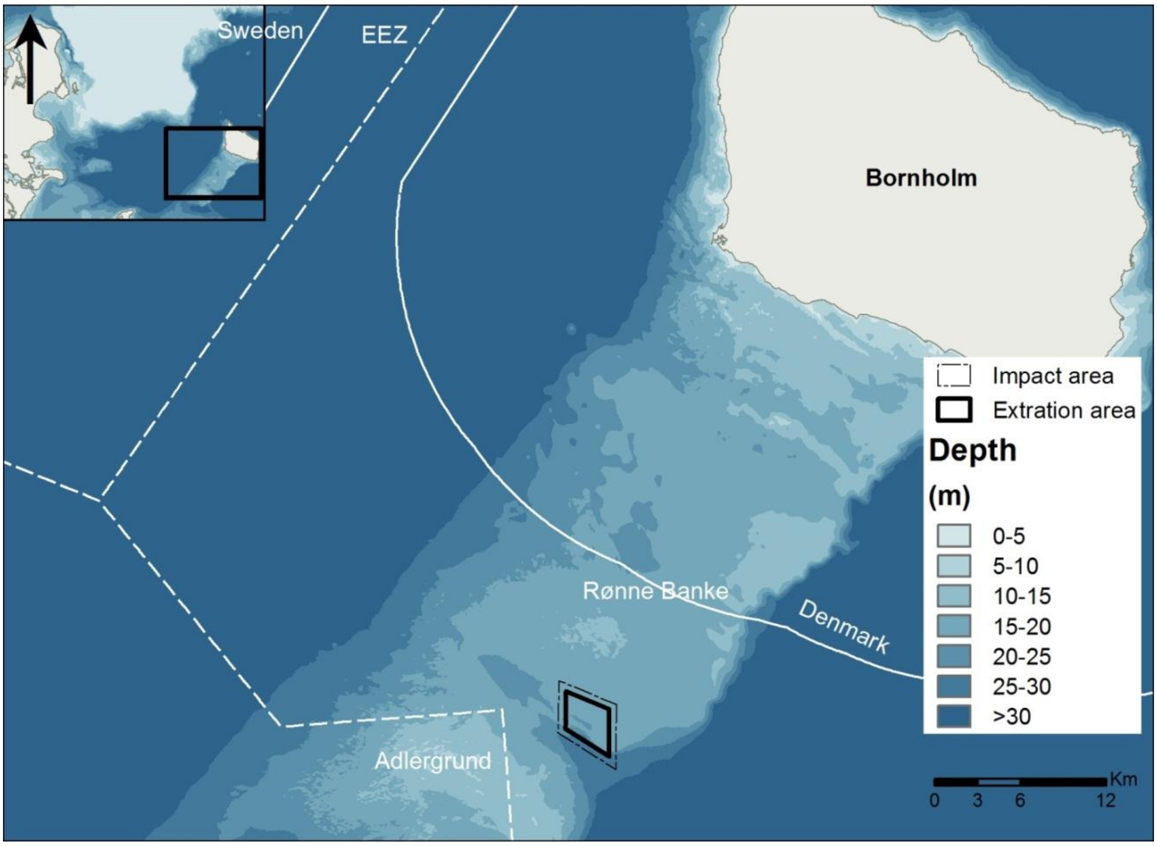
<u>**Final Report**</u>

FEHMARNBELT FIXED LINK
Marine Biology Services (FEMA)

Environmental Impact Assessment (EIA) of Sand Extraction at Rønne Banke

E2TR0026



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ACRONYMS AND ABBREVIATIONS

AFDW: Ash Free Dry Weight

AIS: Automatic Identification System (for ship traffic)

BS: Baltic Sea

Cd: Cadmium

Cr: Chromium

Cu: Copper

D50: Median Grain Size

DW: Dry Weight

EEZ: Exclusive Economic Zone

EIA: Environmental Impact Assessment (in Danish VVM)

EPA: Environmental Nature Agency

H Ac: Higher Action Level (SQG used by the Danish EPA, concentrations above H Ac are considered problematic)

Hg: Mercury

L Ac: Lower Action Level (SQG used by the Danish EPA, concentrations below L Ac are considered unproblematic)

LOI: Loss On Ignition (equivalent to organic content)

Ni: Nickel

OSPAR: Oslo and Paris Commission

PAH: Polynuclear Aromatic hydrocarbons

Pb: Lead

PCB: Polychlorinated Biphenyl

PTS: Permanent threshold shifts (hearing loss in mammals)

S/C: Silt/Clay fraction

Sn: Tin

SQG: Sediment quality guidelines

TBT: Tributyltin

TN: Total Nitrogen

TP: Total Phosphorus

TTS: Temporary threshold shifts (hearing loss in mammals)

VMS: Vessel monitoring system

VVM: Vurdering af Virkninger på Miljøet (EIA)

Year 2014: “year 0”; Year 2015: “year 1”; etc.

Zn: Zink

CONTENTS

Lists of figures and tables are included as the final pages

APPENDICES

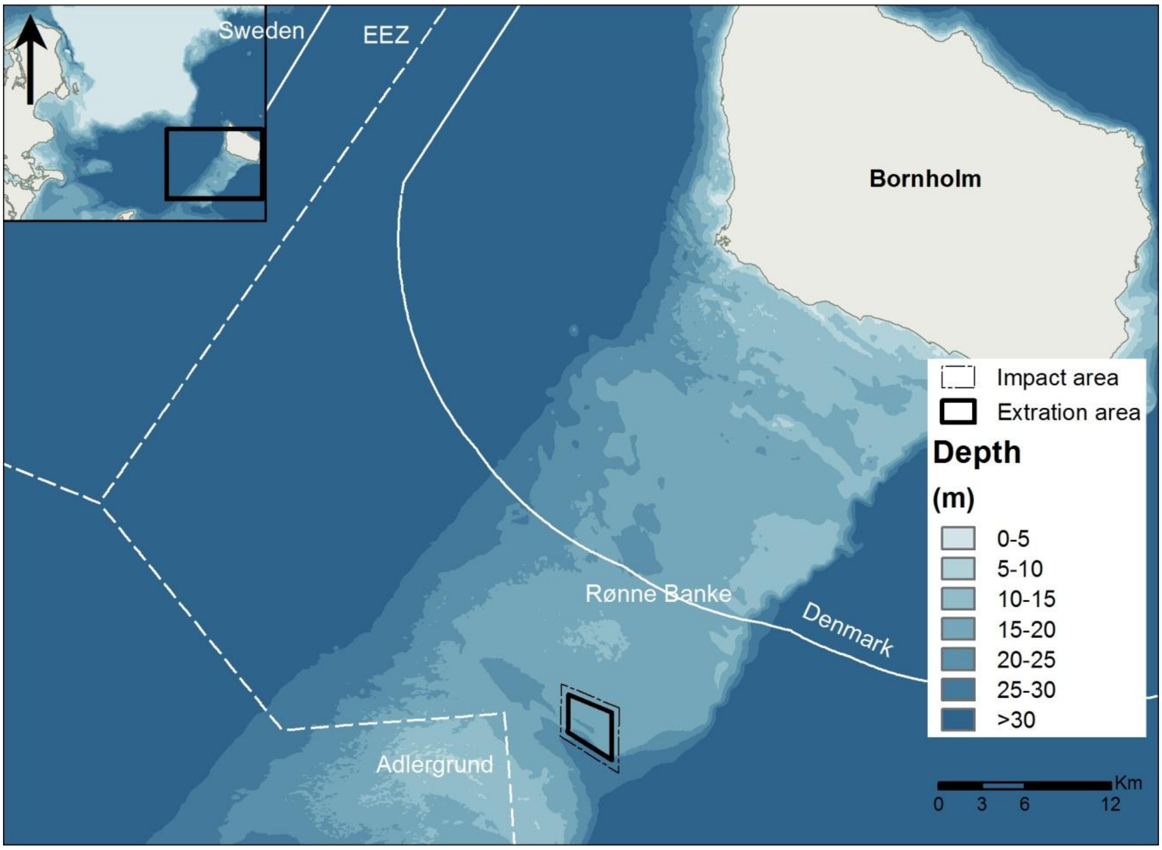
Note to the reader:
In this report the time for start of construction is artificially set to 1 October 2014 for the tunnel and 1 January 2015 for the bridge alternative. In the Danish EIA (VVM) and the German EIA (UVS/LBP) absolute year references are not used. Instead the time references are relative to start of construction works. In the VVM the same time reference is used for tunnel and bridge, i.e. year 0 corresponds to 2014/start of tunnel construction; year 1 corresponds to 2015/start of bridge construction etc. In the UVS/LBP individual time references are used for tunnel and bridge, i.e. for tunnel construction year 1 is equivalent to 2014 (construction starts 1 October in year 1) and for bridge construction year 1 is equivalent to 2015 (construction starts 1st January).

EXECUTIVE SUMMARY

For the construction of the fixed link between Denmark and Germany across the Fehmarnbelt there is a demand for sand and gravel resources. The largest need is for the tunnel solution and thus this solution forms the basis for the Environmental Impact Assessment (EIA) study. The EIA is prepared to investigate and assess possible impacts on the environment from the sand extraction at Rønne Banke. The results from the EIA will make it possible to minimize or avoid undesirable effects from the dredging activities.

According to the sand extraction plan, the 1 mill m^3 of materials required for the tunnel element production has to be extracted from Rønne Banke off the island of Bornholm in the Baltic Sea.

The water depths in the sand extraction area are between 15 and 25 m. The designated extraction area is approximately 9 km^2. Including the surrounding 500 m impact zone the total area is approximately 16.5 km^2. The EIA includes the surrounding impact zone of 500 m.



Area map of Rønne Banke impact area and extraction area.

To form a baseline for the area and the EIA, new information on the resource and the biological conditions acquired during July-August 2011 by GEUS and DHI/FEMA have been combined with the previous investigations in the area.

The designated resource area for the Fehmarnbelt project is located in the south-eastern part of a larger resource area at Rønne Banke and with a distance of more than 2 km to the nearest Nature 2000 area.

In July-August 2011, new seismic data and seabed samples were acquired with the purpose of mapping resources and describing the biological conditions in the investigation area at Rønne Banke. Baseline conditions are described combining new data with existing information. Seismic data have been used to map resources, seabed sediment and substrate types. The physical and biological conditions have been described to assess the possible impacts caused by sand extraction, sediment spill, sedimentation of spill, traffic and noise on the environmental factors water quality, benthic flora and fauna and fishery in and around the planned sand extraction area. The EIA assess the predicted short- and long-term impacts on the environment.

The report is divided into two parts presenting the results from the seismic and acoustic mapping of the sand resources in the first part, and the second part presenting the baseline description and the environmental impact assessment in relation to a possible sand extraction at Rønne Banke.

Resources and sand extraction plan

The designated extraction area at Rønne Banke is approximately 9 km^2. The investigated area includes a surrounding 500 m impact zone and the total area is approximately 16.5 km^2 and is together called the impact area. Water depths in the sand extraction area are between 15 and 25 m, and up to 30 m in the 500 m impact zone.

Resource

The mapped resource area at Rønne Banke is a huge sand body with a layer thickness of up to 12 m mainly deposited as marine or coastal sand deposits formed during the post glacial marine transgression. The uppermost 1 m of Recent to Sub-Recent marine sand is continuously reworked due to wave and current activity. The actual available resource is calculated to 33.6 mill m^3 anticipating that a residual sediment layer of about 1 m is left behind after completing the extraction.

Extraction area

To minimize the physical and biological impacts it has been suggested that the volume of approximately 1 mill m^3 sand needed for the tunnel element production can be produced in a sub-area of 1 x 2 km (2 km^2) where 0.5 to 1 m of the seabed can be extracted. The resource thickness in the sub-area is more than 4 m (see map with resource thickness).

Dredging

The sand extraction from Rønne Banke is recommended to take place by trailing hopper suction dredgers. The volume of the hopper is typical 2-10,000 m^3 corresponding to 1,500 to 7,500 m^3 sand. If the largest Hopper Dredger is used, about 135 cargos of sand will be transported from Rønne Banke to the Fehmarnbelt construction site and 670 cargos if the smallest is used. The trailing suction method leaves the seabed with dredging scars of 1-2 m width and 0.5 – 1 m depth. The sand extraction is an operation for the tunnel element production and is following a dredging plan. According to this plan the activities will take place between November 2014 and April 2016.

Alternative areas

Two alternative resource areas to the Rønne Banke are known from the German continental shelf in the Baltic region: Plantagenet Ground and the Adler Grund. The areas are partly Habitats and Birds Protection Sites (Natura 2000 areas) and the resource is for local use for beach nourishment.

Five alternative resource areas are known on the Danish continental shelf in the Baltic region: Vejsnæs Flak, Keldsnor, Rødbyhavn, Gedser and Gedser Rev. Both the German and the Danish resources are dedicated for local use. More intensive investigations are required if additional resources within these areas should be made available for the construction of the Fehmarnbelt Fixed Link.

The construction of the Fehmarnbelt Fixed Link with raw materials from local sand and gravel pits have also been investigated. The southern part of Zeeland and the surrounding islands have estimated approximately 12.5 mill m^3 resources left in sand and gravel pits. By 2013 less than 10 mill m^3 is left and these materials are planned for local use for construction works and buildings. Hence local land materials are not an available resource for the Fehmarnbelt Fixed Link.

Resources from the project site such as material from e.g. the tunnel trench cannot be reused for backfilling etc. as the material does not live up to the requirements.

0-alternative

In case the Fehmarnbelt Fixed Link is not constructed, there will be no effect on the marine environment from sand extraction.

Quality

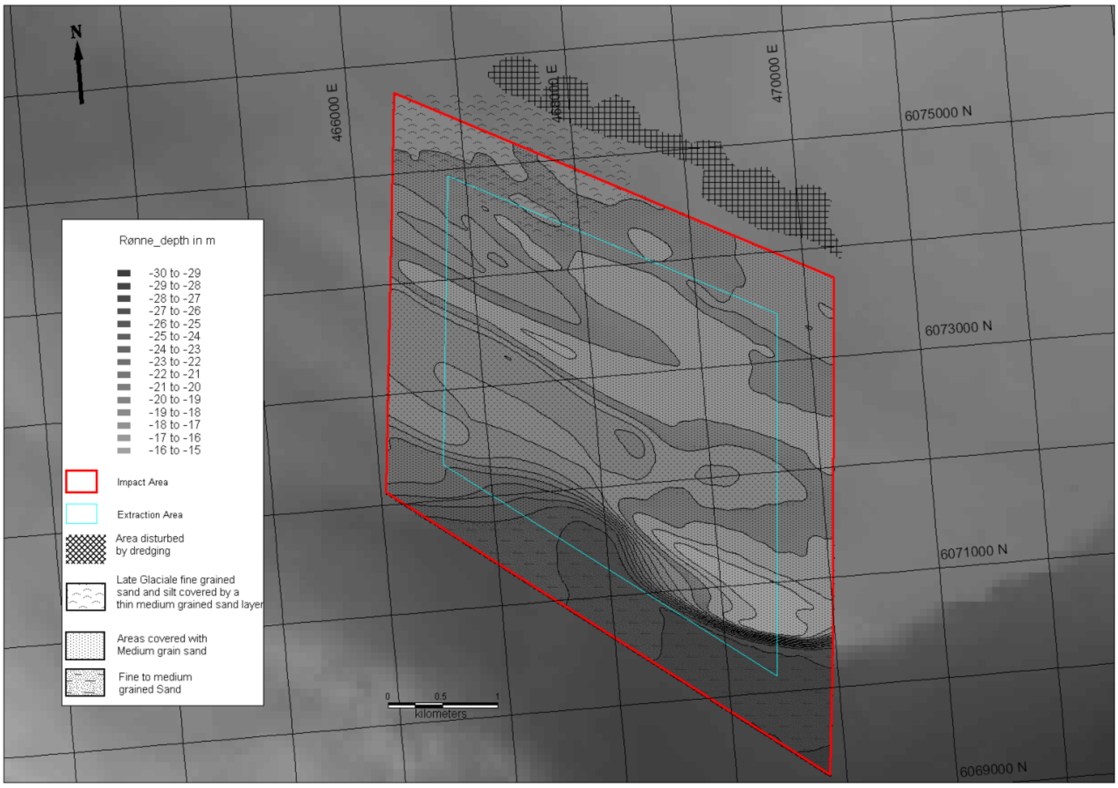
The sand resource at Rønne Banke shall be used as aggregate for concrete production. It is therefore required that the quality of the resource fulfils the requirement for this purpose.

For the construction of tunnel elements it is expected that the aggregate shall comply with the aggressive (harsh) environmental class. Analyses of sand from 6 m-vibrocore samples show that the total content of porous flint varies between 0.0 and 0.3% for the grain size group 0-4 mm. To comply with the aggressive environment class specifications the total porous flint in the aggregate shall be less that 2%. From the results it can be concluded that the sand material at Rønne Banke fulfil these requirement.

Baseline description

Seabed sediments

To characterize and classify the seabed sediment, acoustic data were acquired by use of a side scan sonar system. The data was used for seabed classification subdividing the seabed into classes of different reflectivity. To confirm the initial classification ground-truthing at selected stations was performed by DHI/FEMA in August 2011 using Van Veen grab and video inspections. The stations were the same stations as those used at the fauna sample sites.



Seabed sediment map of Rønne Banke showing the general medium grain size sandy seabed and areas of lag deposits of gravel and cobbles. An A3-version of the map is found in Appendix F.

The seabed in the extraction area and the surrounding 500 m impact area is classified as substrate type 1, medium grained sand with an average grain size between 0.2 and 0.5 mm with some content of gravel and coarser fractions. Recent dredging activities took place outside the Extraction area in the north in an existing sand extraction area.

Sand transport processes

The sediment transport has been estimated based on data on waves and currents (see under Water). The resulting sediment transport conditions are presented in the table below.

Transport capacity [m^3/m/year] for the sand extraction area at Rønne Banke.

Wave height H_S [m]	**Peak wave period, T_p [s]**	**Current speed [m/s]**	**Yearly duration [%]**	**Yearly transport capacity [m^3/m/year] for three water depths**		
				15 m	**23 m**	**30 m**
1	5	0.05	57	0	0	0
2	6	0.15	16	0	0	0
3	7.5	0.25	2.8	1.95	0.03	0
4	8.5	0.35	0.36	1.15	0.26	0.04
				3.1	**0.29**	**0.04**

The computations have demonstrated that there is some sand transport capacity in the sand extraction area, highest at the 15 m and low at 30 m, which indicates that regeneration of the seabed following the sand extraction will take place, especially at 15 m.

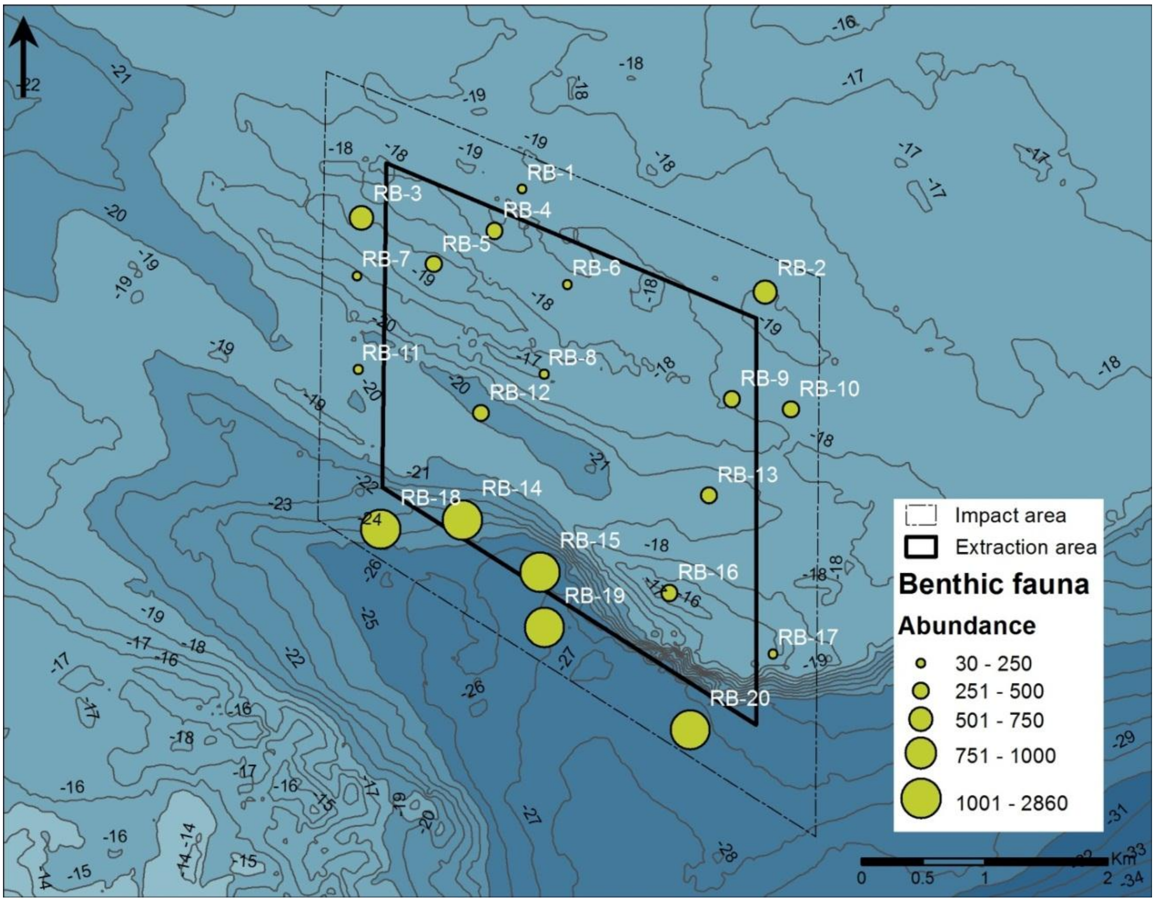
Toxic substances
Toxic substances are heavily bound to organics material. The concentration of organic material in the sediments was measured and found very low (LOI < 0.30 % of WW). The concentration of toxic substances in the sediments at Rønne Banke was calculated to be below threshold values set by the Danish EPA and values set by OSPAR.

Water quality
Data from the Danish monitoring programme (NOVANA) were extracted together with previous investigations to describe the water quality in the area. On a yearly basis, the salinity in the Baltic Sea around Bornholm is stable at 7–9‰ and the water is therefore mesohaline. The water temperature fluctuates throughout the year, following the seasons. In June to August the water becomes stratified at 10-12 meters. The oxygen content is evenly distributed throughout the water column. The oxygen content fluctuates from 9-13 mg/l through the season, with the lowest concentration in the summer period.

The total amount of nutrients (nitrogen TN and phosphorous TP) has also been extracted. TN varied between 11 and 26 µmol/l evenly distributed through the water column and year. TP varied in 2005 from 0.6 to 1.5 µmol/l and was slightly lower in 2006 with observed values between 0.3 and 1.1 µmol/l (the data extraction years). Chlorophyll a concentrations were between 0.5 and 4.5 µg/l throughout the photic zone (0-15 m) throughout the year.

Benthic fauna
Quantitative samples of the benthic fauna and subsamples of the surface sediment were collected at 20 stations at Rønne Banke in August 2011. A total of 14 species and one higher taxon (Oligochaeta) is recorded at Rønne Banke. The average abundance of the benthic fauna was 755 m^{-2} and the range between 30 and 2,860 m^{-2}. The sediment becomes finer and the content of silt/clay and organic matter increases in deeper water in the southern part of the area.

The impact area is characterised by a limited range of water depth and uniform sediment with a low content of organic matter. The species richness is characteristic for shallow, low saline areas of the Baltic Sea. The community of the area resembles the Cerastoderma community. The abundance and biomass of the benthic fauna were low and dominated by a few species of polychaetes (*Pygospio elegans* and *Marenzelleria viridis*) and bivalves (*Mytilus edulis, Mya arenaria* and *Macoma balthica*). The Cerastoderma (Macoma) community is typically found at all depths in The Baltic Sea and is widely distributed in the surrounding areas.



Abundance of the benthic fauna at Rønne Banke in August 2011.

Benthic vegetation

Macro algae were not observed within the impact area, which is the extraction area plus the surrounding 500 m impact zone. Outside the impact area (along transects) only very few small single macro algae of the genus *Laminaria* spp. were observed.

Previous investigations of Rønne Banke sand resources have shown very limited or no hard substrate at the seabed in the areas near the impact area and it is hence not expected that there is benthic vegetation in nearby areas and there has therefore not been conducted vegetation investigations outside the impact area.

There was not observed any macro algae, marine flora or visible concentrations of microalgae (at the seabed surface) in the impact area at the sampling stations.

Fish

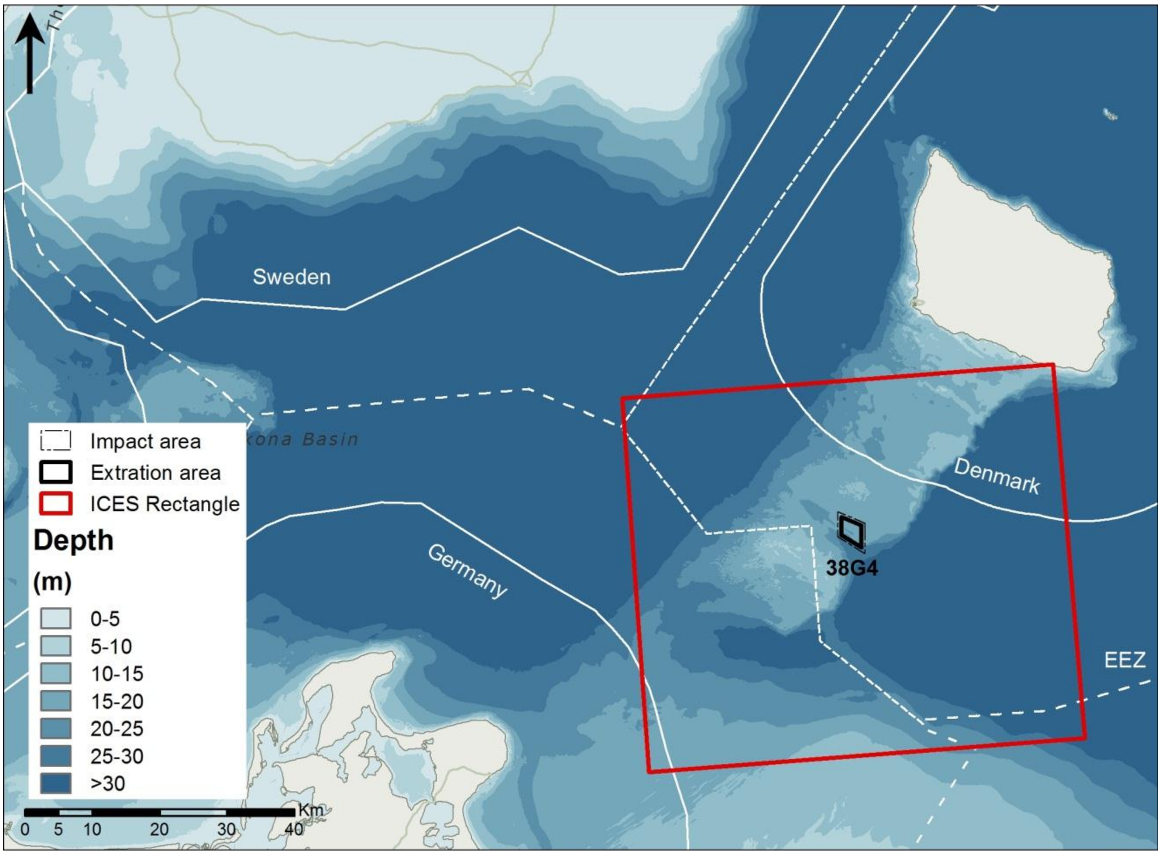
Fish surveys were not undertaken in connections to this investigation thus the baseline description of the fish community within the extraction area of Rønne Banke and the surroundings has been based on both general knowledge, literature on fish in the Baltic Sea and on fish surveys undertaken in the German parts of Adlergrund close to Rønne Banke.

In total 37 fish species are registered in the Rønne Banke-area of which 25 spend their entire life-cycle in the Baltic Sea. The fish community found in the Rønne Banke area can be divided into two categories: pelagic fish living near the surface or in the water column and demersal (benthic) fish species living in, on or close to the seabed. Most of the demersal species prefer a sandy seabed with stones, mussel banks, sea grass and algae. Sandy bottoms are preferred by flatfishes and sandeels – especially important to the sandeels because of their burrowing mode of life, living in the bottom during night and in wintertime. Herring, sprat and cod are the major commercial fish species of the Baltic Sea.

Twaite shad, autumn spawning herring, salmon, cod, eel and sea snail, are included in the HELCOM List of threatened species and categorised as endangered (HELCOM 2007). Salmon and twaid shad are also listed in annex II and V of the Habitats Directive.

Fishery
In the past 10 years, the overall landings of the Danish fisheries in the Western Baltic Sea have decreased by approximately 50%, but they still constitute an important part of Danish fisheries. Historically cod, herring and sprat have made up the vast majority of the catches. Diverse flatfish species, European eel, salmon have also been targeted.

The fisheries in the Baltic Sea are divided by the international fishery zones where national and international fishery regulations and quotas apply and catch data is separated. These zones: ICES rectangles (approx. 30 x 30 nm) are used to form the boundaries for the presentation of the official commercial fisheries data.



The ICES statistical rectangle 38G4 in the Western Baltic Sea. The proposed extraction area is represented by a black rectangle in the centre of the map.

Official data for landings and additional fleet statistics for these rectangle 38G4 were obtained from the Danish Directorate for Fisheries. Data does not include information on vessels less than 8 m (less than 10 m before 2005) because these vessels are not required to fill out logbooks. However, the official catch statistics are considered to contain the essential fisheries information.

Most of the registered fishing trips are undertaken by vessels using bottom trawls and are dominated by vessels between 8-15 m in length. In all, the proportion of fishing trips using trawls and represents about 75 % of the total number of fishing trips. The gill net fishery has decreased considerably and the fishery with seine nets has been very low throughout the entire period.

In order to give a thorough description of the distribution of the fishing activities for large vessels (≥15 m), the Vessel Monitoring System (VMS) data were also obtained from the Danish Directorate for Fisheries. A relative indication of the fishing activity for the large vessels within the extraction area can be obtained by the number of VMS plots in the extraction area compared to the number of plots in the entire ICES 38G4 rectangle This data indicates that the relative importance of the fishery inside the extraction area has declined from more than 1% in 2005 to 0.3% in 2010.

Some trawl fishermen electronically save their trawl tracks on map for the fishing area south of Bornholm, including Rønne Banke and the extraction area. This information indicates how the fisheries are practiced.

In the relatively shallow waters (17-20 m) the fisheries are undertaken only at night with the main fishing season in the second half of the year. In the winter, cod and other commercial species migrate to deeper waters.

The area of Rønne Banke is, according to information from fishermen, an important fishing ground for 10-15 trawlers from Bornholm. For the most active fishermen, up to 40% of their annual turnover can come from this area. Cod is the primary target species with flatfish (primarily flounder and plaice) being an important bycatch. In the summer (June-July) of 2011 there was also an important fishery targeting sandeels in the same area. Fishing for sandeels is carried out during the day-time.

Birds

The extraction site on Rønne Banke does not house any local breeding waterbirds.

A recent review of wintering waterbird populations in the Baltic Sea between 2007 and 2009 included the planned extraction site on Rønne Bank. From the modelled densities provided by the review it is clear that the Long-tailed Duck is the only common species and the densities of Long-tailed Ducks on the extraction site on Rønne Bank were between 10 and 20 birds/km^2.

Available historic and recent data on the occurrence of waterbirds at the extraction site on Rønne Banke document that no species presently occur at the site in concentrations of international importance. The most important occurrence of waterbirds is the concentration of Long-tailed Duck, which regularly exceeds 10,000 birds over the southern part of Rønne Banke and Adler Grund during winter and spring.

Baseline investigations undertaken in relation to the planned wind farms on the Swedish and German parts of Kriegers Flak and Adler Grund have provided the main sources of recent information on the timing and intensity of bird migration through the Arkona Basin. The migration of waterbirds trough the Arkona Basin seems mainly to take place over a relatively broad front, and is dominated by Common Eider and Common Scoter.

Marine mammals

The inner Danish waters and south-western Baltic Sea are inhabited by three species of marine mammals; the harbour porpoise, the harbour seal and the grey seal.

The harbour porpoise is a protected species and listed in the EU Habitat Directives Appendix IV. There have been large-scale visual and acoustic surveys of harbour porpoises, but the Rønne Banke seems to be of little importance for Danish and German porpoises. However, individuals might be spending time in the area foraging or animals migrating eastward into the Baltic Sea.

Harbour seals have haul-outs at Falsterbo, Bøgestrømmen and Rødsand, within 140 km of Rønne Bank, and grey seals have been observed at all these haul-outs Furthermore, Adler Grund (Germany), and Rønne Banke (Denmark) are Natura 2000 areas. The standard data form for Adler Grund lists the occurrence of grey seals and harbour porpoise, and the one for Rønne Banke lists harbour porpoise. Seasonal distribution of grey and harbour seals are not known, but both species are known to be able to move considerable distances from the haul-out sites to foraging areas. Movements of tagged grey seals from the haul-out site on Rødsand indicate that Rønne Banke is crossed regularly by mammals as they move between Rødsand and feeding areas in the northern parts of the Baltic Proper.

Material assets: Cables, ammunition, navigation, recreational interests and marine archaeology

There are no cables in the extraction area. Ammunition is not likely to occur.

Only a small amount of ship traffic passes Rønne Banke. There can be recreational ship traffic in the area, but there are no marinas in the nearby areas.

There are no registrations of ship wrecks within the extraction area (The Heritage Agency of Denmark).

Natura 2000

There are two Danish and two German Natura 2000 sites in the vicinity of Rønne Banke.

Natura 2000 sites in the vicinity of Rønne Banke. DK=Denmark, DE= Germany

Natura 2000-site Id-no	Name	**Distance project site**
DK00VA261	Adler Grund og Rønne Banke (Habitat site)	3
DK00VA310	Bakkebrædt og Bakkegrund (Habitat site)	26
DE1251301	Adlergrund (Habitat site)	5
DE1552401	Pommersche Bucht (Bird protection site)	5

Project pressures

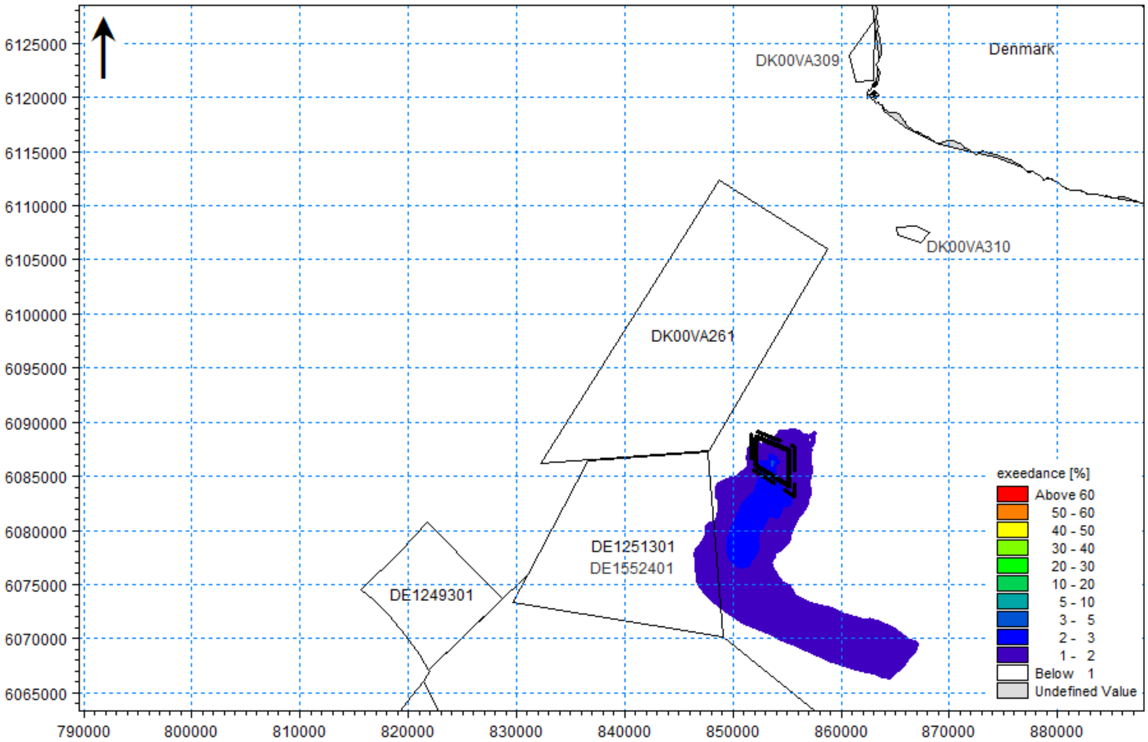
In connections to the project several pressures have been identified to have a possible impact on the sub-factors in the area.

Loss of seabed (sediments and benthic habitats)

The sand extraction will be conducted by using a trailing suction hopper dredger. This dredger type works by dragging a drag head over the bed and sucking the sand into the hopper (the hull) of the ship. This type of dredging will lead to a loss of sediment and benthic habitats in the area where extraction has taken place. The total area of the extraction area (without 500 m impact zone) is 9 km^2. It has been planned that 1 mill m^3 of sand will be extracted, and hence a similar magnitude of sediment and benthic habitats can be lost.

Increase in suspended sediment and deposition
When the sand is extracted, sediment is spilled. Dispersal and deposition of the spilled sediment particles depend on the size of the particles and the hydrodynamic conditions. Spilled sediment will give rise to an increase in suspended sediment concentration and to deposition of the spilled sediment.

Exceedance for suspended sediment concentration (SSC) is assessed using the 2 mg/l, 10 and 15 mg/l. Exceedance is expressed as the time within a selected period, where the SSC exceeds these thresholds. SSC exceedance is assessed for surface (depth 0-1 m below surface) and bottom layers (depth 0-1 m above bottom), respectively. The overall results from the modelling are that the generated plume is quickly dispersed. This means that high SSC concentrations are mainly observed close to the centre of dredging site and that the concentration is below 2 mg/l within a few days.



Exceedance time for the period 1/5 to 1/9 (2005) for the bottom (depth 0-1 m above bottom) of 2 mg/l. Exceedance time is given as percentage days with SSC levels above the threshold in relation to the total number of days (FEHY 2011).

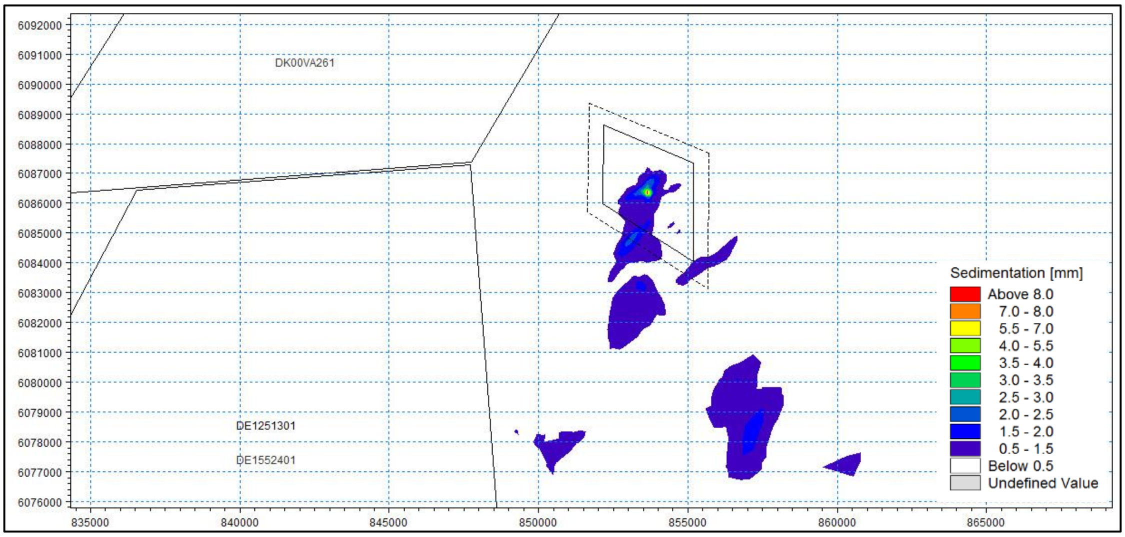
The model results on the deposition show that sediment fraction smaller than 63 µm deposit far from the source but with a thickness smaller than 1.5 mm.

The remaining sediment above 63 µm will settle very close to the location where it was dredged

The maximum deposition of sand is estimated to be up to 10 cm locally within the extracted area just after the trailing suction hopper dredger has passed. Thereafter, the sediment will be spread and incorporated into the local sediment.

The extension is also larger for the one year period than for the summer period as expected because the one year period contains the summer production period.

The order of magnitude of the temporary maximum thickness of the fine sediment is about 1 mm in a limited number of locations south of the extraction area.



The maximum temporary deposition below 63 µm in mm for the full model year (2005).

Organic material, nutrients and toxic substances

Organic materials in the sediment can decompose if released to the water column. This can, if the concentration is high, lead to an increased oxygen consumption and release of nutrients. Release of nutrients can increase the phytoplankton growth. Furthermore, depending on the presence of local pollutant sources and the sedimentary conditions, marine sediments may contain a large number of toxic substances that potentially can be released during dredging and hence impact the aquatic environment. The content of organic material in the sediments (LOI) of the investigation area is very low (between 0.08 and 0.73% DW).

Noise

It is expected that the dredger used for the extraction operation will have a sound power level of 114 dB(A) or less. For the purposes of this report a Trailing suction Hopper Dredger has conservatively been assumed to have a sound power level of 114 dB(A) and at a distance of 2 km from the dredger the noise level is calculated to be 27 dB(A).

There are no indicative limit values for noise from dredging activities, but in recreation areas the limit is 40 dB (A) during the night time. Considering that the Rønne Banke Area is located app. 30 km from the nearest coastline at the south coast of the Bornholm Island, the noise from the dredging operation is regarded not to give rise to noise onshore. The primary receptors of noise are birds (noise in air) and fish and marine mammals (underwater noise). Impacts on these are assessed in the respective chapters.

Underwater noise from the sand extraction is also a factor, which can impact fish, birds and mammals. The underwater noise levels from Trailing Suction Hopper

Dredgers are usually 186-188 dB re 1 µPa rms with the main energy between 100 and 500 Hz (CEDA 2011). The impact on underwater noise will be dealt with in the assessment on the respective factors.

Air Pollution
Ship emission and air pollution in connection with dredging and transport of sand to the construction site of the Fehmarnbelt Fixed Link, is calculated for an expected volume of 1 mill m^3. Total emissions cover dredging at Rønne Banke, transport between Rønne Banke and the construction site at the Fehmarnbelt Fixed Link, offloading and back in ballast. The distance to the construction site is approximately 220 km.

The total emissions of CO_2 are calculated to be between 7,400 and 11,600 tonnes, depending on dredger size. Dredgers of 6- or 10,000 m^3 are most likely to be used and the CO_2 emission is hence 8,500 and 7,400 tonnes, respectively.

Impact of pressures

This impact assessment is part of the environmental impact assessment for the Fehmarnbelt Fixed Link. The criteria for assessing the impact for the sand extraction is to the extent it is possible similar to the criteria used in Fehmarnbelt Fixed Link EIA. The assessment is based on the magnitude of the pressures relevant to the component and factors on which the pressure acts. The assessment is done based on expert judgement in a narrative and qualitatively way, weighting the pressure and the sensitivity of the component. The expert judgement is based on the best available knowledge and scientific studies.

Seabed and coastal morphology
The physical impact on the seabed will be of maximal 9 km^2. Considering the prevalent water depths most of the area can be expected to be recovered within 3-5 years and due to the dominating water depth in the extraction area of 15-20 m a period of 3 years are most likely. It is not expected that the seabed sediment sand fraction and hence the habitat type will change significantly, because all extracted material will be retained after extraction.

Toxic substances
Sediment dredging and disposal activities in Denmark are regulated according to the concentration of toxic substances in the sediments. All concentrations of toxic substances in the sediment at the shallow Rønne Banke is found to be lower than the accepted background values for sediment set by OSPAR except for TBT, which still is much lower than the L Ac set by the Danish EPA and therefore considered unproblematic. There is therefore no impact on the marine environment due to release of toxic substances from dredging activities.

Water quality
The changes in the seabed morphology are too limited to cause any changes in the hydrodynamic regime; meaning that there will be no changes in e.g. salinity, temperature, current and mixing. Consequently, no hydrodynamic based changes in nutrient and oxygen regime and processes will occur.

In the areas where a 0.5 to 1 m thick layer of sand is removed, reductions in oxygen concentrations can potentially occur. When the water column is well mixed and not stratified, oxygen depletion is unlikely. The sand minig takes place in 15-25 m depth. Measurements at a nearby monitoring station in the years 1998 to 2005 show that the water column can be very weakly stratified and oxygen concentration at 20 m depth is close to saturated in August and September months. It is therefore very unlikely that oxygen depletion will occur in the areas where the sand layer is removed.

As the content of organic material in the sediments (LOI) of the investigation area is very low (between 0.08% and 0.73% DW), sand extraction will not give raise to perceptible effects on the concentration of oxygen, nutrients, or chlorophyll a concentrations.

The effect of increased sediment in the water on the light availability for growth of phytoplankton is estimated to be very small because the extend and duration of increased sediment in the water are limited: In the surface water concentrations of 10 - 15 mg/l is expected within about 1 km from the mining area in up to 3% of the time (~ total of 4 days) and concentrations of 2 mg / L are expected in a few km distance in about 3% of the time.

There will hence not be an impact on the marine environment due to changes in water quality.

Benthic fauna
The loss of benthic fauna will happen as a consequence of the loss of seabed hence maximal 9 km^2 of benthic fauna will be lost. The recovery time for the benthic fauna is maximal 5 years. As the impact is temporary and the area relatively small the overall significance on benthic fauna community is low. The overall ecosystem function of the benthic fauna will not be lost as the Cerastoderma (Macoma) community is widely distributed in the Baltic Sea.

Fish
The impacts on the fish are due to the different pressures from the dredging activities, such as noise, increased suspended sediment concentration, deposition and removal of sediments. The most severe impact is the loss of seabed and hence food supply. Since the impact on the food is temporary the impact on the fish is also expected to be temporary.

Fishery
The impacts on the fishery are restricted to loss of fish within the extracted area, due to loss of food source for the fish. This impact is only expected to be occurring within a 5 year period, hereafter a re-colonisation of the benthic infauna and epifauna is expected. Furthermore, the fishery can be impacted due to fishery restrictions during dredging activities. The impact is low and only temporary within dredging periods.

Birds
The impacts on the non-breeding water birds and the migrating birds are negligible and minor, respectively. Despite the fact that the planned dredging site on Rønne Banke is located within 5 km distance from the SPA Pommeranian Bay holding the largest concentration of waterbirds in the German EEZ of the Baltic Sea only very small direct or indirect impacts on the conservation targets of the SPA are foreseen. The habitat displacement impacts and habitat change impacts on waterbirds in the extraction site will be very small (less than 200 Long-tailed Ducks and single individuals of divers and Black Guillemots). The impacts will mainly take place during winter and spring (November-April). Depending on the use of artificial lights on the dredging vessel collisions with migrating waterbirds and landbirds will take place during periods of low visibility. However, given the broad front migration at the site collision risks to migrating waterbirds from the dredging vessel should be expected to be at a low level.

Mammals
The planned sand extraction activities on Rønne Banke will have little impact on harbour porpoises and seals in the area. There are few animals in these areas and the sound levels are not assumed to affect the animals except at very close range. The impact on the marine mammals is so low that the impact is not significant.

Navigation and recreational interests
Only a smaller amount of ship traffic passes Rønne Banke. The extraction activities might cause changing of sailing routes during the extraction period. The impact is regarded as low. Because the area is not an area of recreational interest as such, the impact is regarded as negligible.

Natura 2000
Impact from Rønne Banke sand extraction on the Danish Natura 2000 sites is very unlikely. It is therefore not necessary to prepare an appropriate assessment for the Natura 2000 sites. Impact from Rønne Banke sand extraction on the German Natura 2000 sites is very limited (if any) and will therefore not affect the Natura 2000 sites or the designation basis significantly. It is therefore not necessary to prepare an appropriate assessment for the German Natura 2000 site.

Conclusion

The conclusion is that there will be an impact on the marine environment within the extraction area due to extraction and extraction activities. This is what would be expected. Outside the extracted area the impact is insignificant.

1 INTRODUCTION

1.1 Background

For the construction of the fixed link between Denmark and Germany across the Fehmarnbelt there is a demand for sand and gravel resources. The largest need is for the tunnel alternative, which requires 6 mill m^3 fill for backfilling of the tunnel trench and 1 mill m^3 for the tunnel element production. Thus this alternative forms the basis for this Environmental Impact Assessment (EIA) study.

Based on the existing information of the marine sand and gravel resource distribution in the Baltic Sea, Femern A/S has pointed out Kriegers Flak east of Zeeland and Rønne Banke southwest of the island of Bornholm as potential extraction areas for the construction works.

Prior to the selection of a potential extraction area for the Fehmarnbelt project, GEUS has performed an evaluation for Femern A/S of potential resource areas to be used as backfill materials and for the tunnel element production (Jensen 2009). The evaluation was based on existing data from Danish and German offshore areas and concluded that Rønne Banke will comply with the volume and quality of sand needed for the tunnel element production. The precondition for this EIA is therefore that the resources for the tunnel element production are extracted at Rønne Banke. Based on the investigation an extraction area was designated. The designated extraction area is approximately 9 km^2 and the area including the surrounding 500 m impact zone (*BEK 1452 of 15/12/2009*) the area is approximately 16.5 km^2 (Figure 2.1).

To document the volume and quality of the resource, new data has been acquired during the present study using seismic and acoustic methods followed by ground truthing from video and diver inspections, and collection of sediment samples by a grab. Furthermore, the biological condition of the resource area was investigated. The stations of the sediment and the benthic fauna and flora study were identical.

The present report presents the EIA study, investigating and assessing possible impacts on the environment from the sand extraction at Rønne Banke. The EIA for the Kriegers Flak extraction is reported in a separate report.

The quality of the resource has previously been documented, partly in connection with regional studies for raw materials, i.e. Anthonsen and Lomholt (1998), partly for aggregates for concrete production in connection with the construction of the Øresund Fixed Link (Lomholt and Jensen 1994, Lomholt 1994, Jensen 1992, Larsen 1992 and Binderup and Lomholt 1995).

Several habitat areas (Natura 2000 areas) are located in the vicinity of Rønne Banke. Furthermore, Rønne Banke has been under consideration for a potential wind farm location.

The resource mapping and the data sampling for the EIA have been executed in compliance with the departmental order of raw material ”Bekendtgørelse af lov om råstoffer” (lov nr. 950 of 24/09/2009) §20 together with the departmental order on permission to investigate and extract raw material from the seabed etc. ”Bekendtgørelse om ansøgning om tilladelse til efterforskning og indvinding af råstoffer fra havbunden samt indberetning af efterforskningsdata og indvundne råstoffer” (bek. nr. 1452 of 15/12/2009).

The EIA is done in compliance with Bek. 1452 of 15/12/2009 and the dept. order bek. nr. 126 of 04/03/1999 with changes bek. 1454 of 11/12/2007. The project is covered by § 1, stk. 1, pkt. 2, on raw material extraction of more than 5 mill m^3 in total. The extraction at Rønne Banke itself is only 1 mill m^3 but in total for the Fehmarnbelt project 7 mill m^3 is needed.

Screening of the potential impact on the Natura 2000-sites has been performed in compliance with the Habitats Directive which has been implemented in Danish law and administration through the departmental order "Bekendtgørelse om udpegning og administration af internationale naturbeskyttelsesområder samt beskyttelse af visse arter (bek. nr. 408 of 01/05/2007).

1.2 Objectives

The objective of the present study is to describe the baseline condition at the proposed extraction area and to assess the impacts caused by sand extraction, including impacts of sediment spill, deposition of spill, traffic and noise on water, flora and fauna, as well as fishery. Relevant surveys have been conducted to acquire data on the quality and volume of the Rønne Banke resource and to evaluate if the requirements for the production of the tunnel elements can be fulfilled, and to acquire data on benthic fauna.

Studies of possible spillage from the dredging activities and possible impacts on local habitats from the sand extraction operations on Rønne Banke have been assessed by FEHY (FEHY 2011). The key results are included in this report.

2 PROJECT DESCRIPTION

The need for sand fill for the tunnel element production is 1 mill m^3. Based on previous and new studies it is concluded that a designated extraction area of approximately 9 km^2 at Rønne Banke will comply with the volume and quality of sand needed for the project.

2.1 Rønne Banke

The investigated sand extraction area is situated on the eastern flank of Rønne Banke approximately 30 km south-southwest of the Bornholm Island (Table 2.1, Figure 2.1). The water depths are between 15 and 30 m. The distance to the construction site of the Fehmarnbelt Fixed Link is approximately 220 km.

Table 2.1 Coordinates for the extraction area at Rønne Banke

Longitude	Latitude
14° 29.04	54°49.23
14° 31.74	54°48.43
14° 31.49	54°46.66
14° 28.81	54°47.82

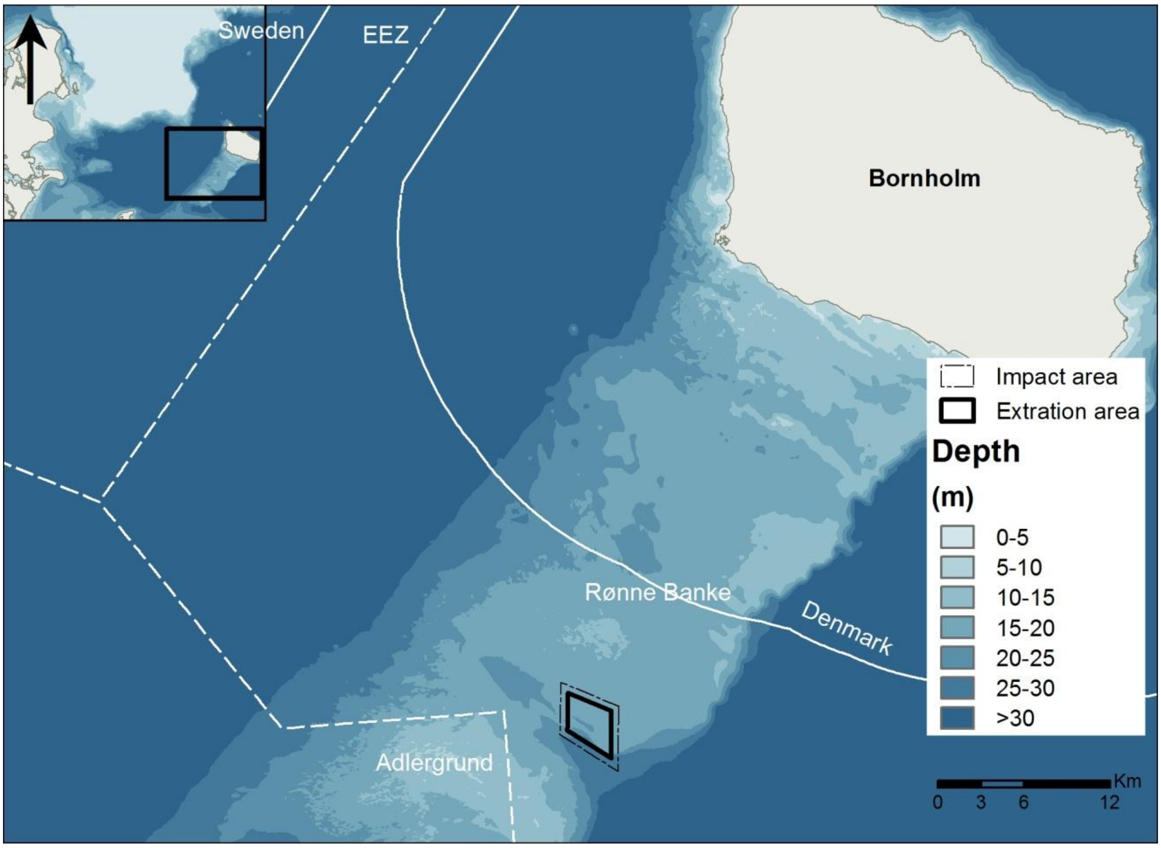


Figure 2.1 Area map of Rønne Banke with indication of extraction area and impact area.

The Rønne Banke is part of an elongated submarine ridge, formed by deep seated fault activities along the Fennoscandic Fault zone, uplifting blocks of Mesozoic rocks, covering the Rønne Banke-Adler Grund area. The initial deposition started in the late Weichselian, but the main part of the resource is deposits of marine or coastal sand formed during the post glacial marine transgression. The extraction area at Rønne Banke is part of a huge sand body with a layer thickness of up to 12 m within the area. The uppermost 1 m of Recent to Sub-Recent marine sand has been reworked several times due to the oscillating shore level during the late and postglacial period which consequently, in general, has resulted in the deposition of very well-sorted sandy sediment.

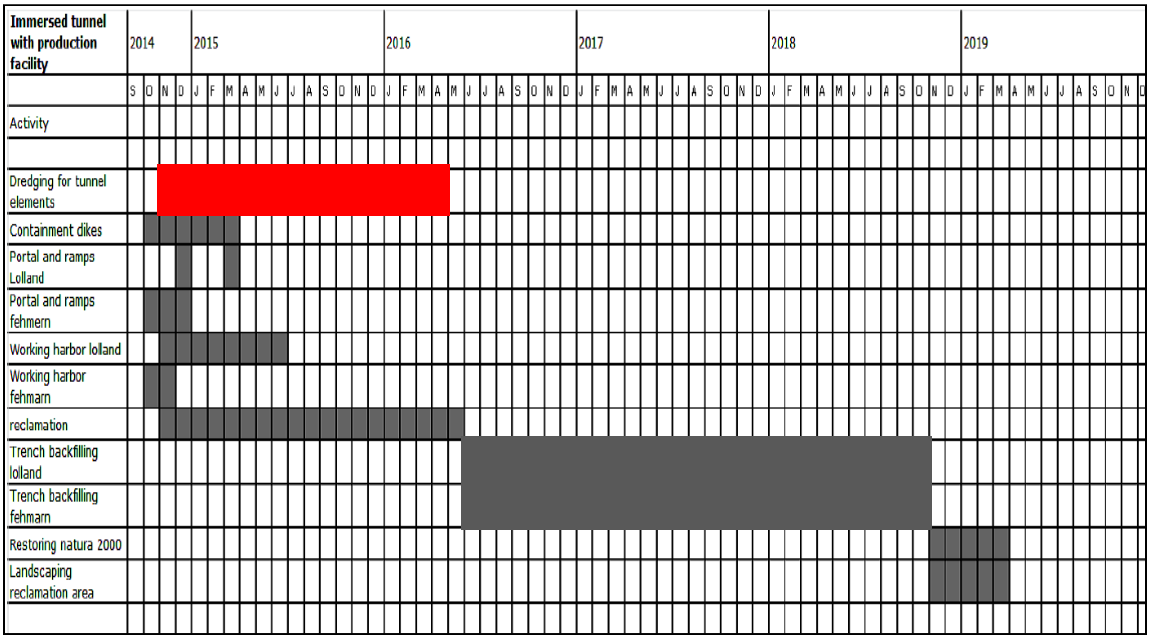
2.2 Methods and equipment used for sand extraction

The sand extraction can be performed by use of dredging vessels either stationary suction hopper dredging or by trailing suction hopper dredging. Both are hydraulic methods where water and sediment is sucked up via a tube by means of centrifugal pumps. Based on previous investigations and similar dredging activities in Danish waters it is expected that the extraction at Rønne Banke exclusively can be performed by trailing suction hopper dredging. The capacity of this type of dredger is typical 2,000-10,000 m^3 corresponding to a load of 1,500 to 7,500 m^3 sand. If a 10,000 m^3 dredger is used, about 135 cargos of sand have to be transported from Rønne Banke to the Fehmarnbelt Fixed Link construction site, and if a 2,000 m^3 dredger is used 670 cargos. After loading the dredging vessel with sand the load is transported to the construction area either by the dredging vessel itself or by reloading sand material to barges for transport. All material will be retained in the hopper, and hence not leaving boulders and stones at the seabed.

The dredging vessel is loading while the vessel slowly moves forward with a speed of typically 2 km/hour. The trailing suction method leaves the seabed with dredging scars of 1-2 m width and 0.5 to 1 m depth. This method is specifically applicable where the resource is relatively thin but has a wide areal distribution. To ensure a rational production procedure and manoeuvring for the vessel the resource area should have a considerable extent. The method has become the most common for extraction of sand and gravel in Denmark.

2.3 The dredging plan

Table 2.2 Time schedule for dredging activities. Red area indicates the dredging for material for the production of tunnel elements.



The dredging is planned to take place between November 2014 and April 2016. The overall time schedule for sand extraction is shown in Table 2.2.

The sand extraction will be a steady operation following the dredging tunnel element schedule However, the operation will be subject to downtime caused by the weather and thus the dredging rates will in periods be higher to keep the time schedule. It is expected that the dredger will work continuously day and night. When the dredger is full, the sand is transported to the project site. After this the dredger returns to the extraction site and resume the dredging activity. This will give 5 extractions per week.

2.4 Area of investigation

In agreement with the legislation for exploration and exploitation of marine raw materials issued by the Danish Ministry of Environment (*BEK 1452 of 15/12/2009)*, the environmental assessment study include apart from the extraction area an impact zone of 500 m surrounding the extraction area. Adding this to the extraction area of 9 km^2, the total the area is approximately 16.5 km^2 (The two areas are shown in Figure 2.2.).

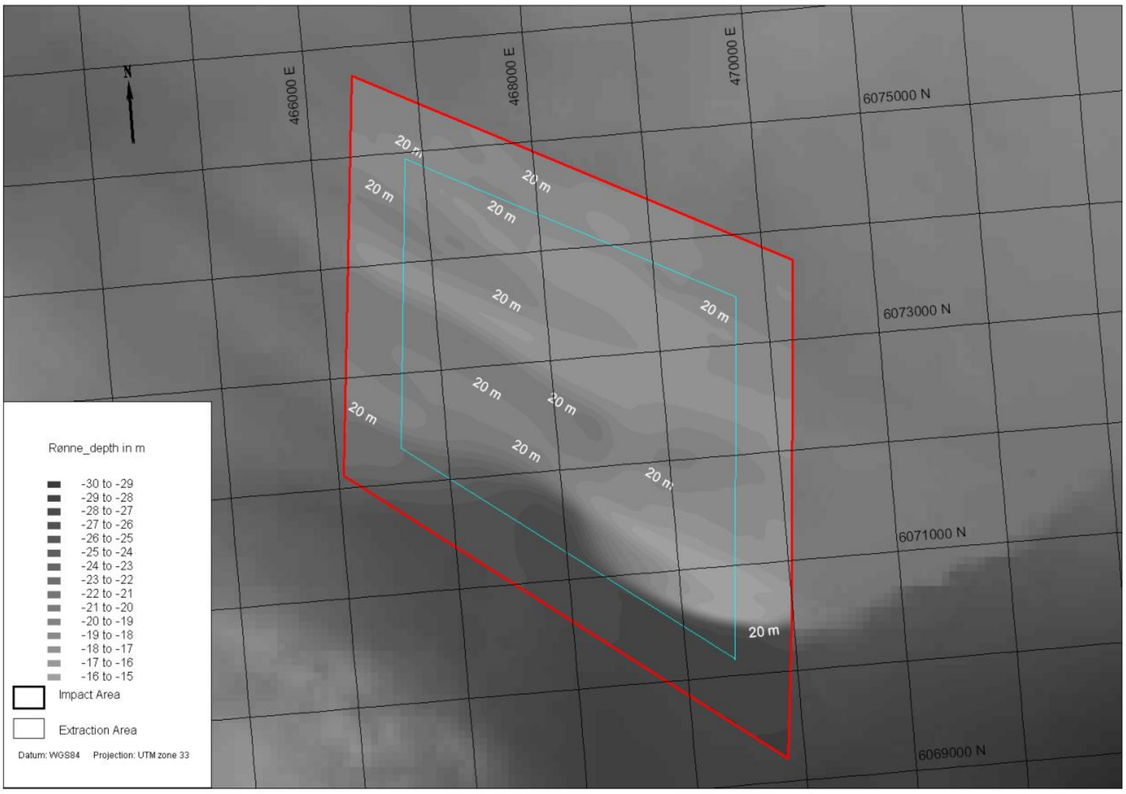


Figure 2.2 Area map of Rønne Banke showing the extraction and impact area together with the bathymetry data. An A3-version of the map is found in Appendix F.

