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List of Abbreviations

AFDW  Ash free dry weight
BSH  Bundesamt für Seeschifffahrt und Hydrographie
CCTV  Closed Circuit Television
C-POD  Autonomous porpoise click detector
DCE  Danish Centre for Environment and Energy (formerly DMU – Danmarks Miljøundersøgelser or in English NERI – National Environmental Research Institute)
DDT  Dichlorodiphenyltrichloroethane
DIN  Dissolved inorganic nitrogen
DMI  Danish Meteorological Institute
DW  Dry weight
EEZ  European Economic Zone
EIA  Environmental Impact Assessment
EU  European Union
GHG  Greenhouse Gases
ICES  International Council for Exploration of the Sea
IMT  Immersed Tunnel
IPCC  Intergovernmental Panel on Climate Change
ITS  Intelligent Transportation System
$L_{aw}$  KB weighted acceleration vibration level
$L_{Aeq,Xh}$  A-weighted equivalent noise within 8 hours during day, 1 hour in the evening and ½ hour during night
$L_{Amax}$  A-weighted maximum noise level (fast)
$L_{den}$  A-weighted day, evening, night noise
$L_{pA,LF}$  Low frequency noise (10 – 160 Hz)
$L_{pG}$  Infra-noise (5 – 20 Hz)
LED  Light Emitting Diodes
LBP  Landschaftspflegerischer Begleitplan (German Landscape Conservation Plan)
LOI  Loss on Ignition
MSL  Mean Sea Level
PAH  Polycyclic Aromatic Hydrocarbons
PCB  Poly-chlorinated Biphenyls
psu  Practical salinity units
PTS  Permanent threshold shift
ROV  Remotely Operated Vehicle
RPM  Revolutions per minute
SCADA  Supervisory Control and Data Acquisition System
SCI  Site of Community Interest
SD  Standard Deviation
SEL  Sound exposure level
SPA  Special Protection Areas
SPL  Sound pressure level
SSC  Suspended sediment concentration
STP  Slurry Treatment Plant
TBM  Tunnel Boring Machine
TBT  Tributyltin
TTS  Temporary threshold shift
UN   United Nations
UVS  Umweltverträglichkeitsstudie (German EIA)
VMS  Vessel Monitoring System
VTS  Vessel Traffic Service
1 Executive Summary

1.1 Introduction

On 3 September 2008 Denmark and Germany signed the State Treaty to establish a fixed link across the Fehmarnbelt. The State Treaty was adopted by the national Parliaments and ratified by the two countries in 2009. The objective of the link is primarily to improve conditions for the transport of passengers and goods between Scandinavia and continental Europe, see Figure 1.1.

The Fehmarnbelt Fixed Link is planned as a combined rail and motorway link with a double-track electrified railway and a four-lane motorway. The 19 km link will run from Rødbyhavn on the Danish side of the Fehmarnbelt to Puttgarden on the island of Fehmarn on the German side.

Denmark is responsible for the planning and design as well as financing, construction and operation of the Fehmarnbelt Fixed Link. The capital, operation and maintenance costs will be recovered through a toll system. Under the provisions of the State Treaty, each country is responsible for the approval of the fixed link in their own territory as well as upgrading of their hinterland infrastructure.

The feasibility studies identified an immersed tunnel and a cable-stayed bridge as the two technical solutions for the link to be studied further. After a conceptual design phase was carried out, Femern A/S selected the immersed tunnel as the preferred solution and the cable stayed bridge as the preferred alternative. The Environmental Impact Assessment (EIA) for the project has investigated both solutions.

Femern A/S decided to conduct an environmental impact assessment of the bored tunnel as it could be an alternative technical solution.

The EIA for the bored tunnel is the subject of this report. The impacts are compared with those of the immersed tunnel to illustrate the environmental advantages and disadvantages of the two solutions, not only with respect to Natura 2000 areas, but also for the project as a whole.
The elaboration of the bored tunnel impact assessment is based on input from the environment consortia FEHY, FEMA, FeBEC, FEBI, FEMM, TGP and COWI who took departure in the immersed tunnel impact assessment (Level 2 reports). When differences were identified an assessment was carried out for the TBM and submitted to TGP and COWI. Based on this input TGP edited and incorporated the assessment in the German UVS, whereupon COWI edited this report.

In some of the assessment chapters deviations between area numbers (ha, m²) can be found, as each environmental component is assessed from a worst case consideration and by use of the area-delimitation which best describes the impact’s extent towards a specific environmental factor. E.g. the assessment of the project’s impact on protected nature on Lolland assumes that the reclamation area goes all the way to the crest of the dyke. However, the assessment of the marine impact in general takes departure in the coastline. There are also deviations regarding the coastline in that the coast can be considered as a coastal zone that stretches to both sides of 0 m DNN and where the border towards the seabed usually is by -6 m DNN.

In all background reports, the time for start of construction is tentatively set to 13 October 2014 for the tunnel and 1 January 2015 for the bridge. However, the actual period for the construction work is not fixed. In the VVM and UVS/LBP, the
terminology is therefore “year 0” (equivalent to year 2014 in the background reports), “year 1”, etc.

1.2  The bored tunnel project

1.2.1  Alignment and major features

The proposed horizontal alignment of the bored tunnel is shown in Figure 1.2. The railway tube is on the eastern side of the two road tubes.

The major features of the bored tunnel solution include:

› Three circular tunnels, each approximately 20 km in length - one tunnel for both railway lines and two tunnels for the motorway, each with two lanes and an emergency lane, see Figure 1.3.
› Cut and cover tunnels at each portal linking the tunnel to the surface.
› Open road and railway ramps that connect to the cut and cover tunnel sections.
› Portal structures and buildings at the entrances to the tunnels.
› Roads and railway lines on land on both sides connecting the respective tunnels to the existing networks.
› Land reclamation areas at both coasts (the majority off the coast of Lolland) for deposition of the materials excavated by the tunnel boring machines.
› Payment systems and facilities for customs and immigration authorities in Denmark and Germany.
› Facilities for operation and maintenance, including support for emergency response services in both Denmark and Germany.
› Modifications of the surrounding secondary road network.
Figure 1.2 Proposed alignment of the bored tunnel

Figure 1.3 Illustration of the three tunnel tubes
The vertical profile of the tunnel is shown in Figure 1.4 along with the geological profile. The tunnels will be bored mainly through glacial till and soft clays. Three tunnel boring machines (TBMs) will operate from the Lolland side and three from the Fehmarn side. The total in-situ volume of bored soil is about 11.7 million m$^3$.

1.2.2 Reclamation areas

Reclamation areas are planned along both the German and Danish coastlines to accommodate the material excavated by the TBMs. The areas will be landscaped into green areas.

The material excavated by the TBMs is slurry which will be dewatered before being deposited in the reclamations. More than 36% of the material will still have a high water content and will resemble thick mud even after the dewatering. Such material will normally take in the order of 4 to 15 years to consolidate to the stage where it can be accessed by people and machines to develop the green areas, depending on the effectiveness of the dewatering and management of the maturing soil. However, it is expected that a technical solution can be found to ensure that the reclamations are ready for development at the end of construction.

The extent of the reclamation area on Lolland is located on either side of the existing harbour, see Figure 1.5. The reclamation area extends approximately 3.7 km east and 3.5 km west of the harbour and reaches approximately 500 m into the Fehmarnbelt.

The total area is approximately 330 ha, with approximately 130 ha west of the harbour and approximately 200 ha east of the harbour.
The extent of the Fehmarn reclamation is shown in Figure 1.6. The reclamation area is designed as an extension of the existing terrain with the natural hill turning into a plateau behind a dike. The shape of the dike is designed to include a new beach close to the residential areas at Marienleuchte. It is intended that the new land is to be landscaped to create an enclosed pasture and grassland habitat.
1.2.3 Land works

A number of infrastructure improvements will be made on land in both Denmark and Germany, including the construction of a new motorway and railway to access the tunnels. An overview of the works on Lolland is shown in Figure 1.7.

The location of the portals is governed by the need for tunnels to be covered by soil with a depth of at least one tunnel diameter in order to ensure stability of the tunnel structure. Where the tunnels approach the land surface they must be covered with additional soil in the form of an embankment to give the required depth of soil and weight over the tunnel. The result is that the portals are situated inland from the coast and not in the reclamation area as is the case for the immersed tunnel. Due to the gentle gradients required for the railway, the rail portal is further inland than the road portal.

A dike will be constructed around the portals to prevent flooding of the tunnels.

The land works include a toll plaza, customs facilities and administration, operation and maintenance buildings.

An overview of the land works on Fehmarn is shown in Figure 1.8. A number of new roads, bridges and underpasses are required to merge the new motorway and railway with the existing infrastructure. The tunnel portals here are also inland from the existing coastline.
Figure 1.7  Land works on Lolland
Figure 1.8  Land works on Fehmarn
1.2.4 Construction facilities

Construction sites with areas of 70-80 ha are required on both Lolland and Fehmarn along with temporary work harbours. The construction sites will contain facilities for support of the TBMs, production of the concrete tunnel lining segments, the plant for dewatering of the slurry produced by the TBMs, concrete batching plants and other equipment and facilities for the construction of the portals, ramps and other infrastructure. The work harbours are principally for the import of construction materials. The greater part of the dewatered slurry produced on the Fehmarn side will be loaded onto barges and transported to the Lolland reclamation.

Two work harbours are required on Lolland, one east and one west of Rødbyhavn. The harbour east of Rødbyhavn and the construction site on Lolland are illustrated in Figure 1.9. The figure also indicates the procedure for filling of the reclamation.

Similarly, the work harbour, construction site and land reclamation on Fehmarn are illustrated in Figure 1.10.

Figure 1.9 Eastern Lolland work harbour and construction site
1.2.5 Construction schedule

The construction time schedule assumes that the bored tunnel project will be split into contracts, all of which involve design and construction. The current time schedule remains provisional and will be developed by the contractors. The overall goal would be to complete the project within a time frame of approximately 8 years, commencing when the first contract is signed.

1.3 Marine environment

1.3.1 Hydrography

Hydrography concerns the parameters water levels, waves, currents, salinity, temperature, stratification and the exchange of water and salt with the Baltic Sea. The marine structures of the bored tunnel project in the form of the reclamations at the Lolland and Fehmarn coasts, the work harbours and the access channels to the harbours may affect the hydrographic conditions.

The assessment studies were made through the extensive use of numerical models and showed that none of the potential impacts are significant. There are either no impacts or negligible impacts on water levels, salinity, temperature and stratification. There are small, local changes to currents and waves in the immediate vicinity of the reclamations and access channels but these are also assessed to be insignificant. The current speeds at the ferry harbour entrances will either be reduced or are not changed so that there is no adverse impact on ferry operations.
Of particular importance is the fact that the exchange of water and salt between the North Sea and the Baltic Sea across the Darss Sill is not affected so that there is no impact on the hydrography or the ecosystem of the Baltic Sea.

1.3.2 Water quality
The impact of the project on water turbidity and on concentrations of nutrients, toxic substances, dissolved oxygen and bacteria has been assessed. The major pressure on the water quality occurs during the construction phase with the spill of fine sediments during dredging of the work harbours and access channels and during the filling of the reclamations. Other potential pressures are the release of nutrients, toxic substances and organic material from the fine sediment spill and waste water discharges.

The sediment spill will temporarily increase the turbidity and reduce the transparency (Secchi depth) by up to 20% in an area of 9,000 ha near the Lolland coast and in Rødsand Lagoon during the most intensive dredging activity in the first six months. The reduction of Secchi depths at other times, and at all times near the coast of Fehmarn, is negligible.

Laboratory analyses of seabed sediments showed that the content of nutrients and toxic substances (heavy metals, PAH, PCB, DDT, TBT) was very low and generally far below the Danish, German and EU standards. There will be negligible impacts on the marine ecosystem.

The oxidation of the organic content of the sediment spill is estimated to be 93kg O₂/day during dredging. This is negligible compared with the amount of dissolved oxygen in the waters in the local dredging areas. Local depressions on the O₂ levels may occur immediately around the dredger, but the concentrations will not fall below the critical level of 4 mg/l.

In summary, the impacts on water quality are insignificant or negligible.

1.3.3 Seabed morphology
The structure of the seabed in Fehmarnbelt varies according to the underlying geology, the lose sediments on the surface, the water depth and the current and wave conditions. The seabed is divided into four types: sand waves, lunate bed forms (crescent shaped dunes like in a sandy desert), other active bed forms (e.g. ribbons) and areas without bed forms. On the Danish side, some areas with bed forms are used for sand mining and other areas for disposal of dredged material. On the German side, sand waves are part of the conservation objectives for the German “Fehmarnbelt” and “Sea area of the eastern Kiel Bight” Natura 2000 areas.

The re clamations and access channels of the bored tunnel project impact only areas without bed forms. An area of 353 ha will be covered permanently by the re clamations and represents 0.9% of the total area of such seabed within 10 km of the alignment. The impact is insignificant.
The work harbours on Lolland and Fehmarn, all work harbour breakwaters and all access channels temporarily impact 68 ha of seabed without bed forms, also an insignificant impact. The work harbour on Fehmarn will be filled after end construction and the breakwaters removed and the seabed reinstated. The access channels will fill naturally over a period of up to 12 years.

The German “Fehmarnbelt” and “Sea area of the eastern Kiel Bight” Natura 2000 areas will not be affected at all, neither will any other area with active bed forms.

1.3.4 Coastal morphology
The coasts of Lolland and Fehmarn within 10 km of the project sites consist of beaches and unprotected shorelines, alongshore coastal protection such as revetments, individual coastal structures such as groynes and the harbours at Rødbyhavn and Puttgarden and the special morphological features of Hyllekrog and Grüner Brink.

On Lolland the reclamations will cover 3.2 km of beaches and 4.3 km of revetment. However, new, compensatory beaches will be established along the edges of the reclamation and the covering of the revetments will not endanger the coast since there will be new revetments along the reclamation. The new beach at the western end of the reclamation will be ready for use in the summer of 2016 so that only one bathing season (2015) will be lost. The other beaches will be ready at the end of the construction period.

5 km of the shore eastward of the reclamation from Hyldtofte Østersøbad to Brunddragene will be subject to significant erosion due to the interruption of the littoral drift by the reclamation. This erosion will be fully mitigated by beach nourishment with 19,000 m³/year of sand. Distribution of nourishment along the coast may be required. Hyllekrog will not be affected by the project.

The reclamations will also cover a number of outlets from pumping stations and a wastewater outfall on Lolland and these will be reconstructed by the project.

The reclamation on Fehmarn will remove 700 m of beach, but, as on Lolland, a new beach will be established on the edge of the reclamation. The beach will be ready at the end of the construction period. There is a small risk of erosion occurring southeast of the reclamation, and this will be monitored and mitigated if necessary. Grüner Brink will not be impacted by the project.

In summary, the impacts on coastal morphology are insignificant provided that the planned mitigation measures are implemented.

1.3.5 Plankton and jellyfish
One potential impact of the project on plankton and jellyfish would be the increase of suspended sediments due to sediment spill, which affects light availability, phytoplanckton production and associated effects on zooplankton due to lower food availability. However, since these effects were assessed as insignificant for the
immersed tunnel, where the sediment spill was about 8 times larger than for the bored tunnel, impacts on plankton will be insignificant. The second potential impact would be due to the release of nutrients from the fine sediments spilled during dredging. An increase in nutrients in the water could lead to an increase in plankton biomass and the level of eutrophication. However, since the release of nutrients from the sediment spill is negligible, there will be insignificant impacts on plankton and jellyfish.

1.3.6 Benthic flora

Benthic flora is found in Fehmarnbelt generally in depths of less than 20 m. Near the Lolland coast the vegetation communities are mainly eelgrass in Rødsand Lagoon and *Furcellaria* and filamentous algae along the open coast. Around Fehmarn there is *Phycodrys/Delesseria* and *Saccharina* in the waters southeast of Puttgarden, eelgrass in Orth Bight on the southern side of the island and *Fucus* in restricted areas of the west coast.

