TECHNICAL REPORT

KYSTVERKET NORWEGIAN COASTAL ADMINISTRATION

SALVAGE OF U864 - SUPPLEMENTARY STUDIES - USE OF DIVERS

REPORT NO. 23916-12

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DET NORSKE VERITAS

TECHNICAL REPORT

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Summary:

The German submarine U-864 was torpedoed by the British submarine Venturer on February 9 1945 and sunk approximately two nautical miles west of the island Fedje in Hordaland. U-864 was carrying about 67 metric tonnes of metallic mercury that implies a threat to the marine environment.

In September 2007 The Norwegian Costal Administration commissioned Det Norske Veritas to further investigate different alternatives to salvage the wreck and remove the mercury from the seabed.

This report is *Study No. 12: Use of divers*, one of twelve supplementary studies supporting the overall report regarding U-864 (Det Norske Veritas Report No. 23916) prepared by Det Norske Veritas (DNV).

This supplementary study has assessed the opportunities for and the risk by using divers to salvage mercury canisters and debris from seabed, and assistance during salvage of U-864. Special attention is on safety, health and environmental issues regarding use of divers compared to use of remotely operated vehicles (ROVs).

DNV's main conclusion is that diving to the depth of U-864 (150 m) is done routinely and no special attention must be given to compression and decompression procedures for the divers according to NORSOK U-100. The risks related to diving can not be assessed before the salvage method is chosen.

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TECHNICAL REPORT

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1 SUMMARY

This report is *Study No. 12: Use of divers*, one of twelve supplementary studies supporting the overall report regarding U-864 (Det Norske Veritas Report No. 23916) prepared by Det Norske Veritas (DNV).

This supplementary study has assessed the opportunities for and the risk by using divers to salvage mercury canisters and debris from seabed, and assistance during salvage of U-864. Special attention is on safety, health and environmental issues regarding use of divers compared to use of remotely operated vehicles (ROVs).

DNV's overall conclusion is:

Diving to the depth of U-864 (150 m) is done routinely and no special attention must be given to compression and decompression procedures for the divers according to NORSOK U-100. The risks related to diving can not be assessed before the salvage method is chosen.

DNV's supporting conclusions are:

C1. Diving to 150 meters, which is the depth of the U-864, is within normal diving depths on the Norwegian shelf. No special attention must be given to compression and decompression procedures for the divers according to NORSOK U-100.

C2. At the depth of U-864 using divers can be considered as a complementary intervention method to ROV-operations.

C3. Compared to ROVs, the use of divers during the salvage process' phases Preliminary Study, Elevation and Pollution abatement on seabed is expected to be beneficial as divers can get better access to the wreck, obtain more information about the situation and stir up less polluted sediments than an ROV.

C4: The criticality (probability and consequence) for each risk related to using divers during salvage of U-864 can not be assessed before the salvage methodology is chosen.

The rest of *Supplementary Study No. 12: Use of divers* details the arguments behind the conclusions.

Den tyske ubåten U-864 ble torpedert av den britiske ubåten Venturer den 9. februar 1945 og sank omtrent to nautiske mil vest for øya Fedje i Hordaland. U-864 var lastet med omtrent 67 tonn med metallisk kvikksølv som utgjør en fare for det marine miljøet.

I September 2007 tildelte Kystverket Det Norske Veritas oppdraget med å nærmere utrede ulike alternativer for heving av vrak og fjerning av kvikksølv fra havbunnen.

2 SAMMENDRAG

Denne rapporten er *Tilleggsutredning nr. 12: Bruk av dykkere*, en av tolv tilleggsutredninger som understøtter hovedrapporten vedrørende U-864 (Det Norske Veritas Report No. 23916) utarbeidet av Det Norske Veritas (DNV).

Denne tilleggsutredningen har vurdert muligheter for og risikoen ved bruk av dykkere til å heve kvikksølvbeholdere og vrakdeler fra havbunnen, og assistanse under en hevingen av U-864. Aspekter tilknyttet helse, miljø og sikkerhet er vurdert spesielt ved når bruk av dykkere er sammenlignet med bruk av fjernstyrt undervannsfartøy (ROV).

DNV sin overordnede konklusjon er:

Dykking ned til U-864 sin dybde (150) gjøres rutinemessig og det kreves ikke særskilte tiltak i forbindelse med kompresjons- og dekompresjonsprosedyrer for dykkerne iht NORSKO U-100. Dykkerrelaterte risikoer kan ikke vurderes før metode for heving er valgt.

DNV underbygger denne konklusjonen med:

C1: **Dykking til 150 meter, som er dybden til U-864, er innenfor normale dykkedybder på norsk sokkel. Det kreves ikke særskilte tiltak i forbindelse med kompresjons- og dekompresjonsprosedyrer for dykkerne iht NORSKO U-100**

C2: **På dybden til U-864 regnes bruk av dykkere som komplementær intervensjonsmetode til bruk av ROV**

C3: **Sammenlignet med ROV, er det forventet at bruk av dykkere under hevingsprosessene Forberedelser, Heving og Fjerning av forurensning fra sjøbunn være fordelaktig fordi de lettere får tilgang til vraket, kan innhente mer informasjon om situasjonen og de virvler opp mindre forurensede sedimenter enn en ROV.**

C4: **Kritikaliteten (sannsynlighet og konsekvens) for dykkerrelaterte risikoer under heving av U-864 kan ikke vurderes før metode for heving er valgt.**

Resten av *Studie nr. 12: Bruk av dykkere* utdyper argumentene bak konklusjonene.