2.5 Sand resource mapping at Rønne Banke

A seismic survey was performed during July/August 2011 with the purpose to document distribution, volume, composition and quality of the resources in the extraction area. The Femern A/S survey vessel *"JHC-Miljø"* was used as platform for this survey. Survey lines were planned with a grid of parallel lines with spacing in north-south direction of 75 m and in addition 5 northwest-southeast cross lines, in a 900 m grid. In total approximately 300 line kilometres and 16.5 km^2 seabed have been covered by the survey (Figure 2.3 and Appendix F).

To optimize the geological information of the resource two high resolution seismic systems were used in parallel: 1) The GeoSpark 200 sparker system (frequence interval 500-2000 Hz) with a penetration of 10-50 m and a vertical resolution of about 0.5 m; and 2) The combined Teledyne/Benthos SIS-1625 Chirp (1-10 kHz)/sidescan sonar system providing information of the uppermost part of the seabed with a penetration of 5-10 m and a vertical resolution in decimetres. As part of the post-processing the chirp data were converted to SEGY format to fulfil the required format for the interpretation software. Technical details on the seismic systems are compiled in Appendix E.

The newly acquired seismic data have been used to delineate the resource within the extraction and impact area. Processing and interpretation was done digitally by use of the interpretation software Geographix. The seabed and the lower horizon of the resource were digitized and the resulting (x,y,z) files exported as ASCII files from Geographix. The resource thickness was subsequently gridded using the MapInfo VerticalMapper gridding software. The resulting grid cell size used is 50 m.

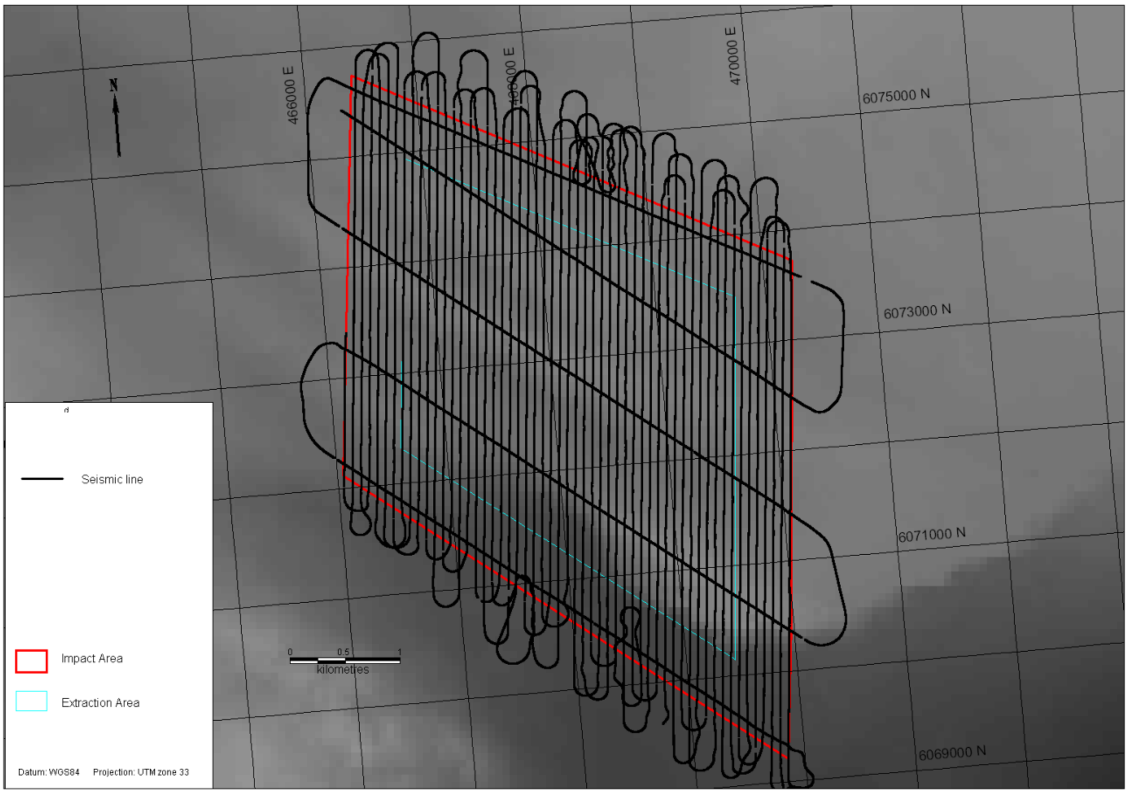


Figure 2.3 Survey lines covering the extraction and impact areas at Rønne Banke. An A3-version of the map is found in Appendix F.

2.5.1 Bathymetry data

Bathymetric data at Rønne Banke was acquired at all the survey lines using an Navisound 215 dual frequency single beam echosounder system. The logged data were corrected to the reference datum online. By that the post-processing included only filtering of outliers. All data were merged into a (x,y,z)-file and subsequently gridded by use of MapInfo Vertical Mapper software using the "Inverse distance weighting" interpolation method. The resulting bathymetric map is shown in Figure 2.2 and Figure 4.4. The depth within the extraction area varies between 15 and 30 m. The deepest area is towards the southeast in the direction of the Bornholmer Basin area. The extraction area has water depths from 15 to 25 m, with a steep slope to the deeper Bornholm Basin. The surrounding impact area has water depths from 15 to 30 m.

2.5.2 Side scan sonar mapping

To characterize and classify the seabed sediment with full coverage, acoustic data was acquired by use of a dual frequency side scan sonar (Teledyne/Benthos SIS-1625 system 100/400 kHz) covering 100 m to each side of the survey tracks ensuring a 125 % coverage of the seabed (Figure 2.3 and Appendix F). The side scan data were stored as XTF-files on board using the Triton-ISIS-software. During the post-processing the XTF-files were converted to geotiff files using the TritonMap software. Subsequently, these geotiff-files represent the individual side scan lines merged into a side scan mosaic (Figure 2.4 and Appendix F). The mosaic is used for seabed classification subdividing the seabed into classes of different reflectivity. To verify the initial classification, ground truthing at selected stations was performed in August 2011 using Van Veen grab and video inspections in connections to this project (Appendix A). The stations were the same stations as those used at the biological sample sites (Figure 4.8). Side Scan data present reflectivity of the seabed, fine grained sand is light in colour and coarse grained sand is darker colours. The seabed in the area is medium grained sand and it covers both light and darker colours. The ground truthing results supported that overall one seabed type is present.

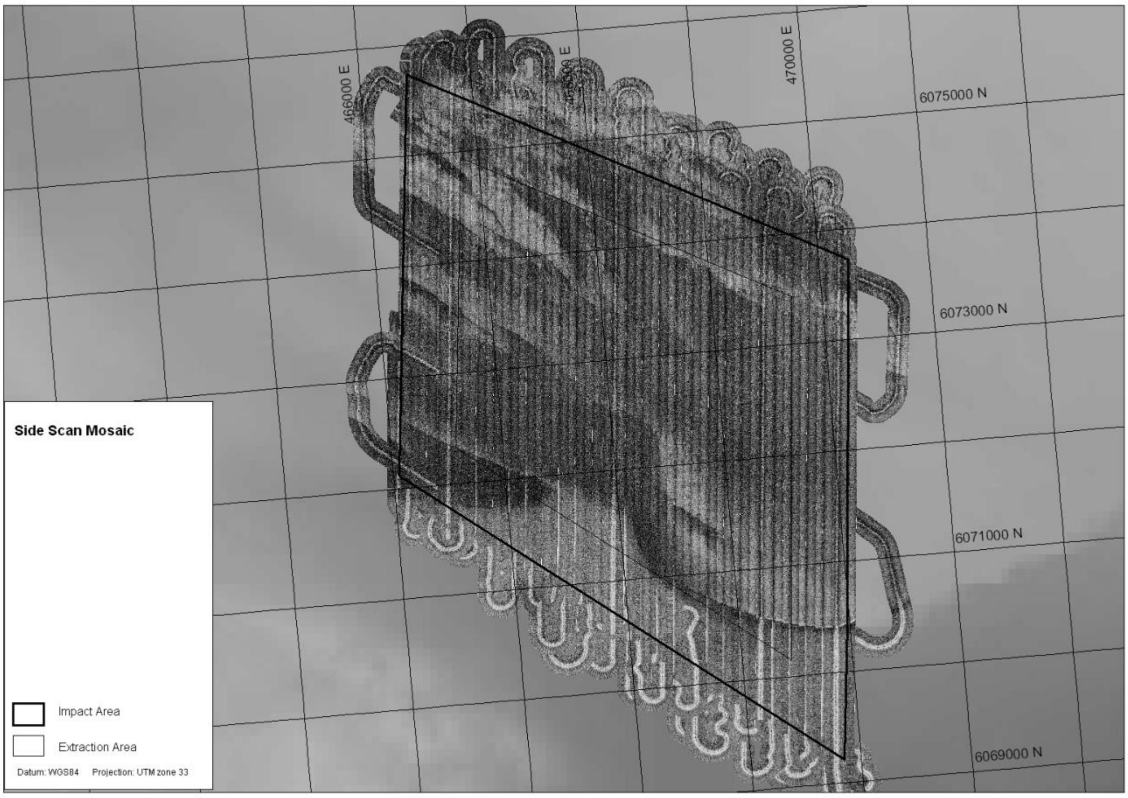


Figure 2.4 Side scan sonar mosaic of the Rønne Banke area. Light coloured area reflect a slightly change in sand grain size. The seabed in the area is medium grained sand and it covers both light and darker colours. An A3-version of the map is found in Appendix F.

2.5.3 Resources and extraction

The acquired seismic data have been used to delineate the resource within the extraction and impact area. Processing and interpretation was done digitally by use of the interpretation software Geographix.

The seabed and resource layers are interpreted together with significant geological horizons to get an overall picture of the distribution of the resources in the area. Five seismic examples from the area are used to illustrate the interpretation and mapping of the sand resources (Figure 2.5).

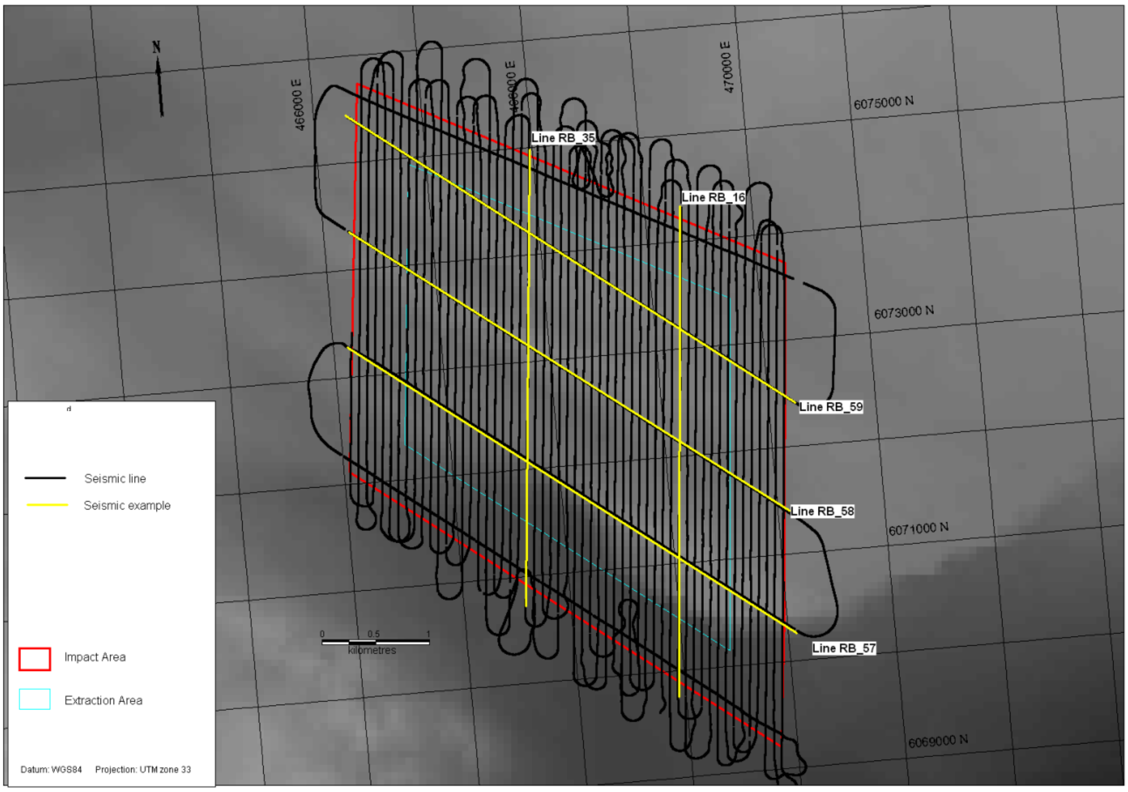


Figure 2.5 Location of seismic examples from the resource mapping at Rønne Banke. An A3-version of the map is found in Appendix F.

As mentioned above the main part of the resource is marine or coastal sand deposits formed during the post glacial marine transgression. The seismic lines is seen because the layer is up to 12 m thick and the uppermost 1 m of the Recent to Sub-Recent marine sand is continuously reworked due to wave and current activity. In the east-west direction the resource sand body increases in thickness from east towards west (Figure 2.6). The two sand bodies consisting of Recent sand and Holocene sand, are regarded as the main resource in the area. The maximum thickness of the sand resource is seen on the southernmost seismic lines RB 57. The deeper geological layer represents Pre-Quaternary sediments, folded by glacial tectonic. The glacial clay and sandy sediments are superseding the Pre-Quaternary layers with variable thicknesses. At the base of the Holocene sand a late glacial sandy/silty layer covers most of the area. It is expected that this layer is relatively coarse grained towards the west getting more fine-grained towards the east.

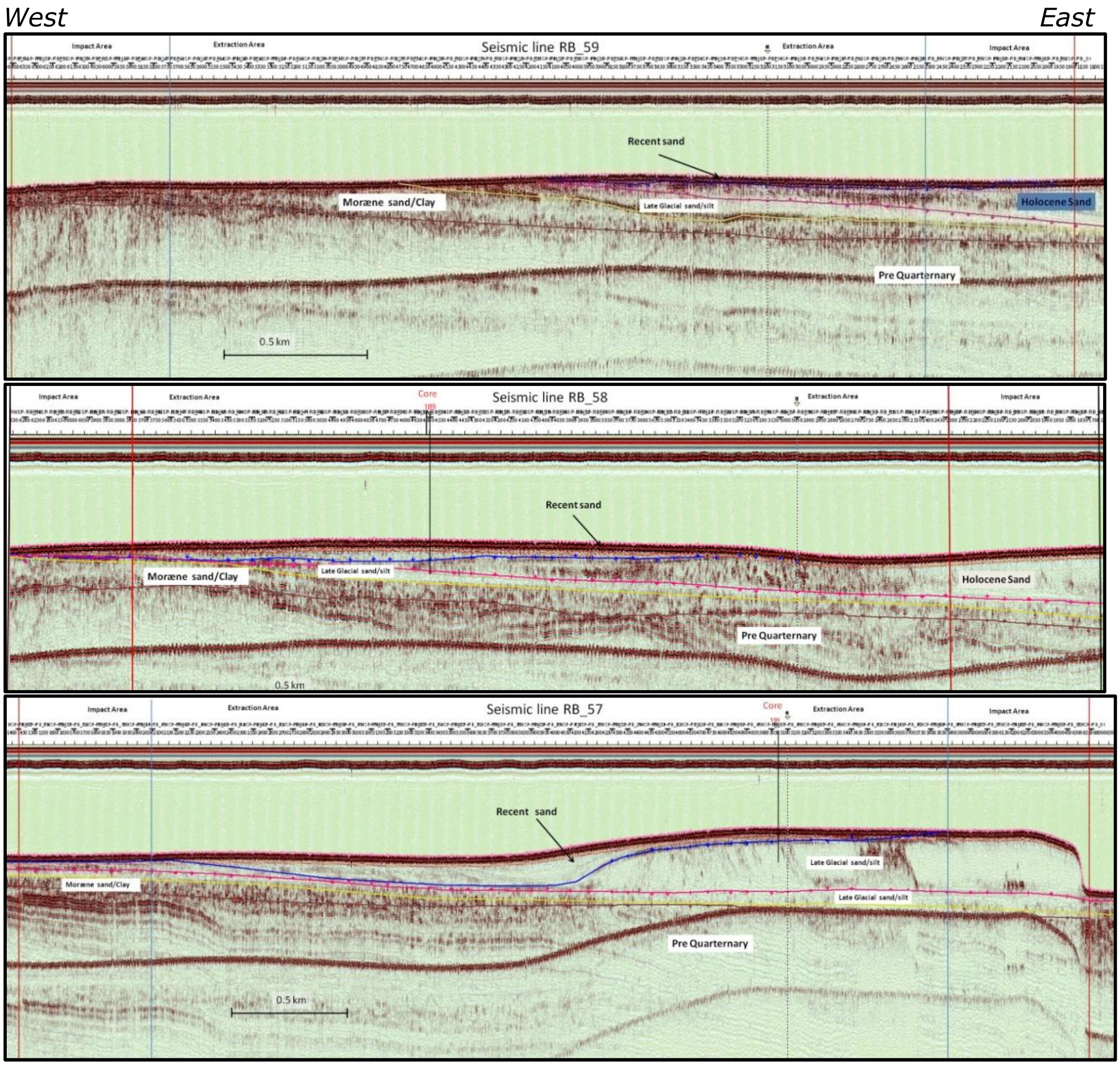


Figure 2.6 Seismic east-west sections of the lines RB_57, RB_58 and RB_59.

At the seismic section RB_57, the inclining reflectors in both sand bodies indicate the direction of sand transport. In the recent sand body a preferable sand accreditation direction is towards the East representing the overall west to east transport of sand. This transport direction is in accordance with the spill simulations for the sand extraction operations on Rønne Banke (FEHY 2011). A sand transport analysis is given in section 4.1.3.

The north-south seismic sections indicate that sand body increase in thickness from the North towards the South (Figure 2.7). The two sand bodies of Recent sand and Holocene sand can be recognised and mapped. In the Holocene sand layer the inclining reflectors in the sand bodies indicating direction of sand transport towards south. In the easternmost part of the area, the seismic profile RB_16, a very steep slope can be seen with no deposits at the foot of the slope, indicating that the material prograding downslope is removed by currents.

South *West*

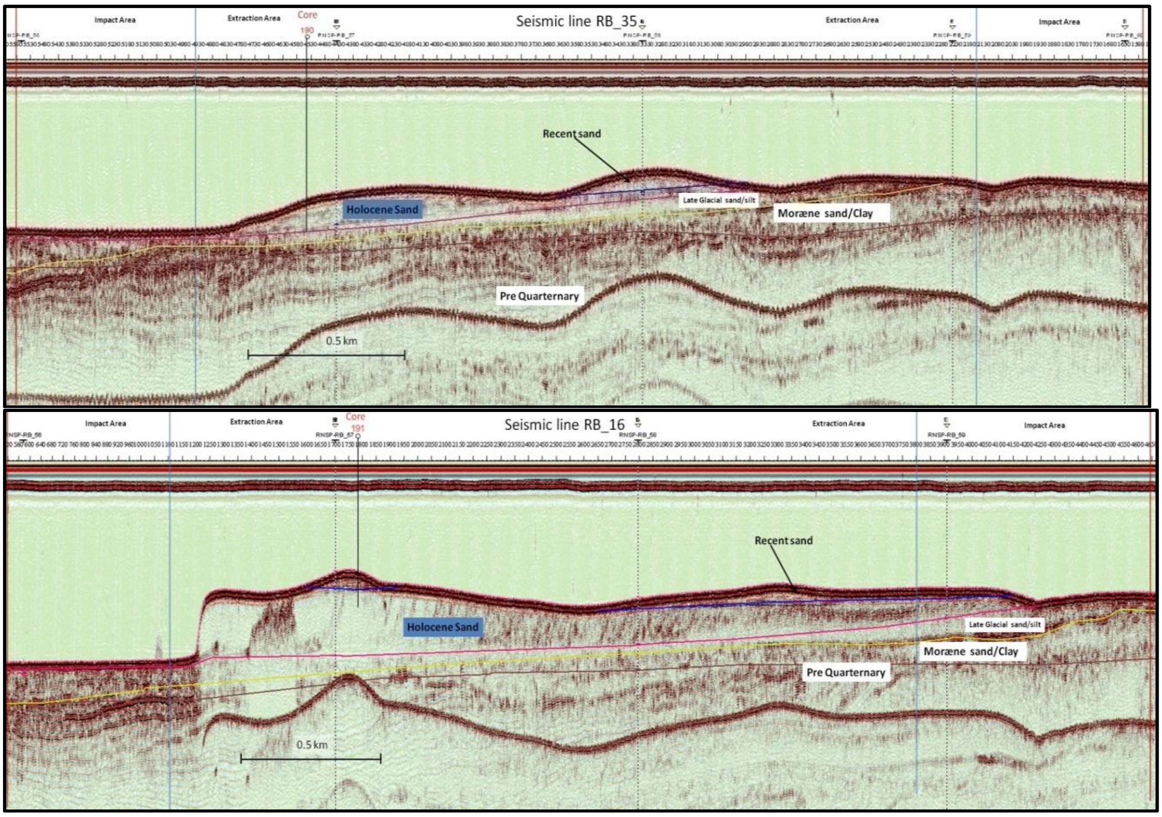


Figure 2.7 Seismic south-north sections of the line RB_35 and RB_16.

The seismic data are interpreted in Geographix program, and the seismic horizons interpreted in the programme are exported as (x,y,z) files for mapping.

The seabed and the base horizon of the sand resource are used as the top and the base of the resource respectively. The two layers are used to calculate the thickness of the sand body using the MapInfo Vertical Mapper gridding software to grid the two surfaces, and to prepare a thickness map. A two-way velocity of 1500 m/s has been used to depth conversion of the Isochore map to thickness map. The MapInfo is used for presentation and final design of the resource map (Figure 2.8).

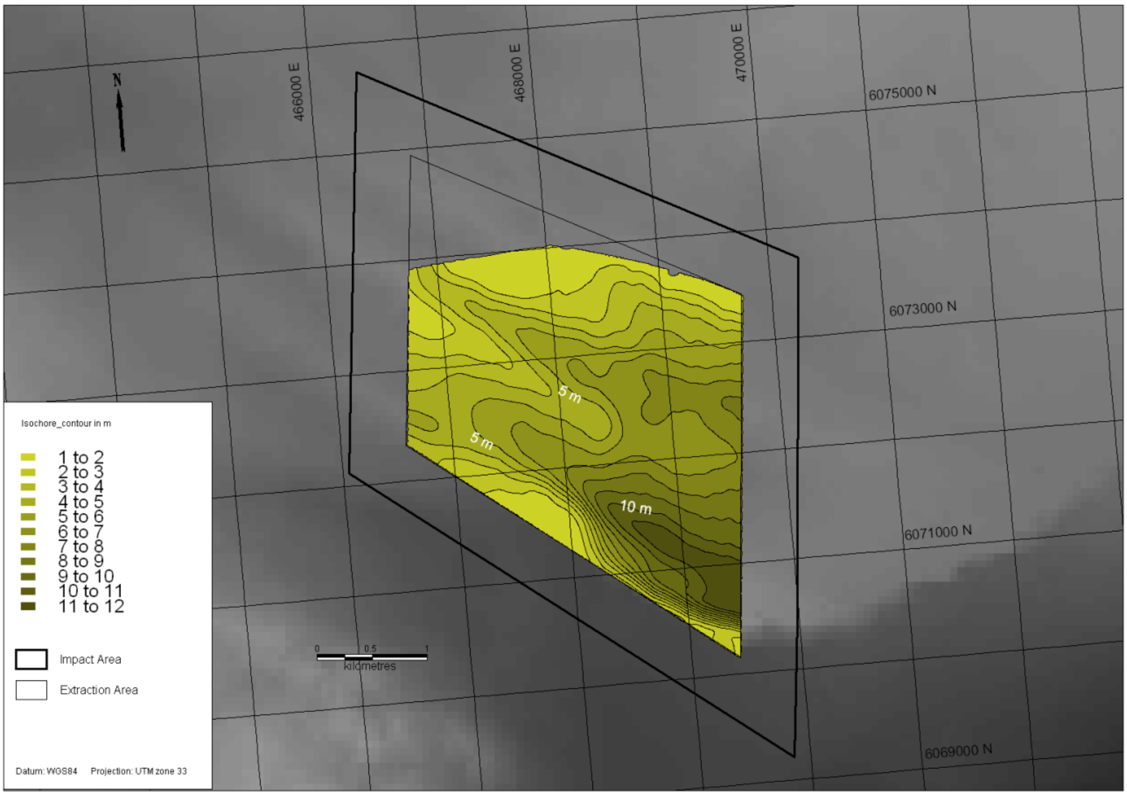


Figure 2.8 The resource volumes have been calculated for each thickness interval 0-1 m, 1-2 m until 11-12 m using the Surface Mapping Software Surfer. The details of the calculations are listed in Table 2.3. Isochore= resource thickness. An A3-version of the map is found in Appendix F.

Quantity

Maximum thickness of the resource is 12 m in the eastern part of the area. The total accumulated resource within the extraction area has been calculated to a total of 41.5 mill m^3. To fulfil requirements from the Danish Nature Agency (Naturstyrelsen) a residual sediment layer of at least 1 m should be left behind after completing the extraction taking into account that certain parts of the resource might have a content of gravel and stones along bedding planes. This leaves the available calculated resource to 33.6 mill m^3 (Table 2.3 column 4).

Table 2.3 Specifications of the mapped resource within the extraction area at Rønne Banke. 1: Resource thickness by 1 m intervals. 2: Volume of intervals, 1000 m^3. 3: Accumulated available resource, 1000 m^3. 4: Actual available resource per depth interval, 1000 m^3.

1	**2**	**3**	**4**
Thickness interval (m)	**Volume (10^3 m^3)**	**Accumulated vol. (10^3 m^3)**	**Resource (10^3 m^3)**
0-1	7,901	7,901	0
1-2	7,446	15,347	7,446
2-3	6,486	21,832	13,932
3-4	5,566	27,399	19,498
4-5	4,517	31,916	24,015
5-6	3,412	35,328	27,428
6-7	2,450	37,778	29,878
7-8	1,476	39,254	31,353

1	2	3	4
Thickness interval (m)	**Volume (10^3 m^3)**	**Accumulated vol. (10^3 m^3)**	**Resource (10^3 m^3)**
8-9	1,408	40,662	32,761
9-10	312	40,974	33,073
10-11	400	41,374	33,473
11-12	142	41,516	33,615
Total	0	41,516	33,615

Quality
The sand resource at Rønne Banke shall be used as aggregate for concrete production and the quality of the resource has been analysed for porous reactive-silica aggregate.

The quality of concrete can be subdivided into 3 groups: a passive, moderate and aggressive (harsh) environmental class. For the construction of tunnel elements it is expected that the aggregate shall comply with the aggressive (harsh) environmental class. The content of porous reactive-silica aggregate such as white flint in the aggregate shall be less that 2%. Four existing 6 m-vibrocores from the GEUS storage, located inside the extraction area (Figure 2.9), have been sampled for sand material used for analysing dense, porous chalcedon flint and porous opal flint. Seventeen samples have been collected from the cores representing sand materials from 0 m to a depth of 3.7 m below seabed. The analysis has been performed by the consultant company PELCON, and the complete report is presented in Appendix E, following the methods for petrographic investigation of sand in accordance with TI-B 52 standard.

Results from analysis are presented in Table 2.4. The total content of porous flint varies between 0.0 and 0.3 % for the grain size group 0-4 mm. It is concluded that the sand material at Rønne Banke fulfil the requiremens for content of porous reactive-silica aggregate such as white flint (less than 2% in aggregate).

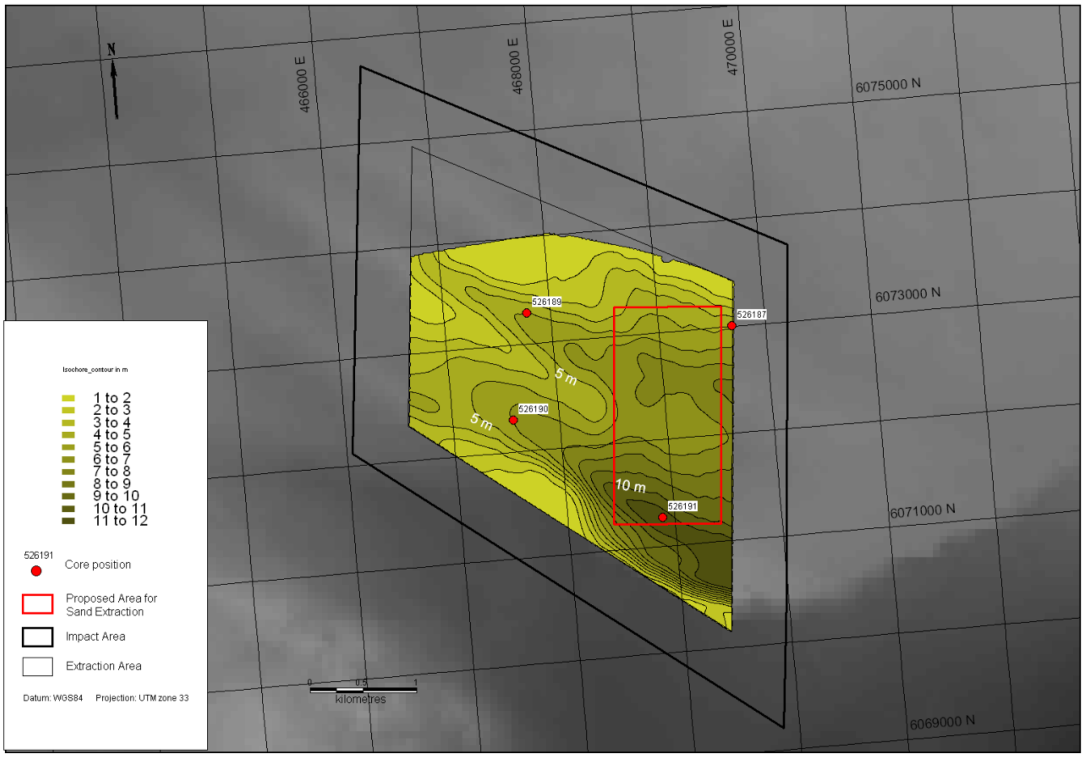


Figure 2.9 *Core positions for sampling of material for testing and analysis. Isochore=resource thickness. An A3-version of the map is found in Appendix F.*

Table 2.4 *Samples for analysis of dense, porous chalcedon flint and porous opal flint.*

1 Sample no	2 Depth Interval (m)	3 Core no	4 Fraction (mm)	5 Total Porous Flint (%)
1	0.00-0.20	526187	0-4	0.1
2	0.80-1.00	526187	0-4	0.0
3	1.80-2.00	526187	0-4	0.3
4	0.00-0.20	526189	0-4	0.0
5	0.60-0.80	526189	0-4	0.1
6	1.40-1.60	526189	0-4	0.1
7	2.40-2.60	526189	0-4	0.1
8	3.40-3.60	526189	0-4	0.0
9	0.00-0.20	526190	0-4	0.1
10	0.50-0.70	526190	0-4	0.0
11	1.50-1.70	526190	0-4	0.0
12	2.50-2.70	526190	0-4	0.0
13	3.50-3.70	526190	0-4	0.0
14	0.00-0.20	526191	0-4	0.0
15	0.80-1.00	526191	0-4	0.0
16	1.80-2.00	526191	0-4	0.1
17	2.80-3.00	526191	0-4	0.0

Extraction area

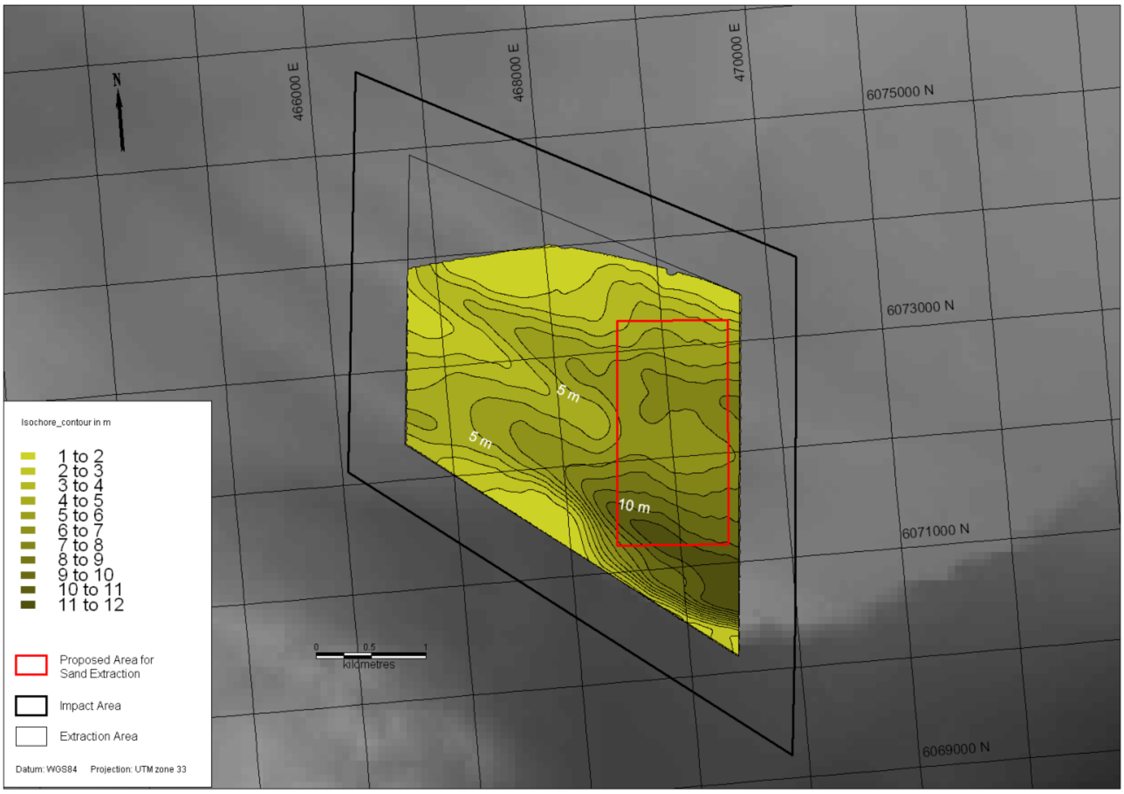


Figure 2.10 Proposed sand extraction area at Rønne Banke marked with red rectangle. Isochore=resource thickness. An A3-version of the map is found in Appendix F.

It is proposed that the extraction of 1 mill m^3 aggregate for the construction work could take place inside an sub-area of 1 x 2 km in the eastern part of the area. This will leave this part of the area after extraction with an increased water depth less than 1 m (Figure 2.10). Furthermore, the deposited material for extraction is of late Holocene age and, by that, of no potential interest with respect to marine archaeology like Stone Age settlements. Layers from this period are expected to be covered by at least 4 m of sand inside the proposed extraction area.

3 ALTERNATIVE RESOURCES AND RAW MATERIAL MARKET

In this chapter alternative areas for extraction of 1 mill m^3 sand for the production of tunnel elements for the Fehmarnbelt Fixed Link are described and assessed. The 0-alternative is the alternative where the resource is delivered from onshore sand pits instead of marine resources. The description of the alternatives is based on Jensen (2009). Marine alternative areas for the extraction are local designated marine sand extraction areas on the German and Danish continental shelf in the Baltic region.

In general, the German and the Danish resources are dedicated for local use in the region and more intensively investigations are required if an increase in resources inside these areas should be mapped and made available for construction of the Fehmarnbelt Fixed Link. Both quality and volume of producible resource in the areas are uncertain.

3.1 Marine resources in the German Sector

On the German continental shelf in the Baltic Sea region two well-known sand resource areas are described: The Plantagenet Ground and the Adler Grund (Figure 3.1).

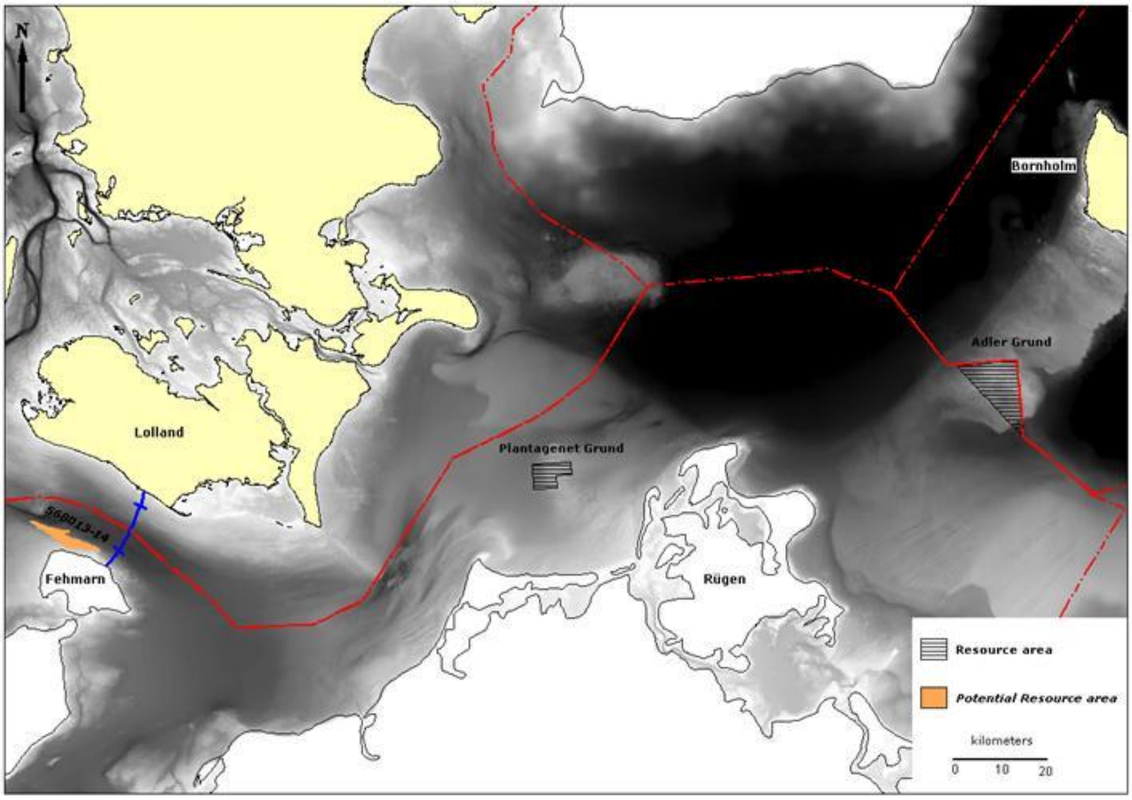


Figure 3.1 Resource areas in the German sector. Blue line indicates the alignment of the Fehmarnbelt Fixed Link.

The Plantagenet Ground near the Rügen Island is a sand and gravel resource of 10 mill m^3. The distance from the area to the Fehmarnbelt Fixed Link is approximately 110 km. The area is partly covered by a Habitat and Bird protection and the resources are used for beach nourishment.

The Adler Grund south west of the Bornholm Island has sand and gravel resources of 10 mill m^3. The distance from the area to the Fehmarnbelt Fixed Link is approximately 220 km. The area is partly covered by SAC and SPA restrictions.

Furthermore two potential sand resource areas are described nearby the Fehmarnbelt Fixed Link corridor: Resource area 568013 and 568014 (marked as potential resource areas in Figure 3.1). The two areas have sand resources of the magnitude of respectively 30 and 45 mill m^3 (Table 3.1). The resources are fine to medium grained sand. Both areas are conservation areas covered by SAC and SPA restrictions. The distance from these areas to the construction site are less than 20 km.

Table 3.1 Details of the two resource areas nearby the Fehmarnbelt Link corridor. (Res. = Resource).

Area	**Res. Volume**	**Res. Thickness**	**Water depth**	**Resource quality**	**Comments**
	mill m^3	m	m		
568013	30	2 – 5	7- 15	Sand Fine-Medium	Environmental Protection
568014	45	1 – 2	15 – 25	Sand Medium-Coarse	Environmental Protection

It is uncertain if the resources described can fulfil the quality requirement of aggregate sand.

3.2 Marine resources in the Danish Sector

On the Danish continental shelf in the Baltic region five existing resource areas are located within a distance of 55 km from the construction area: Vejsnæs Flak, Keldsnor, Rødbyhavn, Gedser and Gedser Rev (Figure 3.2).

The accumulated resource of these areas is approximately 1 mill m^3 of sand (Figure 2.8). Additional resources of between 5 and 10 mill m^3 are documented, but to exploit this resource more documentation of the resource volume and quality are required and an increase in production from the five areas has to pass the parliament. None of the areas are covered by SAC and SPA restrictions.

Further 13 potential sand resource areas (Table 3.2) are mapped in the Fehmarnbelt region. The resource thickness varies between 1 and 3 m. Therefore, if 1 m should be left at the seabed, to preserve the original habitats, the potential resource will decrease drastically.

One area, 568009-11, with a potential resource of 10 mill m^3 is located nearby the construction site for Fehmarnbelt link. It has thin resource thickness of 1-3 m, and needs thorough investigations with the very likely result of less available resource volume for dredging.

Table 3.2 Potential sand resource areas in the Fehmarnbelt region. (Res. = Resource).

Area	**Res. volume** mill m^3	**Res. thickness** m	**Water depth** m	**Ressource quality**	**Comments**
568001	30	2	10 - 20	Sand Fine-Medium	Existing dredging
568002	20	1	6 - 10	Sand Medium	Cables and Ferries
568003	2	1	4 - 8	Sand Fine-Medium	Shallow Water
568004	2	1	4 - 6	Sand Fine-Medium	Wind Farm
568005	2	1	6 - 8	Sand Fine-Medium	Wind Farm
568006	10	1	6- 8	Sand Fine-Medium	Wind Farm
568007	15	2	4 - 10	Sand Fine-Medium	Wind Farm
568009-11	10	1 - 3	12- 18	Sand Medium	Fehmarnbelt trace
568012	3	1 - 2	18 - 22	Sand	Uncertain resource
568015	10	2	18 - 24	Sand Fine-Medium	Environmental Protection
568016a	5 - 10	2	12 - 18	Sand Fine-Medium Coarse	Environmental Protection
568016b	3	1 - 2	8 - 12	Sand – gravel	Environmental protection
568017	3	1	15	Sand	

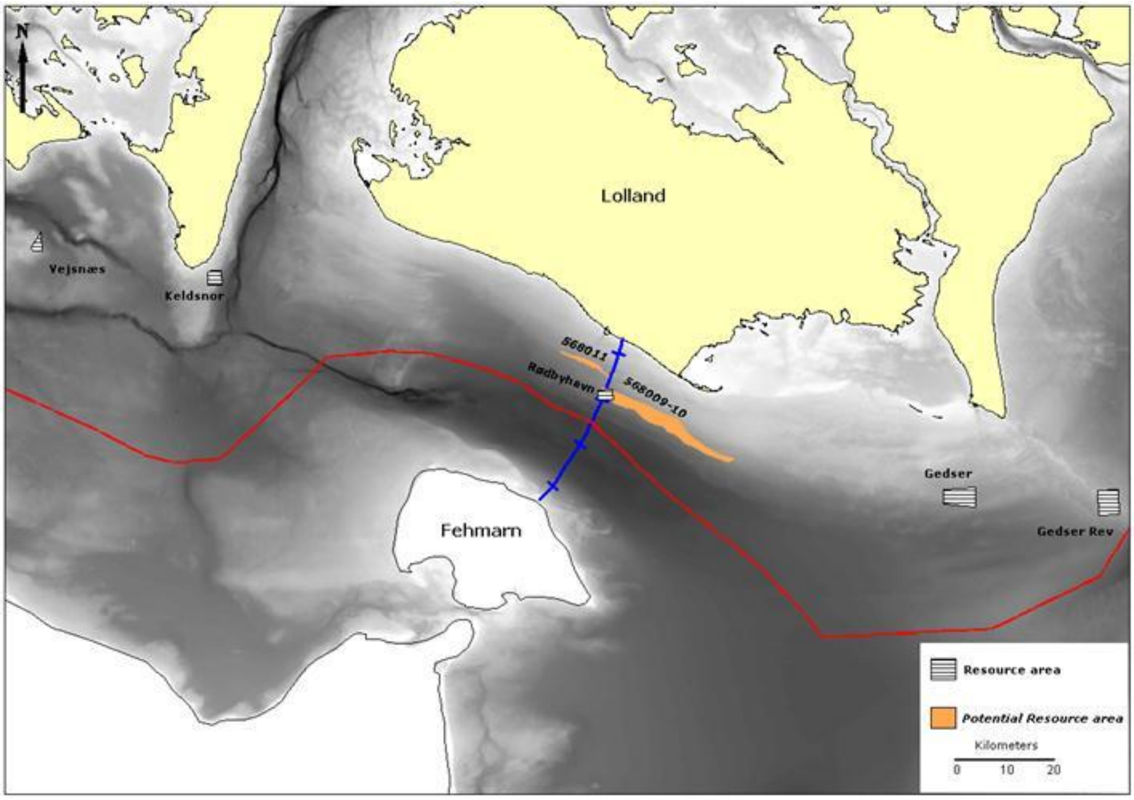


Figure 3.2 Resource areas in the Danish sector. Blue line indicate the alignment of the Fehmarnbelt Fixed Link.

3.3 Onshore resources in the Danish sector

The alternative to marine sand extraction is to retrieve the required raw materials for construction of the Fehmarnbelt Fixed Link onshore from local sand and gravel pits.

Available raw material resources in the southern part of the Danish Island Zeeland and surrounding islands has been estimated in 2006 and constituted approximately 12.5 mill m^3 resources left in sand and gravel pits (Lomholt and Jacobsen 2006). Most of the onshore production, 0.5 mill m^3 per year is used for high quality concrete. The resources left in 2013 are most likely less than 10 mill m^3 - assuming that no new onshore resources have been discovered since 2006 as the probability of this is low.

Considering the total demand for fill and aggregate materials for the construction Fehmarnbelt Fixed Link of 6 mill m^3 sand and the requirement for materials for local constructions and buildings, it can be concluded that local land materials are not a possibility for the resource demand for the Fehmarnbelt Fixed Link.

3.4 Other resources

Sand and gravel resources from the fixed link, such as dredged material from the tunnel trench or other project structures, cannot be used as backfill material etc. The material does not meet the standards and requirements compulsatory to the source.

3.5 0-alternative

In case of not building the Fehmarnbelt Fixed Link there will be no effect on the marine environment from sand extraction.

4 BASELINE DESCRIPTION

4.1 Seabed, bathymetry and sand transport processes

4.1.1 Seabed substrates

Previous sediment analyses (e.g. Anthonsen and Lomholt 1998) indicate that the seabed sediment of this part of the Rønne Banke consists of well sorted homogeneous medium sand. The present study indicated that the surface sediment is medium to coarse grained (Table 4.6).

With an integrating of the acoustic data set and the ground truth data (Chapter 3) the seabed material can be classified into sediment/substrate types following the classification system introduced by the Danish Nature Agency (Naturstyrelsen):

- Type 1: Sand: Areas comprising primarily of sandy substrates with variable amounts of ripples etc. < 1 % gravel and pebbles.

- Type 2: Sand, gravel and pebbles: Areas comprising primarily of sand with variable amounts of gravel and pebbles, and with few scattered stones < 5 %.

- Type 3: Sand, gravel, pebbles and scattered stones covering 5 - 25 %: Areas comprising of mixed substrates with sand, gravel and pebbles with variable amount of larger stones.

- Type 4: Stones covering approximately more than 25%: Areas dominated by larger stones (stone reefs) with variable amounts of sand, gravel and pebbles.

The video inspection of the seabed (Appendix D) shows that nearly the entire seabed in the area is covered by sand with no or only very little indication of sand transport and seabed features derived from seabed transport. Only substrate Type 1 has been recognised in the area (Figure 4.1). Sand ripples have only been recognized on side scan data in a limited area to the southwest. The resolution of the mapping is 50x50m, which has been found to be optimal for interpretations of sidescan data (Leth & Al-Hamdani 2012). By that the seabed in the extraction area and the surrounding 500 m impact area is classified as substrate type 1, medium grained sand with an average grain size between 0.2 and 0.5 mm with some content of gravel and coarser fractions.

To the north of the area recent dredging activity has taken place, leaving the seabed with plenty of scars and spill cones from sand extraction activities (Figure 4.1). In the north-eastern part the area thin medium grained sand covers the seabed, and the structure of late-glacial sediment surface beneath this thin sand cover can be seen at the seabed (Figure 4.1). In the southern area the seabed is covered with medium sand with average grain size around 0.2 mm, at deeper water levels.

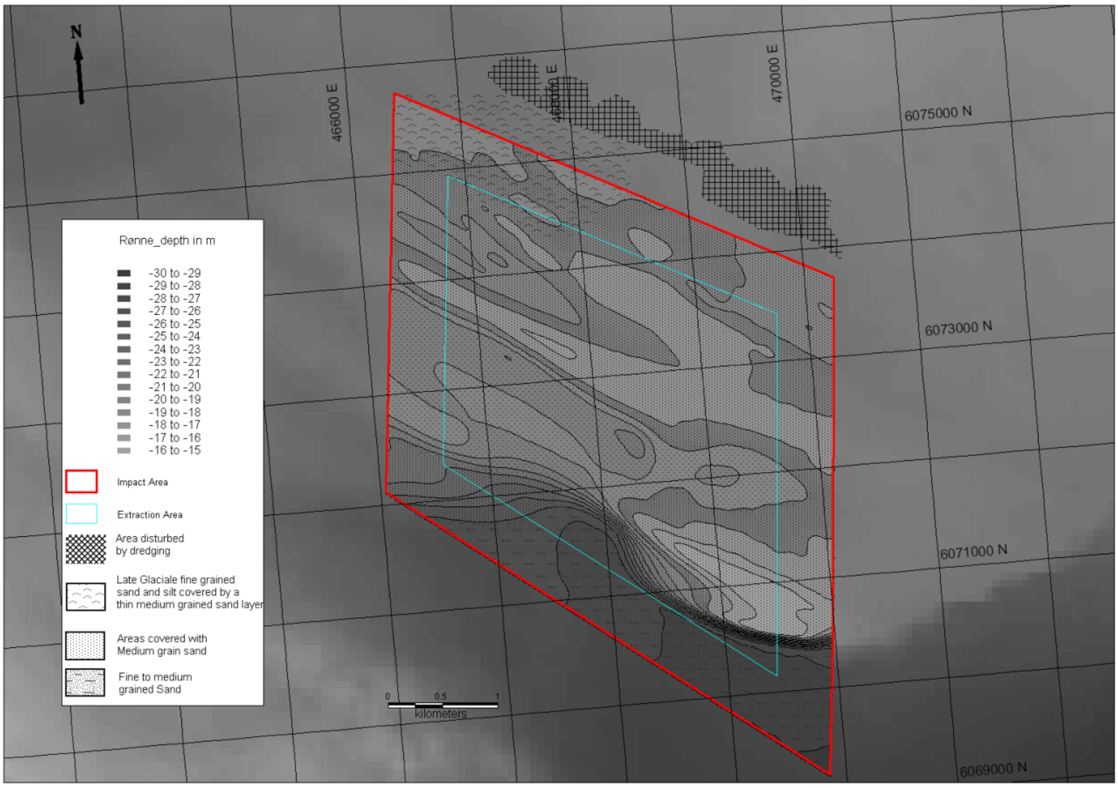


Figure 4.1 Seabed sediment map of the extraction and 500 m impact areas showing the different types of sandy seabed and areas of lag deposits of gravel and cobbles. An A3-version of the map is found in Appendix F.

The video inspection of the seabed shows that part of the seabed in the area is covered by sand ripples in the order of magnitude of decimetres, see photo in Figure 4.2. However, no sand waves or other mega seabed features have been recognized on side scan data from the area.

At few locations the seabed is characterized by the presence of scattered coarse sediments, see photo in Figure 4.3.

Figure 4.2 Photos from the video survey at Rønne Banke, relatively large sand ripples. Photo from video inspection (August 2011).

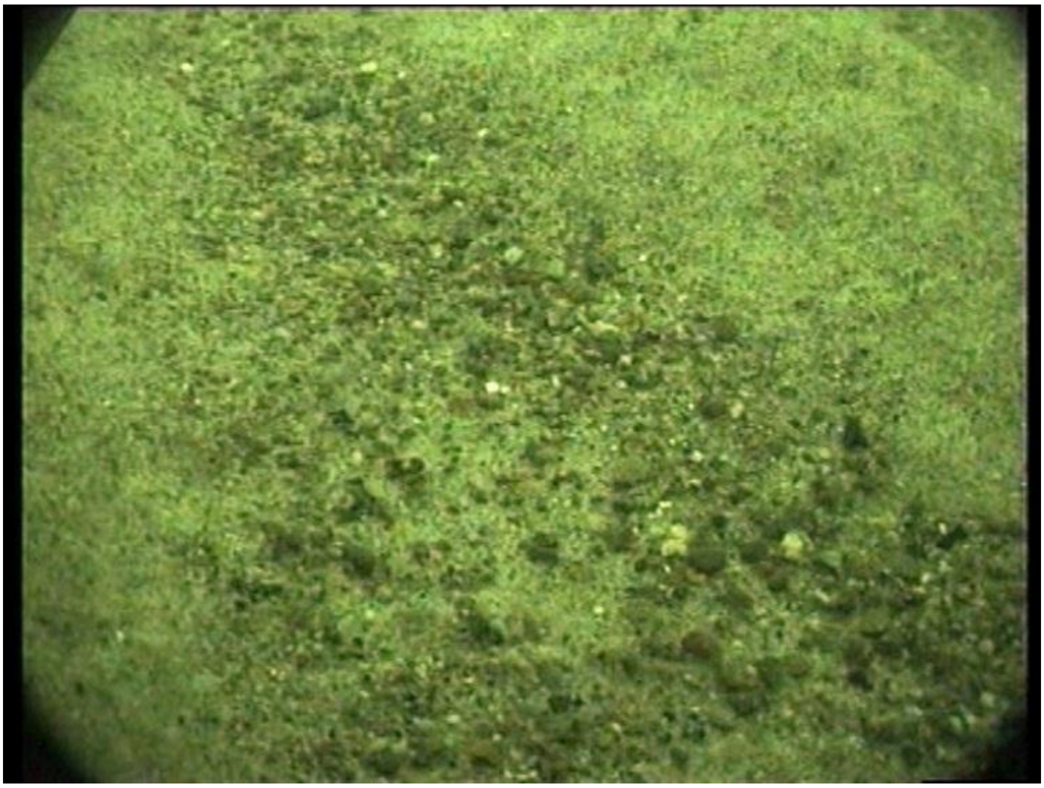


Figure 4.3 Photos from the video survey at Rønne Banke, coarse sediments at the seabed. Photo from video inspection (August 2011).

4.1.2 Bathymetry

The depth at the submarine ridge formed by Rønne Banke and Adler Grund is in generally in the range between 10 and 20 m, however with depths as shallow as 5 m at Adler Grund, see Figure 2.1. The sill separates the Arcona Basin to the west and the Bornholm Basin to the east. A close up of the depth conditions adjacent to and in the extraction area is presented in Figure 4.4. It is seen that the extraction area is located at a south facing slope between Rønne Banke and Adler Grund with depths ranging between 15 and 30 m.

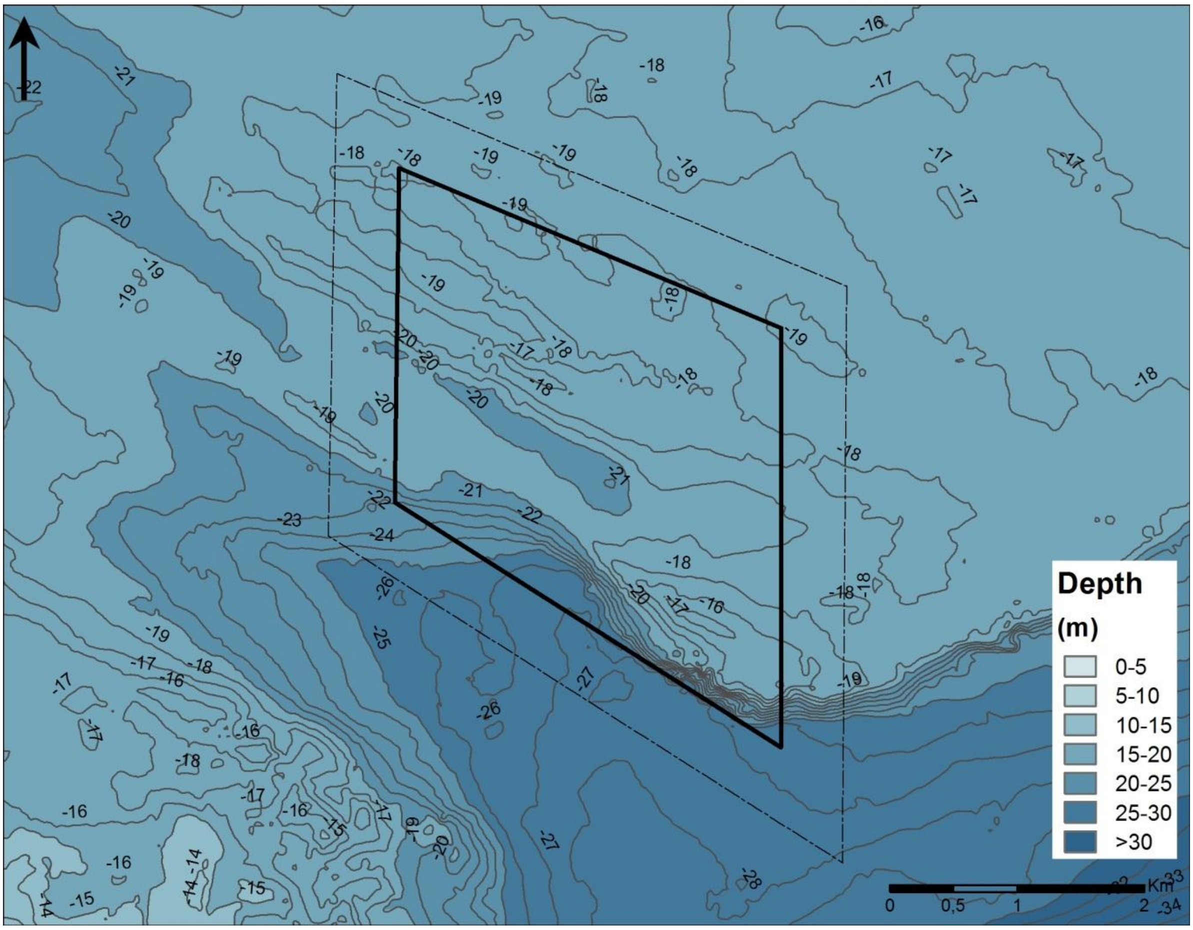


Figure 4.4 Bathymetry at Rønne Banke.

4.1.3 *Sand transport processes*

The transport capacity in the extraction area has been computed using the sediment transport module MIKE 21ST (Mike by DHI 2011). The ST model is based on a deterministic intra-wave formulation of sediment transport computation which calculates the sediment transport rate on basis of given flow and wave fields and it is able to resolve the effects of sediment characteristics such a grain size distribution, sediment fall velocity and density. The following data have been used as basis for the computations:

- Depths of the area, two characteristic depths of 18 and 20 m have been used
- An average mean grain size of d_{50} = 0.45 mm
- Characteristic wave and current conditions and their durations have been extracted from Table 4.2 and Table 4.3 (see below).

It is evaluated that the uncertainty introduced by computing transport capacities on basis of characteristic depths, average seabed sediment characteristics and characteristic wave and current conditions are of minor importance relative to the uncertainty introduced by the lack of information about seabed characteristics.

Wave conditions

The sand transport conditions depend, among other things, on the wave conditions as mentioned above. Data on the wave conditions, for the transport computations have been extracted from the regional model runs conducted in connection with the baseline assessment of the Fehmarnbelt Fixed Link (FEHY 2013). The data covers the period 1.1.1989 to 30.04.2010. They are extracted for the model cells covering the extraction and 500 m impact zone. A wave rose from Rønne Banke is presented in Figure 4.5. The data behind the wave rose is shown in Table 4.1 giving the wave heights vs. directions.

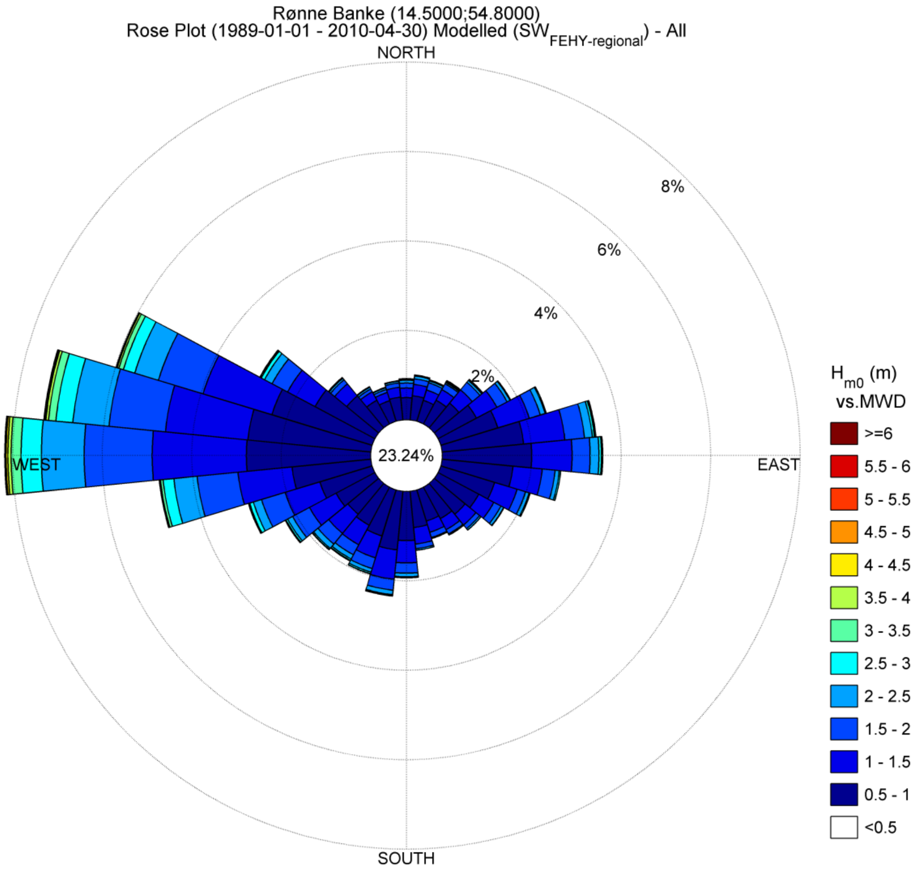


Figure 4.5 Wave rose form Rønne Banke for the period: 1.1.1989 to 30.04.2010. From FEHY Regional SW model (FEHY 2013).