The project pressures affecting benthic vegetation are the footprint (reclamations etc.) suspended sediment, sedimentation, additional solid substrate and changes in coastal morphology.

The reclamations and access channels will remove about 205 ha of *Furcellaria*, 12 ha of filamentous algae, and 34 ha of low coverage (<10%) vegetation at the Lolland side. On the Fehmarn side the loss due to the footprint is much less with only 4 ha of filamentous algae being covered. The permanent loss of *Furcellaria* at the Lolland coast is considered significant.

Suspended sediment due to sediment spill can cause a reduction of growth rates of benthic vegetation due to reduced light intensity at the seabed. During the most intense dredging activities at the Lolland coast 567 ha of *Furcellaria* are affected, but only 56 ha of these to a medium degree. Corresponding figures for filamentous algae are 148 ha and 1 ha respectively. The biomass of macroalgae will be temporarily reduced by 0 to 30% depending on location. The impacts on macroalgae at the Fehmarn coast are negligible.

578 ha of eelgrass in Rødsand Lagoon are affected by suspended sediment, but only 4 ha to a medium degree. The expected temporary reduction of biomass is 0 to 30% at the end of the first growth season.

Overall, the impacts on benthic flora due to suspended sediment are not significant due to the relatively fast recovery of macroalgae and eelgrass within 2 years after the construction period.

Sedimentation of the spilled sediment may affect smaller areas of macroalgae at the Lolland coast only, and the impact is assessed to be insignificant.

The new protective revetments around the reclamations provide additional substrate for macroalgae growth. However, the part of the new hard substrate that is suitable for macroalgae growth is only 0.3% of the existing solid substrate within
the local zone (± 10 km) and will not change the functioning of the ecosystem. Similarly, changes to the coastal morphology will not cause significant changes to the conditions for growth of benthic vegetation.

1.3.7 Benthic fauna

The benthic fauna of Fehmarnbelt have been categorised into nine in- and epifauna communities, named after the main characteristic species of the community:

- **Arctica**: a large marine bivalve mollusc living in the sediment
- **Bathyporeia**: a sand digging shrimp
- **Cerastoderma**: the common cockle, a sediment living saltwater clam
- **Corbula**: also called European clam
- **Dendrodoa**: the sea squirt
- **Gammarus**: an amphipod crustacean
- **Mytilus**: blue mussel
- **Rissoa**: a minute sea snail
- **Tanaissus**: a marine cheliped

The project pressures affecting benthic fauna are the footprint (reclamations etc.) suspended sediment, sedimentation and additional solid substrate.

The project footprint causes the permanent loss of 216 ha of the Mytilus, 115 ha of Bathyporeia, 57 ha of Gammarus and 37 ha of Cerastoderma communities, corresponding to 0.7%, 0.7%, 0.1% and 0.3% respectively of the total community areas in the study area between Great Belt and Gedser. The impacts are classified as insignificant since the low percentages indicate a negligible effect on the ecosystem.

Suspended sediment concentrations from the dredging activities are low and of limited duration, and therefore will not impact benthic fauna directly. The suspended sediment will temporarily reduce phytoplankton biomass (measured as chlorophyll $a$) which is the primary food source for mussels. The mussel biomass is expected to be reduced by 0.5 g/m$^2$. This is assessed to be below the threshold value and within the range of natural variability, and therefore insignificant.

Sedimentation will temporarily affect areas of the Cerastoderma, Gammarus and Mytilus communities. The impacted area corresponds to 0.5% of the assessment area (292,688 ha for the fauna). The total loss of these communities in the local zone corresponds to less than 1% of the communities, which is regarded as insignificant. As with benthic flora, the area of new hard substrate is insignificant compared to the total area available and will not change the functioning of the ecosystem.

1.3.8 Fish ecology

Fehmarnbelt is an important passage way for migrating cod, herring and silver eel and is a spawning area for a number of fish species including cod and flatfish.
During the construction phase changes in the suspended sediment concentrations due to sediment spill, sedimentation, noise and vibration due to construction works and temporary seabed reclamation (Fehmarn work harbour and all work harbour breakwaters) can potentially impact the fish fauna causing avoidance behaviour and mortality.

Sediment spill impacts are considered insignificant since the concentration levels of suspended sediments of 2 mg/l at the surface and 10 mg/l at the seabed are exceeded less than 10% of the time. Sedimentation can bury fish eggs, but the magnitude of the sedimentation is so low and the areas affected so small that there will be no impacts on fish recruitment. The vibrations from the Tunnel Boring Machine (TBM) are assessed to be comfortably less than the threshold level for avoidance behaviour by fish. Impacts due to noise and vibrations from pile driving at the work harbours will be very local and limited in duration, and are considered insignificant for fish.

The permanent loss of sea bed by reclamation is identical to the loss caused by reclamation in the immersed tunnel project. The areas are insignificant compared to the total areas used for spawning, feeding and nursery in the Fehmarnbelt.

Other pressures which are assessed are: reduction of food supply, artificial light, spill of hazardous materials and electromagnetic fields. None of these are assessed to be of any significance to the fish populations.

In summary the establishment and operation of a bored tunnel will only result in insignificant effects on the fish communities and fish migration in Fehmarnbelt.

1.3.9 Marine mammals

In the Fehmarnbelt area, three species of marine mammals occur regularly: the harbour porpoise, *Phocoena phocoena*, the harbour seal, *Phoca vitulina*, and the grey seal, *Halichoerus grypus*. The Fehmarnbelt is believed to provide important habitats for these species. All three species are protected under various conventions and legislation.

The main pressures from the construction and operation of the bored tunnel on marine mammals are noise, habitat loss and habitat change.

Noise during construction is due to dredging, pile driving, construction vessels and the TBMs. The construction vessels and TBMs are assessed to contribute almost nothing to existing noise levels. It is assessed that noise will temporarily affect the hearing of 11 harbour porpoises during intense summer construction and 5 during winter. This assumes that the porpoises remain in the area with high noise levels. No deaths are predicted.

Habitat loss is equal to the areas of the reclamations and temporary construction works. The impacts are insignificant since the lost areas do not overlap with the most important areas for porpoises.
Habitat change will primarily be caused by the sediment spill which can reduce the ability of visual-feeding marine mammals to locate their prey. However, porpoises are well adapted to turbid conditions and will not be affected.

Seals will not be affected by any of the project activities.

In summary, the impacts on marine mammals are between insignificant and no impacts.

1.3.10 Birds

The Fehmarnbelt area is of considerable importance for many bird species. A large number of waterbirds, such as wintering seaducks, moulting swans and many other species spend their non-breeding season in the region. The area also provides suitable and important breeding habitats for several waterbird species. Large parts of the Fehmarnbelt area and adjacent inland habitats are protected as Natura 2000 sites, which have been designated to protect important areas for staging and breeding birds. During spring and autumn large numbers of landbirds and waterbirds pass the Fehmarnbelt area on migration.

The project pressures on birds include:

› Habitat loss from footprint
› Habitat change from sediment spill
› Reduced water transparency
› Disturbance from construction activities
› Barrier effect from construction vessels
› Collision from construction vessels

The limited marine operations mean that the barrier effect and collision with construction vessels are negligible.

The project footprint will cause the displacement of breeding and non-breeding waterbirds during both construction and operation phases. The impacts on breeding waterbirds are assessed to be minor. For non-breeding waterbirds it is estimated that 710 Common Pochard and 7,100 Tufted Duck corresponding to 0.20% and 0.59% of the biogeographic population will be displaced and low numbers of other species.

Sediment spill has only minor effects on benthic flora and fauna and therefore insignificant impacts on the food supply for birds. Sediment spill also reduces water transparency and this is assessed to cause the temporary displacement of about 2,650 Common Eider which will have to go elsewhere for food. However, the population of Common Eider will not be affected since the food supply in the area is not a limiting factor.

Birds will be disturbed by noise, light and physical presence of construction vessels and marine plant. The birds most affected are Eurasian Wigeon, Common Pochard,
Tufted Duck and Common Eider. The number disturbed and the limited duration of the disturbance will not result in any impact on the population.

The overall conclusion is that the bored tunnel will not have any significant impacts on the populations of breeding and non-breeding waterbirds or on migrating species.

1.3.11 Migrating bats
It is well known that bats from some European populations migrate between their summer and winter areas. The winter is spent in Southern and Eastern Europe and they migrate north to Denmark and Scandinavia for breeding in summer. The knowledge about the bat species, their flyways, flight altitudes and distances is very limited.

Bats occur regularly in the Fehmarnbelt coastal area and some species have been proven to migrate across Fehmarnbelt. Bats were observed crossing Fehmarnbelt particularly during autumn. There is no indication that bats would use specific migration corridors and the direction of migration is not clear. It is assumed that bats cross Fehmarnbelt on a broad front and that the alignment area of a planned fixed link does not play a special role for bat migration.

The project pressures on migrating bats are disturbance due to construction activities, habitat change or loss and collision with vessel and vehicle traffic.

The barrier effect and collision effect with construction vessels will be negligible due to the very limited marine traffic.

During tunnel operation the lighting at the ramps and portals gives rise to a permanent collision risk between bats and traffic. The lights attract insects and thereby also bats which seek out the food resource. It is assessed that there is a medium risk of collision for two migrating bat species, viz. Nathusius’ Pipistrelle and Soprano Pipistrelle, while there is a minor risk for Noctule.

Since the tunnel ramps and portals would be below the surrounding ground level, the risk of collision with bats would be reduced. Also, the impairment zone of the tunnel ramp and portal areas at Rødbyhavn and Puttgarden would be relatively small. Furthermore, bats migrate over a broad front and the tunnel alignment is not an important corridor. Thus, it can be expected that only a small proportion of the bats migrating across the Fehmarnbelt would be affected from a potential collision risk with traffic. Therefore, the impact from structures and operation of a bored tunnel in the Fehmarnbelt is assessed as insignificant for migrating bats.

1.3.12 Commercial fishery
The primary catch of commercial species in Fehmarnbelt over the last decade has been sprat by weight and cod by value. However, there are a number of other important species for commercial fishery such as herring, flatfish species (flounder, dab, plaice, turbot, brill and sole), whiting, horse mackerel, European eel, garfish,
salmon and sea trout, which are at times the primary fish targeted or are an important supplement to the overall landings.

Denmark and Germany are, almost without exception, the only countries that undertake commercial fishing in Fehmarnbelt and its regional area. The fishing gear in use consists of trawls, gill nets, pound nets and Danish seine nets.

The bored tunnel project will only have potential impacts on fishery which occurs close to the coasts of Lolland and Fehmarn in the vicinity of the land reclamations and work harbours.

Trawl fishery occurs in deeper waters away from the coasts and will not be impacted by the construction and operation of the bored tunnel. Similarly, Danish seine net fishery does not occur in any areas affected by the project.

The permanent land reclamations will not affect any gill net fishing areas. During construction the work harbours, access channels and the 500 m wide near zone where fishing will be prohibited during construction will affect 23 ha of Danish gill net fishing areas and 56 ha of German areas, corresponding to 0.02% and 0.05% respectively of the gill net fishing area in the Fehmarnbelt region. Sediment spill during dredging will affect 968 ha (1.2% of the Fehmarnbelt region) of Danish fishing areas and 176 ha (0.3%) of German areas, but only for limited periods during the first winter of the construction phase. The low percentages of gill net fishing areas affected justify the assessment of the impact during construction as insignificant.

The land reclamations, work harbours, access channels and the 500 m wide near zone where fishing will be prohibited during construction will cause the loss of 350 ha of pound net fishing area in Danish waters and 51 ha in German waters, corresponding to 5.8% and 2.2% of the pound net fishing areas in the Fehmarnbelt region. The areas impacted in the operation phase are similar. Sediment spill will affect a further 331 ha of Danish pound net fishing areas and 178 ha of German areas. Six of the 82 pound nets at the Lolland coast will be removed by the reclamations. One German pound net fisherman will be potentially affected. The impacts on pound net fishery are assessed to be significant at a local scale but insignificant on a regional scale. This applies to both the construction and operation phases.

1.3.13 Material assets

The material assets in the marine area of the bored tunnel project are windmill parks, sand mining areas, disposal sites for dredged material, submarine cables, harbours, ferry traffic, navigation aids and a military area.

The windmill parks and the disposal sites for dredged material are far from the project site and will not be affected.
A corner of one Danish sand mining area lies over the bored tunnel alignment. The Danish authorities have agreed to close the site if it presents any danger to the project.

Three submarine cables cross Fehmarnbelt and will be covered by the Lolland land reclamation. The owner of the cables has been contacted and does not object to the covering of the cables. There are electricity and communication cables from Marienleuchte to the German military area, but these will not be affected by the project.

With respect to harbours and ferry traffic, the construction activities will be specially planned to avoid significant impacts on their operation. Similarly, the planning of the works and marine traffic will respect the restrictions of the German military area.

In conclusion the impacts on material assets are assessed as insignificant.

1.3.14 Recreation

The marine recreation activities in Fehmarnbelt consist of bathing, water sports (wind surfing, kite surfing, sea kayaking, jet skiing, water skiing etc.) boating (sailing and motor boats), fishing and hunting. The activities occur along most of the coastlines in the study area and principally in summer.

The reclamations will cause the loss of 1.5 km of bathing beaches on the Lolland coast as well as the beach immediately southeast of Puttgarden harbour. The losses will be compensated by the construction of new beaches along the perimeters of the reclamations. The sediment spill during construction will only impact the water turbidity at bathing beaches to a minor degree and the impact is insignificant. This applies to the beaches on both Lolland and Fehmarn.

It is assessed that the project will have minor and insignificant impacts on boating in the construction phase and none in the operation phase. This is due to the fact that the sailors in the area are used to the existing intense commercial shipping traffic in Fehmarnbelt and the 52 daily ferry crossings.

The Lolland reclamation will cause the loss of about 7.7 km of coastline where recreational fishing occurs as well as the popular Rødbyhavn breakwaters. However, on Fehmarn, the reclamation will have little or no impact on recreational fishing. Furthermore, the construction activities are assessed as having no impact on recreational fishing from boats, hobby fishing or fishing from the German commercial angling vessels. The severity of loss during construction on Lolland is assessed to be minor since the number of fishermen affected is small. During operation, the containment dikes around the land reclamations will provide additional opportunities for recreational fishing and the impact is positive.

The project will not impact hunting since very little, if any, occurs along the coasts.
1.3.15 Cultural assets and archaeology
The marine baseline studies identified two ship wrecks and an anchor near the
tunnel alignment. These are not near the coastal construction activities and will not
be affected in any way by the project in either the construction or operation phase.
No evidence of pre-historical settlements along the ancient coastlines was found
for the time being.

1.3.16 Shipping
The major shipping traffic on the T Route through Fehmarnbelt will not be affected
by the bored tunnel project. The supply of construction materials will require a
maximum of two ships per day to Lolland and two to Fehmarn. The transport of the
dried slurry from Fehmarn to Lolland will require a maximum of 10 barges per day
crossing the belt. This traffic is minor compared with the T route traffic and the
ferries. In addition, a VTS system will be established to guide ship traffic and
improve safety.

1.4 Lolland

1.4.1 Landscape and soils
The landscape of Lolland was primarily formed during the last ice age. It is
relatively flat, low lying and with low rolling landscape forms. A 4 m high coastal
dike was built along the south coast in the 1873 to protect the area from flooding
due to storm surge. The lowlands are reclaimed and drained marine areas behind
the dike with soils of marine sands. The soils of the rolling landscape are primarily
clay mixed with stone, gravel and sand.

The construction facilities including the tunnel concrete lining factory and the
dewatering facility for the slurry from the TBM will cover an area of 45 ha of
lowlands and 27 ha of agricultural land. The area will be re-established after
construction is finished. However, during the 8 year construction period the use of
a large and valuable coastal area for the worksite and land reclamation is
considered a significant impact on the landscape.

