photographer) onboard the ship. This was made possible by a ROV performing underwater inspections together with the divers. The vehicle was outside the scope of diver operations to avoid additional risks of underwater collision.

Unfortunately, both lamps failed after approx. 1.5 hours. The survey was carried out with the lighting used by the divers and the remotely operated underwater vehicle (ROV).

## 6.2 Executing photographic documentation using the ROV camera

In order to execute the photographic documentation and photographs for the media, the underwater vehicle ROV was equipped with cameras recording images in Full HD.

The vehicle Seaaye Cougar XT is equipped with standard SD cameras. These cameras are used for driving but are useless for making high quality films. Therefore, a GoPro Hero camera was installed on the vehicle for higher resolution films. This camera was also used for mosaics.

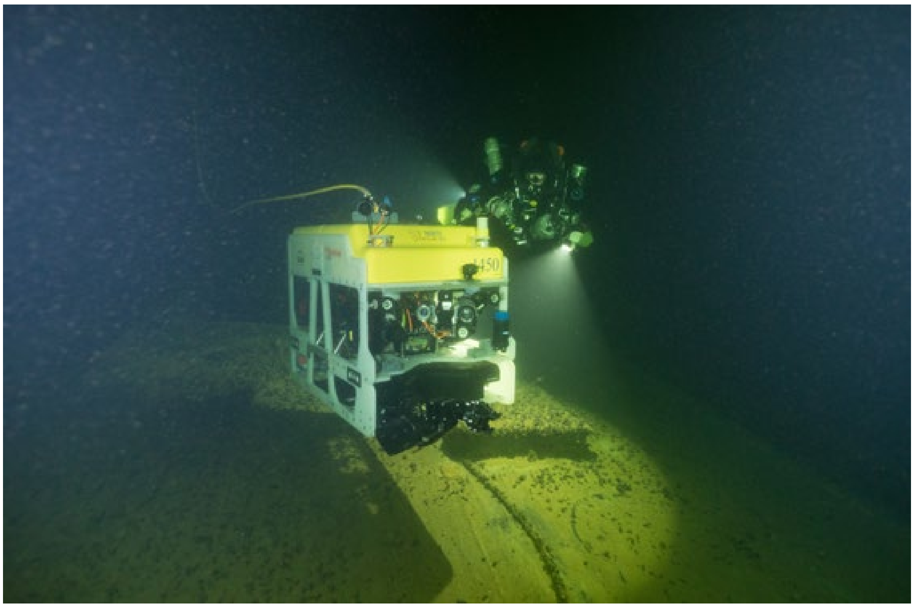


**Photo 22.** A work class ROV Cougar XT (source: 2018 expedition, © S. Paćko)

### 6.2.1 Executing photographs for a mosaic

In addition to the work performed by the divers, a remote control vehicle ROV Cougar XT with a GoPro camera and acoustic camera ARIS were used to document the condition of the decks and boards of the wreck.

The main deck and the boards in the tank area were documented using the ROV with these cameras. It was not possible to make a photographic documentation of the middle section of the deck under the platform connecting the forecastle and the sterncastle, due to an enormous amount of fishing nets, ropes and beams, deck parts and other elements blocking access of the vehicle to this part of the wreck.

The stern and sterncastle as well as the forecastle were also documented. Pictures taken with GoPro were executed in parallel to the measurements performed with the acoustic camera. Due to the poor lightning conditions, the quality of many pictures is poor, the photographs are very dark and do not show too many details. However, a mosaic of the larboard and starboard was made on the basis of the photographs taken by the RPV with GoPro. These parts around the holds do not show significant damage (Photo 23 and Photo 24).

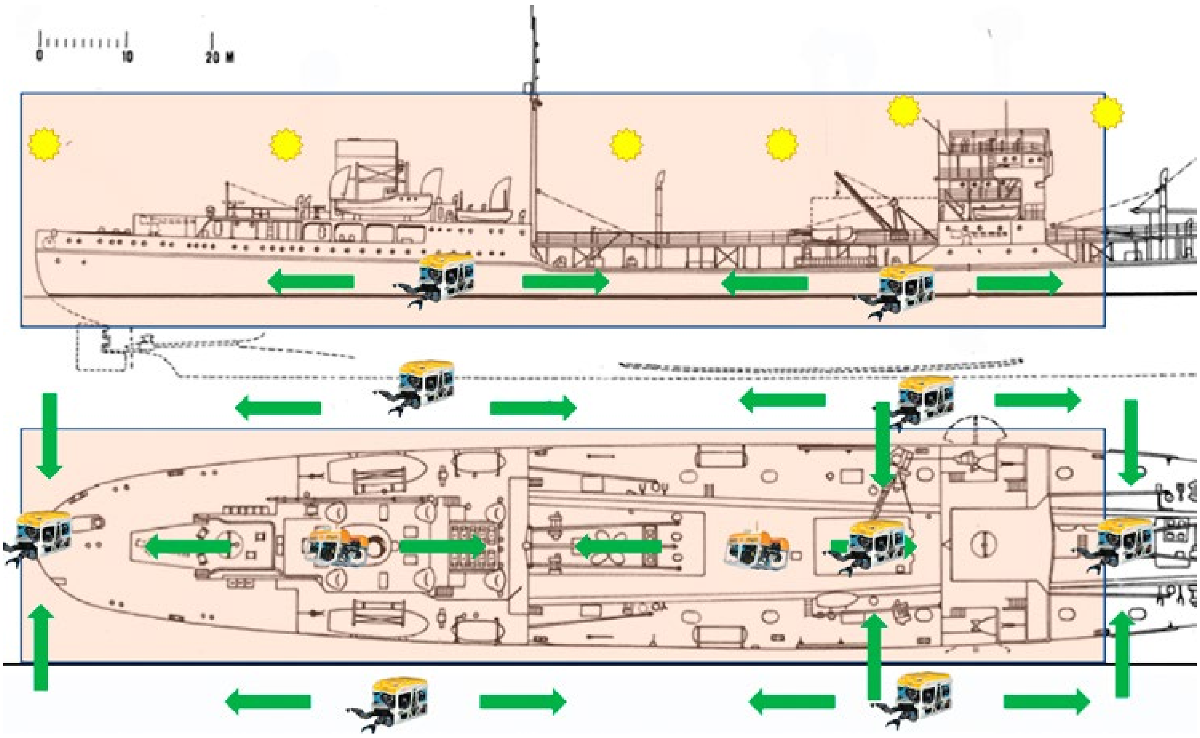


**Figure 23.** Documentation scheme of the Franken using an acoustic camera (own source)

However, on the basis of the mosaic, a very serious damage to the hull was discovered under the forecastle. It is uncertain whether the damage was caused by an explosion during the bomb attack and sinking of the ship, when the ship broke 15 meters further towards the bow, or during the collision of the sinking ship with the sea bottom, or whether the damage was due to the enormous loads currently put on its hull. An analysis of the crack, which runs from the bow towards the stern, indicates that part of this damage is old, as suggested by corroded edges, covered with thick deposits. However, the damage towards the stern seems to be relatively new, as suggested by long, sharp, poorly corroded edges of the plating. The crack in the hull is approx. 10 m long and from 5 to 30 cm wide. (Figure 24 and Photo 25).

**Photo 23.** The starboard next to an oil tank (source: 2018 expedition)

**Photo 24.** The larboard next to the oil tanks, visible branch brought by the Vistula river (source: 2018 expedition)

## 6.2.2 Measuring the plating

The measurements of the thickness of the plating were done by the divers, who had been trained to use the measuring device before the dive. A very thick layer of rust, and in many places also sand and silt, did not permit to get clear measurements of the thickness of the hull plating and inspection hatches on the deck. The results recorded by the divers differed considerably in values and it was decided not to take them into account in the assessment of the wreck condition. The recorded values ranged from 5 to 50 mm. A record of three subsequent measurements of the same spot can hardly be considered reliable, if the values range from 5 to 30 mm and in another case 15 to 50 mm. Such results make the measurement unreliable. After consultations with the supplier of the measurement device, it was considered that the measurements have not been done properly and should be repeated. Another measurement of the plating will be executed in the second half of July, during a diver training, including some technical tasks such as plating measurements will be carried out on the Franken wreck.

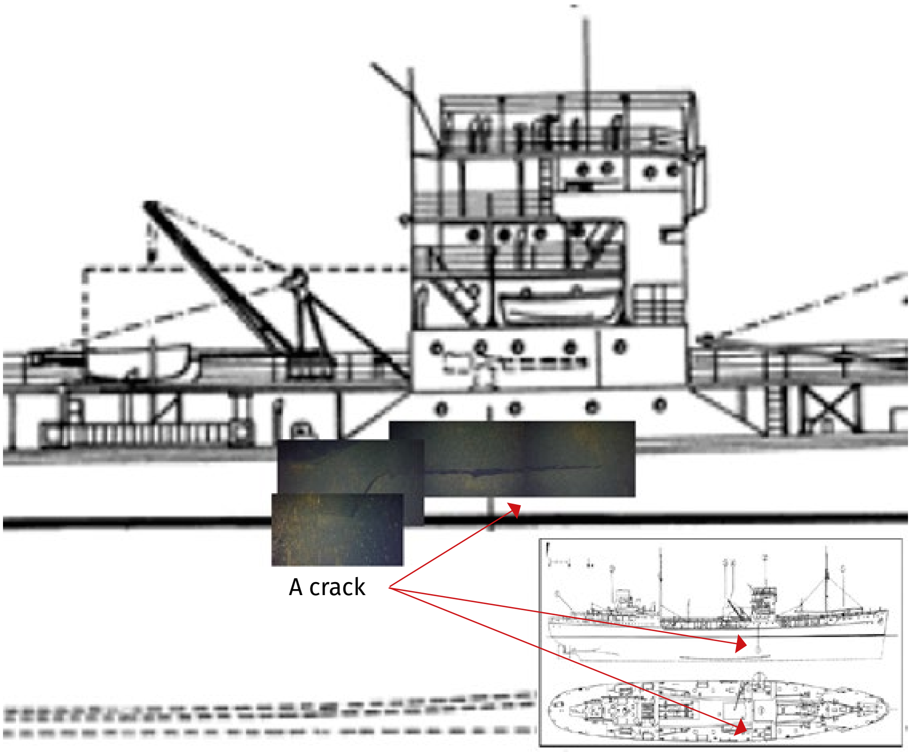



**Figure 24.** A crack in the hull (shown with red arrows) on the starboard, under the forecastle (source: 2018 expedition)

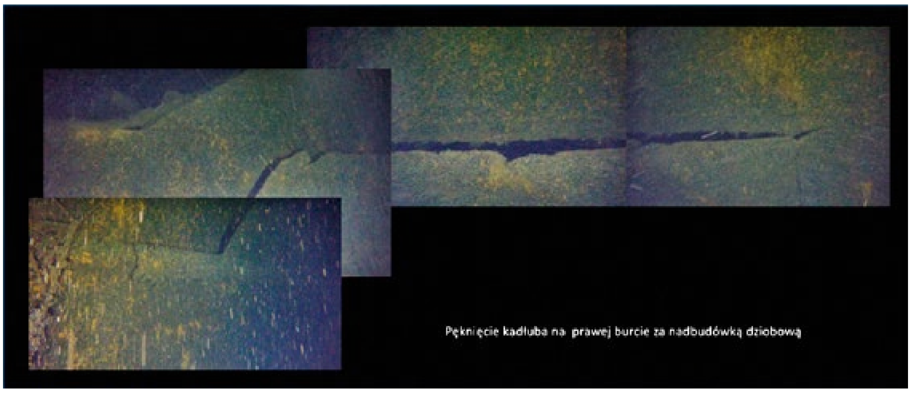
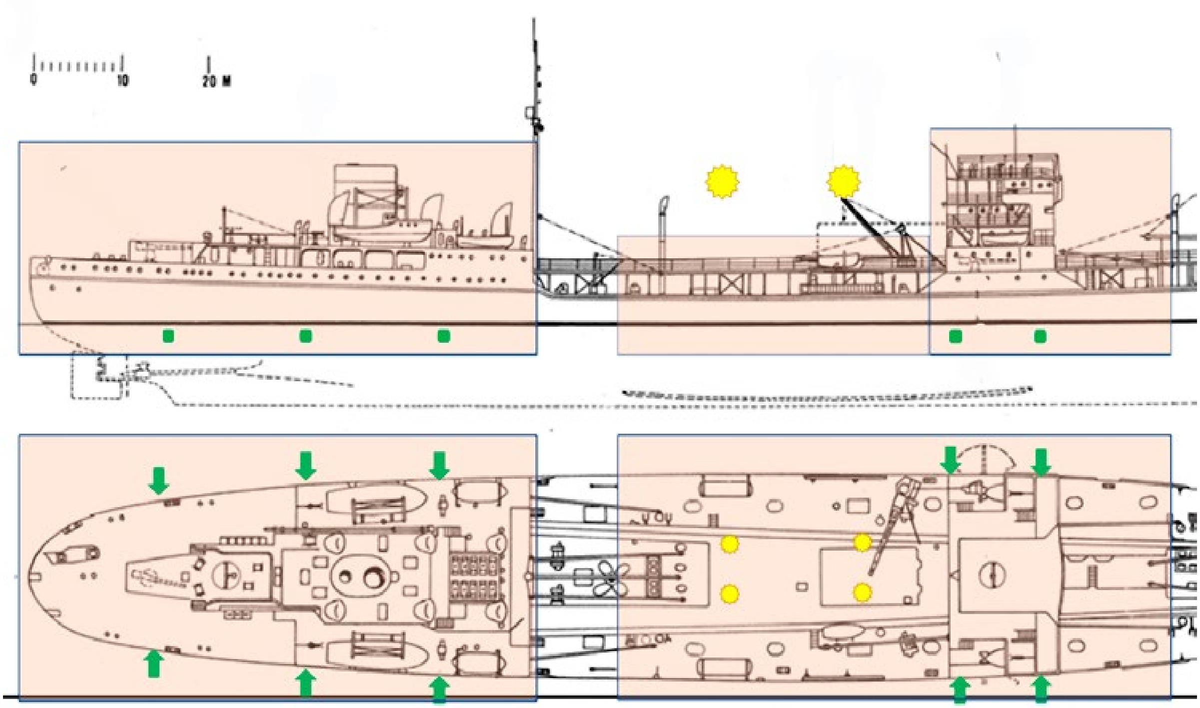



**Photo 25.** A mosaic of the starboard under the forecastle, showing a crack in the hull, 10 m long and 5-30 cm wide (source: 2018 expedition)



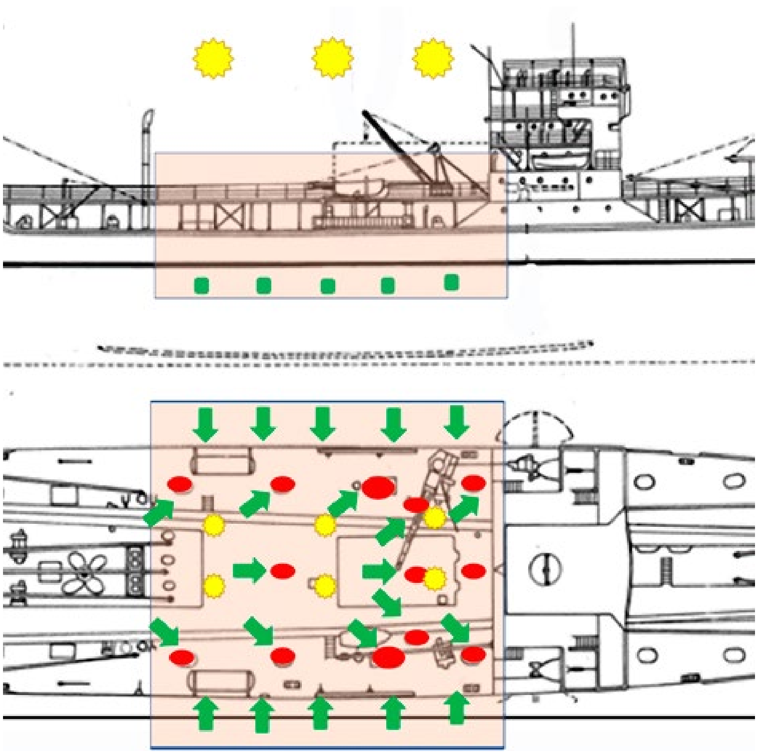



**Figure 25**. Spots where the thickness of the plating was measured: on the left, second day and on the right third day of the diving operation (source: own information)

## 6.2.3 Measuring the plating with an acoustic camera

An important task of the underwater vehicle Cougar XT had consisted of a full acoustic documentation of the wreck, which permitted to make an inventory of large damages of the hull. The current condition of the wreck was identified by making simultaneous photographs and films of the elements of the hull. Acoustic photographs were used for preparing a documentation needed for a safe cleaning of the wreck. Figure 26 shows a section of the deck with a board, approx. 30 m long. This acoustic camera can reach up to 10-12 m inside the deck, showing the equipment and the construction of the main deck.