3 INTRODUCTION

3.1 Background

The German submarine U-864 was sunk by the British submarine Venturer on 9 February 1945, approximately 2 nautical miles west of the island Fedje in Hordaland (Figure 2-1). The submarine was on its way from Germany via Norway to Japan with war material and according to historical documents; U-864 was carrying about 67 metric ton of metallic (liquid) mercury, stored in steel canisters in the keel. The U-864, which was broken into two main parts as a result of the torpedo hit, was found at 150-175 m depth by the Royal Norwegian Navy in March 2003. The Norwegian Costal Administration (NCA) has, on behalf of the Ministry of Fisheries and Coastal Affairs, been performing several studies on how the risk that the mercury load constitutes to the environment can be handled. In December 2006 NCA delivered a report to the Ministry where they recommended that the wreck of the submarine should be encapsulated and that the surrounding mercury-contaminated sediments should be capped. In April 2007 the Ministry of Fisheries and Coastal Affairs decided to further investigate the salvaging alternative before a final decision is taken about the mercury load.

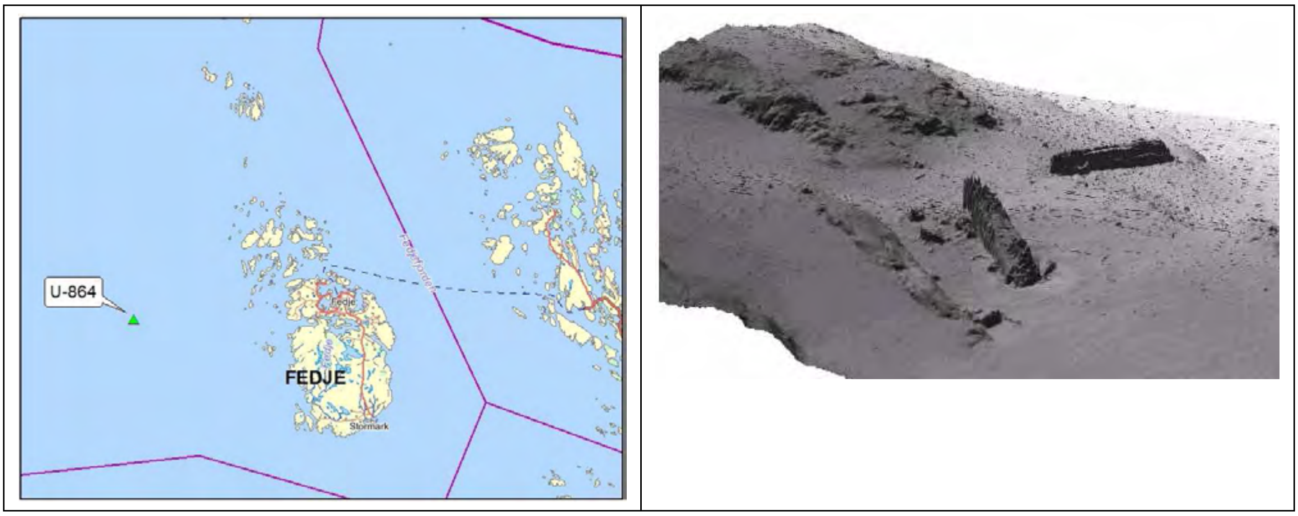


Figure 2-1 Location (left) and a sonar picture of the wreck of U-864 on seabed (right) (from Geoconsult).

3.2 DNV's task

In September 2007 NCA commissioned Det Norske Veritas (DNV) the contract to further investigate the salvaging alternative. The contract includes:

- DNV shall support NCA in announcing a tender competition for innovators which have suggestions for an environmentally safe/acceptable salvage concept or technology. Selected innovators will receive a remuneration to improve and specify their salvage concept or technology.

- DNV shall support NCA in announcing a tender competition for salvage contractors to perform an environmentally justifiable salvage of U-864.
- DNV shall evaluate the suggested salvage methods and identify the preferred salvage method.
- The preferred salvage method shall be compared with the suggested encapsulation/capping method from 2006. (DNV shall give a recommendation of which measure that should be taken and state the reason for this recommendation.)
- DNV shall perform twelve supplementary studies which will serve as a support when the decision is taken about which measure that should be chosen for removing the environmental threat related to U-864. The twelve studies are:

1. *Corrosion*. Probability and scenarios for corrosion on steel canisters and the hull of the submarine.
2. *Explosives*. Probability and consequences of an explosion during salvaging from explosives or compressed air tanks.
3. *Metal detector*. The possibilities and limitations of using metal detectors for finding mercury canisters.
4. *The mid ship section*. Study the possibility that the mid section has drifted away.
5. *Dredging*. Study how the mercury-contaminated seabed can be removed around the wreck with a minimum of spreading and turbidity.
6. *Disposal*. Consequences for the environment and the health and safety of personnel if mercury and mercury-contaminated sediments are taken up and disposed of.
7. *Cargo*. Gather the historical information about the cargo in U-864. Assess the location and content of the cargo.
8. *Relocation and safeguarding*. Analyse which routes that can be used when mercury canisters are relocated to a sheltered location.
9. *Monitoring*. The effects of the measures that are taken have to be documented over time. An initial programme shall be prepared for monitoring the contamination before, during and after salvaging.
10. *Risk related to leakage*. Study the consequences if mercury is unintentionally leaked and spreading during a salvage or relocation of U-864.
11. *Assessment of future spreading of mercury for the capping alternative*. The consequences of spreading of mercury if the area is capped in an eternal perspective.
12. *Use of divers*. Study the risks related to use of divers during the salvage operation in a safety, health and environmental aspect and compare with use of ROV.

3.3 Scope of this report

This report is *Supplementary Study No. 12: "Use of divers"*. The main objectives for this study are to:

- decide whether diving to the depth of U-864 is within the relevant regulations or not
- assess which salvage phases use of divers might be relevant and the related risks

Use of divers will be evaluated in relation to use of remotely operated vehicles (ROV), with a special attention on safety, health and environmental issues.

Norwegian Underwater Intervention AS (NUI) has been involved with this supplementary study, as they possess valuable competence on the topic, and has been the primary source for information when discussing diving history and regulations.