In the operation phase the tunnel portals, ramps, motorway and railway
connections to the existing infrastructure, toll plaza etc. will cover an area of about
78 ha, 14 ha of which is lowland. 1 km of the sea dike will be removed. 8 km of the
old coastal dike behind the reclamation will lose contact with the sea. The tunnel
portals and the 12 m high embankments over the tunnels will be new landmarks.

The land reclamation will provide over 300 ha of new landscape with heights up to
7 m. For the EIA it is assumed that the reclamation will not be ready for
landscaping development into green areas for a period of 4-15 years, which is a
significant impact. However, it is expected that a technical solution will be
developed to ensure that the reclamation will be ready for development at the end
of the construction period. Together, these impacts on landscape are classified as
significant.
1.4.2 Nature areas

A range of nature areas and habitats are protected by the EU Habitats Directive and Birds Directive (Natura 2000 areas) and by § 3 of the Danish Nature Protection Act. In the area on Lolland likely to be impacted by the project the protected § 3 areas include salt meadow, marshland, meadow, lakes, ponds and watercourses. The only Natura 2000 area on Lolland that might be affected is Hyllekrog-Rødsand Lagoon. This is addressed in a separate Natura 2000 assessment section.

The nature areas appropriated during construction are 6.6 ha salt meadow, 0.5 ha marshland, 1.75 ha meadow, 1 lake (Strandholm Lake, 7.7 ha), 3 ponds and 0.7 km of watercourse. All will be mitigated and compensated with new nature areas of at least the same area at nearby locations on Lolland and on the land reclamation. The impacts are therefore assessed as insignificant.

The permanently appropriated nature areas (operation phase) are 2.6 ha salt meadow, 3.4 ha that may be salt meadow, 1 lake (Strandholm Lake), 3 ponds and 0.35 km of watercourse. The meadows and ponds will be permanently replaced by new nature areas at least twice as large, the new lake will be 1.5 times larger and the new watercourse will be 1:1. The implementation of the mitigation and compensation measures will ensure that the residual impacts are insignificant.

1.4.3 Flora and Fauna

The areas of important biological value in the project area are the coastal dike and the salt meadow behind it, a meadow area immediately west of Hyldtofte Østersøbad and the railway yard in Rødbyhavn. These areas are home to a range of protected or threatened plant and animal species which occur in Annex IV of the Habitats Directive, Annex I of the Birds Directive and on the Danish red lists.

Protected and rare plant species are found on the salt meadows in connection with the coastal dike, e.g. various orchids, white sticky catchfly, field cow-wheat, royal fern, species of fungi and mosses. However they occur in large populations all along the 64 km dike and the impact of the project is insignificant. Other protected and rare species occur in the study area but will not be impacted by the project.

No known breeding or resting areas for bats or bat flyways will be destroyed by the project. Amphibians will be transferred from the appropriated ponds to the new ponds and amphibian fences will be established along the motorway. The railway yard will be cleared on a one time basis to maintain a suitable habitat for the rare moths and insects found there.

Some breeding areas for the red-backed shrike (Annex I), bittern, stonechat, garganey and little ringed plover will be destroyed by the project. Mitigation in the form of suitable new breeding places will be established.

The impacts on the coastal dike will remove a part of the habitats for the red list species Glanville fritillary butterfly, two species of ground beetles and European brown hare.
Mitigation measures will protect the populations of the species affected by the project. For example, four fauna passages will be established under the motorway and railway together with a combined fauna and path passage in front of the tunnel mouth. The mitigation and compensation measures will ensure that the residual impacts on flora and fauna are insignificant.

1.4.4 Cultural heritage and archaeology

Cultural heritage and archaeology in the project area on Lolland includes listed buildings and cultural environments, protected archaeological monuments, listed archaeological sites and protected dikes and fences.

Actual loss of known historical and archaeological values is limited to the alterations at the sea dike that partly will be removed and partly disconnected from the sea. This impact is assessed as significant in the operation phase. Archaeological studies carried out as part of the project will add to the understanding of the archaeology of the area and may result in valuable finds.

1.4.5 Recreation

The coastal dike provides recreational opportunities in the form of views, nature and cultural observation, and paths for walking, running and cycling. The beaches west of Rødbyhavn, at the Lalandia holiday centre and at Hyldestofte Østersøbad are important for the local population and tourists in summer. There are also hunting and fishing opportunities in the area including two put-and-take lakes near the construction worksite.

During the construction phase that lasts for 8 years, an 8 km length of the coastline will be dominated by construction activities with implications for the outdoor recreational activities. The path along the dike will be closed and residents in Rødbyhavn, guests at Lalandia amusement park and in the nearby summer house areas will not have access to the coastline and beaches. New beaches will be established, the one at the western end of the reclamation being available for use in the second year of construction and the others the end of construction. Close to the site of the tunnel segment factory there will be light pollution, air emissions and noise.

The impacts on the use of the coastal dike and on fishing during the construction phase are significant.

In the operation phase the increased distance to the beaches and the reduced recreational opportunities associated with the coastal dike are also considered significant impacts. After construction, the reclaimed areas will be developed to be suitable for leisure activities including picnicking, walking, bird watching, water sports in the lagoon and recreational fishing from the containment dike. The impacts in the operation phase are both negative and positive.
1.4.6 Water

The most significant impact on the surface water environment is the removal of Strandholm Lake. A new lake will be established as compensation.

The bored tunnel will remove small sections of water courses. To compensate for this impact it is planned to reopen piped streams and to improve the water flow and the physical environment along the remaining streams. Mitigation measures will ensure that the groundwater lowering required in the construction phase will not affect the water balance in the wet habitats.

1.4.7 Noise and vibrations

The Danish noise standards are recommended limit values. They describe the level at which a minority (approximately 10%) of the noise-impacted persons might feel highly annoyed. If the noise is below the recommended limit values, the Danish EPA do not expect any health effects. The limit values are different for rail traffic, road traffic, ferry traffic or construction noise because the same sound pressure level is perceived differently and results in different levels of annoyance.

In general the construction activities are not expected to cause significant noise impacts, mainly due to the distance to residential areas. However, reclamation works, the slurry treatment plant and the prefabrication of tunnel segments occur 24 hour per day, 7 days per week for five years and, without mitigation, will affect nearby residences. The foundation of the production facilities with pile diving will also create impact in the area. Noise barriers will be established in order to comply with the threshold of 70 dB and 40 dB (day time / night time).

Calculations show that structurally-damaging vibrations are not expected during construction due to the distance to residential areas and other buildings.

In the operation phase nine residences will be affected by rail noise, 18 by road noise without ferry operation and 56 by road noise if ferry operation continues. The ferries presently impact 285 buildings. The impacts during operation of the bored tunnel are classified as an insignificant change compared with today.

Vibrations during the operation phase are a completely marginal issue.

1.4.8 Air quality and local climate

The present air quality of the project area is good with concentrations of all contaminants well below the thresholds specified in the Danish standards. The air quality is presently only marginally affected by just a few sources of air pollution, such as ferries and road traffic.

Possible sources of additional air pollution during the construction phase are construction machinery, tug boats and truck traffic to and from the element production site, as well as emissions from the production site itself. Emissions from the marine activities during the construction phase may also have a local impact. However it is not expected that any of the thresholds will be exceeded due to the
local wind conditions giving a high degree of dispersion. Furthermore, proper construction site environmental management will reduce the risk of exceeding the emission standards on land, and both air pollution and the impact on the local climate during the construction phase are considered to be insignificant.

During operation annual average concentration of NOx within a radius of 200 m from the road tunnel portal will exceed the threshold. However, people will only remain in the area for short periods so their health will not be affected and the impact is insignificant. Thresholds will not be exceeded in areas with permanent residences. There will be an increase in nitrogen deposition in a radius of up to 500 m around the tunnel opening and at a distance of up to 100 m along the motorway, but this is not found to be significant.

1.4.9 Material assets
The material assets which will be impacted by the project are the ferry port, Rødbyhavn sewage treatment plant, the dike, several pumping stations, one industrial plant, farmland and bentonite deposits.

It is not yet clarified if the ferries will continue operation after opening of the fixed link. The bored tunnel will not physically change the port but closing the ferry services might have other consequences.

The outfall from the sewage treatment plant will be extended by the project through the reclamation to ensure its uninterrupted operation. Several pumping stations which drain the hinterland will be obstructed by the land reclamation. The impacts will be mitigated by reconstruction of outfalls by the project. The function of the dike as protection against flooding will not be affected during construction and operation.

The abandoned Klimafisk plant will be removed and a smaller corner of BG Element’s site will be expropriated. 27 ha of farmland will be temporarily expropriated during construction and 55 ha permanently expropriated during operation. The land owners will be compensated.

The project will cover 27 ha of bentonite deposits but the deposits are of poor quality. The total area of available deposits is much larger.

In summary the impacts on material assets during construction and operation are not significant.

1.4.10 Population and health
The greater part of the impacts on population and health are addressed above under recreation, noise and vibrations, air quality and material assets. The remaining potential impacts concern appropriation of a few residences and the activities of the construction workers.
The construction worksite will require the expropriation of two homes, one stone house, four commercial buildings and three buildings for sporting and leisure activities. The permanent works will require the expropriation of a further three homes and two sheds. The owners will be compensated and there will not be any significant impacts on the population as a whole.

The population during construction will be increased by up to 2,000 workers who will use the nearby towns and areas during their leisure time. This will lead to increased traffic but at the same time an increased turnover at local businesses. This is assessed as a significant consequence for the local area, although it can be considered both positive and negative.

1.4.11 Derived socio-economic effects
The derived socio-economic effects concern the project’s impacts on Rødbyhavn residents, farming and fishing industries, energy and water supply, industry, trade and transport, tourism and private and public services. Some have already been addressed above and will not be repeated here.

The consequences of the loss of farmland and potential reduction of productivity close to the motorway are assessed as insignificant because the areas are only a small fraction of the total area of agricultural land on Lolland.

There will be a large increase in the demand for electricity and water during the construction phase. It is assumed that adequate supplies of both will be made available by the local and regional suppliers.

Reduced accessibility may have a minor effect on trade and industry during the construction phase but there are not expected to be any consequences during operation of the fixed link.

During construction the tourist industry may be negatively affected by the reduced access to the coast, particularly for guests at Lalandia, slightly deteriorated quality of bathing waters and disturbance by noise, air pollution and light. On the other hand watching the construction can be an attraction and the workers will also seek out tourist attractions. The consequences for tourism are assessed to be significant during construction, but it cannot be determined if it overall will be negative or positive.

Finally, during construction it is expected that there will be an increased demand for public and private services within the health sector.

1.5 Fehmarn
The procedure for obtaining environmental approval for a project in Germany involves the preparation of two reports, the UVS (Umweltverträglichkeitsstudie) which is the EIA, and the LBP (Landschaftspflegerischer Begleitplan) which is a Landscape Conservation Plan. The UVS reports the magnitude of impacts and
performs the comparison of the different possible solutions while the final solution with specific mitigation and compensation measures is addressed in the LBP.

The impacts of the bored tunnel solution as described in the UVS are summarised below. Any proposed mitigation and compensation measures are derived from the actual impacts and from the measures proposed for the immersed tunnel due to the similarities of the two solutions.

1.5.1 Population and health

Residential areas and surroundings

The construction works will cause the temporary loss of 0.25 ha of residential area in Marienleuchte (very high importance) along with about 38 ha of residential surroundings (medium importance). The permanent structures of the project will result in the loss of parts of the area of a farm (0.08 ha) near Puttgarden and 3.5 ha of residential surroundings near Marienleuchte and Puttgarden.

German standards for noise are specified for various combinations of residential areas, commercial areas and special institutions (hospitals etc.). There are threshold noise levels during day and night specified by law (16th Federal Emission Control Ordinance - BImSchV) and guideline values in a DIN standard (DIN 18005).

There will be a number of intense noise sources on the construction sites on Fehmarn, e.g. bar bending facility, concrete plants, TBM ventilation system, construction traffic and pile driving. Pile driving for the tunnel concrete segment factory and along roads and railway (masts and bridges) is a particularly disturbing source. The assessment shows that – if pile driving is used in construction - the noise guideline levels will be exceeded in residential areas of Marienleuchte and Puttgarden, near the large Puttgarden junction and at one farmhouse. The area-specific guideline values will also be exceeded by other works up to 4 dB(A) during night time, but only in Marienleuchte.

During the operation phase it is the noise from the railway that is the main cause of the exceedence of the guideline noise levels. Due to hinterland infrastructure the threshold noise levels specified by BImSchG the level for residential areas is exceeded by 1dB(A) in an area of 1.3 ha in Bannesdorf. The level for mixed used areas is exceeded by 1-2 dB(A) only in Puttgarden (0.01ha). And the level for sensitive shared community facilities shows an impairment of an area of 0.1 ha at the school of Puttgarden. Comparison with the guideline values according to the DIN standard which is not legally binding results in an impairment of 1.66 ha of residential areas in Bannesdorf.

Visual and sensory impairments are related to construction facilities, permanent structures and operation activities. Mainly residential surroundings of medium sensitivity will be subject to sensory and visual impairment.

Due to the good supply of fresh air in the area of the construction site, the large distance between route and residential area, no relevant impacts on air quality are
to be expected during the construction phase for residential areas. No residential areas with high and very high sensitivity are affected by operation related pollutants.

It is not to be expected that the light emission guideline values will be exceeded by construction activities as there is a sufficient distance to the nearest residential area. Also no additional brightening of residential areas is to be expected due to the lighting of the route (road and railway).

No relevant vibrations are to be expected for the residential areas besides possible impact in the area of an individual farm nearby Puttgarden.

Recreation
The land reclamation and work harbour will cause the loss of the narrow beach of minor importance between Puttgarden harbour and Marienleuchte (0.37 ha during construction, 0.61 ha structure related). A new beach will be established along the edge of the reclamation by the project and will be ready for use at end construction.

Construction noise will result in temporary impairment of a narrow area especially suited for recreation at the western edge of Marienleuchte, but no recreation areas will be impaired by noise greater than 49 dB(A) caused by traffic. Mainly medium sensitive areas of special suitability for recreation near Marienleuchte and Presen will be subject to visual and sensory impairment. The total area with temporary visual and sensory impairment is 83 ha. Structure related impairment is only 1 ha. No recreation areas will be impaired by pollutants or vibration during construction or in operation phase.

Three bicycle paths will be re-routed during construction and re-established at the end of construction.

In summary, there are significant impacts on the population during construction due to noise and visual aesthetics while the impacts during construction are insignificant.

1.5.2 Soil
About 80 ha soils of special importance will be lost and compacted during construction, but will be mainly restored to agricultural use afterwards. The top soil will be removed and stored at the start of construction. At the end of construction the compacted soil will be loosened by ripping and the top soil replaced.

Permanent loss of soils of special importance due to rail, road and embankments add up to 62.3 ha (mainly “Fehmarn black earth” and a small amount of the storm beach areas and cliff structure). Loss of soils of general importance is negligible.

The increase of pollutants in soils due to construction is negligible. Concentrations of NOx may increase in narrow parallel zones next to the road and increased concentrations of particulate matter may occur mostly along the railway track. Due to the new developments in engine technology and the electrification of the
railway, no increased concentrations of benzene are to be expected for the forecast year 2025. Metals such as zinc and lead will also decrease.

Overall, the impacts on soil during construction and operation are insignificant.

1.5.3 Water
“Water” refers to groundwater, streams, lakes and ponds. Ponds are addressed above under flora and fauna below. Structural impacts on water courses are the need to extend the culverts carrying the drainage ditches Drohngabren and Nielandsgraben under road and rail embankments, thereby increasing fragmentation of the water courses. The water resources in the area will be negligibly affected by polluted runoff from sealed areas due to the general use of retention basins.

About 0.5 ha of the “Gewässerschutzstreifen” (protected zone along the coast) will be covered permanently by structures.

The impacts on water are insignificant.