The predominant waves are from W to NW and from easterly directions Figure 4.5.

Table 4.1 Table of wave heights (H_{m0} in meter) vs. directions from Rønne Banke 1 January 1989 to 30 April 2010.

Rønne Banke (14.5000;54.8000)
Percentage Occurence (1989-01-01 - 2010-04-30) Modelled ($SW_{FEHY\text{-}regional}$) - All

H_{m0} (m)

MWD (°N-from)

	[0-0.5[	[0.5-1[	[1-1.5[	[1.5-2[	[2-2.5[	[2.5-3[	[3-3.5[	[3.5-4[	[4-4.5[	[4.5-5[	[5-5.5[	[5.5-6[	[6-6.5[	Total	Accum
[-5.625-5.625[	0.434	0.496	0.216	0.112	0.064	0.021	0.008	0.004	0.000	0.001	0.000	0.000	0.000	1.355	1.355
[5.625-16.875[	0.400	0.545	0.256	0.124	0.064	0.016	0.005	0.003	0.003	0.000	0.000	0.000	0.000	1.414	2.769
[16.875-28.125[	0.425	0.490	0.244	0.167	0.045	0.014	0.011	0.002	0.000	0.000	0.000	0.000	0.000	1.398	4.166
[28.125-39.375[	0.365	0.603	0.271	0.148	0.032	0.022	0.013	0.009	0.006	0.001	0.000	0.000	0.000	1.470	5.637
[39.375-50.625[	0.481	0.718	0.384	0.220	0.052	0.025	0.010	0.001	0.000	0.000	0.000	0.000	0.000	1.890	7.527
[50.625-61.875[	0.538	0.974	0.517	0.260	0.071	0.005	0.013	0.002	0.000	0.000	0.000	0.000	0.000	2.380	9.907
[61.875-73.125[	0.746	1.333	0.735	0.257	0.114	0.025	0.003	0.000	0.000	0.000	0.000	0.000	0.000	3.214	13.121
[73.125-84.375[	0.986	1.830	0.928	0.442	0.177	0.047	0.022	0.010	0.004	0.000	0.000	0.000	0.000	4.445	17.566
[84.375-95.625[	1.000	1.998	0.903	0.404	0.197	0.056	0.027	0.004	0.000	0.000	0.000	0.000	0.000	4.589	22.155
[95.625-106.875[	0.849	1.592	0.657	0.289	0.093	0.033	0.003	0.000	0.000	0.000	0.000	0.000	0.000	3.516	25.672
[106.875-118.125[	0.822	1.258	0.527	0.196	0.084	0.027	0.002	0.000	0.000	0.000	0.000	0.000	0.000	2.915	28.586
[118.125-129.375[	0.729	1.030	0.384	0.180	0.068	0.009	0.003	0.000	0.000	0.000	0.000	0.000	0.000	2.402	30.988
[129.375-140.625[	0.747	0.898	0.311	0.105	0.040	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	2.104	33.092
[140.625-151.875[	0.665	0.799	0.279	0.111	0.027	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.882	34.974
[151.875-163.125[	0.643	0.730	0.262	0.122	0.025	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.783	36.757
[163.125-174.375[	0.632	0.815	0.372	0.104	0.036	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.962	38.720
[174.375-185.625[	0.737	1.099	0.501	0.227	0.083	0.021	0.003	0.000	0.000	0.000	0.000	0.000	0.000	2.670	41.390
[185.625-196.875[	0.758	1.318	0.658	0.247	0.099	0.020	0.012	0.004	0.000	0.000	0.000	0.000	0.000	3.117	44.507
[196.875-208.125[	0.651	1.078	0.511	0.251	0.085	0.036	0.007	0.000	0.001	0.000	0.000	0.000	0.000	2.620	47.127
[208.125-219.375[	0.569	0.965	0.496	0.256	0.105	0.036	0.010	0.006	0.002	0.000	0.000	0.000	0.000	2.444	49.572
[219.375-230.625[	0.623	0.896	0.555	0.308	0.126	0.029	0.007	0.004	0.001	0.000	0.000	0.000	0.000	2.549	52.120
[230.625-241.875[	0.665	0.983	0.673	0.429	0.126	0.042	0.013	0.007	0.001	0.000	0.000	0.000	0.000	2.939	55.059
[241.875-253.125[	0.688	1.222	0.810	0.552	0.192	0.086	0.018	0.007	0.005	0.001	0.000	0.000	0.000	3.580	58.639
[253.125-264.375[	0.929	1.769	1.215	0.917	0.524	0.242	0.056	0.012	0.011	0.005	0.001	0.001	0.000	5.681	64.321
[264.375-275.625[	1.183	2.778	2.105	1.520	0.955	0.454	0.223	0.072	0.040	0.022	0.005	0.002	0.001	9.362	73.683
[275.625-286.875[	1.360	2.762	1.853	1.267	0.812	0.381	0.164	0.060	0.018	0.019	0.008	0.001	0.000	8.706	82.389
[286.875-298.125[	1.239	2.343	1.609	1.042	0.551	0.267	0.105	0.038	0.018	0.005	0.003	0.000	0.000	7.222	89.611
[298.125-309.375[	0.987	1.517	0.697	0.393	0.191	0.081	0.026	0.009	0.003	0.001	0.000	0.000	0.000	3.905	93.516
[309.375-320.625[	0.802	0.929	0.349	0.117	0.043	0.016	0.007	0.001	0.001	0.000	0.000	0.000	0.000	2.264	95.779
[320.625-331.875[	0.592	0.603	0.214	0.073	0.043	0.014	0.001	0.001	0.000	0.000	0.000	0.000	0.000	1.542	97.321
[331.875-343.125[	0.500	0.483	0.192	0.068	0.041	0.010	0.003	0.001	0.000	0.000	0.000	0.000	0.000	1.298	98.619
[343.125-354.375[	0.496	0.514	0.220	0.098	0.038	0.006	0.009	0.000	0.001	0.000	0.000	0.000	0.000	1.381	100.000
Total	23.242	37.367	19.906	11.007	5.202	2.049	0.784	0.256	0.112	0.055	0.017	0.003	0.001	100.000	0.000
Accum	23.242	60.608	80.514	91.521	96.723	98.772	99.556	99.812	99.925	99.979	99.996	99.999	100.000	0.000	0.000

Current conditions

Sand transport conditions depend also on the current conditions. Consequently, current conditions, to be used as basis for the sediment transport computations, have been extracted from FEHY (2013) regional modelling, which covers the period 1 January 1989 to 30 April 2010. Data covering the extraction area and the 500 m impact zone is extracted. The directional distribution of depth averaged currents, a so-called current rose, is presented in Figure 4.6.

There are two main current directions, towards NW to N and towards SSE to ESE.

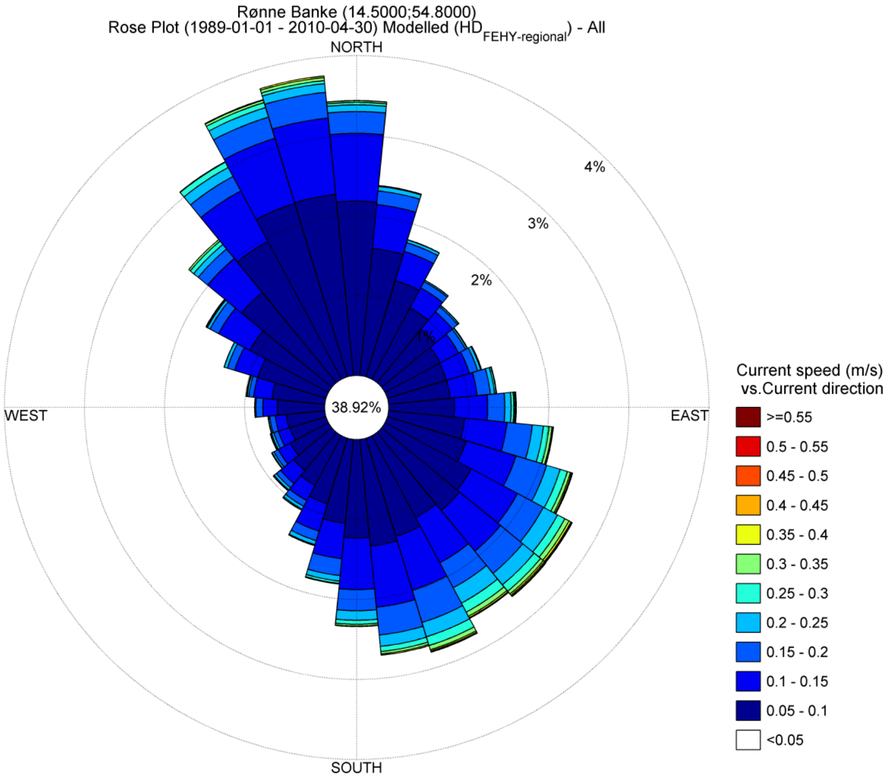


Figure 4.6 Current rose for Rønne Banke for the period 1.01.1989 to 30.04.2010, from FEHY regional HD model: FEHY (2013).

A table presenting the percentage distribution of current speeds vs. directions is presented in Table 4.2. It is seen that the current regime at Rønne Banke is mild, it is e.g. seen that the current speed is below 0.2 m/s in 95.4% of the time., This indicates a low transport regime although some transport takes place as demonstrated in the following transport computations.

Transport conditions

The transport conditions at Rønne Banke have been computed with DHI's MIKE 21ST module (Sediment Transport module) for representative durations of waves and currents extracted from Table 4.1 and Table 4.2 using sand parameters characteristic for Rønne Banke.

The sediment transport program calculates a current profile based on the depth averaged current taking into account the turbulence generated by waves and current. The current direction is the direction in which the current flows. It should be noted that the impact of waves on the sand transport is of secondary importance compared to the current at deep waters.

The results of the sediment computations are presented in Table 4.3.

Table 4.2 Table of depth averaged current speeds vs. direction at Rønne Banke, 1 Jan 1989 to 30 Apr 2010. Depth at extraction point is approximately 20 m.

Rønne Banke (14.5000;54.8000)
Percentage Occurence (1989-01-01 - 2010-04-30) Modelled ($HD_{FEHY\text{-}regional}$) - All

Current speed (m/s)

Current direction (°N-to)	[0-0.05[	[0.05-0.1[	[0.1-0.15[	[0.15-0.2[	[0.2-0.25[	[0.25-0.3[	[0.3-0.35[	[0.35-0.4[	[0.4-0.45[	[0.45-0.5[	[0.5-0.55[	[0.55-0.6[	Total	Accum
[-5.625-5.625[	1.798	2.179	0.847	0.272	0.084	0.032	0.020	0.003	0.000	0.000	0.000	0.000	5.236	5.236
[5.625-16.875[	1.665	1.599	0.550	0.171	0.057	0.007	0.005	0.000	0.000	0.000	0.000	0.000	4.053	9.289
[16.875-28.125[	1.508	1.258	0.381	0.113	0.037	0.004	0.000	0.000	0.000	0.000	0.000	0.000	3.302	12.591
[28.125-39.375[	1.321	1.011	0.283	0.090	0.019	0.001	0.001	0.000	0.000	0.000	0.000	0.000	2.726	15.317
[39.375-50.625[	1.109	0.863	0.285	0.083	0.019	0.002	0.001	0.000	0.000	0.000	0.000	0.000	2.363	17.680
[50.625-61.875[	1.067	0.785	0.259	0.097	0.023	0.004	0.001	0.002	0.001	0.000	0.000	0.000	2.238	19.918
[61.875-73.125[	1.037	0.772	0.300	0.107	0.040	0.010	0.001	0.002	0.000	0.000	0.000	0.000	2.267	22.185
[73.125-84.375[	1.004	0.773	0.338	0.167	0.051	0.019	0.003	0.002	0.003	0.000	0.000	0.000	2.361	24.546
[84.375-95.625[	1.024	0.820	0.416	0.214	0.078	0.035	0.014	0.008	0.007	0.002	0.000	0.000	2.619	27.165
[95.625-106.875[	1.113	0.955	0.532	0.318	0.139	0.072	0.037	0.009	0.004	0.004	0.001	0.000	3.181	30.346
[106.875-118.125[	1.040	1.029	0.649	0.401	0.177	0.094	0.041	0.016	0.009	0.003	0.000	0.002	3.460	33.806
[118.125-129.375[	1.108	1.223	0.655	0.366	0.201	0.103	0.059	0.027	0.011	0.004	0.003	0.003	3.762	37.568
[129.375-140.625[	1.052	1.264	0.659	0.359	0.185	0.104	0.045	0.020	0.014	0.004	0.003	0.003	3.712	41.280
[140.625-151.875[	1.026	1.161	0.641	0.354	0.218	0.127	0.059	0.020	0.004	0.005	0.002	0.000	3.617	44.897
[151.875-163.125[	1.136	1.283	0.702	0.423	0.186	0.116	0.055	0.018	0.014	0.002	0.000	0.000	3.934	48.831
[163.125-174.375[	1.180	1.340	0.769	0.348	0.143	0.065	0.030	0.015	0.001	0.000	0.000	0.000	3.892	52.723
[174.375-185.625[	1.133	1.231	0.645	0.264	0.119	0.051	0.023	0.006	0.000	0.000	0.000	0.000	3.472	56.195
[185.625-196.875[	1.143	1.052	0.446	0.213	0.068	0.029	0.008	0.002	0.000	0.000	0.000	0.000	2.961	59.156
[196.875-208.125[	1.055	0.857	0.358	0.124	0.054	0.012	0.001	0.000	0.000	0.000	0.000	0.000	2.461	61.617
[208.125-219.375[	0.983	0.702	0.218	0.081	0.041	0.015	0.000	0.001	0.000	0.000	0.000	0.000	2.041	63.659
[219.375-230.625[	0.887	0.621	0.212	0.066	0.035	0.011	0.003	0.001	0.001	0.000	0.000	0.000	1.836	65.494
[230.625-241.875[	0.872	0.540	0.172	0.060	0.025	0.006	0.001	0.001	0.000	0.000	0.001	0.000	1.678	67.172
[241.875-253.125[	0.928	0.470	0.151	0.061	0.028	0.011	0.003	0.001	0.001	0.002	0.004	0.000	1.659	68.831
[253.125-264.375[	0.922	0.483	0.139	0.068	0.016	0.005	0.001	0.001	0.000	0.001	0.000	0.000	1.635	70.465
[264.375-275.625[	1.069	0.589	0.183	0.087	0.014	0.002	0.000	0.000	0.000	0.000	0.000	0.000	1.944	72.410
[275.625-286.875[	1.162	0.664	0.229	0.060	0.021	0.010	0.005	0.000	0.000	0.000	0.000	0.000	2.151	74.561
[286.875-298.125[	1.215	0.889	0.304	0.095	0.042	0.001	0.000	0.002	0.000	0.000	0.000	0.000	2.548	77.108
[298.125-309.375[	1.439	1.113	0.444	0.121	0.037	0.010	0.009	0.002	0.000	0.000	0.000	0.000	3.176	80.285
[309.375-320.625[	1.537	1.461	0.549	0.152	0.073	0.055	0.026	0.000	0.000	0.000	0.000	0.000	3.853	84.137
[320.625-331.875[	1.642	1.953	0.717	0.205	0.128	0.074	0.006	0.002	0.000	0.000	0.000	0.000	4.727	88.864
[331.875-343.125[	1.851	2.265	0.851	0.278	0.124	0.065	0.032	0.009	0.000	0.000	0.000	0.000	5.474	94.338
[343.125-354.375[	1.897	2.275	0.961	0.324	0.109	0.039	0.037	0.021	0.000	0.000	0.000	0.000	5.662	100.000
Total	38.923	35.479	14.846	6.144	2.591	1.188	0.525	0.188	0.070	0.026	0.012	0.007	100.000	0.000
Accum	38.923	74.401	89.248	95.392	97.983	99.171	99.696	99.884	99.954	99.980	99.993	100.000	0.000	0.000

The yearly transport capacities have been computed for durations of wave heights and current speeds representative for the yearly conditions as represented in Table 4.1 and Table 4.2.

Table 4.3 Yearly transport capacity [m^3/m/year] for the sand extraction area at Rønne Banke.Representative wave heights and current speeds extracted from Table 4.1 and Table 4.2.

Wave height H_S [m]	**Peak wave period, T_p [s]**	**Current speed [m/s]**	**Yearly duration [%]**	**Yearly transport capacity [m^3/m/year] for three water depths**		
				15 m	**23 m**	**30 m**
1	5	0.05	57	0	0	0
2	6	0.15	16	0	0	0
3	7.5	0.25	2.8	1.95	0.03	0
4	8.5	0.35	0.36	1.15	0.26	0.04
				3.1	0.29	0.04

The above computations have demonstrated that there is hardly any transport under normal conditions in the sand extraction area but that there is some sand transport capacity during rare events, highest at the 15 m and lowest at 30 m water depth. The fact that the bulk of the transport takes place during extreme events is a normal transport pattern. The magnitude of the yearly transport capacity decides the speed of the regeneration process but the regeneration of the seabed cannot be computed exactly, because the detailed characteristics of the seabed following the sand extraction are unknown. On basis of the above computations and considerations it is concluded that the computed amount of transport is sufficient to regenerate the seabed following the sand extraction. The regeneration rate is strondly dependent of the water depth. The regeneration process is further described in 5.3.2.

4.2 Toxic substances in seabed sediment

Toxic substances are bound to organic compounds and very fine particles of the sediments.

To survey the occurrence of organic matter in the extraction and 500 m impact area, samples of surface sediment (down to 5 cm) were collected in August 2011 and analysed for organic content (LOI) and dry weight (DW) (see Appendix A). The results of the analyses show that the organic content (LOI) is less than 0.73% DW for all samples (Table 4.6). Furthermore, the median grain size (D50) is between 0.187 and 0.695 mm; classified as medium sand (Anthonsen and Lomholt 1998). The low content of organic matter resembles what is found in a previous analysis done in connection to an investigation done at the German park of Kriegers Flak and western part of Adler Grund. Here the content of organic matter in the sediments was below 1% at water depths below 35 m (Institut für Ostseeforschung Warnemünde 2003).

The sediment in the extraction and impact areas does thus contain very little organic material and fine particles which potentially can carry toxic substances. Consequently, chemical analyses of the sediment have not been executed. Deduced from the scarcity of organic material, the content must be expected to be below detection limit (FEMA 2013a, Herut and Sandler 2006).

The nearest sampling station where toxic substances has been analysed is the Arkona W sampling station, which is situated in the Arkona Basin west of Rønne Banke (Figure 4.7). It is part of the Danish National Monitoring Programme of Water Environment and Nature, NOVANA, and has been sampled annually over a longer period until 2009. Data from 2008 (the latest sampling) has been retrieved from the National Database for Marine Data, MADS (DMU web database 2011). The Arkona W is a relatively deep sampling station (45 m) and functions as a sediment trap for fine sediments. The station represents therefore the 'worst case' as toxic substances will be accumulated in this area and the concentration must be expected to be much higher than in the shallow areas of Rønne Banke.

In Table 4.4 the concentrations measured in 2008 at the Arkona W sampling station have been corrected for the organic content (LOI) from the sampling at Rønne Banke to make data from current project comparable to the sediment quality guidelines given by "Oslo and Paris Commision to protect the NE Atlantic agiainst polution", OSPAR (2009) and the Danish EPA (BLST 2008). The OSPAR values are based on unpolluted background concentrations. To correct the data, the concentration of toxic substances have been calculated per LOI for Arkona W and then multiplied with the LOI for the samples at Rønne Banke. The estimation is hence a worse case value for Rønne Banke, as it is not a trap for sediment and adhered toxic substances.

The evaluation of pollutant levels in sediments is usually based on so called sediment quality guidelines (SQG) that generally are derived based on three different approaches: 1) definition of criteria from data sets from toxicity experiments with polluted sediment (toxicological criteria), 2) defining criteria based on data from unpolluted sediments (background levels) or 3) a combination of both approaches. In Table 4.4 is listed a selection of SQG that are accepted by environmental authorities and that includes some of the lowest criteria values available. OSPAR (2009) values are based on background concentrations (before pollution) and accepted exceedence from background concentrations, while the Danish EPA (BLST 2008) values are based on both toxicological and background data. Danish authorities operate with two sets of criteria values, Lower Action level (L Ac) and Higher Action level (H Ac), where values below L Ac are considered unproblematic.

*Table 4.4 Sediment quality guidelines (OSPAR (absolute) values from OSPAR (2009); Danish EPA values from BLST 2008). LOI = loss on ignition *Data from 2001, ** sum of 9 compounds.*

		Arkona W 2008	**Rønne Banke (calculated values)**	**OSPAR**	**Danish L Ac**	**Danish H Ac**
PAH (total)**	mg/kg	2.4	0.05	0.35	3	30
PCB (total) (2001)	µg/kg	2.3*	0.05	1.09	20	200
TBT	µg Sn/kg	1.77	0.03	0	7	200
Cd	mg/kg	0.771	0.01	0.37	0.4	2.5
Cu	mg/kg	53.45	1.01	27	20	90
Hg	mg/kg	0.459*	0.01	0.07	0.25	1
Ni	mg/kg	44.35	0.84	36	30	60

		Arkona W 2008	Rønne Banke (calculated values)	OSPAR	Danish L Ac	Danish H Ac
Pb	mg/kg	95.95	1.81	38	40	200
Zn	mg/kg	149.5	2.83	122	130	500
Average LOI (2011)		15.6 (14.9*)	0.30			

The calculated concentrations of toxic substances at Rønne Banke are all below the accepted threshold values given by OSPAR as well as the Danish EPA. The concentration of TBT is very close to the OSPAR threshold (0.03 µg Sn/kg) but compared to the Danish EPA thresholds, TBT is much lower than the L Ac and is therefore not considered problematic.

A previous EIA on sand extraction at Rønne Banke from 1995 (Øresundskonsortiet 1995a) also calculated the concentrations of heavy metals, PCB and hydrocarbons. This investigation also concluded that the concentrations of toxic substances were very low.

4.3 Salinity, temperature and water quality

NOVANA data on the salinity and temperature as well as water quality, are retrieved from MADS database (DMU web database 2011). There are no sampling stations at Rønne Banke but data has been retrieved from the nearest sampling station (Figure 4.7) near the coast of Bornholm (the station Rønne). Samplings have been done down to 20 m. Data is supported with previous investigations in the nearby area, where possible.

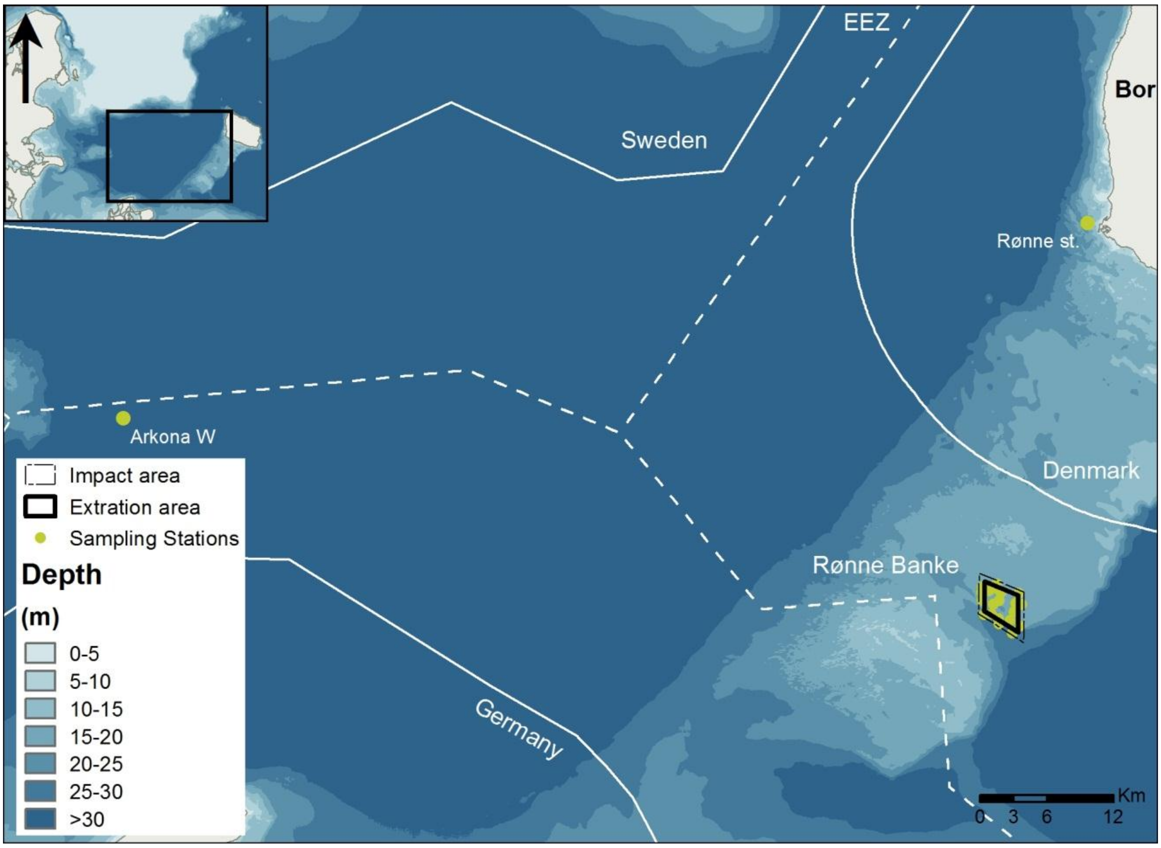


Figure 4.7 NOVANA sampling station Rønne, near Bornholm (water quality) and Arkona W (toxic substances) (DMU web database 2011).

Salinity
On a yearly basis, the salinity in the Baltic Sea around Bornholm is stable at 7–9‰ and the water is therefore mesohaline (DMU web database 2011, Rambøll Danmark 2008, Institut für Ostseeforschung Warnemünde 2003). There is not observed a halocline (Rambøll Danmark 2008).

Temperature
The water temperature fluctuates throughout the year, following the seasons. In June to August the water becomes stratified at 10-12 meters (DMU web database 2011).

Oxygen
The oxygen content at Rønne Banke was measured at 1 and 19 m. Data shows that the oxygen concentration is evenly distributed throughout the water column (DMU web database 2011). The water column is hardly stratified and oxygen concentration at 20 m is almost saturated (see Table 4.5). The oxygen content fluctuates from 9-13 mg/l through the season, with the lowest concentration in the summer period. In connection to the Nord Stream pipeline project the oxygen content at a deep sampling station north-east of Bornholm has been measured to be between 11–12 mg/l in the top 50 m (Rambøll Danmark 2008).

Table 4.5 *Ratio of salinity and between bottom water (20 m) and mixed surface water (0-10 m), and ratio between oxygen concentration on bottom water and surface water. Data extracted from MADS*

	Salinity		**Dissolved oxygen**	
	August	**Sept**	**August**	Sept
	20 m/0-10 m		**20 m/0-10 m**	
1998	100%	105%		93%
1999	117%	103%	83%	84%
2000	117%	103%	86%	98%
2001	100%	101%		
2002	107%	113%	95%	74%
2003	107%	100%	84%	95%
2004	101%	101%	81%	91%
2005	110%	102%	94%	91%
2006	102%	105%	90%	98%
Average	107%	104%	88%	90%

Nutrients
The total amount of nitrogen, TN and phosphorous, TP were also measured as part of the NOVANA programme. Data from the sampling station from 2005 and 2006 show that the TN varied between 11 and 26 µmol/l evenly distributed through the water column and year. TP varied in 2005 from 0.6 to 1.5 µmol/l and was in 2006 slightly lower with observed values between 0.3 and 1.1 µmol/l.

Chlorophyll a
Observations in 2005 and 2006 showed that chlorophyll a concentrations were between 0.5 and 4.5 µg/l throughout the photic zone (0-15 m) throughout the year (DMU web database 2011).

4.4 Benthic fauna

The baseline description for benthic fauna is based on a field survey conducted at Rønne Banke in August 2011. The results are compared to earlier investigations.

Quantitative samples of the benthic fauna and subsamples of surface sediment were collected at 20 stations at Rønne Banke in August 2011 (Figure 4.8)

The methods of sampling and analysis are described in Appendix A and the results of the surveys in Appendix B, Appendix C and Appendix D.

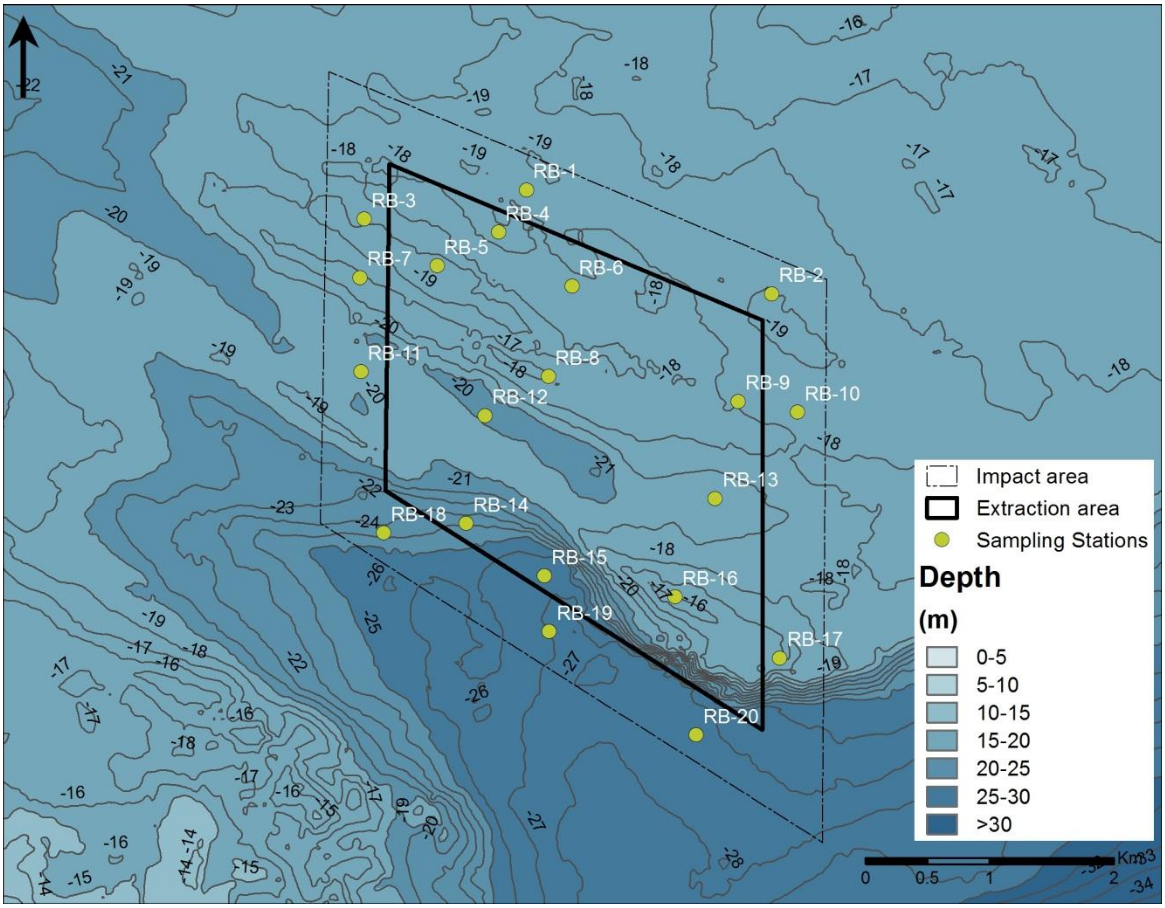


Figure 4.8 Map of fauna stations at Rønne Banke sampled in August 2011.

4.4.1 Number of species, abundance and biomass

Number of species

A total of 14 species and one higher taxon (Oligochaeta) was recorded at Rønne Banke. The number of species depends on the number of samples (area of the sea-bed) collected. However, as appears in Figure 4.9, the sampling programme was adequate to describe the species present in this shallow, low saline area of the Baltic Sea.

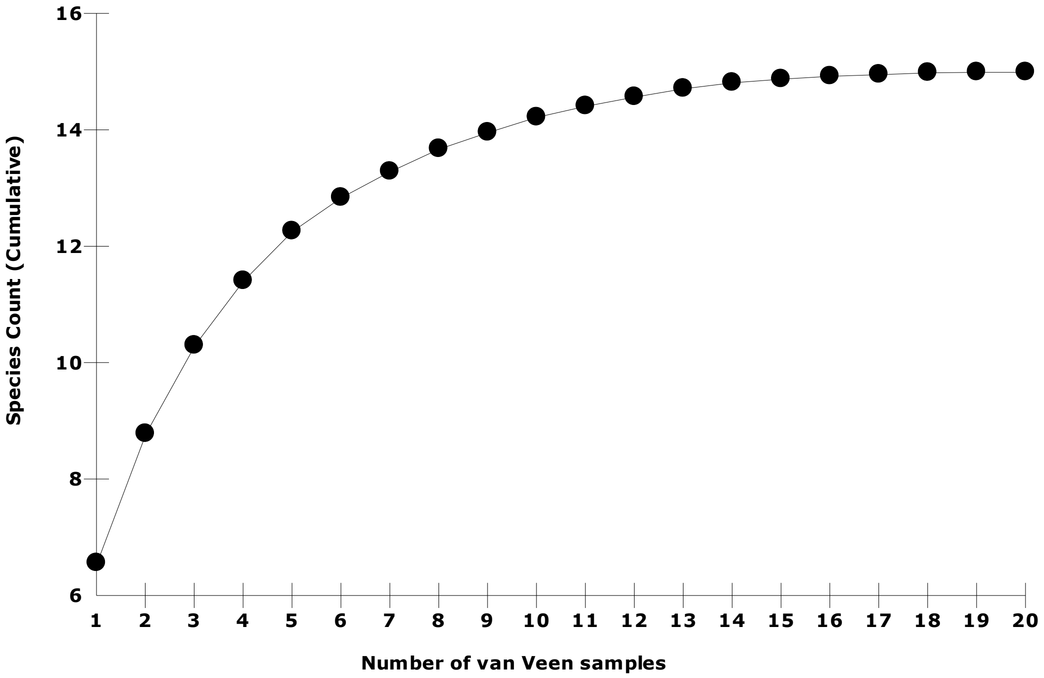


Figure 4.9 Cumulative number of species vs. number of van Veen samples collected at Rønne Banke in August 2011.

The average number of species was 7 per 0.1 m^{-2} and the range between 2 and 12 per 0.1 m^{-2} at the stations (Table 4.6). The number of species was atypically low at station RB-7. Ten species or more was recorded at four stations (RB-14, RB-15, RB-19 and RB-20) in the southern and deeper part of the survey area (Figure 4.8).

Table 4.6 Water depth, number of species, abundance and biomass of the benthic fauna (in AFDW = ash free dry weight) and dry weight (DW), loss on ignition (LOI), median grain size (D50) and share of silt/clay (S/C) measured in the surface sediment at Rønne Banke in August 2011.

Station	**Depth**	**Number of species**	**Abundance**	**Biomass**	**DW**	**LOI**	**D50**	**S/C**
	M	0.1 m^{-2}	m^{-2}	gAFDW m^{-2}	% WW	% DW	mm	% DW
RB-1	19.0	5	240	0.469	82	0.20	0.438	0
RB-2	19.6	6	640	0.742	85	0.20	0.625	0.008
RB-3	20.2	7	670	0.777	79	0.24	0.259	0.015
RB-4	19.9	6	330	0.594	86	0.29	0.593	0.017
RB-5	20.0	6	410	0.262	80	0.21	0.372	0.008
RB-6	17.8	4	230	0.293	84	0.21	0.549	0
RB-7	17.9	2	30	0.082	85	0.25	0.622	0
RB-8	17.4	5	250	0.284	84	0.25	0.485	0
RB-9	18.3	5	280	0.154	86	0.33	0.695	0
RB-10	18.5	6	350	0.561	87	0.20	0.550	0
RB-11	20.5	7	160	0.310	84	0.08	0.463	0
RB-12	20.6	5	290	0.195	84	0.11	0.472	0
RB-13	20.3	4	490	0.453	85	0.73	0.690	0
RB-14	25.0	12	2,200	9.736	76	0.35	0.224	0.065

Station	Depth	Number of species	Abundance	Biomass	DW	LOI	D50	S/C
	M	0.1 m^{-2}	m^{-2}	gAFDW m^{-2}	% WW	% DW	mm	% DW
RB-15	27.4	12	1,730	7.291	76	0.38	0.191	0.080
RB-16	15.7	7	270	0.604	85	0.16	0.579	0
RB-17	16.4	7	220	0.232	84	0.19	0.454	0
RB-18	24.0	8	1,040	1.383	81	0.33	0.474	0.044
RB-19	27.6	10	2,860	1.626	76	0.61	0.191	0.280
RB-20	28.5	10	2,400	2.817	73	0.58	0.187	0.320
Range	**15.7-28.5**	**2-12**	**30-2,860**	**0.082-9.74**	**73-87**	**0.08-0.73**	**0.187-0.695**	**0-0.320**

Abundance
The average abundance of the benthic fauna was 755 m^{-2} and the range between 30 and 2,860 m^{-2} (Table 4.6 and Table 4.7). However, the abundance was extremely low at station RB-7. The abundance was above 1,000 m^{-2} at five stations in the southern and deeper part of the area (Figure 4.10).

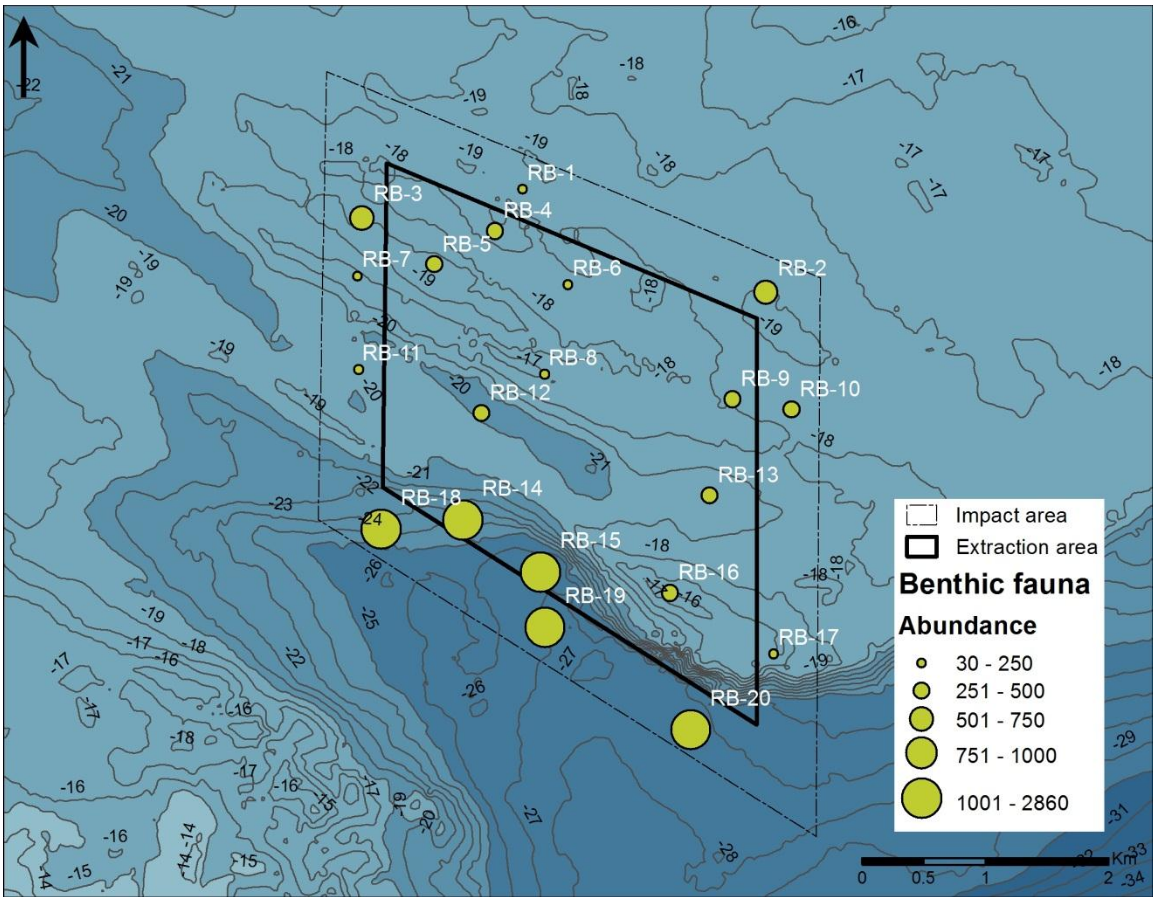


Figure 4.10 Abundance of the benthic fauna at Rønne Banke in August 2011.

Biomass
The average benthic biomass was 1.443 g AFDW m^{-2} and the range between 0.082 and 9.74 g AFDW m^{-2} (Table 4.7). The biomass was lowest at station RB-7. The bi-

omass was highest and above 1 gAFDW m^{-2} at five stations in the deeper south-western part of the area (Table 4.7).

4.4.2 Common and dominant species

The average abundance and biomass of the benthic fauna are summarized in Table 4.7.

Table 4.7 Average abundance and biomass of the species recorded at Rønne Banke in August 2011 by DHI/FEMA.

Species	Abundance (m^{-2})	% of Abundance	Biomass (gAFDW m^{-2})	% of Biomass
Polychaetes				
Bylgides sarsi	20	2.7	0.0137	0.95
Hediste diversicolor	32	4.2	0.1501	10.40
Marenzelleria viridis	198	26.2	0.0691	4.79
Pygospio elegans	269	35.6	0.0506	3.51
Oligochaeta	76	10.0	0.0105	0.73
Bivalves				
Cerastoderma glaucum	5	0.6	0.0318	2.20
Macoma balthica	20	2.7	0.2048	14.19
Mya arenaria	14	1.8	0.1442	9.99
Mytilus edulis	86	11.3	0.7484	51.86
Gastropoda				
Hydrobia ulvae	2	0.3	0.0003	0.02
Crustaceans				
Bathyporeia pilosa	14	1.8	0.0073	0.51
Diastylis lucifera	4	0.5	0.0004	0.02
Diastylis rathkei	1	0.1	0.0017	0.12
Gammarus salinus	10	1.3	0.0041	0.28
Monoporeia affinis	8	1.0	0.0063	0.43
Total	**755**	**100**	1.443	100

Polychaetes and oligochaetes

The polychaetes accounted for 69% of the total benthic abundance and 20% of the total biomass.

The sedentary tube building *Pygospio elegans* was present at most stations and accounted for 36% of the benthic abundance and 3.5 % of the biomass (Table 4.7). The average abundance of the species was 269 m^{-2} and the range between 20 m^{-2} and 1230 m^{-2} (Appendix B).

The spionid polychaete *Marenzelleria viridis* was the second most abundant species and accounted for 26% of the average benthic abundance and 4.8% of the biomass. The species was present at all stations (Appendix B). The average abundance of *Marenzelleria viridis* was 198 m^{-2} and the range between 10 m^{-2} and 1140 m^{-2}. The high abundance of *Marenzelleria viridis* is remarkable because the species is non-indigenous (alien) and introduced to European waters in recent years probably via ballast water from the core area at the east coast of America (Kirkegaard 1996). *Marenzelleria viridis* was first recorded in England in 1979 and in Holland in 1983 (Jensen and Knudsen 2005). Since the first appearance in the southern Baltic in 1985 *Marenzelleria viridis* has dispersed rapidly and was recorded in the Gulf of

Finland in 1990 and in the Åland archipelago in 1993 (Perus and Bonshoff 2004, Hietanen et al. 2007).

Hediste (Nereis) diversicolor was recorded at most stations. The species accounted for 4% of the average abundance and 10 % of the biomass due to the large size (Appendix C).

The semi pelagic *Bylgides sarsi* was recorded at four deeper stations in densities between 40 m^{-2} and 190 m^{-2} (Appendix B).

Unidentified species of oligochaetes were recorded at 80% of the stations. The species accounted for 10% of the average abundance and less than 1% of the biomass.

Bivalves
The four species recorded accounted in average for 16% of the benthic abundance and 78% of the biomass (Table 4.7). The Baltic Tellin *Macoma balthica* was recorded at 30% of the stations. The abundance was between 20 m^{-2} and 130 m^{-2}. The species accounted for 3% of the average abundance and 14% of the biomass (Table 4.7). The population was composed of both young bivalves and older year classes Figure 4.11 shows the number of species versus shell length. The distribution of the year classes is relevant for determining the recovery time after a possible impact a project. The older the community structure is the longer recovery time.

Mya arenaria was the most common species and recorded at 60% of the stations. The abundance was mostly low and the species accounted for 2% of the average abundance but 10 % of the biomass (Appendix B and Appendix C). The shell length of most specimens was between 5 mm and 20 mm (Figure 4.11).

The distribution of the common mussel *Mytilus edulis* was recorded at 40 % of the stations. Common mussels were the most abundant bivalve and accounted for 11 % of the average abundance and 52 % of the biomass. However, the species was only recorded in larger numbers (>100 m^{-2}) at three stations (RB-14, RB-15 and RB- 19) in deeper water in the southern part of the area (Figure 4.8). The mussels were rather small and the shell length of most of the mussels was between 5 mm and 10 mm (Figure 4.11).

The cockle *Cerastoderma glaucum* was scarce and only recorded in low numbers at 25% of the stations. The population consisted mostly of small specimens with a shell length between 5 mm and 10 mm (Figure 4.11).

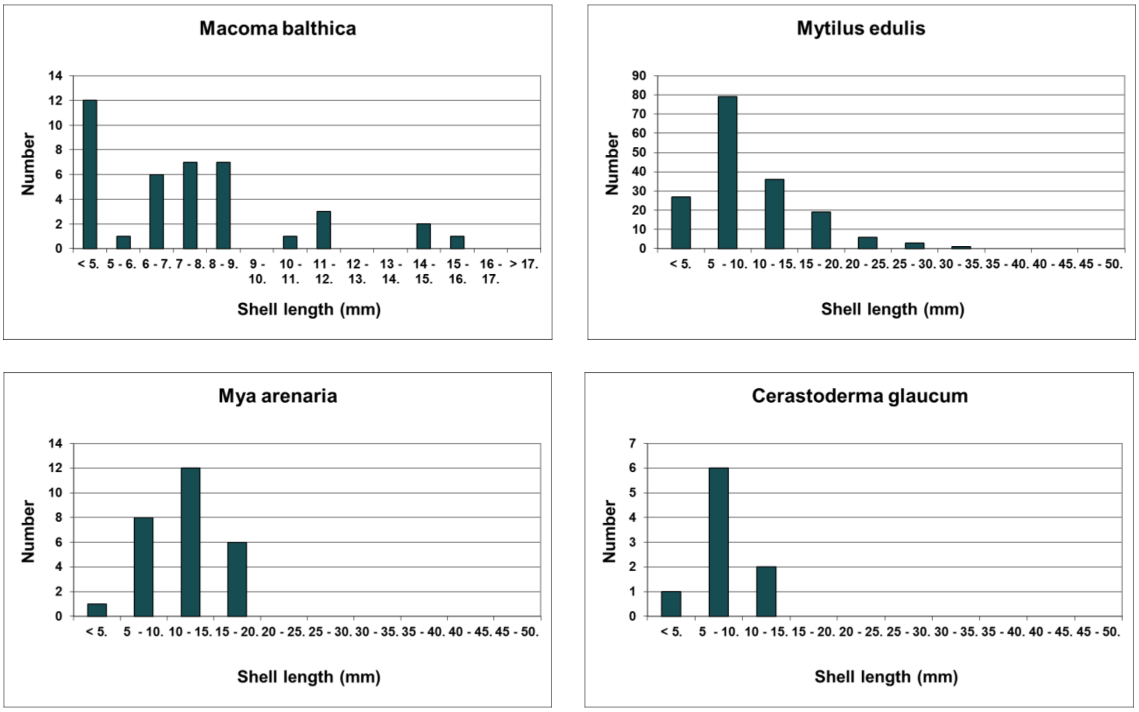


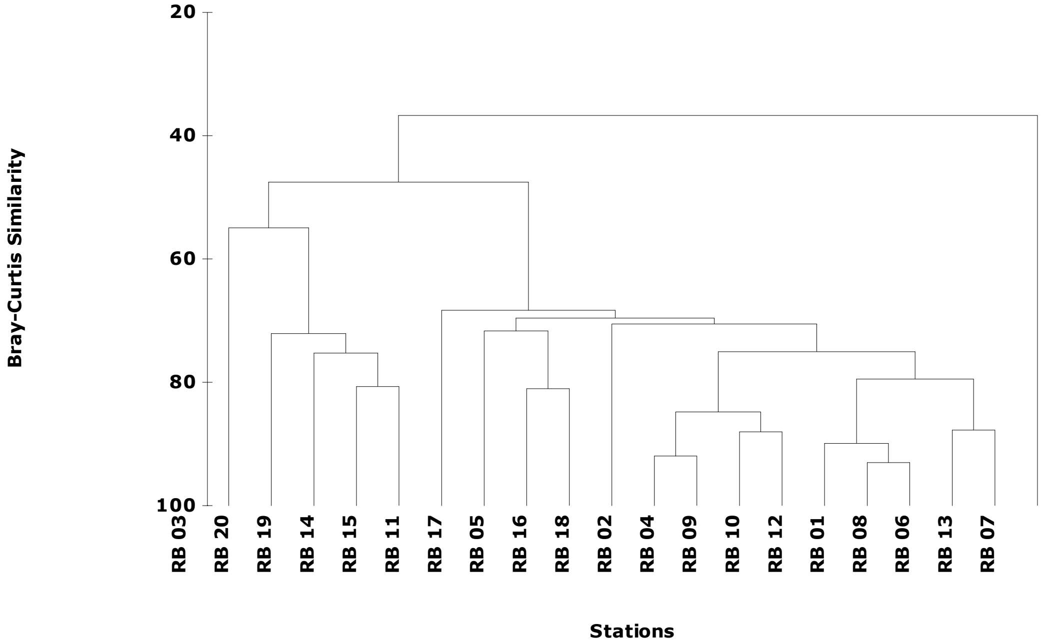
Figure 4.11 Shell length distribution of Macoma balthica, Mya arenaria, Mytilus edulis and Cerastoderma glaucum.

Gastropoda
The mud snail *Hydrobia ulvae* was extremely scarce and the abundance very low (Table 4.7).

Crustaceans
Crustaceans were the most diverse taxonomic group. However, the five species were scarce and only accounted for 5% of the average benthic abundance and 1.4% of the biomass. *Bathyporeia pilosa* was the most common species and present at half of the stations. However, the abundance was mostly low. The two cumacean species *Diastylis rathkei* and *Diastylis lucifera* were only recorded in deeper water in the southern part of the area (Appendix B).

4.4.3 Structure of the benthic community
The Bray-Curtis similarity index and the ordination were calculated to investigate the community structure based on abundance and biomass, respectively. The program SIMPER was used for the analyses.

Analysis based on abundance
The results of the classification and ordination are presented in Figure 4.12 and Figure 4.13, respectively.



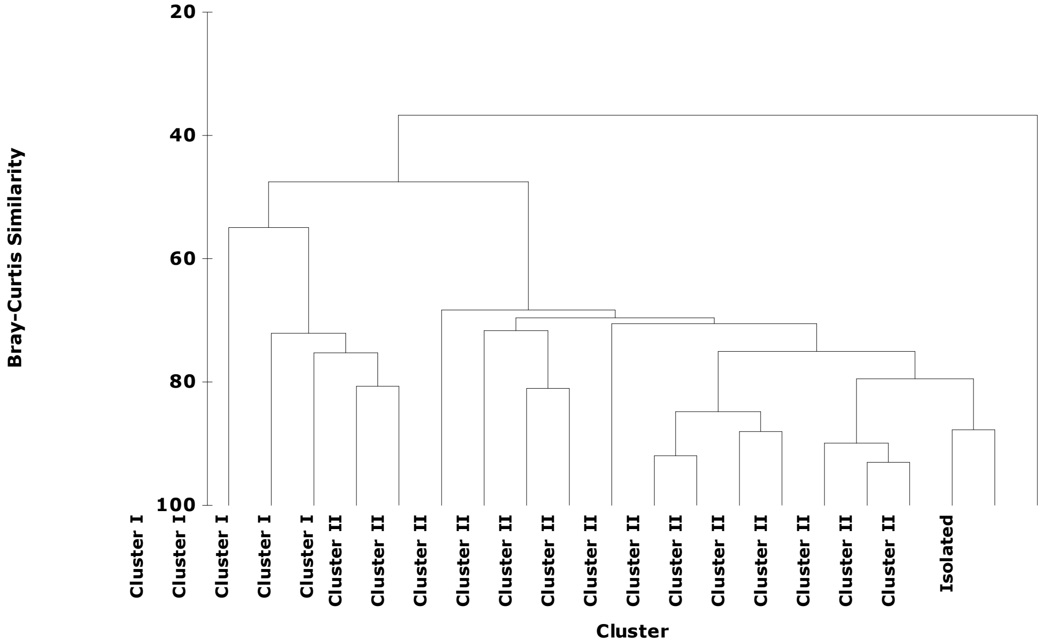


Figure 4.12 Results of classification based on abundance of the species at the fauna stations in August 2011. Stations (top) and delineation of two clusters of stations (bottom).

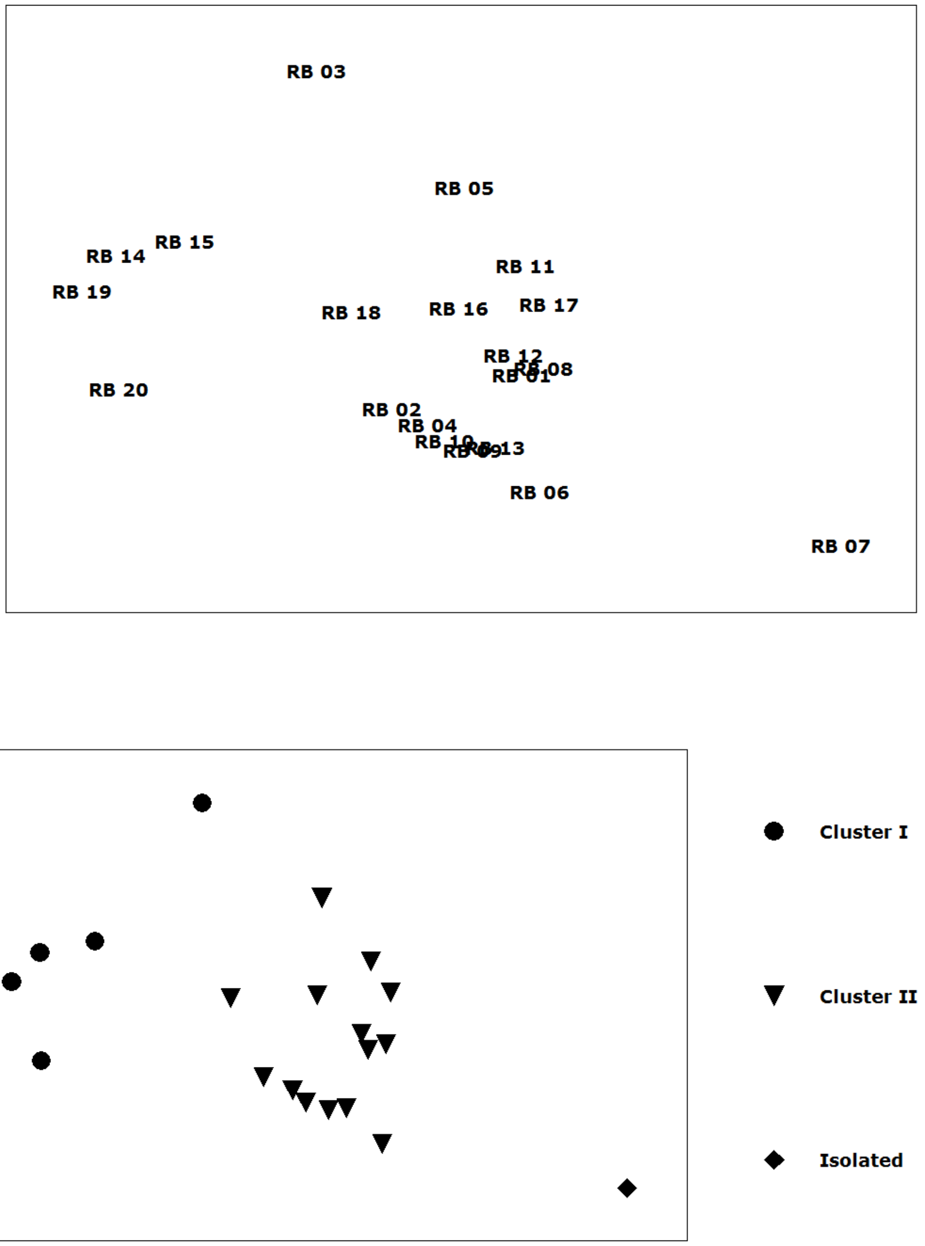


Figure 4.13 Results of ordination based on abundance of the species at the stations in August 2011. Stations (top) and delineation of two clusters of stations (bottom). Stress=0.1.

The similarity of the benthic fauna was more than 40% if one atypical station (RB-7) is disregarded. Two clusters of stations may be separated. The clusters of stations are characterised in Table 4.8.

Table 4.8 Similarity and average abundance of the species, which contributed 90 % to the similarity in Cluster I and II in August 2011. Based on SIMPER (Clarke and Gorley 2001). Bold: species contributing most to the similarity.

Variables	Cluster I	Cluster II	Isolated
Similarity	66.7	73.5	
Stations: number	5	14	1 (RB-7)
Water depth (m)	20.2-28.5	15.7-24.0	17.9
Abundance (m^{-2})	1972 (670-2860)	371 (160-1040)	30
Species contributing 90%			
Pygospio elegans	**628 (21.9)**	**159 (26.6)**	
Marenzelleria viridis	654 (20.9)	47 (20.3)	20
Macoma balthica	74 (11.6)		
Mytilus edulis	334 (9.4)		
Bylgides sarsi	80 (7.2)		
Mya arenaria	30 (6.6)		
Hediste diversicolor	28 (5.5)	34 (20.2)	10
Gammarus salinus	36 (5.5)		
Cerastoderma glaucum	14 (2.9)		
Oligochaeta		96 (21.4)	
Bathyporeia pilosa		16 (5.2)	

Cluster I included station RB-3 in addition to four stations RB-14, RB-15, RB-19 and RB-20 in the southern and deeper part of the area. The benthic fauna is characterized by a high abundance of polychaetes (*Pygospio elegans* and *Marenzelleria viridis*), bivalves (*Mytilus edulis* and *Macoma balthica*) and the crustacean *Gammarus salinus*.

Cluster II included the remaining stations except the isolated station RB-7. The stations were distributed in the shallow part of the area. The abundance of the benthic fauna was low compared to the abundance at Cluster I stations. In addition to the polychaetes *Pygospio elegans* and *Marenzelleria viridis*, oligochaetes, the polychaete *Hediste diversicolor* and the crustacean *Bathyporeia pilosa* also contributed to the similarity.

The isolated station RB-7 was characterised by an atypical low number of species and abundance.

Analysis based on biomass

The results of classification and ordination based on biomass are presented in Figure 4.14 and Figure 4.15, respectively.

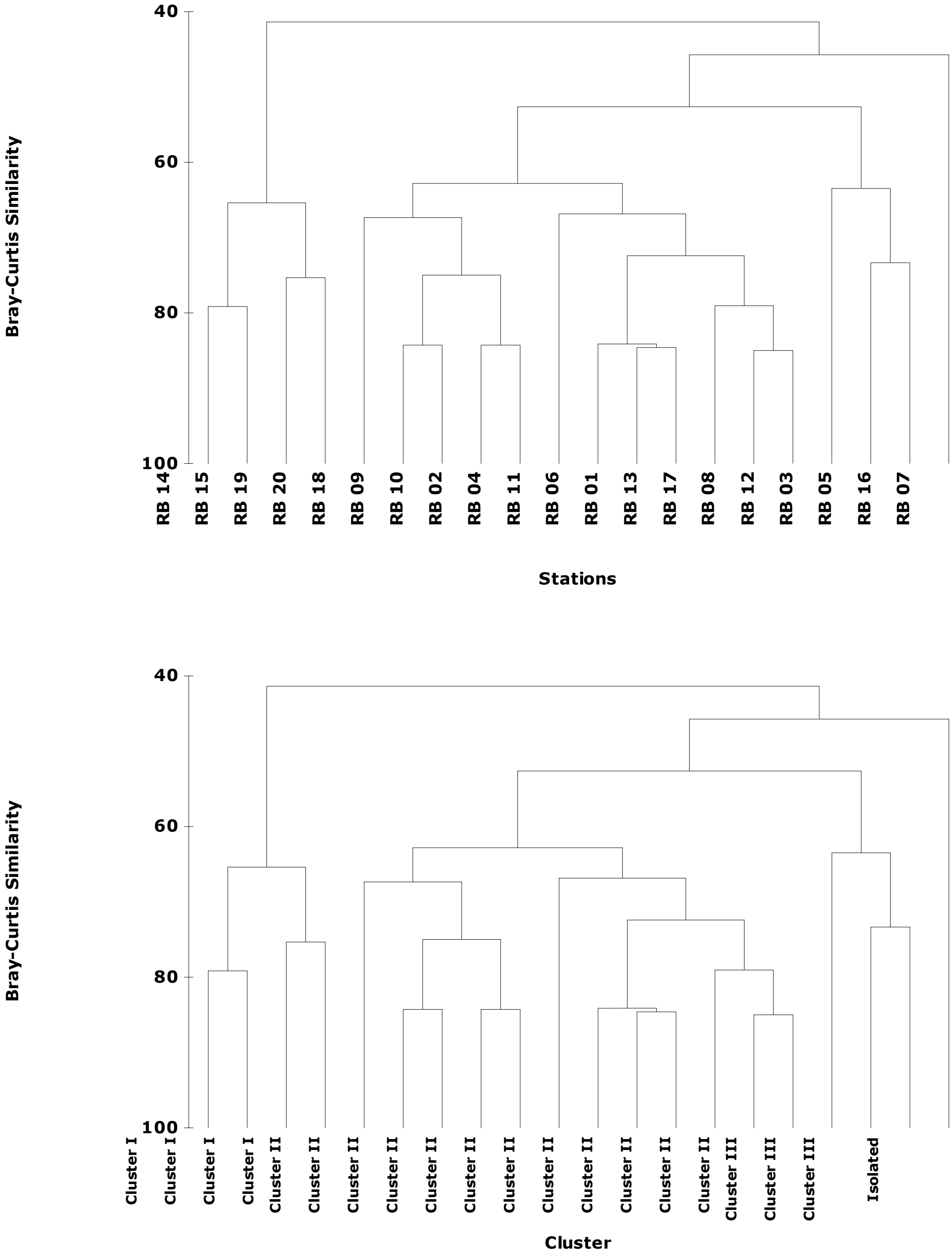


Figure 4.14 Results of classification based on biomass of the species at the stations in August 2011. Stations (top) and delineation of three clusters of stations (bottom).