- Chapter 4 discusses the possibility of diving to the depth of u-864
- Chapter 5 assesses benefits and risks by using divers in salvaging u-864

4 DIVING TO THE DEPTH OF U-864

DNV's conclusion is:

C1: Diving to 150 meters, which is the depth of the U-864, is within normal diving depths on the Norwegian shelf. No special attention must be given to compression and decompression procedures according to NORSOK U-100.

Diving operations similar to those suggested in chapter 5.2 is normally referred to as *Manned Underwater Intervention*, and is considered an alternative method to other intervention methods, like the use of ROV.

In 1991 the Norwegian authorities introduced a distinction between *normal diving* and *deep water diving* operations. The term deep water diving is used in relation to diving operations to depths below 180 meters. The wreck of U-864 is situated on a depth of 150 meters and is therefore considered well within the zone of normal diving operations. This report focuses on normal diving operations to depths less than 180 meters.

Saturation diving is the relevant method for diving operations when diving to the depths of the U-864 wreck (150 metres). Appendix A briefly describes a generic saturation diving operation and some relevant studies on the risks related to saturation diving are presented.

4.1 Regulations

Petroleum related diving on the Norwegian shelf is strictly regulated under the provisions of i.a. the Petroleum act. For detailed provisions, it is mostly referred to the NORSOK-standard U-100 "Manned Underwater operations". The supervisory body is the Petroleum Authority, which does not directly control the diving companies, but has contact with each operator (oil company).

Inshore diving in Norway is given in "the Diving regulations" stipulated by the Working Environment Act. It has very limited references to saturation and bell diving.

Since diving at Fedje will for most practical issues be more similar to offshore than inshore diving, DNV and NUI finds it most sensible to base the requirement on offshore practise. All relevant requirements of NORSOK U-100 should be applied. The formal version of this standard is from 1999, but it has lately been through a revision (2nd edition) which was on public enquiry in 2007. The edition is expected to be public early in 2008. NORSOK U-100 states that only diving to depth deeper than 180 m needs special attention to compression and decompression procedures. As U-864 is situated on a depth of 150 meters, no such special considerations are needed.

5 BENEFITS AND RISKS BY USING DIVERS IN SALVAGING U-864

DNV's conclusion is:

C2. At the depth of U-864 using divers can be considered as a complementary intervention method to ROV-operations.

C3. Use of divers during the salvage process' phases Preliminary Study, Elevation and Pollution abatement on seabed is expected to be beneficial as they can get better access to the wreck, obtain more information about the situation and stir up less polluted sediments than an ROV.

C4: The criticality (probability and consequence) for risks related to using divers during salvage of U-864 can not be assessed before the salvage methodology is chosen.

Chapter 5.1 presents some general information about the present practice related to saturation diving, and advantages and disadvantages by using saturation divers in general. Chapter 5.2 assesses when saturation divers could be useful during a salvage of U-864, and chapter 5.3 assesses the associated risks.

5.1 The present best practice related to intervention

C2. At the depth of U-864 using divers can be considered as a complementary intervention method to ROV-operations.

Apart from the possible mercury contamination, explosives and pressurised gas cylinders (localisation, contact with, inspection, handling etc), the challenges should be similar to what experienced offshore dive teams are used to handle.

Remote intervention has been the dominant underwater (UW) intervention method used by the oil companies operating in Norwegian sector during the period starting in the 1990's and a few years into 2000. During the last two to three years this has changed towards considering diving- and remote-intervention as complementary UW intervention methods, for depth less than 180 meters. Before deciding which method to use, the following factors must be considered:

- Need for flexibility
- Available time and vessel
- Total operational costs
- Safety, health and environmental issues (SHE)

Often a combined solution is chosen because both methods have their strong sides.

The main advantages related to the use of saturation divers are the great flexibility of the diver with his manual dexterity directly integrated with vision and sensitivity. In a possible salvage operation of U-864, the divers' ability to work carefully to avoid further breakage to already weakened mercury cylinders is thought to be of great benefit compared to use of ROV. Also operating close to bottom where sediments are contaminated by mercury, divers are expected to have a better ability to minimise stir up and spreading of contaminants than an ROV. In general any necessary task where fine tactility and visual control is needed, the diver will be of great value. In addition to situations where vision is limited.

The main disadvantages of using divers in the salvage of U-864 are the inherent risks related to putting humans under water and subjecting them to high pressure. A result of the high pressure is the disadvantage of long decompression times required. Divers may need about one week decompression time after being subjected to the pressure of 150 meters water depth.

Appendix B presents previous experiences where divers have been used during salvage operations.

5.2 Use of divers during salvage of U-864

DNV's conclusion is:

C3. Compared to ROVs, the use of divers during the salvage process' phases Preliminary Study, Elevation and Pollution abatement on seabed is expected to be beneficial as divers can get better access to the wreck, obtain more information about the situation and stir up less polluted sediments than an ROV.

This chapter gives a description of how divers can be utilized to support the process when salvaging U-864. As a basis for discussion, DNV has used the high-level generic salvage process description illustrated in Figure 5-1.

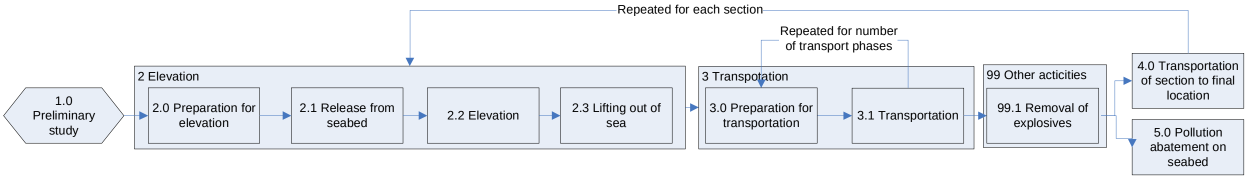


Figure 5-1 General description of a salvage process

Given the operation procedures and regulations related to diving, DNV has identified the following general salvage phases as the most relevant phases for using divers:

Phase 1.0 Preliminary study

DNV and NUI expect that the use of divers during a Preliminary study phase can be beneficial.