1.5.4 Flora
The dominating biotope on Fehmarn is agricultural land with a few belts of trees and hedges.

The habitats protected in Germany are defined in § 30 BNatSchG (in conjunction with § 21 LNatSchG).

A total of 2.7 ha of the legally protected habitats with very high importance as biotopes will be lost during both construction and operation phases. About half of the losses will be of non-restorable coastal habitats.

During construction five ponds (protected small bodies of water) which are important for amphibians will be lost. Compensation will be provided in the form of new ponds in the adjacent landscape. Amphibians will be transferred to the new ponds. The number and location of the ponds is to be agreed with authorities.

A small part of a hedge row near a road and small area of natural re-growth in the wind farm park are also lost. A vegetated area of coastal sand dunes and beach at the work harbour will be lost and cannot be restored.

As protected habitats, three ponds are lost by the permanent structures along with small areas of a tree-lined road, a hedge row, natural re-growth and a spit west of Marienleuchte. New ponds will be constructed as compensation.

The largest individual habitat lost (0.68 ha) is the beach covered by the land reclamation.
In total, 83 ha biotopes are lost during construction of which 77.5 ha is arable land of minor importance, 0.75 ha of medium importance (sections of water courses, shrubs, grassland, trees) and 0.01 ha of high importance (semi-dry grassland). The vast majority of the biotopes can be restored or compensated after they have been used temporarily for construction.

The permanent project structures will require acquisition of a total 65 ha of which 56.5 ha is arable land of minor importance, 4.7 ha of medium importance (sections of water courses, shrubs, grassland, trees) and 0.3 ha of high importance (semi-dry grassland).

The only flora area of very high importance close to the project area is the disused railway yard south of Puttgarden, but it is not affected by the project.

No critical concentrations of pollutants and nutrients will be reached or exceeded for the vegetation.

The impacts on flora during construction and operation are assessed as insignificant provided the mitigation and compensation measures are implemented.

1.5.5 Fauna

Three areas of medium importance for bats (hunting and mating grounds) will be affected by loss (about 5.5 ha). The areas comprise only structures at the edge of the B 207 and at the edge of the railway, all of which will be restored or rebuilt in a similar manner in the course of the project. No specific habitats in the sense of nursery roosts and winter quarters are affected by the project. Only in two areas is there an additional collision risk of medium severity for bats. There will not be any construction-, structure- or operation-related impairments by light for especially sensitive bat species.

The permanent structures will cause the loss on about 69 ha of bird breeding areas while the temporary construction works will affect about 84.5 ha. Although the areas are relative large they are only mostly of medium or minor importance for birds and are arable land. The project will cause medium additional fragmentation of bird habitats and minor to medium additional risks for road deaths of individuals. During construction phase there is no relevant collision risk. Noise in the operation phase will impact an area of 298 ha in zones with different severity. However, it must be noted that the impaired areas are already subject to existing impairment by noise and disturbances caused by the B 207 and railway. Only especially sensitive breeding pairs occur in the affected areas and they have apparently become accustomed to the present noise level. The impact zones subject to permanent noise and other disturbances and the construction-related impact zone largely overlie one another. The disturbance due to temporary construction noise is assessed to impair an additional area of 208 ha. As in the operation-related impacts, so in the construction-related impairment at least the southern section is already impaired by noise and other disturbances at this point.

The loss of resting places for resting birds by the project is negligible.
Amphibians will be impacted through the permanent loss of seven ponds suited for amphibians in areas of permanent structures and construction activities. Full compensation with new ponds will be implemented, see flora section above. Besides loss of habitat structures, additional fragmentation of amphibian habitats by the project is assessed as negligible. For reptiles the fragmentation/danger of collision of medium severity is more decisive for the habitats of reptiles than their loss, as the habitats lost to the structures are at the edge of the railway embankment. These areas will be restored after the completion of the bored tunnel.

Deer and hare (red-listed) are common in the study area and are sensitive to fragmentation and traffic. However the area is already fragmented by the B 207 / railway dividing the island of Fehmarn into an eastern and western part and the traffic prediction does not indicate any noticeable increase in road kills.

With respect to insects one pond of high importance and four of minor importance for dragonflies will be lost. New ponds will be established as compensation. The railway yard is important for moths but is not affected by loss by the project. Lighting during construction will attract moths and the impairment is assessed as medium to high. Damped lighting will be used at the tunnel portals during operation and considering that the project will only have a negligible impact on moths.

The overall impact on fauna during construction and operation is insignificant provided the mitigation and compensation measures are implemented.

1.5.6 Biodiversity

No areas of high to very high importance for biodiversity in conservation areas, habitat complexes or habitat networks will be lost.

In the area south of the Puttgarden junction up to the southern edge of the railway system, there will be losses in sections of the “Flying Bird Line”, which is a functional area of biodiversity with medium importance. However, their function as a habitat network line will be restored in the short to medium term. The unused marshalling yard with very high importance for red listed plants will not be affected.

The beach section between the Puttgarden ferry port and Marienleuchte is a habitat complex with medium importance, but no especially significant species (Annex IV-species, strictly protected species, red list species) with the exception of a red listed plant species will suffer loss. With respect to the ecosystem diversity, beach habitats and a coastal cliff section will be affected, with the latter to be categorized as non-restorable.

All in all, the impact on biodiversity is minor and insignificant due to small areas of only medium important being affected.
1.5.7 Landscape

The landscape in the study area on Fehmarn consists mainly of farming land which is either open and uniform with hedge rows in some places or is characterised by special features such as tree lined roads or wide views of the sea. There are also coasts and lowlands which contain more nature and built-up areas with traffic infrastructure. These different types of landscape are defined as landscape units.

The project construction site between Puttgarden and Marienleuchte will cause the temporary loss of 84.5 ha. The area is mainly farmland which will be restored after end construction. A small area of 0.5 ha of coastal landscape with a segment of the cliff structure east of the work harbour will be lost and cannot be restored. Larger areas will be subject to visual and sensory impairment by the construction site and construction activities, viz. 277 ha, the great majority of which (about 250 ha) is farmland and is only affected to a medium or minor degree.

The permanent project structures (portals, motorway, railway, buildings and embankments) will cause the loss of 68.5 ha of the landscape. Apart from 0.5 ha loss of coastal area almost all of the area is farmland of medium to minor importance. An area of 202 ha is subject to visually and sensory impairment, 97% to a medium or minor degree. Visual fragmentation effects occur with respect to visual connections from the agrarian landscape to the Baltic Sea, but are restricted to the coastal area between the ferry harbour and the project.

The land reclamation will provide about 23 ha of new landscape and will be landscaped and ready for development into green areas at the end of the construction period.

Impacts on landscape are assessed to be significant during construction and insignificant during operation.

1.5.8 Cultural heritage and material assets

Cultural heritage

The bored tunnel project will not result in the loss of any important or protected cultural or archaeological assets on Fehmarn. Eight marl pits in the construction site will be lost but are only of minor importance. There is always the potential that the construction works will reveal individual archaeological finds which will be assessed at that time.

The historical lighthouse at Marienleuchte will be slightly impaired during the construction phase by noise and also visually due to its proximity to the construction site.

Material assets

The material assets on Fehmarn which will be affected by the project consist of the main road B 207, the railway, some secondary roads, the windmill park at Presen, a small area (0.25 ha) of green corridors at the western edge of Marienleuchte and a small area (0.08 ha) of a farm area east of Puttgarden.
The main road and railway will be improved by the project and the secondary roads will be re-routed so that all will maintain their function through both construction and operation phases. It is likely that up to five wind mills will be removed and it may be possible to re-erect them elsewhere.

In summary the impacts on cultural heritage and material assets are assessed as insignificant in both the construction and operation phases.

1.5.9 Air quality and local climate
The situation regarding air quality is very similar to that on Lolland. The present air quality of the project area is good with concentrations of all contaminants well below the thresholds specified in the German standards. The air quality is presently only marginally affected by just a few sources of air pollution, such as ferries and road traffic.

During the construction phase temporary emissions of exhaust gases from construction machinery and traffic will occur. Emissions of dust from earth stock piles and unsealed surfaces may also occur during construction, but can be prevented by mitigation measures.

All alternatives for the fixed link estimate a similar land traffic volume for the construction phase (between 50 and 150 trucks per day). Most of the construction material will be transported by ships to the working harbour.

There will be no significant impacts on air quality in the construction phase due to the wind conditions on Fehmarn which ensure a high degree of dispersion.

The German standards of air quality which are relevant for human beings will not be exceeded during operation.

The pollution in the relevant impact zones (zone 1: 90-100% of the standard value, zone 2: 50-90% of the standard value) are considered for human beings. The pollutants (PM$_{10}$, PM$_{2.5}$ and NO$_2$) reach impact zone 1 only in the portal area. Here the annual average concentration of NO$_2$ within a radius of 200 m from the road tunnel portal will exceed the threshold, but thresholds will not be exceeded in areas with permanent residences. In the impact zone 2 there are impairments by PM$_{10}$ in a 50 m wide parallel zone along the motorway and railway. All impairments induced by air pollution are considered under the environmental factors soil, water and population.

The impacts on air quality and local climate are insignificant.

1.6 Climate
In total the Greenhouse Gas (GHG) emission from construction of the bored tunnel amounts to 2.5 million ton CO$_2$ equivalents. This is 0.7 million tons or 39% more than the immersed tunnel. To provide a basis for understanding the magnitude of
the additional emissions, the total emissions for Denmark for the full construction period will be of the order of 400 million tons CO₂ equivalents.

CO₂ embodied in concrete is the main contributor with 39% of the total GHG emission from construction works for the BTM. The high emission is because of very high energy consumption associated with the cement production. Another important source is CO₂ embodied in steel for reinforcement etc., which contributes another 24%. Steel production also requires very high energy consumption. Electricity consumption for the tunnel excavation and related activities (slurry treatment) contribute 23% while machinery accounts for 7% and transport for 4%. Other contributors are relatively insignificant.

Electricity consumption during the operation of the bored tunnel is identical with the consumption estimated by the design group for the immersed tunnel. This results in CO₂ emissions during operation of 3,900 tons annually. It is estimated that the use of materials for maintenance and large replacements will result in CO₂ emissions of around 2,000 tons annually.

The impacts of the project on regional and global climate are assessed as insignificant. Similarly, the type and magnitude of the project’s impacts on the environment are not expected to change significantly when the effects of global warming have changed the climate, water levels, ecosystem etc.

### 1.7 Sand mining on Rønne Banke

Approximately 1.1 million m³ of sand with low fines and low salt content is required for the concrete for the bored tunnel project. The sand will be mined from Rønne Banke off the coast of the Danish island of Bornholm.

A comprehensive EIA of the sand mining activities on Rønne Banke was carried out for the immersed tunnel which requires approximately the same volume of sand as the bored tunnel. The EIA considered all marine environmental issues and found that the impacts were insignificant (no impacts on most issues) outside the actual extraction area. This conclusion is assumed to be valid also for the bored tunnel since the sand requirements are approximately the same.

### 1.8 Cumulative impacts

Cumulative impacts arise when a number of planned projects within the same area would have an impact on the same environmental factors at the same time. In the marine area there are a number of existing and planned windmill parks to be considered while on land the extension and upgrading of the motorway and railway infrastructure connecting to the fixed link may have cumulative impacts.

The Nysted and Rødsand II windmill parks existed during the baseline studies and therefore any impacts due to them are included in the baseline data and the assessments for the bored tunnel. The other Danish and German parks are far from the project site where the bored tunnel has no impacts. The German windmill parks
near Rønne Banke will not be affected by the sediment spill from the sand mining on Rønne Banke and there will be no cumulative impacts.

Concerning the infrastructure projects on land, cumulative impacts can potentially occur in the limited area where the bored tunnel project ends and the infrastructure projects start. Both projects will give rise to loss of farmland, noise during construction, landscape impacts and barrier effects. Both projects will implement compensation for lost farm and nature areas and provide fauna passages to reduce the barrier effects. The landscape is already impaired by the existing motorways and railways and the significant impacts of the bored tunnel structures are assessed to dominate over the cumulative impacts of the other land works. Therefore no significant cumulative impacts are assessed to occur on land.

1.9 Natura 2000 areas

The only Natura 2000 area impacted by the project is the Danish Hyllekrog and Rødsand Lagoon area. The impacts are due to the sediment spill during dredging activities at the Lolland coast (work harbours and access channels) and backfilling of the work harbours. The fine sediments in suspension enter and settle in Rødsand Lagoon and potentially can impact water quality, benthic flora and fauna and birds. However, all the impacts have been found to be insignificant.

5 km of the shore eastward of the Lolland reclamation from Hyldetofte Østersøbad to Bunddragene would be subject to significant erosion without the implementation of beach nourishment to fully mitigate the impacts.

The German Fehmarnbelt Natura 2000 areas are not impacted in any way.

1.10 Mitigation and compensation

A number of mitigation and compensation measures will be implemented to ensure that the residual impacts are reduced as much as can be justified or, in most cases, are insignificant. The principal mitigation and compensation measures are:

- New beaches at the Lolland and Fehmarn coasts to replace those covered by the land reclamations. The new beach at the western end of the Lolland reclamation will be ready for use two years into construction and the others at end construction.

- Beach nourishment of approximately 19,000 m³/year of sand to prevent erosion east of the land reclamation on Lolland.

- Reconstruction of outlets for Rødbyhavn sewage treatment plant and for pumping stations draining the land behind the Lolland coastal reclamation.

- The timing of the dredging at the Lolland coast will be selected to reduce impacts on macroalgal and eel grass during their growth season.
› The owners of all land areas temporarily or permanently lost will be compensated by rental or purchase of their properties.

› The land surface and soil conditions at the construction sites on Lolland and Fehmarn will be reinstated after end construction.

› New ponds for amphibians and new, suitable nature habitats will be established to compensate for those lost due to the project construction and operation footprint. The land reclamations will be developed with nature areas, ponds and green areas also as part of the compensation.

› Establish fauna passages under the new motorway and railway to reduce fragmentation of the animal populations.

› Subdued lighting which reduces attraction of insects and bats and which does not disturb the local population will be used in the construction and operation phases.

› Recreational facilities such as walking and cycle paths will be rerouted during construction and restored after construction. Facilities such as walking and cycle paths, picnic areas, bird watching and fishing will be established on the new land reclamations.

In Germany there is a general requirement for monetary compensation for all unavoidable impacts which are not negligible. Such compensation is only developed for the preferred solution, the immersed tunnel. The compensation measures described above are so-called “in kind” compensation where, for example, the lost environment is replaced with a similar environment in the immediate vicinity, e.g. compensating the loss of ponds with the construction of new ponds.

1.11 Summary of significance of impact

The summary of the significance of the environmental impacts of the bored tunnel is shown in Table 1.1. The significance is that after implementation of the mitigation measures and the “in kind” compensation measures.