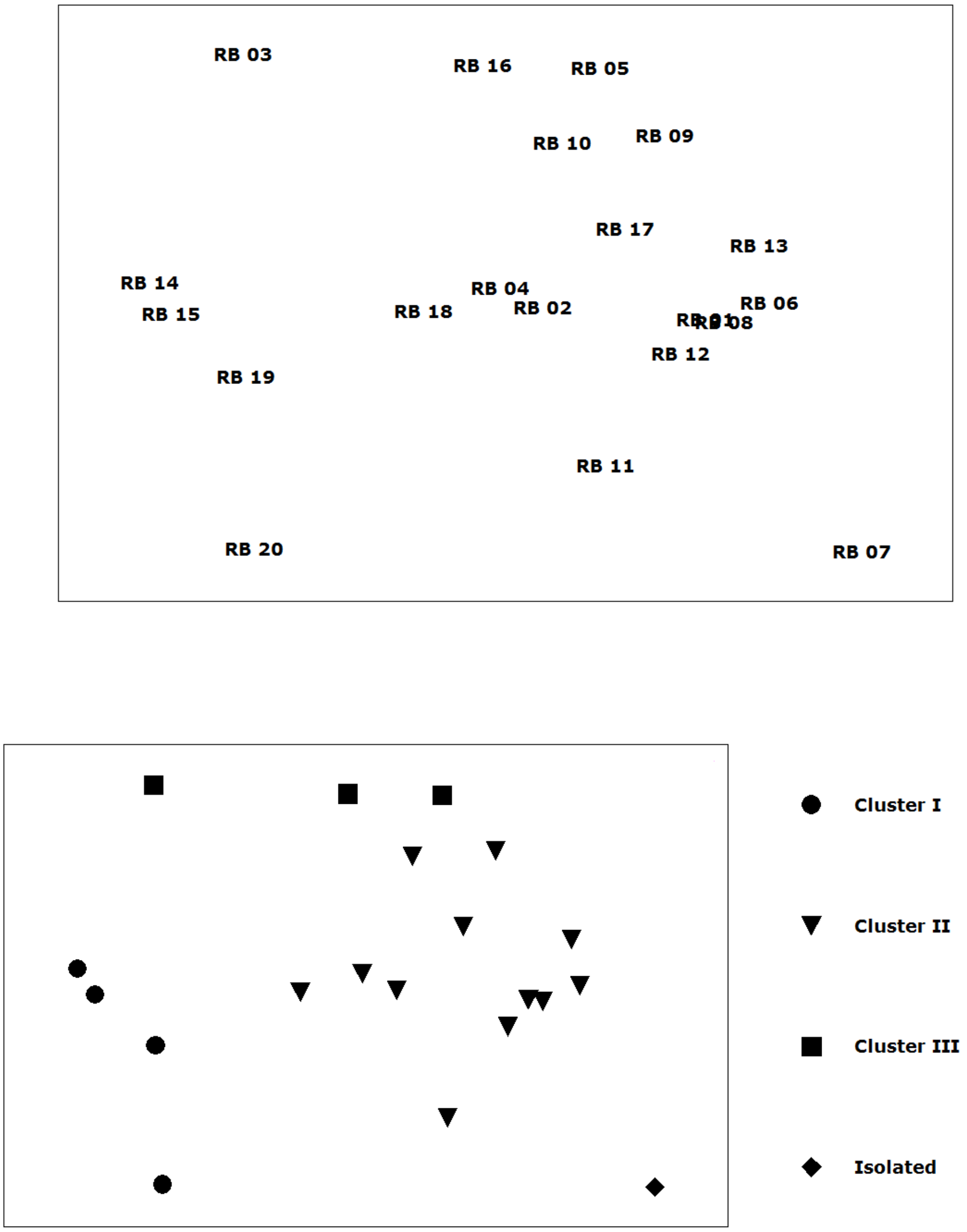


Figure 4.15 Results of ordination based on biomass of the species at the stations in August 2011. Stations (top) and delineation of three clusters of stations (bottom). Stress=0.13

The similarity of the benthic fauna was more than 40%. Three clusters of stations and one isolated station (RB-7) may be separated. The three clusters of stations are characterised in Table 4.9.

Table 4.9 *Similarity and average biomass of the species, which contributed 90 % to the similarity at Cluster I, II and III in August 2011. Based on SIMPER (Clarke and Gorley 2001). Bold: species contributing most to the similarity.*

Variables	Cluster I	Cluster II	Cluster III	Isolated
Similarity	69.3	67.9	66.7	
Stations: number	4	12	3	1 (RB-07)
Depth (m)	25-28.5	16.4-24.0	15.7-20.2	17.9
Biomass (gAFDW m^{-2})	5.37 (1.63-9.74)	0.47 (0.15-1.38)	0.55 (0.26-0.78)	0.082
Species contributing 90%				
Mytilus edulis	**3.70 (22.0)**			
Macoma balthica	0.81 (16.6)			
Pygospio elegans	0.13 (13.3)	0.03 (18.9)	0.05 (21.1)	
Marenzelleria viridis	0.14 (13.0)	0.06 (20.6)	0.02 (14.4)	0.05
Bylgides sarsi	0.07 (10.1)			
Hediste diversicolor	0.06 (7.7)	**0.21 (35.4)**		0.03
Mya arenaria	0.36 (7.2)	0.08 (5.8)	0.17 (17.7)	
Oligochaeta		0.02 (13.9)		
Cerastoderma glaucum			**0.15 (27.2)**	
Bathyporeia pilosa			0.01 (11.7)	

Cluster I included the same stations (RB-14, RB-15, RB-19 and RB-20) as Cluster I in the analysis based on abundance except that station RB-3 is included in Cluster III in the analysis based on biomass. The stations are located in the southern and deepest part of the area. The benthic fauna was characterised by a high biomass and in addition to *Mytilus edulis*, which contributed most to the similarity, a number of other species (*Macoma balthica*, *Pygospio elegans*, *Marenzelleria viridis* and *Bylgides sarsi*) was also important for the similarity of the benthic fauna.

Cluster II included twelve stations distributed in both shallow and deeper water. The biomass of the benthic fauna was rather low and the polychaete *Hediste diversicolor* contributed most to the similarity of the benthic fauna. However, the abundant polychaetes *Pygospio elegans* and *Marenzelleria viridis* and oligochaetes were also important for the similarity.

Cluster III included three stations (RB-3, RB-5 and RB-16) in shallow water. The biomass of the benthic fauna was rather low and the cockle *Cerastoderma glaucum* contributed most to the similarity. However, the polychaetes *Pygospio elegans* and *Marenzelleria viridis*, the bivalve *Mya arenaria* and the crustacean *Bathyporeia pilosa* were also of importance for the similarity of the benthic fauna.

4.4.4 Importance of environmental factors

The structuring importance of water depth and the variables measured in the sediment (dry weight, loss on ignition, median grain size and the silt/clay content of the sediment) to the benthic community was analysed using BioEnvir (Clarke and Gorley 2001). The silt/clay fraction of the sediment was zero at 55% of the stations (Table 4.6).

The results of the analysis based on benthic abundance and biomass are shown in Table 4.10.

Table 4.10 Spearman coefficient of correlation based on benthic abundance and biomass and environmental variables measured in the sediment at Rønne Banke in August 2011.

Environmental variables	**Based on abundance**	**Based on biomass (AFDW)**
Dry matter	0.623*	0.642*
Median grain size of sediment	0.622*	0.628*
Silt/clay fraction of sediment	0.546	0.541
Water Depth	0.492*	0.509*
Loss on ignition (LOI)	0.198	0.236
*Best combination	0.658	0.683

Water depth, dry matter and the median grain size of the sediment were the combination of factors contributing most to the structure of the benthic community. Both the combination of factors and the single factors are important. However, the factors are correlated. The dry weight of the sediment is higher in coarser sediments and both factors declines in deeper water. At the same time the silt/clay fraction and the content of organic matter (loss on ignition) increases in deeper water. In parallel to the changes in the structure of the sediment and the potential content of food (organic matter), the number of species, abundance and biomass of the benthic fauna increases with increasing depth. In addition to the changes in the sediment, the higher salinity in deeper water has also a major influence on the changes in the benthic fauna.

4.4.5 Comparison with earlier surveys

The benthic fauna was surveyed in 1995 (Øresundskonsortiet 1995a). This report has not been available. However, the results of the surveys in 1995 are summarised in (Øresundskonsortiet 1995b). The benthic fauna was typical a shallow water ("Macoma/Cerastoderma", see section 4.4.6) community dominated by few species of polychaetes, bivalves and crustaceans. The benthic fauna was uniform, but the abundance and biomass was highest in the southern and deepest part of the area. Similar spatial differences were recorded in 2011 and are mainly attributed to the higher salinity and more fine grained sediment with a higher content of organic matter in deeper water. A previous study at the German part of Adler Grund shown that there was observed 69 species at 63 sampling stations at water depths in this area were down to 42.5 m (Institut für Ostseeforschung Warnemünde 2003). All species, but one (*Diastylis lucifera*), in our study were represented in the species list from Adlergrund. The higher species number in the German study is most likely due to more sampling stations and several deep sampling stations.

4.4.6 Summary

The surface sediment consisted mainly of medium and coarse sand in shallow water. The sediment becomes finer and the content of silt/clay and organic matter increases in deeper water in the southern part of the area. The species richness was low and characteristic for shallow, low saline areas in the Baltic Sea. The abundance and biomass of the benthic fauna were low and dominated by a few species of polychaetes (*Pygospio elegans* and *Marenzelleria viridis*) and bivalves (*Mytilus edulis, Mya arenaria* and *Macoma balthica*). The similarity of the benthic fauna was high and the spatial differences in the structure of the benthic community was associated with differences in water depth and associated changes in the structure of the sediment such as the content of organic matter and a higher salinity in deeper water. The benthic fauna community at all stations resembles a shallow water community, which predominantly is found above a seasonal halocline and which is associated soft bottom that is muddy to sandy. This community was defined in the baseline report for the Fehmarnbelt Fixed Link, FEMA 2013 and is named the Cerastoderma community. The Cerastoderma community is historically called the Macoma community. The name Cerastoderma was adapted to reflect this characteristic species of the community, which is not abundant in many other communities. *Macoma balthica* is also present in the community (thereby the classical naming) but is also abundant in many other communities.

It is expected due to this and the previous investigation that the Cerastoderma/Macoma community is present in the shallow areas south of Bornholm (Øresundskonsortiet 1995a, Rambøll Danmark 2008).

4.5 Benthic vegetation

Video observations of flora and seabed structure were conducted in connections with the sampling of the benthic fauna at the same 20 sampling stations (Figure 4.8). Each station was recorded for one minute and videos were analysed for the presence of benthic flora. In the impact area neither macroalgae nor visible concentrations of microalgae at the seabed surface were observed.

Previous investigations of Rønne Banke sand resources have shown very limited or no hard substrate at the seabed in the areas near the impact area (Anthonsen and Lomholt 1998). This was cooperated by the present studies. It is hence not expected to find benthic vegetation in the investigation area or in nearby areas.

4.6 Fish and fishery

4.6.1 Fish

Fish surveys were not undertaken in association with this study. Thus the baseline description of the fish community in the extraction area of Rønne Banke is based on both general knowledge and literature on fish in the Baltic Sea and on fish studies undertaken in the German parts of Adlergrund close to Rønne Banke. The studies are based on data collected in 2003-4. Since more recent data don’t exist, these data are used as as basis for the assessment

Relatively little is known about species composition, habitats, genetic diversity, ecology and endangerment of the fish community of the Baltic Sea (HELCOM 2002). This is in particularly the case for fish species that are not exploited by the commercial fisheries.

Biodiversity is low in the Baltic Sea due to its geological character as a very young brackish sea with a prehistory of being a freshwater lake. Many species are precluded due to the low oxygen levels and to fluctuating and progressively lower salinities as one move from the outer to the innermost parts of the Baltic. Thus the number of marine species is greater in the Kattegat and the western Baltic Sea, while the number of freshwater species (40 species) is more predominant in the eastern and northern Baltic Sea (Thiel et al. 1996).

Herring (*Clupea harengus*), sprat (*Sprattus sprattus*) and cod (*Gadus morhua*) are the major commercial fish species of the Baltic Sea. The status of these stocks has been monitored for decades with the longest record available for the eastern Baltic cod; since the mid-1940s.

The Baltic cod stocks peaked in the late 1970s and early 1980s. Since the 1980s, a climate-induced decrease in the cod reproductive volume, i.e., the amount of water with favourable conditions for successful hatching of cod eggs, has caused high cod egg mortality (ICES 2007a). This, together with very high fishing pressure, has resulted in low abundance of the cod stock since the early 1990s. However, some recovery in the eastern (east of Bornholm) cod spawning stock biomass has been observed during the past three years (ICES 2010). Reductions of the predation pressure by cod, accompanied by favourable hydrographical conditions, has allowed the sprat stock to increase since the late 1980s, which together with herring has strongly dominated the Baltic fish communities since then. This shift to domination by a pelagic fish community represents a profound change in the marine ecosystem, also called a "regime shift" (Alheit et al. 2005).

Cod (*Gadus morhua*) occurs in two populations or stocks in the Baltic Sea: eastern and western Baltic cod. These populations overlap in ICES subdivision 24 west of Bornholm Island. Spawning in the western Cod stock takes place in the deeper parts of the Western Baltic from January-April, somewhat earlier than the eastern stock (March-September) (Nissling and Westin 1997).

In periods with a strong inflow of new saline and oxygen-rich water from the North Sea various fish species migrate into the Baltic Sea. However, due to unfavourable environmental factors (essentially low salinity and temperature), these fish are unable to form self-sustaining populations in the Baltic Sea; they include, for example, such species as whiting (*Merlangus merlangus*), European anchovy (*Engrauli encrasicolus*) and mackerel (*Scomber scombrus*).

Herring (*Clupea harengus*) occur in large schools throughout the Baltic Sea, with clearly distinct stocks in different areas. Herring tend to make seasonal migrations between coastal archipelagos and open sea areas, spending summer and winter in the open sea areas and staying closer to the coast in spring and autumn. Herring have adhesive eggs and spawn on the seabed or on vegetation in coastal areas, which are sensitive to low oxygen concentrations and high concentrations of suspended solids. Since the early 1970s the spring spawning stocks have been dominating in the Baltic Sea, while the autumn spawning stocks have strongly decreased. Main spawning period in the Western Baltic is from March-May (ICES 2007b). Rønne Banke is not considered to be an area where herring spawn due to the absence of suitable substrate (primarily vegetation).

Sprat (*Sprattus sprattus*) occur in large schools throughout the Baltic Sea, seeking out warmer water layers during different seasons and avoiding areas where water temperature drops to less than 2-3°C. Sprat is an open-sea "pelagic" species and spawning and the distribution of its planktonic eggs is restricted to deeper parts of the Baltic Sea (Baumann et al. 2006). According to Swedish authorities (Fiskeriverket 2008) spawning also takes place in more coastal areas (depth 10-40 m) of the Western Baltic Sea, where the spawning period is from March-August.

Sandeels (*Ammodytes* sp.) are non-migratory species, living within a sandy substrate during night and winter and swimming in schools in the pelagic during daytime. Sandeels lay their eggs in the sand, and the sand grains of a certain size adhere to them. *A. marinus* is sawn in winter time, *A. tobianus* spawns in early spring and autumn (Whitehead et al. 1986). Sandeels constitutes an important part of the food for gadoids and other predatory fish.

Flounder (*Plathichtys flesus*) can be divided into two ecological distinct groups: one southern with pelagic eggs and one northern with demersal eggs. The southern Baltic flounder migrate between coastal feeding areas and spawn in the deep basins. They have larger, pelagic eggs that are adapted to floating despite the low salinity. Flounder spawn in spring (ICES 2007c).

Turbot (*Psetta maxima*) are mainly stationary, but migrate in spring and autumn between shallow and deeper waters. Turbot is a summer spawner. Eggs are not buoyant at salinities below 20‰, which means that the eggs of Baltic Sea turbot are demersal instead of pelagic. Spawning takes place in relatively shallow waters (10-40 m) and the metamorphosing post larvae migrate towards shallower depths near the shore (Florin 2005).

Plaice (*Pleuronectes platessa*) spawn only in the relatively saline water of the Western Baltic Sea and the deeper areas in the Central Baltic. Spawning takes place in winter, from December-February. Eggs are pelagic (Florin 2005).

Salmon (*Salmo salar*) usually follows schools of herring and sprat. Salmon spawn in rivers.

Eel (*Anguilla anguilla*) enter the Baltic Sea as glass eels coming from the Atlantic Ocean. Recruitment has declined over the last 25 years. Migration back to the Atlantic Ocean takes place from August to October. The swimming depth during migration is close to the surface. However, they dive to deeper water several times during the night hours (Westerberg et al. 2007).

Species known to occur in the Rønne Banke area

Danish fish studies have not been undertaken on Rønne Banke. However, the fish community in the German economic zone (EEZ zone) on the western part of Rønne Banke and partly on Adler Grund just to the south of Rønne Banke (Figure 2.2) has been investigated by Thiel and Winkler (2007). Because depths and sediment conditions in these areas are similar to those of Rønne Banke it can be assumed that the fish communities in both areas are also similar.

Other sources of information on the fish assemblages in the Rønne Banke area come from the archives of the Danish Museum of Natural History, commercial fishery logbooks, interviews of fishermen and diverse literature from that part of the Baltic.

In total 37 fish species are registered in the Rønne Banke-area (Table 4.11) of which 25 spend their entire life-cycle in the Baltic Sea area. Four of the species are anadromous, spawning and growing up in rivers running into the Baltic Sea. Three species, the catadromous eel and the highly migratory lumpsucker and garfish, spend significant parts of their life outside the Baltic Sea. The freshwater species bullhead (*Cottus gobio*) does not belong to the brackish water assemblage associated to the Rønne Banke and is only observed in the area on rare occasions. The remaining 8 species also only occur sporadically, and have their main distribution outside the Baltic Sea.

The fish community found in the Rønne Banke area can be divided into two categories: pelagic fish living near the surface or in the water column: Herring, sprat, salmon, trout, garfish, sandeel (pelagic in daytime), twaite shad, and demersal (benthic) fish species living in, on or close to the seabed: Cod, sandeel (in night and in wintertime), flatfish-species, eel and lumpsucker (demersal when feeding, pelagic during migration), bull-rout, gobies (transparent goby partly pelagic). Most of the demersal species prefer sandy seabeds with stones, mussel banks, sea grass and algae. Sandy bottoms are especially important to the sandeels because of their burrowing mode of life, living in the bottom during night and in wintertime.

Table 4.11 Fish species known to occur in the Rønne Banke area. Species names given in bold: Species native to, and spawning in the Baltic Sea area (BS).

Species	Habitat (Whitehead et al. 1986)	Reproduction	Ref.*
Cod (*Gadus morhua*)	Demersal or in intermediate water layer	Pelagic eggs Spawning in BS	1,2,3,4
Whiting (*Merlangius merlangus*)	Shallow water, usually 30-100 m, above the bottom often near surface	Pelagic eggs	1,3,4
Saithe (*Pollachius virens*)	Offshore and inshore, midwater, in surface and bottom layer	Pelagic eggs	4
Pollack (*Pollachius pollachius*)	Offshore and inshore, midwater, in surface and bottom layer	Pelagic eggs	3
Haddock (*Melanogrammus aeglefinus*)	Offshore, benthic at 30-40 m depth, occasionally in midwater	Pelagic eggs	4
Plaice (*Pleuronectes platessa*)	Demersal on mixed bottoms, from a few meters to about 100 m	Pelagic eggs Spawning in BS	1,2,3,4
Dab (*Limanda limanda*)	Demersal on sandy bottoms, from a few meters to about 100 m	Pelagic eggs Spawning in BS	1,2,3,4
Flounder (*Platichthys flesus*)	Demersal at shallow depths with soft bottoms	Pelagic eggs Spawning in BS	1,2,3,4
Turbot (*Psetta maxima*)	Demersal on sandy and stony bottoms down to about 70 m	Demersal eggs Spawning in BS	1,2,3,4
Brill (*Scophthalmus rhombus*)	Demersal on sandy bottoms, shallow waters	Pelagic eggs Spawning in BS	4
Lemon sole (*Microstomus kitt*)	Demersal on stony bottoms at 20-200 m	Pelagic eggs	4
Common sole (*Solea vulgaris*)	Demersal on sandy and muddy bottoms, from shallow waters down to 200 m	Pelagic eggs	4
Herring (*Clupea harengus*)	Pelagic, juveniles occurring in shallow water near spawning grounds, moving into deeper waters after two years	Demersal eggs Spawning in BS	1,2,3,4
Sprat (*Sprattus sprattus*)	Pelagic, migrating between winter feeding and spring and summer spawning grounds	Pelagic eggs Spawning in BS	1,3,4
Atlantic mackerel (*Scomber scombrus*)	Pelagic, migratory	Pelagic eggs	4
Garfish (*Belone belone*)	Pelagic, migratory	Demersal eggs Spawning in BS coastal areas	4
Horse mackerel (*Trachurus trachurus*)	Pelagic	Pelagic eggs	4
Lumpsucker (*Cyclopterus lumpus*)	Benthic on rocky bottoms usually between 50-150 m. Highly migratory	Demersal eggs, Moving inshore to spawn (also in BS)	2,4
Sandeel (*Ammodytes* sp.)	Offshore (A. marinus) and inshore (A. tobianus) waters. Within sandy substrate during night and in winter. Swimming in schools in the pelagic	Demersal eggs Spawning in BS	1,2,3,4

Species	Habitat (Whitehead et al. 1986)	Reproduction	Ref.*
	during day-time		
Greater sand-eel (*Hyperoplus lanceolatus*)	Inshore and offshore to about 60 m depth. Commonly associated with Ammodytes species.	Demersal eggs Spawning in BS	3,4
Sea snail (*Liparis liparis*)	Benthic in depths from subtidal to less than 300 m	Demersal eggs Spawning in BS	3
Viviparous eelpout (*Zoarces viviparus*)	Benthic on rocky shores under stones and among algae, down to 40 m.	Viviparous Spawning in BS	2,3,4
Rock gunnel (*Pholis gunnellus*)	Benthic, shallow waters but descend-ing to deeper water especially in win-ter	Demersal eggs Spawning in BS	3
Bull-rout (*Myoxocephalus scorpius*)	Benthic on rocky bottoms with sand or mud, 20-50 m	Demersal eggs Spawning in BS	2,3,4
Hooknose (*Agonus cataphractus*)	Benthic in inshore waters, deeper in winter. Prefers sandy bottoms, rarely with stones	Demersal eggs Spawning in BS	2,3,4
Four-bearded rockling (*Rhinonemus cimbrius*)	Benthic on soft mud or sand, 20-650 m	Pelagic eggs Spawning in BS	3
Three-spined stickleback (*Gasterosteus aculeatus*)	Estuaries and coastal waters, shoaling offshore outside breeding season (spring)	Demersal eggs Spawning in BS	2,4
Eel (*Anquilla anguilla*)	Demersal, Pelagic during migration	Catadromous Spawning outside BS	1,2,3,4
Transparent goby (*Aphia minuta*)	Nektonic, surface to 70-80 m, over sand, mud, eel-grass etc.	Demersal eggs Spawning in BS	3,4
Sand goby (*Pomatoschistus minutus*)	Benthic, inshore sand and muddy sand , shallow down to about 20 m	Demersal eggs Spawning in BS	3
Black goby (*Gobius niger*)	Benthic, inshore waters down to 50-75 m, on sand or mud, in sea-grass or algae	Demersal eggs Spawning in BS	3
Two-spotted goby (*Gobiusculus flavescens*)	Inshore, midwater around weed-grown structures down to 20 m	Demersal eggs Spawning in BS	3
Atlantic salmon (*Salmo salar*)	Pelagic, migratory	Anadromous Spawning in rivers	1,3,4
Sea trout (*Salmo trutta trutta*)	Pelagic, migratory	Anadromus Spawning in rivers	1,2,4
Smelt (*Osmerus eperlanus*)	Pelagic, migratory	Anadromous Spawning in rivers	3
Twaite shad (*Alosa fallax*)	Pelagic, migratory	Anadromous Spawning in rivers	2,4
Bullhead (*Cottus gobio*)	Demersal in freshwater and low salini-ty waters, migratory	Demersal eggs spawning in freshwater	3

*References: 1) Logbooks 2005-2010, ICES rectangle 38G4.2) Danish Museum of Natural History, 3) Janssen et al. 2008, Thiel and Winkler 2007, Kloppmann et al. 2003, Thiel et al. 2008. 4) Interviews of fishermen. BS = Baltic Sea

Twaite shad, autumn spawning herring, salmon, cod, eel and sea snail, are included in the HELCOM List of threatened species and categorised as endangered (HELCOM 2007). Salmon and twaid shad are also listed on annex II and V of the Habitats Directive.

4.6.2 Fishery

In the past 10 years, the overall landings of the Danish fisheries in the Western Baltic Sea have decreased by approximately 50%, but they still constitute an important part of Danish fisheries.

Historically cod, herring and sprat have made up the vast majority of the catches. Diverse flatfish species, European eel, salmon have also been targeted.

The fisheries in the Baltic Sea are divided by the international fishery zones where national and international fishery regulations and quotas apply and catch data is separated. These zones, ICES rectangles (approx. 30 x 30 nm), are used to form the boundaries for the presentation of the official commercial fisheries data.

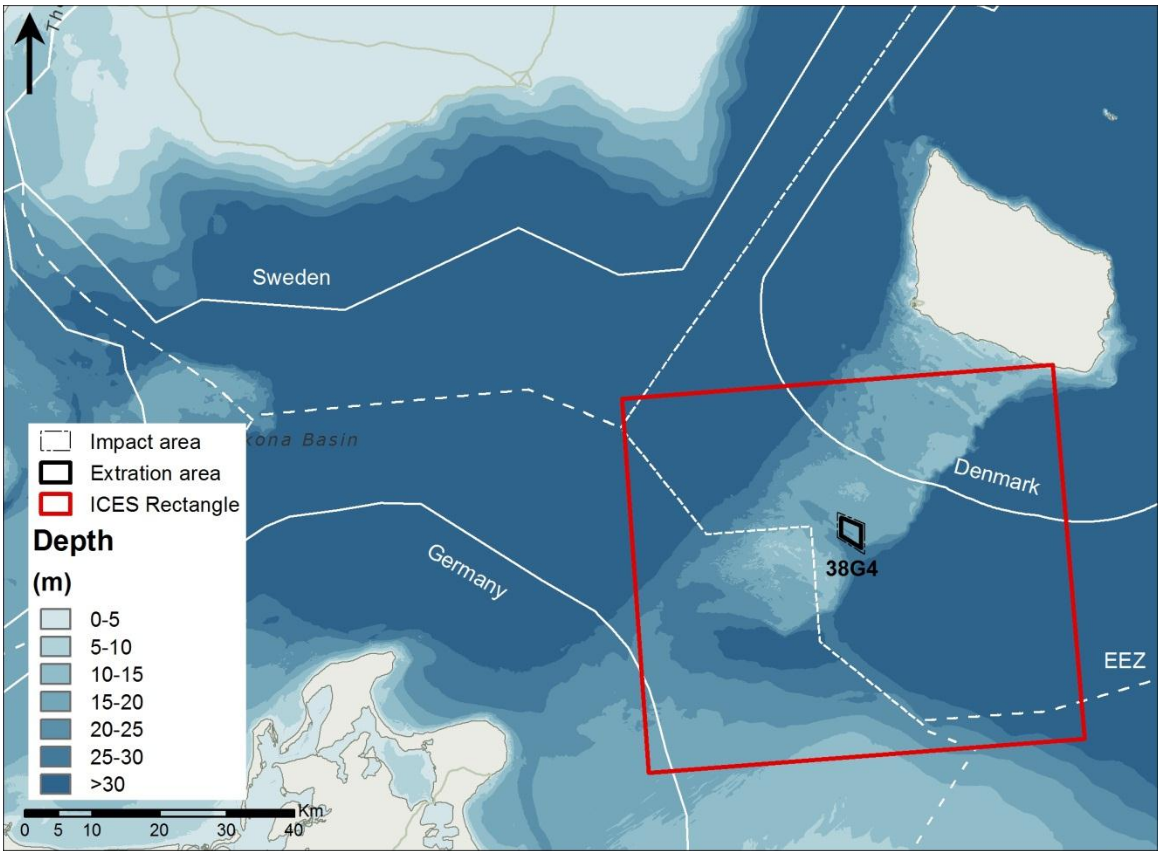


Figure 4.16 The ICES statistical rectangle 38G4 in the Western Baltic Sea. The proposed extraction area is represented by a black rectangle in the centre of the map.

The proposed area for sand extraction at Rønne Banke is situated in ICES rectangle 38G4 (Figure 4.16). Official data for landings and additional fleet statistics for this rectangle were obtained from the Danish Directorate for Fisheries. Data does not include information on vessels less than 8 m (less than 10 m before 2005) because these vessels are not required to fill out logbooks. However, because vessels of these lengths primarily fish in the vicinity of their home harbour and only catch a small part of the fish in the relevant ICES rectangle, the official catch statistics are considered to contain the essential fisheries information.

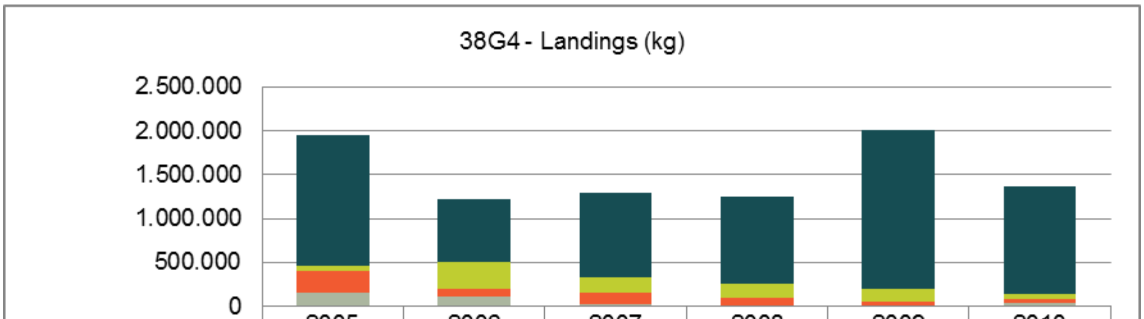
It is important to note that the sand extraction area constitutes less than 1% of the area of ICES rectangle 38G4.

In order to give a thorough description of the distribution of the fisheries by large vessels (≥15 m), additional Vessel Monitoring System (VMS) data were obtained from the Danish Directorate for Fisheries. Data are available from 2005.

To supplement the official fishery statistics, which are bound by the spatial resolution of the ICES rectangles, group and individual consultation meetings were held with relevant Danish vessel owners and their representatives. Supplementary to VMS, plotter data were obtained from two trawler-fishermen from Bornholm Island.

Landings and gear types
Landings from ICES 38G4 have fluctuated between 1200-2000 tons (14-26 mill DKK in value) over the last 6 years (Figure 4.17).

The landings according to gear (Figure 4.20) show that the trawl fisheries are by far the most prominent in ICES 38G4 and its relative importance has been increasing during recent years. In contrast, landings from gill netters in the same period have been declining to the present low level. Fishing with seine nets, and to a lesser extent "other gear" (long lines etc.) have been relatively limited, without any trend in the period.



	2005	2006	2007	2008	2009	2010
Bottom trawl	1.482.570	713.384	951.549	999.025	1.818.760	1.228.906
Pelagic trawl	58.604	301.008	184.961	153.775	139.560	53.174
Seine nets	7.590	5.920	12.481	0	2.775	14.675
Gill/trammel nets	246.503	80.832	106.045	91.430	37.276	25.892
Other gear	148.187	112.013	30.475	6.080	12.841	43.820

Figure 4.17 Annual (2005-2010) landings (kg) and their values (1000 DKK) from ICES 38G4 according to gear types (Danish Directorate of Fisheries – logbook and vessel registration FVM 2011).

Seasonality of landings according to gear, value and fish species
The seasonality of the landings from ICES 38G4 (Figure 4.18) show that a large majority of landings are from bottom trawl fishing and that most of the trawling activity is taking place in the second half of the year. Fishing with pelagic trawl and gill nets is relatively more pronounced in the first half of the year.

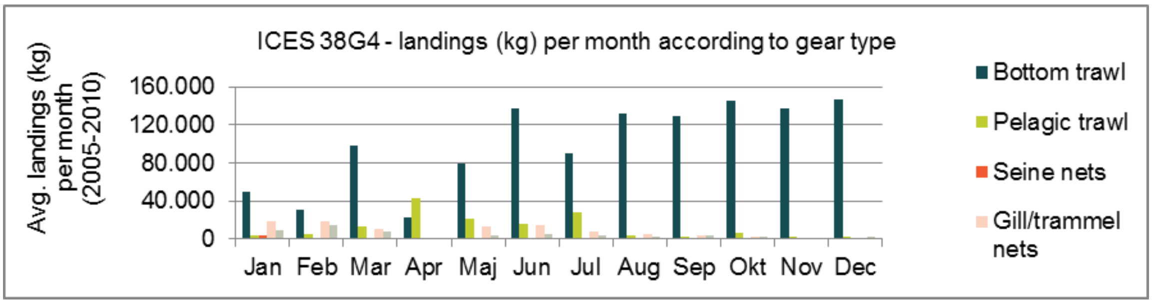
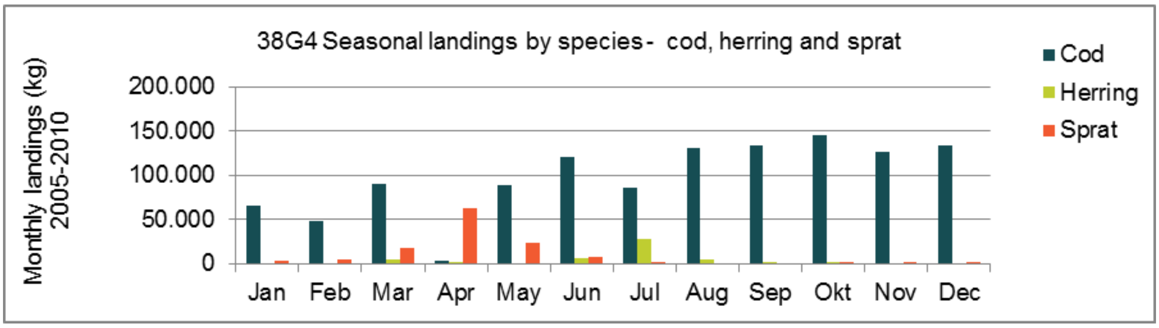


Figure 4.18 Average landings (kg) per month in ICES 38G4 according to gear type (Danish Directorate of Fisheries logbook and vessel registration FVM 2011).

The average monthly landings (2005-2010) for the most important commercial species for ICES rectangle 38G4 are given in Figure 4.19.

Monthly landings of cod are at its highest level during the period May-December, but significant catches are also taken in the first part of the year. Landings of the two pelagic species herring and sprat peak in March-July and are not represented in the commercial fisheries for the remaining part of the year.

Plaice and flounder dominate the flatfish catches. Landings are low in the summer months (April-July) and increase during the autumn. Landings of flounder peak in January while landings of plaice peak in the last months of the year.



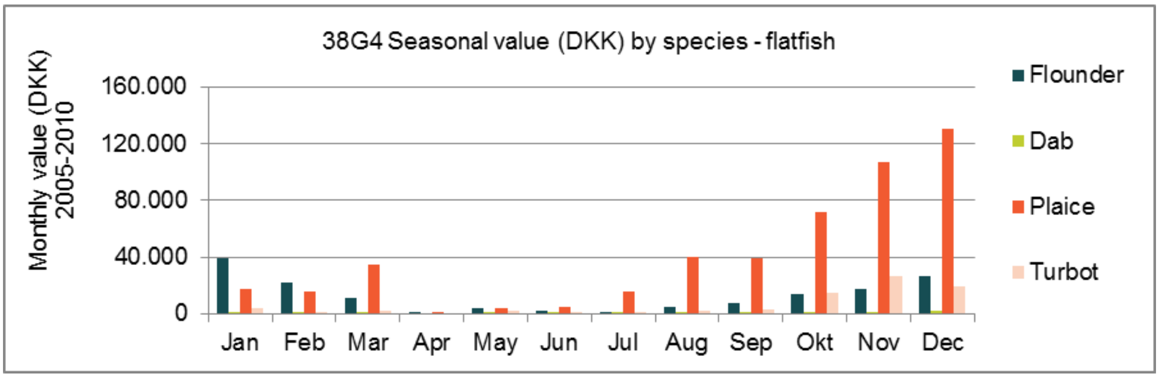


Figure 4.19 Seasonal landings of the most important fish species from ICES 38G4 (Danish Directorate of Fisheries – logbook registration FVM 2011).

Cod was by far the economically most important commercial species. The value of cod landings was more than 10 times the value of the combined landings of all the other commercial species. The value of the plaice landings represented the next most important fishery; however this value was only approximately 3% of the value of cod landings.

Fishing activity according to size of vessel, gear type and basis harbour
The number of registered fishing trips can be used as a proxy for fishery activity in ICES 38G4 (Table 4.12). As mentioned earlier this data does not include vessels less than 8 m in length, which are generally not considered to participate in the fisheries in the extraction area.

Most of the registered fishing trips are undertaken by vessels using bottom trawls and are dominated by vessels between 8-15 m in length. In all, the proportion of fishing trips using trawls has been increasing and at present represents about 75% of the total number of fishing trips. For vessels >15 m almost all the fishing trips are undertaken by vessels using trawls. The gill net fishery has decreased considerably since 2005 and the fishery with seine nets has been very low throughout the entire period.

Table 4.12 Number of registered fishing trips in ICES 38G4 (Danish vessels ≥ 8m) (Danish Directorate of Fisheries – logbook and vessel registration).

Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
8-15 meter	1,638	757	495	396	512	629
Bottom trawl	740	325	292	226	393	448
Gill nets	642	222	145	134	88	119
Pelagic trawl	5	14	5	1	1	1
Other gear	251	196	53	35	30	61
>15 meter	396	232	178	192	299	175
Bottom trawl	344	175	150	171	276	165
Gill nets	25	16	9	11	2	0
Pelagic trawl	8	22	14	10	14	4
Seine nets	5	3	2	0	2	3
Other gear	14	16	3	0	5	3
Total	2,034	989	673	588	811	804

According to logbook data for the period 2005-2010 vessels with their basis harbours on Bornholm have annually landed more than 70% of the total landings from ICES 38G4. Vessels from Rødvig, Klintholm and Bagenkop have landed approximately 11%, while 6% of the landings are from vessel with their basis harbours in north and west Jutland. Cod has been the most important species for vessels from all harbours (Table 4.13).

Table 4.13 Annual average landings from 2005-2010 according to vessels from the most important harbours and commercial species (Danish Directorate of Fisheries – logbook registration FVM 2011).

Bagenkop, Klintholm, Rødvig			**Bornholm harbours**		
Species and groups	Landings (kg)	Value (DKK)	Species and groups	Landings (kg)	Value (DKK)
Cod	122,474	1,773,171	*Cod*	836,444	12,110,041
Herring/Sprat	37,833	47,065	*Herring/Sprat*	101,218	148,098
Flatfish	10,838	105,253	*Flatfish*	50,712	485,515
Unspecified	852	10,996	*Unspecified*	83,965	776,328
Total	**171,996**	**1,936,485**	**Total**	**1,072,339**	**13,519,982**

West and North Jutland harbours			**Other harbours**		
Species and groups	Landings (kg)	Value (DKK)	Species and groups	Landings (kg)	Value (DKK)
Cod	79,006	1,143,846	*Cod*	126,966	1,838,209
Herring/Sprat	5,833	6,510	*Herring/Sprat*	26,333	33,323
Flatfish	8,892	80,148	*Flatfish*	4,981	40,579
Unspecified	1,013	9,513	*Unspecified*	2,100	22,851
Total	**94,744**	**1,240,017**	**Total**	**160,380**	**1,934,961**

Fishing distribution according to VMS data

As of 2005, all Danish fishing vessels ≥15 m are required to operate a satellite-based vessel monitoring system (VMS) which registers the position of each vessel at regular time intervals. These data makes it possible to map the distribution of fishing activity. Vessel speeds lower than 4.5 knots for trawlers, 2 knots for gill netters and 3 knots for seine netters are considered to indicate speeds when fishing activities are taking place.

The number of small vessels (8-15 m) operating in the area is greater than the number of large vessels (≥15 m) (see Table 4.14).

It is well known that trawlers often fish along specific tracks which depend on the bottom topography, especially avoiding heterogeneous bottoms with stones and boulders which make fishing with bottom gear impossible or very difficult and full of risk to damage gear. Fisheries with stationary gear, primarily gill nets, are generally carried out in areas with mixed bottoms, partly because spatial conflicts with trawlers are minimal and because areas with structure such as stones and boulders on the bottom are good fishing areas.

As it is seen from the mapping of the fishing distribution in the area west of Bornholm Island (Figure 4.20) a significant trawling route passes through the proposed extraction area. No fishery with larger gill netters and seiners are taking place inside the extraction area. The large gillnetting vessels, the majority coming from west coast harbours, generally undertake their fisheries west of the Natura 2000 area (west of the extraction area) and east of Rønne Banke (Figure 4.20).

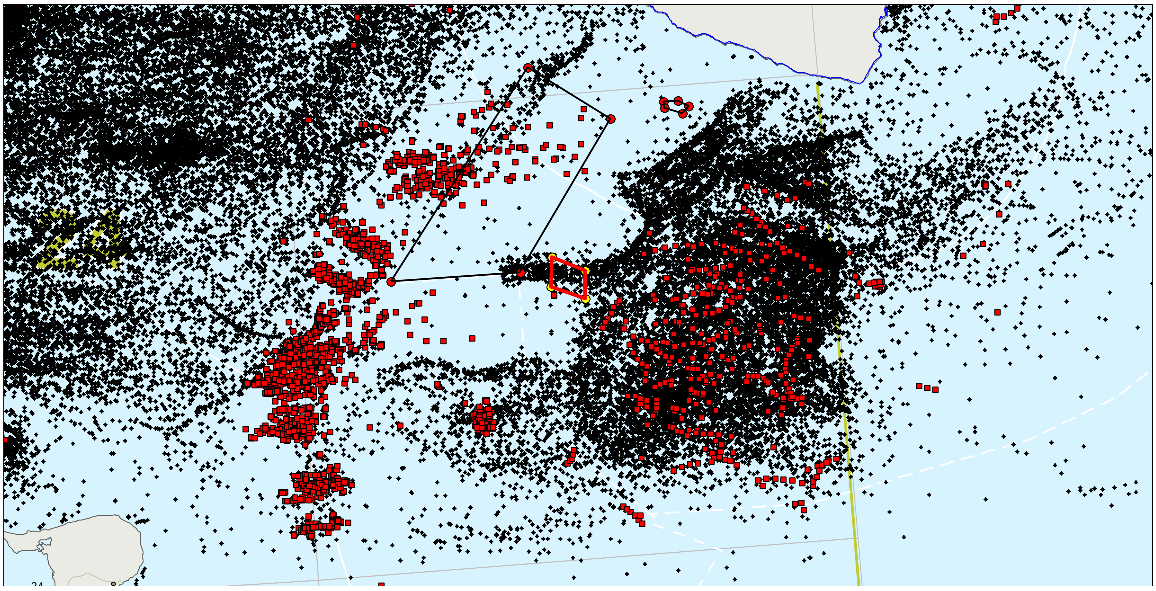


Figure 4.20 The distribution of the fishing activity of Danish trawlers (black dots), gill netters (red dots) and seiners (green dots) in the Baltic Sea south and west of Bornholm Island (ICES 38G4). The distribution of plots is derived from VMS data for vessels ≥15 m in the period 2005-2010. The proposed extraction area is represented by a red rectangle in the centre of the map. The Natura 2000 area to the west of this area is indicated by black lines representing its borders.

A relative indication of the fishing activity for large vessels (≥15 m) within the extraction area can be obtained by the number of VMS plots in the extraction area compared to the number of plots in the entire ICES 38G4 rectangle (Table 4.14). This data indicates that the relative importance of the fishery inside the extraction area has declined from more than 1% in 2005 to 0.3% in 2010. It is important to note that this information only represents the larger vessels (≥15 m) in the area and does not indicate their landings. Similar data is not available for vessels less than 15 m, which account for approximately 60 % of the total landings in ICES 38G4.

Table 4.14 Registered VMS plots (trawlers≥15m) in the extraction area and in ICES 38G4.

Year	Extraction area	ICES 38G4	% effort in area
2005	49	4,009	1.2
2006	24	2,733	0.9
2007	22	2,356	0.9
2008	16	2,782	0.6
2009	6	4,101	0.1
2010	8	2,567	0.3

Fishing activity according to information from fishermen

Some trawl fishermen electronically save their trawl tracks on map plotters and to a certain degree share these with each other. This is exemplified for the fishing area south of Bornholm, including Rønne Banke and the extraction area. This information supports the distribution of the fisheries indicated by VMS data, but also gives an indication of how the fisheries are practiced. The trawling pattern indicates that trawl tracks can encompass the entire route from a position north of Adler Grund (Approx. pos. 14°22Ø, 54°49 N) to a point south of Arnager Reef (Figure 2.1). The duration of trawl tracks is from 6 to 13 hours (longest in pair trawling) and a distance of 21- 45 nautical miles. If trawling is undertaken through the southern part of the trawl route that passes through the extraction area then the duration of trawling is approximately 6-8 hours (21-28 nautical miles).

In the relatively shallow waters (17-20 m) the fisheries are undertaken only at night with the main fishing season in the second half of the year. In the winter, cod and other commercial species migrate to deeper waters.

The area of Rønne Banke is according to information from fishermen an important fishing ground for 10-15 trawlers from Bornholm. For the most active fishermen, up to 40% of their annual turnover can come from this area. Cod is the primary target species with flatfish (primarily flounder and plaice) being an important bycatch. In the summer (June-July) of 2011 there was also an important fishery targeting sandeels in the same area. Fishing for sandeels is carried out during the day-time.

According to interviews with local fishermen not one of the smaller local gill netters and long liners are active in the extraction area – most of their fishery is carried out in more coastal areas.

4.7 Birds

The extraction site on Rønne Banke does not house any local breeding waterbirds. Accordingly, the baseline description is focused on the occurrence of non-breeding waterbirds which stage and feed locally, and the regional characteristics of bird migration.

4.7.1 Non-breeding waterbirds

A recent review of wintering waterbird populations in the Baltic Sea based on coordinated censuses between 2007 and 2009 included the planned extraction site on Rønne Banke (Skov et al. 2011). The censuses included the country-wide surveys undertaken in Danish waters during the winter of 2007/08 (Petersen et al. 2010). From the modelled densities provided by the review it is clear that the Long-tailed Duck is the only common species with a total abundance estimate of 12,000 birds (Figure 4.21, Table 4.15). The densities of Long-tailed Ducks on the extraction site on Rønne Banke were between 10 and 20 birds/km^2 (Skov et al. 2011). According to Durinck et al. (2004) mean densities of Black Guillemot of 0.8 birds/km^2 occurred at the extraction site during midwinter in the early 1990es (Table 4.15). Danish waterbird monitoring data from 2004 and 2008 corroborate the findings for Long-tailed Duck, Common and Velvet Scoter.

Table 4.15 Reported densities of wintering waterbirds at Rønne Banke (from Durinck et al. 1994 and Skov et al. 2011).

Species	Density (birds/km^2)
Red-throated/ Black-throated Diver (*Gavia stellate/arctica*)	0.1 – 0.2
Red-necked Grebes (*Podiceps grisegena*)	0 – 0.01
Long-tailed Duck (*Clangula hyemalis*)	10 – 20
Common Scoter (*Melanitta nigra*)	0.25 – 0.5
Velvet Scoter (*Melanitta fusca*)	< 0.1
Little Gull (*Larus minutus*)	0.01 – 0.09
Common Gull (*Larus canus*)	0.1 – 4.99
Herring Gull (*Larus argentatus*)	0.1 – 4.99
Great Black-backed Gull (*Larus marinus*)	0.1 – 0.49
Razorbill (*Alca torda*)	0 – 0.99
Common Guillemot (*Uria aalge*)	0.1 – 0.99
Black Guillemot (*Cepphus grylle*)	0.8

The review of waterbirds in the German EEZ by Garthe (2003) based on baseline surveys prior to development of marine wind farms adds the following details on regular occurrence of species of seabirds and seasonality on Adler Grund south of the extraction site on Rønne Bank: Red-throated/Black-throated Divers (winter, spring), Common Eider (spring), Long-tailed Duck (winter, spring), Common Gull *Larus canus* (winter, spring), Herring Gull *Larus argentatus* (winter, spring, autumn), Great Black-backed Gull *Larus marinus* (winter, spring, autumn), Lesser Black-backed Gull *Larus fuscus* (spring, autumn), Common Guillemot *Uria aalge* (winter, spring), Razorbill *Alca torda* (winter, spring) and Black Guillemot (winter, spring).

Historic and recent data on the occurrence of waterbirds at the extraction site on Rønne Banke document that no species presently occur at the site in concentrations of international importance. The most important occurrence of waterbirds is the concentration of Long-tailed Duck which regularly exceeds 10,000 birds over the southern part of Rønne Banke and Adler Grund in winter and spring. Within a distance of less than 50 km (to the southeast), concentrations of wintering waterbirds of high international importance are found in the Pomeranian Bay (Figure 4.21, Skov et al. 2011, Durinck et al. 1994). Other seaducks, divers and Red-necked Grebes seem to use the area regularly, albeit in low densities. More pelagic species like auks and gulls also use the area; aggregations of large gulls are typically associated with intensive fishing activities.

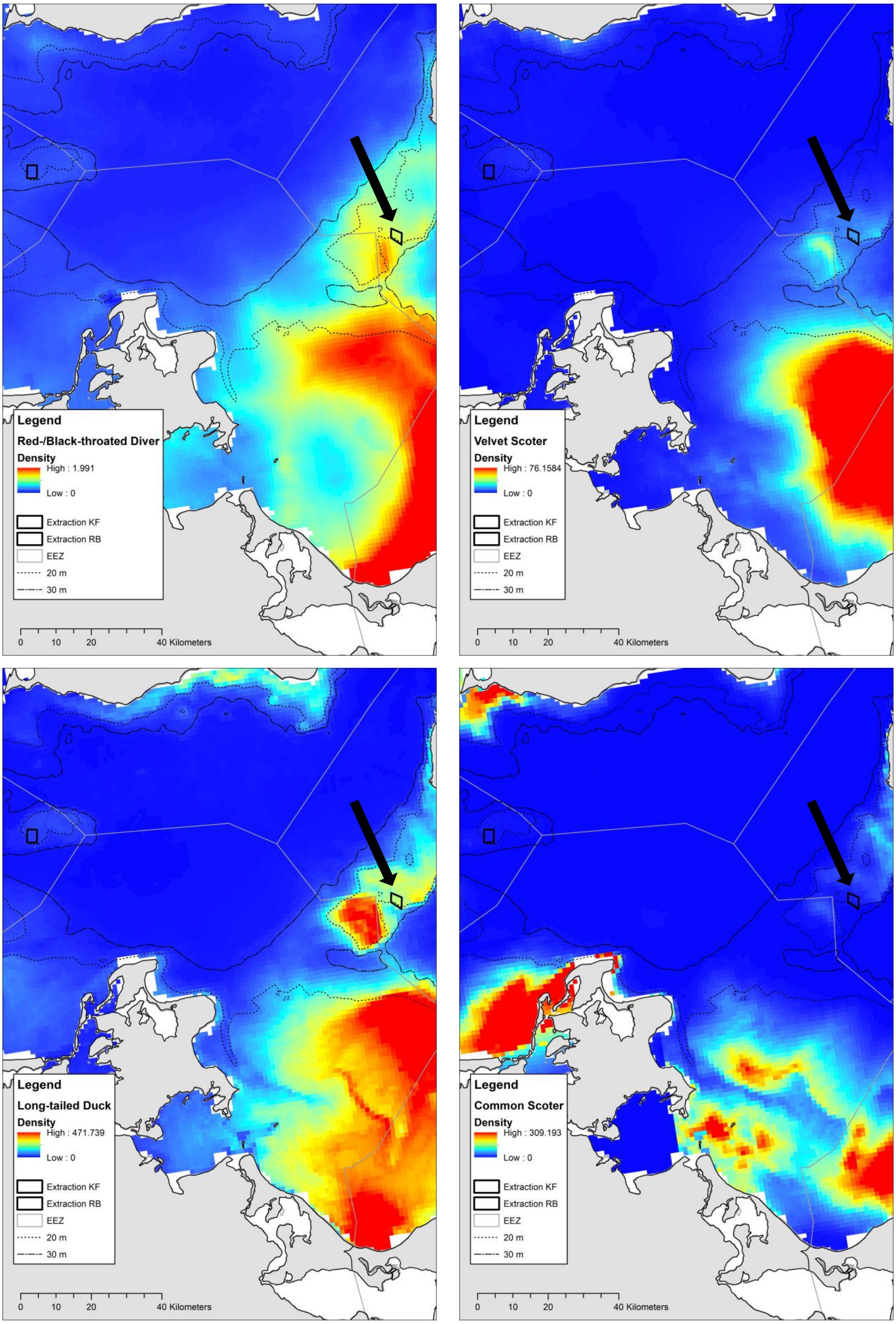


Figure 4.21 Distribution of selected species of waterbirds during winter in relation to the location of the sand extraction site. The map shows mean densities (birds per km^2) from 2007 to 2009; modelled on the basis of Danish, German, Swedish and Polish aerial and ship-based line transect data (Source: modified from Skov et al. 2011). KF: Kriegers Flak and RB: Rønne Banke. The extraction site at Rønne Banke is marked by an arrow.

4.7.2 *Bird migration*

Baseline investigations undertaken in relation to the planned wind farms on the Swedish and German parts of Kriegers Flak, which is also situated in the Arkona Basin, and Adlergrund (Arkona Becken Südost, Ventotec Ost 2) have provided the main sources of recent information on the timing and intensity of bird migration through the Arkona Basin. The migration of waterbirds trough the Arkona Basin seems mainly to take place over a relatively broad front, and is dominated by Common Eider, Barnacle Goose *Branta leucopsis* and Common Scoter. The radar study by Petterson (2003) from the Swedish south coast indicated that 30% of the waterbirds were moving within a distance of 10 km from the coast, while the remaining 70 % were dispersed over a wide front without any obvious use of specific corridors.

The migration of landbirds through the region is markedly different during day and night both with respect to dominating species and migration altitude. Recorded flight intensities during night indicate that the flux of birds peaks on very few nights (Kube et al. 2004). During spring, nocturnal migration was most intense 5-6 hours after sunset, and during autumn 3-4 hours after sunset, indicating recruitment areas in Mecklenburg and southern Sweden, respectively (Kube et al. 2004). Diurnal migration was less intense, and showed no obvious peaks.

The diversity of bird migration can be quite high, as shown by counts of visual migration at Krieger's Flak (65 days, German part) in which 116 species were observed. The vertical distribution of migrating birds showed the same general trends documented by other studies that birds tend to fly at lower altitudes during head winds and at lower altitudes during the day as compared to during the night. Overall most bird echoes during night were recorded in the lower 200 m (IfAÖ 2003).

4.8 *Marine mammals*

The inner Danish waters and south-western Baltic Sea are inhabited by three species of marine mammals; the harbour porpoise (*Phocoena phocoena*), the harbour seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). All three species are piscivorous; hence most likely they feed regularly on fish in the areas where they occur.

4.8.1 *Harbour porpoise*

The harbour porpoise is a strictly protected species listed in the EU Habitat Directives Appendix IV. It is also a major animal of concern in the ASCOBANS agreement under the Bonn Convention. It is the most common cetacean in Danish waters, and is also the only cetacean known to use the Danish waters in all aspects of its life cycle.

Harbour porpoises have been observed in the Danish and German regions of the Baltic Sea through aerial and ship-based visual surveys, satellite-tagged individuals and passive acoustic monitoring using T-PODs and opportunistic observations (Figure 4.22, Figure 4.23, Figure 4.25, Figure 4.26, Figure 4.28). Although none of these studies were designed specifically to document the use of Rønne Banke, they provide general information about the occurrence of mammals in the region.

The large-scale visual and acoustic surveys of harbour porpoises in all European waters in the summers of 1994 and 2005 (Hammond et al. 2002, 2006) show that even though porpoises are relatively abundant in Danish waters their abundance decline rapidly throughout the Danish and German part of the Baltic Sea from west to east (Teilmann et al. 2008).

These studies indicate that porpoises occur in low density at Rønne Banke (Scheidat et al. 2008, Teilmann et al. 2008). There seems to be a slight difference between summer and winter distributions, with a small increase in likelihood of occurrence during the summer period (Figure 4.22 and Figure 4.26, Teilmann et al. 2008, Verfuss et al. 2007). The passive acoustic monitoring data shown in Figure 4.26 was collected in 2005, but the same study also collected data during parts of 2002 as well as all of 2003 and 2004. The data from these years showed a very similar pattern to the one in 2005 (Verfuss et al. 2007). As the same pattern emerges from the visual and acoustic data the seasonal difference in abundance is judged as genuine, and not solely an artefact caused by more calm sighting conditions during summer. The large-scale decrease in occurrence of porpoises east of Darss Sill is also evident from the passive acoustic monitoring data collected by Verfuss et al. (2007) and shown in Figure 4.26. The decrease in the occurrence of harbour porpoises east of the Dars sill was further documented during the study of satellite tagged animals from the Belt Sea undertaken as part of the Fehmarnbelt Fixed Link baseline studies (Figure 4.27).

In summary, Rønne Banke seems to be of little importance for Danish and German porpoises. However, individuals, either spending time in the area foraging or animals migrating eastward into the Baltic Sea might still be affected.

It is currently challenging to assign porpoises occurring at Rønne Bank to any distinct population. Genetic studies by Wiemann et al. (2010) indicate that at least two genetically distinct populations of porpoises occur in the Baltic Sea: one in the Skagerrak and another in the BeltSea with seasonal overlaps in the Kattegat (see also Sveegaard et al. 2011). Although some further differences between the Belt Sea and the Inner Baltic were found, this was not statistically significant and did not separate a third genetically distinct population for the Inner Baltic. Porpoises occurring in the Rønne Bank area could thus belong to the population of the Belt Sea and Kattegat. This is supported by the FEMM telemetry studies that clearly showed that all position signals in the Rønne Bank area where from individuals that were caught in the Belt area (for a more detailed discussion, see FEMM Baseline report, Nehls 2012).

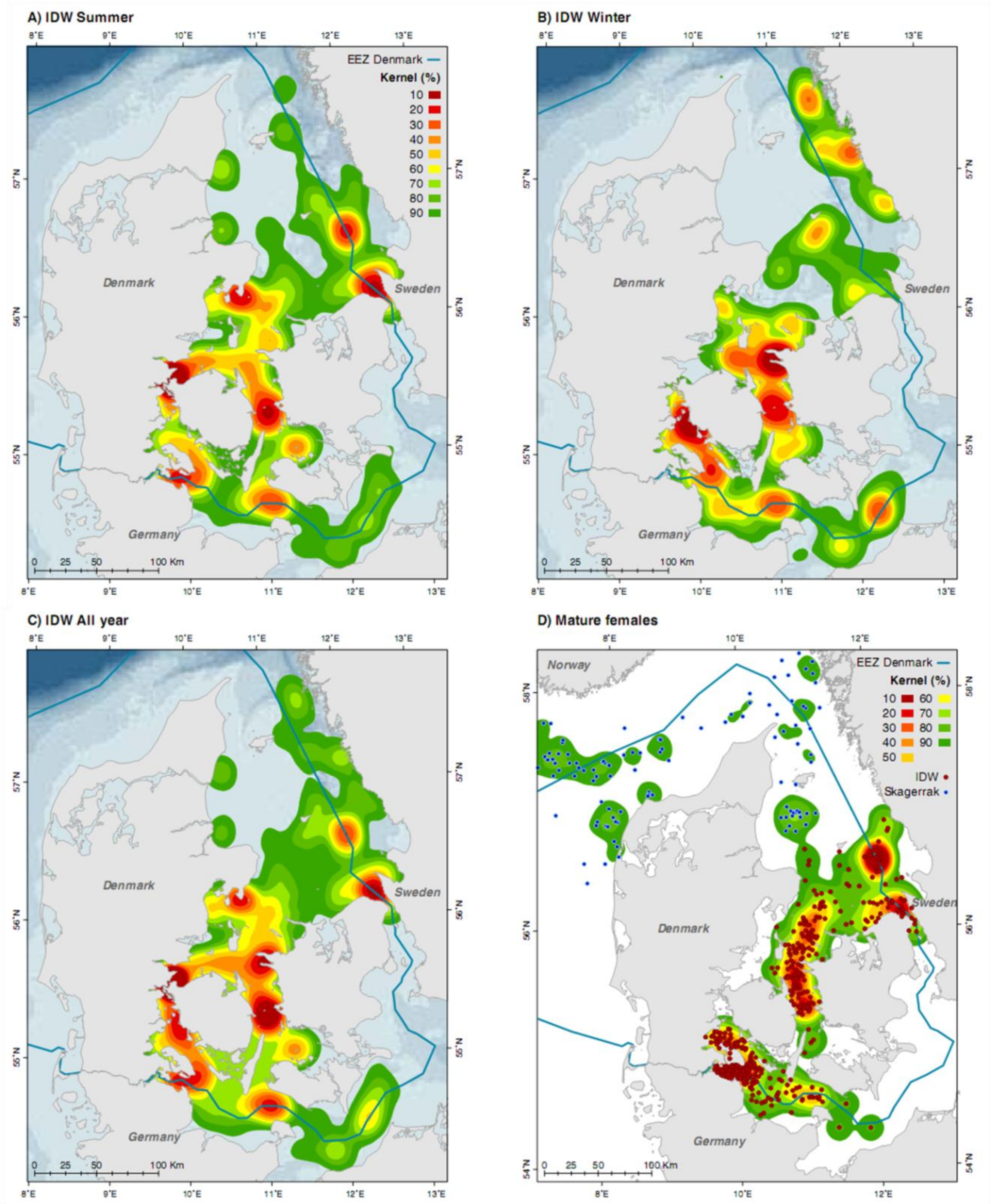


Figure 4.22 Distribution of harbour porpoises from satellite tagging of 37 animals in inner Danish waters 1997-2007. Colour scale is based on kernel density estimations in 10 intervals (low % = high density). A) Distribution during summer, B) Distribution during winter, C) All year distribution, and D) Kernel and transmitted locations for 8 of the satellite tracked individuals (tracked all year and all females). From: (Teilmann et al. 2008).