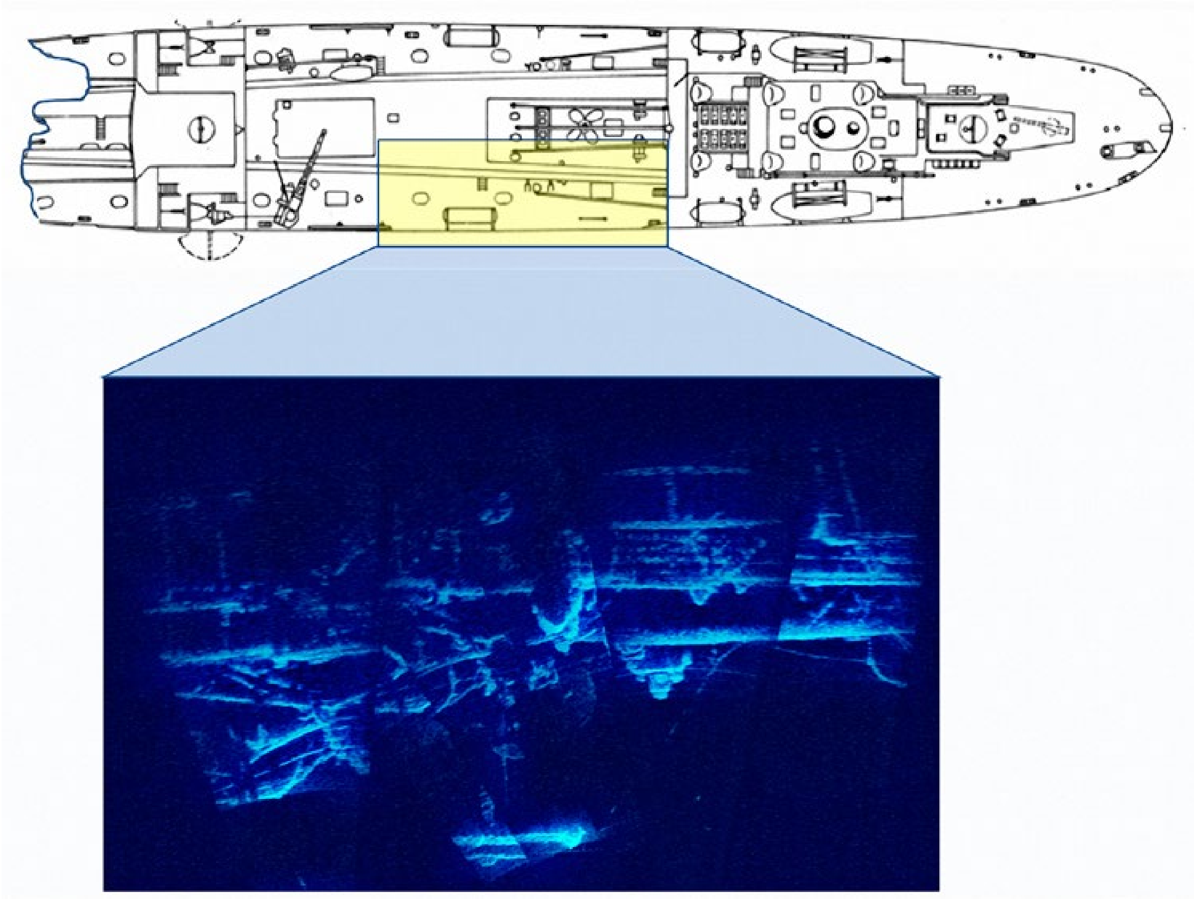


Figure 26. A mosaic of images from an acoustic camera ARIS, showing the main deck and the larboard section of approx. 30 m, from the sterncastle towards the forecastle (source: 2018 expedition)

Although the interpretation of these photos is difficult, it is possible to make a complete picture of the deck in its current state. It is not possible to obtain a point cloud used to create 3D pictures, but it is possible to make a mosaic of images by projection on a plane. This will make the information more depleted, but is useful for assessing the number and type of obstacles, which can appear on the road of a vehicle performing the cleaning. It is recommended to use this device as a source of information impossible to obtain by other means.

# 7 SAMPLING THE SEA BOTTOM FOR CHEMICAL ANALYSIS

When analysing the condition of the wreck, one can easily assume, considering the scope of damages and the types of oil loaded on the ship, that there is a high probability, that some heavy oil had already leaked from the tanks and remains at the sea bottom, in the vicinity of the wreck. Therefore, two sampling methods were used for sampling the sea bottom around the wreck. The survey was carried out in two zones. One zone was situated at a distance of 30-50 m from the wreck. The samples were gathered using a vibraprobe VKG 3 (the cores 3 m long). Another zone was closer, and samples were gathered at a distance of less than 10 m, on an elevation in the middle section of the wreck and in a depression, where the greatest contamination could be expected, as well as many other objects (including unexploded bombs and ordnance), which fell out of the ship during sinking.

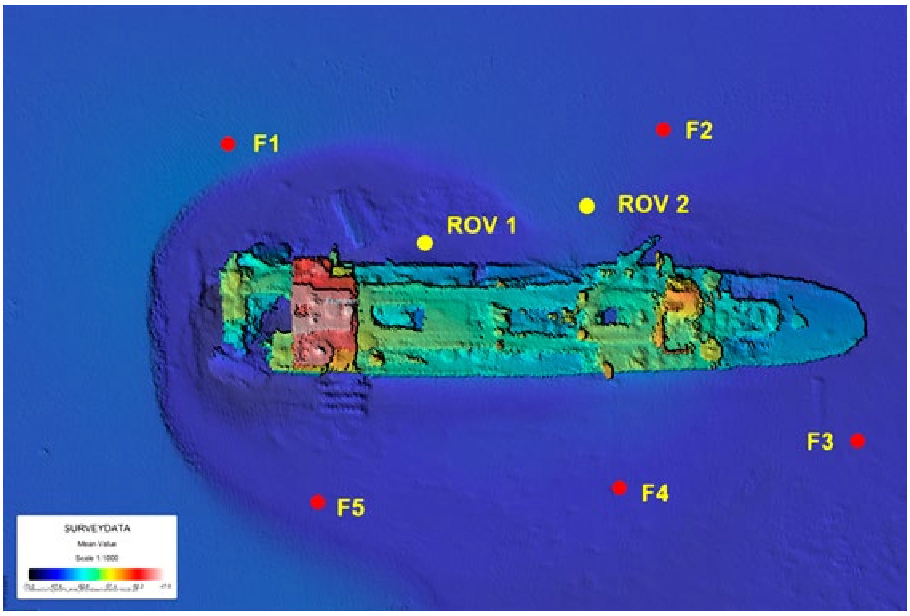



**Figure 27.** Location of the samples in respect to the wreck position (F1-F5 taken by a vibraprobe, ROV 1 and 2 taken by a remote control vehicle) (own source on the basis of data of the Maritime Institute in Gdańsk)

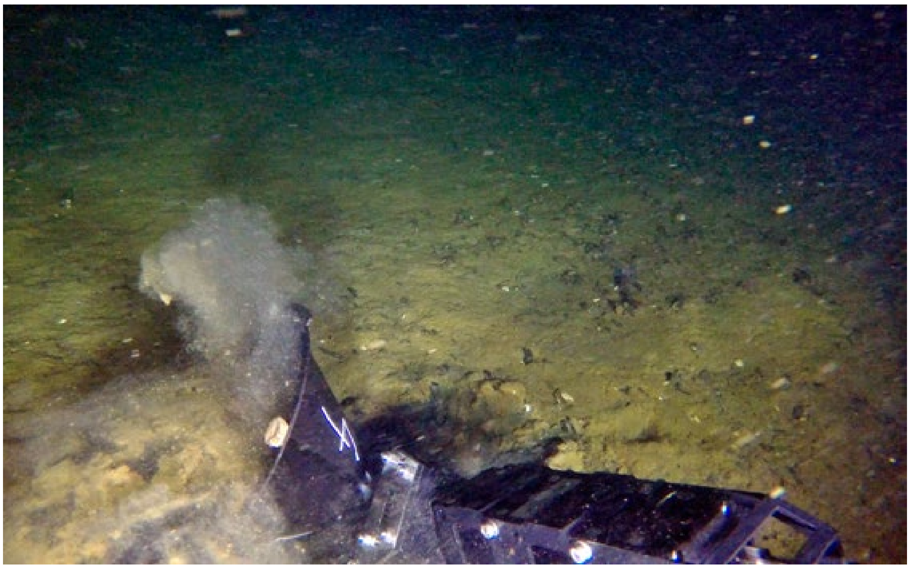


**Photo 26.** Sampling the sea bottom with a ROV next to the wreck (source: 2018 expedition)

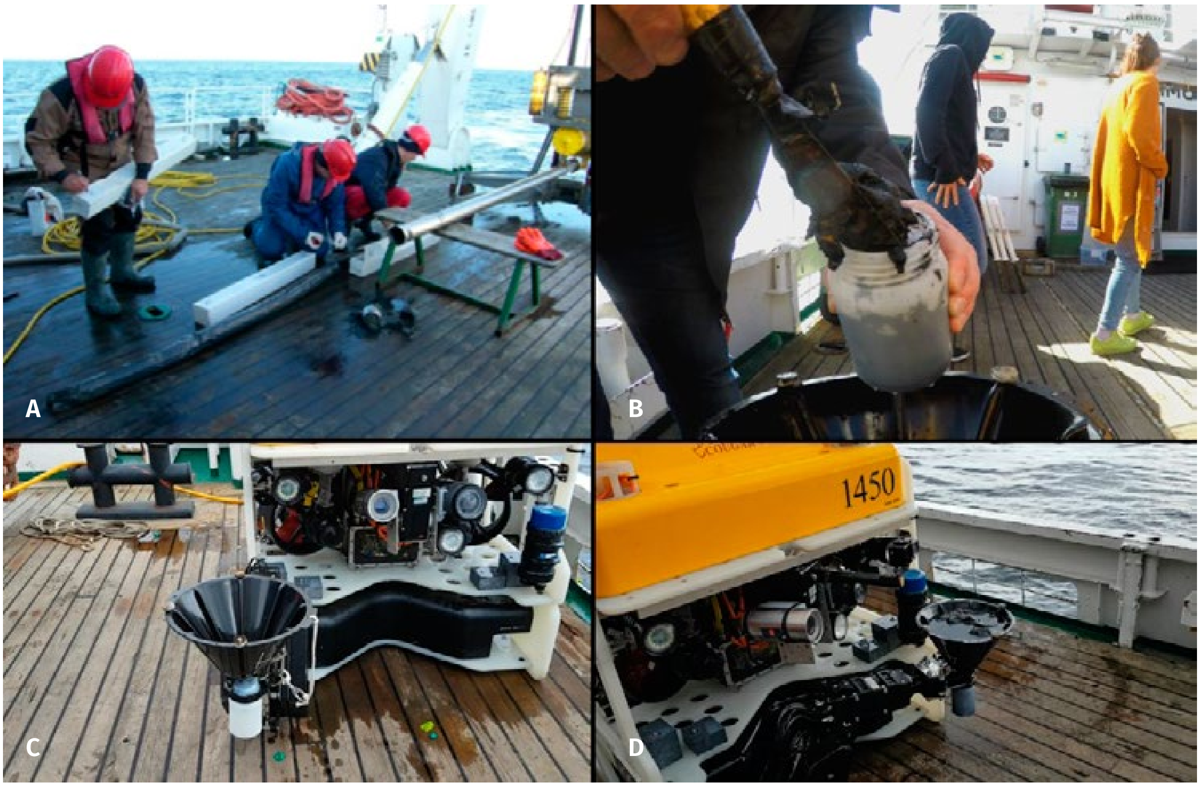



Photo 27. Methods used for sampling the sea bottom around the Franken (LT – vibroprobe VKG 3, RT – collecting the sample into a container send to the laboratory, LB – ROV vehicle with a probe before descending to the bottom, RB – ROV with a collected sample) (source: 2018 expedition)

Sampling in the zone situated closer to the wreck was done using a remote control vehicle, because the use of a vibroprobe without strict supervision of the place, where sampling is carried out could result in a detonation of an unexploded bomb. There are many unexploded ordnance around the wreck.