Relevant tasks are:

- Get an overview and assess the situation on the seabed.
- Evaluate where and how to position lifting equipment.

- Evaluate what kind of equipment should be used during the salvage.
- Locate and remove mercury canisters on the surface of the seabed.
- Assist in the identification of obstacles that may influence the salvage.

In all operations minimal disturbance of the polluted sediments on the seabed is crucial. Utilizing the divers' flexibility and ability to effectively monitor the operations can be very valuable in this respect.

Divers are suited to effectively get an overview and assess the situation on the seabed. This may prove valuable when planning the salvage operation in detail.

It is crucial that lifting equipment is properly designed and take into account the state of the wreck and how it is positioned on seabed. Divers may be used to verify that the suggested equipment is well suited, and may suggest alterations where necessary.

During the surveys that have been performed, two mercury canisters have been brought to the surface. Both canisters were located in proximity of the wreck. Unidentified mercury canisters on or near the surface of the seabed can be damaged during a salvage operation. A detailed scan of the seabed in the area around the wreck may identify other mercury canisters and reduce the risk of further mercury pollution. Divers are suited to effectively remove this kind of debris.

As a result of the torpedo hit, the mid section of the submarine is destroyed and a large amount of debris is spread out on the seabed around the wreck. Some of this debris may obstruct the positioning of lifting equipment or influence other parts of the salvage process. Divers can assess what debris needs to be removed and the equipment needed for removal.

Phase 2 Elevation

As illustrated in the process description in Figure 5-1, the elevation phase comprises several sub processes. DNV and NUI assess that divers would be most useful in the initial stages of the elevation phase; Preparation for elevation (2.0) and Release from seabed (2.1)

Relevant tasks are:

- Clearing the way for lifting equipment, assist in the removal of debris.
- Checking the positioning of lifting equipment.
- Monitoring of release from seabed.

Divers can be very useful in the removal of debris in order to clear the area around the wreck, e.g. for positioning of lifting equipment. This can be manually moving the small objects to a lifting cradle or assisting positioning of lifting equipment on heavier items.

Once the area around the wreck is sufficiently cleaned of obstructing objects, the divers can assist in the positioning of the lifting equipment to the hull of U-864. The divers can also assist in controlling that the lifting equipment is properly secured and are in the intended position. The assistance needed will vary depending on the chosen salvage method.

For safety reasons the divers should leave the area before the elevation commences. The salvor could consider having divers remaining in the diving bell at a safe distance during the release from seabed phase to assist if the wreck needs to be replaced on the seabed for adjustments before being elevated to the surface, e.g. if the positioning of the lifting equipment is not optimal or the hull shifts position.

When the wreck is ready for elevation to the surface, divers can return to pressure chamber on the diving vessel. Based on the process described above DNV does not consider the use of divers to be relevant in other parts of the elevation phase. This may change depending on the method proposed by the salvors.

Phase 5.0 Pollution abatement on seabed

The salvage operation includes pollution abatement on the seabed. The salvors may use several methods in order to remove the environmental risk related to the polluted seabed. Depending on the chosen method, divers may assist in this operation.

Relevant tasks are:

- Locate mercury canisters within the target area.
- Collect debris and mercury canisters.
- Prepare and attach lifting equipment on debris when clearing seabed (preparation for search with metal detector).
- Assist in removal of polluted sediments in hot spot areas.

The polluted target area on the seabed is approximately 30 000 square meters. In order to minimize the risk of future spreading of mercury it may be relevant to search the target area especially for locating mercury canisters. Several methods for scanning the seabed have been proposed e.g. using metal detector (see *Supplementary Study No. 3:Metal detector* for more information).

As noted above, divers can be an effective tool for both location and removal of objects on the seabed, either separately, or in combination with other methods.

As stated above, divers are particularly effective if used in the removal of smaller objects on the seabed, and may be valuable in preparing and attaching lifting equipment to larger debris for elevation to the surface.

Divers may also assist in the removal of polluted sediments, e.g. increased precision when dredging in areas with particularly high sediment concentration of mercury.

Other activities where use of divers may be relevant

The NCA has previously attempted to gain access to the keel in order to determine the location of mercury canisters. Removing the entire mercury cargo without salvaging the wreck has been suggested.

The attempt to reach the keel by ROV in 2005 was abandoned. Geoconsult reported that the aft section of the submarine shifted position as a result of dredging around the keel in order to gain access to the storage rooms where mercury is expected to be stored. Later survey revealed a gap that had appeared between the hull and the surrounding sediments as a result of the hull shifting position. This indicates the instability of the wreck in its current position.

Given proper safety precautions, it is assumed that divers could gain access to the keel without removing as much sediments as an ROV needs when performing a similar operation. Divers can assist in obtaining information about the status of the mercury cargo. Either prior to lifting the wreck from the seabed, or to assess the tools needed to remove the mercury without salvaging the wreck. This way divers can contribute to reducing the risk of mercury spreading when lifting the wreck from seabed, or when maneuvering in order to gain access to the keel.

The use of divers in relation to the removal of explosives is considered in *Supplementary Study No. 2: Explosives*, and is therefore not considered in detail here. If explosives or ordnance is located, the location should be marked without affecting the object, and further investigated and evaluated by the Norwegian Defense before action is being taken. Moving of explosives should only be done by using ROV under supervision of experts from the Norwegian Defense.

5.3 Risks related to use of divers when salvaging u-864

DNV's conclusion is:

C4: The criticality (probability and consequence) for risks related to using divers during salvage of U-864 can not be assessed before the salvage methodology is chosen.