<table>
<thead>
<tr>
<th>Environmental factor or component</th>
<th>Significance of environmental impacts</th>
<th>Construction</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrography in Fehmarnbelt</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Hydrography in Baltic Sea</td>
<td>No impact</td>
<td>No impact</td>
<td>No impact</td>
</tr>
<tr>
<td>Water quality in Fehmarnbelt</td>
<td>Significant</td>
<td>Insignificant</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Water quality in Baltic Sea</td>
<td>No impact</td>
<td>No impact</td>
<td>No impact</td>
</tr>
<tr>
<td>Seabed morphology</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Coastal morphology</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Environmental factor or component</td>
<td>Significance of environmental impacts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction</td>
<td>Operation</td>
<td></td>
</tr>
<tr>
<td>Plankton and jellyfish</td>
<td>Insignificant</td>
<td>No impact</td>
<td></td>
</tr>
<tr>
<td>Benthic flora</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Benthic fauna</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Fish ecology</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Marine mammals</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Birds</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Migrating bats</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Commercial fishery</td>
<td>Significant for pound net fishery</td>
<td>Significant for pound net fishery</td>
<td></td>
</tr>
<tr>
<td>Material assets</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Recreation</td>
<td>Insignificant</td>
<td>Positive for recreational fishing</td>
<td></td>
</tr>
<tr>
<td>Cultural heritage and archaeology</td>
<td>No impact</td>
<td>No impact</td>
<td></td>
</tr>
<tr>
<td>Shipping</td>
<td>Insignificant</td>
<td>No impact</td>
<td></td>
</tr>
<tr>
<td><strong>Lolland</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscape and soil</td>
<td>Significant</td>
<td>Significant</td>
<td></td>
</tr>
<tr>
<td>Flora and fauna</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Cultural heritage and archaeology</td>
<td>Insignificant</td>
<td>Significant</td>
<td></td>
</tr>
<tr>
<td>Recreation</td>
<td>Significant</td>
<td>Significant</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Noise and vibrations</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Air quality and local climate</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Material assets</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Population and health</td>
<td>Significant due to construction workers</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Derived socio-economic effects</td>
<td>Significant for tourism</td>
<td>Positive for tourism</td>
<td></td>
</tr>
<tr>
<td><strong>Fehmarn</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population and health</td>
<td>Significant due to noise and visual aesthetics</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Fauna</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Flora</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Biodiversity</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Landscape</td>
<td>Significant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Cultural heritage and material assets</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Air quality and local climate</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
<tr>
<td>Climate</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td></td>
</tr>
</tbody>
</table>
### 1.12 Environmental inspection and monitoring programme

An environmental inspection and monitoring programme for the construction and operation phases will be developed at the appropriate time. For this EIA only an outline of the programme is described.

The purposes of the inspection and monitoring programme are:

- To verify that the project is compliant with prevailing standards, requirements and thresholds for construction and operation.
- To monitor that any adverse impacts are as predicted in the environmental impact assessments.
- To monitor that mitigation and compensation measures function as assumed.
- To be able to implement corrective action if necessary.

The inspection and monitoring programme will be based on the following main component packages:

- Requirements for inspections at the construction site in compliance with statutory environmental requirements.
- Requirements for control of sediment spill during dredging operations in the interests of verifying spill rates and compliance with contractually specified requirements.
- Monitoring of implementation of mitigation and compensation measures.
- Monitoring of selected biological/chemical components.

Sediment spill control is a key parameter in relation to the potential marine impacts on, e.g. benthic flora and fauna, and is therefore also important as regards the implementation of any mitigation measures (e.g. reduction in dredging intensity) which may be required to reduce impacts in the marine environment. This is the only possibility for feedback monitoring in the present project, i.e. when the monitoring can result in an immediate requirement for the dredging contractor to reduce spill in order to prevent impacts. All other monitoring activities will only be able to reveal impacts after they have occurred.

Sediment spill will occur during the actual dredging of the work harbours and their access channels, and when unloading barges and draining the sedimentation basins in the planned land reclamation zones.
Monitoring of implementation of mitigation and compensation measures will be performed to track their progress in order to ensure that the predicted ecological functionality is achieved. This targeted monitoring process may also cover specially protected species.

The purpose of monitoring selected biological components is two-fold. The intention is, first, to verify basic model assumptions, and second, to document the actual environmental status by means of selected parameters which are representative of the ecosystems. These would consist specifically of statutory parameters, such as the Natura 2000 areas' designation basis, the Water Framework Directive's and Marine Strategy Framework Directive's requirements for good qualitative status of bodies of water and the preservation of good environmental status in marine ecosystems.

1.13 Comparison with Immersed Tunnel

The comparison of the impacts of the bored tunnel and the immersed tunnel is made qualitatively. It is simply stated which solution has an advantage over the other without attempting to estimate the degree of advantage.

The comparison is made assuming that the mitigation and “in kind” compensation measures are implemented.

The development of the Lolland land reclamation is an important issue in the comparison of the bored and immersed tunnels. For the immersed tunnel the method of dredging and deposition of the spoil in the reclamation will ensure that part of it is ready for development two years into the construction period and the rest will be ready at the end of construction at latest. For the bored tunnel the impact assessment assumes that the reclamation will not be ready for development until 4 – 15 years after the end of construction despite the fact that it is expected that a technical solution can be found to ensure that it is ready at end construction. In this comparison of bored and immersed tunnels it would be unfair to the bored tunnel not to us the same conditions as for the immersed tunnel in this respect. Therefore it is assumed that the technical solution will be found so that the reclamation will be ready at the end of construction for the bored tunnel alternative.
Table 1.2  
**Comparison of bored tunnel and immersed tunnel**

<table>
<thead>
<tr>
<th>Component</th>
<th>Bored Tunnel (BTM)</th>
<th>Immersed tunnel (IMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Marine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrography</td>
<td>No difference</td>
<td></td>
</tr>
<tr>
<td>Water quality</td>
<td>Advantage due to reduced sediment spill</td>
<td></td>
</tr>
<tr>
<td>Seabed morphology</td>
<td>Advantage due to no (temporary) impact on bed forms</td>
<td>Advantage due to less beach nourishment required for the Lolland coast east of the reclamation</td>
</tr>
<tr>
<td>Coastal morphology</td>
<td></td>
<td>Advantage due to less beach nourishment required for the Lolland coast east of the reclamation</td>
</tr>
<tr>
<td>Plankton and jellyfish</td>
<td>Advantage due to much smaller area with reduced Secchi depth during construction</td>
<td></td>
</tr>
<tr>
<td>Benthic flora</td>
<td>Advantage due to reduced sediment spill</td>
<td></td>
</tr>
<tr>
<td>Benthic fauna</td>
<td>Advantage due to reduced sediment spill</td>
<td></td>
</tr>
<tr>
<td>Fish ecology</td>
<td>Advantage due to reduced sediment spill</td>
<td></td>
</tr>
<tr>
<td>Marine mammals</td>
<td>Advantage due to reduced noise and disturbance from marine construction activities</td>
<td></td>
</tr>
<tr>
<td>Birds:</td>
<td>Advantage due to reduced sediment spill and no tunnel trench</td>
<td>Advantage due to reduced displacement of birds caused by sediment spill and to reduced barrier effects and collision with marine vessel and plant. Advantage due to reduced barrier effects and collision with marine vessel and plant.</td>
</tr>
<tr>
<td>Water birds</td>
<td>Advantage due to reduced displacement of birds caused by sediment spill</td>
<td>Advantage due to reduced displacement of birds caused by sediment spill and to reduced barrier effects and collision with marine vessel and plant. Advantage due to reduced barrier effects and collision with marine vessel and plant.</td>
</tr>
<tr>
<td>Migrating birds</td>
<td>Advantage due to reduced displacement of birds caused by sediment spill</td>
<td>Advantage due to reduced displacement of birds caused by sediment spill and to reduced barrier effects and collision with marine vessel and plant. Advantage due to reduced barrier effects and collision with marine vessel and plant.</td>
</tr>
<tr>
<td>Migrating bats</td>
<td>No difference</td>
<td></td>
</tr>
<tr>
<td>Commercial fishery</td>
<td>Advantage due to reduced sediment spill and no tunnel trench</td>
<td></td>
</tr>
<tr>
<td>Material assets</td>
<td>Advantage due to no impact on one sand mining area</td>
<td></td>
</tr>
<tr>
<td>Recreation</td>
<td>Advantage due to reduced marine construction activities</td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Comparison</td>
<td></td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Bored Tunnel (BTM)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cultural heritage and archaeology</td>
<td>No difference</td>
<td></td>
</tr>
<tr>
<td>Shipping</td>
<td>Advantage due to reduced marine construction activities</td>
<td></td>
</tr>
<tr>
<td><strong>Lolland</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscape and soils</td>
<td>Advantage due to reduced area of construction sites and production facilities</td>
<td></td>
</tr>
<tr>
<td>Land reclamation</td>
<td>Advantage since the area will be landscaped and ready for development of green areas and new nature areas 1.5 years earlier (end construction).</td>
<td></td>
</tr>
<tr>
<td>Nature areas (§3 areas)</td>
<td>Advantage due to reduced area of construction sites and production facilities</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Advantage due to reduced area of construction sites and production facilities</td>
<td></td>
</tr>
<tr>
<td>Flora and fauna</td>
<td>Advantage due to reduced area of construction sites and production facilities</td>
<td></td>
</tr>
<tr>
<td>Air quality and local climate</td>
<td>No difference</td>
<td></td>
</tr>
<tr>
<td>Noise and vibrations</td>
<td>No difference</td>
<td></td>
</tr>
<tr>
<td>Material assets</td>
<td>Advantage due to no impact on Syltholm windmill park or on the RGS 90 polluted soil treatment plant</td>
<td></td>
</tr>
<tr>
<td>Cultural heritage and archaeology</td>
<td>Advantage due to reduced area of construction sites and production facilities</td>
<td></td>
</tr>
<tr>
<td>Recreation</td>
<td>Advantage since the area will be landscaped and ready for development of recreational facilities 1.5 years earlier (end construction).</td>
<td></td>
</tr>
<tr>
<td>Population and health</td>
<td>No difference</td>
<td></td>
</tr>
<tr>
<td>Derived socio-economic effects</td>
<td>No difference</td>
<td></td>
</tr>
</tbody>
</table>
### Component Comparison

<table>
<thead>
<tr>
<th>Component</th>
<th>Bored Tunnel (BTM)</th>
<th>Immersed tunnel (IMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fehmarn</strong></td>
<td>Advantage overall due to less disturbance from noise, less impacts from air pollution and less loss of recreational areas.</td>
<td>Advantage due to less loss of surroundings of residential areas and less visual disturbance.</td>
</tr>
<tr>
<td>Population and health</td>
<td>Advantage due to less loss of surrounding of residential areas and less visual disturbance.</td>
<td>Advantage due to smaller construction site giving less temporary loss and compaction of soil.</td>
</tr>
<tr>
<td>Soil</td>
<td>Advantage due to less loss of protected areas and less pollution of surface water.</td>
<td>Advantage overall due to less loss of ponds and less fragmentation of water courses.</td>
</tr>
<tr>
<td>Water</td>
<td>Advantage due to smaller area of construction site and permanent structures.</td>
<td>Advantage due to less loss of areas important for breeding birds.</td>
</tr>
<tr>
<td>Fauna</td>
<td>Advantage due to less loss of areas important for breeding birds.</td>
<td>Advantage due to smaller area of construction site and permanent structures.</td>
</tr>
<tr>
<td>Flora</td>
<td>Advantage due to less loss of areas important for breeding birds.</td>
<td>Advantage due to smaller area of construction site and permanent structures.</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>Advantage due to less loss of beach biotopes.</td>
<td>Advantage due to less loss of beach biotopes.</td>
</tr>
<tr>
<td>Landscape</td>
<td>Advantage due to less loss and less visual disturbance of landscape units.</td>
<td>Advantage due to less loss and less visual disturbance of landscape units.</td>
</tr>
<tr>
<td>Cultural heritage and material assets</td>
<td>Advantage due to smaller area of construction site and permanent structures giving less loss of possible archaeological sites and less impact on Windpark Presen.</td>
<td>Advantage due to smaller area of construction site and permanent structures giving less loss of possible archaeological sites and less impact on Windpark Presen.</td>
</tr>
<tr>
<td>Air quality and local climate</td>
<td>No difference</td>
<td>No difference</td>
</tr>
<tr>
<td>Climate</td>
<td>Advantage due to less GHG emissions in construction phase</td>
<td>Advantage due to less GHG emissions in construction phase</td>
</tr>
<tr>
<td>Sand mining on Ronne Banke</td>
<td>No difference</td>
<td>No difference</td>
</tr>
<tr>
<td>Cumulative impacts</td>
<td>No difference</td>
<td>No difference</td>
</tr>
<tr>
<td>Natura 2000</td>
<td>Advantage due to no impact on the German Fehmarnbelt area and reduced impact on the Danish Hylekrog-Radsand area</td>
<td>Advantage due to no impact on the German Fehmarnbelt area and reduced impact on the Danish Hylekrog-Radsand area</td>
</tr>
</tbody>
</table>
An overall conclusion can be obtained by aggregating the impacts taking into account the fact that the components do not all have the same environmental weighting or importance. The differences in the impacts which dominate the comparison are:

› The bored tunnel has less impact on most marine issues due to the reduced sediment spill and no tunnel trench.

› The bored tunnel has less impact on most issues on Lolland due to the reduced area required for the construction site.

› The land reclamations on Lolland and Fehmarn will be landscaped and ready for development with green areas, nature (§3) areas and recreational facilities at the end of the construction phase. The construction phase for the bored tunnel is 1.5 years longer than for the immersed tunnel giving an advantage to the immersed tunnel.

› The bored tunnel has larger impacts on most environmental issues on Fehmarn due to the larger areas required for the construction site and permanent structures.

› The bored tunnel will result in the emission of 0.7 million tons or 39 % more green house gases in the construction phase.

› The bored tunnel does not impact the German Fehmarnbelt Natura 2000 area and has reduced impact in the construction period on the Danish Hyllekrog-Rødsand Natura 2000 area.

The overall conclusion is that there is a slight but indecisive advantage for the bored tunnel.
2 Introduction

This report concerns the study of environmental impacts of the bored tunnel alternative for the Fehmarnbelt Fixed Link.

2.1 Background and framework for the project

On 3 September 2008 Denmark and Germany signed the State Treaty to establish a fixed link across the Fehmarnbelt. The State Treaty was adopted by the national Parliaments and ratified by the two countries in 2009.

The Fehmarnbelt Fixed Link is planned as a combined rail and motorway link with a double-track electrified railway and a four-lane motorway. The 19 km link will run from Rødbyhavn on the Danish side of the Fehmarnbelt to Puttgarden on the island of Fehmarn on the German side, crossing the Danish – German border midway between the coastlines of the two countries.

The link connecting Scandinavia with Northern Germany will be important for the whole of Europe. The objective of the combined road and rail link is primarily to improve conditions for the transport of passengers and goods. Overall, traffic links will improve greatly from Scandinavia to Germany and eastwards toward the Baltic regions.

Denmark is responsible for the planning and design as well as financing, construction and operation of the Fehmarnbelt Fixed Link. The capital, operation and maintenance costs will be recovered through a toll system.

Under the provisions of the State Treaty, each country is responsible for the approval of the fixed link in their own territory as well as upgrading of their hinterland infrastructure.

In Denmark the State Treaty was ratified by the adoption of Act No. 285 of 15 April 2009 on Project Planning for a fixed link over the Fehmarnbelt, with associated land facilities in Denmark. On the basis of this law the Transport Minister gave the state-owned company, Femern A/S, the responsibility to prepare, investigate, plan and design the Fehmarnbelt Fixed Link. The construction of the
fixed link will be adopted in a separate Construction Act which will also include the environmental approval.

In Germany it is necessary to have two project applicants, one for the rail and one for the road. Femern A/S is the project applicant for the railway section of the link in Germany, while the Schleswig-Holstein State Agency for Road Construction and Transport, Department of Lübeck (Landesbetrieb für Verkehr und Straßenbau des Landes Schleswig-Holstein, Lübeck Niederlassung), is the project applicant for the motorway section of the link in Germany.

The planning and approval process in Denmark and Germany has begun. This involves environmental investigations, geotechnical investigations and investigations relating to maritime safety. In both countries an environmental impact assessment (EIA) will be carried out as a part of the national approval procedures in accordance with national legislation in the two countries. In accordance with the Espoo convention on EIA in a transboundary context, a report on transboundary impacts will be submitted to the countries of the Baltic Sea region.

Before any proposal for a Construction Act is submitted, the EIA will be concluded, approvals will be obtained from the authorities in both Germany and Denmark and an international hearing will be held for the countries of the Baltic Sea region in accordance with the Espoo Convention.

### 2.2 Alternative solutions for the fixed link

The fixed link across Fehmarnbelt forms part of the Transeuropean network (TEN-T). It connects the Copenhagen-Malmö region (with connection to the rest of Scandinavia) with the Hamburg-Lübeck region (with connection to the rest of the European continent), see Figure 2.1. Thus, the link will supplement the existing fixed link across Øresund.