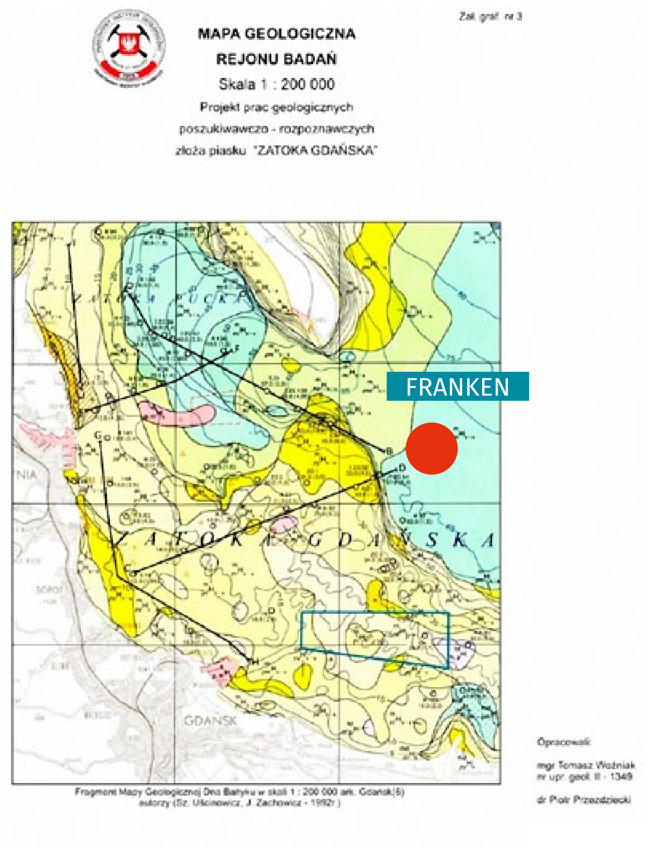



Figure 28. A section of a Geological Map of the Baltic Sea bottom, scale 1:200 000 (the Gdańsk Bay) (source: PIG 1992)

In order to determine how the spilled oil will sink into the sea bottom, it is necessary to define the geological conditions, which have an impact on the sea bottom under the wreck (and its possible reaction in the future). For this purpose, data from the National Geological Research Institute in Gdańsk was used (Figure 28). The geological structure of the surface layer of the sea bottom around the wreck was analysed on the basis of the historical data, a map of surface sediments on a 1:500.000 scale (National Geological Institute Sopot – Warsaw 1995) and field work.

## 7.1 Methodology for water and sediment analysis

**The bottom sediment samples were analysed for the content of**:

a) humidity, total organic carbon, phenols, ether extract ,

b) non-polar aliphatic hydrocarbons (mineral oil),

c) polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCBs).

These physical and chemical indicators were identified in the Laboratory of the Environmental Department in the Maritime Institute in Gdańsk, with the implemented quality management system in accordance with PN-EN ISO/IEC 17025:2005, certified with PCA No. AB 646. The methods used for each parameter are shown in Table 2.

Table 2. **Identification of the methods of bottom sediment tests**

| No. | Parameters | Test method |
|---|---|---|
| 1 | Humidity in 1050 C | Determined by weighing. Test procedure PB-11 3rd edition of 15.03.2010 |
| 2 | Total organic carbon | Infrared spectrometry according to the standard PN-ISO 10694:2002 and PN-EN 13137:2004 |
| 3 | Phenols (Phenolic indicator) | Spectrometry with 4-aminoantipyrin after distillation acc. to PN-ISO 6439:1994 |
| 4 | Ether extract | After acidification with hydrochloric acid samples were extracted with light petroleum in the Soxhlet apparatus on a water bath for 4 hours. The extract was dried with anhydrous $Na2SO4$, ether was distilled and the residue was dried in 40°C and determined by weighing |
| 8 | Non-polar aliphatic hydrocarbons (mineral oil) | Gas chromatography after extraction of analytes in hexane. Determination on GC-MS chromatography |
| 9 | Polycyclic aromatic hydrocarbons (PAH) | Extraction of analytes with dichloromethane from samples. Determination of polycyclic aromatic hydrocarbons with GC-MS chromatography (Gas chromatography with a mass spectrometry detector). Own procedure PB-09. 2nd edition of 10.05.2007 |
| 10 | Polychlorinated biphenyls (PCBs) | Extraction of analytes from samples with a mixture of hexane / acetone. Determination of polychlorinated biphenyls (PCBs) in acetone extracts with GC-MS chromatography (Gas chromatography with a mass spectrometry detector. Own procedure PB-09. 2nd edition of 10.05.2007 |

## 7.2 **Test results**

The results of the tests of bottom sediments collected near the Franken wreck were presented in the Test Report No. 120/18 of 05.06.2018, placed at the end of this report and in Table 3. The content of the identified substances were compared with the values typical for sediments in the southern Baltic and the Gdańsk Bay and the limit values set out in Annex 1 of the Regulation of the Minister of Environment of 16.04.2002 on the types and concentrations of substances contaminating the excavated material (Journal of Laws, No. 55, item 498 of 16.04.2002).

Table 3. **Summary of the results of the sediment analysis with the literature values typical for the research area and with the Regulation of the Minister of Environment (*Journal of Laws, No. 55, item 498 of 16.04.2002 and Journal of Laws 2015, item 796*)**

| No | Type of test | Unit | Bottom sediments collected near the Franken wreck | | Limit value [2] | Literature |
|---|---|---|---|---|---|---|
| | | | Sample ROV 1 | Sample ROV 2 | | |
| 1 | Humidity 105°C | % | 71,1±9,6 | 72,7±9,8 | no data | no data |
| 2 | Total organic carbon (TOC) | % s.m. | 17,55±5,58 | 14,26±4,54 | no data | 4-8%[3] |
| 3 | Phenols | mg/kg s.m. | 17,4 | 7,37 | no data | 0,13-30[9] sediments in the vicinity of the Stuttgart wreck |
| 4 | Ether extract | mg/kg s.m. | 187 584 | 87 716 | no data | 330-24 000[9] sediments in the vicinity of the Stuttgart wreck |
| Petroleum hydrocarbons | | | | | | |
| 1 | Mineral oil ($C_{12}$ – $C_{35}$) | mg/kg s.m. | 62 987±12597 | 32 816±6563 | 50[7] Finland<br>100[7] Estonia, Latvia<br>300[7] Germany | <0,01-57,0[8] sediments from the marine dumping site in Gdynia<br>200-600[8] sediments from the harbour site |
| Polycyclic aromatic hydrocarbons (PAH) | | | | | | |
| 1 | Naphthalene | mg/kg s.m. | 4,7±1,4 | 3,6±1,1 | 1,5 | 0,5085) |
| 2 | Acenaphthylene | mg/kg s.m. | 4,3±1,3 | 2,18±0,65 | 1,5 | 0,003-0,384[5] |
| 3 | Acenaphthene | mg/kg s.m. | 128±38 | 62±18 | 1,5 | <0,050– 0,182[5] |
| 4 | Fluorene | mg/kg s.m. | 119±36 | 47±14 | 1,0 | 0,066-0,205[5] |
| 5 | Phenanthrene | mg/kg s.m. | 478±143 | 206±62 | 1,0 | no data |
| 6 | Anthracene | mg/kg s.m. | 74±22 | 60±18 | 1,0 | no data |
| 7 | Fluoranthene | mg/kg s.m. | 313±94 | 186±56 | 1,0 | 0,005-0,290[5] |
| 8 | Pyrene | mg/kg s.m. | 194±58 | 116±35 | no data | no data |
| 9 | Benz(a)anthracene | mg/kg s.m. | 82±33 | 48±19 | no data | no data |
| 10 | Chrysene | mg/kg s.m. | 66±20 | 41±12 | no data | no data |
| 11 | Benz(b)fluoranthene | mg/kg s.m. | 48±14 | 27,8±8,3 | no data | no data |
| 12 | Benz(k)fluoranthene | mg/kg s.m. | 46±14 | 24,7±7,4 | no data | no data |
| 13 | Benz(a)pyrene | mg/kg s.m. | 62±19 | 33±10 | no data | no data |
| 14 | Indenol(1,2,3,-cd)pyrene | mg/kg s.m. | 45±14 | 22,0±6,6 | no data | no data |
| 15 | Dibenz(a,h)anthracene | mg/kg s.m. | 104±31 | 4,0±1,2 | no data | no data |
| 16 | Benz(g,h,i)perylene | mg/kg s.m. | 11,2±3,4 | 14,5±4,4 | no data | no data |
| 17 | Total PAH | mg/kg s.m. | 1 780±597 | 899±302 | ≤ 10 | no data |
| Polychlorinated biphenyls (PCBs) | | | | | | |
| 1 | PCB 28 | mg/kg s.m. | p.0,0001 | 0,0010±0,0002 | no data | no data |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 | PCB 52 | mg/kg s.m. | p.0,0001 | 0,0031±0,0012 | no data | no data |
| 3 | PCB 101 | mg/kg s.m. | p.0,0001 | p.0,0001 | no data | no data |
| 4 | PCB 118 | mg/kg s.m. | 0,0043±0,0022 | 0,0055±0,0028 | no data | no data |
| 5 | PCB 138 | mg/kg s.m. | 0,0091±0,0027 | 0,0186±0,0056 | no data | no data |
| 6 | PCB 153 | mg/kg s.m. | 0,0102±0,0041 | 0,0194±0,0078 | no data | no data |
| 7 | PCB 180 | mg/kg s.m. | 0,0110±0,0038 | 0,0207±0,0072 | no data | no data |
| 8 | PCB total (IUPAC nr 28, 52, 101, 118, 138, 153, 180) | mg/kg s.m. | 0,0346±0,0145 | 0,0683±0,0287 | 0,3 | <0,0171[6)] |

**1)** Annex 1 of the Regulation of the Minister of Environment of 16.04.2002 on the types and concentrations of substances contaminating the excavated material (*Journal of Laws, No. 55, item 498 of 16.04.2002*); **2)** Regulation of the Minister of Environment of 11 May 2015 on the recovery of waste outside installations and equipment (*Journal of Laws 2015, item 796*); **3)** Szczepańska, Uścinowicz, 1994; **4)** Uścinowicz, Zachowicz 1994, **5)** Uścinowicz et al., 2008; **6)** Jonsson, Kankaanpaa, 2003; Uścinowicz 1999; **7)** Sapota et al., 2013; **8)** Dembska et al., 2012; **9)** Dembska et al., 2016

The bottom sediments collected around the Franken wreck were characterised by a significant organic carbon content, at the level of 14-17%, which indicates that sediments are rich in organic matter. They were heavily contaminated with petroleum substances. The ether extract ranged from 87 716 to 187 584 $mg \cdot kg^{-1}$dm, mineral oils from 32 816 to 62 987 $mg \cdot kg^{-1}$d.m., and total PAH from 899 to 1780 $mg \cdot kg^{-1}$d.m. The concentrations of the tested substances exceeded the values typical for the Gdańsk Bay, by approx. 10× (Naphthalene) to 1000× (Fluoranthene). The tested sediments contained high levels of phenols, ranging from 7.37 to 17.4 $mg \cdot kg^{-1}$d.m., and high concentrations of Polychlorinated biphenyls (PCBs), ranging from 0.03 to 0.07 $mg \cdot kg^{-1}$d.m. and was approx. 2-4× higher that the value identified in the bottom sediments of the Gdańsk Bay.

The concentration of tested substances indicate a contamination pf the tested sediment, probably with oil from the wreck.

When comparing the test results of samples, it was noted that the concentration of tested substances was approx. 2 times higher in sample No. 1 than in sample No. 2.

The results obtained during the tests of sediments collected around the Franken wreck are much higher than the results obtained in 2016. Bottom sediments collected around the Franken wreck in 2016 were characterised by the following levels of contaminants: ether extract 348-773 $mg \cdot kg^{-1}$DM, mineral oils 51-109 $mg \cdot kg^{-1}$dm, phenols 0.12-0.26 $mg \cdot kg^{-1}$DM, organic carbon 21-50 $mg \cdot kg^{-1}$DM, total PAH 0.035-0.76 $mg \cdot kg^{-1}$dm, total PCBs 0.0008-0.0056 $mg \cdot kg^{-1}$DM However, this comparison does not clearly indicate a significant deterioration of the state of bottom sediments around the Franken wreck over the period of 2 years. First of all, we do not exactly know the location of sampling points in 2016. They were probably collected further away from the wreck than the samples collected in 2018. Secondly, the samples collected in 2016 are core samples, taken with cores approx. 1.7-3.0 m long. For analytical tests, the samples were averaged over the entire length of the core. This could have resulted in lower values, because the lower layers are usually less contaminated that surface layers of sediments.

In 2018, the test samples were collected in the close vicinity of the wreck (near field), due to the use of an underwater vehicle to collect the samples. The samples were collected from the surface layer, to the depth of approx. 15 cm.

## 7.3 Comparing the test results with the limit values resulting from the relevant legislation

**The values of PAH** in the bottom sediments were compared to the limit values set out in the Regulation of the Minister of Environment of 11 May 2015 on the recovery of waste outside installations and equipment (*Journal of Laws 2015, item 796*) and the Regulation of the Minister of Environment of 16.04.2002 on the types and concentrations of substances contaminating the excavated material (*Journal of Laws,* *No. 55, item 498 of 16.04.2002*), repealed on 23 January 2013, setting up limit values. The comparison indicates that the concentrations of PAH listed in the above mentioned Regulation (benz(a) anthracene (<1.5 mg·kg$^{-1}$DM), benz(b)fluorantene (<1.5 mg·kg$^{-1}$DM), benz(k)fluorantene (<1.5 mg·kg$^{-1}$DM), benz(ghi)perylene (<1.0 mg·kg$^{-1}$DM), benzo(a)pyrene (<1.0 mg·kg$^{-1}$DM), dibenz(ah)anthracene (<1.0 mg·kg$^{-1}$DM), indeno (123cd)pyrene (<1.0 mg·kg$^{-1}$DM) has been exceeded for all limited substances. This proves a high contamination of the bottom sediment in this area. When the total concentration of the 16 PAH exceeds 8 mg·kg$^{-1}$DM, the ground becomes a waste.

**The values of polychlorinated biphenyls (PCBs)** in the bottom sediments were compared to the limit values set out in the Regulation of the Minister of Environment of 11 May 2015 on the recovery of waste outside installations and equipment (*Journal of Laws 2015, item 796*) and the Regulation of the Minister of Environment of 16.04.2002 on the types and concentrations of substances contaminating the excavated material (*Journal of Laws, No. 55, item 498 of 16.04.2002*), repealed on 23 January 2013, setting up limit values. The comparison indicates that the limit concentrations of the total PCB congeners 28, 52, 101, 118, 138, 153 and 180 (< 0.3 mg·kg$^{-1}$) has not been exceeded for any of the samples, collected at any depth. On this basis, it can be concluded that the bottom sediments collected in the vicinity of the Franken wreck are not contaminated by the compounds of the PCBs to the extent that would prevent the processing or recycling of the waste or its disposal at sea.

There are currently no Polish legal standards setting out limit **values for mineral oils**, which indicate the contamination of bottom sediments. Such regulations exist in the Baltic countries, such as Estonia, Finland, Germany, Latvia, Lithuania and Russia. Most of these countries specify the limit values, defined as first limit value and second limit value. If the content of hazardous substances in the dredged sediment does not exceed the first limit value, than the sediment is considered to be clean and remain at the sea bottom. However, if the content of hazardous substances exceeds the second limit value, the sediment is contaminated and cannot remain at the sea bottom. For example, in Latvia the limit values amount to 100 mg·kg$^{-1}$dm (first limit value) and 400 mg·kg$^{-1}$dm (second limit value) and in Finland 50 mg·kg$^{-1}$dm. (first limit value) and 1500 mg·kg$^{-1}$dm (second limit value) (Sapota et al., 2013). When comparing the values of the concentration of mineral oils from the survey area (32 816 to 62 987 mg·kg$^{-1}$dm,) with the limit values, it can be concluded that the tested sediment is contaminated by mineral oils.