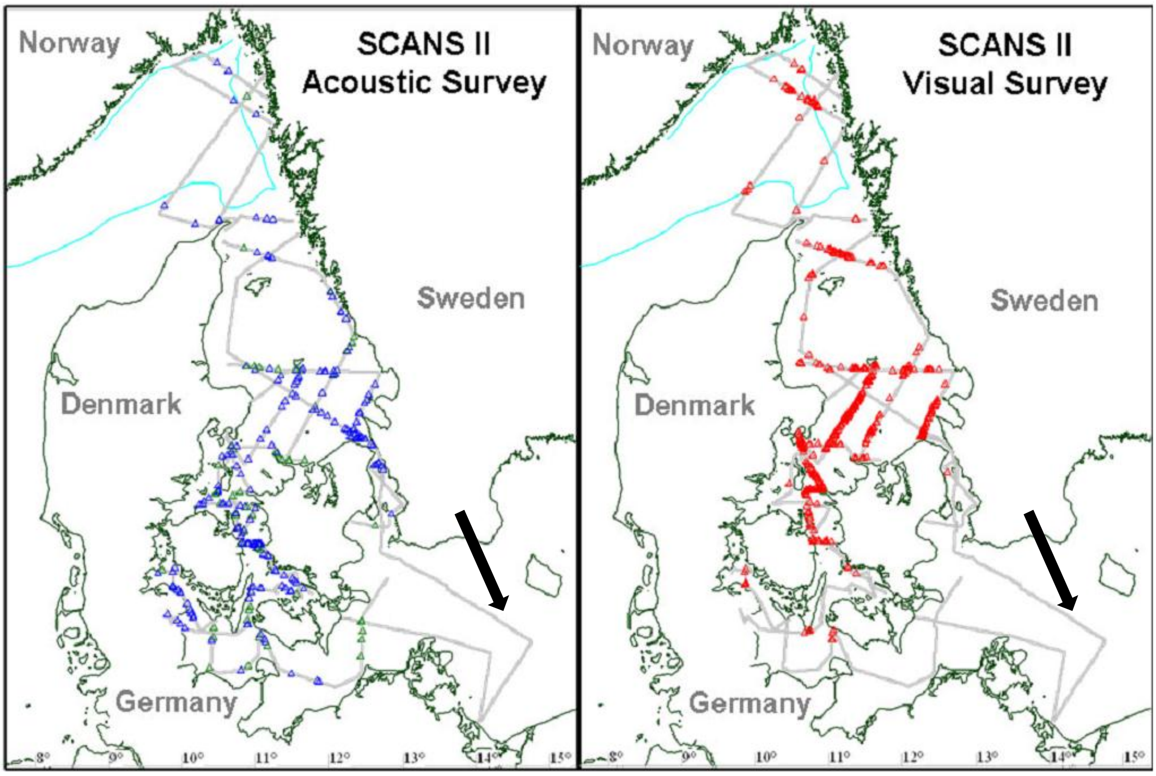


Figure 4.23 *Survey plot from the vessel 'Skagerrak' during the SCANS-II survey 29th of June to 14th of July 2005. Acoustic detections are shown with blue triangles on the left panel. Visual sightings are shown with red triangles on the right panel. The sailed route is shown as a grey line. From (Teilmann et al. 2008). Rønne Banke is marked by an arrow.*

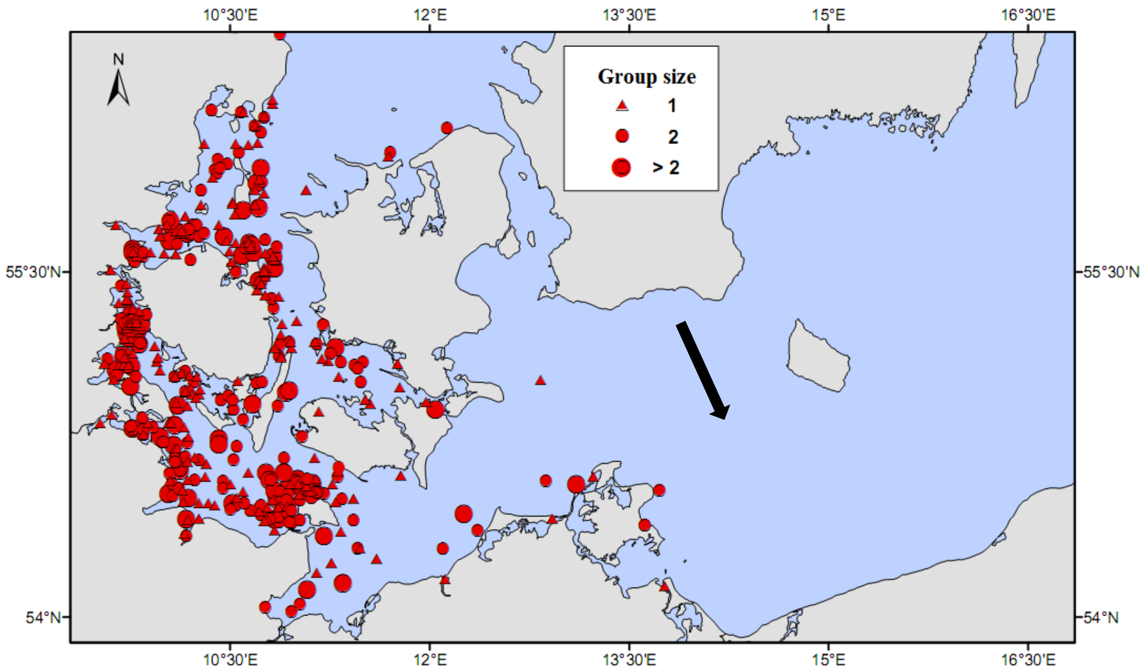


Figure 4.24 *Anecdotal sightings of harbour porpoises in Danish and German Baltic Sea waters, 1980 to 2002. Modified after (Gilles et al. 2006). Rønne Banke is marked by an arrow.*

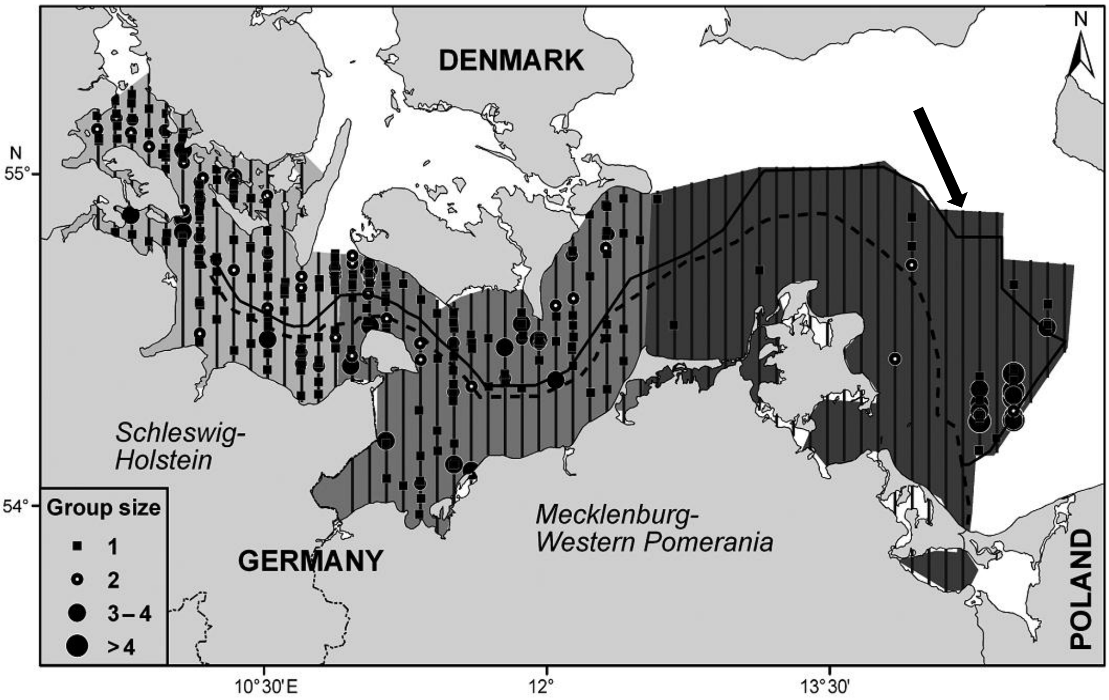


Figure 4.25 Aerial survey track lines and visual observations of harbour porpoises in a study from (Scheidat et al. 2008). The different shades of grey represent different study areas in the Scheidat study.

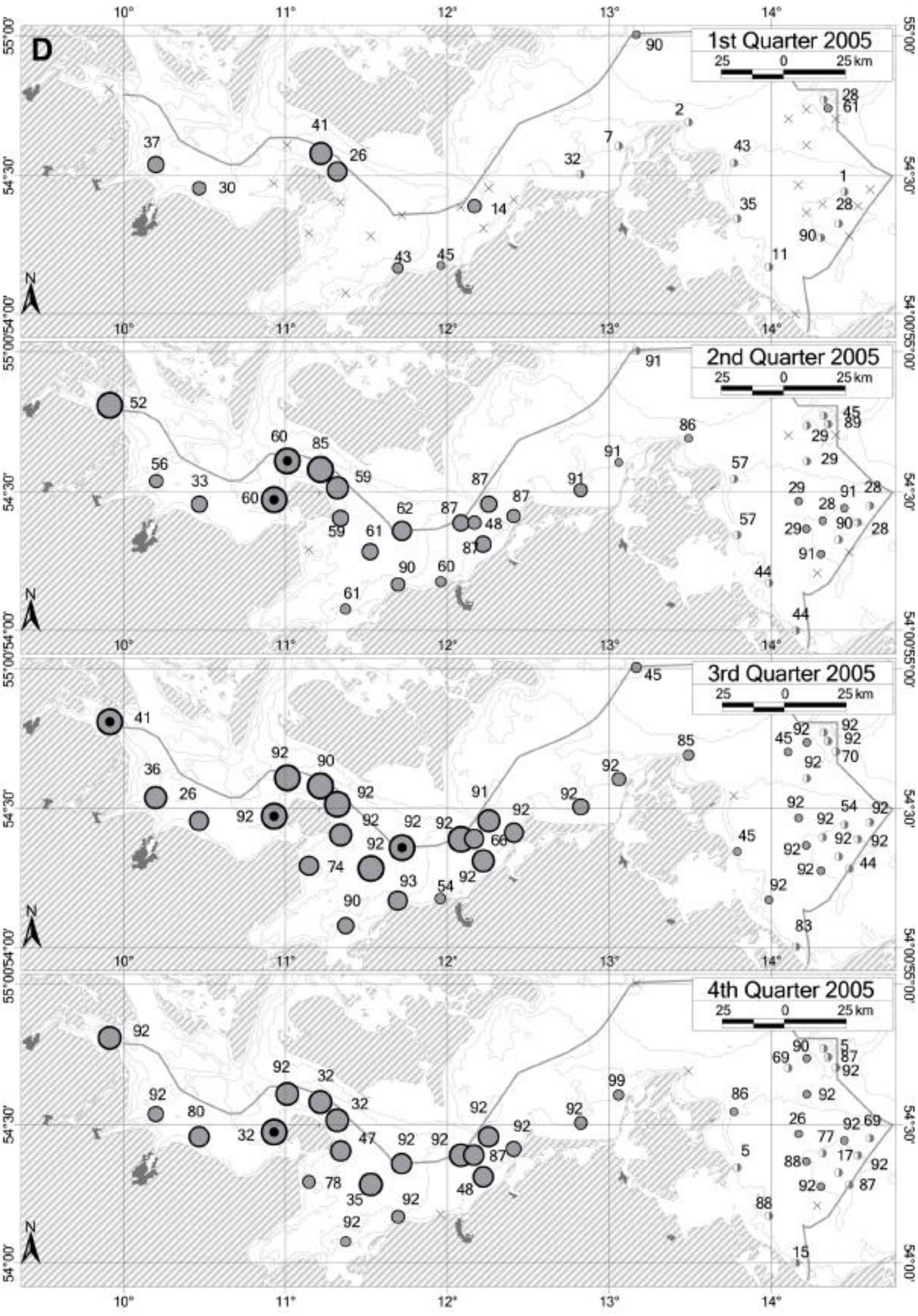


Figure 4.26 Acoustic detections of harbour porpoises in Denmark and Germany using T-PODS. As T-PODs have an effective detection range of app. 300 m, the immediate area of the extraction site was not covered. Yet, the data of the relative occurrence of proposes using click detectors is still very useful in describing distribution patterns over larger areas. Figures are from Verfuss et al. (2007). The data shown is the percentage of porpoise-positive days per monitoring period at the measuring positions for each quarter of the year in 2005. The size of the dots is proportional to the percentage. The number of monitoring days is given next to the dots. Measuring positions at which no data were gathered for the specific quarter are marked with grey crosses.

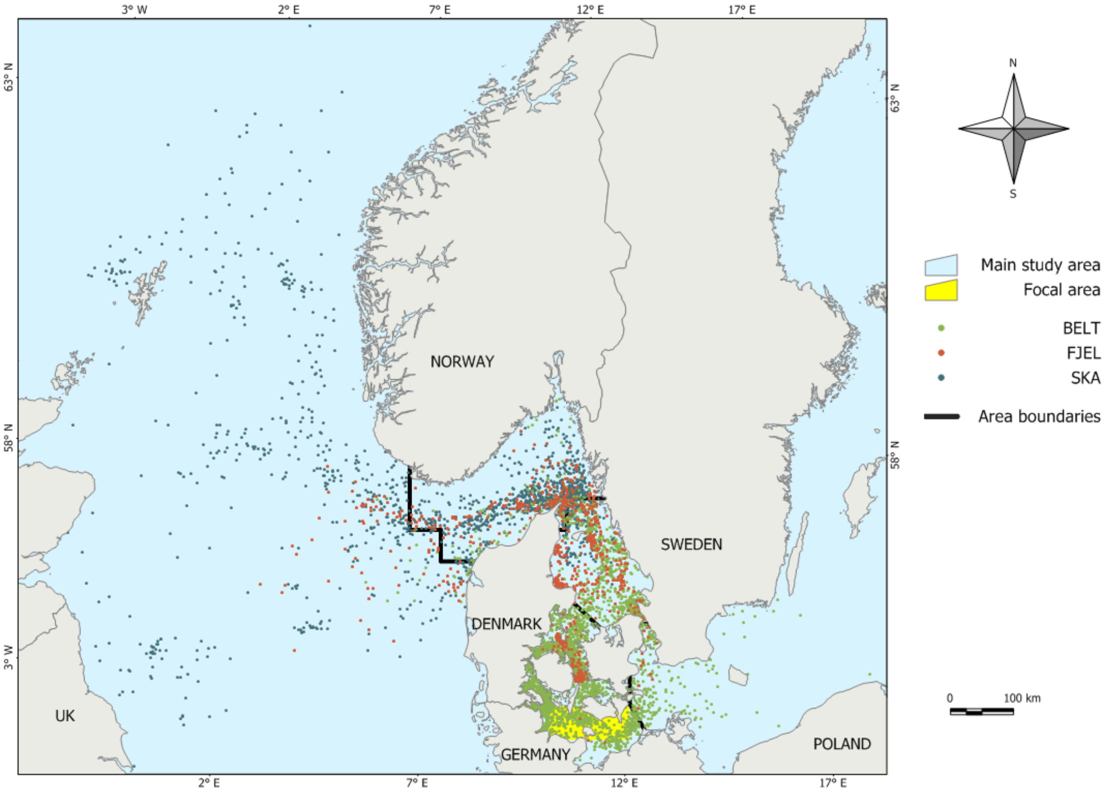


Figure 4.27 Filtered locations for all 82 harbour porpoises tagged between 1997 and 2010, coloured by tagging location. BELT (Belt Sea) = green; FJEL (Fjellerup) = orange; SKA (Skagerrak) = dark blue. The Fehmarnbelt focal study area in shown in yellow From FEMM (2011).

4.8.2 Harbour seals and grey seals

Harbour seals and grey seals are also found throughout the Danish waters, where both species are known to breed (Olsen et al. 2010, Härkönen et al. 2007). Harbour seals have haul-outs at Falsterbo, Bøgestrømmen and Rødsand, within 140 km of Rønne Banke, and grey seals have also been observed at all these haul-outs (Laursen 2001). Grey seals are also found at Christians Ø north-east of Bornholm. In 2010 up to 80 seals was observed. Furthermore, Adler Grund (Germany), and Rønne Banke (Denmark) are Natura 2000 areas (Figure 6.1). The standard data form for Adler Grund lists the occurrence of grey seals and harbour porpoise, and the one for Rønne Banke lists harbour porpoise. Seasonal distribution of grey- and harbour seals are not known, but both species are known to be able to move considerable distances from the haul-out sites to foraging areas (Dietz et al. 2003, Sjöberg et al. 1995). Movements of tagged grey seals from the haul-out site on Rødsand indicate that Rønne Banke is crossed regularly by animals as they move between Rødsand and feeding areas in the northern parts of the Baltic Proper (Dietz et al. 2003, Figure 4.28). Both species feed on a wide variety of fish.

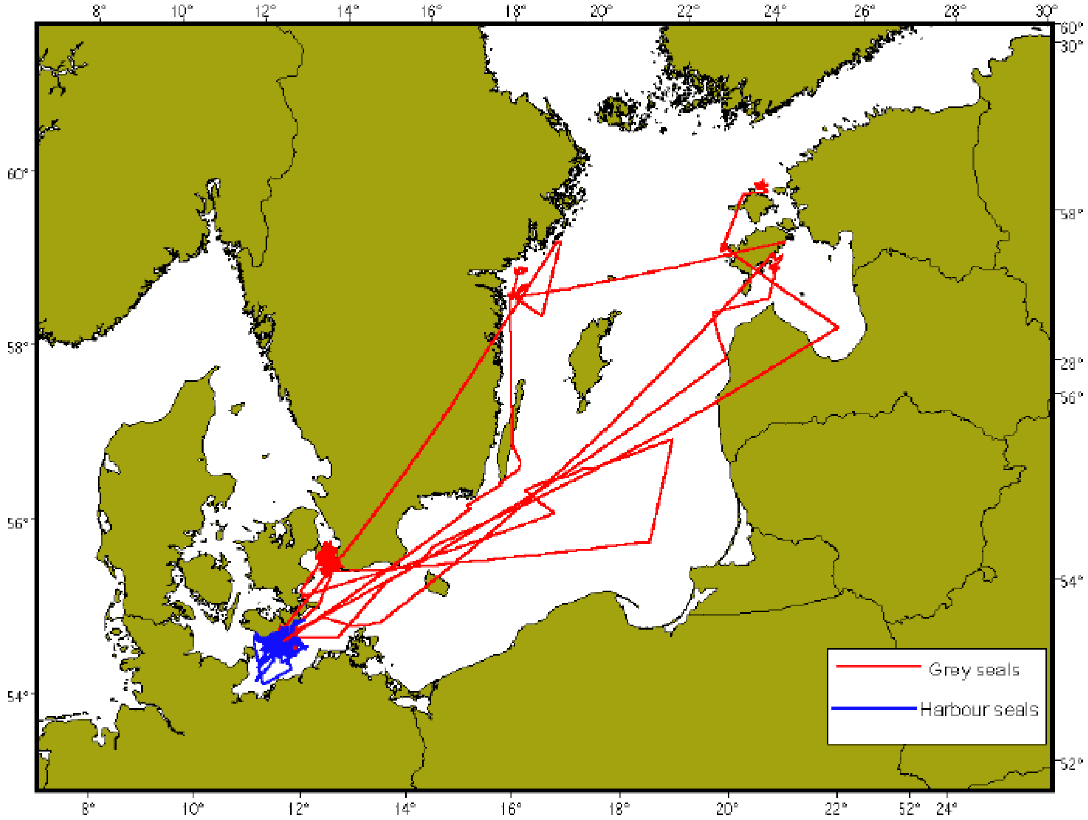


Figure 4.28 *Movements of seals from Rødsand seal sanctuary from satellite tagging of six grey and four harbour seals 2001-2002. From: Dietz et al. (2003).*

For the FEMM study, four adult and one juvenile harbour seal where tagged and their movements documented (study period 2009-2010). None of them was tracked in the Rønne Bank area (see Figure 3). In addition two juvenile grey seals where tagged and although both of them covered relatively large distances during the tagging period (October 2009 – April 2010), no position fixes were obtained directly in the Rønne Bank Area (see Nehls et al. 2012; Figure 4.29). Additional tagging was undertaken by NERI in 2010 on three grey seals and one harbour seal captured at Rødsand. The harbour seal moved west into the inner Danish waters. The three grey seals covered a large area with one them showing repeated position fixes in the areas west of Bornholm which is adjacent to Rønne Bank (Figure 4.30). In summary, the occasional appearance of both harbour and grey seals in the Rønne Bank area can't be ruled out.

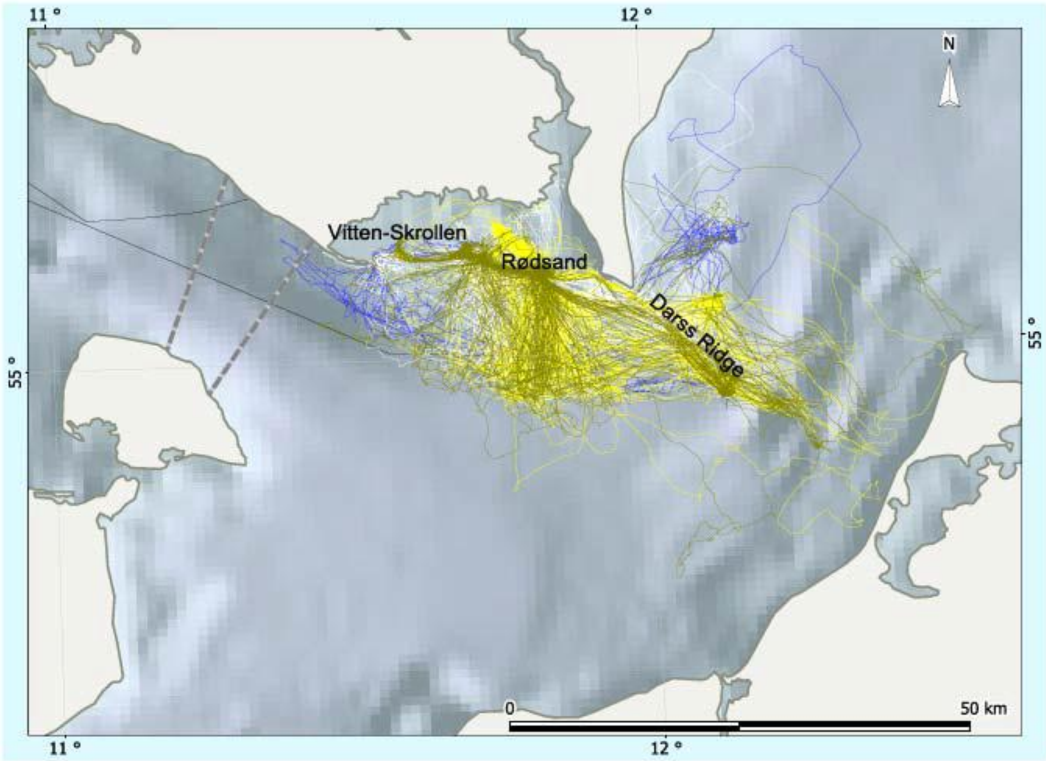


Figure 4.29 Combined tracks of 4 adult harbour seals tagged for the FEMM study (from Nehls et al. 2012)

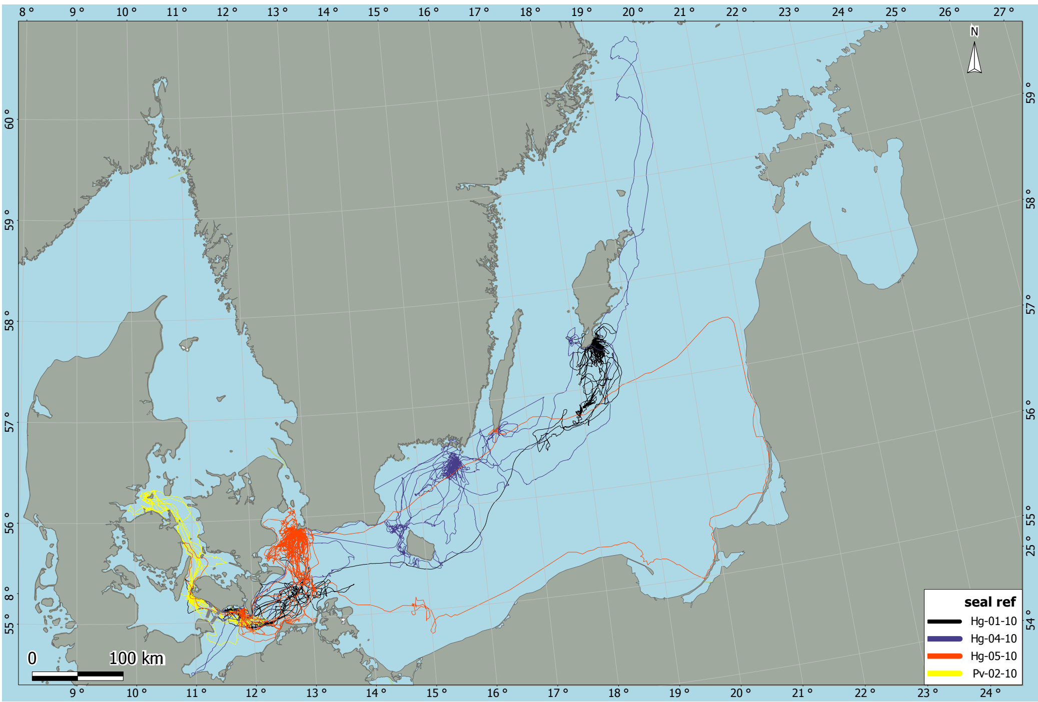


Figure 4.30 Tracks of the four seals (three grey – Hg; one harbour – Pv) tagged with GPS/GSM tags in 2010. Data supplied by The Crown Estate for FEMM (from Nehls et al. 2012)

4.9 Material assets, ammunition and recreational interests

4.9.1 Cables

The National Survey and Cadastre (Kort & Matrikelstyrelsen) has published charts with cabling in the Danish marine area. Chart no. 188 (Kort & Matrikelstyrelsen 2011) covers the Baltic Sea around Bornholm. It covers also Rønne Banke and shows that no cabling is present in the Rønne Banke area.

4.9.2 Ammunition

In Danish waters there have been sporadic findings of ammunition, but there are no arguments for a more thourough investigation in the extraction area, as it is not considered a high risk area (GEUS 2012).

4.9.3 Navigation

The Danish Maritime Safety Administration (Farvandsvæsenet) collects in a database information about the ship traffic pattern in the marine area based on AIS data (Automatic Identification System). The AIS collects the real-time ship locations.

Figure 4.31 shows the traffic pattern for 2009 based on AIS data transmitted by Larger ships (Danish Maritime Safety Administration 2011). The chart covers the area between Sweden and Germany, west of Bornholm and west of Krieger's Flak. Krieger's Flak and Rønne Banke are marked on the chart. The main traffic routes passes around Rønne Banke, but do not cross Rønne Banke. However, a smaller amount of traffic passes Rønne Banke.

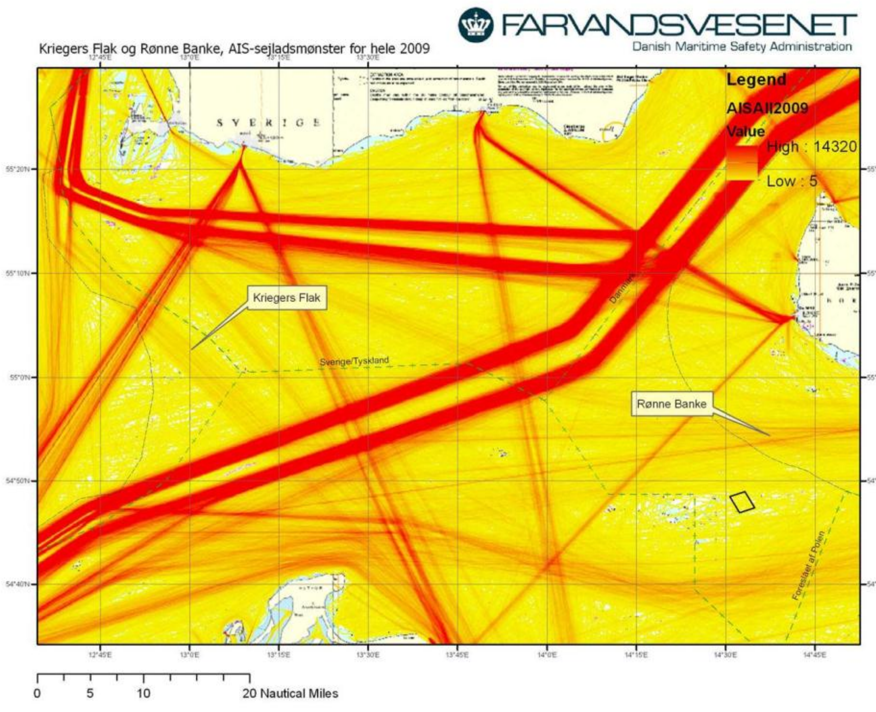


Figure 4.31 Ship traffic pattern south of Sweden and east of Bornholm. The sand extraction area is marked in black. Danish Maritime Safety Administration (2011).

4.9.4 Recreational interests

Recreational interests in case of ship traffic can occur, but there are no marinas in the nearby areas.

4.10 Marine archaeology

The National Survey and Cadastre (Kort & Matrikelstyrelsen) has published charts showing wrecks in the Danish marine area. Chart no. 188 (Kort & Matrikelstyrelsen 2011). In addition The Heritage Agency of Denmark holds a database of registered wrecks in the Danish marine area. Data extracted from this database and plotted on Chart no. 188 show that no wrecks are registered within the extraction area or within the 500 m impact zone). Accordingly, no wreck was observed during the side scan study.

Settlements have not been registrered within the extraction area. In addition, many metres of sand are deposited on top of the layers above sealevel, and potential settlements will therefore not be impacted by the extraction activities. Further investigations have therefore not been considered necessary.

5 IMPACTS ASSESSMENT

5.1 Environmental components assessed

Table 5.1 presents the environmental factors, sub-factors and components assessed in connections to the project. The categorisation follows the guideline used for the EIA for Fehmarnbelt Fixed Link. Some of the components are not relevant for this project and are marked na.

Table 5.1 Assessed components and how they fit into the environmental factor framework defined for the Fehmarnbelt Fixed Link .

Factor	Sub-factor	Components	Assessed/NA
Fauna and flora (including biodiversity)	Marine plankton	Planktonic flora Planktonic fauna Jellyfish	NA
	Marine benthic fauna	In- and epifauna communities including blue mussels	Assessed
	Marine fish	Migration Spawning Feeding/nursery	Assessed
	Marine mammals	Harbour Porpoise Harbour Seal Grey Seal	Assessed
	Birds	Non-breeding waterbirds Breeding waterbirds Bird Migration	Assessed
	Migrating bats	-	NA
Soil	Marine Soil (including marine landscape)	Sea bed morphology Coastal Morphology Sea Bed Chemistry	Assessed Assessed Assessed
Water	Marine waters	Seawater Hydrography Seawater Quality	NA Assessed
Cultural heritage	Marine archaeology	-	Assessed
Other material assets	Other marine material assets	-	Assessed
Natura 2000	-	Designation basis	Assessed

Impact on the hydrography, plankton and migrating bats has not been assessed. Hydrography and plankton will not be impacted by the sand extraction because the project does not create barriers, which can change the water flow in the area. Furthermore the pressures from the project are so short-term and minor that a shadow effect, hydrographical changes, addition of nutrients or an increase in phytoplankton could not be measured. Knowledge on migrating bats across marine areas is very sparse. It is assumed, though, that the bats migrate broadly (as birds), meaning that they use the entire marine area. Because the extraction is temporary and very local is not likely that there will be an impact on the migrating bats.

This impact assessment is part of the environmental impact assessment for the Fehmarnbelt Fixed Link. The criteria for assessing the impact for the sand extraction will to the extent it is possible be similar to the criteria used in Fehmarnbelt Fixed Link EIA. It will be stated in the section if a criterion is used. The assessment will be based on the magnitude of the pressures relevant to the component and factors on which the pressure acts. The assessment will be done based on expert judgement in a narrative and qualitatively way, weighting the pressure and the sensitivity of the component. The expert judgement will be based on the best available knowledge and scientific studies.

5.2 Project pressures

In connections to the project more pressures have been identified to have a possible impact on the environmental sub-factors in the area. Table 5.2 gives a presentation of all identified possible pressures from the extraction project.

Table 5.2 Presentation of possible direct and indirect pressures from the extraction project at Rønne Banke.

Pressure
Loss of sediments and benthic habitats due to removal of seabed
Increase in concentration of suspended matter due to spilled sediments
Increased deposition due to spilled sediments
Increased nutrient loading and release of organic material and toxic substances due to spilled sediments
Increased noise due to extraction activities (dredger)
Increased air pollution due to spilled sediments (dredger)

5.2.1 Loss of seabed (sediments and benthic habitats)

The sand extraction will be conducted by using a trailing suction hopper dredger. This dredger type works by dragging a drag head over the bed and sucking the sand into the hopper (the hull) of the ship. The dredger will be moving during the dredging operation and the outcome will be a deepening along the dredging path. The dredger will keep dredging until there is enough material in the hopper to make emptying feasible. This means that excess water and sediment will be flowing from the dredger during dredging. This is the so-called overflow. A smaller spill will occur at the drag head due to the disturbance of the bed.

This type of dredging will lead to a loss of sediment and benthic habitats in the area where extraction has taken place. The total area of the extraction area (without 500 m impact zone) is 9 km^2. It has been planned that 1 mill m^3 of sand will be extracted, and hence a similar magnitude of sediment and benthic habitats can be lost.

5.2.2 Suspended sediment and deposition

When the sand is extracted, sediment is spilled. Dispersal and deposition of the spilled sediment particles depend on the size of the particles and the hydrodynamic conditions. The general pattern is that the finer particles; e.g. silt-clay, are carried further away than larger because they have a relatively lower settling velocities.

In order to quantify the sediment spill, the dispersal and deposition of sediment spill from dredging was computed using the Mike by DHI MT module (FEHY 2011). The temporal and spatial accumulation and re-suspension of spilled sediments have been modelled for the project scenario based on a dredging plan provided by Femern A/S (FEHY 2011). The results were available in time steps of 1 hour and with a spatial resolution of 100-5000 m. To achieve relevant data for the assessment, these data was post-processed. The average (1 h) size of the deposited sediment (cm) was extracted as well as the duration (days with exceedance compared to natural conditions) of the deposition. The same was done for the suspended sediment concentration. The following conditions form the basis of the simulations:

- Simulations have been done for 1 year (2005) to represent the entire dredging period.
- All dredging is conducted within one year at the highest capacity of the dredger
- Consequently the full model year simulates the dredging of 2.6 mill m^3, i.e. 2.6 times the required quantity (1.0 mill m^3 sand).
- Dredging is fixed to the centre of the extraction area
- Sediment spill was modelled in 8 hour cycles where spill occurred one hour per cycle.
- The spillage is 5% of the extracted sediment at the surface due to the overflow and 1% at the bottom (an assumption).
- The grain size distribution of the spill at the drag head is identical to the grain size distribution of seabed sediment.
- Only the fine material with d < 63 µm (clay-silt) is spilled in the overflow. These finder sediment fractions will be dispersed. Coarser particles are predicted to settle within dredging site (close to the dredger, and within 20 minutes after dredging) (FEHY 2011).
- The concentration of the fine fraction is 0.64% of the total sand content. This proportion is based on the observed structure of the sediment at the extraction site (FEHY 2011).
- The year 2005 has been used as hydrographical model year. Each year has identical hydrographical conditions. Year 2005 is in general considered representative and used in assessment in relation to the Fehmarnbelt Fixed Link (FEHY 2011).

Given the above conditions, the spill scenario simulates the maximum extraction rates expected, i.e. the extraction rates occurring when the trailing hopper suction dredgers are operating at their maximum capacity all year round for the model year (2005). The modelled results are hence a “worst case” result.

As the summer period from May to August is the productive period (growth season), the modelled data is shown below for the summer period for the exceedance plots and for the deposition (deposition). In addition, the maximum deposition is shown for a full year period (2005) and for the summer period.

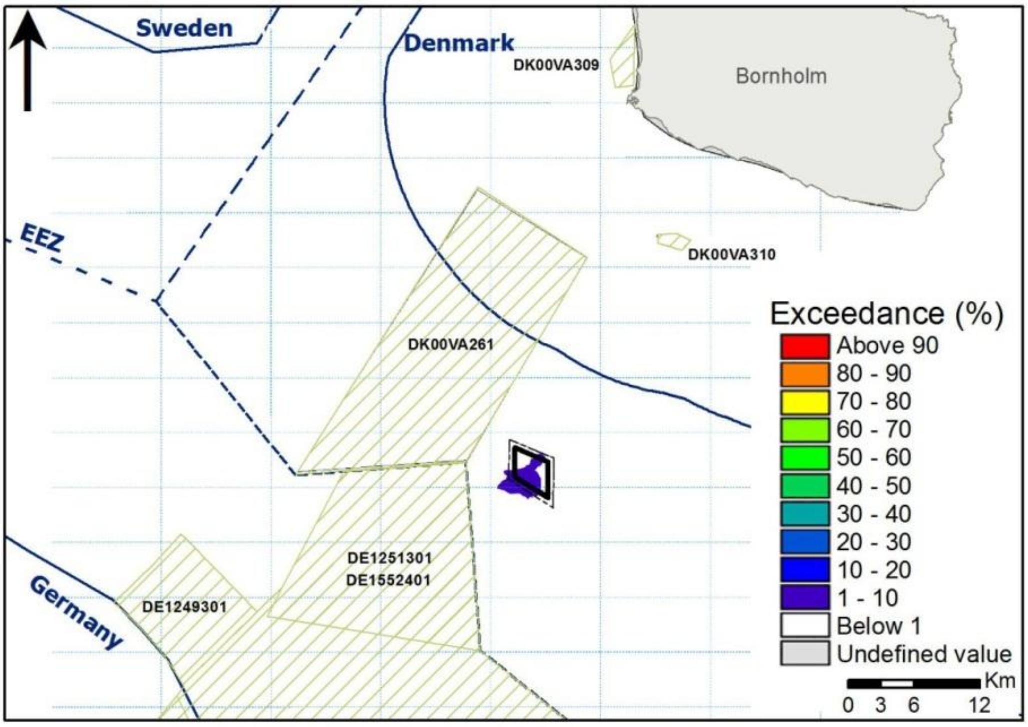
The extraction is fixed in the centre of the extraction area, but the impact pressure will be extrapolated to cover the entire area for the environmental impact assessments.

Suspended sediment concentration
Exceedance for suspended sediment concentration (SSC) is assessed using 2 mg/l, 10 and 15 mg/l as thresholds. Exceedance is expressed as the time within a selected period, where the SSC exceeds these values. SSC exceedance is assessed for surface (depth 0-1 m below surface) and bottom layers (depth 0-1 m above bottom), respectively. The overall results from the modelling are that the generated plume is quickly dispersed. This means that high SSC concentrations are mainly observed close to the centre of dredging site and that the concentrations are below 2 mg/l within a few days. Data is extracted for the spill report, (FEHY 2011).

The maximum SSC at the surface exceeds 2 mg/l in about 1-3% of the time (2-3 days) at the very centre of the extracted area and has a plume extension of about 5 km from the extraction source for 1-2% of the time (1-2 days). Maximum plume extension is about 2 km for the 10 mg/l exceedance limit and about 1 km for the 15 mg/l exceedance limits. In summary, the sediment is quickly dispersed from the surface under the influence of both currents and settling of the particles (FEHY 2011).

The 2 mg/l exceedance plot show that the bottom plume is transported in south-south-eastern direction following the bathymetry depth curves south-east of Rønne Banke (Figure 5.1). This is due to a gradient in the currents from shallower waters over the bank (higher currents) to deeper water (lower currents). These currents result in a higher concentration and longer periods with particles in suspension. Maximum exceedance time is in the order of 1 to 3%. Maximum plume extension is around 20 km in south-eastern direction.

The 10 mg/l and 15 mg/l exceedance plots show a smaller extension of the plume with a limited extension to the south of 5 km and 3 km from the source, respectively. Exceedance values are in the order of 1% of the time.



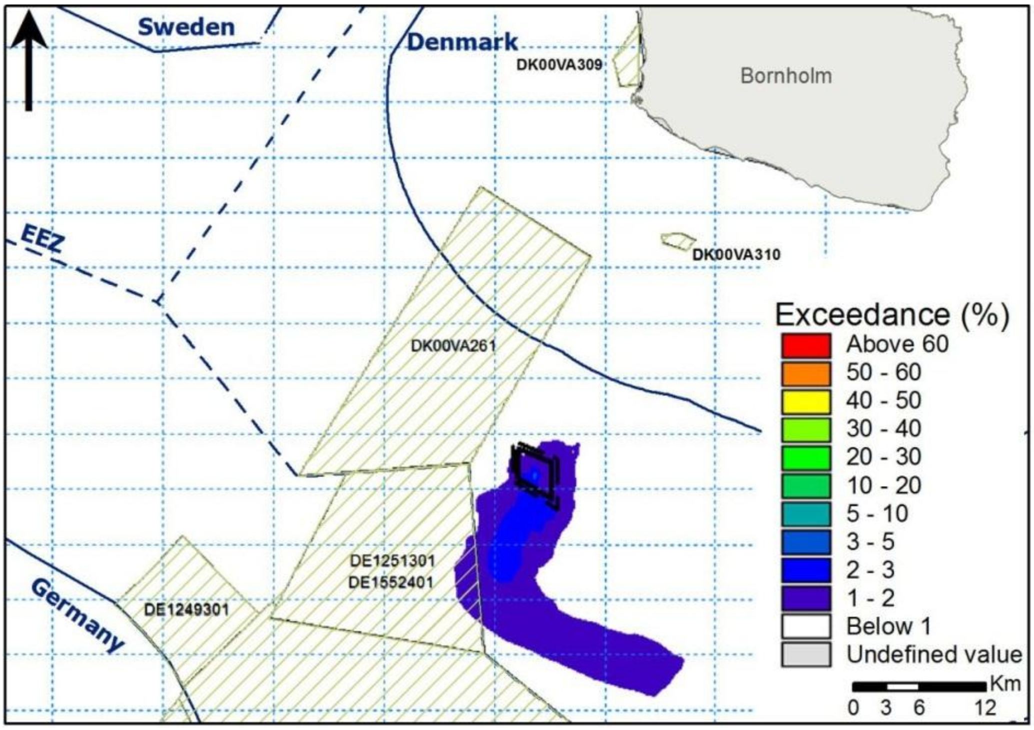


*Figure 5.1 Exceedance time and at the end of the period 1/5 to 1/9 (2005) for the top – 1 m below surface (upper panel) and bottom- depth 0-1 m above bottom (lower panel) of **2 mg/l**. Exceedance time is given as percentage days with SSC levels above the threshold in relation to the total number of days (FEHY 2011). Labels with DE and DK mark the Natura 2000 areas within the area.*

Deposition

The thickness of the sediment fraction smaller than 63 µm deposit far southeast from the source with a thickness smaller than 1.5 mm, for both the summer period and for a full model year. The extension of the deposition is less than 1 km^2.

The maximum deposition of sand (coarser particles) is estimated to be up to 10 cm locally within the extracted area just after the trailing suction hopper dredger has passed. Thereafter, the sediment will be spread and incorporated into the local sediment.

The order of magnitude of the temporary maximum thickness of the fine sediment is about 1 mm in a limited number of locations south of the extraction area (Figure 5.2).

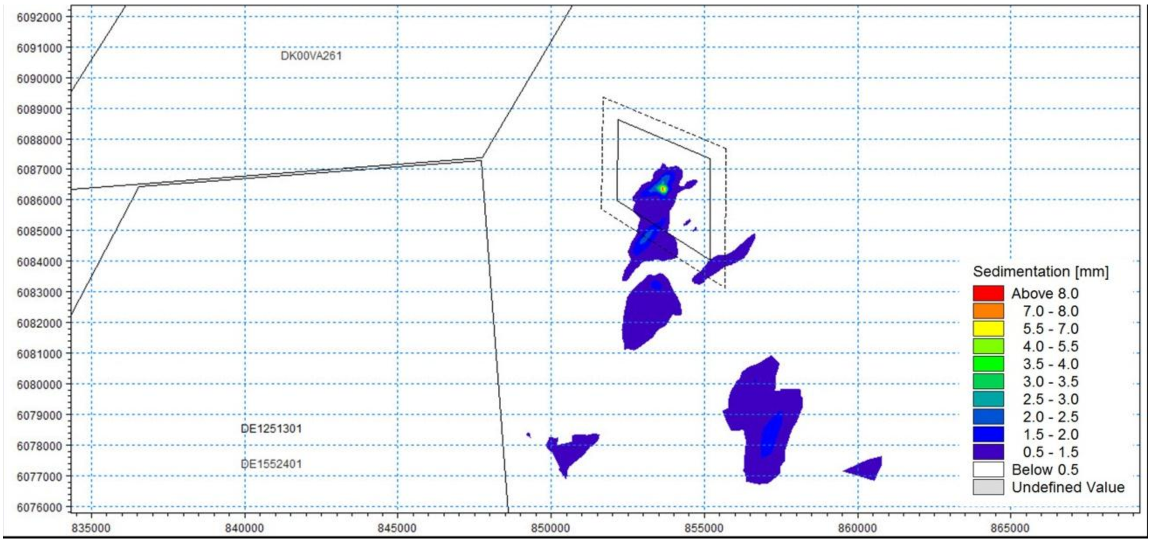


Figure 5.2 The maximum temporary deposition below 63 µm in mm for the full model year (2005). Labels with DE mark the Natura 2000 areas within the area. Numbers at the axes indicate the scale in metres.

The differences between the extensions of the maximum temporarily deposition show the effect of re-suspension due to the waves removing the sediment from the bed. It explains why the deposition patches of the maximum temporary deposition maps are larger because they only show the maximum deposition at some point in time.

5.2.3 Sediment organic material, nutrients and toxic substances

Organic materials in the sediment can, if released to the water column, cause an increased release of nutrients and increased oxygen consumption due to decomposition of the organic material. Release of nutrients can increase the phytoplankton growth. Furthermore a consequence of high content of organic matter may, depending on the presence of local pollutant sources and the sedimentary conditions, be presence of a large number of toxic substances that potentially can be released during dredging and hence impact the aquatic environment (FEMA 2013a, Herut and Sandler 2006).

The concentration of organic material in the dredged sediments does therefore express the risk of release of nutrients and toxic substances to the water column and increase in oxygen consumption in the water column and at the deposition sites.

As seen in Table 4.6 (section 4.4) the content of organic material in the sediments (LOI) of the investigation area is very low (between 0.08 and 0.73% DW).

5.2.4 Noise

The primary noise sources on a dredger are the diesel motors that provide propulsion to the dredge. In addition there would be secondary noise sources such as generators, pumps and gearboxes. It is expected, that the dredger used for this operation will have a sound power level of 114 dB (A) or less. For the purposes of this report a Trailing suction Hopper Dredger has conservatively been assumed to have a sound power level of 114 dB (A) and at a distance of 2 km from the dredger the noise level is calculated to be 27 dB (A).

There are no indicative limit values for noise from dredging activities, but in recreation areas the limit is 40 dB (A) during the night time. Considering that the Rønne

Banke Area is located app. 30 km from the nearest coastline at the south coast of the Bornholm Island, the noise from the dredging operation is regarded not to give rise to noise onshore. The primary receptors of noise in air are birds and seals and underwater noise fish and marine mammals.

Underwater noise from the sand extraction is also a factor, which can impact fish, birds and mammals. The underwater noise levels from Trailing Suction Hopper Dredgers are usually 186-188 dB re 1 µPa rms with the main energy between 100 and 500 Hz (CEDA 2011). The impact on underwater noise will be dealt with in the assessment on the respective factors.

5.2.5 Air pollution

Ship emission and air pollution in connection with dredging and transport of sand to the construction site of the Fehmarnbelt Fixed Link, is calculated for an expected volume of 1 mill m^3 (Trafikministeriet 1996). In addition the following references have also used been for the evaluation: NERI (2008), Olsen et al. (2009) and ORBITAL (2010).

As a basis for the calculation the average emission rates is used, see Table 5.3. Trailing Hopper Dredgers with different capacity and performance with load capacity at 2000, 2600, 6000 and 10,000 m^3 have been used in the calculations. Capacities of 6- or 10,000 are most likely to be used.

Total emissions cover dredging at Rønne Banke, transport between Rønne Banke and the construction site at the Fehmarnbelt Fixed Link, offloading and transport back to the excavation site (in ballast). The distance to the construction site is approximately 220 km.

Table 5.3 Total air pollution, extraction 1 mill m^3 sand at Rønne Banke (Trafikministeriet 1996, NERI 2008, Olsen et al. 2009 and ORBITAL 2010..

Rønne Banke		**CO_2**	**NO_x**	**HC**	**SO_2**	**Particles**
		g/ton/km	**g/ton/km**	**g/ton/km**	**g/ton/km**	**g/ton/km**
Emission		11.097	0.032	0.295	0.009	0.007
Offloading	Load capacity	CO_2	NO_x	HC	SO_2	Particles
	m^3	ton	ton	ton	Ton	Ton
	2,000	10,000	270	8	150	6
	2,600	11,600	310	9	180	7
	6,000	8,500	220	7	130	5
	10,000	7,400	200	6	110	5

The total emissions of CO_2 are calculated to be between 7,400 and 11,600 tonnes, depending on dredger size. The total emission from Denmark was approximately 50 Megatons in 2008 (excluding shipping).

5.3 Impact of pressures

The assessment of predictable impacts will be based on the magnitude of the pressures relevant to the component and factors on which the pressure acts. The assessment is done based on expert judgement in a narrative and qualitatively way, weighting the pressure and the sensitivity of the component. The expert judgement will be based on the best available knowledge and scientific studies.

The impact assessment is done on a worst case scenario:

- The spill scenario is at least 2.6 times worse than the actual scenario (model scenario: all dredging occurs in 1 year, 2.6 mill m^3 is extracted instead of 1 mill m^3 (see explanation section 5.2).

- The actual removal of the seabed is less than the assessed. The assessment accounts for 9 km^2 of seabed removed, but because the dredging will occur down to 0.5 to 1 m only 1-2 km^2 of the 9 km^2 will be actually be removed (if the entire area is dredged at a depth and 0.5 m 4.5 mill m^3 of sand is extracted – only 1 m^3 is needed). Since it is not known what area and exactly how large an area, the assessment is done for the entire extraction area.

5.3.1 Coastal morphology

The closest coast is located about 30 km NE off the extraction area, on the shore of Bornholm.

There are three items to be considered in the evaluation of the possible impact of the sand extraction on the coastal conditions:

a. Will the sand extraction directly undermine the coastal profile along the east coast of Bornholm?

b. Does the lowering of the seabed impact the wave conditions in the extraction area?

c. Will a possible impact on the waves have an impact on coast of Bornholm?

Ad. a. The sand extraction will not undermine the coastal profile because of the long distance to the shore and the relatively deep waters in the area between the coast and the extraction area.

Ad. b: The sand extraction in the extraction area will on the average lower the seabed with maximal 1 m (but will most likely be 0.5 m), i.e. from a depth of about 17 to 21 to about 18 to 22 m. This about 5% increase in the water depth over the extraction area of 9 km^2 will have insignificant impact on the wave conditions in the deepened area and absolutely no impact on the wave conditions more than 30 km away from the sand extraction area. Furthermore the predominant waves at Rønne Banke travel away from the coast.

Ad. c: Only a very small percentage of the waves along the coast of Bornholm will have passed the dredging area, as only a very small percentage (~5%) of the waves comes from the direction interval pointing towards the dredging area. It can thus be concluded that the dredging at Rønne Banke does not change the wave conditions along the coast of Bornholm.

It can consequently be concluded that there will be no impact on the coastal stability along the south coast of Bornholm due to the sand extraction at Rønne Banke.

The next closest cost is located about 60 km SW of the extraction site, at Rügen, Germany. Based on similar assessments as for the coast of Bornholm it can be concluded that the extraction will not impact the coastal stability of the German coast.

5.3.2 *Seabed morphology*

The original seabed in the extraction area will be removed in the dredged areas down to an area of approximately 0.5 - 1m, see Section 2.2. Investigations of the sediment structure in connections to this investigation have shown that even though there have been previous dredging activities, the sediment composition has not changed significantly (section 2.5). The grain size and the sand fractions are the same in the entire area.

It has been documented that the transport capacity of the seabed sediments (sand) in the extraction area varies considerably with the depth from about 3.0 m^3/m/year at 15 m depth to less than 0.1 m^3/m/year at 30 m depth. The transport situations are only occurring under very rough wave conditions typically for duration of 1 to 2 weeks per year. As mentioned in section 2.5.3 the extraction will be performed by trailing suction hopper dredgers, where all the material will be retained in the hopper. To give an estimate of the recovery time of the seabed it is assumed that the drag head of the major trailing suction hopper dredgers will have a width of 2.5 to 3 m, and leave the dredging trenches at a maximum of 2 m wide and approximately 0.5 to 1 m deep. The volume of an individual dredging trench will therefore be in the order of 1 m^3/m.

The recovery of the disturbed seabed morphology is dependent of the transport capacity in the disturbed area. The recovery of the seabed is therefore estimated for two depths.

Recovery of the seabed at 15 depth

The transport capacity at 15 m depth is in the order of magnitude of 3.0 m^3/m/year, which is relatively large compared to the volume of the dredging trenches. Consequently, it will only take ~ 0.3 year (1 [m^3/m]/3.0 [m^3/m/year]) before the dredging trenches are filled. It can be concluded that the impact of the dredging on the seabed will be eliminated after one to two seasons at 15 m depth.

Recovery of the seabed at 30 depth

The transport capacity at 30 m depth is less than 0.1 m^3/m/year which is so small that it will take many years before the dredging trenches are filled, potentially it will take ~ 10 years (1 [m^3/m]/0.1 [m^3/m/year]). The actual dredging water depth is between 15 and 25 m, so the seabed recovery time will be an intermediate between the two scenarios.

Mean recovery time

It can be concluded that the dredging trenches will disappear within a time period of 5 years and most likely within a period of 3 years due to the water depth (most of the area has water depths between 15 and 20 m). This is also supported by the previous investigations as stated in section 2.2. Furthermore, it should be stated that the actual size of the dredged area will be 1-2 km^2, and hence roughly about 80% of the selected extraction area will be unaffected by the dredging. The impact on the seabed is then severe within the 3 years dredging is taken place, and recovery will take place thereafter. Recovery is expected to take place during the following 3-5 years.

5.3.3 *Toxic substances*

Sediment dredging and disposal activities in Denmark are regulated according to the concentration of toxic substances in the sediments. All concentrations of toxic substances in the sediment at the shallow Rønne Banke is found to be lower than the accepted background values for sediment set by OSPAR (OSPAR 2009) and the L Ac set by the Danish EPA (BLST 2008) and therefore considered unproblematic (see section 4.2). There is therefore no impact on the marine environment due to release of toxic substances from dredging activities.

5.3.4 *Salinity, temperature, water quality*

The changes in the seabed morphology are too limited to cause any changes in the hydrodynamic regime; meaning that there will be no changes in e.g. salinity, temperature, current and mixing. Consequently no hydrodynamic based changes in nutrient and oxygen regime and processes will occur. Local oxygen depletion in areas with extraction holes is not likely to appear as the seabed will not be left with deep holes from the dredging activities.

Depending on the method of sand extraction and the environmental conditions at mining site the activity may leave deep depressions in the seafloor (static suction hopper) with propensity to collect organic material and develop anoxic conditions (Norden Andersen et al. 1992; Szymelfenig et al. 2006) or the dredging activity leave shallow furrows on the seafloor, linear, curved or crossing (trailer suction hopper; the preferred method). Shallow furrows allow exchange of water in the pits thus minimizing the risk for development of low oxygen levels.

As long as the water column is un-stratified or well-mixed, oxygen depletion at seafloor will be very unlikely. In well-mixed environments oxygen that is consumed can be replenished by re-aeration from the atmosphere and oxygen produced by primary producers in the upper water layers.

Sand mining at Rønne Bank will take place in the depth interval 15-25 m. Assuming that the monitoring station Rønne, at a depth of 20 m is representative for the sand mining area, the risk for oxygen problems in sand mining furrows is small because the water column is hardly stratified and oxygen concentration at 20 m is almost saturated (see Table 5.4).

Potentially, nutrient and oxygen concentration may also be affected by changes in the concentration of organic material due to release from dredged sediments. If large amounts of organic material is released to the water a re-oxidation of reduced substances (H_2S) can take place (FEMA 2013a), which reduced the oxygen concentration. As the sediments did not contain H_2S (the sediments was purely sand and not anoxic muddy sediments (Appendix D), this reduction will not lead to oxygen degradation. The degradation of the organic material can potentially lead to a minor decrease oxygen concentration and a release of nutrients (FEMA 2013a).

As seen in Table 4.6 (section 4.4) the content of organic material in the sediments (LOI) of the investigation area is very low (between 0.08 and 0.73 % DW). Such low levels cannot give rise to perceptible effects on the concentration of oxygen, nutrients, or chlorophyll a concentrations.

Potentially an increase in suspended sediment concentrations (SSC) can result in a reduction in light availability, which can impact the growth of phytoplankton. It is, however, not likely that the increase in SSC, which is predicted for this project, (section 5.2.2) will have any impact on the growth of the plankton, as the sediment spill has a limited extend and duration: The maximum SSC at the surface exceeds 2 mg/l in about 1-3% of the time (2-3 days) at the very centre of the extracted area and has a plume extension of about 5 km from the extraction source for 1-2% of the time (1-2 days). Maximum plume extension is about 2 km for the 10 mg/l exceedance limit and about 1 km for the 15 mg/l exceedance limits.

There will hence not be an impact on the marine environment due to changes in water quality.

5.3.5 *Benthic fauna*

Impact on benthic fauna from sand extraction the can be due to

- Loss of benthic habitat
- Increased deposition
- Increased suspended sediment concentration
- Oxygen deficiency

Loss of benthic fauna habitat
The loss of benthic fauna habitat will correspond to the area exploited for sand extraction; i.e. the maximal extracted area is 9 km^2. The loss of fauna in this area will be total as the upper approximately 0.5 - 1 m of sediment will be removed. It must also be stated that not the entire area will be dredged and the impact hence will be much smaller (max. 2 km^2).

Re-colonisation of the seabed after ended dredging activities, will take place by migration of adult species and settling of larvae from nearby unaffected areas. The nature of the area that they are re-colonising will similar to pre-project conditions (section 2.5.3). Most of the species, which are abundant at Rønne Banke, especially polychaetes and oligochaetes (which accounts for 79% of the abundance and 21% of the biomass) have a relatively short life cycle and will most likely re-establish after one or two growth seasons. Mussels (which account for 16% of the abundance and 78% of the biomass) have a longer life cycle and re-establishment will take longer. *Macoma balthica* and *Mytilus edulis* have a generation time of approximately 2-4 years while *Mya arenaria* have a generation time of 2-5 years. The re-colonisation could be hampered by the seabed recovery processes. This is however very rapid for the shallower parts of the area. Re-establishment of the biodiversity and biomass of the benthic fauna community in the impacted area will therefore most likely take place within 5 years after dredging has stopped (Amager Strandpark I/S 2005).

The reestablishment of the seabed will not hamper the recolonisation process as the sand processes in the extraction area will resemble the existing seabed processses, which the benthic fauna is already adapted to.

Suspended sediment concentration (SSC)
Several groups of benthic invertebrates can be affected by high SSC. Suspension-feeders such as mussels, clams and other bivalves, barnacles, or tunicates are most sensitive to high concentrations of SS, because the solids can dilute their primary food (i.e. phytoplankton) and overload the filter-feeding apparatus. In general, other feeding groups are less sensitive as long as other water quality issues such as dissolved oxygen and toxic substances are not affected negatively along with high SSC. High SSC can lead to reduced growth, in extreme cases also to negative growth. Depending on concentration, the consequence can be mortality if the duration is long compared to the typical turnover of body mass for a specific species and individual.

Suitable criteria for the impact on the benthic fauna from increased SSC has also been discussed and defined in the EIA for Fehmarnbelt Fixed Link (FEMA 2013c). These criteria have been adopted in the present EIA. The threshold for no impact is defined as 25 mg/l (FEMA 2013c); meaning that the benthic fauna can cope with an increase in SSC (exceedance) below this limit. As appears from the exceedance plot (Figure 5.1) only within 3 km from the dredging site do the sediment concentrations exceed 15 mg/l (section 5.2.2) and this will happen less than 1-3 % of the time. Hence the SSC will rarely and only very close to the dredger and for very short time exceed 25 mg/l. Consequently it can be concluded that the benthic fauna will not be impacted as a result of the increased SSC.

Deposition
Generally, macrofauna can cope with the deposition levels occurring in their natural environment and will remain unaffected due to its burrowing/escaping ability (Miller et al. 2002, Gibbs and Hewitt 2004). The sensitivity to deposition does however vary with species, dependent on if they are sessile or mobile, the type of deposition (instant or gradually deposition) and type of deposited material (clay, sand etc.) (Essink 1999; Lisbjerg et al. 2002).

In the EIA for the benthic fauna communities of Fehmarnbelt, a set of criteria for the pressure deposition has been defined on the basis of scientific literature and expert judgements (FEMA 2013c). In this connection it has been established that deposition below 3 mm, regardless of the duration of the deposition, the rate of deposition and the fauna community, will have no impact on the benthic fauna.

The maximum deposition within less than 500 m from the dredger is less than 3 mm at any point in time (Figure 5.2). Consequently, there will be no impact on the benthic fauna due to deposition of the sand fraction less than 63 µm.

Deposition of sand and the fine sand/silt fraction (> 63-63 µm particles) within the extraction area will mostly occur in areas where the benthic fauna has been directly affected by removal of the sediment and habitat loss. The deposition within the extraction area will therefore not add significantly to the impact on the benthic fauna.

Oxygen deficiency
As mentioned in section 5.3.4 it is assessed that there is no increased risk of oxygen deficiency in the furrows or the dredging scares and no impacts on the benthic fauna is expected.

Overall conclusion
It is evident that the only severe pressure on the benthic fauna is the destruction of the seabed in the dredged areas. The area lost is estimated to be 9 km^2 (though the actual area will be smaller). The impact is reversible and the fauna community will recover within 5 years. The Cerastoderma community is widely distributed in the Baltic Sea and the temporary impact in the extracted area will not be significant to the overall biomasses and abundances of benthic fauna in the area, hence the function of the ecosystem in the area will still be intact.

Considering the prevalently south-southeast spreading of the plumes which only exceeds 15 mg/l at 1-3% of the time, the thickness of deposition outside the dredged area is less than 1.5 mm it can be concluded that there will be no impact on the benthic fauna outside the extracted areas.

5.3.6 Benthic vegetation
Potentially an increase in suspended sediment concentration (SSC) can result in a reduction in light availability at the seabed, which can impact the growth of benthic vegetation. It is not likely that the increase in SSC seen in this project (section 5.2.2.) will have any impact on the benthic vegetation. Furthermore, there is almost no vegetation in the area and an impact is negligible.

5.3.7 Fish
The potential physical and biological impact of sand and gravel extraction is site-specific depending upon numerous factors such as the extraction method employed, bottom current strength, sediment mobility and bottom topography. The most serious physical impacts potentially having implications to fish are:

- Loss of sediment and changes in seabed morphology

- Increase of suspended sediment concentration in the water column
- Increase of deposition
- Increase of underwater noise

Alteration of seabed structure related to screening (returning of material to the sea floor) may also be an issue for some extraction projects but not the present (section 6.1.2).

In the following the impacts on fish of these pressures are assessed. As there is limited data for the baseline description of the fish populations, the conclusions are based on the possible presence of the fish species and populations deduced from data from 2003-2004.

Loss of sediment and changes in seabed morphology (habitats)
The most obvious impact of sand extraction is the removal of the substrate and the resulting destruction of its infaunal and epifaunal biota.