Comprehensive feasibility studies of the environmental and other aspects of the project were conducted in the period 1995 – 1999 (COWI-Lahmeyer, 1999). The feasibility study resulted in a number of feasible solution models, including a cable-stayed bridge, a suspension bridge, an immersed tunnel and a bored tunnel. These solution models were compared and evaluated based on criteria such as environmental impacts, traffic capacity, safety, technical design as well as investment, operation and maintenance costs. It was concluded that a cable-stayed bridge was the preferred technical solution and an immersed tunnel as the preferred alternative solution. The Danish-German State Treaty specified that both solutions should be investigated in parallel.

Studies carried out by Femern A/S since the feasibility study have shown that an immersed tunnel will carry fewer risks in both the construction and operation phases than a cable stayed bridge. Therefore Femern A/S has reversed the recommendation of the feasibility study and the immersed tunnel is now the preferred solution and the cable stayed bridge the preferred alternative.
The impacts of the bored tunnel are compared with those of the immersed tunnel (Chapter 1 Executive Summary) to illustrate the environmental advantages and disadvantages of the two solutions, not only with respect to Natura 2000 areas, but also for the project as a whole.

![Figure 2.1 Location of the fixed link across Fehmarnbelt at the Danish-German border](image)

### 2.3 Legal framework

The principal EU Directives, Danish and German laws and statutory orders and International Conventions governing the execution of an EIA and obtaining environmental approvals are listed below.
2.3.1 EU Directives


Birds Directive 79/409/EEC of 2 April 1979 defining Special Protected Areas (SPA) which are also Natura 2000 areas.


2.3.2 Denmark


Museums Law, no. 1505 of 14 December 2006 (with respect to archaeology).


Selection and administration of Natura 2000 areas and protection of selected species, Statutory Order no. 408 of 1 May 2007.


Fishery Law, no. 978 of 26 October 2008, Ministry of Food, Agriculture and Fishery.


Coastal Protection Law, no. 267 of 11 March 2009.

Law on environmental objectives for waters and Natura 2000 areas, no. 932 of 24 September 2009.


Environmental Protection Law, no. 879 of 26 June 2010.


2.3.3 Germany
Gesetz über Naturschutz und Landschaftspflege af 29/07/2009 (Bundesnaturschutzgesetz).


Raumordnungsplan für die ausschließliche Wirtschaftszone (AWZ) in der Nordsee und in der Ostsee af 19/12/2009 (Raumordnungsplan).

Gesetz zur Ordning des Wasserhaushalts af 31/07/2009 (Wasserhaushaltsgesetz).

Raumordnungsgesetz af 22/12/2008.

Landschaftsrahmenplan für den Planungsraum II: November 2003

2.3.4 International conventions
Convention on the International Regulation for Preventing Collisions at Sea, IMO 1972.

Ramsar Convention of 2 February 1971 defining areas of international importance for birds.
3 Technical Description of the Bored Tunnel

3.1 Major features

The major features of the bored tunnel solution include:

› Three circular tunnels, each approximately 20 km in length - one tunnel for both railway lines and two tunnels for the motorway, each with two lanes and an emergency lane

› Cut and cover tunnels at each portal linking the tunnel to the surface

› Open road and railway ramps that connect to the cut and cover tunnel sections

› Portal structures and buildings at the entrances to the tunnels

› Roads and railway lines on land on both sides connecting the respective tunnels to the existing networks
land reclamation areas at both coasts (the majority off the coast of Lolland) for deposition of the materials excavated by the tunnel boring machines

- Payment systems and facilities for customs and immigration authorities in Denmark and Germany

- Facilities for operation and maintenance, including support for emergency response services in both Denmark and Germany

- Modifications of the surrounding secondary road network

### 3.2 Alignment

The horizontal alignment of the bored tunnel is shown in plan in Figure 1.2 and in longitudinal profile in Figure 1.4. The route passes east of Puttgarden, crosses Fehmarnbelt and reaches Lolland east of Rødbyhavn. The road tunnels are almost straight under Fehmarnbelt while there is a soft curve in the railway tunnel.

![Horizontal alignment of the bored tunnel](image-url)
The actual alignment and landfall locations are based as closely as possible on the Immersed Tunnel corridor that was chosen in a process which included environmental considerations in addition to the costs and technical issues of connecting to the existing infrastructure. The environmental considerations led to the definition of a "low impact corridor" within which the final alignment could be chosen.

Figure 3.2  Geological longitudinal profile of the bored tunnel

3.3 Tunnel design

3.3.1 Motorway and railway tubes

Each tunnel tube is bored with two tunnel boring machines (TBM), each of which starts from excavations on land from Denmark and Germany, respectively, to meet halfway below the Fehmarnbelt. During the boring process, mechanical equipment is used to loosen and remove precisely the quantity of soil required to install the concrete lining that makes up the tunnel wall. The process makes it possible to establish the permanent tunnel deep underground without the need for access to the surface other than at the tunnel entrances.

The railway tunnel has a total length of 21.2 km and the motorway tunnels are 19.6 km long. The motorway's physical interface with the existing infrastructure on land is identical to that of the immersed tunnel project on Fehmarn, but geographically approximately 250 m further inland on Lolland, while the railway interface is 2 km further inland on Fehmarn and 700 m on Lolland relative to the immersed tunnel project. This is because the portal structures are deeper than for the immersed tunnel project and also located further inland.
Various thicknesses of concrete lining are used, depending on the varying load and soil conditions along the alignment.

Thus three TBMs start on Lolland and three on Fehmarn, and the six boring machines meet in pairs below the Fehmarnbelt, where the individual tunnel tubes are joined.

The bored tunnel structures are formed in two parts:

› A pre-cast, segmented, circular concrete lining, consisting of a number of short rings, each of which is approximately 2 m long. Each ring consists of up to 11 individual segments.

› The internal structural components, consisting of a number of pre-cast or in-situ cast concrete elements that are used for road or rail decks, including supporting structures, and for walls in access roads and plant rooms, among other things.

The railway tunnel has a nominal internal diameter of 15.2 m, while the two road tunnels have an internal diameter of 14.2 m (Figure 3.3 and Figure 3.4).

The motorway is approximately 11 m wide, and the road tubes are located west of the railway tunnel. Each road tube contains two traffic lanes, one emergency lane, marginal strips and a step barrier at the walls. At the top of the circular cross-sections, the necessary jet fans and signage are installed.

Figure 3.3  Cross section of the two road tubes
The motorway tubes contain an approximately 2 m wide fireproof side gallery with access from the emergency lane. There will be access via fireproof doors for every approximately 100 m. The gallery also provides access to the levels below the road deck (on the lower floor) via stairs or ramps.

This lower floor contains the necessary plant rooms, a cable duct and a rescue and service road with access for all vehicles of full normal height and with sufficient width to allow two vehicles to pass each other.

The railway tunnel is divided in the middle by a fireproof central gallery and is thus divided into two fire-separated tubes, each with a width of approximately 6 m. Emergency walkways are arranged on both sides of each track and jet fans are installed at the top of each tube.

The dimensions of the railway tubes allow trains to travel through them at speeds of up to 200 km/h, whilst keeping the pressure waves from the trains within an acceptable limit.

The fireproof gallery in the middle is divided into four levels:

- Level -1: Access road for rescue and service vehicles - access to this level from the railway deck on level 0 is via ramps or stairs. Appropriate access roads for rescue vehicles are established in both portal buildings
- Level 0: Gallery at the same level as the railway deck with direct access from each railway tube. Internal gallery width is 1.1 m
- Level +1: Plant room with access for maintenance staff via stairs from level 0. Internal width is 2.5 m
- Level +2: Cable duct – access to this level is via stairs or ladder from level 1. Internal width of the cable duct is 1.8 m

The plant rooms house the electrical transformers that convert high voltage from the main electrical supply into lower voltage that is used for the various tunnel installations. Pump stations and rooms for safety systems, fire protection, lighting, etc. are also established.
3.3.2 Tunnel technical installations

Power
The electrical power supply supports all systems within the tunnels and the portal buildings except for the railway traction power. A number of high voltage cables with transformers will be installed in the plant rooms.

Electricity from Danish sources will be used to power the full length of the tunnels for normal operation. A German supply will power the German landside facilities under normal operating conditions.

Ventilation
The ventilation system consists of several sub-systems:

- Ventilation of the road and rail tubes
- Ventilation/cooling of plant rooms in the tubes
- Ventilation of the central gallery between the road tubes
- Ventilation/cooling in the portal buildings

The road and rail tubes are provided with a system of jet fans to assist ventilation when necessary (Figure 3.3 and Figure 3.4). The system is capable of handling normal operation as well as maintenance and emergency situations. During normal
operation the tunnel will primarily be self-ventilating due to the piston effect of vehicles and trains dragging air through the tunnel.

**Fire protection and suppression**

A water-based deluge system will be installed in both road and rail tubes. The system is designed to limit the size and spread of a fire, and thus has a number of positive safety effects, including:

› Better conditions for self-rescue  
› Better conditions for intervention by fire and rescue services  
› Protection of the tunnel structure and fixed equipment from excessive damage until fire and rescue services appear

The system is divided into short zones. The relevant zones are activated by the control room operator on the basis of information from the monitoring systems.

The deluge system is designed to keep any fire under control until the arrival of the fire services. Upon their arrival, it is expected that the fire brigade will assume control of the event (assisted by the tunnel authorities). A separate permanently pressurised fire hydrant system will provide water for the fire services, enabling them to extinguish the fire.

**Tunnel drainage**

A drainage system will be established in the tunnel tubes to cater for rainwater runoff from the approach ramps, seepage, wash-water, spillages and fire-fighting water. Pump sumps will be provided at 2.4 – 2.5 km intervals to pump the liquids to the portal buildings where they will be treated in accordance with environmental regulations before being discharged to Fehmarnbelt.

The water used for cleaning the road tubes contains the same pollutants as normal storm water run-off from a motorway, with a content of heavy metals, polycyclic aromatic hydrocarbons (PAH), oil and suspended solids. There will also be soap in the wash water.

In case of accidents a mixture of chemical spills and fire fighting water can be collected and contained by the drainage system for subsequent processing.

**Lighting**

Lighting within the road tubes is of primary importance for safety, particularly the prevention of traffic accidents, but will also have a significant influence on the aesthetic impression of the tunnel environment. Creative lighting with different shades of colour and decorations on the tunnel walls will relieve or reduce any discomfort users may have from driving in a tunnel. See Figure 3.3.

The road tube lighting will account for a significant part of the power consumption within the tunnel. However, the rapid development of LED light sources will probably make it possible to fulfil the lighting requirements with significantly lower energy consumption than with the present technology.
In the event of a power failure, part of the lighting system will be powered by an emergency supply. A secondary lighting system will include a series of lighting components aimed at creating safe conditions for exiting the tunnel. Escape routes will thus be lit and unambiguous signage such as lit door surrounds, lit exit signs and roadway guidance lights will be installed.

Permanent lighting is not planned in the rail tubes. However, emergency lighting will be provided for use in the event of evacuation. See Figure 3.4.

Communication
The communication systems comprise an array of different systems for use during normal operation and during emergencies.

During normal operation, public broadcast radio within the tunnel and the provision of antennae for mobile telephones will provide the comfort required by the tunnel users. In case of emergency, users can phone from one of the emergency stations in the tunnel, and the tunnel staff can address persons in the tunnel via a Public Address system (PA system).

The Closed Circuit Television system (CCTV) is also a key system, which will provide detailed information on all incidents in the road and rail tubes. During incidents or emergencies a public address system in combination with an Intelligent Transportation System (ITS) will be used to guide road users and regulate traffic. In addition, the fire and rescue services’ radio systems will provide an independent communication system for the emergency services.

Traffic management
Road traffic is supervised in a control and supervision centre located in the portal building on the Danish side. The rail system is supervised by the Danish and German rail traffic control.

An Intelligent Transportation System (ITS) will be installed to manage traffic inside the road tubes and on the landside approach motorways on both Fehmarn and Lolland.

The system comprises signs with variable commands or text, for example speed limits and warning signs in addition to supplementary text messages. The ITS will be used in both normal and emergency situations to communicate necessary information and control the flow of traffic by, for example, lane or tube closures or changes in the speed limit.

All vehicles passing the tunnel portals will be monitored and guided by the system. Toll systems for road traffic will also be established at the portal buildings.

SCADA
The SCADA (Supervisory Control and Data Acquisition) system supervises and controls all the technical systems in the tunnel and the portal buildings, with the exception of the rail system, which is supervised by Danish and German rail traffic control.
The primary supervision centre linked to the SCADA system will be in a control room in the Lolland portal building. This is supplemented by a secondary control room in the Lolland portal building and an emergency control room on Fehmarn. The SCADA system facilitates maintenance and assists in creating a high level of safety and reliability.

Railway systems
The rail systems inside the tunnel include the following:

- Railway tracks
- Catenary systems
- Signalling and control systems

3.4 Reclamation areas
Reclamation areas are planned along both the German and Danish coastlines to accommodate the material excavated by the TBMs. The areas will be landscaped into green areas.

The size of the reclamation area on the German coastline has been minimised. Two larger reclamation areas are planned along the Danish coastline on both sides of Rødbyhavn. These will absorb the majority of the material from the bored tunnels.

The material excavated by the TBMs is slurry which will be dewatered before being deposited in the reclamations. More than 36% of the material will still have a high water content and will resemble thick mud even after the dewatering. Such material will take in the order of 4 to 15 years to consolidate to the stage where it can be accessed by people and machines to develop the green areas, depending on the effectiveness of the dewatering and management of the maturing soil.

3.4.1 Lolland
The extent of the reclamation area on Lolland is located on either side of the existing harbour, see Figure 1.5. The reclamation area extends approximately 3.7 km east and 3.5 km west of the harbour and reaches approximately 500 m into the Fehmarnbelt.

The total area is approximately 330 ha, with approximately 130 ha west of the harbour and approximately 200 ha east of the harbour.

The existing dike along the coastline will be largely retained and will continue to function as the storm surge dike. Stone protection will be placed in front of the new reclamation areas facing the sea.
New beaches will be established within the reclamation areas to the west. One beach is connected to the existing harbour via a series of small channels that are interlinked to a long lagoon for recreational activities, water sport, swimming, etc.

To the east there will also be a lagoon with two openings towards Fehmarnbelt and with breakwaters at the openings to limit the wave flow into the lagoon area – this lagoon will have a more natural wetland appearance.

In its final form, the reclamation area will consist of three types of landscape: recreation areas, wetlands and grasslands - each with different natural conditions and potential uses, see Figure 3.6 and Figure 3.7. The different areas can still be modified to provide the best conditions for wildlife and recreational activities.
Figure 3.6  Lolland portal and ramps

Figure 3.7  Landscaping of reclamation on Lolland
3.4.2 Fehmarn

The extent of the Fehmarn reclamation is shown in Figure 1.6. The reclamation area is designed as an extension of the existing terrain with the natural hill turning into a plateau behind a dike. The shape of the dike is designed to include a new beach close to the residential areas at Marienleuchte.

It is intended that the new land is to be landscaped to create an enclosed pasture and grass-land habitat.

![Figure 3.8 Fehmarn reclamation area, portals and ramps](image)

3.5 Land works – Lolland

A number of infrastructure improvements will be made on land in both Denmark and Germany, including the construction of a new motorway and railway to access the tunnels. An overview of the works on Lolland is shown in Figure 3.9.
Figure 3.9  Overview of the works on Lolland
3.5.1 Portals and ramps
The location of the portals is governed by the need for tunnels to be covered by soil with a depth of at least one tunnel diameter in order to ensure stability of the tunnel structure. Where the tunnels approach the land surface they must be covered with additional soil in the form of an embankment to give the required depth of soil and weight over the tunnel. The actual locations were chosen through a qualitative optimisation of costs and environmental impacts (loss of existing land surface under the added cover and due to excavation for ramps).