## 7.4 **Conclusions**

The test results indicate possible contamination of the samples of sediments collected around the Franken wreck with the oil from the sunken vessel. This is evidenced by very high values of mineral oils, PAH, substances extracted with light petroleum and phenols, as well as high value of organic carbon.

In order to determine the degree of contamination of bottom sediments around the wreck, as well as the risks posed to the marine environment, the density of the sample collection sites of surface sediments should be higher. In addition, core samples should be collected in the most contaminated areas, to conduct the analysis of different layers and determine the depth to which the sediment can be contaminated by oil spills.

The values of the samples collected in the close vicinity of the wreck (near field) dramatically exceed the limit values. The level of PAH in a bottom depression amounted to 1780 mg/kg DM, which means that the limit values have been exceeded more than 200 times, and the value of the sample collected on an elevated sea bottom (near field) amounted to 899 mg/kg DM, which mean that the limit value has been exceeded by 120 times.

The level of mineral oils in each kilogram of dry matter exceeds the limit value by 500-1000 times. A large quantity of phenols, ether extracts and very large quantity of organic carbon were found in the composition of detected substances. The presence of such a large amount of organic carbon indicates that a quick sedimentation of organic substances (apart from contamination) takes place around the wreck. This is not surprising, because the wreck lies within the range of water flowing from the Vistula river (it is located just in front of the Vistula river mouth) and the verge of the Gdańsk Deep, where the conditions for biological life are extremely unfavourable due to shallow layers of hydrogen sulphide.

# 8 THE RISKS OF THE FUTURE CLEANING OPERATION

When deciding to clean up a wreck from oil, all the risks that could occur should be take into account. One of them is the state of its construction, stable at the moment, but undetermined and at risk of collapse (see large crack in the hull). Another risk is caused by a big number of unidentified objects, which can be unexploded ordnance on the wreck (both in the hold and on the deck, probably many of them scattered around the wreck) (Photo 28, Photo 29, Photo 30).

Working conditions for the cleaning company can be very limited. Before starting the clean-up, it might be necessary to conduct a wide-ranging investigation to detect unexploded ordnance, or even removal of unexploded ordnance by a disposal team from the wreck (if such objects are found and identified). This significantly increases the costs of the clean-up work, increases the vigilance of divers or the team responsible for the use of the remotely operated vehicle, because any unwise action can put at risk human life and cause an uncontrolled spill. The insurance costs of such operation will be significantly higher.

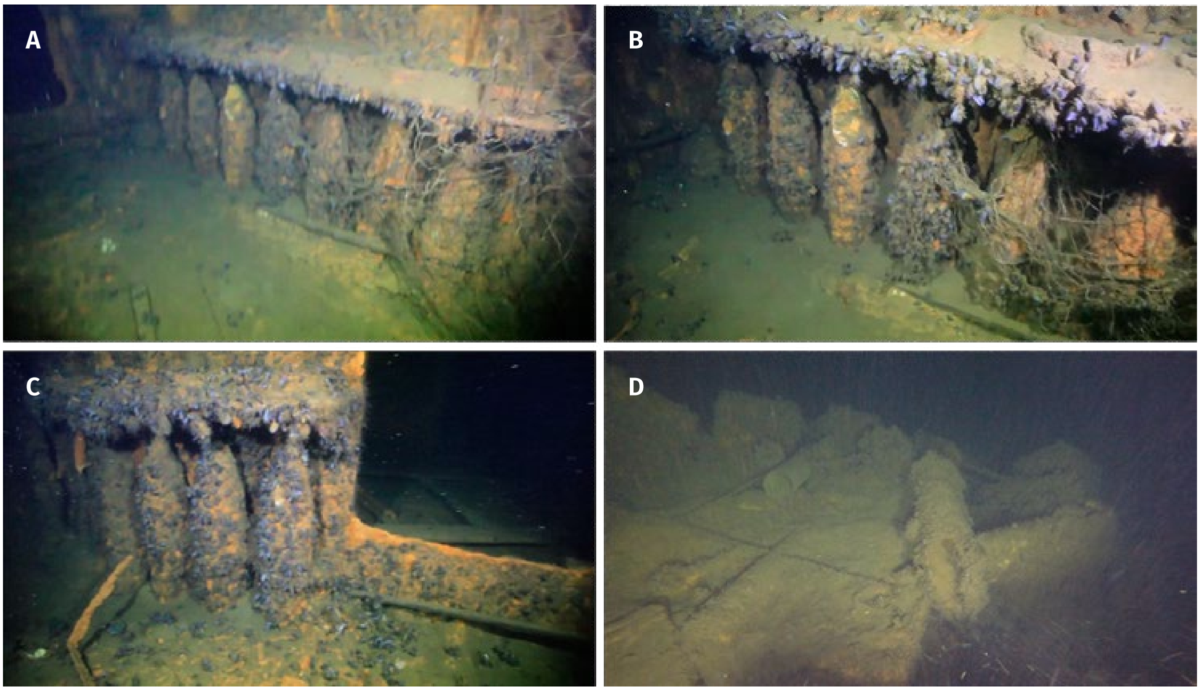



**Photo 28.** The artillery emplacement of an anti-aircraft gun, 150 mm calibre with 150 mm ammunition in ammunition park, placed on the board and in the stern, ammunition scattered on the upper deck (source: 2018 expedition, © T. Trojanowicz)

The presumption of unexploded ordnance was made on the basis of the war diary of the German Naval Headquarters (for the war theatre in the Baltic), Maritime Warfare Command (German: Seekriegsleitung). From this source, we know that on 22nd April 1945, **the following ammunition was onboard the Franken ship**:

- 1000 missiles, calibre 150 cm for the NÜRNBERG cruiser,
- 1000 missiles, calibre 150 for destroyers from the Thiele group,
- 1750 missiles, calibre 127 mm for destroyers from the Thiele group
- undefined amount of AA ammunition.

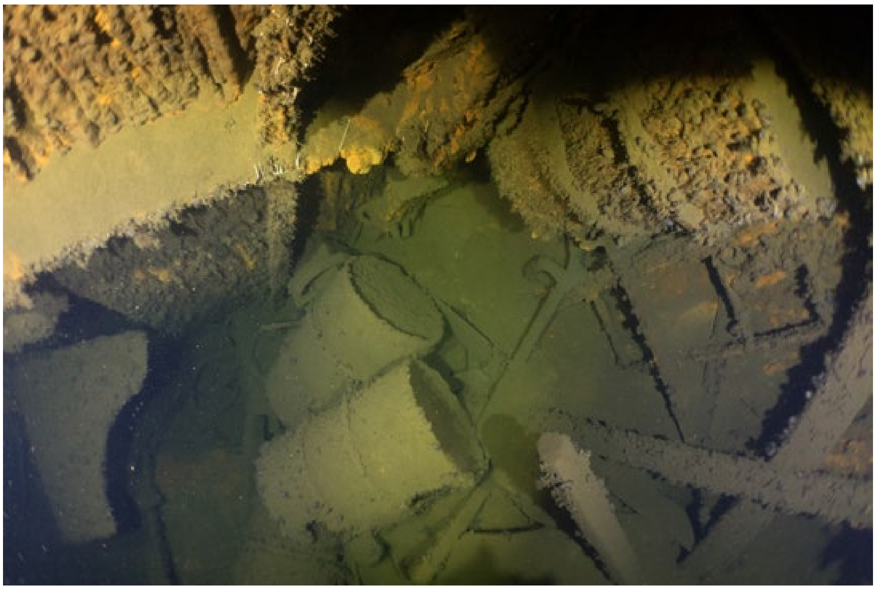
The Franken was armed with 3 guns, calibre 150 mm, 6 AA guns of 37 mm, 16 guns of 20 mm and one rocket launcher to combat low-flying aircrafts. **For self-defence, the Franken had in its loads**:

- 3× 200 (equals 600) missiles, calibre 150 mm,
- 6× 2 000 (equals 12 000) missiles, calibre 37 mm,
- 16× 2 000 (equals 32 000) missiles, calibre 20 mm,
- 8 wire-guided missiles.

There are no records on the transfer of ammunition to other vessels, although according to the description of the war during that period, it is unlikely that the ammunition necessary to carry out war operations would not be used (transferred to combat vessels). However, it is very likely that the ammunition needed for self-defence remained on the Franken (it was partly used during the defence on the day of the sinking).

Photo 29. Boxes with unknown content (possibly with parts, although they look like a boxes with small calibre ammunition) on the main deck, under the forecastle (source: 2018 expedition, © M. Czermiński)

Photo 30. Barrels with unknown substance in the well of the control unit of oil valves (source: 2018 expedition, © M. Czermiński)



# 9 THE CONCLUSIONS FROM THE RESEARCH EXPEDITION

1. **The current loading of the Franken wreck is unknown.** During the expedition it was not possible to determine clearly which tanks contain oil. However, it was possible to identify, which tanks do not contain oil because of their current state, mainly unsealing. The collected photographic and film documentation shows that the tanks, which look sealed, could contain 4608 tonnes of different types of oil. At the moment of sinking, the ship was full of stocks, including 2.7 thousand tonnes of oil (3.136 $m^3$) not including the oil needed for the ship's engine. Almost half of the volume of the tanks is still sealed, without any access from the outside, which means that each of the 5 sealed tanks can be filled with oil. The sealed tanks have a volume between 573 tonnes to 1221 tonnes.
2. On 23rd – 26th April 2018, the divers carried out underwater investigations from the LITORAL ship. **They spent approx. 60 hours underwater**, including 13 hours on the wreck.
3. On 23rd – 26th April 2018, the group operating the underwater remote control vehicle executed 12 underwater investigations. In total, **the ROV spent approx. 30 hours underwater**, including 20 hours taking pictures and films of the wreck (assisting the divers for 10 hours) and 10 hours for the inspection of the entire wreck.
4. **Many photographs and several hours of film were made**:
   - For the use in the film promoting the project,
   - To make films in VR (3D) – 5 points (including 2 points by divers, 3 by the ROV)
   - Photographs for communicational and technical purposes (hundreds).
5. Despite the search, it was not possible to find places, where oil spills could be filmed. Cracks and other critical spots on the wreck, indicating "an imminent disaster" were filmed. **The photographs show the scope of damages of the hull**, its elements and tank covers.
6. A few hundred photographs were made to execute a documentary mosaic used to create a 3D photogrammetric image of the deck and broadsides of the Franken in the place where the oil tanks are located. The collected material is suitable for use as a documentation of the wreck condition, used for the analysis of the damages.
7. There is a possibility to execute a mosaic from film frames made according to a specified procedure (for a mosaic). The frames will be used to make a mosaic of the port side and a section of the deck.
8. Both broadsides were inspected in the places, where tanks are located (partly by divers and more precisely by the ROV. No cracks or leaks were found. **The broadsides are significantly damaged in several places** (with broken hull plating). These damages occur around the forecastle, where the tanks were destroyed during the hull fracture after the bomb attack.
9. Oil sampling containers were placed in the locations of leaks. Such sampling device of own construction was placed near one of the hatches to a hold, without visible effects.

10. The divers carefully inspected the covers of the hatches (Photo10 to 16), where there is the highest probability of oil leakages. No leakages were spotted. This means that:
    - The covers of the tanks are still tight,
    - There is still no perforation on the main deck, exposed to direct impact of salt water,
    - The tanks below the deck are filled with oil or some other substance, which protects the steel of the hull from corrosion, therefore the condition of the deck is unexpectedly good.
11. **Some tanks were badly damaged during the bomb attack and after sinking** (Photos 17 -19). A large part of the board is detached on the larboard, under the forecastle. The tank is probably empty, but there is a great chance that oil is trapped under the deck, in the frames and in some other well--hidden places. Despite the attempts, it was not possible to enter the tank. Therefore, it cannot be excluded that the tank is filled with heavy oil at the bottom, or light oil in its upper part. According to the divers, a similar situation is encountered in the forecastle, where oil may remain in the recesses and niches.
12. On the basis of the mosaic, **a very serious damage to the hull was discovered under the forecastle**. It is uncertain whether the damage was caused by an explosion during the bomb attack and sinking of the ship, when the ship broke 15 meters further towards the bow, or during collision of the sinking ship with the sea bottom, or the damage was due to the enormous loads currently put on its hull. An analysis of the crack, which runs from the bow towards the stern indicates that part of this damage is old, as suggested by corroded edges, covered with thick deposits. The damage towards the stern is relatively new, as suggested by long, sharp, poorly corroded edges of the plating. The crack in the hull is approx. 10 m long and from 5 to 30 cm wide.
13. **An important task of the underwater vehicle Cougar XT had consisted of a full acoustic documentation of the wreck,** which permitted to make an inventory of large damages of the hull. The current condition of the wreck was identified by making simultaneous photographs and films of the elements of the hull. Acoustic photographs were used for preparing a documentation needed for a safe cleaning of the wreck. The documentation (Figure 26) shows a section of the deck with a board, approx. 30 m long. This acoustic camera can reach up to 10-12 m inside the deck, showing the equipment and the construction of the main deck.
14. **The values of the samples collected in the close vicinity of the wreck (near field) dramatically exceed the limit values.** The level of PAH in a bottom depression amounted to 1780 mg/kg DM, which means that the limit values have been exceeded more than 200 times, and the value of the sample collected on an elevated sea bottom (near field) amounted to 899 mg/kg DM, which mean that the limit value has been exceeded by 120 times.
15. **The level of mineral oils in each kilogram of dry matter exceeds the limit value by 500-1000 times. The presence of such a large amount of organic carbon indicates that a quick sedimentation of organic substances (apart from contamination) takes place around the wreck**.
16. A large quantity of phenols, ether extracts and very large quantity of organic carbon were found in the composition of detected substances.
17. The presence of such a large amount of organic carbon indicates that a quick sedimentation of organic substances (apart from contamination) takes place around the wreck. This is not surprising, because the wreck lies within the range of water flowing from the Vistula river (it is located just in front of the Vistula river mouth) and the verge of the Gdańsk Deep, where the conditions for biological life are extremely unfavourable due to shallow layers of hydrogen sulphide.
18. When deciding to clean up a wreck from oil, **all the risks that could occur should be take into account**. One of them is the state of its construction, stable at the moment, but undetermined and at risk of collapse (see large crack in the hull). Another risk is caused by a big number of unidentified objects, which can be unexploded ordnance on the wreck (both in the hold and on the deck, probably many of them scattered around the wreck).

**19.** Working conditions for the cleaning company can be very limited. Before starting the clean-up, it might be necessary to conduct a wide-ranging investigation to detect unexploded ordnance, or even removal of unexploded ordnance by a disposal team from the wreck (if such objects are found and identified). This significantly increases the costs of the clean-up work, increases the vigilance of divers or the team responsible for the use of the remote control vehicle, because any unwise action can put at risk human life and cause an uncontrolled spill. The insurance costs of such operation will be significantly higher.