5.3.1 Top risks related to relevant process steps

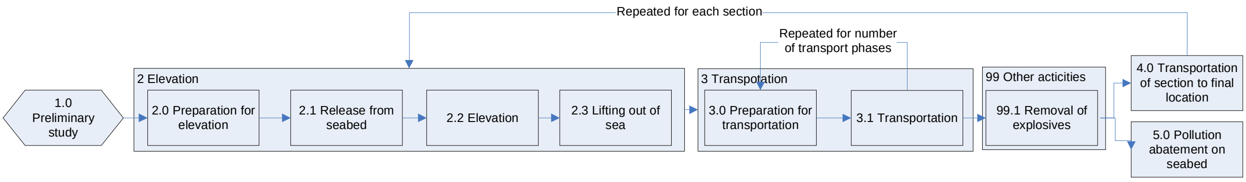


Figure 5-2 General description of a salvage process (same as Figure 5-1)

DNV has assessed the most relevant risks present related to use of divers when salvaging U-864, using a general description of a salvage process (Figure 5-2). General divers' risks related to diving are not considered, for this DNV refers to studies described in Appendix A. The risks are presented in Table 5-1 on page 12.

Table 5-1 Most relevant risks related to use of divers when salvaging U-864

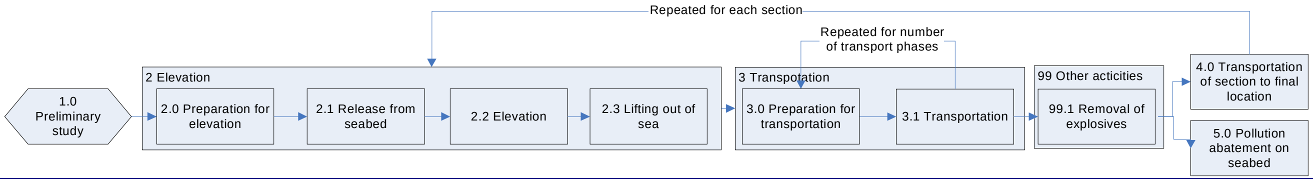
Risk	Name	Description
Phase 1.0 Preliminary study (general risks)		
R1	The wreck slide or shifts position as a result of influence from divers or equipment	**Front section:** • The front section is positioned in a slope of up to 15 degree angle. • There is uncertainty about the stability of the front section of the submarine. • Based on their evaluation of the sediments, Norwegian Geotechnical Institute (NGI) does not expect the structure of the top sediments to affect the stability of the submarine. **Aft section:** During the 2006 survey of U-864, Geoconsult attempted to gain access to the keel by dredging around the aft section of the wreck. This resulted in a significant shift in the position of the wreck and gives an indication of the instability of the aft section.
R2	Sediment slide caused by imposed pressure from divers or equipment	Calculations show a vulnerability to slope failure around the front section of the submarine if it is exposed to pressure e.g. from objects placed on the seabed. Geotechnical calculations shows that the weight of a diver alone is not expected to be large enough to set off a sediment slide. Placement of heavier objects on the seabed however may set off a sediment slide if placed in the wrong area. The nature of a slope failure is uncertain. A slug failure is expected to have limited effect, but if there is a canyon effect, the effect is larger and the risk of spreading contaminated masses to new areas is large. It may also cause shifting of the front section and, in worst case, significant movement.
R3	Ordnance are set off as a result of impact from divers or their equipment	Ordnance (ammunition, grenades) may be spread in the area around the submarine. There is a theoretical possibility that these can be set of as a result of change in ambient conditions (pressure/weight). This may be caused either by the divers themselves or by the placement of objects on the seabed where the ordnance is located. Experience from the salvage of U-534, another World War Two (WWII) German submarine, indicates that the ordnance are relatively stable when handled appropriately. Caution must be taken and ordnance should be clearly marked when located. For more information about ordnance, see *Supplementary Study No. 2: Explosives.*
R4	Mercury contamination of divers due to exposure to contaminated water and sediments cause negative health effects	During the operations on the seabed around the U-864, the divers will be exposed to hazardous contaminants. Specialized personnel protective equipment (PPE) is necessary. Mercury is highly toxic. Divers bringing mercury or mercury contaminated sediments into the diving bell may result in negative health effects.

Phase 2.0 Preparation for elevation		
R5	Injury due to malfunction or wrong handling of lifting equipment for the wreck	Heavy equipment is needed to lift the submarine hull from the seabed and elevate it to the surface. If divers are to assist in the placement of this lifting equipment, they will be exposed to risk related to malfunctions or wrong handling of this equipment. Mistakes may be fatal for the divers.
R6	Hull collapse while divers are in proximity of the wreck causing injury of fatality	The condition of the wreck is unknown. A hull collapse may occur when heavy equipment is mounted in order to lift the wreck. If divers are in the proximity of the wreck when heavy equipment is placed on the wreck they may be caught and squeezed under parts of the wreck if it collapses.
Phase 2.1 Release from seabed		
	N/A	DNV expects that regulations for diving operations will require that the diving vessel is relocated away from the area during lifting.
Phase 2.2 – 4.0		
	N/A	DNV evaluates that using divers in these phases is not feasible due to operational risks (phase 2.2 and 2.3) or not relevant (phase 3.0, 99 and 4.0).
Phase 5.0 Pollution abatement on seabed		
R7	Injury due to malfunction or wrong handling of lifting equipment for debris	Divers may assist if parts of the seabed need to be cleaned of debris. Movement of large debris during handling constitutes a risk for the divers if they are closely involved in the operation. If divers are in the proximity of the moving large debris, either assisting the movement, or as a result of wrong handling of the lifting equipment, they may sustain injuries e.g. get caught under debris or between the debris and outcrops of bedrock.

5.3.2 Risk analysis of the salvage phases

A salvage method has not yet been chosen and risks associated with diving depend on the nature of the chosen method. The identified risks presented in Table 5-2 are therefore not assessed.