The result is that the portals are situated inland from the coast and not in the reclamation area as is the case for the IMT. The road portal is 50 m from the existing dike and the rail portal a further 550 m inland. The road portal is closer to the coast since the vertical slope can be greater for a road (3.5%) than a railway (1.25%). See Figure 3.6 and Figure 1.7, the latter also showing the added cover (made ground) over the tunnels.

The portals and ramps can be constructed in an open excavation. The principles of the structure are illustrated in Figure 3.11. The launch box is a concrete structure where the TBMs start excavation. The portal building will be placed on top of the tunnel. Depending on the final landscaping, the portal building could be constructed below or above the surface. The cut and cover section is a concrete cast in-situ tunnel and could be followed by a light attenuation zone which eases the transition from tunnel to open air. Finally, the ramp brings the road or rail up to the natural surface. The road ramp will have a length of approximately 500 m and the rail ramp 1,700 m.

![Figure 3.10 Location of Lolland portals and ramps](image-url)
The ramp and light attenuation zone will be constructed as an open U-formed concrete construction. The rail ramp will have an emergency road at the side. This emergency road stretches along the whole length of the ramp and will function as a service road, as well as an emergency road. Ground anchors will be required along much of the ramp length to counteract buoyancy.

The required cutting will be done by an open excavation. The ramp consists of a watertight structure with a retaining height at a minimum of +0.3 m MSL. Above this level, slopes to the crest of the dikes are applied.

### 3.5.2 New motorway and railway

A new four lane motorway is to be constructed on Lolland for approximately 3.5 km north of the ramp. The road will be connected to a future upgrade of the motorway leading into the Danish hinterland.

This new motorway rises out of the tunnel and passes onto an embankment. The remainder of the route of the motorway is approximately at level. Towards the northern end of the motorway, a new interchange is provided to connect to the local road system.

A new electrified twin track railway is to be constructed on Lolland for approximately 3.0 km north of the ramp. Like the motorway, this new railway will be connected to a future railway upgrade leading into the Danish hinterland.

### 3.5.3 Toll plaza and customs area

A facility for motorway toll collection will be established on the Danish landside. The collection method has not yet been decided. Therefore, a traditional toll station is included in the conceptual design. This is located immediately north of Færgevej, as shown in Figure 3.12.
A lay-by is provided beside the motorway to the tunnel in each direction for use by Danish authorities’ police- and customs officials. The customs areas are located next to the proposed site for the toll station, as shown in Figure 3.12.

The lay-bys have been designed so that they can also be used for maintenance purposes or by the emergency response services.

3.5.4 Modification of side roads
The construction of the landside motorway will require some of the side roads on Lolland to be diverted. The roads affected include Østersøvej, Strandholmsvej and Humlegårdsvej. Other roads will require minor modifications.

3.5.5 Secondary structures
New landside bridges will be required on Lolland at the following locations:

› Near the portal building to provide access to both carriageways for emergency and maintenance traffic
› Where the proposed motorway intersects the side road Færgevej
› Where the proposed railway intersects the side road Færgevej
› A new road bridge as part of the new motorway interchange on Lolland

A number of small drainage culverts will be required as part of the landside works.

Figure 3.12 Possible location of toll station and customs areas on Lolland
3.5.6 Storm surge protection
The storm surge protection consists of a system of dikes around the perimeter of the portal and ramp area and is designed to protect the tunnels and portal building against flooding. The perimeter dike is shown in the principle sketch in Figure 3.11.

The flood protection structures are designed to accommodate the natural settlement of the south coast of Lolland, a sea level rise due to global warming and a 1 in 10,000 years storm surge frequency. If sea level rise due to climate change is in line with the predicted trend, provisions have been made for the dikes to be raised at a later time to an even higher level equivalent to the level in 120 years’ time, by the addition of an extra layer of 0.5 m.

The dike around the road portal and ramp will continue until the road level reaches the crest level of the dike (+5.75 m MSL). This is not possible for the rail due to the low permissible gradients. In the event of an extreme storm surge rising above +2.5 m MSL, provision has been made for storm surge protection barriers to be placed across the railway at the end of the railway ramp.

3.5.7 Drainage within dike perimeter
The surface water within the dike perimeter is divided into two categories:

- Run-off from the motorway and rail ramp area
- Run-off from the landscaped slopes, outside the ramp areas

The run-off from roads is potentially contaminated with pollutants. Drainage systems are therefore installed within the ramp areas to carry this run-off down to the main sump, located beneath the portal building (shown in principle in Figure 3.13). From here, the run-off will pass through a system of pumps to a discharge tank and will subsequently be treated before being discharged into the Fehmarnbelt.

The rainwater that accumulates on the slopes outside the ramps will be discharged without treatment. This run-off is therefore piped to a green sump from where it is discharged directly into the Fehmarnbelt.
3.5.8 Drainage outside dike perimeter

The run-off from the motorway and railway is collected in closed pipes or open ditches, and discharged after treatment via existing watercourses into the Fehmarnbelt.

It is envisaged that the northern sections of the structures on Lolland will drain into the existing watercourse system. The water collected is led to new retention basins with oil separators and sand traps in order to treat run-off and retain any polluted spillages. For the southern section of the alignment, nearest the portal building but outside the dike, it is envisaged that run-off can be discharged into the Fehmarnbelt.

Rainwater that falls directly onto the dike (and not onto the road or railway) will drain into shallow open ditches at the foot of the dike. As this water has not come into contact with the road or railway, it can be treated as “green water” and discharged directly from the system without further treatment.

3.6 Land works – Fehmarn

An overview of the land works on Fehmarn is shown in Figure 1.8.
Figure 3.14  Overview of land works on Fehmarn
3.6.1 Portals and ramps

The design of the Fehmarn portals and ramps are in principle similar to that on Lolland. The road and rail portal locations are separated and both are further inland than for the IMT as shown in Figure 3.15. The road portal is 350 m from the present coastline and the rail portal is 950 m.

The road ramp will have a length of approximately 350 m and a gradient of 3.5%. The rail portal will be situated on the south side of the hill on Fehmarn. The ramp will have the same maximum gradient as the tunnel, at 1.25%. The length of the ramp will measure approximately 1,400 m, including the cut and cover part.

![Figure 3.15 Location of Fehmarn portals and ramps](image)

3.6.2 New motorway and railway

A new four lane motorway is to be constructed on Fehmarn for an approximately 3.5 km section south of the portal building. It will ultimately be connected to a future upgrade of the motorway leading to the German mainland.

This new motorway rises out of the tunnel and passes over an embankment and a bridge crossing the existing harbour railway. The remainder of the motorway is approximately at level with the surrounding terrain. Towards the southern end of the motorway, a new interchange is built to connect to the existing local road system.

A new electrified dual track railway is to be constructed on Fehmarn for an approximately 3.5 km section south of the portal building. Like the motorway, this new railway will be connected to a future upgrade of the railway leading to the German mainland.
A new railway junction will be built approximately 2.5 km south of the portal building, allowing trains to both access the existing railway to the harbour and continue towards the tunnel.

### 3.6.3 Customs area
A lay-by is built on both sides of the proposed motorway for use by German authorities. The lay-bys can also be used for maintenance purposes or by emergency response services. The locations of the customs areas are shown in Figure 1.8.

### 3.6.4 Modification of side roads
The construction of the motorway and railway on land will require some of the side roads on Fehmarn to be diverted or modified. The roads affected include Marienleuchter Weg and Rethen, located between Puttgarden and Marienleuchte, and Dorfstraße, south of Puttgarden. Other roads will require minor modifications.

### 3.6.5 Secondary structures
New bridges will be required on Fehmarn at the following locations:

- Where the proposed railway intersects Rethen
- Where the proposed motorway intersects Marienleuchter Weg
- Where the proposed motorway crosses the existing harbour railway
- A new road bridge as part of the new motorway interchange on Fehmarn (not part of this project)
- A new road bridge over the proposed railway adjacent to the motorway interchange (not part of this project)

A number of small ditches will be required as part of these works on land.

### 3.6.6 Storm surge protection
The protection of the tunnels, portals and ramps against flooding from storm surges will be achieved in the same way as described for Lolland in section 3.5.6 above.

### 3.6.7 Drainage within dike perimeter
The drainage systems within the dike perimeter on Fehmarn will be designed in accordance with German regulations and will in principle be similar to those on Lolland, see section 3.5.7 above.

### 3.6.8 Drainage outside dike perimeter
Rainwater management along the new alignments will aim to prevent flooding and erosion as well as improve water quality through the inclusion of basins for retention and treatment. The run-off from the motorway and railway is collected in
closed pipe systems, and is after treatment discharged into either existing watercourses or directly into the Fehmarnbelt.

The southern sections on Fehmarn will drain into the existing drainage system. The quantity of run-off discharged into these watercourses must be controlled in accordance with the guidance of the German water authorities. Retention basins are therefore provided with sufficiently large volumes to store run-off and control the outflow into the existing watercourses. Retention basins will also be installed as part of the motorway’s drainage system to allow cleaning of the rainwater and separation of pollutants such as oil.

Rainwater that falls outside the dike (and not onto the road or railway) will drain into shallow open ditches at the foot of the dike. As this water has not come into contact with the road or railway, it is discharged without further treatment.

3.7 Construction works

This section describes the construction of the bored tunnel, with particular focus on the temporary work harbours, the tunnel construction and lining, the slurry dewatering and the filling of the reclamation areas.

3.7.1 Resource requirements

Table 3.1 indicates the approximate requirements for the major resources that will be needed to construct the tunnel permanent works. These quantities are subject to variation during the detailed design.

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete in tunnel lining</td>
<td>1,842,000 m³</td>
</tr>
<tr>
<td>Reinforcing steel for tunnel lining</td>
<td>246,000 tonnes</td>
</tr>
<tr>
<td>Concrete for internal structures in tunnels</td>
<td>1,281,000 m³</td>
</tr>
<tr>
<td>Reinforcing steel for internal structures in tunnels</td>
<td>160,000 tonnes</td>
</tr>
<tr>
<td>Structural concrete for launch boxes, portals, portal buildings, cut &amp; cover and ramps</td>
<td>274,000 m³</td>
</tr>
<tr>
<td>Reinforcing steel for structural concrete</td>
<td>3,430 tonnes</td>
</tr>
<tr>
<td>Tie down anchors</td>
<td>Approx. 3,000</td>
</tr>
<tr>
<td>Armour rock for coast protection</td>
<td>340,000 m³</td>
</tr>
</tbody>
</table>
3.7.2 Temporary work harbours

Three temporary work harbours are planned: two on the Danish side at Rødbyhavn and one on the German side at Puttgarden.

The Danish work harbour east of Rødbyhavn will be located immediately east of the landfall of the tunnel (Figure 1.9 and Figure 3.17) and will be integrated into the production site for the construction of the tunnel lining. During peak production a certain number of vessels use the harbour simultaneously. The vessels will bring in construction materials like armour rock, gravel, sand, cement and reinforcement and barges will bring spoil from the slurry separation plant on Fehmarn.

The second Danish work harbour will be west of Rødbyhavn (Figure 3.18) and will be used solely to supply the materials required for the reclamation, i.e. armour rock and spoil from the slurry separation plant.

The Fehmarn work harbour will be located on the eastern side the reclamation area (Figure 1.10 and Figure 3.20). It will serve the same purposes as the main Lolland work harbour.

The work harbours will be dredged to provide the necessary depth for access by the ships and barges. The main work harbours will require the depths of -9.5 m MSL while the second Danish harbour requires -7.5 m MSL for the tugs and barges with spoil for the reclamation. Access channels with the same depths will be required for all three work harbours.

How the harbours and work sites will be finally arranged and which activities will take place where is to a great extent dependent on the preferences of the consortia of contractors. The descriptions given here have been made under the following overall assumptions:

› The harbours with work sites are established in the initial phase of the project.

› The work harbours and work sites are temporary. After completion of the construction works, quay walls, breakwaters, buildings and pavements will be removed and the harbours filled in accordance with the plans for the reclamation areas. The access channels will not be filled.

Each of the temporary work harbours will require the following:

› A navigable access channel
› A harbour basin with manoeuvring space for vessels
› A quay to unload vessels
› A service jetty for staff
› A hard covered area for storage as part of the quay structure
Figure 3.16  Main Lolland work harbour and construction site
Figure 3.17 Layout of the main Lolland work harbour

Figure 3.18 Layout of Lolland work harbour west of Rødbyhavn

Figure 3.19 Fehmarn work harbour and construction site
3.7.3 Dredging methods

Mechanical dredging with backhoes is envisaged to be used for the work harbours and access channels. The volumes of excavation are shown in Table 3.2. All the dredged material at the Lolland side will be clay till while on the Fehmarn side it will be a mixture of clay till and sand. The total in-situ volume of dredging will be 2,590,000 m³.

The dredged material will be re-used in the reclamations or stored in a depot for later refilling of the harbour basins. It is assumed that the dredged material will maintain its in-situ characteristics to a certain extent.
Table 3.2  Dredging volumes (m$^3$ in-situ) for work harbours

<table>
<thead>
<tr>
<th>Basin</th>
<th>Lolland east (main) harbour</th>
<th>Lolland west harbour</th>
<th>Fehmarn harbour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harbour basin</td>
<td>698,000</td>
<td>362,000</td>
<td>794,000</td>
</tr>
<tr>
<td>Access channel</td>
<td>477,000</td>
<td>124,000</td>
<td>135,000</td>
</tr>
<tr>
<td>Total</td>
<td>1,175,000</td>
<td>486,000</td>
<td>929,000</td>
</tr>
</tbody>
</table>

3.7.4 Tunnel construction and lining

The tunnels are bored and lined with concrete rings by six tunnel boring machines, each of which must carry out the almost 10 km of boring from land to the connection point below the Fehmarnbelt.

Boring method

A bored tunnel is created with a tunnel boring machine, which in principle is a mobile factory.

![Tunnel boring machine](image)

The boring operation takes place by the soil ahead of the machine being loosened by using a number of cutting discs and teeth fitted in the rotating cutter head at the front end of the tunnel boring machine. The hardened teeth are used to cut/loosen the softer materials, while the circular discs break down stones and boulders. The cutter head rotates slowly (typically 3-5 RPM) while being pressed forwards. The bored soil is transported into a collection chamber via holes in the cutter head, as shown in Figure 3.22.

The cutter head is enclosed in a watertight steel shield which protects against any soil and water ingress until the permanent concrete lining (concrete rings) can be installed, which will then serve the same purpose.
The cutter head is specially manufactured to match the specific soil conditions and the size and length of the bored tunnel. In the Fehmarn project, all six boring machines are expected to be slurry-shield TBMs that operate using a special mixture of slurry containing bentonite. This stabilises the boring front (the soil) in front of the cutter head and is further mixed with the bored materials so that they can be pumped through a pipeline to the respective separation plants on land.

On larger slurry TBMs, it is possible to create access to the cutter head for maintenance under atmospheric conditions without any risk of the boring machine and its back-up system being flooded in the event of high water pressure at the excavation face.

As each tunnel boring is very long and passes through several different types of soil, which can cause high wear on the cutter head, regular maintenance of the cutter head and its cutting tools is essential. All the cutting tools can be replaced by the TBM personnel under atmospheric conditions. In an emergency, it may be necessary to access the working chamber in front of the cutter head. This access is complicated by the fact that there is a total pressure in front of the cutter head of up to approximately 6 bar.

Access to the working chamber can take place via air locks in the front section of the tunnel boring machine. The air locks allow tunnel personnel without specialist training to operate under pressures of up to 3.6 bar. At a pressure of more than 3.6 bar, special divers are required to enter the working chamber, which complicates
the work considerably. It is estimated that up to two such interventions will be required on each TBM to undertake such repairs.

The boring machines are equipped with a stone crusher fitted at the base of the machine. This crusher breaks down large stones into smaller pieces that can be transported with the other materials in the slurry through the pipeline to land. The primary method of handling boulders and stones is to crush them while they are still firmly fixed in the soil in front of the cutter head. The boulders are broken down to a suitable size so they can pass through the openings of the cutter head to the stone crusher.