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# 10 REVIEW OF WRECK CLEAN-UP METHODS THAT COULD BE USED AT THE FRANKEN WRECK

Among the very many clean-up methods used at wrecks, which pollute or could pollute the marine environment, only those used to clean-up wrecks, which contain oil and no contamination was discovered in their location. The Franken is one of such wrecks. At the moment, no spills of heavy oil have been noted around the wreck and its tanks contain an unknown quantity of oil, which can be released and contaminate the ecosystem of the Gdańsk Bay. The analysis was limited to the methods that best suit the local conditions. Those that can be used under current conditions were chosen:

- Backfilling the whole wreck, including the contaminated sediment,
- Pumping oil from the wreck with diving systems and hot-tapping system,
- Pumping oil from the wreck using remote control systems (ROV) and hot-tapping.

In selecting the clean-up and pumping operations from the wreck, the need to use other technologies should also be considered to assist the sea bottom clean-up and protect against secondary contamination, such as:

- booms,
- skimmers,
- oil, water and sediment separators,
- mobile and floating tanks,
- burning oil on water surface.

In addition, high likelihood of the presence of unexploded ordnance, ammunition, explosives, chemical warfare, other dangerous chemical substances should be considered.

## 10.1 Comparing the methods and proposals for cleaning the tanks of the Franke from oil

After analysing of the collected environmental data, geological data, the results of chemical, ecotoxicological and biological analysis of photographic data and the results of the plating measurements executed during the expedition on 23rd – 29th April 2028 and after carrying out study work on modern methods of removing oil from wrecks lying on seabed, it was concluded that at present the following methods of protecting the environment from uncontrolled oil spills from the tanks of the Franken can be recommended.

### 10.1.1 Backfilling the wreck and the contaminated sediment

Although the backfilling of the wreck and contaminated sediment can introduce pollutants into the water during backfilling, under the pressure of the sand on the sea bottom during backfilling, it may be considered effective (not necessarily recommended) and fulfilling the project objectives. Putting a geotextile or another isolating layer on the backfill surface (the type of isolating layer should be determined), stopping the backfill layer from a quick penetration into the contaminated sediment and pressing the oil out through this backfill layer should limit release of pollutants into the water. Additional research should help to determine the necessary thickness of the backfill and the backfilling technology. When combining the dredging works near the Northern Port and other tracks leading to the ports, there is a possibility to significantly reduce the costs by using the dredging spoils in the wreck area instead of a dump site. The moral dilemma remains to be solved. Do we have the right to leave the problem to the next generations, counting on remediation of the isolated contamination, or refrain any actions by exposing the present generation to the contact with contaminated food (fish), risk oil spills on the beaches, which will exclude them from exploitation for months or even years, risk irreversible losses in the ecosystem of the Gdańsk Bay.

### 10.1.2 Pumping oil from the wreck with diving systems and hot-tapping system

At present, this is the most widely used method of removing oil from wrecks. It is a modern technology, which consists of fixing pumps on the sides, bottom and decks of the wreck to remove oil from closed tanks and oil used for its propellers. The method is useful when emptying tanks which contain different chemicals. The system is composed of valves, including valves to regulate the pressure in the emptied tanks, heating systems for heavy oil, clamping system, pumps, overflow and load tanks etc. The system is operated by professional diver team, with the skills and knowledge on how to use this method at sea. The depth to which such a system can be used is limited to the physical capabilities of divers and their constraints. It usually does not exceed 100 metres for saturation diving. At depths greater than 100 metres automatic systems operated by the ROV are more often used.

### 10.1.3 Pumping oil from the wreck using remote control systems (ROV) and hot-tapping

A technology similar to the hot tapping system operated by divers, which replaced by a remote control robots, prepared to operate at depths up to 3.000 metres (and more, if needed).

In this system, all dangerous works are executed by large robots capable of being underwater for hours or days, performing heavy duties with manipulators operated in real time mode from the deck of supervising vessels (usually dynamic positioning vessels).

Mixed methods can be used, i.e. covering the wreck with an insulation layer to stop the oil spill, cleaning the tanks using the hot-tapping system and allowing for self-remediation of the remaining area or cleaning the tanks using the hot-tapping system and capping the entire contaminated area with a layer of backfill.

## 10.2 Detailed analysis of each of the proposed methods

### 10.2.1 Capping the contaminated area

*Capping* consists of covering contaminated sediment with a layer of clean material, which remains in place to isolated the contaminated layers from the environment. The cap may consist of clean sediments, sand, gravel, stones. A more complex cap may contain geotextiles or other synthetic material and other permeable or impermeable materials in multiple layers. The caps may contain an addition of an active substance, in the form of organic carbon or other modified forms to slow down the flow of contaminants in the cap (U.S. EPA 1998; U.S. EPA, 2004). In total, three types of caps can be identified:

- **Conventional capping** – consisting of sand or other natural materials, directly on the contaminated layer of sediment,
- **Reinforced capping** – with an additional layer of stones or backfill to provide additional protection against high velocity currents,
- **Composite capping** – composed of several layers of sand, stones and geotextile, providing better isolation.

*Capping* is used in cases, where removal of the contamination would be too expensive, impractical and could cause further spread of contamination. The method may also be effective as a provisional measure, until effective cleaning methods are found, in the case if the oil leakage in the water is limited to one zone and stable (Fitzpatrick, 2013). This technology is best suited to retain volatile and semi-volatile organic compounds (including polychlorinated biphenyls, PCB and polycyclic aromatic hydrocarbons PAH), pesticides and metals (www.cpeo.org). Capping is also used if the source of contamination is significantly weakened or when natural purification process is too slow. The choice of this method also arises from availability of adequate quality and quantity of capping material (NRC, 1997).

A prerequisite for the use of capping for contaminated sediment is the cessation of the original leakage as well as hydrological conditions not causing surface disturbances of the seabed, because strong currents could move the capping materials. An important factor is the availability of the capping material and the resistance of the seabed in the location of the cap, because it must maintain the capping. The depth of the seabed is another important factor, because it the capping reduces the space available for water traffic (www.cpeo.org).

The cap should be composed of an internal layer with grains growing towards the bottom, to prevent collapse of the heavy material. It is also necessary to reduce the permeability of the capping by using another impermeable and erosion-resistant external or by injecting of a hardening material (eg. cement or fly ash) into the surface cap (Alcaro et al., 2007). When using a geotextile layer with active substance in the cap (eg. Organic carbon or organic loam), the material is supplied in rolled-up form, placed on contaminated sediment and covered with sand or other conventional capping material of suitable thickness so as to provide a suitable benthos habitat (U.S. EPA, 2004).

**Application examples**

The capping material can be placed on the seabed from a barge with a conventional hopper dredger or using a submerged diffuser with a pipeline, with a tremie or a pipeline connected with a ROV equipped with cameras. More illustrations of machines used for capping can be found in the document of the EPA and *Army Corps of Engineers* (U.S. EPA, 1998; U.S. ACE, 1998).

*Capping* was often used to remediate the sediments contaminated with different substances (among others, petroleum compounds), including marine areas near the shore. The document U.S. EPA (1998), U.S. ACE (1998) and ITRC (2014) contain examples of projects using capping of different structure in the cases of different types of contaminants, including the petroleum compounds.

The capped area requires a long-term monitoring to verify the integrity of the cap and to ensure that the contaminating substances do not migrate.

Another option consists of backfilling the contaminated area wreck with sand, including the wreck (Figure 29) and adding a concrete cover. This solution is taken into account in the cases requiring extensive cleaning or where the cleaning operation could pose a substantial risk, especially in the case of war wrecks with numerous unexploded ordinance at the sea bottom. The Franken is such a case. There is a large amount of ammunition used for the 150 mm anti-craft guns and smaller calibre guns spread on the deck, around the wreck and in the loads, as well as the ammunition carried as load. Backfilling of the entire wreck was suggested in the case of the USS Montebello and the German U-boot, U-864 (Barrett, 2011).

### The costs

The costs of this technology cover the material, transport, storage and application, as well as the monitoring carried out during and after the operation to control the capping and contaminants. The basic cost of the material is mainly affected by its availability and transport costs.

*National Research Council* categorises the capping costs as moderate and estimates the costs at 1 $\$/yd^3$, that is 1.3 $\$/m^3$ (NRC, 1997). Additional costs are associated with possible modifications and improvements of the capping, such as, for example, addition of active carbon to the capping or use of an active capping mat. The EPA publication estimates the costs of such modifications to approx. 35 $\$/m^2$ (2013).

On the basis of the information on current prices of collection, transport and placement of 1 $m^3$ of the seabed sediment (sand, loam), received from the Maritime Office in Gdynia and from dredging companies, carrying out dredging operations in the Gdańsk Bay, the estimated costs of such operation amounts to 6-12 Euro/$m^3$ of this material. The costs of additional materials (eg. geotextile) and their deposition are not included in the estimate.

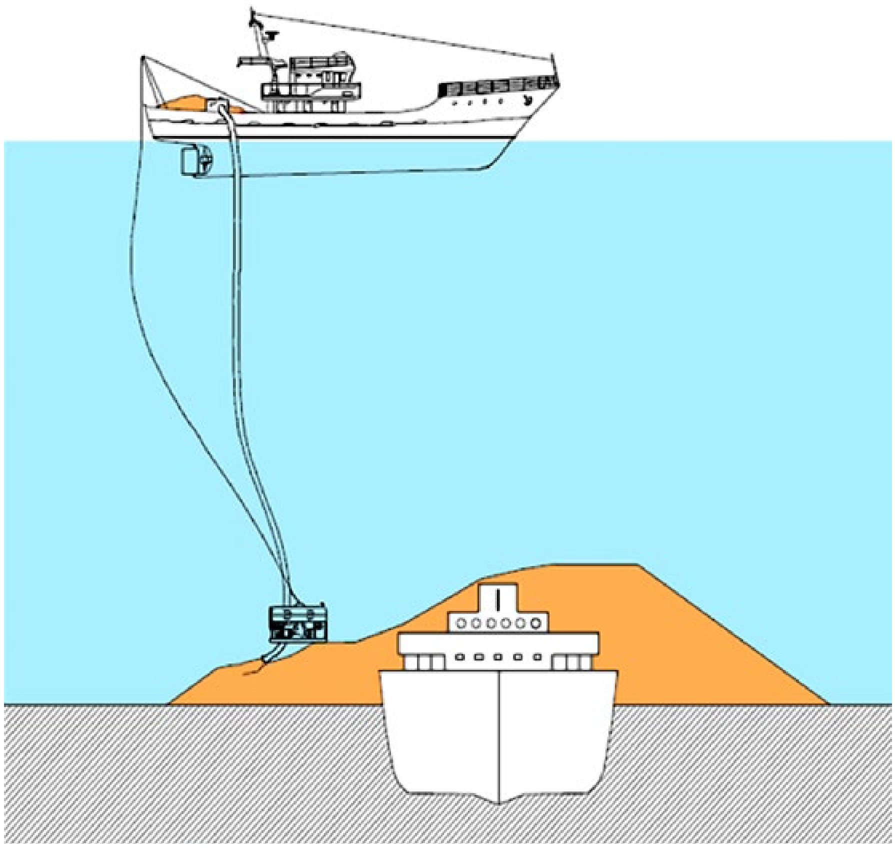


**Figure 29.** Backfilling the wreck with sand using a ROV (Alcaro i in., 2007)

### Advantages

*Capping* isolates the contaminants and minimises their dispersion. Moreover, capping of contaminated seabed with clean sediment provides stable geochemical conditions and supports chemical and biological degradation of contaminants, in particular, if the material contains active compounds (Alcaro et al., 2007; NRC, 1997). A sandy cap can provide a clean habitat for the re-colonisation of organisms (Hull et al., 1999). This method is minimally invasive, does not cause significant damage or permanent removal of the benthos. In addition, a well-designed and placed cap should reduce the risk for fish and other organisms and create desirable (aerobic) conditions by changing the sea depth (Himmelheber, 2008). In relations to dredging, capping does not cause significant disturbances in the sediments and water column, eliminates the risk of suspension, dispersing and leaking of the contaminated sediment. The method is relatively uncomplicated and does not require the removal, disposal and deposition of the sediment. The operation is usually quicker than sediment removal and less costly. It requires less equipment and more conventional one and uses locally accessible materials (U.S. EPA, 2004, Himmelheber, 2008).

#### Restrictions

There is a risk that after placing the first layer of the capping material, the sediments may be released to the water column and as a result of consolidation create a mass flow (www.cpeo.org; Himmelheber, 2008; U.S. EPA 2005). Capping may be difficult under certain conditions without disturbing the contaminated sediment. The contaminants remain in the environment and may be released when the cap is moved (as a result of stronger currents and waves, which may cause a faster erosion of the cap). This can be prevented by using a capping reinforced with a layer of a thicker material. Capping the sea bottom may to some extent affect and alter the habitats of benthic organisms (Himmelheber, 2008). Capping with clean sediment weakens the primary contamination, which is important for the subsequent removal or remediation of sediments. The capping requires constant monitoring of its integrity (NRC,1997). Restrictions in maritime traffic may be required (U.S. EPA, 2004).

**In the case of this project, the method can be considered useful, but inadequate for specific conditions, which exist on the Franken wreck. The lack of contamination of the seabed around the wreck and easy access to the tanks suggest one or two methods based on hot-tapping described below.**

Nevertheless, the method may be considered as effective and comprehensive solution to the problem. The main reason is:

- relatively **low cost of the materials used** (it takes approx. 400 to 600 thousand $m^3$ of sand to cover 30 thousand $m^2$ of an area , including the wreck and the sea bottom in its vicinity);
- relatively **low cost of the operation**, because of a standard (low) cost of equipment and work technology;
- **widely available knowledge** on technical conditions to be fulfilled;
- **positive experiences** on the biological effects of an interference with the sea bottom (despite temporary limitation of the absence of the risk of permanent elimination of the macrobenthos around the capping placed over a contaminated area;
- **no permanent restrictions for navigation** in the capping area (restrictions only during the backfilling of the protective layer;
- **small risk of secondary contamination** of the sea bottom and water during the operation;
- **lack of time limit** – the operation can be carried out at any time of the year, preferably in winter, there is no need to complete the operation at once;
- possibility **to combining several dredging investments** with wreck capping, eg. the planned fairway to the Northern Port and the container terminal in Gdańsk;
- the lack of certainty that the protective layer will be sufficiently flexible and resistant to maintain full impermeability is a disadvantage, therefore there is a need for additional (multiannual) surveys of water currents and waves and their impact on the capping, as the protective layer may be washed away and the wreck can be uncovered;
- permanent loss of an object with great tourist value is a disadvantage;
- at the same time, there is a risk that during capping of layers of material the structure of the wreck, weakened by corrosion, will collapse and cause a spill of a large amount of oil and in consequence, uncontrolled maritime disaster.