Table 5-2 Risk related to saturation diving (including Figure 5-1)



Risk	Name	Relevance								
R1	The wreck slide out or shifts position as a result of influence from divers or their equipment	Relevant	Relevant	Relevant						
R2	Sediment slide caused by imposed pressure from divers or their equipment	Relevant	Relevant	Relevant						Relevant
R3	Ordnance are set off as a result of impact from divers or their equipment	Relevant	Relevant	Relevant						Relevant
R4	Mercury contamination of divers due to exposure to contaminated water and sediments cause health effects	Relevant	Relevant	Relevant						Relevant
R5	Injury due to malfunction or wrong handling of lifting equipment for the wreck		Relevant	Relevant						
R6	Hull collapse while divers are in proximity of the wreck causing injury of fatality	Relevant	Relevant	Relevant						
R7	Injury due to malfunction or wrong handling of lifting equipment for debris									Relevant

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APPENDIX

A

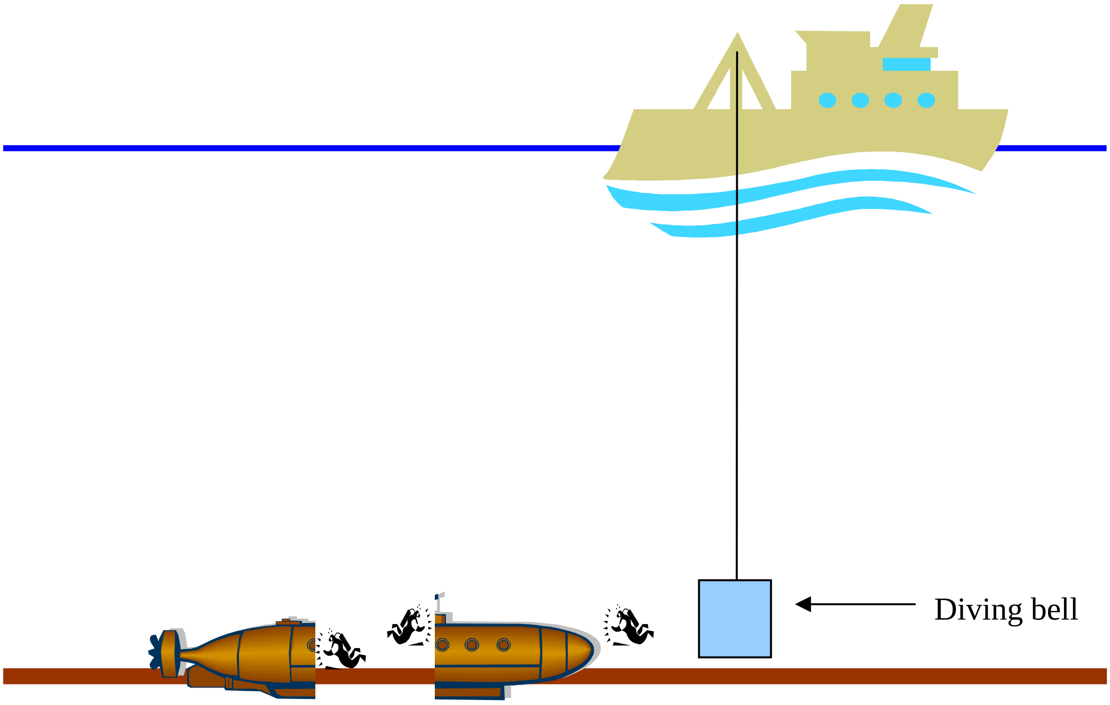
GENERAL DESCRIPTION OF DIVING OPERATIONS

A1. Normal diving operations - Diving between 50-180 m

Professional diving to more than 50 m performed with a diving bell is called *saturation diving*. In these operations helium-oxygen mixes (heliox) are used as breathing gas. The divers stay at a constant pressure corresponding to the relevant working depth all the time. Sleep and rest is done in pressure chambers on a surface vessel. A diving bell is used to move to and from the depth where the operations are performed.

A typical operation can be as follows:

- The divers enter the diving bell directly while it is connected to the diving complex on the surface vessel.
- The bell is then disconnected from the chambers and is lowered to the bottom or working depth.
- On the work depth, the door can be opened since the pressure inside the bell is kept at the corresponding pressure with the outside.
- One or two divers enter the water while at least one stays in the bell as a standby diver.
- While they are working in the water they are connected to the bell and further to the surface through umbilicals. The operations are monitored by people on surface using ROV.
- When the work or lockout period is through, the divers re-enters the diving bell and the bell is then hoisted back to the vessel and connected to the chamber system.
- The dive team who have finished their shift will then return to their living chamber. Usually another fresh team will be ready to enter the bell and go down to continue the work while the first team will be resting.



A2. Evolvement of saturation diving as a work method

Diving bells with open bottom (resembling a church bell) have been used for practical diving for several hundred years. But a bell that can be closed for so called ”Transfer Under Pressure” (TUP) was not made before after World War I. It was also done some scattered trials with saturation diving, but there was no significant evolvement of this diving method until after 1960. US Navy has been leading in the following development, with contributions from France and UK. The evolvement of diving operations has mainly been motivated by the need for assisting submarines in emergency situations.

The first commercial saturation system was made and used for dam construction work in USA in 1965. This system was used in petroleum related work in Gulf of Mexico in 1966. After this, there came a substantial growth in saturation diving worldwide.

In the Norwegian sector of the North Sea the first saturation dive was to 145 m, done in 1974. By 1978 dives to 200m were carried out. Since then a lot of research and development (R&D) has been done to enable safer and deeper diving operations.

In later years saturation diving is carried out routinely to more than 300 m water depth, e.g. in Brazil. In the North Sea the deepest operational diving depth have been 246 m, but since 1989 no operational diving to more than 180 m has been performed on the Norwegian shelf.

A3. Investigations into the health risks related to saturation diving

The health implications of deep water diving has been debated by professionals throughout the world for a long time. One particular problem with saturation diving has been the High Pressure Neurological Syndrome (HPNS) caused by compressions to more than 180 m /6/. In the case of U-864, the maximum relevant diving depth is approximately 150 meters. By diving to 150 m this syndrome is practically non-existing /4/, even if some divers show changes on the EEG (electroencephalogram) /5/.

In the following sections we present some results from studies that have been performed on the health risks related to commercial diving operations. They offer information about which health issues saturation diving can induce.