Complete benthic fish recovery in a dredged area may take from one month to fifteen years or more depending upon the source stock of colonizing species and their immigrating distances (ICES 1992).

The conclusion on the loss of benthic fauna is that reestablishment of perennial populations of mussels and thus the reestablishment of the biomass of benthic animals in the extraction area would probably take up to 3-5 years, while the abundance of species with short life cycles would take approx. 1-1½ years (section 6.4). It can be assumed that this is the time frame needed for the benthic prey composition for fish to return to what it was previous to material extraction. However, the implications of a change in food abundance and prey composition to fish are difficult to predict as many fish are flexible in their choice of prey and eat and adapt to what is available. It can be assumed that when the food resource has re-established itself the impact will be negligible (maximum 5 years), but before the benthic fauna has returned to a similar level prior to material extraction the impact can be considerable in the extraction area.

Besides having a possibleeffect on the food resources for fish, material extraction in an area can also have an effect on fish habitats. It is expected that the seabed and hence the habitat will be changed considerably during the extraction period but not significantly after extraction has ended as the seabed characteristics is not expected to be changed (section 2.2 and section 6.1.2). In general the impact of these effects are species specific – for example, if sediment grain size changes this could have a negative impact on sandeel species (if these species are present in the extraction area) that have very specific habitat demands for the sand composition on the bottom. Sandeels contribute to the diet of many important gadoid species (cod, whiting etc.) as well as turbot thus a decrease in the sandeel stock size will potentially affect the stocks of other species (ICES 1992). The sandeel species are non-migratory and have very specific habitat demands for the substrates they live in. Thus these species are particular vulnerable for removal and changes in seabed material. Sandeel species prefer sandy substrates with medium to coarse grain sizes (0,25-1,2 mm) while sediments with a fine grain fraction (silt, clay, fine sand) of more than 10% are avoided (Jensen et al. 2003). Therefore both the seabed left after dredging and the recovered seabed is suitable for the sandeel species (characterised as medium sand grain size with minor content of fine particles).

Suspended sediment
The increase in suspended sediment and water turbidity associated with the dredging process will periodically cause fish to avoid or move away from an area. This is only expected to be temporary. Some fish species may be attracted to the area by

the “odour trail” of the crushed benthos. This effect is often experienced by fishermen in areas heavily fished with beam trawls in the North Sea (pers. comm.). The concentration of the material in sediment plumes is not necessarily the critical factor for fish avoidance, but should be combined with the exposure time to give a true picture of the potential risk of a given influence of suspended material (Newcombe and McDonald 1991).

Laboratory experiments for herring and cod have shown that they display an avoidance response when silt and limestone particles are as low as 3 mg/l (Westerberg et al. 1996). Benthic fish such as flatfish species are much more tolerant of suspended material compared to pelagic species such as herring and sprat. For example, plaice have survived 14 days of exposure to 3000 mg/l of clay and silt.

Early life stages of fish are usually more vulnerable to sediment plumes than adults because they generally are more sensitive to suspended material and less capable of escaping. Thus, concentrations in the range of milligrams per litre can be lethal for eggs and larvae, while for juveniles and adults this effect is not expected until concentrations reach levels of grams per litre (Engell-Sørensen and Skyt 2002).

Impacts of suspended material on fish eggs depends on whether they are spawned in the open water (pelagic eggs) or whether they are spawned on the sea bed (benthic eggs) – eventually with parental care.

Sediment spill may affect benthic fish eggs by covering them and reducing oxygen flow. Other than reducing oxygen availability, sediment that adheres to pelagic fish eggs can also cause them to sink into depths and thereby into water layers that do not have the optimum oxygen conditions. Sediment-response experiments were performed as a part of the Fehmarnbelt Fixed Link impact assessment (Petereit and Franke 2011). In general, they concluded that exposure of cod, flounder and herring eggs to concentrations of 1000 mg sediment/l had only a few significant impacts on their survival and overall fitness. Sediment free treatments did have on average higher survival and hatch rates; however this was not significant due to the high variability among replicates. Other experiments have shown that cod eggs exposed to 5 mg/l suspended sediment are still buoyant while exposure up to 100 mg/l suspended sediment will increase their mortality by significantly reducing egg buoyancy (Rönnbäck and Westerberg 1996). Furthermore (Kiørboe et al. 1981) performed herring exposure experiments with different constant concentrations of suspended silt (5-300 mg/l) and a short-term high concentration (500 mg/l) of suspended silt at different stages of embryonic development and found embryonic development was unaffected. They stated that “as far as suspended particles are concerned, no harmful effects of dredging to herring spawning grounds are likely to occur”. Since the duration of the relatively low concentrations of SSC is very limited in connections to the dredging activities, the impact on egg is regarded as very low to negligible.

Fish larvae use sight to localise their prey. Larvae of species such as plaice, sole, turbot and cod see their prey when they are within a few millimetres distance (one body length) and can survive a few days without food. The more turbid water is the more difficult it is for fish larvae to localise their prey (de Groot 1980, Johnston and Wildish 1982).

Fine particles in water will also get caught in the gills of fish larvae and reduce oxygen uptake (de Groot 1980). Mortality rates of cod larvae in suspended sediment concentrations of 10 mg/l were observed to increase significantly (Westerberg et al. 1996).

If benthic fauna, which is the main prey for many fish species, is impacted by sediment plumes then this could indirectly have an impact on fish populations. Since it has been assessed that the benthic communities will not be impacted by suspended sediment from the dredging activities, this will not have an impact on the fish populations.

A threshold for avoidance behaviour has been set in the Fehmarnbelt project to 10 mg/l suspended sediment for pelagic fish species such as herring, sprat, whiting and cod, while densities of 50 mg/l has been set for more benthic species such as flatfish and shallow water species. The threshold value for avoidance response by migrating silver eel was set to 100 mg/l.

Computer simulations of material extraction activity on Rønne Banke have shown that increased suspended sediment from the extraction operation are generally quickly dispersed and that the levels are relatively low in comparison with natural background concentrations. Suspended sediment plume extension at the surface for the 10 mg/l exceedance limit, which can trigger an avoidance response in pelagic fish, is approximately 2 km (FEHY 2011). The suspended sediment plumes are mostly localized close to the extracted area and are only visible a couple of days during the summer period (May – August) at the surface.

In an area south of the dredging zone, the 10 mg/l exceedance plot shows the plume near the bottom can extend approximately 5 km south of the dredged area (Figure 5.2) in 1-2% of one year. Thus in very short periods of time during material extraction the more sensitive species that are affected by suspended sediment levels >10 mg/l might flee from or avoid an area of between 2-5 km. However, because spill scenarios suggest that minimum suspended sediment levels will only occur in a very short time, the overall impact of this pressure is considered to be very limited in space and time.

Deposition
The impact upon the benthic ecosystem of deposition of suspended material from plumes and re-deposition from material screening is not normally as severe as that resulting from the direct removal of the substrate and its indigenous fauna (ICES 1992). However, deposition and re-deposition from turbidity plumes and the practice of screening out material and returning this directly back to the sea floor may alter the substrate in the extraction area and surroundings.

One of the prime risks of increased deposition or re-deposition is the smothering of fish eggs on spawning grounds. Sandeels lay their eggs in the sand, and sand grains of a certain size adhere to them. When sandeel eggs are fully covered with fine material, the development of the embryo will be negatively affected, resulting in a less successful hatching (ICES 1992). Demersal eggs from other species such as turbot, herring, bull rout, gobies etc. may also be susceptible to smothering. There is, however, no information on whether these species spawn in the planned area of extraction.

Analysis of maximum temporary deposition shows that at some point in time it is likely that up to one millimetre of fine sediment will deposit in a few spots south of the extracted area. This temporary deposition will be removed by re-suspension. Thus, final deposition maps show that there is practically no remaining deposition on the seabed away from the extracted area (Figure 5.2). The impact on the fish is therefore low and the temporary (months).

Thus, after the seabed naturally re-establishes over time it is not expected that there will be an impact on the fish community due to deposition and re-deposition of screened material.

Noise
The noise from ships traffic and extraction activities will typically be within sound frequencies of (80-200 Hz and 130-200 dB) which can be perceived by most species. The distance in which different species can perceive sounds also depends on background noise (wind, currents and waves – measure to more than 100 dB at 10 Hz) which during strong winds can be greater than the noise that is generated during material extraction (Vella et al. 2001). In addition, the noise from ships traffic can be considerably greater (>150 dB at 100-1000 Hz) (Vella et al. 2001).

Fish species sensitive to sound such as herring and cod can hear intensive noise generated from structures at distances of several kilometres. Depending on the natural and man-made background noise, this could trigger an avoidance response. There is a large uncertainty of what noise levels generated by structures can trigger avoidance responses of other fish species (flatfish species, sculpins etc.) which are less sensitive to noise (Thomsen et al. 2006).

According to the threshold levels triggering avoidance responses of sensitive fish species to sound, avoidance reactions will typically occur when fish are 100-200 m from vessels and particularly noisy vessels may elicit an avoidance response at distances as great as 400 m (Mitson 1995).

In general, potential noise from the extraction vessels and extraction methods may create noise levels triggering some avoidance response by hearing sensitive fish in the near vicinity of extraction, but this will only be for a few days and at most will probably displace fish only short distances from the noise source. The impact is thus considered negligible to minor.

Threatened and declining species
The species Twaite shad, autumn spawning herring *(Clupea harengus subsp.)*, salmon, cod, eel and sea snail, known to occur in the Rønne Banke area, are included in the HELCOM list of threatened and declining species of lampreys and fishes (HELCOM 2007), and salmon and twaid shad are listed in annex II and V in the Habitats Directive. All these species are widely distributed in the western Baltic and therefore Rønne Banke is not considered to be an area of specific importance. Only the sea snail *(Liparis liparis)* and herring spawn in the regional marine environment and have demersal eggs that could potentially be affected by material extraction. However, at present there is no documentation that Rønne Banke is a spawning area for either of these species.

Conclusion
In summary increases in suspended sediment and noise in periods of intense dredging activity and heavy ships traffic may affect fish in the extraction area and lead to periodical decreases in the abundance of fish in the area. However, fish will with great probability return to the area and an impact on the local fish populations over a longer period is highly unlikely. However, it cannot be ruled out that intensive activity during spawning periods can result in a long (approximately 1-5 years) but not permanent negative impact on local populations. In particular for the stationary species and species with specific habitat or seabed substrate demands (sandeel, sculpins and gobies etc.) may experience such impacts.

Substrate removal, and to a much lesser extent deposition and re-deposition of screened seabed material will have a considerable, but only temporary impact of approximately 1-5 years on the prey for demersal fish species. Maximal 9 km^2 of the area is impacted by dredging, and there will be a temporary impact within the extracted area of the fish by removal of sediments, together with food supply and habitats.

The overall significance of the dredging on the fish populations in the Southern Baltic Sea area is regarded as minor.

5.3.8 *Fishery*

The impact on the fisheries due to the dredging operations is a combination of the effects on the fishery resource (fish and shellfish) and on the fishermen's possibility to undertake their fisheries:

- Changes in the distribution of fishery resources (fish)
- Restriction of fishing activities
- Changes in the distribution of fishery with bottom trawl due to obstructions at the seabed

The effects on the fisheries due to the dredging operations are a combination of the effects on the fishery resource (fish and shellfish) and on the fishermen's possibility to undertake their fisheries. The impact will be assessed in the following sections.

Changes in the distribution of fishery resources (fish)

Assessment of direct losses to fishermen arising from sand and gravel extraction depends entirely on the fishery concerned and the nature of impacts on it. Only a fishery with trawl is undertaken in the extraction area on Rønne Banke. Both a trawl fishery and a gill net fishery are undertaken with large gill net vessels in an area to the southeast. There is no Danish seine net fishery in or near the extraction area and thus assessment of potential impacts to this type of fishery are not relevant.

The impact on the fish (the resource) is assessed in section 6.5.1. During the dredging phase there will be an impact on the fish resource due to dredging activities. The impact will primarily be on the trawl fisheries since the impact on the fish is within the dredged area. The impact will only be short term (days).

After the dredging has ended the impact on the trawl fisheries on the area is temporary and depends on the recovery of the seabed infauna, which is assessed to be up to 5 years. After this period it is expected that the fish will return to the area. Since the fish can be re-distributed to other area due to increased deposition there can be a low impact on the trawl fishery in the area. This is only temporary and will be negligible after a few months.

The impact on net-fishing is negligible since impact primarily occurs within the extraction area, where net fishing does not take place.

Restriction of fishing activities

Some fishermen argue that the loss to the fisheries in these circumstances is mainly due to a loss of access to traditional fishing grounds rather than a direct loss of fish. The fish (like the fisheries) will merely be redistributed elsewhere for a time. However, in circumstances when a discrete area supports an important, local seasonal fishery of migrating fish, any redistribution of fish or the fisheries may have economic consequences, and the best approach in these circumstances is to time extraction operations to allow access to fishermen during this seasonal window.

An impact on the undertaking of fisheries is only short term (days during the extraction period) and in a small area. The extent of this impact will thus depend on when and for how long the extraction vessel will be in fishing areas and whether there will be zones restricting the fisheries during this time.

There are no restrictions on the net fishing activities.

Changes in the distribution of fishery with bottom trawl due to obstructions at the seabed

As all extracted material will be retained in the dredge hopper, and large boulders and stones will not be left at the seabed. Furthermore the resource is a homogenous sand resource without stone and boulders. Thus bottom trawls are not expected to be obstructed by stones and boulders in this extraction project.

5.3.9 Birds

In the following the assessment of impacts of the extraction activities on birds is outlined. The assessment is split into the following pressure caused directly by the project and by interaction with other environmental factors:

- Noise - localized habitat displacement caused by disturbance from the dredger.
- Habitat change caused by reductions in available food supply due either to direct (extraction) or indirect (sediment dispersal) effects of the extraction works.
- Risk of collision with migrating birds.

Non-breeding waterbirds

Noise - habitat displacement

Habitat displacement effects on waterbirds during sand extraction may vary as a function of the local densities of sensitive waterbird species which regularly use the site. Waterbirds respond in different ways to approaching vessels. While some species are attracted to vessels as they expect food (gulls following fishing vessels) other species show a negative response and flush if a vessel approaches at a certain distance. The response differs not only between species but also in relation to the status of a species in its annual cycle, the function of the area and social structure of waterbird assemblages. Waterbirds are especially sensitive during moult while reaction distances are smaller during the winter months (Thiel et al. 1992). Species like Common Scoter and divers exhibit large response distances of 1–2 km (Bellebaum et al. 2006, Schwemmer et al. 2011). The response distance usually increases with flock size making large aggregations more vulnerable to disturbance.

Of the species occurring in medium or higher densities at the extraction site on Rønne Bank, four (Red-throated Diver, Black-throated Diver, Long-tailed Duck, Black Guillemot) have been identified as being sensitive to disturbance (see Table 5.4). Based on the available information about planned dredger activities it is assumed, that these species will be displaced within the given distance.

Table 5.4 Reported response of waterbirds to shipping (Bellebaum et al. 2006, Schwemmer et al. 2011).

Species	Response to shipping
Red-throated Diver (*Gavia stellata*)	1-2 km
Black-throated Diver (*Gavia arctica*)	1-2 km
Great Crested Grebe (*Podiceps cristatus*)	100-500 m
Red-necked Grebe (*Podiceps grisegena*)	100-500 m
Common Eider (*Somateria mollissima*)	100-500 m
Long-tailed Duck (*Clangula hyemalis*)	100-500 m
Common Scoter (*Melanitta nigra*)	1-2 km

Velvet Scoter (*Melanitta fusca*)	1-2 km
Razorbill (*Alca torda*)	100-500 m
Common Guillemot (*Uria aalge*)	100-500 m
Black Guillemot (*Cepphus grylle*)	100-500 m
Little Gull (*Larus minutus)*	< 500 m

As the numbers of waterbirds using the area shows strong seasonal variability, the potential habitat displacement of divers, Long-tailed Duck and Black Guillemot will depend on the timing of extraction activities with the largest impacts conceived during winter and spring (November-April). Given the impacted areas (9 km^2) and densities of the sensitive species the number of birds which the dredger potentially will disturb will be in the range of less than 200 Long-tailed Ducks and single individuals of divers and Black Guillemots. Accordingly, the habitat displacement impacts on waterbirds will be very small.

Habitat change caused by reductions in available food supply

The key food resources to waterbirds are mussels and fish. The benthic fauna is dominated by mussels, which comprise approximately 78% of the total benthic biomass. During the extraction period no reduction in the biomass of mussels due to increased concentrations of suspended sediments are expected and disturbance effects on potential benthic prey organisms living in the extraction site are assessed as being limited. As the loss of removed seabed is 9 km^2 at Rønne Banke the maximum number of impacted Long-tailed Ducks can be estimated at less than 500 individuals.As the recovery time of the mussels is expected to be 5 years, the impacted area will have no long-term impacts on waterbirds.

Sediment dispersal affecting available food supplies of fish and foraging conditions for diving waterbirds is estimated to be small-scale. The simulations of the dispersal of suspended matter showed that the generated plume due to extraction operations is quickly dispersed, and the plume was mainly located within the extraction area limits and only visible a few days in total. The plume is only detected further away at low concentrations (2-10 mg/l), and only around 2 or 3 km from the dredging area and only for about 1-2% of the time.

Bird migration - collision risk

The collision risk of generally flying and especially migrating birds is considered a problem particularly in the marine environment. There are no natural obstacles on the migration at sea; birds might be attracted by the lights of the vertical structures, which is a well-known phenomenon from various illuminated structures at sea; in addition, in particular slowly manoeuvring birds and birds flying in formations might misjudge or underestimate the risk; last but not least, in situations of low visibility or inclement weather birds might simply not be able to recognize ships and other the man-made structures, and show strong attraction responses to strong artificial lights.

Many studies on collisions with ships have reported that passerines are being killed in larger numbers than other birds. Large-scale mortality can often be related to the artificial lights used on ships, with strong omnidirectional light potentially attracting and killing the largest numbers of birds (Rich and Longcore 2005). Still, it's important to recall that passerines outnumber other bird species on migration by at least an order of magnitude, and hence the relative impact may not be highest for passerines. In fact, larger species may be more sensitive to collision with ships. Merkel and Johansen (2011) analysed light-induced killings of waterbirds in Greenland waters, and reported up to 88 casualties at a single ship per night. The rate of collision was clearly associated with increment weather conditions and low visibility.

However, given the broad front migration of waterbirds at the site collision risks to migrating waterbirds from the dredging vessel should be expected to be at a low level with no or minor consequences for the populations passing the site.

Overall conclusion is that the risk collision will not be significant for the migrating bird populations.

5.3.10 Mammals

In the following the assessment of impacts of the extraction activities on marine mammals is outlined. The assessment is split into the following pressure caused directly by the project and by interaction with other environmental factors:

- Increased noise
- Increased suspended sediment
- Reduced prey availability

Increased Noise

It is planned that at Rønne Banke a Trailing Suction Hopper dredger will be used for the Sand Extraction. For this type of dredger, some measurements of acoustic emission are available (see ITAP 2007 and Robinson et al. 2011). According to them the sound produced by sand extraction is assumed to be of relatively low frequencies; with main energy below 1000 Hz, Figure 5.3, ITAP 2007) though recent investigations indicate that there may be higher frequencies when extracting gravels (Robinson et al. 2011). Figure 5.3 shows the frequency spectrum of the dredging sound in 1/3 octave bands. This kind of representation is suitable for impact assessments since in biological hearing systems, sound is integrated over several frequency filters that are app. 1/3 octave wide (see Thomsen et al. 2006). It can be seen that most sound energy is well below 1 kHz with a steady decline in sound pressure levels at higher frequencies.

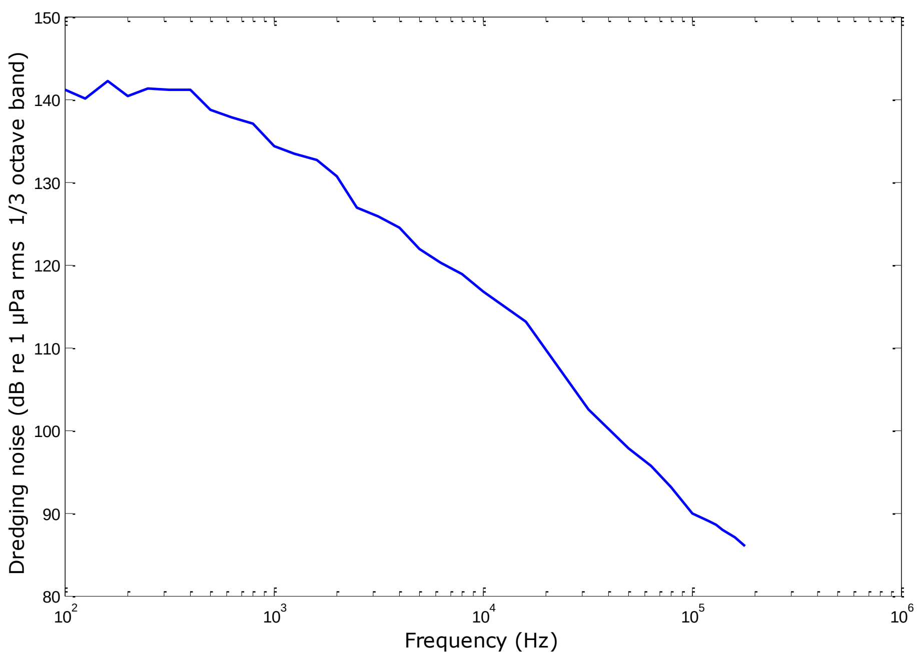


Figure 5.3 *Underwater sound from the trailing suction hopper dredger Thor-R (modified from ITAP 2007, extrapolated from 40 to 100 kHz) measured at 300 m distance.*

Sound use and hearing in harbour porpoises and harbour seals

The harbour porpoise uses sounds for echolocation and possibly for communication. Echolocation is used to navigate and forage. Harbour porpoises echolocate by emitting intense ultrasonic clicks and listening for the returning echoes reflected by objects impinged by the sound. The frequency content of the sounds is centred around 130 kHz and has a source level of up to around 200 dB re 1µPa pp (Villadsgaard et al. 2007). There are indications that clicks are used for communication purposes as well, where the clicks are repeated in sequences of stereotyped repetition rates (Clausen et al. 2010).

The hearing capabilities of harbour porpoise have been investigated in several studies (Andersen 1970, Popov et al 1986, Kastelein et al. 2002). In addition to the thresholds of the audiograms harbour porpoise hearing is increasingly directional the higher the frequency. This improves their echolocation capabilities by making them less susceptible to background noise in directions other than the one of the returning echoes (Kastelein et al. 2005). For the impact assessment, the best way of describing hearing is by defining a masked detection threshold such as the one shown in Figure 5.4. For the harbour porpoises, we have used the audiogram by (Kastelein et al. 2002). Together with this we have documented the likely ambient sound spectrum at Rønne Banke as taken from literature data for areas with high shipping. It can be seen that for lower frequencies (app. up to 800 Hz) detection is depending on the hearing sensitivity (= the red line in the graph). For the higher frequencies, detection is depending on the ambient sound levels as these are higher than the detection threshold in the audiogram.

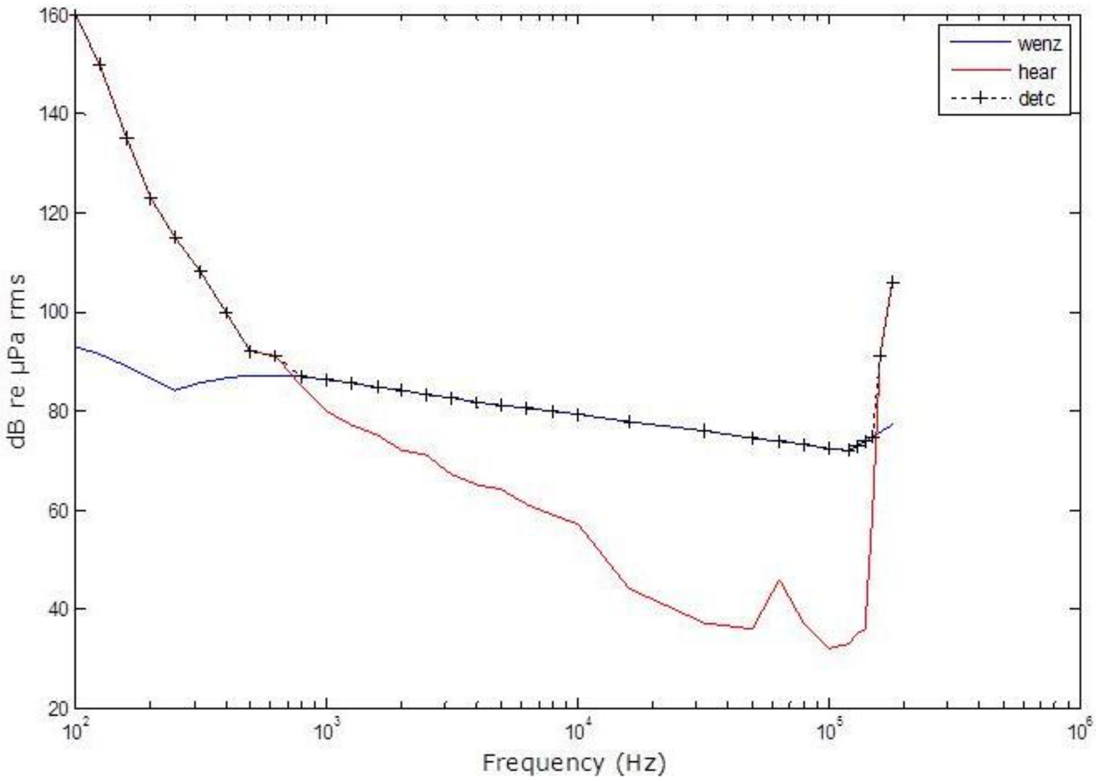


Figure 5.4 *The masked detection threshold (+) for harbour porpoise. The red line indicates the audiogram of a harbour porpoise (modified from Kastelein 2002) and the blue line indicates the expected background noise at Rønne Banke given by the Wenz curve for heavy shipping noise in shallow water. The background noise is measured in 1/3 octave bands.*

During the mating season in the summer, male harbour seals maintain underwater territories through long-lasting low-frequency rumbles (van Parijs et al. 2000). Grey seals also use underwater sounds for communication both during and outside the mating season. Both these signals can be affected by noise.

Harbour seals are amphibious animals with acute hearing both in air and under water and their hearing has been studied extensively (Møhl 1968, Kastak and Schusterman 1998). The hearing of grey seals on the other hand has only been investigated in a single study (Ridgway and Joyce 1975). In the grey seal study auditory evoked potentials were used, which is not directly comparable to the psychophysical data obtained from harbour seals. Still, grey seal hearing abilities are assumed to be comparable to the hearing abilities of harbour seals (Schusterman 1981, Richardson et al. 1995) and hearing thresholds for harbour seals are generally recommended as a conservative estimate for the hearing thresholds of other phocids (Southall et al, 2007). The masked detection threshold for the harbour seal is given in Figure 5.5. It can be seen that for seals, that have a very good hearing in the lower frequencies, detection is solely depending on the ambient sound level.

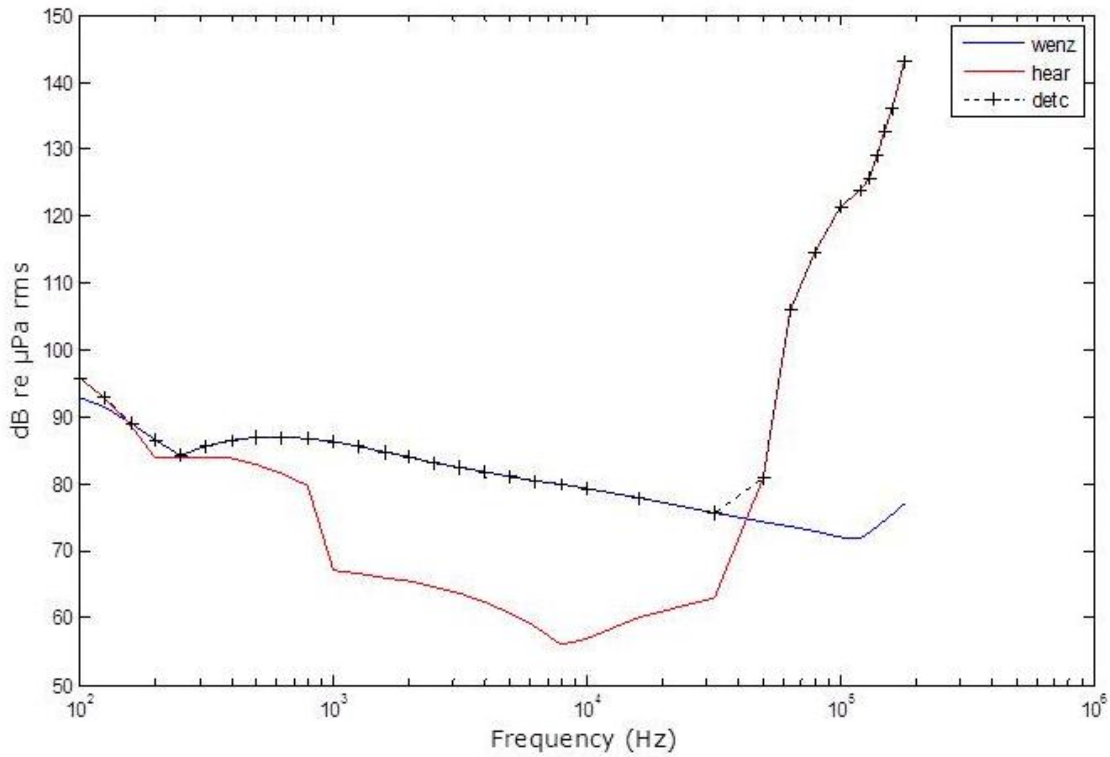


Figure 5.5 *The masked detection threshold (+) for harbour seal. The red line indicates the audiogram of a harbour seal (modified from Kastak and Schusterman 1998, Møhl 1968) and the blue line indicates the expected background noise at Rønne Banke given by the Wenz curve for heavy shipping noise in shallow water. The background noise is measured in 1/3 octave bands.*

Estimated impact zones for sound

The effect of sound on marine mammals can be divided into four general categories that largely depend on the individual's proximity to the sound source:

- Detection
- Masking
- Behavioural changes
- Physical damages

It is important to realise that the limits of each zone of impact are not sharp and that there is a large overlap between the different zones. Furthermore, especially behavioural changes, masking and detection critically depends on the background noise level and the behavioural and physiological states of the animals.

In the first step, the detection thresholds of the sound source was obtained by comparing the masked detection threshold of the harbour porpoise and the harbour seal (see Figure 5.4, Figure 5.5) with the 1/3 octave sound from the source extrapolated to different distances. The ranges at which underwater sound sources can be detected by marine mammals are in many cases surprisingly large: for pile driving operations they can extend many tens or perhaps hundreds of kilometres (Thomsen et al. 2006; Tougaard et al. 2009).

In Figure 5.6 and Figure 5.7 the detection range for harbour porpoises and harbour seals is shown. It can be seen that – depending on the frequency – dredging sound can be detected over quite large ranges by both species with an overall larger detection zone for harbour seals compared to porpoises. Seals have a better hearing sensitivity at lower frequencies where the dredger has most acoustic energy than harbour porpoises.

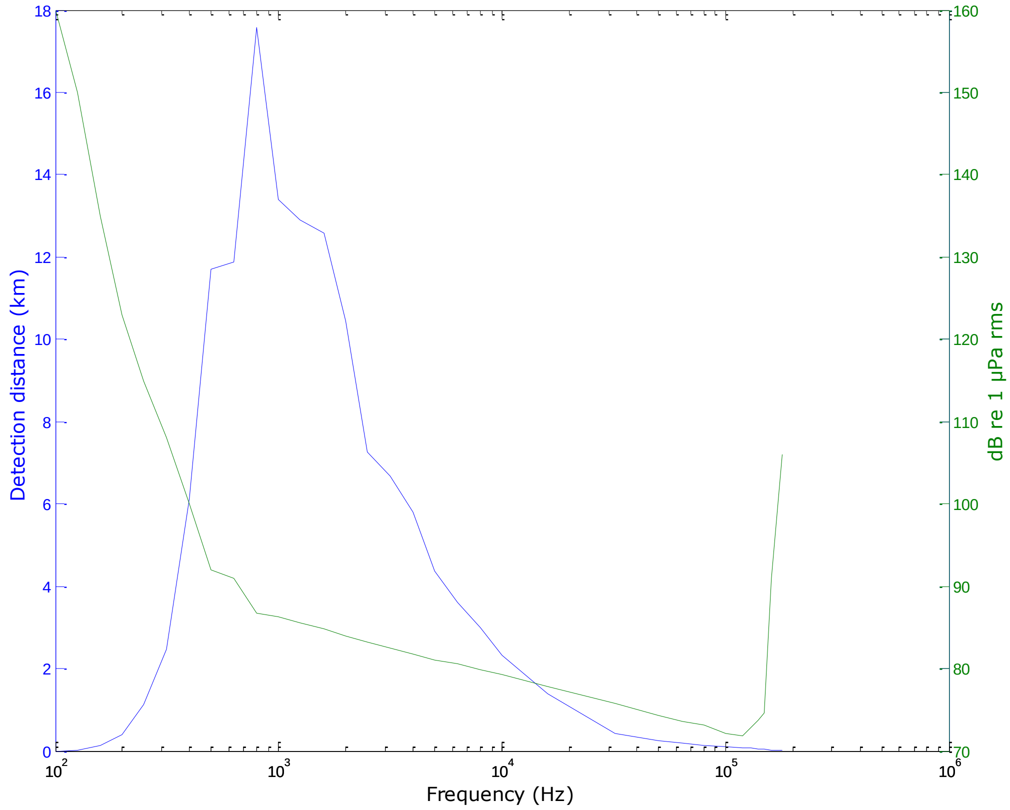


Figure 5.6 *Dredging noise detection by the harbour porpoise. The green line is the masked hearing threshold (from Figure 5.7) and the blue line shows the detection distance for the different frequencies, calculated assuming spherical spreading and normal frequency dependent absorption, and also assuming that the dredging sound is detectable at distances where the background noise and the dredging sound is of the same intensity.*

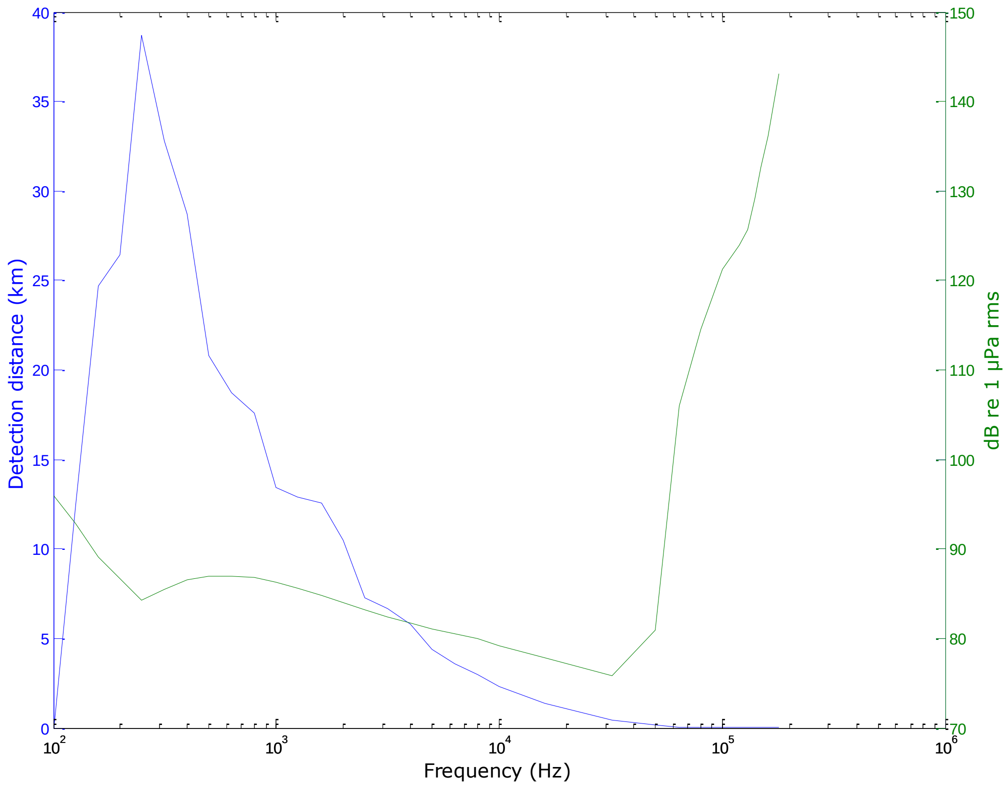


Figure 5.7 Dredging sound detection by the harbour seal. The green line is the masked hearing threshold and the blue line shows the detection distance for the different frequencies, calculated assuming spherical spreading and normal frequency dependent absorption, and also assuming that the dredging sound is detectable at distances where the background noise and the dredging sound is of the same intensity.

Masking of biological relevant signals by the dredging sound can happen anywhere in the detection zone. Harbour porpoises rely heavily on acoustic signals for all aspects of foraging and navigation but may also use acoustic signals during e.g., sexual displays. Masking of any of these signals may have serious consequences for the overall fitness of the animal. Yet, as porpoises use sounds in the ultrasonic range where dredging sound energy is potentially very minimal, harbour porpoise signals are not likely to be masked by dredging.

Seals, on the other hand, may rely heavily on their hearing for especially foraging and social interactions. Masking of relevant signals by noise can therefore have serious implications for seals. The range within which masking (i.e. the reduction in detection distance to a sound source due to increased levels of noise) takes place does not have a well-defined limit but depends very much on the strength of the signal to be detected by the animal and the frequency overlap between biological signal and noise. For seals it is especially communication signals that may be masked, but also signals important for navigation and prey detection can be affected. However, due to the uncertainty over signal strength in seals, no impact ranges for masking can be given.

The behavioural changes can potentially range from strong reactions such as panic or flight to more moderate reactions where the animal may orient itself towards the sound or move slowly away. However, behaviour is inherently difficult as the animals' reaction may depend on season, behavioural state, age, sex, as well as frequency and time structure of the sound causing behavioural changes. This does, however, not mean that behavioural changes should not be considered, since behavioural changes in some cases may be the only impact.

(Southall et al. 2007) defines behaviour on a scale of 0 to 9, where 0 is no behavioural change and 9 is regular panic. This scale can be reduced to 3 categories based on the severity of the behavioural changes (≥6; 5-4; 3-0). For the harbour porpoise the exposure limits for behavioural changes given by (Southall 2007) are 80 dB re 1 µPa rms for category 0-3, 100 dB re 1 µPa rms for category 5-4, and 120 dB re 1 µPa rms for category ≥6. Behavioural changes in seals caused by underwater sound are according to (Southall et al. 2007) 120 dB re 1 µPa rms for the 0-3 category and 130 dB re 1 µPa (rms) for the category 4-5. These values are all based on pulsed sounds but may give an indication of which levels can cause behavioural changes. Measurements in the nearby Fehmarnbelt Area indicate that ambient background noise levels in in the region are exceeding 120 dB re 1 µPa at many places. These levels are similar or in excess to the levels for behavioural changes in the higher category behaviour changes given by (Southall et al. 2007). It is therefore unlikely that porpoises would react to sound at these levels. If the dredging sound exceeds these relatively high background noise levels, or if the sound at certain frequencies exceeds the masked threshold this could elicit behavioural changes (Table 5.5). If animals stay in an area where they are exposed to high noise levels it is likely that they habituate to these levels. Therefore, it is possible that any behavioural changes caused by dredging in Rønne Banke with its supposedly relatively high background noise levels may be more similar to the lower category behaviours in Southall et al. (2007) even though the sound levels exceed the threshold for the higher categories. Recent research indicates that harbour porpoises leave areas during sand extraction at distances of at least 600 m. However, the reactions were relatively short term (Diederichs et al. 2010). The impact on the behaviour is regarded as insignificant.

Physical damages to the hearing apparatus lead to permanent changes in the animals' detection threshold (PTS) which are caused by the destruction of sensory cells in the inner ear. If hearing loss does occur it is usually only temporary (TTS) and the animal will regain its original detection abilities within a few hours. PTS has not been investigated in the harbour porpoise, but a study by (Lucke et al. 2009) measured TTS in the harbour porpoise when exposed to a single sound pulse and found a TTS limit of 199.7 dB re 1 µPa pp. For harbour seals (Southall et al. 2007) gives at PTS limit of 218 dB re 1 µPa peak (above which PTS may occur) for seals under water, this value is based on a study of a single animal. For seals under water the TTS limit defined by Southall et al. (2007) is 152 dB re 1 µPa rms and is, once again, based on studies of a single harbour seal (the same individual also used for the PTS data).

Table 5.5 lists the effects and the maximum range from the sound source at which behavioural and physical effects may occur. For both porpoises and seals TTS effects on single animals may take place at very short distances from the dredger. Given the low density of harbour porpoise on Rønne Banke the number of animals potentially displaced by dredging activities will also be very small, and hence the habitat displacement impact will be negligible. No habitat displacement is predicted for seals. More long term behavioural implications of noise in the Baltic Sea have been investigated for the harbour porpoises during construction of the Nysted wind farm, and though the porpoises initially left the area (Carstensen 2006) there seems to be little long term effect of wind farms on the porpoise population (Nabe-Nielsen 2011). The impact is hence insignificant.

Table 5.5 Maximum distance for PTS, TTS, behavioural changes and detection of Thor-R assuming spherical spreading and frequency dependant absorption. Thresholds for PTS and TTS for harbour seals are from (Southall et al. 2007) and TTS threshold for harbour porpoise is from (Lucke et al. 2009).

Impact type	Threshold for harbour porpoise (dB re 1 µPa rms)	Maximum range	Threshold for harbour seal (and grey seal) (dB re 1 µPa rms)	Maximum range
PTS	-	-	218 (p)	-
TTS	200 (pp)	< 1 m	152	17 m
Behaviour ≥6	120	600 m	-	-
Behaviour 4-5	100	7 km	130	200 m
Behaviour 0-3	80	-	120	600 m
Detection		18 km		38 km

Suspended sediment
The extraction activities will inevitable cause sediment dispersal affecting the transparency of the local areas. The extension/propagation of the plumes is strongly dependent on the local current conditions at the time of construction. However, sediment plumes are not expected to cause any direct impact on seals and porpoises, but may reduce the availability of prey, especially juvenile fish. However, since the affected areas are expected to be very small compared to the total area available to the animals on Rønne Banke and the duration of the impact is short, the impact is regarded as insignificant.

Prey availability
The effect on availability of prey is assessed as very low. Especially juvenile fish are sensitive and some effect is expected during the extraction period (section 6.5.1). However, since the affected areas are expected to be very small compared to the total area available to the animals on Rønne Banke and the duration of the impact is short, no significant negative impact due to sediment dispersal are expected.

Overall conclusion
The overall conclusion is that the impact on the marine mammals present in the area is very low and insignificant on a population level.

5.3.11 Material assets, ammunition and recreational interests

Cables
There are no cables in the extraction area hence there will be no impacts.

Ammunition
It is not likely that there is ammunition in the area.

Navigation and recreational interests
The impact on the ship traffic due to dredging activities can be:

- Increase in ship traffic
- Change in sailing routes and recreational interests
- Risk of collision

Heavy ship traffic occurs in the Baltic Sea, but all the main traffic routes passes around Rønne Banke and not through. However, a smaller amount of traffic do pass across Rønne Banke and minor impact may occur for this traffic as they may have to change their sailing route to avoid the extraction area. Approximately 135-670 cargos will be transported from the extraction area to the construction site. Compared to the total amount of ship traffic in Fehmarnbelt (approximately 38,000 ships in 2010 and an additional 34,000 crossing ferries per year) the impact is regarded as negligible. This is also the case for recreational ship traffic.

The risk of collision is regarded as low because there is sufficient room for relocation of the traffic. The ship traffic in the area is not restricted to channels (fairways) within the extraction area and ship traffic can change sail routes. The impact on navigation is regarded as negligible.

5.3.12 Marine archaeology

The baseline study did not observe any wrecks in the extraction area. Similarly, settlements have not been registered.

6 NATURA 2000

6.1 Baseline description

Natura 2000 is a network of protected areas in the European Union. The network includes areas designated under the Habitats Directive and the Birds Directive. The aim of the network is to ensure a favourable conservation status designation basis of the area. The designation basis is composed of a number of physical habitats and species. Two Danish and two German Natura 2000 sites are in the vicinity of the project site (Figure 6.1).

A screening of the potential impact on the Natura 2000-sites has been performed in compliance with the Habitats Directive which has been implemented in Danish law and administration through the departmental order "Bekendtgørelse om udpegning og administration af internationale naturbeskyttelsesområder samt beskyttelse af visse arter (bek. nr. 408 of 01/05/2007). According to §7 of the departmental order a screening must be carried out to establish if there is a potential impact on the designation basis in the Natura 2000-site. The aim is to establish if it is necessary to perform an appropriate assessment.

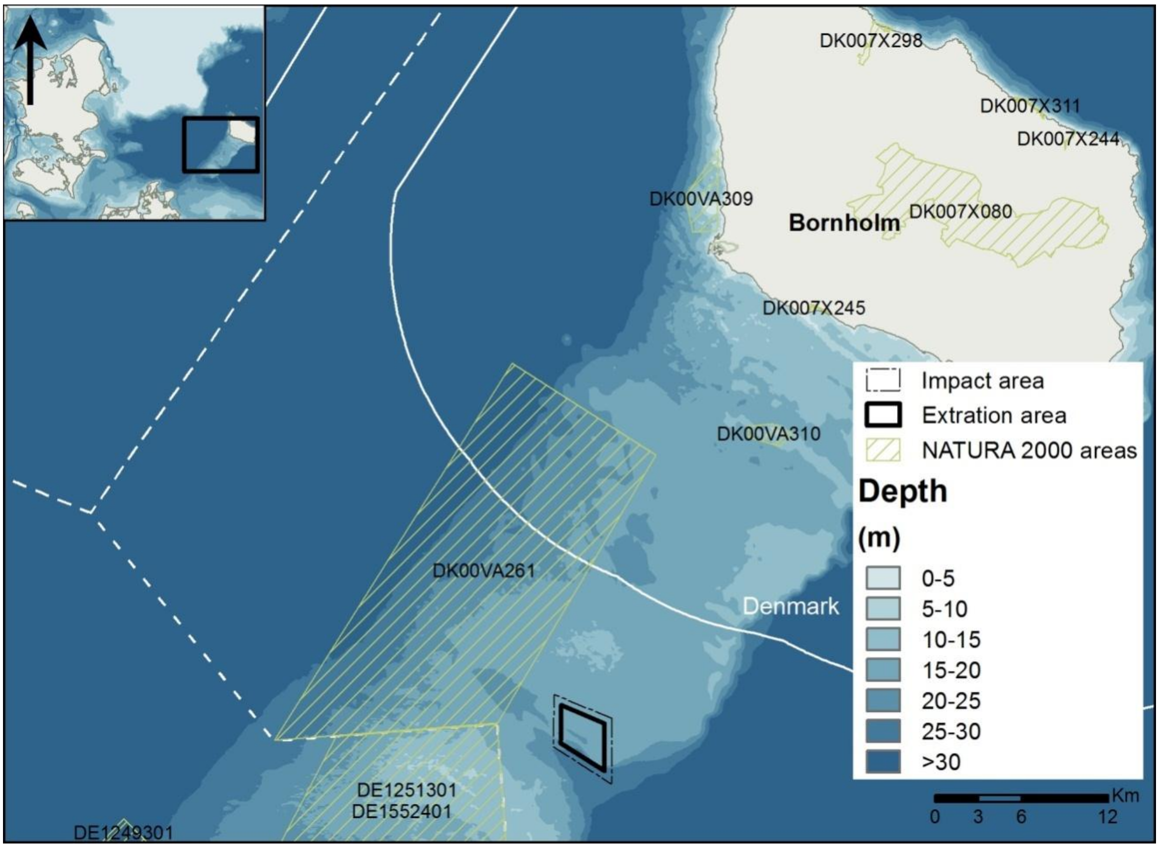


Figure 6.1 Natura 2000 sites situated in the vicinity of the sand extraction area. DK00VA310 (H212) "Bakkebrædt og Bakkegrund", DK00VA261 (H261) "Adler Grund og Rønne Banke" and DE1251301 "Adlergrund" are located closest to the area. DE1552401 refers to the Bird protection site "Pommersche Bucht" and DE1249301 refers to the German area "Westliche Rønnebanke ". The area DE652302 "Pommersche Bucht mit Oderbank" is situated further away from the project area. Natura 2000 sites farther away or at land are not considered.

In Table 6.1 the Natura 2000 sites near Rønne Banke are presented together with the extension of the site, distance to the project site and the designation basis for each Natura 2000 site.

Table 6.1 *Natura 2000-sites close to the extraction area at Rønne Banke. Id-number, name, designation basis (with specification of habitat id. code from annex 1 of the Habitats Directive), areal size of each site (ha) and shortest distance to the extraction area (km).*

Natura 2000-site Id-no	**Name**	**Designation basis**	**Area (ha)**	**Distance to project site**
Danish areas				
DK00VA261	Adler Grund og Rønne Banke (Habitat site)	• Sandbanks which are slightly covered by sea water all the time • Reef (1170)	31,910	3
DK00VA310	Bakkebrædt og Bakke-grund (Habitat site)	• Reef (1170)	229	26
German areas				
DE1251301	Adlergrund (Habitat site)	• Sandbanks which are slightly covered by sea water all the time (1110) • Reef (1170) • Gery seal (*Halichoerus grypus)* • Habour porpoises *(Phocoena phocoena)*	23,397	5
DE1552401	Pommersche Bucht (Bird protection site)	Annex I birds: • Black- throated diver (*Gavia arctica*) • Red-throated diver *(Gavia stellata)* • Little gull (*Larus minutus)* • Slavonian grebe (*Podiceps auritus)* Migratory Birds (only Latin names): *Alca torda, Cepphus grylle, Clangula hyemalis, Larus argentatus, Larus canus, Larus fuscus, Larus marinus, Larus ridibundus, Melanitta fusca, Melanitta nigra, Phalacrocorax carbo, Podiceps cristatus, Podiceps grisegena, Somateria mollissima, Uria aalge*	200,417	5
DE1249301	Westliche Rönnebank	• Reef (1170) • Harbour porpoise (*Phocoena phocoena*)	8,601	26

DE652302	Pommersche Bucht mit Oderbank	• Sandbanks which are slightly covered by seawater all the time (1110) • Harbour porpoise (*Phocoena phocoena*) • Sturgeon (*Acipenser sturio*) • Twaite shad (*Alosa fallax*)	110,115	34

Conservation status and objectives

Danish sites
The Danish National Research Institute (NERI, now University of Aarhus) has prepared a report on "Criteria for Favourable Conservation Status for Eight Marine Habitat Types" (Dahl el al. 2005). The conservation status for 1110 Sandbanks and 1170 reefs in Danish waters have not been assessed, but in general the environmental status for coastal waters and the open inner Danish waters is assessed as having unfavourable conservation status. It is therefore likely that the conservation statuses for both habitat types are unfavourable. The Danish water authorities have not determined what the objectives should be to reach favourable conservation status for the Danish habitat sites. The main threats towards Habitat site Bakkebrædt and Bakkegrund have been identified to be: Fishery, eutrophication and anthropogenic toxic substances (Miljøministeriet 2011). Main threats have not been identified for the site "Adler Grund og Rønne Banke"

German sites
The German site Adlergrund has previous been a sand extraction area with many extraction activities. The general conservation objectives for the area have been set as follows for the habitat types and the species designated for this site:

- Maintenance and restoration of the site's specific ecological functions, biological diversity and natural hydrodynamics;
- Where applicable, restoration to near-natural condition of areas modified by past sediment extraction;
- Maintenance and restoration at favourable conservation status of habitats type 1110 and 1170 together with their characteristic and endangered ecological communities and species;
- Maintenance and restoration at favourable conservation status of the following Habitats Directive species and their natural habitats: Harbour Porpoise and Grey Seal.

6.2 Screening

6.2.1 Impacts on habitats

Danish sites
Increase in suspended sediment concentration (SSC) and deposition can potentially impact habitats such as reefs and sandbanks which are slightly covered with seawater at all times.

Model simulations of spreading and deposition of sediment spilled during dredging show that no SSC or deposition takes place in the Danish Natura 2000 (Figure 5.1 and Figure 5.2). Impact from Rønne Banke sand extractions is very unlikely and will therefore not affect the Danish Natura 2000 areas or the designation basis significantly.

German sites
The Natura 2000 sites "Pommersche Bucht", "Westliche Rønnebanke" and "Pommersche Bucht mit Oderbank" are situated 5, 26 and 34 km away from the project area. Model simulations of spreading and deposition of sediment spilled during dredging show that the sandmining is not expected to increase sedimentation or concentrations of suspended sediment in these areas (Figure 5.1 and Figure 5.2). It is therefore assessed that impact of sediment spill is unlikely and sediment spill will not impact the sandbank and reef habitats in these Natura 2000 areas.

For the Natura 2000 site "Adlergrund" the model simulations of deposition show that fine sediment (grain size smaller than 63 µm) does not deposit at the site (FEHY 2011). Even if it is assumed that all dredging takes place in the areas closest to the Natura 2000 areas, the deposition height will be less than 1.5 mm (which is regarded as negligible, see section 5.3.5) and will not reach farther away than 500 m. In comparison, the shortest distance to the Natura 2000 areas is approximately 3 km.

The suspended spill sediment (grain size <63 µm) at the bottom does reach Adlergrund for short periods and in low concentrations. In 2-3% of the time between 1st May and 1st September, the 2 mg/l threshold is exceeded in the outermost eastern part of the site (Figure 5.1). This exceedance corresponded to a period of 2.5 days. Even with the worst case scenario simulated and assuming that all dredging takes place close to the Natura 2000 area, the predicted concentrations never exceed 10 mg/l in the Adlergrund.

Since the magnitude of the pressure is very small and the time period (2.5 days in total) and the impacted area is very limited it is unlikely that the objectives to maintain and restore the favourable conservation status of habitats type 1110 and 1170 together with their characteristic and endangered ecological communities and species are violated.

It should also be emphasized that the model simulations are very conservative. The model has simulated a dredging of 2.6 mill m^3 sand, which is more than twice the actual amount needed (FEHY 2011). The excess deposition is hence conservative and will most likely be smaller than the model results show. The impact of sediment spill on the Natura 2000 site "Adlergrund" is therefore even smaller than assessed, and will be insignificant.

6.2.2 Pressures on protected species

Strictly protected species under annex IV of the Habitats Directive and the protected species under the Birds Directive can potentially be impacted by the following direct pressures:

For the protected birds the pressures can be identified as: Habitat displacement due to noise, habitat change due to changes in food supply, collision of migrating bird (section 5.3.9)

For the protected fish and mammals the pressures can be identified as: Noise, increased suspended sediment, prey availability (section 5.3.6 and 5.3.10, respectively).

Birds
The bird protection site SPA DE1552401 represents the main concentrations of waterbirds found in the German EEZ of the Baltic Sea, and houses several populations of international importance, including Red-throated/Black-throated Diver 1450, Slavonian Grebe *Podiceps auritus* 500, Long-tailed Duck 130,000, Velvet Scoter 43,000 and Common Scoter 170,000. As disturbamce amd impact on food resouces are limited to the dredging site (5 km from the protection site, impact on the waterbirds will be negligible. The potential of collisions between the dredging vessel and waterbirds moving between the SPA and feeding areas on Rønne Banke are assessed as being rather limited, as the largest concentrations of waterbirds on Rønne Banke are found more than 40 km south of the dredging site (Figure 4.21).

Waterbird species are also mentioned in the standard data form for the German SCIs; DE1251301 Adler Grund Red-throated/Black-throated Diver, Little Gull). No or limited impacts are expected on the species in the SCI as they are located 4 km (Adlergrund) from the dredging site on Rønne Banke.

Mammals
Harbour porpoise is part of the designation basis for the SCIs Adlergrund, Westliche Rönnebank and Pommersche Bucht mit Oderbank. In addition, grey seal is part of the designation basis for Adlergrund. Given the permanent and temporary threshold shifts (hearing loss in mammals), the PTS and TTS limits (Table 6.1) it is very unlikely that such effects will occur for harbour porpoises and grey seals in these SCIs. Similarly, the sound levels from sand extraction are not of sufficient intensity to provoke any behavioural reactions in seals even at relatively close range. Masking of especially communication sounds may be possible for seals, but the extent of this is not likely to counter the concervation objectives of the sites.

For harbour porpoises masking effects will most likely be negligible, due to the difference in frequency content between the sounds used by the animal and the noise produced by sand extraction. The sound pressure levels from sand extraction could potentially cause behavioural reactions, but with no or very small long-term effects on the animals.

Our assessment has shown that avoidance reactions are expected in porpoise to a distance of 600 m. The nearest Natura 2000 site (Adler Grund and Rønne Banke) is 3 km away. Thus, the conservation objectives of these Natura 2000 sites are not negatively affected by the proposed dredging operation.

Article 12 of the EU Habitats Directive requires that member states should take measures to establish a system of strict protection for the animal species listed in Annex IV. The only species in the region listed under Annex IV is the harbour porpoise. The article 12 of the Habitats Directive prohibits the deliberate capture or killing of specimens (including injury) and the deliberate disturbance of marine mammals. The project will not lead to killing or injuring of porpoises. A short term behavioural reaction is expected in a relatively small area around the sandmining (600 m). Porpoises occurring in the Rønne Bank area most likely belong to the population of the Belt Sea and Kattegat which comprise several thousand individuals. The behavioral response of some individuals will not lead to any population level effects and therefore not significantly disturb harbour porpoises in the area. It is also very likely that porpoises that might have been temporarily displaced will reoccur in the area. Thus any function that the area might have for the porpoises (for example as a place to forage) is not affected. The obligations of Article 12 of the Habitat Directive are thus not violated by the project.

Fish
Sturgeon (*Acipenser sturio*) and Twaite shad (*Alosa fallax*) are part of the designation basis for the German Natura 2000 site DE652302 Pommersche Bucht mit Oderbank. The site is situated 34 km from the sand extraction area at Rønne Banke and the results of the modelled sediment spill show that the sand extraction is not expected to increase sedimentation or concentrations of suspended sediment in this area. There are no audiograms of *A. fallax* but they possess a swimbladder and therefore could be sensitive to sound pressure. Unpublished studies suggest that sturgeons hear between 100 and 1000 Hz with no information on sensitivity (see Gill et al. 2012. Due to the very limited information, it is difficult to assess the impacts of dredging noise on the two species. However, since the site is 34 km away from the dredging area it is most likely that the dredging sound would be covered by ambient sound and therefore not detectable for the fish. Thus a possible impact of noise is unlikely. It is therefore assessed that impact of the sand extraction at Rønne Banke is unlikely to impact Sturgeon (*Acipenser sturio*) and Twaite shad (*Alosa fallax*) in this Natura 2000 area.

Conclusion

Impact from Rønne Banke sand extraction on the Danish Natura 2000 sites, habitat sites H212 and H261 is assessed as insignificant. It is therefore not considered necessary to prepare an appropriate assessment for the Natura 2000 sites.

Impact from Rønne Banke sand extraction on the German Natura 2000 areas Pommersches Bucht, Rönnebank and Pommersche Buch mit Oderbank is not expected, and it will therefore not affect the designation basis significantly. Impact from Rønne Banke sand extraction on the German Natura 2000 site Adlergrund is very limited (if any) and will therefore not affect the Natura 2000 sites or the designation basis significantly. It is therefore not necessary to prepare an appropriate assessment for the German Natura 2000 site.

7 CUMULATIVE IMPACTS

Cumulative impacts are defined as the aggregated impact from the Fixed Link project and other projects that are carried out at the same time. Projects that are planned to take place within the same geographical area, and at the same time are threrefore considered although details on these project are not yet available.

The Danish Ministry of Climate, Energy and Building (DMCEB) has recently published an update of the Danish Strategy for localisation of the future wind farms until 2025 (Danish Ministry of Climate, Energy and Building 2011). These plans include two wind parks at Rønne Banke with a total capacity of 400 MW with minimum 12 kilometre distance to Bornholm. However, no implementation date is included in the plans. There is competing interest at Rønne Banke because Rønne Banke contains big resources for extraction. The present EIA describes the extraction of sand from Rønne Banke in an area which is situated about 15 kilometres southwest of the planned wind park. This means that the planned wind park will not affect the sand extraction at Rønne Banke and vice versa. It is obvious that in the near future Rønne Banke will be developed into a region of relatively intense human activities, which will cause disturbance and habitat displacement on waterbirds and marine mammals. Depending on the time schedules for constructing the wind farms these impacts will be augmented by the planned dredging activities.

In summary, cumulative impacts are not likely between the sand extraction project and the wind park projects. The impacts on the benthic fauna communities and the consequently minor impacts on the fish will only be temporary and full recovery is expected within a time period of five years. It is foreseen that there will be an impact on the benthic fauna in the locations of the planned wind parks (there has not yet been executed impacts assessments of this). The impact is limited to the areas close to the wind farms. The distance between the wind parks and the extraction area are so large and the impact so limited that it cannot be expected that the impact on the overall Cerastoderma community at Rønne Banke and the Baltic Sea will be significantly impacted. The benthic fauna will hence still sustain its ecological function in area.

8 MITIGATION AND COMPENSATION

8.1 Sand Extraction Strategy

The volume of approximately 1 mill m^3 sand needed for the concrete production can be produced in a sub-area of the designated extraction area to minimize the physical and biological impacts. Figure 8.1 shows a recommendation of such a sub-area and Table 8.1 gives the coordinates of the rectangle. The sub-area is 1 x 2 km (2 km^2; i.e. reducing the extraction + impact area to 22%). Limiting the extraction area requires that 1-2 m of the seabed can be extracted. At the recommended sub-area the resource thickness is more than 4 m. Thus, the extracted part of the seabed is constrained to the Holocene sand, and layers of potential marine archaeological interest, such as potential submerged Stone Age settlements, are not at risk as these layers and are expected to be covered by approximately 4 m of sand. The minimize extraction area will move the dredging further away from the Natura 2000 areas.

Mitigation of impacts on fishery can be carried out by a close and continuous contact with active fishermen in the area, or with a person with knowledge on fishery on board the dredging vessel; a measure which has proven to be able to reduce the level of possible conflicts.