**On the basis of the current state of knowledge on the wreck and its surroundings, the use of this technology in the case of the Franken wreck should be strongly rejected.**

### 10.2.2 Hot-tapping and pumping oil from the wreck tanks, assisted by diver and a remote vehicle ROV

The hot-tapping technology, both with the divers and the ROV is very similar and will be described as one single measure.

In the case oil is trapped in the wreck tanks and is easily accessible, the hot-tapping technology is the most effective and modern method to retrieve the oil. The hot-tapping technology can be operated by divers (Figure 30), as with the ship Cleveco (Davin, Witte, 1997) or Mississinewa (U.S. Navy Salvage Report, 2004).

Due to the risks faced with divers, which increase with water depth, special ROV vehicles were designed (*Remotely Operated Vehicles*) to remove oil at greater depths. The technology based on ROV operating the hot-tapping device was first used in the case of oil spill from the Prestige ship, at 3500 m depth. A remote vehicle ROLS (*Remote Offloading System*) by FRAMO and a Hot Tapping Machine, designed by Respol, were used to retrieve oil from the tanks of sunken vessels (Figure 31). ROLS was also used on other vessels, such as Estonia, Levoli Sun, Yuil No. 1 and Osung No 3., Bow Marine (IMO, 2011; Michel et al., 2005).

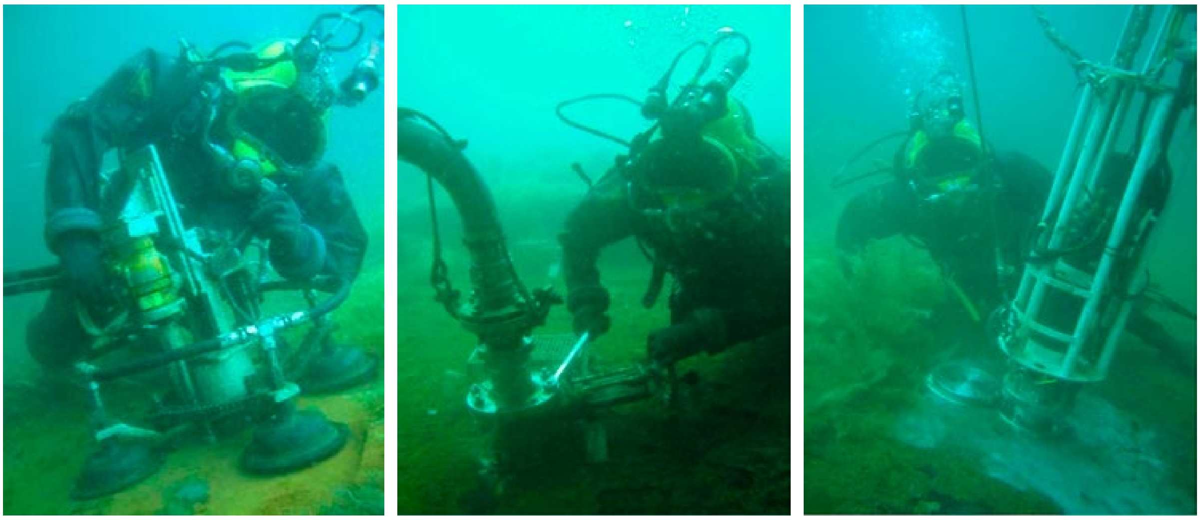


**Figure 30.** Divers clean the wreck using the hot-tapping technology (U.S. Navy Salvage Report, 2004)

In his study, Alfons Håkans presents the operation of oil retrieval from a wreck, using ROV and hot-tapping (SS Park Victory and MS Estonia) (Figure 32). **The operation carried out with a ROV is composed of the following steps**:

- cleaning the hull before measurements and penetration,
- analysing the state of the oil tank and the access,
- measuring the thickness of the plating,
- determining the location of the frame and the access point,
- installing the valve,
- installing the hot-tapping device,
- connecting the ROV with the hot-tapping device and transfer to place of operation,
- penetrating with the hot-tapping device and installing a release valve in the tank,
- the hot-tapping device installs the pressure compressing valve,

- ROV checks twice the valve,
- ROV conducts a self-closing device to the release valve,
- optional devices: Double Bottom Tool, Booster Discharge Pump Unit and oil viscosity control system,
- retrieving oil from the wreck,
- End of the operation.

During the operation, the hot-tapping device (Figure 32) adheres to the hull of the wreck. It is equipped with cutting tools, used to cut an opening. The oil suction valves and pressure compressing valves are then introduced. The oil is extracted with a vacuum suction pipe to the tank floating at water Surface. If the oil is too dense (due to the type and low temperature), heating equipment is introduced to the tank to increase the oil temperature and reduce its viscosity, which allows to pump it out. After retrieving the oil, the valves are closed (Michel et al., 2005; NOAA, 2013).

Taking into account the use of ROV and hot-tapping technology to retrieve the oil, the following criteria need to be defined to select appropriate equipment: water depth, sea and air condition, state and structure of the wreck, quantity of oil to be pumped out, type of oil and its proprieties (in particular its viscosity), number and location of tanks in the wreck, access to the tanks, water temperature ad water currents (Michel et al., 2005).

In the case of some wrecks, especially dating from the war, it is first necessary to determine whether there is oil in the tanks. Since the recovery of oil from SS Jacob Luckenbach wreck, *neutron backscatter*

**Figure 31.** Hot-tapping device used at Prestige wreck


**Figure 32.** ROV with Hot Tapping device produced by Alfons Håkans (Estonia and Park Victory cases info 2015-12-08 KR.pdf)

*system* is used assess the presence of oil in the wreck tanks. In 2011, the location of oil in the Montebello wreck, which sunk in 1941 at the depth of 274 m was determined using the *neutron backscatter system*. The results of the research were approved by FOSC (*Federal On-Scene Coordinators*) (NOOA, 2013).

There is a wide variety of vacuum pumps, from simple diaphragm pumps to high-volume vacuum rotary pumps. Very viscous, heavy oil or debris can block the suction pipe. In such case, viscosity reducing methods should be used to increase the pumping efficiency. The most common method consists of heating with heaters and pumping hot water or steam. Another method consists of mixing with light oil, eg. diesel. This method was used for the Erika tanker wreck. There is also a method, which consists of adding substances to increase the viscosity to such a level, that oil becomes like a semi-fluid rubber. This lowers the risk of spill (NOAA, 2013; Michel et al., 2005).

### Examples of use

The method of retrieving oil from a wreck with the use of ROV and a hot-tapping device was used several times on shipwrecks, for example the operations carried out by the Finnish company, Alfons Håkans in the Baltic Sea, on Park Victory and M/S Estonia, Brita Dan and Coolaroo wrecks (www.environment.fi). Below, operations on two wrecks, described by Alfons Håkans (*Estonia* and *Park Victory* cases info 2015-12-08 KR.pdf).

### The case of the Park Victory wreck

The oil removal operation from a 50-year old wreck was conducted for 6 years. The wreck was in poor condition and oils emissions had been detected during several summers. First, the coal, which had blocked access to the tanks had to be removed. A pump of the *air lift* type by Mammouth was operated by a ROV, assisted by divers. Then, 30 holes were made and a vacuum pump TAIFUN was connected. Due to low water temperature close to the bottom, the tanks were heated with hot steam, water and compressed air. In total, the operation took 5.000 hours for both ships, 1.200 hours for the divers underwater and 1.700 hours for the ROV inspections. 410 tonnes of heavy oil was removed. The total cost was 21.3 million FIM.

### The case of the M/S Estonia wreck

The operation of oil removal begun in 1996 and lasted until 2006. The ROLS system, together with oil removal system TAIFUN and a ROV. 4 drilling machines were used. Light oil, then heavy oil, located under a double bottom were pumped out. Mechanical separation of water in centrifugal separator was carried out.

#### Advantages of this method

The pumping method with the use of a ROV and a hot-tapping device permits to remove the oil from the wreck tanks more precisely than old generation pumping systems, among others, due to the improved visual access. The use of the ROV for pumping the oil enables faster oil pumping operations and at greater depths, without breaks needed for personnel rotation, as in the case of the pumps operated by divers. It also allows to conduct the operation in more unfavourable weather conditions. The method significantly reduces the risk of oil leakage and dispersion during pumping and allows the oil tanks to be completely emptied (Alcaro L. et al., 2007; Michel et al., 2005; NOAA, 2013).

#### Limitations

The method has limitations in terms of the amount of oil retrieved and the retrieval time. The retrieval process is slow. The method is very expensive and complicated in terms of the logistics. It requires experienced personnel and advanced electronic equipment, as well as a large platform to support the equipment. The extracted oil requires transport, must be disposed or recycled. Breaks due to the weather are inevitable (Alcaro L. et al., 2007; Michel et al., 2005; NOAA, 2013).

**This method can be considered useful for this project,** as a solution to solve the problem. It can be considered that it is a useful and environmentally friendly method for quick retrieval of oil from wrecks. Engagement of divers or use of the ROV to remove oil in this project may be necessary, in case of confirming the presence of oil in the tanks.  There are several issues, that need to be solved:

- the need to "dredge" (remove the sediment around the bottom part of the wreck) to get access to bottom tanks. This will generate enormous costs, due to the time-consuming nature of this process, as well as the complexity of the work carried out with specialised equipment and by divers,
- high costs of equipment used to clean the tanks,
- a large number of people and equipment from the highest price range (Table 4),
- the need to provide transportation and disposal of recovered oil,
- very low and reparable environmental damages (it is the least invasive method of removing oil from the wreck),
- low risk of secondary contamination of the sea bottom and water in the vicinity of the wreck during the operation.

#### Costs

The total costs of oil retrieval from the tanks depend on a number of factors, such as the quantity of oil, its viscosity, the number of tanks, the depth, water and weather conditions, the structure of the wreck, its state, and the cost of making access to the tanks. Logistic factors are also important, such as availability of supplies and equipment to carry out the operation, range of the stock, working time and breaks, costs of mobilisation and demobilisation, the costs of disposing the removed oil (Hassellöv, 2007, Alfons Håkans *Estonia* and *Park Victory* cases info 2015-12-08 KR.pdf)

Tables 4 and 5 present examples of operations carried out with hot-tapping assisted by divers and by a ROV, as well as the costs.

Table 4. **Hot-tapping operations, assisted by divers** (based on: NOAA, 2013; McGrath, 2011)

| Vessel | Retrieval year | Characteristics | Oil retrieved | Total cost | Unit cost |
|---|---|---|---|---|---|
| Princess Kathleen | 2010 | Heavy oil, hydrogen sulphide, depth 40 m. Poor state of the wreck (riveting) | 2 620 barrels | 14 million $ | 5 344 $/barrel (125 $/gallon) |
| USS Mississinewa | 2003 | Heavy oil, small depth Tanks easily accessible Low complexity of the operation | 42 000 barrels | 4.5 million $ | 107 $/barrel (2.55 $/gallon) |
| Jacob Luckenbach | 2002 | Heavy oil Depth 52 Very sensitive surroundings | 2 450 barrels | 20 million $ | 8 164 $/barrel (194 $/gallon) |
| Erika | 1999 | Heavy oil Wreck in two parts, at 100 and 130 m, located at a distance of 18 km | 11.200 tonnes | >200 million € | 18 857 €/tonne (448.9 €/gallon) |

Table 5. **Hot-tapping operations, assisted by a ROV** (based on: NOAA, 2013 oraz McGrath, 2011, Alfons Håkans Estonia and Park Victory cases info 2015-12-08 KR.pdf)

| Vessel | Retrieval year | Characteristics | Oil retrieved | Total cost | Unit cost |
|---|---|---|---|---|---|
| Prestige | 2004 | Heavy oil Depth 3650 m | 91 000 barrels | 132.6 million $ | 1 460 $/ barrel |
| Park Victory | 1994-2000 | Heavy oil Cold water Depth 20-40 m | 410 $m^3$ of heavy oil | 21.3 FIM (15.5 million PLN) | 9.14 €/litre 9140 €/$m^3$ |
| M/S Estonia | 1996-2006 | Heavy and light oil Depth 60-80 m | 418 $m^3$ (including 302 $m^3$ of different types of oil) | No data | No data |
| Osung No.3 And Yuil No.1 | 2001 | Heavy oil Depth 69 m Sensitive ecosystem | 4 600 barrel | 13 million $ | 2 826 $/barrel |

## 10.3 **Auxiliary supporting technologies for oil removal**

In addition to the above mentioned methods for removing oil from the sea bottom or from wrecks, auxiliary technologies aimed at stopping or removing the oil drifting in water column or at water surface are used. Below are those that can be applied in the case of the Franken wreck and can be used as protective measures for removing oil from the sea bottom, and reducing any leakage, in the case oil is released into the water during retrieval operations (IMO, 2005).

### 10.3.1 **Booms**

Booms are elastic barriers made of flotations, sub-surface skirt and ballast. They surround floating oil to prevent its spread over the water surface and divert its stream. They can be towed between two vessels in the open sea, located in front of the shore, to protect certain areas against pollution. There are different types of booms, differing in construction and use: flexible, pneumatic, absorbing (www.sebekfireman.host247.pl/straz/wiedza/n18.htm). Oil collected in the boom may be removed using *skimmers* or special vacuum pumps (IMO, 2005; ITOPF, 2014; Marine Pollution Clean-up Manual, 2013; Preston i in., 1997). An example of such technology is a turbidity curtain produced by ELASTEC (www.elastec.com/turbiditycurtains).

### 10.3.2 **Skimmers**

Skimmers are used to recover oil from water surface and separated it from water. This operation depends on the oil layer, viscosity and sea conditions. The oil is collected into the tank and then discharged to the collector with a hose. Skimmers are most effective when combined with booms. There are different types of skimmers: pump, desiccant, adhesive and screw-type (IMO, 2005; ITOPF, 2014; Marine Pollution Clean-up Manual, 2013; Preston et al., 1997).

### 10.3.3 **Other pumps**

**The EDDY** – dredging pump, used for oils high viscosity, specialised in extraction solids in suspension, sand and thicker sediments, treats high viscosity oil as solids (www. eddypump.com; IMO, 2011).