Norwegian Government Commission - Study on diving on the North Sea pioneer period, 2001

The Norwegian offshore diving has been heavily debated in the media and political forum. Interest groups of so-called “pioneer divers” (usually meaning a diver who has dived in petroleum related activity before 1990) have raised the issue about whether offshore diving have led to fatal accidents, suicides and long-term health problems. In 2001 the Norwegian government appointed an independent Commission of Enquiry to investigate all circumstances related to diving in the North Sea in the pioneer period (1965 to 1990). This Commission state i.a. (NOU 2003:5):

“After an average of about 14 years in the North Sea, the majority are in a satisfactory state of health based on the information they have supplied. However, a relatively high proportion have acquired appreciable health problems, illustrated by the fact that almost one-fifth are disabled, and that a number of divers complain of concentration, memory and hearing impairments. The same symptoms are documented in Norwegian and foreign investigations alike. It seems probable that the extreme stress to which many North Sea divers have been exposed at work has been a significant factor behind the disorders that a number of them have developed.”

But they also say in their conclusion:

“The (fortunately) steep decline in serious accidents in the 1980s on both sides of the North Sea can to some extent be ascribed to improved rules and oversight of compliance with the rules. Another important reason was the switch to saturation diving which considerably reduced time pressure on the seafloor.”

ELTHI (Examination of Long Term Health Impact of diving)

A British study /8/ investigated a much larger group of divers, including still active divers and concluded that the health-related quality of life was similar for divers as for offshore workers and within normal values. But more divers than offshore divers complained about “forgetfulness and loss of concentration”. There have been some conferences on the issue of long-term-health-effects of diving. In the last one in Bergen /9/, there were still rather large discrepancies on whether it has been proved that “normal diving” will lead to health effects that are important to the diver’s quality of life.

Scanpower – study on risk for fatality and serious diseases for divers, 2005

Scandpower was given the task to present objective description of the risk for fatality and serious disease for divers involved in the current activities in the Norwegian sector. In their report /10/ they estimate a Fatal Accident rate (FAR) for diving in the UK and Norwegian sector from 1990-2003.

The study registered 27 fatalities per 100 million saturation man-hours. This result corresponds to an individual risk per annum (IRPA) of around 0.0006.

This should put this type of diving in the group of acceptable activities, although any means should be taken to reduce risk. The Scandpower states that it was a much bigger challenge to handle the question of long-term health effects. This is partly because the existing studies differ with regards to whether the observed changes are reducing quality of life. They also assume that the diving as it is done today will result in less risk of long-term health effects, since frequencies of decompression illness and life-threatening incidents have been significantly reduced after 1990.

Petroleum Safety Authority Norway - Diving on the Norwegian shelf

The Petroleum Safety Authority Norway (PTIL) has a Safety forum consisting of representatives from the authorities’, workers’ and employers’ organisations. In later years, there have been great discussions in Norwegian media about the safety level of today’s diving. The discussions are based on claims against the Norwegian State from Norwegian pioneer divers with health problems, thought to be related to diving around 20 years ago. As a result of this the Safety forum made an evaluation resulting in the report “Dykking norsk sokkel” /1/.

PTIL collects statistics on the diving operations on the Norwegian shelf and HSE incidents related to this activity. Figure 6-1 gives an overview of the evolvement of activity and HSE related incidents in the past two decades. As the graph shows, the level of activity dropped significantly on in the beginning of the 1990’s but has picked up in the last few years. The graph also shows that the number of personal injuries is on a significantly lower level compared to the late 1980’s. Some experts attribute the somewhat increased number of near misses to a generation change in saturation diving, resulting in a reduction in the experience level of the divers. DNV has not found studies to confirm this.

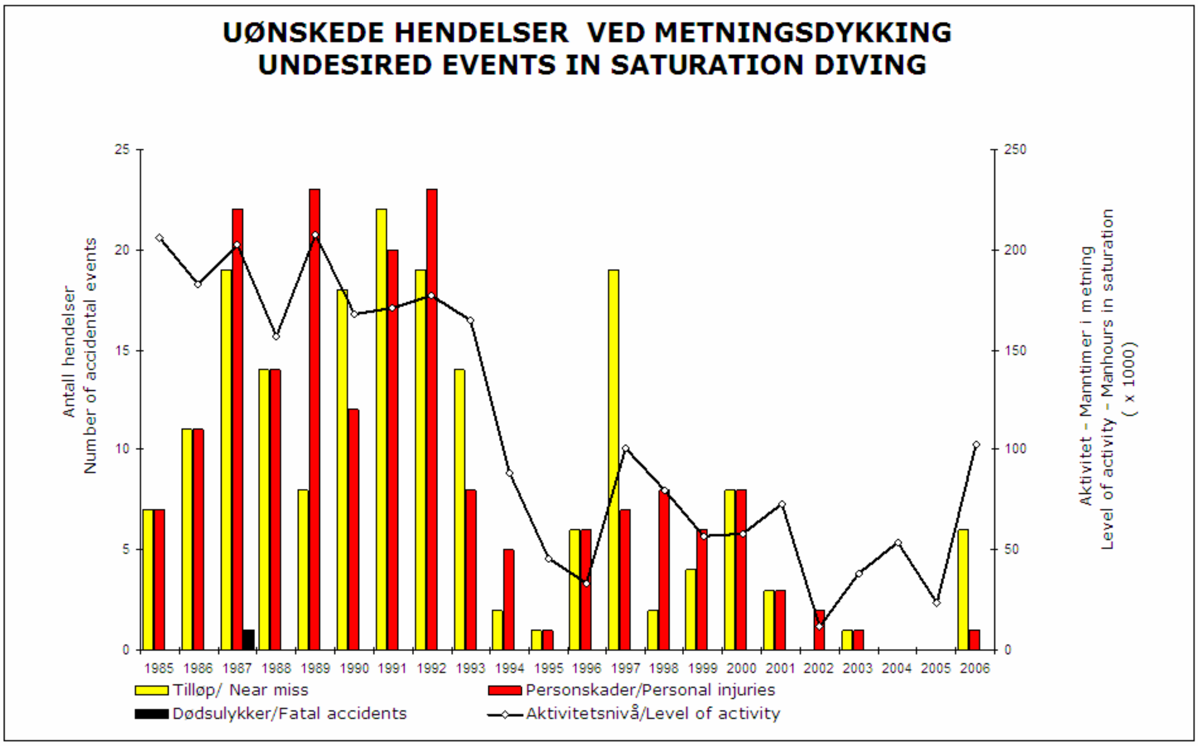


Figure 6-1 Undesired events in saturation diving, PTIL database /2/

Main findings in the reports presented:

In the Scandpower report it is stated that most of the diving in the Norwegian sector has been done in the depth range 70 – 160 m. And after 1990 no operational dives to more than 180 m have been done. In the UK sector there has been a significant amount of diving to 200m on the Magnus field. Diving to 160 m, which is the Statfjord depth, is done routinely, and frequently.

The PTIL study conclude that diving on the Norwegian shelf today is within the frame conditions set in the regulations and in accordance with accept criteria for SHE risk. But they, in line with Scandpower, recommend further evaluations of the existing regulations, i.e. with regard to long term health surveillance and post diving career plans.

Based on the results from the studies DNV must conclude that given compliance with the rules an regulations for saturation diving, diving to a depth of 150 m, which constitutes the depth of U-864, can be considered within the acceptance zone for safe diving operations.

A4. Diving in contaminated water

The studies above indicate that diving operations in it self present risks for the divers, all though assessed acceptable. These risks are compounded by the presence of hazardous materials in either the water or the sediments on the seabed.

The US Navy published the report Guidance for Diving in Contaminated Waters (Direction of Commander Naval Sea Systems Commando 15 January 2008). This report looks on both evaluation criteria and guidelines for diving operations and equipment.

In this report, they define the following categories and definitions of contaminated water:

Contaminated Water Categories	Definitions
Cat 1	a. Grossly contaminated b. Extreme Risk of Injury (or even death) (Note 1) c. Fully encapsulated Diver (inc. Surface Exhaust) (Note 2)
Cat 2	a. Heavily contaminated b. High Risk of Injury (Note 3) c. Fully encapsulated Diver (in water exhaust)(Note 2)(Note 4)
Cat 3	a. Moderately contaminated b. Some risk of Injury (especially if ingested) c. Full face mask (skin covered as necessary)(Note 5)
Cat 4	a. Baseline contamination (EU Bathing Water 'Sufficient' or better) b. Low risk of Injury(Note 6) c. Standard diving dress

Figure 6-1 US Navy - Contaminated water categories

During the operations on the seabed around the U-864, the divers will be exposed to mercury contaminated water and sediments. Given the results from previous surveys /3/, the water contamination will be at Cat 2 or Cat 3. Specialized personnel protective equipment (PPE) is necessary.

Precautions against exposure to mercury also need to be taken during the decontamination of the divers, which should take place as soon as possible after they leave the contaminated area and preferably before entering the diving bell.

Offshore diving operations in Norway related to the oil and gas sector may involve contact with polluted elements like oil and sludge. The divers may then use an extra protective suit outside the diving suit, which can be removed before entering the diving bell, leaving most of the pollution outside, and minimising the need for decontamination inside the diving bell. This should be considered used if diving is performed in the contaminated area near the U-864.

APPENDIX

B

PREVIOUS EXPERIENCES WITH DIVING IN SALVAGE OPERATIONS

Throughout history salvage has been one of the most important tasks for divers. The capability to rescue crew from sunken submarines has been of special importance in the evolvement of diving operations. Diving support in the salvage of cargo and vessels has also been of great interest. Examples are:

- In 1981 the gold cargo of HMS Edinburgh was taken up from 245 m depth in the Barents Sea.
- In 1993 the wreck of the German submarine U-534 was recovered from 60 meters water depth outside Denmark with the assistance of divers.
- In 1994 the German WWII vessel Blücher were to be emptied of oil in Drøbaksundet, in the Norwegian Oslo Fjord. This was planned as an intervention without use of divers, but the unmanned intervention was unsuccessful. Saturation divers were mobilized and carried out the task efficiently at 70 meters depth.
- Saturation divers from the North Sea were mobilized in the attempt to assist the crew in the Russian submarine Kursk that sunk in the Barents Sea in 2001. Unfortunately they were too late, but it was demonstrated how useful divers can be in unforeseen tasks of this kind. In the later phase, when Kursk was salvaged, divers were again useful and did excellent work at 110 meters depth.

Divers can normally be mobilized quickly to assist in various operations. Vessels and crews are in practically continuous operation, primarily with petroleum related work. The diving activity is not necessarily continuous in the Norwegian sector, but a handful of diving support vessels (DSV) are to a large extent in continuous operation on missions either in Norway or UK, regularly crossing the border between the Norwegian and British sector.

In the mid 1990’s management in Statoil and Hydro declared the goal to become independent of divers by year 2000. This turned out to be unrealistic. A group initiated by Statoil, reported /11/ hat it is necessary to strengthen the dive support capacity as diving services will be necessary in the near future. The report gives a number of necessary actions. Among these are building of new DSVs and education of all categories of dive competence. Therefore, education of bell/saturation divers is planned to start in Bergen in 2008.

Worldwide there are at the moment 23 DSVs being built. Of these, four will be owned by Norwegian companies and these will all be finished before end of 2009.

Presently three companies are actively running offshore diving operation in Norway: Acergy, Subsea7 and Technip. Technip runs a diving contingency service administered by StatoilHydro, primarily to be able to repair pipelines on the sea bottom. The activity level on the Norwegian shelf has varied around 50-100 000 man-saturation hours in the later years, but activity has increased since 2005, probably because of renewed faith in diving operations similar to those of Statoil Hydro.