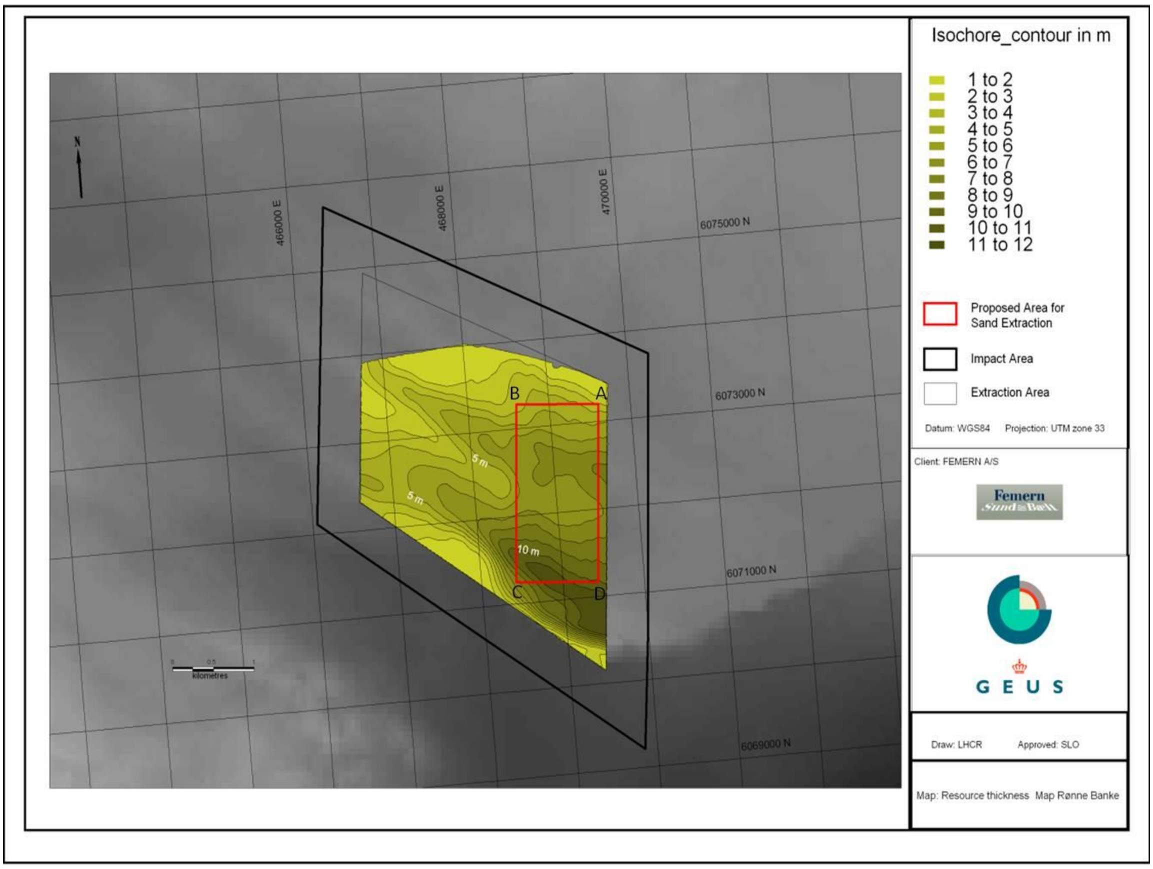


Figure 8.1 Proposed sand extraction area at Rønne Banke.

Table 8.1 Coordinates for the recommended extraction area. The points refer to Figure 8.1.

Recommended area	Easting	Northing	Longitude	Latitude
A	469592	6073188	14 31.61671	54 48.29644
B	468583	6073273	14 30.67416	54 48.33846
C	468434	6071283	14 30.54821	54 47.26513
D	469428	6071201	14 31.47570	54 47.22447

9 KNOWLEDGE GAPS

No major gabs are identified which weakens the impact assessment. This EIA is based on expert knowledge based on scientific references and on data collected as part of the baseline study. Some uncertainties linked to the background material or the related investigations is observed and addressed in the relevant assessment sections. The use of another type of dredger and the impact of this is not assessed in the current assessment report. The knowledge on this use and therefore the impact is not known.

10 MONITORING PROGRAMME

Femern A/S has assessed that the monitoring programme at Krieger's Flak should contain the following:

Phase 1: Investigation of the environmental conditions before the extraction takes place.

The seabed shall be mapped by side sonar scan and video recording along transects within the extraction area. Samples of sediments shall be taken for the evaluation of the physical and chemical conditions of the seabed. Besides this, benthic fauna samples shall be taken at sampling stations in the area. Furthermore, video monitoring of flora shall be done.

These investigations have already been carried out.

Phase 2: Surveillance of the environmental conditions during extraction

Investigations of water discharge from the overflow from the dredger by spot tests. The investigations are executed to verify that the assumptions for the predicted sediment spill calculations (spill rate, grain size distribution and settling velocities) are correct. This also contributes to the certainty about the environmental impact assessment.

Phase 3: Documentation of the environmental conditions immediately after ended extraction activities

Side scan and video inspection of the seabed shall be performed along transects in the areas and it may, after agreement with the Danish Nature Agency, be used to document the reestatblishment of the seabed.

11 ENVIRONMENTAL IMPACTS AND OVERALL CONCLUSION

The overall conclusion on the environmental impact assessment is that there will be impacts on the marine environment within the extracted area. The impact is due to loss of seabed, which directly impacts the benthic fauna community in the area, which again indirectly lead to impacts on the fish and fishery.

The physical impact on the seabed will be of maximal 9 km^2. The recovery time of the seabed varies from 0.3 years to 10 years depending on the water depth. The recovery time is most likely an intermediate of the two scenarios. It is not expected that the seabed sediment sand fraction and hence the habitat type will change significantly, because all extracted material will be retained after extraction and the left seabed is of similar nature as the pre-project.

The loss of benthic fauna will happen as a consequence of the loss of seabed; hence maximal 9 km^2 of benthic fauna will be lost. The recovery time for the benthic fauna is maximal 5 years. As the impact is temporary and the area relatively small the overall significance on benthic fauna, the Cerastoderma community is low. The overall ecosystem function of the benthic fauna will not be lost as the Cerastoderma community is widely distributed in the Baltic Sea.

The impacts on the fish are due to the different pressures from the dredging activities, such as noise, increased suspended sediment concentration, deposition and removal of sediments. The most severe impact is the loss of seabed and hence food supply. Since the impact on the food is temporary the impact on the fish is also expected to be temporary.

The impacts on the fishery are restricted to loss of fish within the extracted area, due to loss of food. Furthermore the fishery can be impacted due to fishery restrictions during dredging activities. A potential conflict and impact can be avoided by planning and communication with the fishermen.

The impacts on the non-breeding waterbirds and the migrating birds are negligible and minor, respectively. Despite the fact that the planned dredging site on Rønne Banke is located within 5 km distance from the SPA Pommeranian Bay holding the largest concentration of waterbirds in the German EEZ of the Baltic Sea only very small direct or indirect impacts on the conservation targets of the SPA are foreseen. The habitat displacement impacts and habitat change impacts on waterbirds in the extraction site will be very small (less than 200 Long-tailed Ducks and single individuals of divers and Black Guillemots). The impacts will mainly take place during winter and spring (November-April). Depending on the use of artificial lights on the dredging vessel collisions with migrating waterbirds and landbirds will take place during periods of low visibility. However, given the broad front migration at the site collision risks to migrating waterbirds from the dredging vessel should be expected to be at a low level.

The planned sand extraction activities on Rønne Banke will have negligible impact on harbour porpoises and seals in the area. There are few animals in this area and the sound levels are not assumed to affect the animals except at very close range. It is concluded that the impact on the marine mammals is not significant.

There is no impact on the coastal morphology, protected species or the Natura 2000 areas.

Consequently, the overall conclusion is that there will be impact on the marine environment within the extraction area due to extraction and extraction activities. Outside the extracted area, the impact is very limited. Furthermore the impacts in the extraction area are temporary and do not have significant impacts on the environment of the region of the Baltic Sea. Disturbance of marine mammals should however be taken into consideration when planning the dredging operations.

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Methods of sampling and analysis of benthic fauna

Methods of sampling and analysis of benthic fauna

Survey program

The survey program at Rønne Banke included:

- Collection of quantitative samples of the benthic fauna at 20 stations
- Collection of sub-samples of surface sediment at 20 stations
- Biological screening based on underwater-video records at 20 stations

Allocation of sampling stations

The 20 sampling and video survey stations were allocated in consultation with GEUS on the basis of the results the surveys of the sediment types conducted by GEUS. The stations were placed with the aim to represent differences in seabed characteristics and water depths both in the extraction area (10 stations) and in the 500m wide impact area (10 stations) around the extraction area.

At a meeting between Naturstyrelsen and Femern A/S the position of the sampling stations was agreed before the field surveys was initiated.

The position and water depth at the stations are shown in Table 1.

Table 1 Position and water depth at the surveys stations at Rønne Banke in August 2011.

Station	Longitude WGS84	Latitude WGS84	Depth m	Sampling depth Cm
RB-1	14° 30.0465	54° 49.0713	19.0	9
RB-2	14° 31.8229	54° 48.5381	19.6	16
RB-3	14° 28.8149	54° 49.0014	20.2	11
RB-4	14° 29.8134	54° 48.8989	19.9	15
RB-5	14° 29.3332	54° 48.7740	20.0	14
RB-6	14° 30.3319	54° 48.6390	17.8	9
RB-7	14° 28.7509	54° 48.7488	17.9	14
RB-8	14° 30.1013	54° 48.2563	17.4	14
RB-9	14° 31.5090	54° 48.0840	18.3	18
RB-10	14° 31.9465	54° 48.0178	18.5	20
RB-11	14° 28.7002	54° 48.3410	20.5	14
RB-12	14° 29.6047	54° 48.1087	20.6	11
RB-13	14° 31.2787	54° 47.6722	20.3	22
RB-14	14° 29.3977	54° 47.6484	25.0	10
RB-15	14° 29.9552	54° 47.3952	27.4	10
RB-16	14° 30.9197	54° 47.2600	15.7	22
RB-17	14° 31.6677	54° 46.9588	16.4	22
RB-18	14° 28.7764	54° 47.6361	24.0	15
RB-19	14° 29.9581	54° 47.1525	27.6	11
RB-20	14° 30.9941	54° 46.6553	28.5	12

Sampling of benthic fauna and sediment

One (1) van Veen sample (unit area: 0.1 m^{-2}) was collected at each station. The quality of the sample was inspected through a lid on top of the sampler. The penetration of the grab sampler into the sediment was measured, cfr. Table 1. A subsample of the uppermost 5 cm of the sediment was collected in a marked plastic bag, stored in a cooling box and later frozen until analysis.

The sampler was opened and emptied into a tub. The structure, colour and stratification of the sediment were noted in a field log.

Water was added and the sediment was gently suspended and sieved through a 1 mm floating sieve. The sieving residue including the benthic fauna was transferred to a plastic bucket and fixated in 4% buffered formaldehyde. The bucket was marked with area, date and station number on the outside and a note with similar information was placed inside the bucket.

The field surveys were conducted 25 august 2011 using the ship JHC-Miljø. The water depth at the stations was recorded from the echo-sounder of the ship.

Underwater-video surveys

In addition to the sampling of benthic fauna and sediment a biological screening of the seabed was conducted at the 20 stations (BEK nr. 1452 af 15/12/2009).

An underwater-video mounted on a frame was lowered close to the seabed. The quality was monitored on a screen and a record of 2-3 minutes duration was obtained while the ship was maintained in position as far as possible. The video-surveys were conducted 22 and 24 August 2011 using DHI's ship DHIVA.

Representative pictures at each station are presented in Appendix 4.

Laboratory analysis – benthic fauna

The samples were analyzed at Dansk Biologisk Laboratorium. Dansk Biologisk Laboratorium is a part of the FEMA group. The fauna method has been harmonized in connections to the Fehmarnbelt Fixed Link baseline studies, and the used method is identical to the method use for the baseline study of the Fehmarnbelt area (FEMA 2013a).

In short, each of the 20 samples was treated individually. The samples were sieved in a 0.5mm sieve in order to remove formaldehyde before sorting. All animals were sorted out using a sorting lamp and the sorting efficiency was controlled using a low power microscope. The animals were identified to species level (except for Oligochaeta) and counted. The shell length of bivalves was measured with a digital caliper.

The total biomass of the individual species including shells of bivalves was determined as total wet weight, dry weight at 105°C in 18-24 hours or until stabile weight was reached and as ash free dry weight (AFDW) after burning in a muffle oven at 550°C for 2 hours.

Laboratory analysis – sediment

The samples were analysed at the Biological Laboratory at DHI for the following variables:

Dry weight (DW) - expressed in % of the wet weight (WW)

Loss on ignition (LOI) - a measure of organic matter expressed in % DW

Median grain size of the sediment (D_{50}) – expressed in µm

Silt/clay fraction (SC) below 63 µm of the sediment – expressed in % DW

Dry weight and loss on ignition was analysed according to DS 204 and the mechanical sieve analysis and determination of median grain size and silt/clay fraction according to (DHI/IOW Consortium et. al. 2009).

Statistical analysis

The software package Primer v5 (Clarke and Gorley 2001) was used to analyse the structure of the benthic community based on fourth root transformed abundance and biomass data (AFDW) and Bray-Curtis similarity. Environmental data (depth and the variables measured in the sediment) was transformed (log x+1) and similarity calculated as Euclidean distance.

References

Bekendtgørelse om ansøgning om tilladelse til efterforskning og indvinding af råstoffer fra havbunden samt indberetning af efterforskningsdata og indvundne råstoffer. BEK nr. 1452 af 15/12/2009.

Clarke, K. R. & R.N. Gorley (2001). PRIMER v5. User Manual/Tutorial. PRIMER-E-Ltd.

DHI/IOW Consortium et. al. (2009). Procedures for sediment sampling and analysis. Femern Bælt A/S, July 2009.

FEMA (2013). Fehmarnbelt Fixed Link EIA. Fauna and Flora – Baseline. Benthic Marine Fauna of the Fehmarnbelt Area. Report No. E2TR0020.

A P P E N D I X   B

Abundance of benthic fauna species

Taxa	Species	RB-1	RB-2	RB-3	RB-4	RB-5	RB-6
Polychaeta	*Bylgides sarsi*	0	0	0	0	0	0
Polychaeta	*Hediste diversicolor*	60	60	0	20	10	10
Polychaeta	*Marenzelleria viridis*	50	220	220	40	40	20
Polychaeta	*Pygospio elegans*	50	170	350	90	330	20
Oligochaeta	Oligochaeta	70	170	0	160	0	180
Bivalvia	*Cerastoderma glaucum*	0	0	20	0	10	0
Bivalvia	*Macoma balthica*	0	0	20	0	0	0
Bivalvia	*Mya arenaria*	0	10	20	10	10	0
Bivalvia	*Mytilus edulis*	0	10	0	10	0	0
Gastropoda	*Hydrobia ulvae*	0	0	0	0	0	0
Crustacea	*Bathyporeia pilosa*	10	0	30	0	10	0
Crustacea	*Diastylis lucifera*	0	0	0	0	0	0
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	0	10	0	0	0
Crustacea	*Monoporeia affinis*	0	0	0	0	0	0
Abundance (m^{-2})		**240**	**640**	**670**	**330**	**410**	**230**
Number of species (0.1 m^{-2})		**5**	**6**	**7**	**6**	**6**	**4**

Taxa	Species	RB-7	RB-8	RB-9	RB-10	RB-11	RB-12
Polychaeta	*Bylgides sarsi*	0	0	0	0	0	0
Polychaeta	*Hediste diversicolor*	10	40	20	20	30	30
Polychaeta	*Marenzelleria viridis*	20	30	10	40	30	30
Polychaeta	*Pygospio elegans*	0	50	80	120	50	190
Oligochaeta	Oligochaeta	0	60	160	140	10	30
Bivalvia	*Cerastoderma glaucum*	0	0	0	0	0	0
Bivalvia	*Macoma balthica*	0	0	0	0	0	0
Bivalvia	*Mya arenaria*	0	0	10	20	0	0
Bivalvia	*Mytilus edulis*	0	0	0	0	10	0
Gastropoda	*Hydrobia ulvae*	0	0	0	10	0	0
Crustacea	*Bathyporeia pilosa*	0	70	0	0	10	10
Crustacea	*Diastylis lucifera*	0	0	0	0	0	0
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	0	0	0	20	0
Crustacea	*Monoporeia affinis*	0	0	0	0	0	0
Abundance (m^{-2})		**30**	**250**	**280**	**350**	**160**	**290**
Number of species (0.1 m^{-2})		**2**	**5**	**5**	**6**	**7**	**5**

Taxa	Species	RB-13	RB-14	RB-15	RB-16	RB-17	RB-18
Polychaeta	*Bylgides sarsi*	0	40	80	0	0	0
Polychaeta	*Hediste diversicolor*	50	40	10	20	60	50
Polychaeta	*Marenzelleria viridis*	20	350	490	10	20	100
Polychaeta	*Pygospio elegans*	240	580	400	120	40	680
Oligochaeta	Oligochaeta	180	20	40	60	10	120
Bivalvia	*Cerastoderma glaucum*	0	40	0	10	0	0
Bivalvia	*Macoma balthica*	0	130	20	0	0	30
Bivalvia	*Mya arenaria*	0	60	40	30	10	20
Bivalvia	*Mytilus edulis*	0	780	570	0	0	10
Gastropoda	*Hydrobia ulvae*	0	0	20	0	10	0
Crustacea	*Bathyporeia pilosa*	0	0	10	20	70	30
Crustacea	*Diastylis lucifera*	0	30	10	0	0	0
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	120	40	0	0	0
Crustacea	*Monoporeia affinis*	0	10	0	0	0	0
Abundance (m^{-2})		**490**	**2200**	**1730**	**270**	**220**	**1040**
Number of species (0.1 m^{-2})		**4**	**12**	**12**	**7**	**7**	**8**

Taxa	Species	RB-19	RB-20	AVR AB	% AVR AB	No. of Stations	% of Stations
Polychaeta	*Bylgides sarsi*	90	190	20	2.7	4	20
Polychaeta	*Hediste diversicolor*	50	40	32	4.2	19	95
Polychaeta	*Marenzelleria viridis*	1070	1140	198	26.2	20	100
Polychaeta	*Pygospio elegans*	1230	580	269	35.6	19	95
Oligochaeta	Oligochaeta	0	100	76	10.0	16	80
Bivalvia	*Cerastoderma glaucum*	10	0	5	0.6	5	25
Bivalvia	*Macoma balthica*	100	100	20	2.7	6	30
Bivalvia	*Mya arenaria*	30	0	14	1.8	12	60
Bivalvia	*Mytilus edulis*	230	90	86	11.3	8	40
Gastropoda	*Hydrobia ulvae*	0	0	2	0.3	3	15
Crustacea	*Bathyporeia pilosa*	0	0	14	1.8	10	50
Crustacea	*Diastylis lucifera*	40	0	4	0.5	3	15
Crustacea	*Diastylis rathkei*	10	10	1	0.1	2	10
Crustacea	*Gammarus salinus*	0	10	10	1.3	5	25
Crustacea	*Monoporeia affinis*	0	140	8	1.0	2	10
Abundance (m^{-2})		**2860**	**2400**	**755**	**100**	**20**	**100**
Number of species (0.1 m^{-2})		**10**	**10**				

A P P E N D I X   C

Biomass (AFDW) on benthic fauna species

Taxa	Species	RB-1	RB-2	RB-3	RB-4	RB-5	RB-6
Polychaeta	*Bylgides sarsi*	0	0	0	0	0	0
Polychaeta	*Hediste diversicolor*	0.366	0.376	0	0.116	0.129	0.214
Polychaeta	*Marenzelleria viridis*	0.071	0.221	0.037	0.058	0.006	0.030
Polychaeta	*Pygospio elegans*	0.014	0.023	0.085	0.011	0.056	0.002
Oligochaeta	Oligochaeta	0.017	0.029	0	0.020	0	0.047
Bivalvia	*Cerastoderma glaucum*	0	0	0.166	0	0.056	0
Bivalvia	*Macoma balthica*	0	0	0.281	0	0	0
Bivalvia	*Mya arenaria*	0	0.085	0.186	0.253	0.002	0
Bivalvia	*Mytilus edulis*	0	0.008	0	0.136	0	0
Gastropoda	*Hydrobia ulvae*	0	0	0	0	0	0
Crustacea	*Bathyporeia pilosa*	0.001	0	0.021	0	0.013	0
Crustacea	*Diastylis lucifera*	0	0	0	0	0	0
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	0	0.001	0	0	0
Crustacea	*Monoporeia affinis*	0	0	0	0	0	0
Biomass (gAFDW m^{-2})		**0.469**	**0.742**	**0.777**	**0.594**	**0.262**	**0.293**

Taxa	Species	RB-7	RB-8	RB-9	RB-10	RB-11	RB-12
Polychaeta	*Bylgides sarsi*	0	0	0	0	0	0
Polychaeta	*Hediste diversicolor*	0.027	0.206	0.041	0.092	0.189	0.072
Polychaeta	*Marenzelleria viridis*	0.055	0.027	0.001	0.003	0.07	0.08
Polychaeta	*Pygospio elegans*	0	0.008	0.021	0.034	0.015	0.036
Oligochaeta	Oligochaeta	0	0.001	0.019	0.021	0	0.001
Bivalvia	*Cerastoderma glaucum*	0	0	0	0	0	0
Bivalvia	*Macoma balthica*	0	0	0	0	0	0
Bivalvia	*Mya arenaria*	0	0	0.072	0.409	0	0
Bivalvia	*Mytilus edulis*	0	0	0	0	0.018	0
Gastropoda	*Hydrobia ulvae*	0	0	0	0.002	0	0
Crustacea	*Bathyporeia pilosa*	0	0.042	0	0	0.008	0.006
Crustacea	*Diastylis lucifera*	0	0	0	0	0	0
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	0	0	0	0.01	0
Crustacea	*Monoporeia affinis*	0	0	0	0	0	0
Biomass (gAFDW m^{-2})		**0.082**	**0.284**	**0.154**	**0.561**	**0.310**	**0.195**

Taxa	Species	RB-13	RB-14	RB-15	RB-16	RB-17	RB-18
Polychaeta	*Bylgides sarsi*	0	0.022	0.05	0	0	0
Polychaeta	*Hediste diversicolor*	0.379	0.066	0.001	0.026	0.121	0.406
Polychaeta	*Marenzelleria viridis*	0.003	0.068	0.082	0.007	0.04	0.095
Polychaeta	*Pygospio elegans*	0.044	0.106	0.086	0.02	0.004	0.13
Oligochaeta	Oligochaeta	0.027	0.001	0.002	0.001	0.001	0.02
Bivalvia	*Cerastoderma glaucum*	0	0.14	0	0.235	0	0
Bivalvia	*Macoma balthica*	0	0.98	0.068	0	0	0.586
Bivalvia	*Mya arenaria*	0	0.902	0.427	0.314	0.029	0.113
Bivalvia	*Mytilus edulis*	0	7.388	6.549	0	0	0.018
Gastropoda	*Hydrobia ulvae*	0	0	0.003	0	0.001	0
Crustacea	*Bathyporeia pilosa*	0	0	0.004	0.001	0.036	0.015
Crustacea	*Diastylis lucifera*	0	0.005	0.001	0	0	0
Crustacea	*Diastylis rathkei*	0	0	0	0	0	0
Crustacea	*Gammarus salinus*	0	0.053	0.018	0	0	0
Crustacea	*Monoporeia affinis*	0	0.005	0	0	0	0
Biomass (gAFDW m^{-2})		**0.453**	**9.736**	**7.291**	**0.604**	**0.232**	**1.383**

Taxa	Species	RB-19	RB-20	Average biomass	% Average bio-mass
Polychaeta	*Bylgides sarsi*	0.044	0.158	**0.0137**	**0.95**
Polychaeta	*Hediste diversicolor*	0.13	0.045	**0.1501**	**10.40**
Polychaeta	*Marenzelleria viridis*	0.219	0.21	**0.0691**	**4.79**
Polychaeta	*Pygospio elegans*	0.183	0.134	**0.0506**	**3.51**
Oligochaeta	Oligochaeta	0	0.003	**0.0105**	**0.73**
Bivalvia	*Cerastoderma glaucum*	0.038	0	**0.0318**	**2.20**
Bivalvia	*Macoma balthica*	0.5	1.681	**0.2048**	**14.19**
Bivalvia	*Mya arenaria*	0.092	0	**0.1442**	**9.99**
Bivalvia	*Mytilus edulis*	0.407	0.444	**0.7484**	**51.86**
Gastropoda	*Hydrobia ulvae*	0	0	**0.0003**	**0.02**
Crustacea	*Bathyporeia pilosa*	0	0	**0.0073**	**0.51**
Crustacea	*Diastylis lucifera*	0.001	0	**0.0004**	**0.02**
Crustacea	*Diastylis rathkei*	0.012	0.022	**0.0017**	**0.12**
Crustacea	*Gammarus salinus*	0	0	**0.0041**	**0.28**
Crustacea	*Monoporeia affinis*	0	0.12	**0.0063**	**0.43**
Biomass (gAFDW m^{-2})		**1.626**	**2.817**	**1.443**	**100**

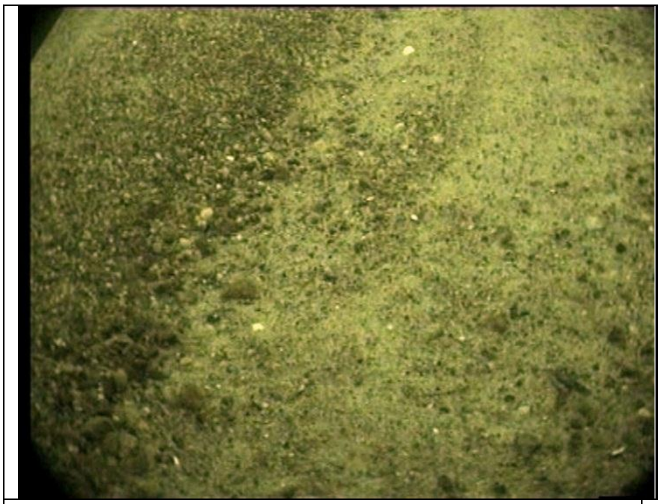
A P P E N D I X   D

Description of sediment and seabed

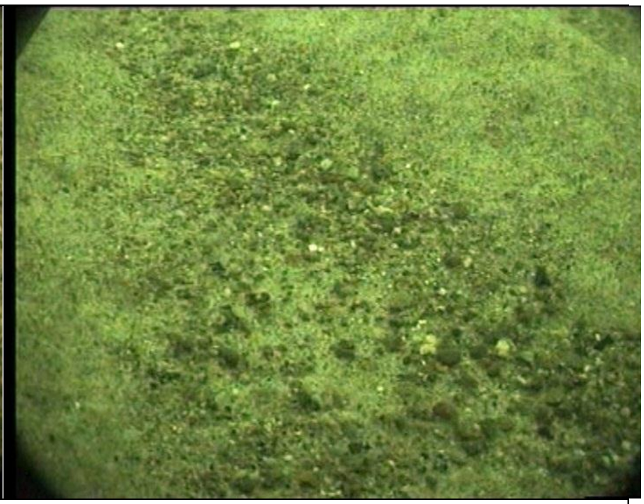
Rønne Banke
Description of the seabed and pictures at the stations where underwater video was recorded 24 August 2011

Station	Depth (m)	Description of the seabed (about 50 m²)
RB-1	19.0	100% coarse sand, some shells
RB-2	19.6	100% coarse sand, some shells
RB-3	20.2	100% coarse sand, some shells
RB-4	19.9	99% coarse sand, 1% gravel/small stones
RB-5	20.0	99% medium sand, 1% gravel/small stones
RB-6	17.8	99% coarse sand, 1% gravel/small stones
RB-7	17.9	99% coarse sand, 1% gravel/small stones
RB-8	17.4	99% coarse sand, 1% gravel/small stones
RB-9	18.3	99% coarse sand, 1% gravel/small stones
RB-10	18.5	100% coarse sand
RB-11	20.5	97% coarse sand, 3% gravel/small stones
RB-12	20.6	95% coarse sand, 5% gravel/small stones
RB-13	20.3	100% medium/coarse sand
RB-14	25.0	95% coarse sand, 5% gravel/small stones
RB-15	27.4	95% coarse sand, 5% gravel/small stones
RB-16	15.7	50% coarse sand, 45% gravel, 5% common mussels
RB-17	16.4	100% coarse sand
RB-18	24.0	97% coarse sand, 3% common mussels
RB-19	27.6	95% medium sand, 5% common mussels
RB-20	28.5	97% fine sand, 3% common mussels

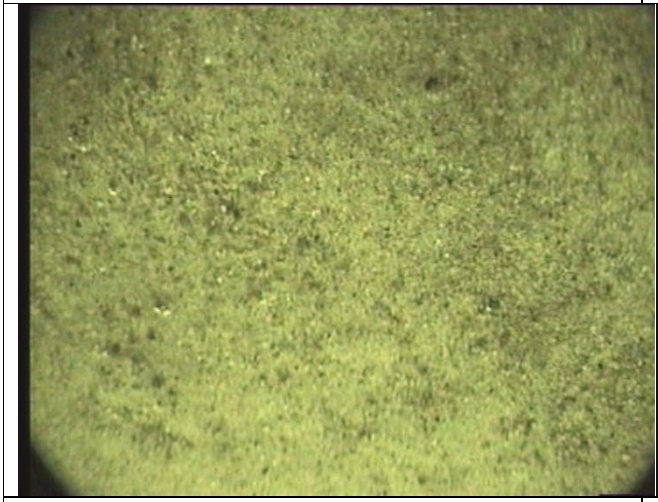
Comments
High contents of suspended matter accumulated close to the bottom especially at deeper stations. One minute of underwater video was recorded at each station equal to about 50 m² of seabed. Two pictures from each record are presented below.



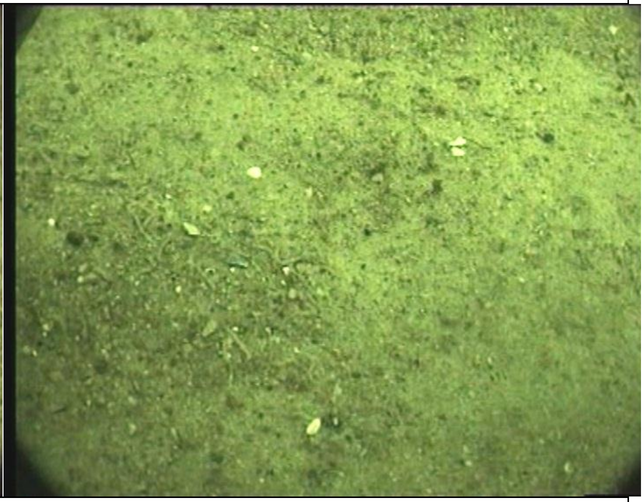
Rønne Banke Station 1: Photo A (RB1-1)



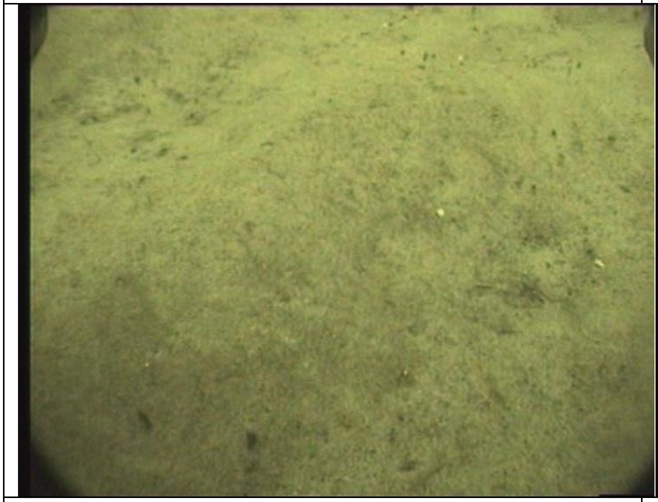
Rønne Banke Station 1: Photo B (RB1-2)



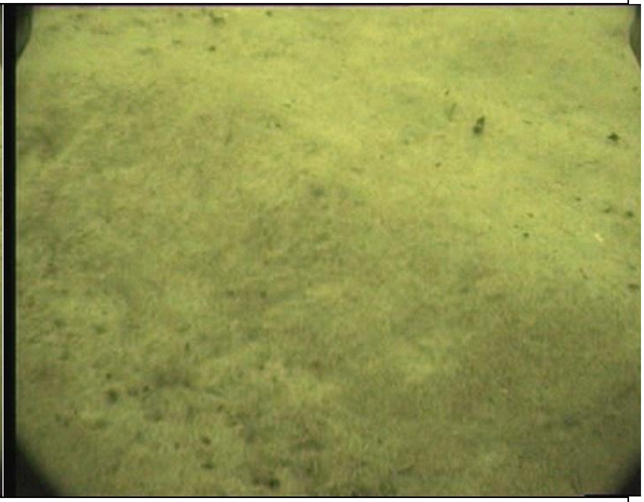
Rønne Banke Station 2: Photo A (RB2-1)



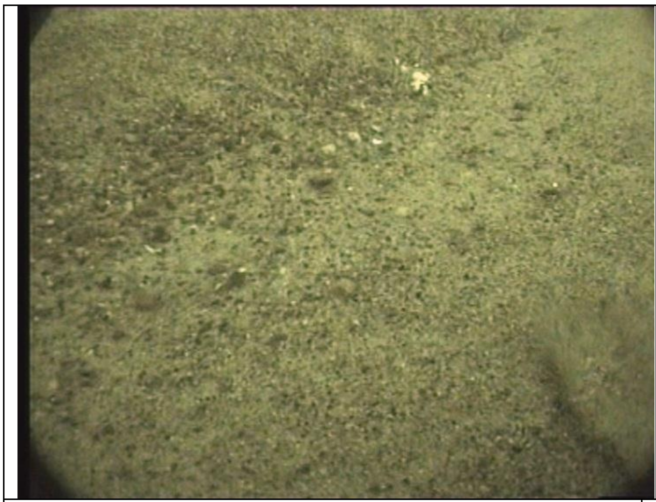
Rønne Banke Station 2: Photo B (RB2-2)



Rønne Banke Station 3: Photo A (RB3-1)

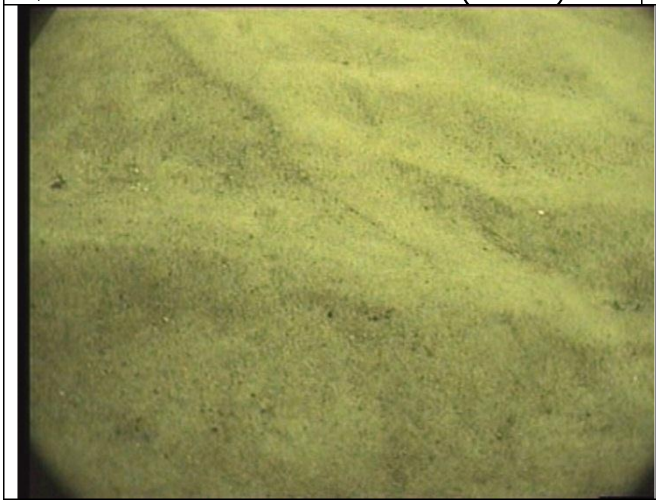
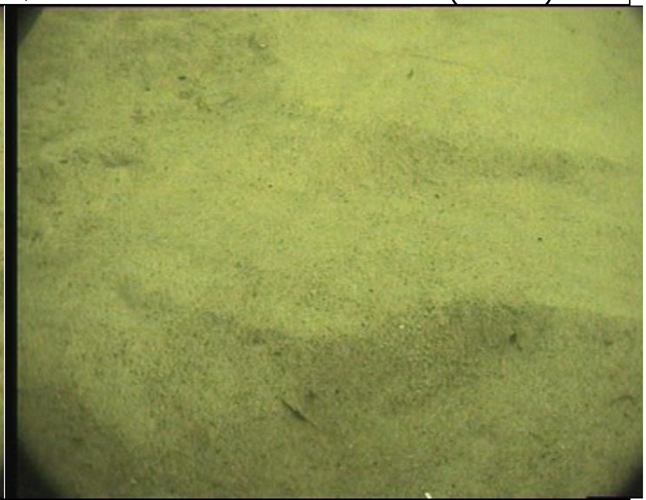


Rønne Banke Station 3: Photo B (RB3-2)



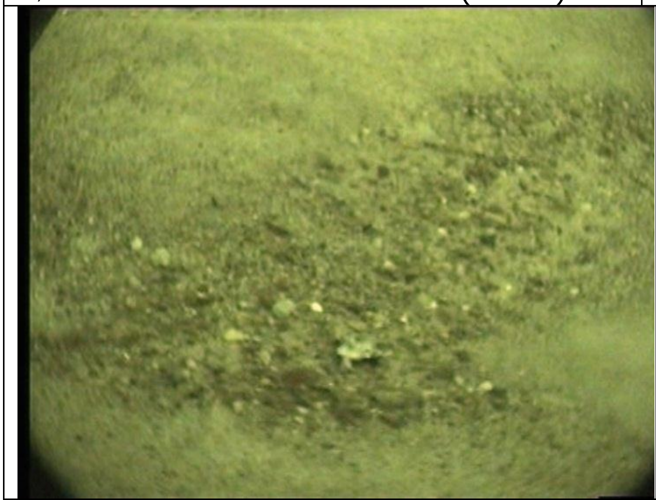
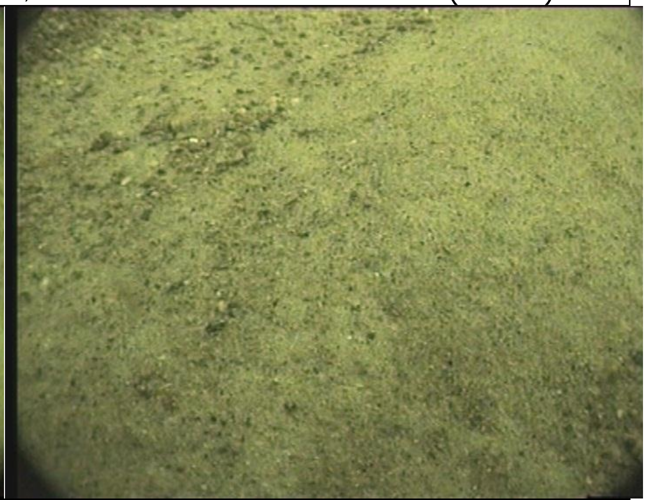

Rønne Banke Station 4: Photo A (RB4-1)

Rønne Banke Station 4: Photo A (RB4-2)

Rønne Banke Station 5: Photo A (RB5-1)

Rønne Banke Station 5: Photo A (RB5-2)

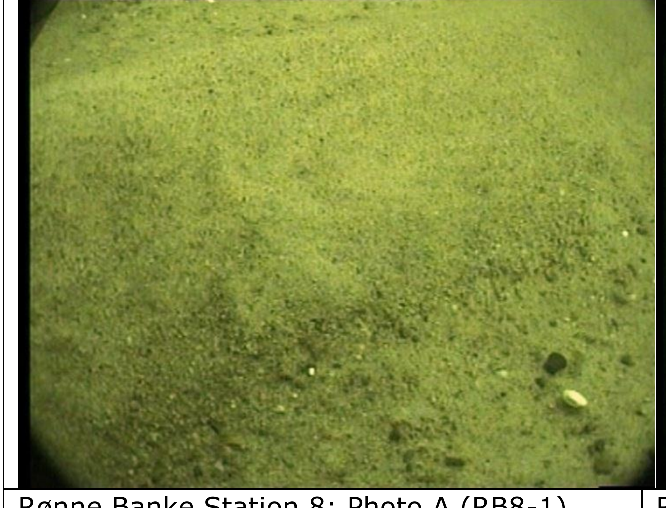



Rønne Banke Station 6: Photo A (RB6-1)

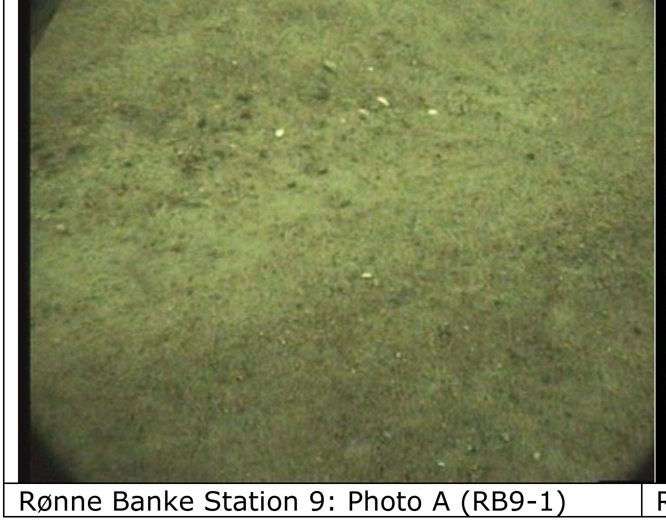
Rønne Banke Station 6: Photo A (RB6-2)

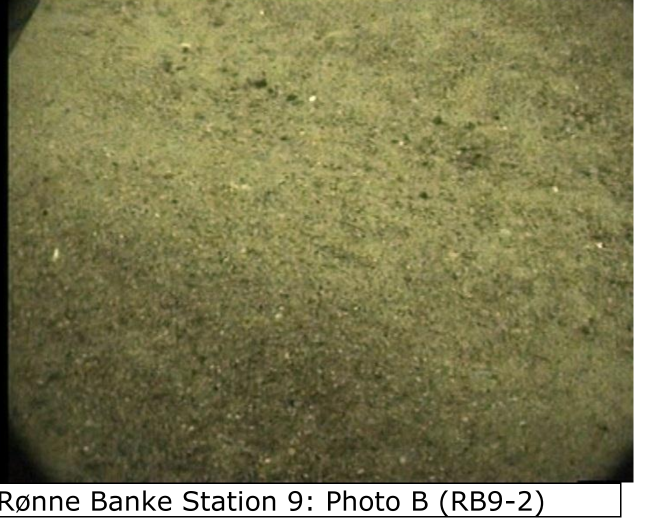

Rønne Banke Station 7: Photo A (RB7-1)


Rønne Banke Station 7: Photo B (RB7-2)


Rønne Banke Station 8: Photo A (RB8-1)

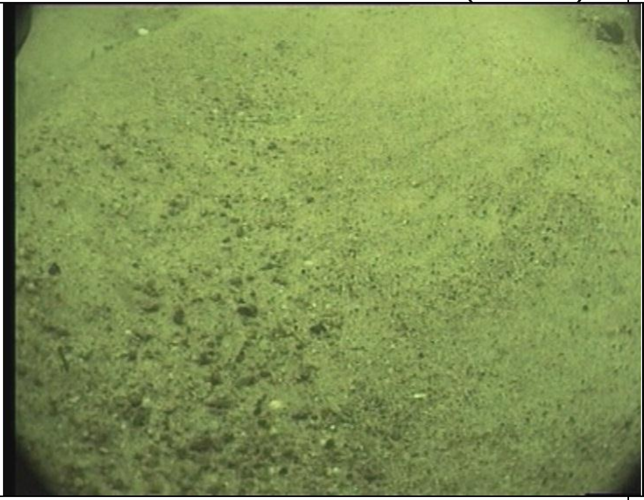
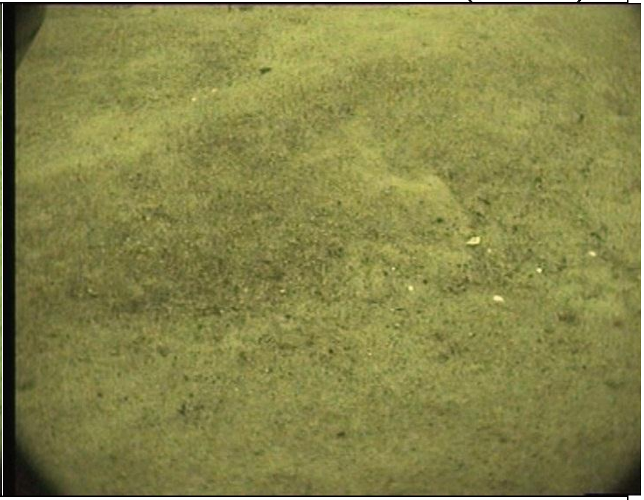

Rønne Banke Station 8: Photo B (RB8-2)


Rønne Banke Station 9: Photo A (RB9-1)

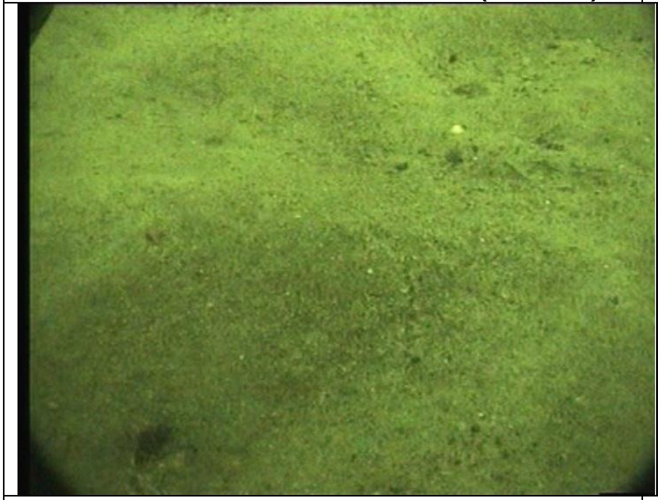
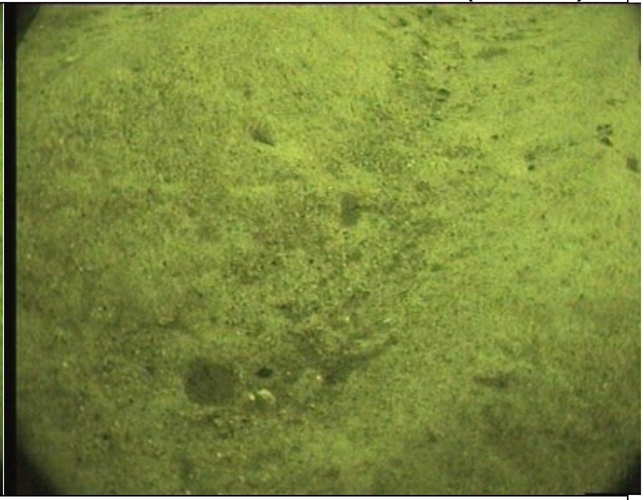

Rønne Banke Station 9: Photo B (RB9-2)

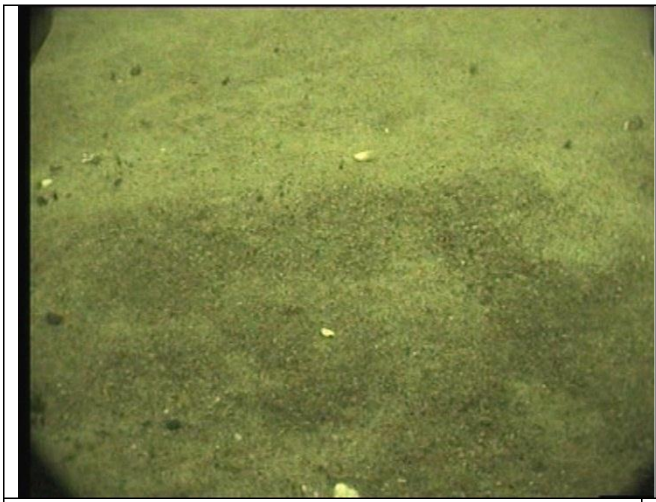
Rønne Banke Station 10: Photo A (RB10-3)	Rønne Banke Station 10: Photo B (RB10-4)

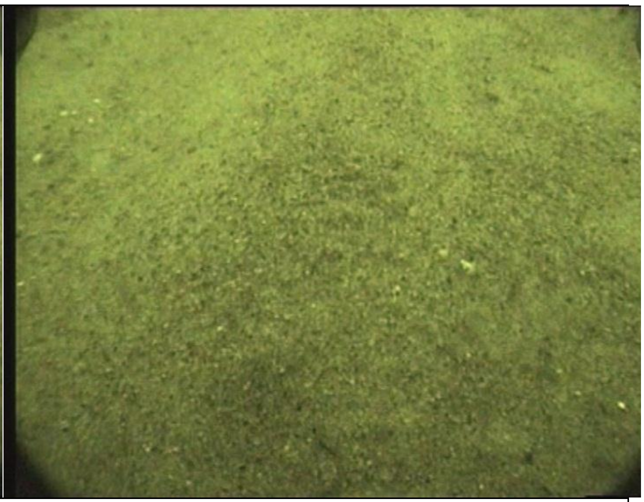
Rønne Banke Station 11: Photo A (RB11-1)	Rønne Banke Station 11: Photo B (RB11-4)

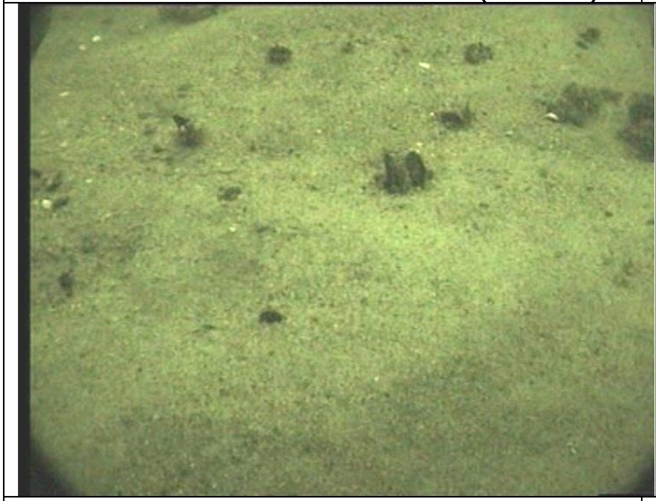
Rønne Banke Station 12: Photo A (RB12-1)	Rønne Banke Station 12: Photo B (RB12-2)



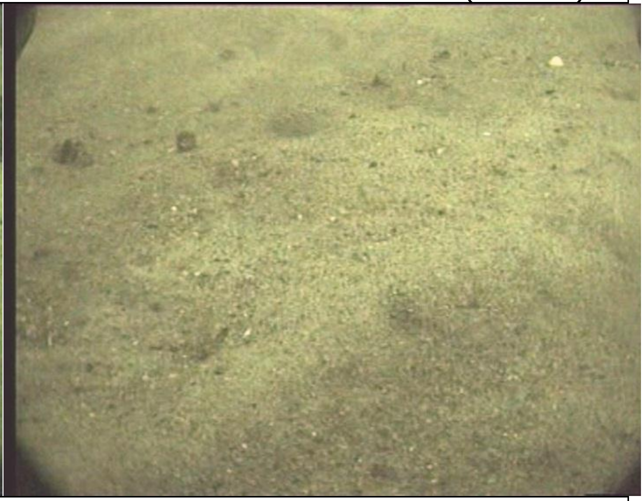
Rønne Banke Station 13: Photo A (RB13-1)



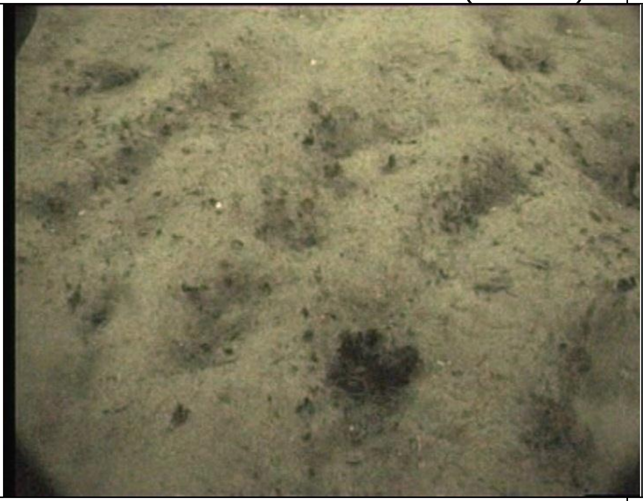
Rønne Banke Station 13: Photo B (RB13-2)



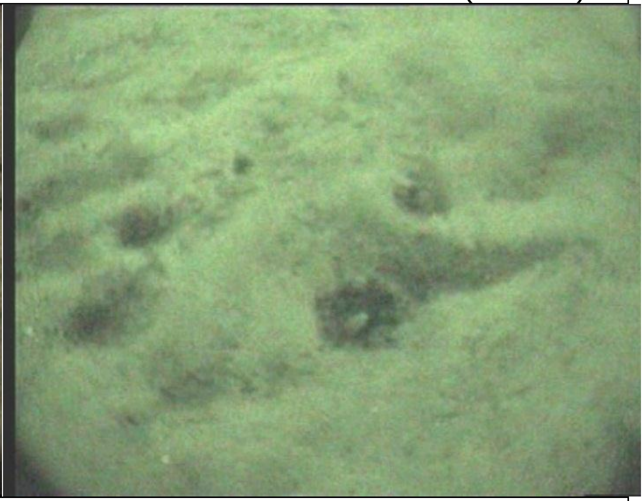
Rønne Banke Station 14: Photo A (RB14-1)



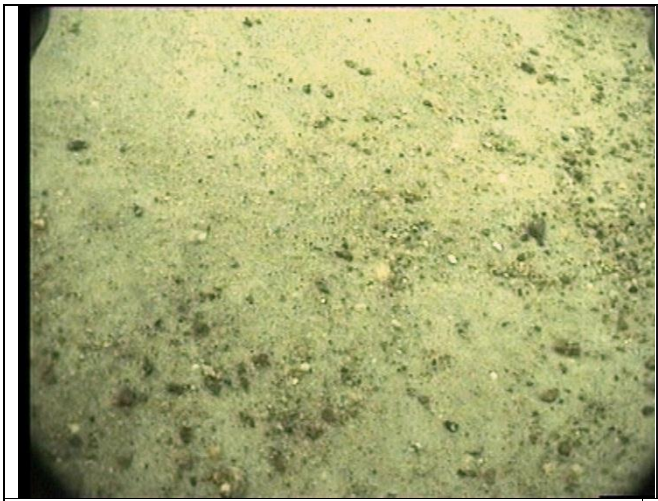
Rønne Banke Station 14: Photo B (RB14-2)

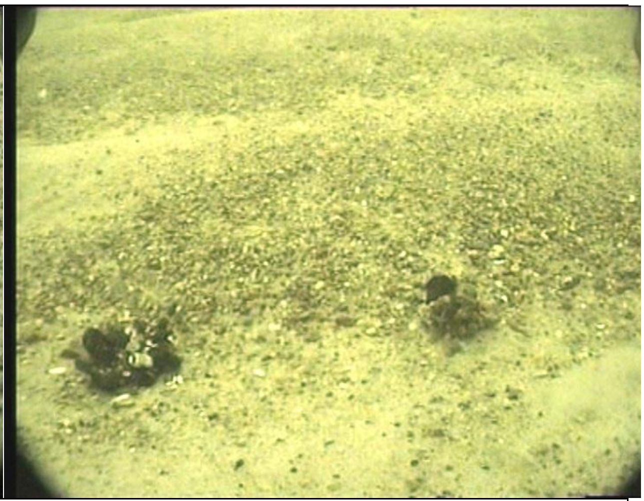


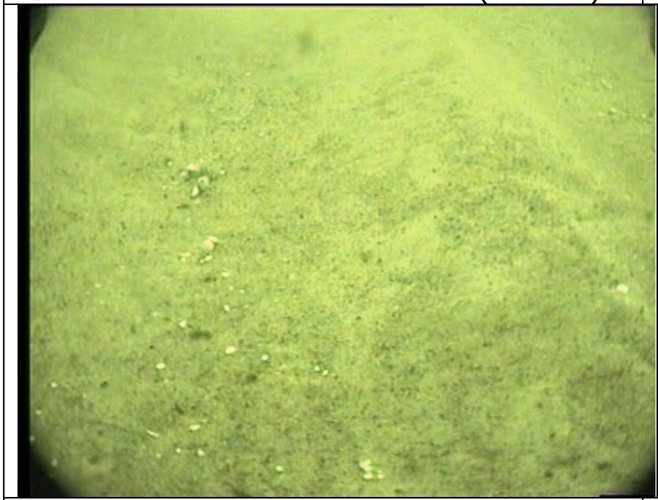
Rønne Banke Station 15: Photo A (RB15-1)

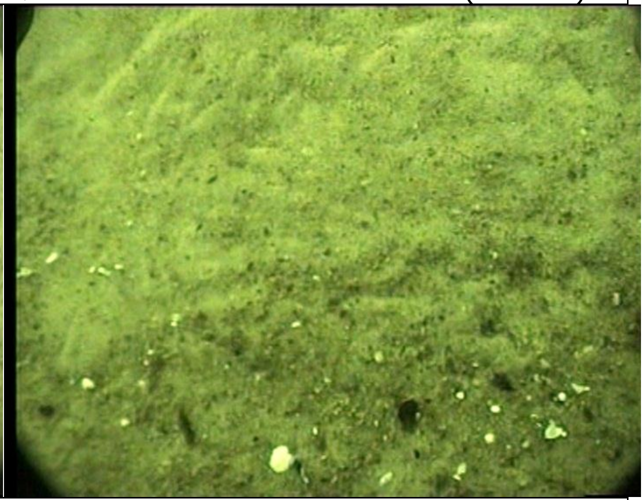


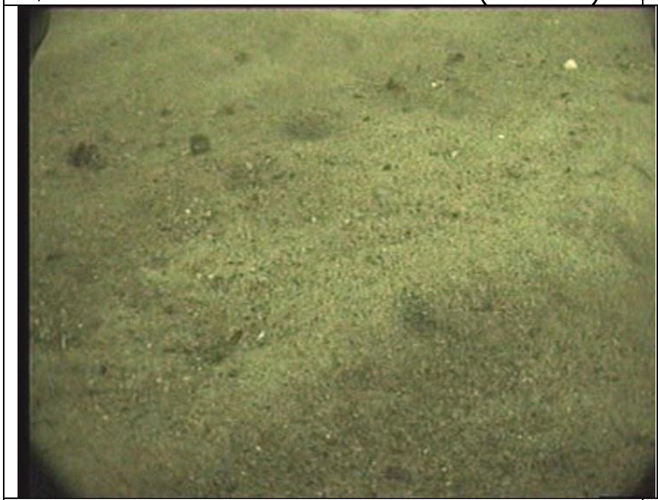
Rønne Banke Station 15: Photo B (RB15-2)

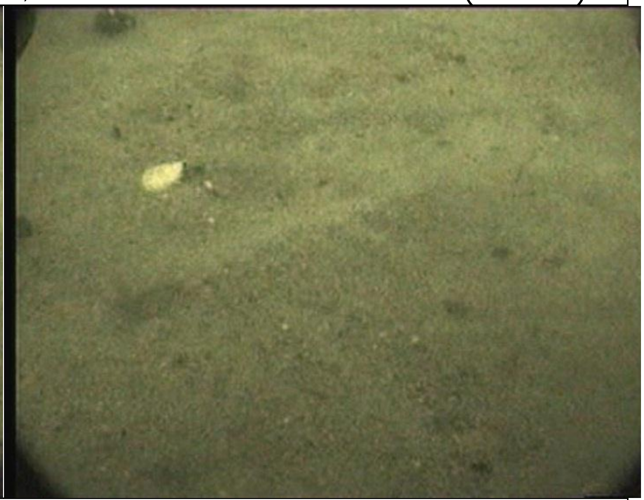

Rønne Banke Station 16: Photo A (RB16-1)

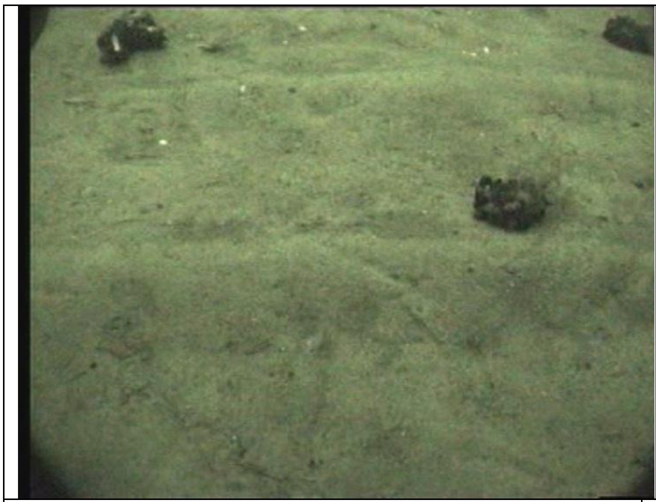
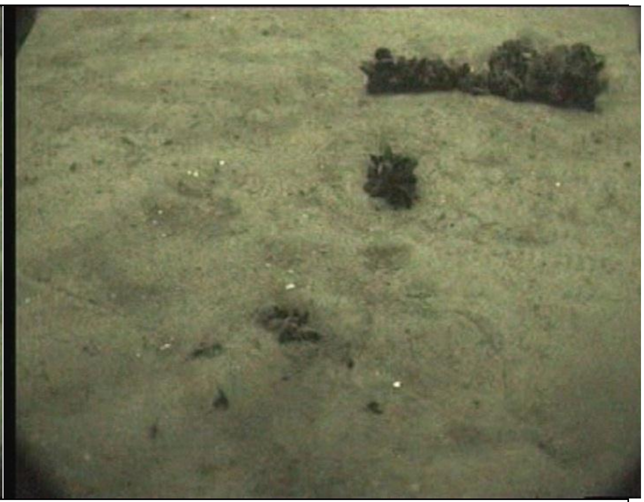

Rønne Banke Station 16: Photo B (RB16-2)


Rønne Banke Station 17: Photo A (RB17-1)

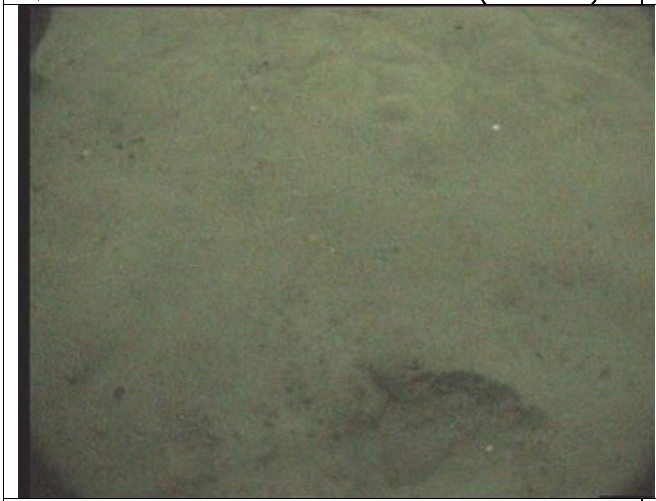
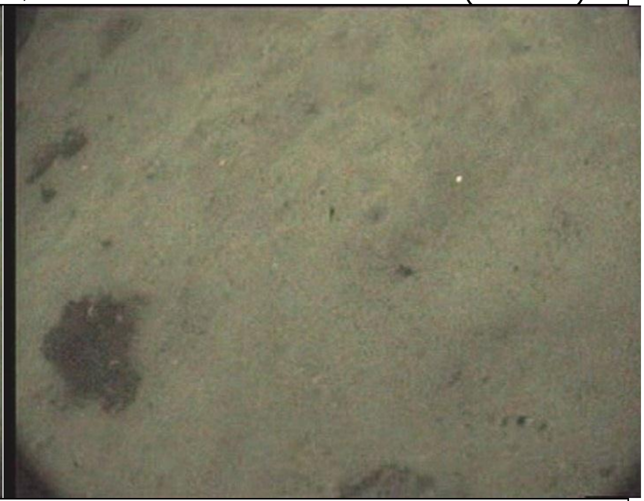

Rønne Banke Station 17: Photo B (RB17-2)


Rønne Banke Station 18: Photo A (RB18-1)


Rønne Banke Station 18: Photo B (RB18-2)

Rønne Banke Station 19: Photo A (RB19-1)	Rønne Banke Station 19: Photo B (RB19-2)

Rønne Banke Station 20: Photo A (RB20-1)	Rønne Banke Station 20: Photo B (RB20-3)

APPENDIX E

Seismic/acoustic equipment specifications

NaviSound 200 Series

PRODUCT SPECIFICATION

PORTABLE HYDROGRAPHIC SINGLE-BEAM ECHOSOUNDERS

- *Portable, highly compact, lightweight unit*
- *Broadband frequency agile*
- *Multiple bottom digitizing with single frequency for sediment and vegetation surveys*
- *Supports single or alternating channel operations*
- *High-performance, easy-to-operate, and very reliable*

RESON's NaviSound 200 Series are highly portable, single-beam echosounders that offer a range of high-performance features. With a selection of models, the NaviSound 200 Series supports a wide range of hydrographic survey applications.