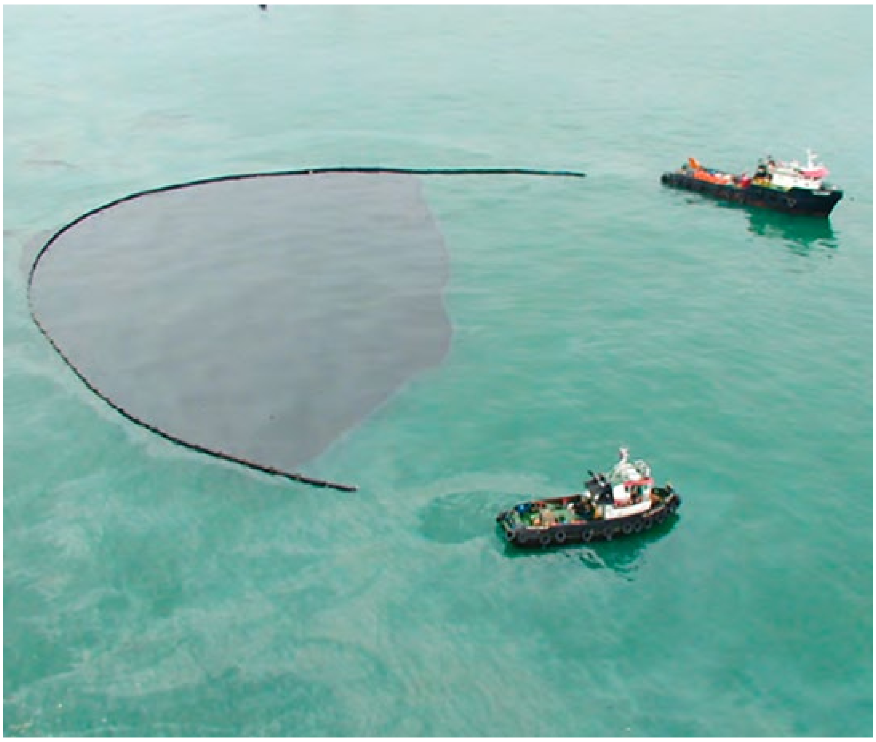


**Figure 33.** A boom in open waters (ITOPF, 2014)

**The OSBORS** (*Oil Stop Bottom Oil Recovery System*) produced by American Pollution Control Corporation (AMPOL) is a remote dredger designed to recover oil at the bottom, equipped with a centrifugal pump and suction hose (IMO, 2011; NOAA, 2013) (Figure 35).

**Manual pumps** – are operated by divers, permit to remove liquid oil from water surface or in water. The pump is equipped with a suction head and connected to a ship with long cable to transport the removed oil (Hansen, 2011; IMO, 2011).

## 10.3.4 Oil, water and sediment separators

Oil collected from water Surface may requires separation from the water. W tym celu przeprowadza się sorpcję oleju i wody oraz grawitacyjne oddzielenie osadu w specjalnym systemie dekantacji zainstalowanym na barce. Wodę odprowadza się z powrotem do morza, a oddzielony olej spalany jest na miejscu lub wywożony (Hansen, 2011; Fitzpatrick, M. et al., 2013).

## 10.3.5 Other technologies

In addition to the above mentioned technologies, depending on the measure used and on the conditions at sea and oil type, other technologies are used in oil spill responses:

- **Dispersants,** dispersing the oil spilled on water surface.
- **Sorbents**, oil-absorbing substances or materials, may be of organic (eg. peat) or inorganic origin (eg. Volcanic ash, clay).
- **Gelling agents** and other substances which change the physical state of the oil to facilitate its extraction.
- **Mobile and floating tanks**, towed tanks and tanks installed onboard a vessel or barge (allowing temporary storage of contaminants) (www.epa.gov; Marine Pollution Clean-up Manual, 2013; NOAA, 2013; Walker, 2003).

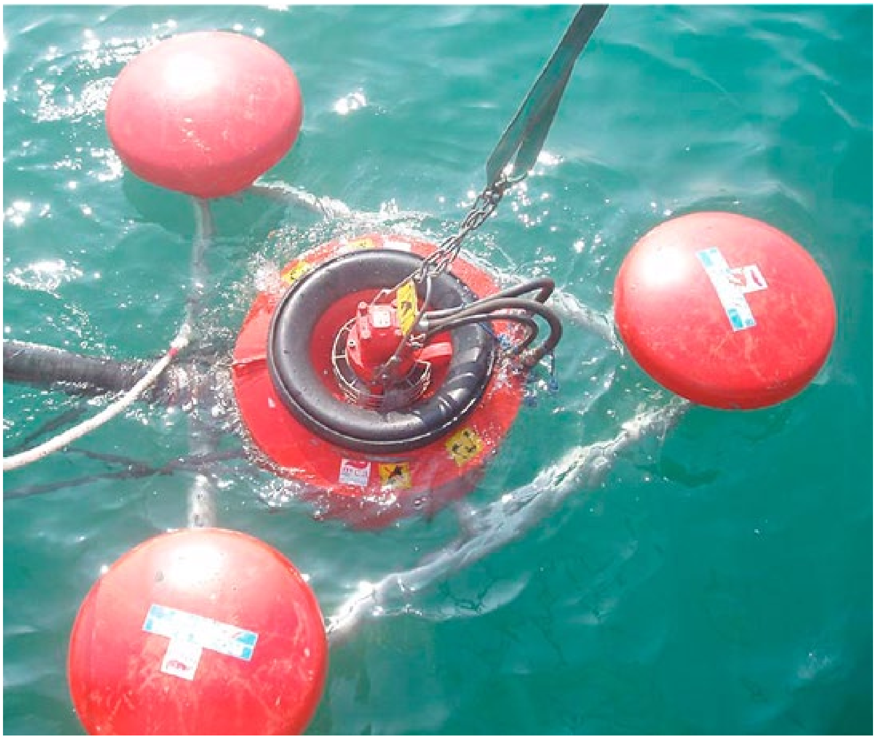


Figure 34. Overflow skimmer (Marine Pollution Clean-up Manual, 2013)

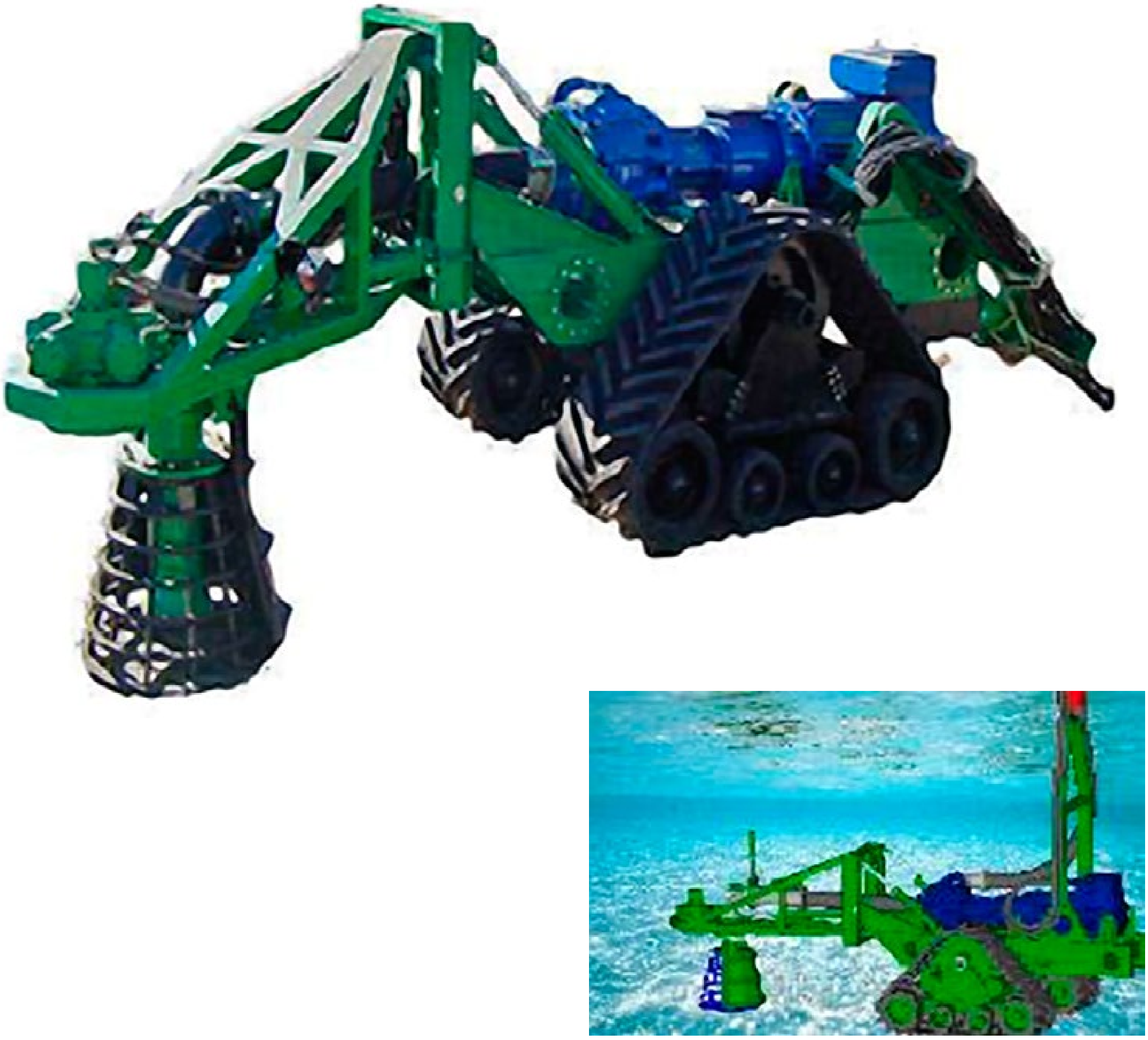


**Figure 35.** OSBORS unit to retrieve oil from the bottom (NOAA, 2013)

# 11 GENERAL COSTS

Each case of a maritime disaster described in the literature, as a result of which it was necessary to remove the residua toxic load or only oil from ship tanks is different. It is difficult to estimate the costs of removing the contamination before the operation. The implementation of the operation and its costs may differ from the planned ones, especially if oil is removed from an old wreck and there is no information, how much oil is in the tanks, how it is distributed and what is the access to the tanks. Other important factors of cost estimation are the depth of the wreck, the available technology and equipment, the distance from the wreck to the operation base, and even the time of the year, weather, water and air temperature. Therefore, cost estimation must take into account various cost elements, which we cannot influence. The guide of the American Agency EPA presents in detail all the cost elements, that need to be taken into account in estimating the planned remedial operation documented during a feasibility study (U.S. EPA, 2000). The main elements include mobilisation, demobilisation, monitoring including analyses and sampling, collecting and separating water, removing the contaminated sediment and its storage, capping, in situ operations, ex-situ operations, transport and storage of contaminated sediment and elements related to professional technical services, design, planning, management and inspections.

## 11.1 Factors affecting planning for oil assessment and removal operations from wrecks

The NOAA publication (2013) on risk assessment on potentially polluting wrecks presents the factors that affect the assessment and removal of the oil. These factors include:

- oil/oil type and properties (primarily viscosity)
- oil volume
- water depth
- bottom currents
- sea state (eg. protected waters, open sea)
- weather conditions
- resources at risk (sensitive habitats)
- distance from the shore, distance from mobilisation place, logistical support
- vessel configuration (eg. tank locations, ventilation and piping systems, location of tank baffles, general construction)
- vessel construction (eg. plate thickness, riveting, welding)
- vessel age (date of construction, modernisations, sinking)
- wreck condition (eg. broken sections, corrosion)
- wreck orientation (eg. upright, upside down)
- safety factors (eg. presence of munitions, hazardous materials, derelict fishing gear
- other cargo (may still block access to tanks and void space)
- historical/cultural concerns (historical significance, war grave).

The publication (2013)presents the costs of oil removal, estimated on the basis of past oil removal operations (as of 2012). The following factors were taken into account in cost estimation: water type, dept, oil viscosity, water temperature, wreck condition and vessel characteristics. Taking into account these factors, the Franken wreck can be allocated under "complex" or "highly complex" operations (cost range for these operations is estimated respectively at: 5-20 million $ and 20-100 million $).

Table 6. **Assessing factors influencing the costs of oil removal operations** (as of 2012)

| Complexity of operation | Waters | Depth metres/ feet | Oil viscosity | Water temperature | Wreck condition | Vessel factors | Distance from mobilisation point | Cost range |
|---|---|---|---|---|---|---|---|---|
| Simple | Protected | 20 / 65 | Low | High | Good | Not very old.<br>Optimal construction.<br>Not very damaged.<br>Thick plating.<br>Low location sensitivity. | Local | $ 1-5 M |
| Moderate | Problems with weather or sea condition | 20-50 / 65-164 | Medium | Moderate | Medium | Not very old.<br>Stable structure.<br>Not very damaged.<br>Thick plating of the hull.<br>Low location sensitivity. | Regional | $2 – 7 M |
| Complex | Open | 50-250 / 164-820 | High | Low | Weak | Old.<br>Multiple structure damage.<br>High location sensitivity<br>. | Distant | $ 5-20+ M |
| Highly complex | Open | ≥ 250 / ≥ 820 | High | Very low | Very weak | Very old.<br>Poor structure.<br>Severely damaged.<br>Covered with corroded plating.<br>Highest location sensitivity. | Distant | $ 20-100+ M |

↔ Interrelated factors

One of the highest costs that need to be taken into account are the staff and equipment costs, used during the cleaning operations.

In marine rescue, the staff, rescue equipment and service costs, including oil removal from wrecks are calculated according to the SCOPIC clause (Special Compensation P&I Clause) (www.lloyds.com). The costs of services and equipment are contained (as of 2014) in the tables (Table 7, Table 8).