NaviSound 200 echosounders provide reliable depth measurements in a convenient, easy-to-operate unit. Advanced features include multiple bottom digitizing with a single frequency for sediment and vegetation surveys. Besides its compact size and low weight, the NaviSound 200 enclosure provides the highest possible water resistance.

An affordable side-looking sonar (SLS) option that records dual-sided imagery is also available for selected NaviSound 200 models.

Individual NaviSound 200 models are as follows:

- **NaviSound 215:** Enhanced single-beam echosounder that uses one receiver channel to operate two transducers in true real-time, alternating frequency operation
- **NaviSound 210:** Basic, one-channel, single-beam echosounder for hydrographic survey operations
- **NaviSound 205:** One-channel single-beam echosounder for light surveying

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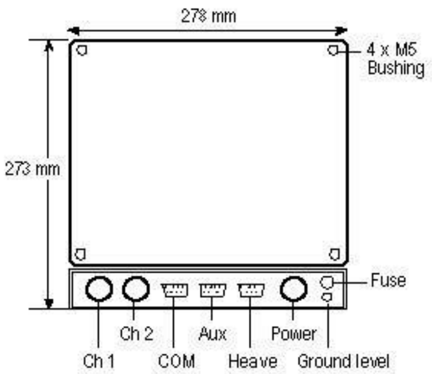
NaviSound 200 Series System Specifications

TECHNICAL DETAILS

Frequencies:	User-selectable frequencies from 15-600 kHz. Standard 28-35 and 190-225 kHz
Impedance:	100 Ohm (others on request)
Max power:	300 W
Power control:	Manual or automatic
Pulse length:	Manual, 5 steps
Units:	Meters & feet
Resolution:	1 cm (210 & 215) 1 dm (205)
Accuracy:	1 cm at 210 kHz (1 sigma), 7 cm at 33 kHz (1 sigma) (assuming correct sound velocity, transducer draft)
TVC detection level:	20 Log (depth)
Additional feature:	Built-in barcheck utility
Sound velocity calibration:	1350 - 1600 m/sec in 1 m/sec step
Transducer draft comp:	0 - 99.99m
Graphics:	
Recording:	11 cm wide thermal paper recorder
Resolution:	800 pixels (gray shades)
Transfer speed:	20 lines/sec
Serial interfaces:	1: Communication 2: Heave input 3: Auxiliary input (DGPS) 4: Repeater output
Dimensions:	273 x 278 x 115 millimeters (11 x 11 x 4.5 inches)
Weight:	5.5 kg (12 lbs)
Supply voltage:	10 - 28 VDC (external AC converter available)
EMC radio noise:	CE approved

REAR VIEW



MODEL COMPARISON

NaviSound	**205**	**210**	**215**
Output resolution:	dm	cm	cm
Depth Range:	0.5-100m	0.2-600m	0.2-600m
Channels/Transducers:	1/1	1/1	1/2
Max. sounding rate (PRF):	5 Hz	20 Hz	20/10 Hz
Heave input:	-	✓	✓
NMEA output:	✓	✓	✓
DESOxx output protocol:	-	✓	✓
Supports SLS option	-	✓	✓
AC Converter Option	✓	✓	✓

Scope of delivery: NaviSound 200 Series User's Manual, DC power cable, RS-232C communication cable for PC, spare paper, transducer connector(s), and fuses & thermal head cleaning kit

Version: B42-PDF-0202

Due to our policy of continuous product improvement, RESON reserves the right to change specifications without notice.

SIS-1625 Seafloor Imaging System

SIDE SCAN SONAR / PROFILER

Combined Chirp/CW Side Scan Sonar/ Sub-bottom Profiling System

The SIS-1625 Seafloor Imaging System has quickly become the industry standard for shallow water (<2000M) seafloor survey operations. This field proven, highly versatile survey tool offers a fully digital platform capable of collecting high resolution chirp side scan/sub-bottom data, as well as a full suite of customer selected sensor data. The high resolution, extended range chirp data and multiple data sensor capability provide the surveyor with a significant savings in instrument cost and survey time.

One Workstation

Topside system consists of:

- Chirp DSP based side scan sonar, operating at 100/400 kHz simultaneously, allows a full 1000 meter swath, with resolution equivalent to much higher frequency systems.
- Chirp DSP/CW based sub-bottom profiling, operating in the 1 to 10 kHz region, allows maximum sediment penetration with greatly improved resolution.
- Gain, TVG, image correction, color palette, and other programmable parameters are under trackball control.
- Digital interface provided for thermal graphic recorders.

One Tow Vehicle—TTV-290

The TTV-290 is a fully digital platform with standard Chirp side scan/sub-bottom transducer arrays, digital multiplexor, subsea electronics, and RS-232 ports for optional sensors.

- Hydrodynamically stable tow vehicle includes pitch, roll and heading sensors, optional position responder/ transponder, and other customer selected sensors.
- 0.5° side scan sonar horizontal radiation pattern,combined with broad band Chirp DSP match filter processing, provides optimal cross-track and along track resolution.
- Tow vehicle operates in depths up to 2000 meters.

ACOUSTICS
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SIS-1625 Seafloor Imaging System

One Cable—CL-160 Communications Link

The comm link was designed through a program to develop a full ocean depth telemetry module for a multisensor seafloor mapping system.

- Two-way communication with tow vehicle over single coax with digital high speed multiplexor. Standard cable length—up to 10,000 meters.
- Digital multiplexor for single coaxial tow cables. Communication rates: sonar data—up to 5 megabit/sec; uplink status—9600 bits/sec; downlink command—9600 bits/sec.

SPECIFICATIONS

CL-160 Shipboard Sub-System	
Chirp Processing:	Sonar/status control PC based workstation; 5-DSP based sonar matched filter processing channels.
Display:	High resolution video display.
Recording:	Large capacity hard drive, DVD writable, other..
Status Display:	Vehicle pitch, roll, heading (standard); speed, altitude, and depth (optional). Customer input ship position, vehicle position, event marks; all status data recorded.
Sonar Display:	Side scan port, starb; dual channel sub-bottom; all sonar data recorded.
Corrections:	Slant range and speed; beam angle/grazing angle.
Multiplexor:	Digital MUX for coaxial cables (ADSL).
Sonar Data:	up to 5 megabit/sec.
Uplink Status:	9600 bit/sec.
Downlink Command:	9600 bits/sec.
Power Supply:	110/220 VAC autosensing.
Side Scan	
Side Scan Transducers:	Multi-element array, dual channel 100/400 kHz 0.5° horizontal beam; 60° vertical beam.
Frequency:	100/400 kHz band swept FM; 4.5 cm resolution.
Processing:	Calibrated transmit waveform stored in ROM; match filter FFT digital signal processing.
Swath Selection:	25 meters to ±500 meters.
Sub-Bottom	
Transducer:	Transmit projector array; line array receiving hydrophone; 30° conical radiation pattern.
Frequency:	1 kHz to 10 kHz swept FM (4 KW output), synchronous with side scan.
Resolution:	5 cm.
Processing:	Calibrated transmit waveform stored in ROM; matched filter FFT digital signal processing.
Scale Selection:	25 meters to 500 meters full scale.
TTV-290 Tow Vehicle Sub-System	
Depth rating:	2000 meters.
Vehicle Dimensions:	18 inches (45 cm) OD x 64 inches (162.6 cm) long.
Weight:	In air: 300 lbs (136 Kg); in water: 170 lbs (77 Kg).

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www.benthos.com

Geo-Spark 200 Multi-tip Sparker

The GEO-SPARK series is a new generation of very high-resolution multi-tip sparkers and HV pulsed power supplies developed / manufactured by Geo-Resources Instruments.

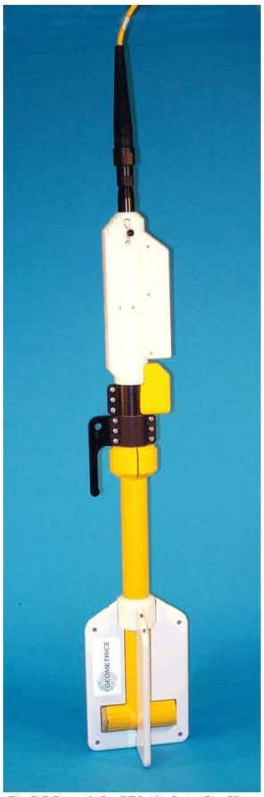
The GEO-SPARK-200 source system is capable to acquire very high-resolution (< 30 cm) seismic profiles of the "shallow" sub-bottom strata. Depending on the energy level, the geology and water depth, the effective penetration can exceed 300 - 400 msec below seabed.

Specifications GEO-SPARK 200 Multi-tip Sparker

Dimensions:	H x W x D = 55 x 75 x 105 cm
Overall Weight	55 kg
Shipping	Standard Euro pallet / container 60 x 80 x 120 cm
Frame	Marine quality stainless steel (316)
	Entirely passivated c/w aluminium protection anodes
Array Depth	Adjustable from 10 cm to 40 cm below surface
Array Geometry	Planar configuration of 0.75 x 1.00 m for enhanced downward projection of acoustic energy
Number of Tips	Number of active Electrode Modules (1 - 4) corresponding to 50, 100, 150, or 200 tips can be selected onboard.
Diameter of Tips	Electrode Modules are available with: Small diameter tip, surface = 0.45 mm^2, for low power per tip Large diameter tips, surface = 2.50 mm^2 , for high power per tip
Energy Level	Recommended max energy per tip in PE mode: 3 Joule / tip for small diameter tips 12.5 Joule / tip for large diameter tips
Standard Configuration	For use with the Geo-Spark 1000 PPS, a combination of 2 modules with 50 small diameter tips plus 2 modules with 50 large diameter tips
Primary Pulse Length	Around 0.5 msec
Dominant Frequencies	Between 500 - 2000 Hz, depending on the selected energy level see attached spectra
PE Mode	The Geo-Spark 200 multi-tip sparker is specifically designed for operation with the Geo-Spark 1000 High Voltage Pulsed Power Supply in **Preserving Electrode Mode.** In this patented mode the electrodes have negative potential with respect to the frame (ground referenced). This mode reduces the **electrode wear to practically zero**.
HV Tow / Power Cable	Coaxial HV cable, Kevlar reinforced, double insulated, LOW EM emission
Material / Colour	High quality Polyurethane, orange
Outer Diameter:	27 mm
Bending Radius	400 mm
Weight	1.07 kg /m
Inner Cores	4 x 6 mm^2 PU insulated
Outer Braiding	1 x 25 mm^2 PU insulated
Strength Member	4 tons
Wet Termination	4 special HV connectors, each rated for 6 kV pulses of 5 kA
	1 flat stainless steel frame connector
Dry Termination	5 eye connectors to patch panel
Patch Panel	Heavy duty, custom-made HMPE distribution box for connection of HV cable to the Geo-Spark 1000 PPS, allows to connect each electrode module independently

G-882 MARINE MAGNETOMETER

- *CESIUM VAPOR HIGH PERFORMANCE – Highest detection range and probability of detecting all sized ferrous targets*
- *NEW STREAMLINED DESIGN FOR TOW SAFETY – Low probability of fouling in lines or rocks*
- *NEW QUICK CONVERSION FROM NOSE TOW TO CG TOW – Simply remove an aluminum locking pin, move tow point and reinsert. New built in easy carry handle!*
- *NEW INTERNAL CM-221 COUNTER MODULE – Provides Flash Memory for storage of default parameters set by user*
- *NEW ECHOSOUNDER / ALTIMETER OPTION*
- *NEW DEPTH RATING – 4,000 psi !*
- *HIGHEST SENSITIVITY IN THE INDUSTRY – 0.004 nT/Hz RMS with the internal CM-221 Mini-Counter*
- *EASY PORTABILITY & HANDLING – no winch required, single man operation, only 44 lbs with 200 ft cable (without weights)*
- *COMBINE TWO SYSTEMS FOR INCREASED COVERAGE – Internal CM-221 Mini-Counter provides multi-sensor data concatenation allowing side by side coverage which maximizes detection of small targets and reduces noise*



G-882 with Weight Collar Depth Option & Altimeter

Very high resolution Cesium Vapor performance is now available in a low cost, small size system for professional surveys in shallow or deep water. High sensitivity and sample rates are maintained for all applications. The well proven Cesium sensor is combined with a unique and new CM-221 Larmor counter and ruggedly packaged for small or large boat operation. Use your computer and standard printer with our MagLogLite™ software to log, display and print GPS position and magnetic field data. The G–882 is the lowest priced high performance full range marine magnetometer system ever offered.

The G-882 offers flexibility for operation from small boat, shallow water surveys as well as deep tow applications (4,000 psi rating, telemetry over steel coax available to 10Km). The G-882 also directly interfaces to all major Side Scan manufacturers for tandem tow configurations. Being small and lightweight (44 lbs net, without weights) it is easily deployed and operated by one person. But add several streamlined weight collars and the system can quickly weigh more than 100 lbs. for deep tow applications. Power may be supplied from a 24 to 30 VDC battery power or the included 110/220 VAC power supply. The tow cable employs high strength Kevlar strain member with a standard length of 200 ft (61 m) and optional cable length up to 500m with no telemetry required.
A rugged fiber-wound fiberglass housing is designed for operation is all parts of the world allowing sensor rotation for work in equatorial regions. The shipboard end of the tow cable is attached to an included junction box or optional on-board cable for quick and simple hookup to power and output of data into any Windows 98, ME, NT, 2000 or XP computer equipped with RS-232 serial ports.

The G-882 Cesium magnetometer provides the same operating sensitivity and sample rates as the larger deep tow model G-880. MagLogLite™ Logging Software is offered with each magnetometer and allows recording and display of data and position with Automatic Anomaly Detection and automatic anomaly printing on Windows™ printer! Additional options include: MagMap2000 plotting and contouring software and post acquisition processing software MagPick™ (free from our website.)

The G-882 system is particularly well suited for the detection and mapping of all sizes of ferrous objects. This includes anchors, chains, cables, pipelines, ballast stone and other scattered shipwreck debris, munitions of all sizes (UXO), aircraft, engines and any other object with magnetic expression. Objects as small as a 5 inch screwdriver are readily detected provided that the sensor is close to the seafloor and within practical detection range. (Refer to table at right).

The design of this high sensitivity G-882 marine unit is directed toward the largest number of user needs. It is intended to meet all marine requirements such as shallow survey, deep tow through long cables, integration with Side Scan Sonar systems and monitoring of fish depth and altitude.

Typical Detection Range For Common Objects

Ship 1000 tons	0.5 to 1 nT at 800 ft (244 m)
Anchor 20 tons	0.8 to 1.25 nT at 400 ft (120 m)
Automobile	1 to 2 nT at 100 ft (30 m)
Light Aircraft	0.5 to 2 nT at 40 ft (12 m)
Pipeline (12 inch)	1 to 2 nT at 200 ft (60 m)
Pipeline (6 inch)	1 to 2 nT at 100 ft (30 m)
100 KG of iron	1 to 2 nT at 50 ft (15 m)
100 lbs of iron	0.5 to 1 nT at 30 ft (9 m)
10 lbs of iron	0.5 to 1 nT at 20 ft (6 m)
1 lb of iron	0.5 to 1 nT at 10 ft (3 m)
Screwdriver 5 inch	0.5 to 2 nT at 12 ft (4 m)
1000 lb bomb	1 to 5 nT at 100 ft (30 m)
500 lb bomb	0.5 to 5 nT at 50 ft (16 m)
Grenade	0.5 to 2 nT at 10 ft (3 m)
20 mm shell	0.5 to 2 nT at 5 ft (1.8 m)

MODEL G-882 CESIUM MARINE MAGNETOMETER SYSTEM SPECIFICATIONS

OPERATING PRINCIPLE:	Self-oscillating split-beam Cesium Vapor (non-radioactive)
OPERATING RANGE:	20,000 to 100,000 nT
OPERATING ZONES:	The earth's field vector should be at an angle greater than 6° from the sensor's equator and greater than 6° away from the sensor's long axis. Automatic hemisphere switching.
CM-221 COUNTER SENSITIVITY:	<0.004 nT/$\sqrt{}$Hz rms. Up to 20 samples per second
HEADING ERROR:	±1 nT (over entire 360° spin)
ABSOLUTE ACCURACY:	<2 nT throughout range
OUTPUT:	RS-232 at 1,200 to 19,200 Baud
MECHANICAL:	
Sensor Fish:	Body 2.75 in. (7 cm) dia., 4.5 ft (1.37 m) long with fin assembly (11 in. cross width), 40 lbs. (18 kg) Includes Sensor and Electronics and 1 main weight. Additional collar weights are 14lbs (6.4kg) each, total of 5 capable
Tow Cable:	Kevlar Reinforced multiconductor tow cable. Breaking strength 3,600 lbs, 0.48 in OD, 200 ft maximum. Weighs 17 lbs (7.7 kg) with terminations.
OPERATING TEMPERATURE:	-30°F to +122°F (-35°C to +50°C)
STORAGE TEMPERATURE:	-48°F to +158°F (-45°C to +70°C)
ALTITUDE:	Up to 30,000 ft (9,000 m)
WATER TIGHT:	O-Ring sealed for up to 4,000 psi (9000 ft or 2750 m) depth operation
POWER:	24 to 32 VDC, 0.75 amp at turn-on and 0.5 amp thereafter
ACCESSORIES:	
Standard:	View201 Utility Software operation manual and ship kit
Optional:	Telemetry to 10Km coax, gradiometer (longitudinal or transverse), reusable shipping case
MagLog Lite™ Software:	Logs, displays and prints Mag and GPS data at 10 Hz sample rate. Automatic anomaly detection and single sheet Windows printer support

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE ***12/03***

GEOMETRICS

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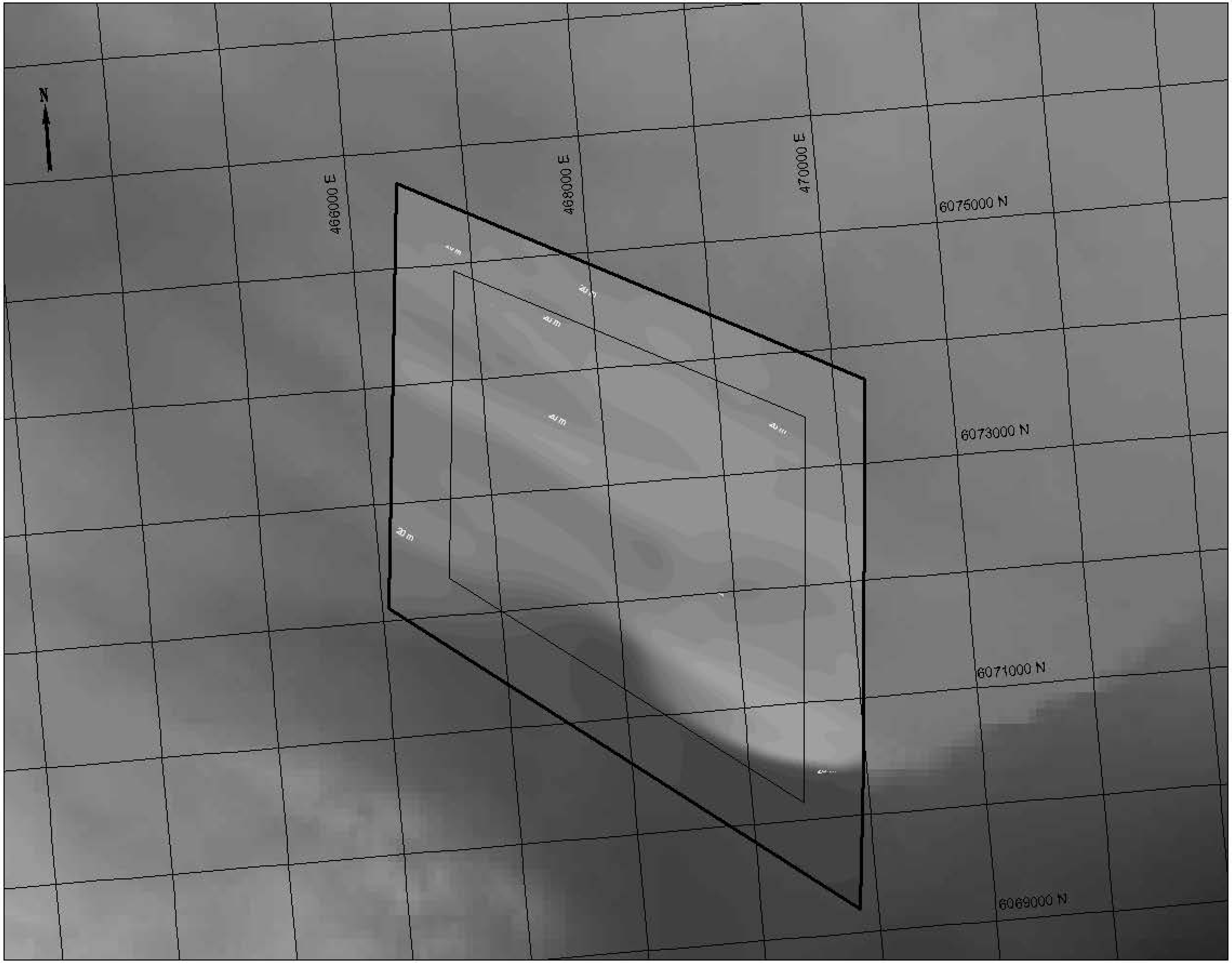
A P P E N D I X   F

Survey, sediment and resource maps in A3-format



Rønne_depth in m

-30 to -29
-29 to -28
-28 to -27
-27 to -26
-26 to -25
-25 to -24
-24 to -23
-23 to -22
-22 to -21
-21 to -20
-20 to -19
-19 to -18
-18 to -17
-17 to -16
-16 to -15

Impact Area

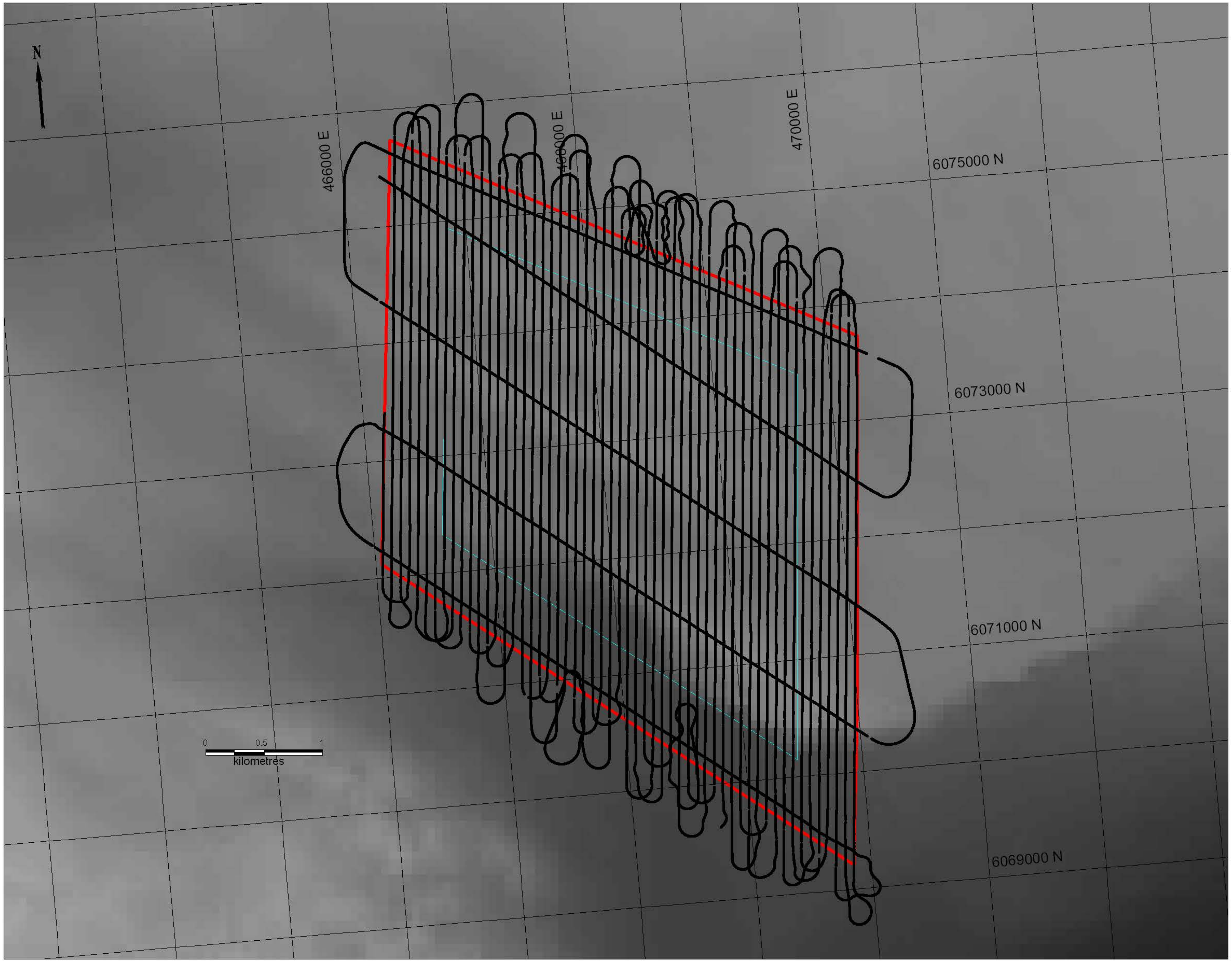
Extraction Area

Datum: WGS84 Projection: UTM zone 33

Client: FEMERN A/S

Draw: LHCR Approved: SLO

Map: Depth Map Rønne Banke



Seismic line

Impact Area

Extraction Area

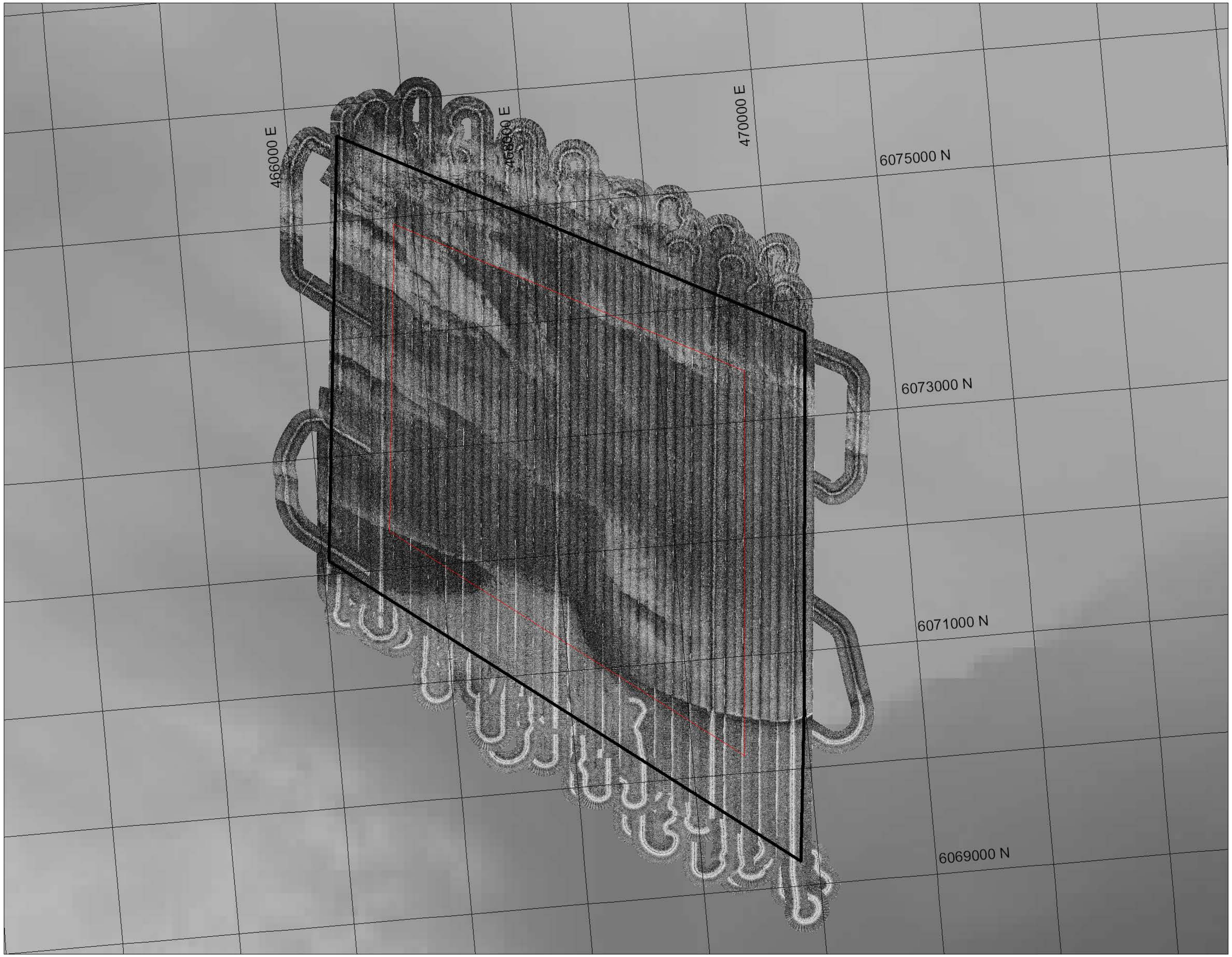
Datum: WGS84 Projection: UTM zone 33

Client: FEMERN A/S

GEUS

Draw: LHCR Approved: SLO

Map: Survey lines



Side Scan Mosaic

Impact Area

Extraction Area

Datum: WGS84 Projection: UTM zone 33

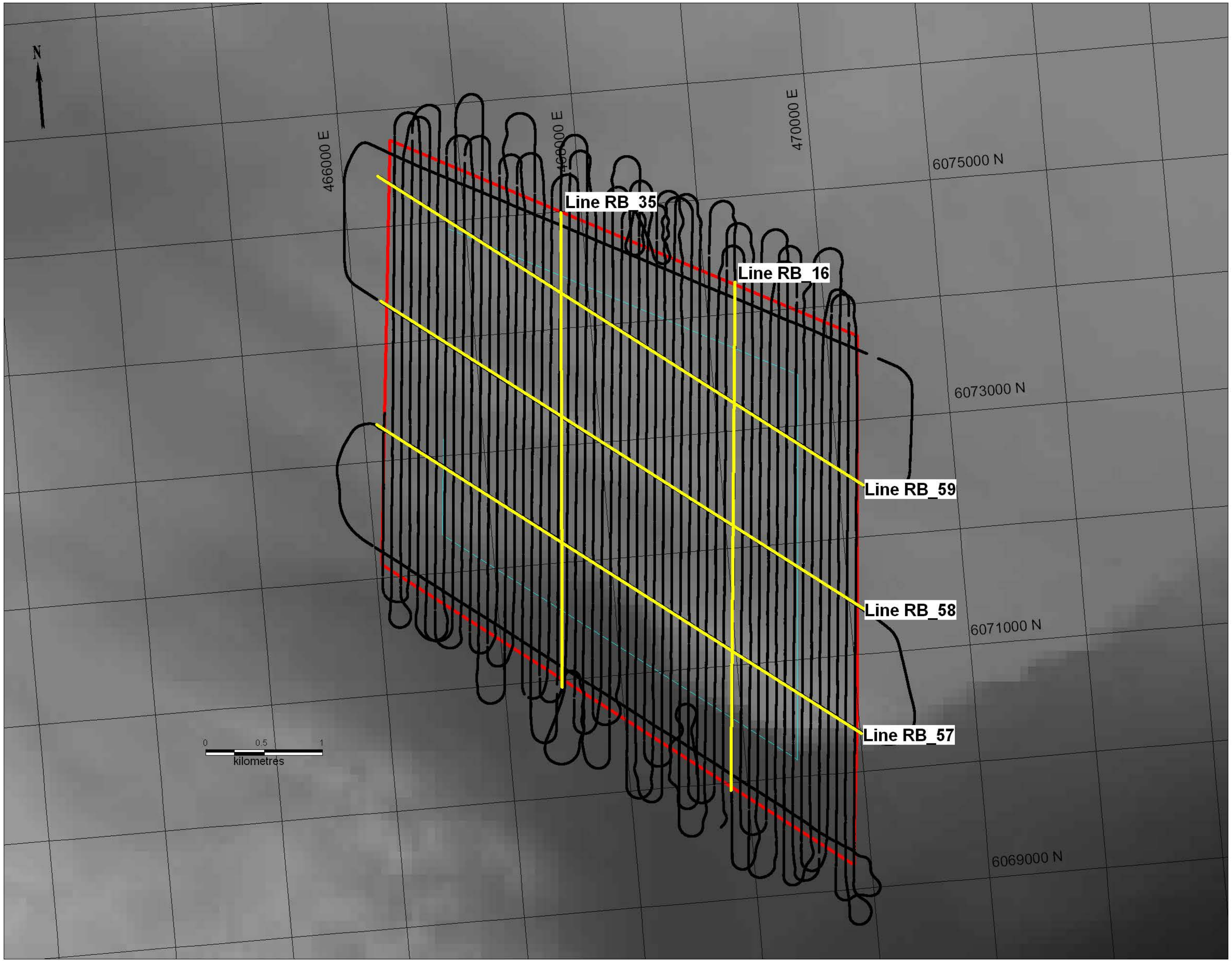
Client: FEMERN A/S

Femern Sund≈Bælt

GEUS

Draw: LHCR Approved: SLO

Map: Side Scan Mosaik Rønne Banke



Seismic line

Seismic example

Impact Area

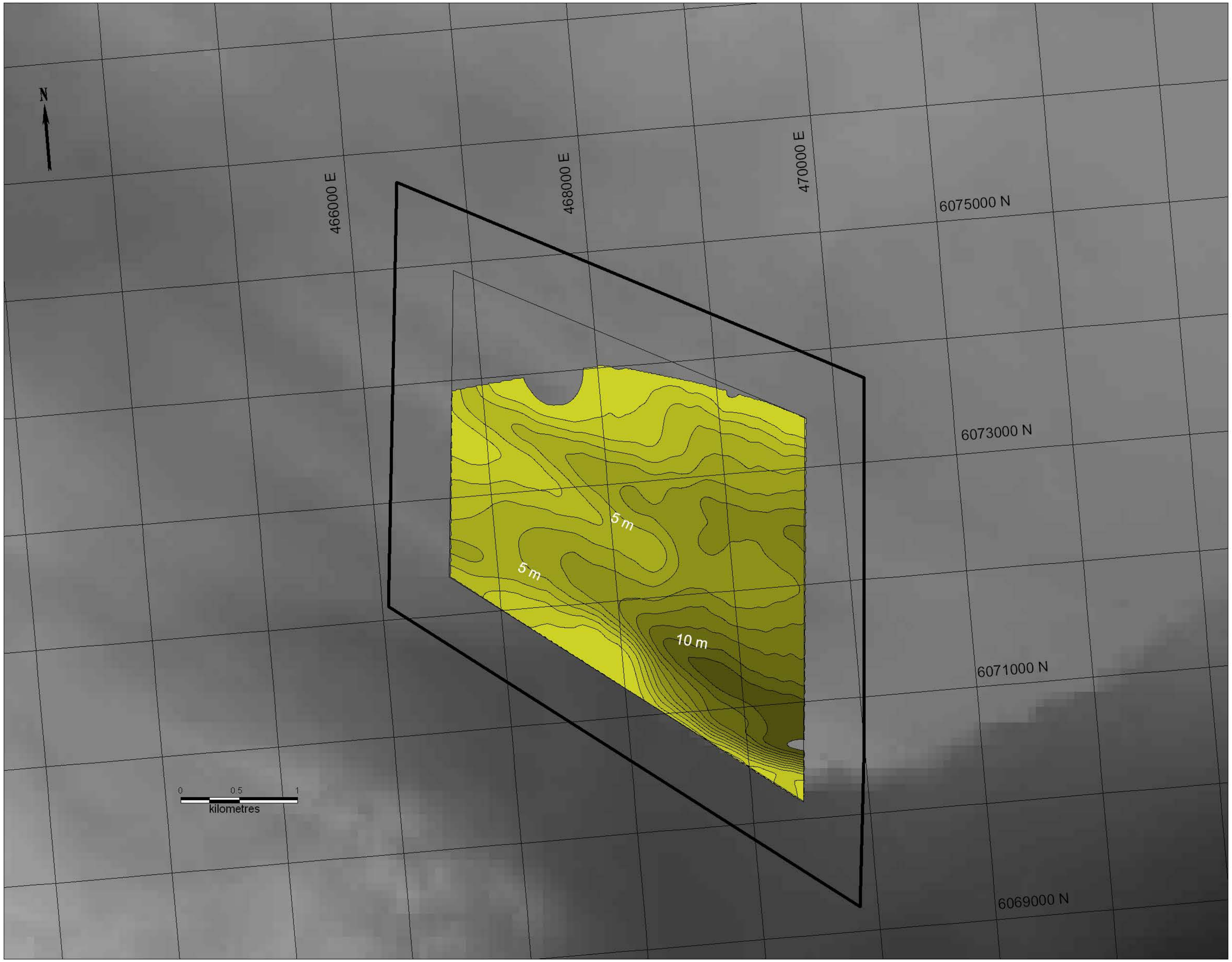
Extraction Area

Datum: WGS84 Projection: UTM zone 33

Client: FEMERN A/S

Draw: LHCR Approved: SLO

Map: Survey lines



isochore_contour in m

- 1 to 2
- 2 to 3
- 3 to 4
- 4 to 5
- 5 to 6
- 6 to 7
- 7 to 8
- 8 to 9
- 9 to 10
- 10 to 11
- 11 to 12

Impact Area

Extraction Area

Datum: WGS84 Projection: UTM zone 33

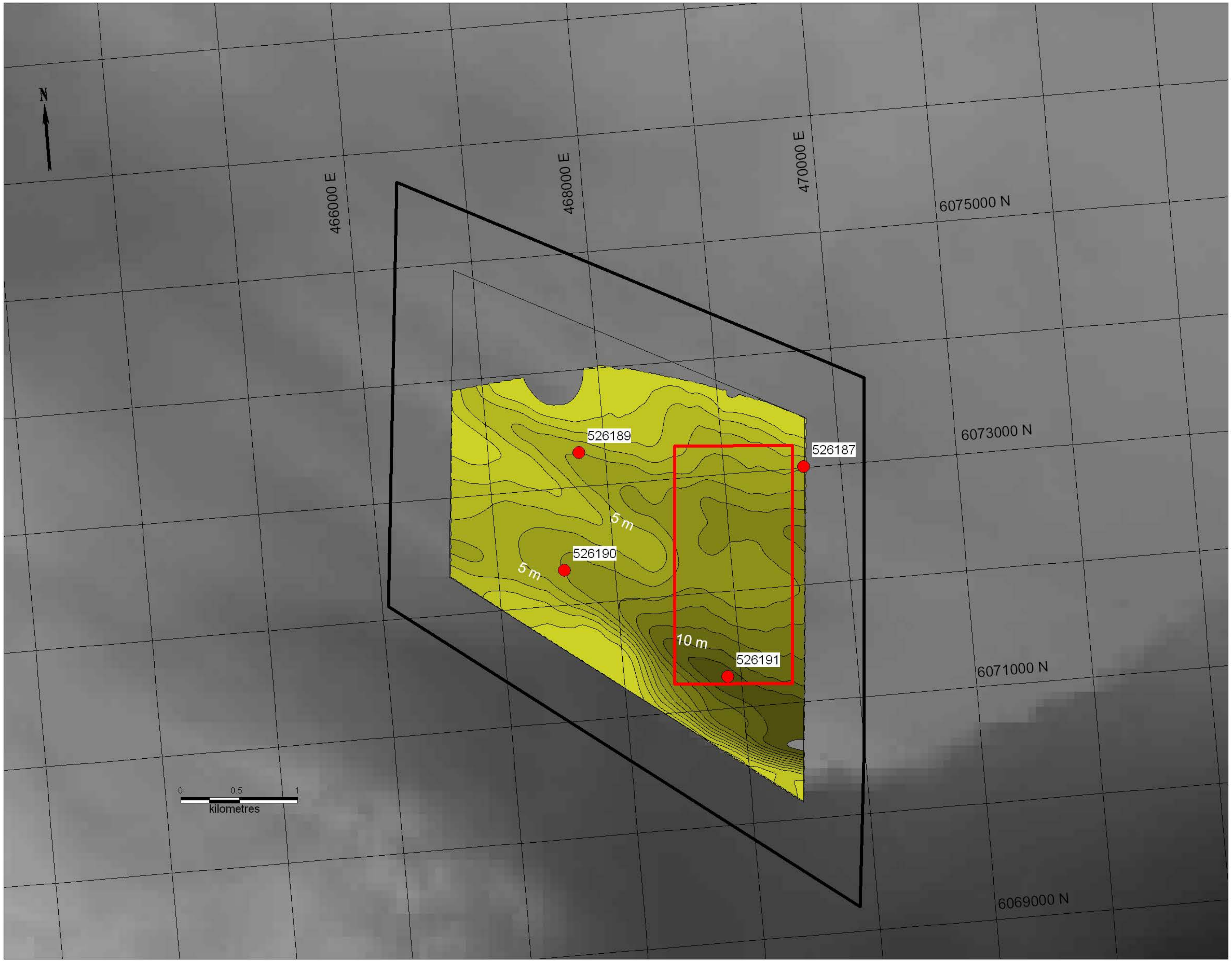
Client: FEMERN A/S

Femern Sund≈Bælt

GEUS

Draw: LHCR Approved: SLO

Map: Resource thickness Map Rønne Banke



Isochore_contour in m

1 to 2
2 to 3
3 to 4
4 to 5
5 to 6
6 to 7
7 to 8
8 to 9
9 to 10
10 to 11
11 to 12

526191 Core position

Proposed Area for Sand Extraction

Impact Area

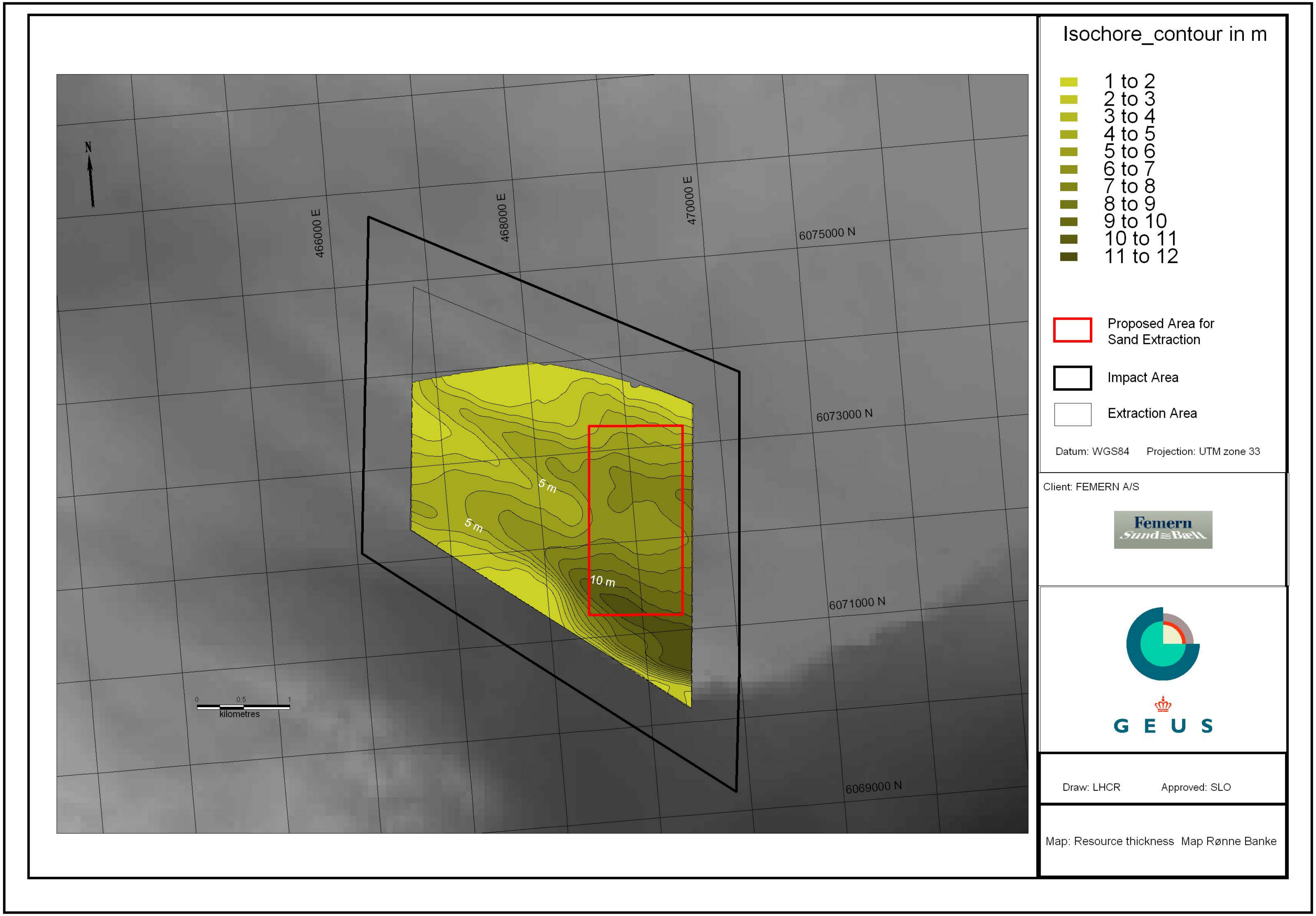
Extraction Area

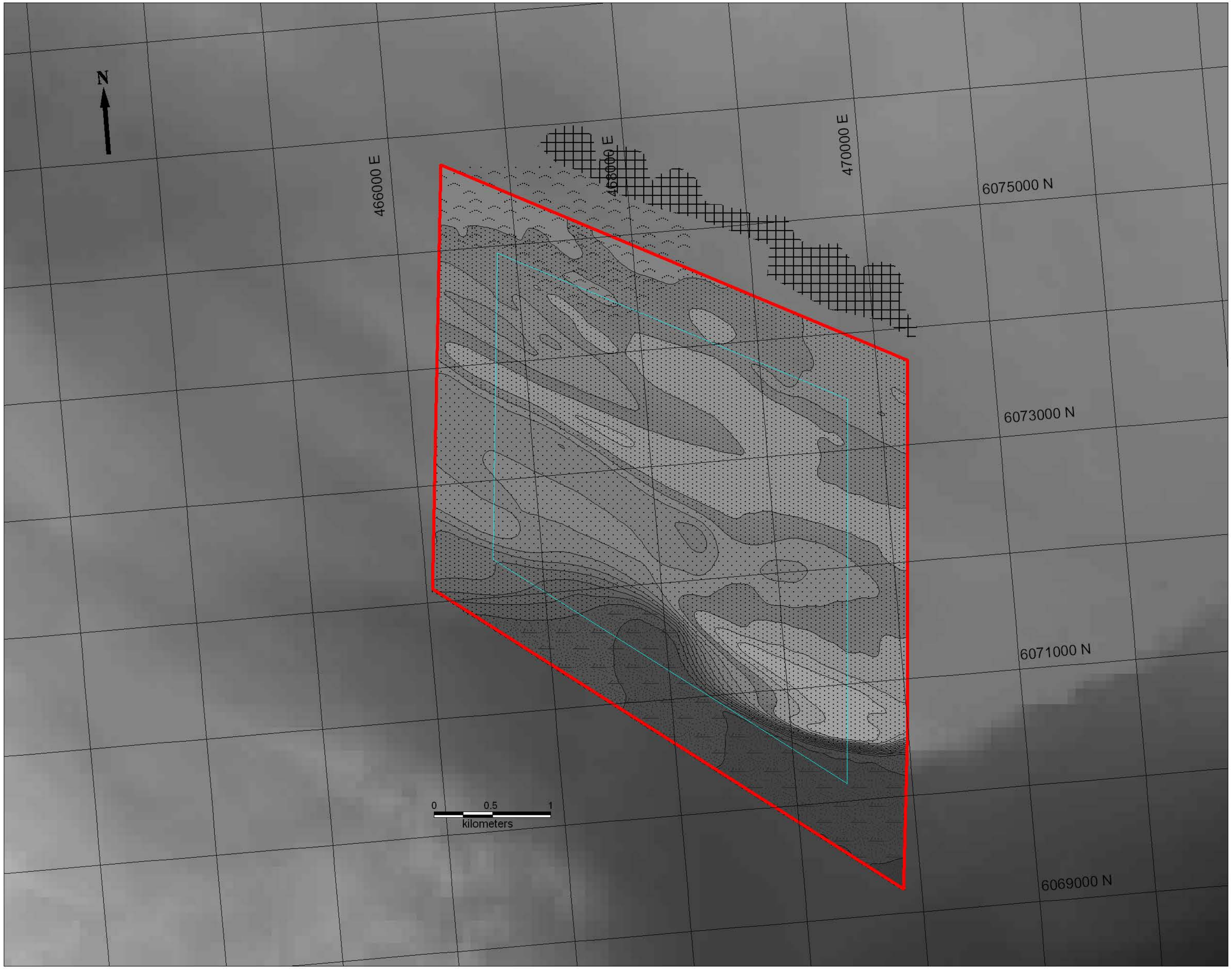
Datum: WGS84 Projection: UTM zone 33

Client: FEMERN A/S

Draw: LHCR Approved: SLO

Map: Resource thickness Map Rønne Banke


Isochore_contour in m
1 to 2
2 to 3
3 to 4
4 to 5
5 to 6
6 to 7
7 to 8
8 to 9
9 to 10
10 to 11
11 to 12
Proposed Area for Sand Extraction
Impact Area
Extraction Area
Datum: WGS84
Projection: UTM zone 33
Client: FEMERN A/S
Femern Sund≈Bælt
GEUS
Draw: LHCR
Approved: SLO
Map: Resource thickness Map Rønne Banke
N
466000 E
468000 E
470000 E
6075000 N
6073000 N
6071000 N
6069000 N
5 m
5 m
10 m
0
0.5
1
kilometres



Rønne_depth in m

-30 to -29
-29 to -28
-28 to -27
-27 to -26
-26 to -25
-25 to -24
-24 to -23
-23 to -22
-22 to -21
-21 to -20
-20 to -19
-19 to -18
-18 to -17
-17 to -16
-16 to -15

Impact Area

Extraction Area

Area disturbed by dredging

Late Glaciale fine grained sand and silt covered by a thin medium grained sand layer

Areas covered with Medium grain sand

Fine to medium grained Sand

Client: FEMERN A/S

Femern Sund≈Bælt

GEUS

Draw: LHCR

Approved: SLO

Map: Seabed sediment

A P P E N D I X   G

Petrographic analysis of 17 core samples

PELCON
Pelcon Materials & Testing ApS
Vandtårnsvej 104
DK-2860 Søborg, Danmark
+45 39 56 50 00
pelcon@pelcon.dk
www.pelcon.dk
CVR nr. 2797 0397

Prøvningsrapport

GEUS
Østervoldgade 10
1350 København K
Att.: Peter Steen Lomholt

Søborg, den 3. oktober 2011

Undersøgelse:	**Indhold af reaktive korn**
Metode:	TI-B 52: 1985
Materiale:	17 sandprøver (Modtaget 14.09.2011)
Prøve mrk.	1-17; se vedlagte liste (Rekvirentoplysning)
Udtagningssted:	Rønne banke (Rekvirentoplysning)
Rekvirent:	GEUS
Sags nr.:	11-181

Efter aftale med Peter Steen Lomholt, GEUS, har vi analyseret 17 modtagne sandprøver for indhold af alkalikiselreaktive korn i henhold til TI-B 52.

Analyseresultater er vedlagt.

Pelcon Materials & Testing ApS

Peter Laugesen
Seniorgeolog, Cand. scient

Prøvemærkning

Rønne Banke 2011 for Femern A/S				
NR	Prøve nr	Dybde	Boring nr	Årstal
1	526187-000-020	0.00-0.20	526187	1994
2	526187-080-100	0.80-1.00	526187	1994
3	526187-180-200	1.80-2.00	526187	1994
4	526189-000-020	0.00-0.20	526189	1994
5	526189-060-080	0.60-0.80	526189	1994
6	526189-140-160	1.40-1.60	526189	1994
7	526189-240-260	2.40-2.60	526189	1994
8	526189-340-360	3.40-3.60	526189	1994
9	526190-000-020	0.00-0.20	526190	1994
10	526190-050-070	0.50-0.70	526190	1994
11	526190-150-170	1.50-1.70	526190	1994
12	526190-250-270	2.50-2.70	526190	1994
13	526190-350-370	3.50-3.70	526190	1994
14	526191-000-020	0.00-0.20	526191	1994
15	526191-080-100	0.80-1.00	526191	1994
16	526191-180-200	1.80-2.00	526191	1994
17	526191-280-300	2.80-3.00	526191	1994

Bemærkninger:

Sandet i prøve nr. 3 fremstår lidt mørkt, som hvis det havde et humus-indhold. I så fald bør sandet testes for humus-indhold inden det foreslås anvendt til beton.

Indhold af reaktive korn (TI-B 52: 1985)

Udført: September-oktober 2011 af Peter Laugesen

Sags nr. 11-181

<table>
<tr><th>Prøve-mrk.</th><th>Fraktion
(mm)</th><th>Fraktions-andel
(g)</th><th>Fraktions-andel
(%)</th><th>Tyndslib</th><th>Total
(pkt.)</th><th>TCF
(%)</th><th>PCF
(%)</th><th>POF
(%)</th><th>Total porøs flint
(%)</th></tr>
<tr><td rowspan="5">1</td><td>0-2</td><td>1024,44</td><td>98,5</td><td>0-2</td><td>2977</td><td>0,00</td><td>0,03</td><td>0,07</td><td>0,1</td></tr>
<tr><td rowspan="2">2-4</td><td rowspan="2">16,1</td><td rowspan="2">1,5</td><td>2-4 A</td><td></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>2-4 B</td><td></td></tr>
<tr><td>0-4</td><td>1040,55</td><td>100,0</td><td colspan="2">(Note 1→)</td><td>0,0</td><td>0,0</td><td>0,1</td><td>0,1</td></tr>
<tr><td>>4</td><td>10,46</td><td colspan="7">(Note 2)</td></tr>
</table>

<table>
<tr><th>Prøve-mrk.</th><th>Fraktion
(mm)</th><th>Fraktions-andel
(g)</th><th>Fraktions-andel
(%)</th><th>Tyndslib</th><th>Total
(pkt.)</th><th>TCF
(%)</th><th>PCF
(%)</th><th>POF
(%)</th><th>Total porøs flint
(%)</th></tr>
<tr><td rowspan="5">2</td><td>0-2</td><td>1362,59</td><td>97,5</td><td>0-2</td><td>3198</td><td>0,00</td><td>0,00</td><td>0,00</td><td>0,0</td></tr>
<tr><td rowspan="2">2-4</td><td rowspan="2">34,8</td><td rowspan="2">2,5</td><td>2-4 A</td><td></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>2-4 B</td><td></td></tr>
<tr><td>0-4</td><td>1397,38</td><td>100,0</td><td colspan="2">(Note 1→)</td><td>0,0</td><td>0,0</td><td>0,0</td><td>0,0</td></tr>
<tr><td>>4</td><td>19,65</td><td colspan="7">(Note 2)</td></tr>
</table>

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(mm)</th><th>Fraktions-andel
(g)</th><th>Fraktions-andel
(%)</th><th>Tyndslib</th><th>Total
(pkt.)</th><th>TCF
(%)</th><th>PCF
(%)</th><th>POF
(%)</th><th>Total porøs flint
(%)</th></tr>
<tr><td rowspan="5">3</td><td>0-2</td><td>1058,11</td><td>99,7</td><td>0-2</td><td>3730</td><td>0,08</td><td>0,08</td><td>0,24</td><td>0,3</td></tr>
<tr><td rowspan="2">2-4</td><td rowspan="2">3,2</td><td rowspan="2">0,3</td><td>2-4 A</td><td></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>2-4 B</td><td></td></tr>
<tr><td>0-4</td><td>1061,28</td><td>100,0</td><td colspan="2">(Note 1→)</td><td>0,1</td><td>0,1</td><td>0,2</td><td>0,3</td></tr>
<tr><td>>4</td><td>0,00</td><td colspan="7">(Note 2)</td></tr>
</table>

Forklaring:

TCF: Tæt chalcedon flint.
PCF: Porøs chalcedon flint.
POF: Porøs opal flint.
Note 1: *Fraktionsandelene er indregnet i det samlede indhold i 0-4mm.*

Note 2: *Overkorn (>4mm) indgår ikke i analysen.*

Indhold af reaktive korn (TI-B 52: 1985)

Udført: September-oktober 2011 af Peter Laugesen

Sags nr. 11-181

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
4	0-2	659,96	98,8	0-2	3292	0,00	0,00	0,00	0,0
	2-4	7,7	1,2	2-4 A					
				2-4 B					
	0-4	**667,66**	**100,0**		(Note 1→)	0,0	0,0	0,0	**0,0**
	>4	1,70	*(Note 2)*						

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
5	0-2	1188,07	92,8	0-2	3008	0,07	0,07	0,00	0,1
	2-4	92,3	7,2	2-4 A	2071	1,2	0,32	0,00	0,3
				2-4 B	2016				
	0-4	**1280,36**	**100,0**		(Note 1→)	0,1	0,1	0,0	**0,1**
	>4	16,31	*(Note 2)*						

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
6	0-2	1067,96	94,2	0-2	3071	0,07	0,00	0,00	0,0
	2-4	66,0	5,8	2-4 A	2339	0,4	0,96	0,21	1,2
				2-4 B	2343				
	0-4	**1133,91**	**100,0**		(Note 1→)	0,1	0,1	0,0	**0,1**
	>4	9,57	*(Note 2)*						

Forklaring:

TCF: Tæt chalcedon flint.
PCF: Porøs chalcedon flint.
POF: Porøs opal flint.

Note 1: *Fraktionsandelene er indregnet i det samlede indhold i 0-4mm.*
Note 2: *Overkorn (>4mm) indgår ikke i analysen.*

Indhold af reaktive korn (TI-B 52: 1985)

Udført: September-oktober 2011 af Peter Laugesen

Sags nr. 11-181

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
7	0-2	1153,24	99,0	0-2	3064	0,13	0,07	0,00	0,1
	2-4	12,1	1,0	2-4 A					
				2-4 B					
	0-4	**1165,29**	**100,0**	(Note 1→)		0,1	0,1	0,0	**0,1**
	>4	6,26	*(Note 2)*						

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
8	0-2	1243,92	99,5	0-2	3028	0,07	0,00	0,00	0,0
	2-4	6,8	0,5	2-4 A					
				2-4 B					
	0-4	**1250,69**	**100,0**	(Note 1→)		0,1	0,0	0,0	**0,0**
	>4	5,99	*(Note 2)*						

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
9	0-2	1121,89	99,3	0-2	3430	0,03	0,06	0,00	0,1
	2-4	7,5	0,7	2-4 A					
				2-4 B					
	0-4	**1129,35**	**100,0**	(Note 1→)		0,0	0,1	0,0	**0,1**
	>4	1,43	*(Note 2)*						

Forklaring:

TCF: Tæt chalcedon flint.
PCF: Porøs chalcedon flint.
POF: Porøs opal flint.

Note 1: *Fraktionsandelene er indregnet i det samlede indhold i 0-4mm.*
Note 2: *Overkorn (>4mm) indgår ikke i analysen.*

Indhold af reaktive korn (TI-B 52: 1985)

Udført: September-oktober 2011 af Peter Laugesen

Sags nr. 11-181

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
10	0-2	1120,15	97,0	0-2	3581	0,03	0,00	0,00	0,0
	2-4	35,2	3,0	2-4 A					
				2-4 B					
	0-4	**1155,36**	**100,0**	(Note 1→)		0,0	0,0	0,0	**0,0**
	>4	2,57	*(Note 2)*						

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
11	0-2	1376,23	93,0	0-2	3170	0,09	0,00	0,00	0,0
	2-4	103,6	7,0	2-4 A	2460	1,4	0,08	0,00	0,1
				2-4 B	2249				
	0-4	**1479,80**	**100,0**	(Note 1→)		0,2	0,0	0,0	**0,0**
	>4	41,82	*(Note 2)*						

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
12	0-2	1201,47	96,8	0-2	3720	0,11	0,00	0,00	0,0
	2-4	39,4	3,2	2-4 A					
				2-4 B					
	0-4	**1240,84**	**100,0**	(Note 1→)		0,1	0,0	0,0	**0,0**
	>4	8,43	*(Note 2)*						

Forklaring:

TCF: Tæt chalcedon flint.
PCF: Porøs chalcedon flint.
POF: Porøs opal flint.

Note 1: *Fraktionsandelene er indregnet i det samlede indhold i 0-4mm.*
Note 2: *Overkorn (>4mm) indgår ikke i analysen.*

Indhold af reaktive korn (TI-B 52: 1985)

Udført: September-oktober 2011 af Peter Laugesen

Sags nr. 11-181

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
13	0-2	1405,33	97,0	0-2	3573	0,08	0,00	0,03	0,0
	2-4	43,3	3,0	2-4 A					
				2-4 B					
	0-4	**1448,63**	**100,0**		(Note 1→)	0,1	0,0	0,0	**0,0**
	>4	40,95	*(Note 2)*						

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
14	0-2	1359,79	92,6	0-2	3506	0,00	0,00	0,00	0,0
	2-4	109,1	7,4	2-4 A	2133				
				2-4 B	1950				
	0-4	**1468,84**	**100,0**		(Note 1→)	0,0	0,0	0,0	**0,0**
	>4	52,12	*(Note 2)*						

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
15	0-2	1162,90	93,0	0-2	3256	0,15	0,00	0,00	0,0
	2-4	87,6	7,0	2-4 A					
				2-4 B					
	0-4	**1250,47**	**100,0**		(Note 1→)	0,1	0,0	0,0	**0,0**
	>4	24,59	*(Note 2)*						

Forklaring:

TCF: Tæt chalcedon flint.
PCF: Porøs chalcedon flint.
POF: Porøs opal flint.

Note 1: *Fraktionsandelene er indregnet i det samlede indhold i 0-4mm.*
Note 2: *Overkorn (>4mm) indgår ikke i analysen.*

Indhold af reaktive korn (TI-B 52: 1985)

Udført: September-oktober 2011 af Peter Laugesen

Sags nr. 11-181

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
16	0-2	1217,22	93,7	0-2	3558	0,20	0,06	0,00	0,1
	2-4	82,5	6,3	2-4 A	2499	0,5	0,63	0,00	0,6
				2-4 B	2571				
	0-4	**1299,75**	**100,0**		(Note 1→)	0,2	0,1	0,0	**0,1**
	>4	19,65	*(Note 2)*						

Prøve-mrk.	Fraktion (mm)	Fraktions-andel (g)	Fraktions-andel (%)	Tyndslib	Total (pkt.)	TCF (%)	PCF (%)	POF (%)	Total porøs flint (%)
17	0-2	1107,61	99,6	0-2	2965	0,03	0,03	0,00	0,0
	2-4	4,7	0,4	2-4 A					
				2-4 B					
	0-4	**1112,27**	**100,0**		(Note 1→)	0,0	0,0	0,0	**0,0**
	>4	1,19	*(Note 2)*						

Forklaring:

TCF: Tæt chalcedon flint.
PCF: Porøs chalcedon flint.
POF: Porøs opal flint.

Note 1: Fraktionsandelene er indregnet i det samlede indhold i 0-4mm.
Note 2: Overkorn (>4mm) indgår ikke i analysen.