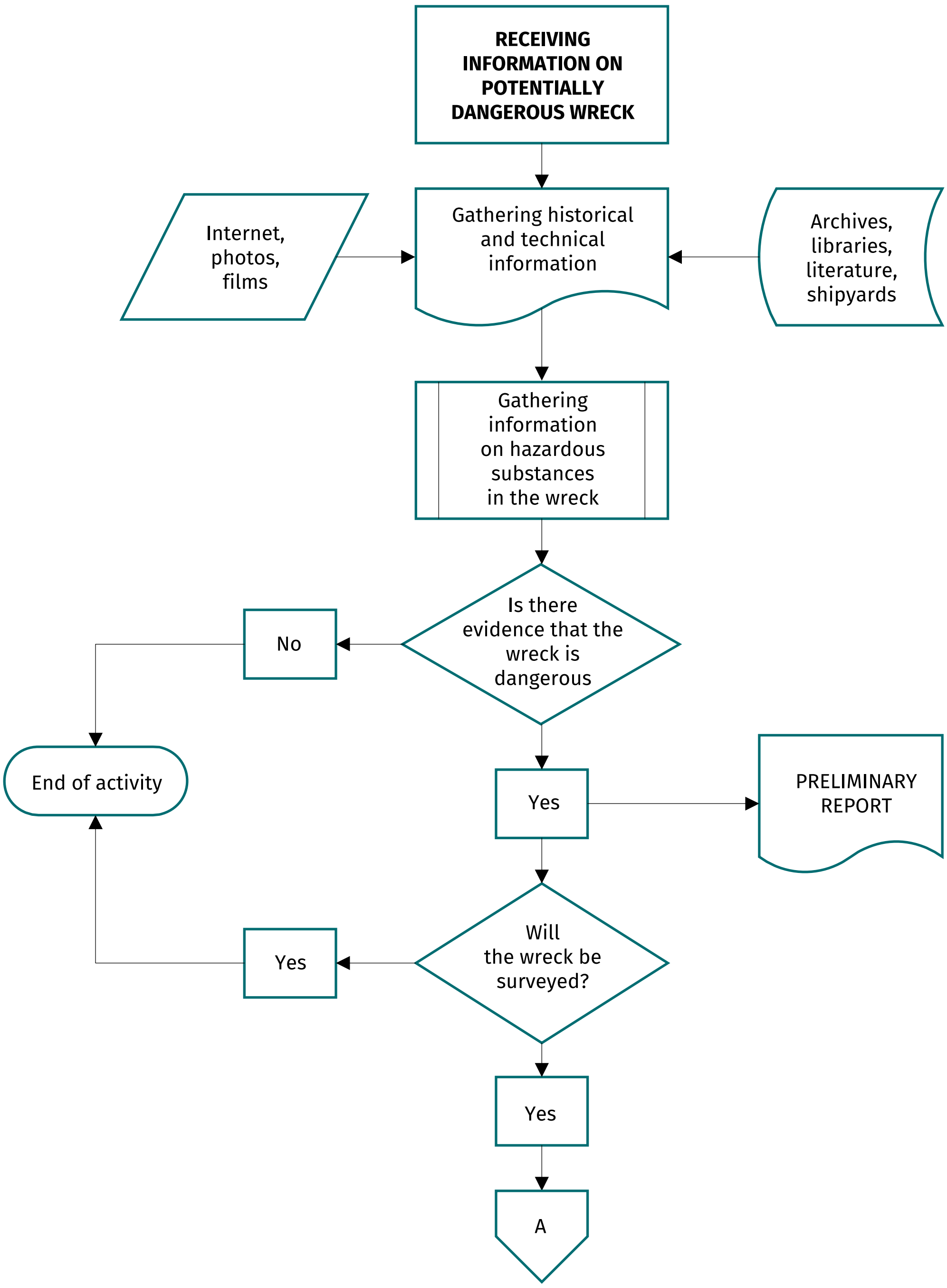
Table 7. **Daily Staff rates**

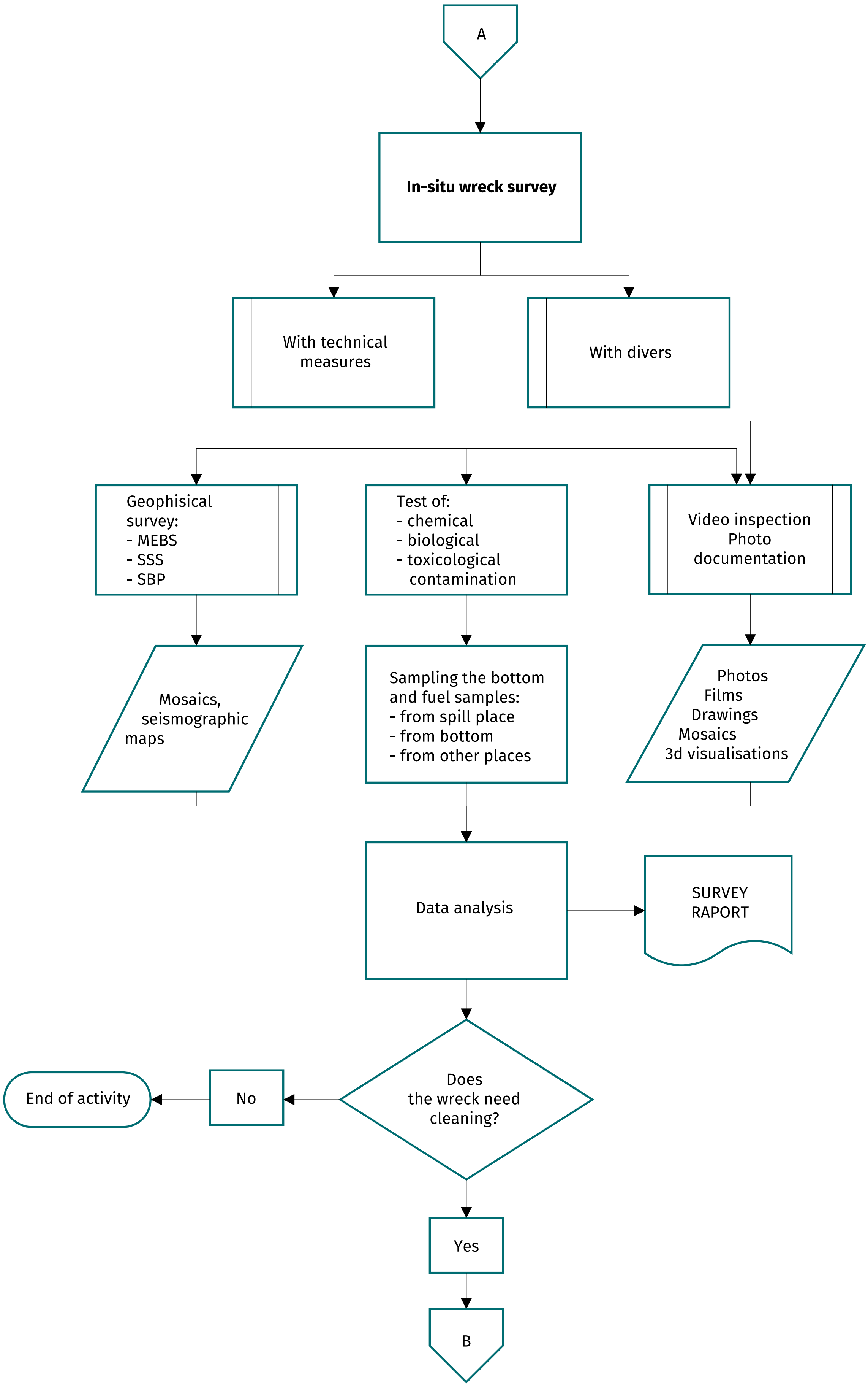
| Personnel | US $ |
|---|---|
| Office administration, including communications | 1,361 |
| Salvage Master | 2,029 |
| Naval Architect or Salvage Officer/Engineer | 1,692 |
| Assistant Salvage Officer/Engineer | 1,356 |
| Diving Supervisor | 1,356 |
| HSE qualified diver or his equivalent but excluding saturation or mixed gas drivers | 1,217 |
| Salvage Foreman | 1,014 |
| Riggers, Fitters, Equipment Operators | 812 |
| Specialist Advisors – Fire Fighters, Chemicals, Pollution Control | 1,361 |

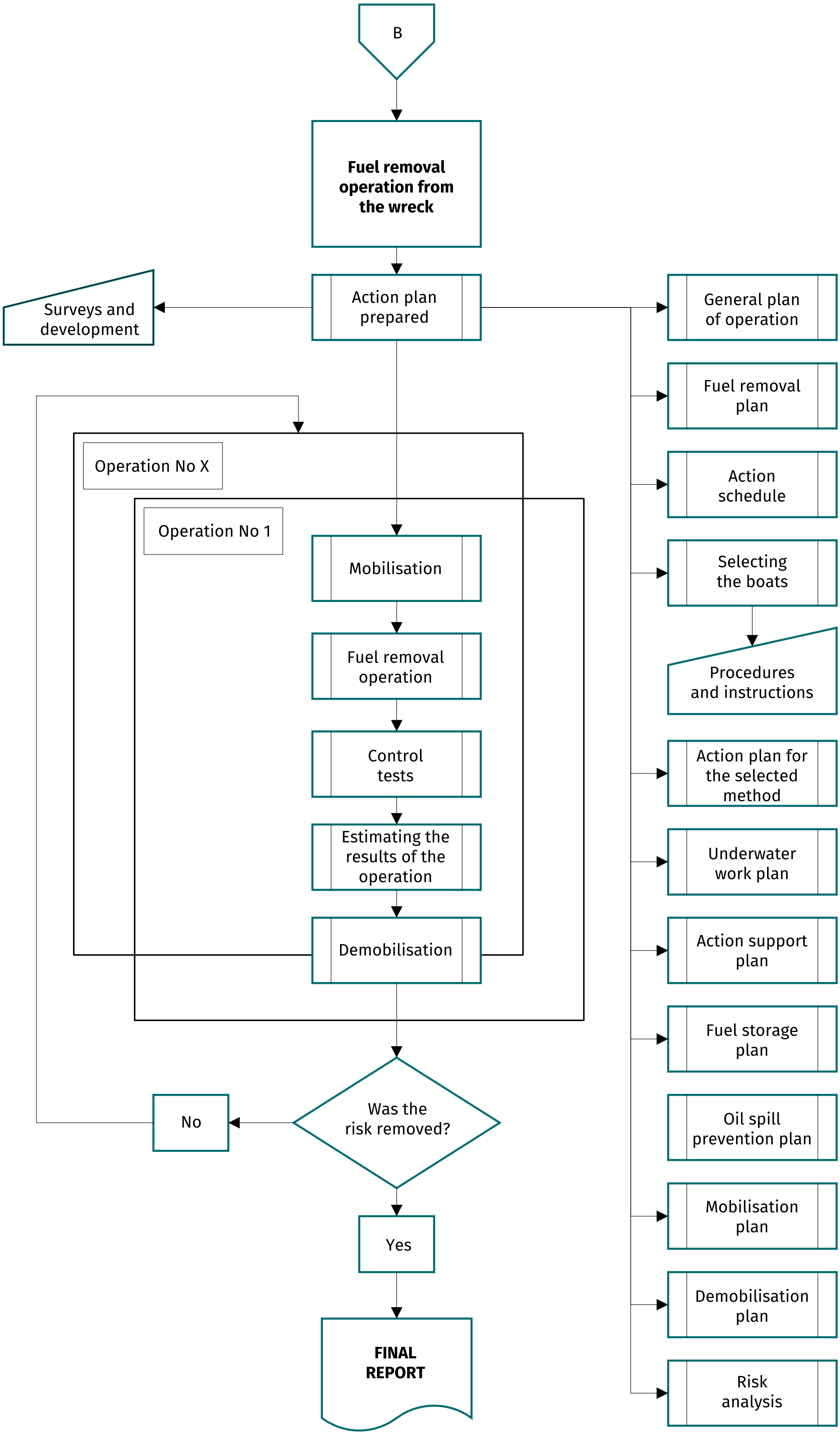
Table8. **Costs of equipment (cost of rental per day)**

| Portable salvage equipment | US$ |
|---|---|
| Hot Tap Machine, including support equipment | 1,351 |
| Air Lift 8” | 405 |
| Oil Boom, 48”, per 10 metres | 263 |
| Pumping Equipment Air 3 „Hydraulic 8” | 117<br>1,351 |
| Air Hose 2” | 11 |


## 11.2 General scheme of operating procedure on potentially hazardous wrecks




A
In-situ wreck survey
With technical measures
With divers
Geophisical survey:
- MEBS
- SSS
- SBP
Test of:
- chemical
- biological
- toxicological contamination
Video inspection
Photo documentation
Mosaics, seismographic maps
Sampling the bottom and fuel samples:
- from spill place
- from bottom
- from other places
Photos
Films
Drawings
Mosaics
3d visualisations
Data analysis
SURVEY RAPORT
Does the wreck need cleaning?
No
End of activity
Yes
B


B
Fuel removal operation from the wreck
Action plan prepared
Surveys and development
General plan of operation
Fuel removal plan
Action schedule
Selecting the boats
Procedures and instructions
Action plan for the selected method
Underwater work plan
Action support plan
Fuel storage plan
Oil spill prevention plan
Mobilisation plan
Demobilisation plan
Risk analysis
Operation No X
Operation No 1
Mobilisation
Fuel removal operation
Control tests
Estimating the results of the operation
Demobilisation
Was the risk removed?
No
Yes
FINAL REPORT

The presented scheme covers three main steps:

1. Receiving information on the existence of a dangerous wreck and deciding whether the wreck is really dangerous;
2. In-situ survey to determine the type and the scale of the risk;
3. Conducting the oil removal operation.

Each step is essential for assessment process of wreck condition and the state of the surroundings, for getting the information on the environmental status of the wreck location, undertaking risk mitigation measures as well as measures aimed improving the environmental status.

The sequence of the steps is not incidental, the final product of each step is the starting point for actions undertaken in the next step. Not every studied case will require further actions. In the absence of any evident risk, exit strategies were elaborated.

## 11.3 A preliminary cost estimate of the oil removal operation from the Franken wreck

It is extremely difficult to obtain the information on the cost of oil removal operation. All companies dealing with wreck cleaning make cost estimates for each project, depending on may factors (as mentioned in this report). Some use the SCOPIC (Special Compensation P&I Clause, others own price lists. None of the companies asked for cost estimate gave even an approximate price of such service.

**Approximate costs of some modules can be calculated on the basis of unofficially obtained information:**

Step I **Investigation and preliminary assessment of the volume of oil in the tanks**:

- Mobilisation/demobilisation of the equipment
- Conducting surveys
- Preparing the report

Step II **Cleaning operation**:

- Action plan
- Mobilisation/demobilisation of the equipment
- Cleaning operation
- Tank protection after oil removal
- Disposal of removed oil
- Report

Step III **Periodic controls of the environmental status**:

- Mobilisation/demobilisation
- Measurements
- Report

**Cost estimate of removal operation** depends on the selected technology:

- with divers
- with ROV

**Logistical support is important**, including:

- Distance from the ports:
  - Base
  - Loading
  - Unloading
  - Supply
  - Shelter
- Access to local resources, such as:
  - Tug vessels
  - Barges for transporting recovered oil
  - Transportation to/from the port (transfer of staff and materials)
  - Refineries and incineration plants

As a rule, oil removal works carried out with divers are much more expensive (the daily rate) than works operate by remote vehicles. The reason is the need to use larger, modern, dynamic positioning vessels, equipped with a huge number of safety systems for diving at high depths, especially when divers work under full saturation, such as a complex of decompression chambers, diving bells with underwater sections, advanced oxygen, water, energy supply systems, working chambers and diving bells, which must ensure an uninterrupted operation at 300%. The daily cost of hiring a large diving team, supervision, a large number of staff servicing the diving team, other supporting Staff constitutes one of the most costly elements of the final cost for each day of work (it could amount to 150 to 200 thousand (and more) Euro per day).

The operations conducted with the use of remote vehicles ROV are cheaper (the daily rate), because they do not require such big vessels and expensive staff (although the ROV operators are also very expensive) and such as large number of supporting staff.

However, the situation is not so clear and obvious. The options engaging divers last usually much shorter, because well trained and equipped divers work much faster and are more efficient, but their working time underwater is very limited. On the other hand, modern remote vehicles can work for 24 h/day (with operator shifts), and although they work slower, they do not have any working time limits, they do not get tired, do not become sick, and most importantly, they are not limited by water depth.

Considering that there are 5-6 tanks to be cleaned at the Franken wreck, and 3-4 to be checked (including the most difficult tanks to reach in the machinery room), the time necessary to complete the operation will amount to approx. 30 days for the diving team and 45 days for the ROV team. **There, it could be assumed that the cost estimate for this operation is in the range of 6-8 million Euro.**

**However, this cost estimate should be considered as optimistic. The real cost of this operation could reach 10-20 million Euro.**

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STOP THE OIL SPILLAGE

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