All the materials are pumped to large separation plants on land that separate the bored materials from the slurry, which is reused.

Immediately behind the shield, the permanent concrete lining is installed in the form of segments that make up a full ring. The individual segments are installed with a special crane. Mortar is used as grouting between the concrete ring and the soil to ensure full contact between the tunnel structure and the surrounding soil.

For the bored tunnel, the investment costs of the TBMs amounts to less than 10 per cent of the total construction costs, but the performance of each of the six TBM’s is paramount to the success of the project. TBM functionality has to take into account the specific conditions such as high water pressure, the large diameter tunnel, the abrasive nature of the soil, the properties of the unique paleogene clay and the presence of boulders. Although all of these issues can be designed for, it is quite a challenge to construct a tunnel facing all of these conditions; however, although very challenging, it is considered technically feasible. No existing projects have ever made such a large tunnel over such a long distance, and it is therefore considered that this project cannot be considered as proven construction technology.

**Internal concrete lining**

Each of the three tunnels will be lined with approximately 10,000 concrete rings, each consisting of 11 segments. A total of 330,000 segments will therefore be cast. Each ring consists of ten standard segments and one wedge-shaped element that 'locks' and secures the finished concrete ring in position.

Each segment is provided with a sealing rubber gasket along the sides. As the segments are installed, the gaskets are pressed together so that water cannot penetrate into the tunnel through the joints. The gaskets can withstand water pressure of up to 15 bar. Each segment is bolted to the adjacent segment in the ring, and each ring is also bolted to the adjacent ring.

The segments are installed by using special equipment from inside the tunnel boring machine which, by using a vacuum erector, lifts the individual segments and places them in position.

The thickness of the linings is expected to be at least 600 mm in sections where the tunnel passes through the hard, glacial clay-till. The Puttgarden area, on the other
hand, has more difficult soil conditions which may require a thicker concrete lining of approximately 750 mm in all three tunnels.

Installation of other internal concrete elements
Some other important structural elements for the tunnel construction are:

› Motorway deck and railway deck
› Galleries at road and track level
› Sub-tunnel refuge and plant rooms
› Cable ducts
› Ramp structure
› Sump rooms

The motorway and railway decks and the rooms and galleries in the tunnel will be built with pre-cast elements, where possible. This will make it possible to transport and install these elements immediately behind the TBM. They will be installed with a rolling gantry cranes working right behind the TBMs.

Mid-tunnel docking of the TBMs
In order to optimise the entire boring process and limit wear on the boring machines, the project is planned in such a way that two boring machines will bore each of the 20 km tunnels, each starting from the respective coasts, with each TBM boring 10km.

When the two boring machines meet below the Belt, the machines' outer shield will create the necessary protection to establish a safe working chamber for the concluding construction works, including in-situ casting of the internal concrete lining. The rest of the boring machine will then be dismantled and removed including the associated back-up system.

Production of tunnel boring machines
The tunnel boring machines are fabricated outside the construction site by a specialist producer. The number of producers who have previously produced tunnel boring machines of the size and quality required is limited to the European mainland, Japan or North America.

The purchase of the tunnel boring machines, with contract negotiations, design, production, delivery and installation on site, is a critical activity - the production of the 6 boring machines in itself is estimated to last in the order of 12 months. It is also important for the portals and lunch boxes to be ready at the time at which the machines are delivered and installed.

3.7.5 Slurry dewatering
The material excavated by the TBMs will be in the form of a slurry with particles ranging from rocks to clay balls, sand, silt and clay fully dispersed in the water. The material must be dewatered before it can be deposited in the reclamations and this requires special Slurry Treatment Plants (STPs) on both Lolland and Fehmarn.
In-situ geology
Based on the geotechnical information available, it is possible to predict the nature of the material that will be excavated on both sides and will require processing, see Table 3.3.

Table 3.3  Soil quantities excavated by the TBMs

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Quantity (in-situ m$^3$)</th>
<th>Lolland</th>
<th>Fehmarn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay till with floes of Palaeogene clay</td>
<td>552,459</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Palaeogene clay</td>
<td>2,296,979</td>
<td>16,186</td>
<td></td>
</tr>
<tr>
<td>Clay till lower glacial unit</td>
<td>742,438</td>
<td>1,224,247</td>
<td></td>
</tr>
<tr>
<td>Clay till upper glacial unit</td>
<td>2,275,235</td>
<td>4,626,662</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5,867,111</strong></td>
<td><strong>5,867,095</strong></td>
<td></td>
</tr>
</tbody>
</table>

Slurry Treatment Plant
The STP is designed in accordance with the composition of the slurry. Figure 3.23 shows the proposed schematic arrangement of the plant. The plant consisted of a combination of sieves, hydrocyclones in three stages and chamber filter presses.

![Figure 3.23 Typical Slurry Treatment Plant schematic arrangement](image)

The slurry first passes through a series of sieves which remove all particles larger than 3 mm. The screen overflow (solids) are discharged to a conveyor belt system and taken away for storage. The remaining slurry, called underflow, is pumped to the first hydrocyclone stage.
Hydrocyclones separate solids from fluid by centripetal forces induced by the geometry of the devices. The first stage separates particles from 3 to 0.5 mm (coarse sand), the second 0.5 to 0.1 mm (sand-silt) and the third 0.1 to 0.01 mm (silt-clay). The final filter chamber presses removes particles less than 0.01 mm (clay).

The underflow from the first and second hydrocyclone stages is coarse enough to be sieved producing solid material with a low water content. On the other hand the combined material produced by the third hydrocyclone stage and the filter presses will still have a high water content after processing and is referred to as “cake” or “mud”.

Note that some of the slurry containing the finer particles is recycled to the TBM after mixing with additional bentonite as necessary.

The plant grades the materials into the following fractions:

- Spoil that can be reused/incorporated immediately
- Spoil that cannot be reused immediately, and needs further stabilising before it can be used/incorporated
- Water
- Residual material waste and any contaminated soil

Table 3.4 shows the typical natural grading of the materials, based on the input quantities. This preliminary table does not make any allowance for water content or of the use of flocculants, but does show clearly the nature of the material to be processed.

<table>
<thead>
<tr>
<th>Table 3.4 Predicted soil grading of material from the STP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In-situ quantity (m³) / %</strong></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td><strong>Particle size (mm)</strong></td>
</tr>
<tr>
<td>Lolland</td>
</tr>
<tr>
<td>Fehmarn</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

The water is processed in a water treatment plant on site to a suitable level for direct discharging into the sea, or into a local watercourse.
The potential for reuse of the various solid materials will depend largely on the water content, and the resulting strength of the material. The project assumes that all material from the STPs to some extent can be used for land reclamation in the following areas:

- Approximately 15% of the volume for the Puttgarden land reclamation area – the materials are transported from the separation plant via conveyor belts either to dumpers for further transport or directly into the land reclamation area.
- Approximately 85% of the volume for the Lolland land reclamation area:
  - Transported from Fehmarn via a conveyor belt to a ship or barge sailing to the work harbours on Lolland
  - Further transport is by conveyor belt either to dumpers for further transport or directly into the land reclamation area
- Controlled disposal facility for any contaminated residual product

Approximately 36% of the material (Table 3.4) is expected to be fine-grained - less than 0.01 mm. It will be more difficult to reuse this fraction of very fine material, but it is assumed that it also can be handled as part of the reclamation works. The proposed separation method is expected to reduce the water content to an acceptable level. However, the weak strength of the material means that driving with vehicles and even walking on top of the reclamation may not initially be possible everywhere. International experience indicates that it will take in the order of 4 to 15 years for the soil to consolidate to the stage where it can be accessed by people and machines to develop the green areas, depending on the effectiveness of the dewatering and management of the maturing soil. After this period the land can be developed or otherwise used freely without further soil management.

However, for the Fehmarnbelt Fixed Link it is important that the reclamation is ready for development latest at the end of construction since the green areas on the reclamation are proposed as part of the compensation for lost green areas. It is expected that a technical solution can be found, e.g. mixing the clay with the other coarser fractions before deposition in the reclamation. The actual solution will be elaborated at the appropriate time.

### 3.7.6 Reclamation method

The material to be placed in the reclamation areas consists of a combination of:

- TBM excavated and dewatered spoil
- Mechanical dry excavation from portals and ramps
- Mechanically dredged material from work harbours and access channels

The soil structure is disturbed or, in the case of the TBMs, destroyed by the excavation process and the volume to be placed in the reclamation is greater than the in-situ volume. The bulking factor depends on the material and the excavation method and varies from 1.2 for the mechanically excavated soils to 2.0 for the finest fraction from the TBMs. The result is that the volume of material to be placed in the reclamation is approximately 22 million m³.
36% of the volume will of the fine-grained material, with a consistency of a soft cake, but could be more like that of a thick mud, depending on the effectiveness of the dewatering process. In all cases, the material will require special treatment in the reclamation in order to make it suitable for the final purpose of green nature and recreational areas.

The method for filling the reclamation areas is shown in principle in Figure 3.24.

- First the outer containment dikes are constructed and protected with rock armour.
- Then a series of internal dikes are constructed from the coarse fractions.
- Finally the soft cake/mud and other fill are placed in between the internal dikes.

The fine-grained material may still have a water content of 75% when it is deposited in the reclamation and will only consolidate if provision is make for draining the soil. This is achieved by placing layers of sand at regular vertical intervals in the cake/mud as illustrated in Figure 3.25. The water draining from the cake/mud will collect on the impermeable layer of Palaeogene clay balls and can be pumped away. However this is a slow process, particularly when the surface is not protected from rain, and it may be some years before the cake/mud is consolidated.
Figure 3.25  Proposed internal structure in the reclamation areas

3.7.7 Lolland and Fehmarn construction sites

The temporary construction sites required for the construction of the tunnels, portals, ramps and portal buildings constitute the largest construction areas in the project.

The construction sites will include the following activities:

› Factory for pre-casting the tunnel lining segments
› Storage area for pre-cast segments
› Separation plants for handling the bored soil material with associated storage area
› Office and workshop facilities

The present availability of hotels, restaurants, leisure and entertainment facilities is limited near the construction sites, particularly on Fehmarn. Therefore it is foreseen that temporary facilities will be established for, e.g. hotels, housing, restaurant or canteen, stores, entertainment, welfare, offices for client and contractor and parking.

It is estimated that an area of 30 ha will be required for each TBM worksite, i.e. a total of 90 ha on both Lolland and Fehmarn. Possible layouts for the construction sites are illustrated in Figure 3.24 and Figure 3.26 for Lolland and Fehmarn respectively. Figure 3.27 and Figure 3.28 show the suggested layout of the two constructions sites.
Figure 3.26  Fehmarn construction site
Figure 3.27 Layout of Lolland construction site
3.7.8 Construction of portal buildings and ramps

The portals and ramps will be constructed in an open excavation. Land-based excavation methods will be used. Due to the requirement to provide a certain amount of ground cover to allow tunnel boring, a relatively deep construction pit is needed. Dewatering with deep pressure relief wells will be required to keep the excavations free of water and to counteract buoyancy which would cause failure of the base.

The road and rail tunnels are separated so that separate portal buildings are needed. The buildings can be placed on top of the tunnels and it is assumed that the area available will be large enough to accommodate all the required equipment.
The tunnel portals will be built at the same time as the production and delivery of the tunnel boring machines. This requirement drives the entire construction programme for both the portal buildings and ramp structures on Fehmarn and Lolland.

In order to be ready for the first TBM to be launched, the portals and ramps need not be totally complete. However, it is essential that the following elements are finished:

› Initial launching box for the boring machines and headwall structure
› Dikes to protect the portal buildings and the new land reclamation areas
› Temporary work harbours with access channels
› Temporary sea defences, sufficient to protect the portal area until the permanent sea defences are in place

There are also a number of non-critical works which do not need to be completed prior to the launching of the TBMs:

› Casting of non-critical parts of the cut and cover tunnel
› Casting of concrete ramps
› Construction of cable ducts
› Completion of permanent dikes and permanent sea defences
› Construction of portal buildings
› Earthworks for the road and railway ramps, including drainage works
› Laying of motorway road base and asphalt and installation of motorway equipment

3.7.9 Earth balance

A basic assumption of the earth balance is that it should be closed, i.e. all soil is to be reused within the project. This will result in the reuse of any surplus soil as land reclamation on Lolland and Fehmarn. The earth balance is demonstrated in Table 3.5.

Table 3.5 Earth balance summary

<table>
<thead>
<tr>
<th>Item</th>
<th>Bulked volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavated and imported soils</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Excavation TBM</strong></td>
<td></td>
</tr>
<tr>
<td>Lolland</td>
<td>8,656,000</td>
</tr>
<tr>
<td>Fehmarn</td>
<td>9,160,000</td>
</tr>
<tr>
<td><strong>Portals and ramps</strong></td>
<td></td>
</tr>
<tr>
<td>Lolland rail</td>
<td>1,996,000</td>
</tr>
<tr>
<td>Lolland road</td>
<td>892,000</td>
</tr>
</tbody>
</table>
**Item** | **Bulked volume (m³)**
--- | ---
Fehmarn rail | 1,370,000
Fehmarn road | 1,093,000

*Work harbours including access channels*

Lolland east | 1,410,000
Lolland west | 583,000
Fehmarn | 1,115,000

*Imported soils*

For landscaping | 740,000
For production sites | 0
For top sand layer in reclamations | 240,000

**TOTAL excavated and imported volume** | **27,255,000**

*Proposed soil reuse*

Backfill rail and road portals Lolland | 1,663,000
Backfill rail and road portals Fehmarn | 1,194,000
Overburden and embankments Lolland (dry) | 1,039,000
Overburden and embankments Fehmarn (dry) | 835,000
Dike construction Fehmarn | 176,000
Dike construction Lolland | 715,000
Landscaping Lolland | 230,000
Landscaping Fehmarn | 230,000
Fehmarn reclamation area | 2,250,000
Lolland reclamation area | 18,923,000

**TOTAL reuse volume** | **27,255,000**

3.7.10 Power and water supply

The TBM's and the STPs require a large power supply. During the construction phase it is estimated that 55 MW will be required on both the Lolland and Fehmarn sides.
SEAS-NVE, the power supply company on Lolland has indicated that they may be able to provide the necessary power from substations in Rødby or Rødbyhavn (to be confirmed). This will allow a 100% back-up in the case of failure of one of the sources. (To be confirmed.)

The existing grid on Fehmarn, owned by E.ON Netz, cannot provide the necessary power. If E.ON Netz is to provide the power it would be necessary to lay new high voltage cables over distances of 20 – 32 km. The construction time including EIA would be 3-5 years, which would mean an unacceptable delay to the project.

The only alternative is to establish a temporary power plant on the site. A solution with 4x20MW units would be suitable since it would provide the flexibility for construction, operation and services. The fuel would be either gas or diesel. The location of the temporary plant could be within the construction site or off-shore on a vessel.

The fresh water requirements of the construction sites cannot readily be supplied by available sources on Fehmarn and it is therefore expected that fresh water will be delivered to the sites by tanker by sea. On Lolland the water supply company is investigating the possibilities of developing a new well field to have sufficient supplies and the availability has yet to be confirmed.

3.7.11 Construction workforce
It is estimated that the total man-hours for the construction of the bored tunnel are in the region of 30,000,000 hours. This figure is provisional as the final workforce is determined by the contractors selected to perform the works.

The initial construction works begin with the design and production of the six TBM s, establishment of construction sites with workshops, office and accommodation facilities and dredging to create the necessary work harbours. The workforce will thus gradually be increased throughout the first year of the construction period.

Accordingly, there will be a lower level of activity in the concluding phase of the project, which consists of the many different installations inside the tunnel, including the railway systems. This period will be followed by a period of testing and commissioning of the tunnel including the railway.

3.7.12 Construction schedule
The construction time schedule assumes that the bored tunnel project will be split into contracts, all of which involve design and construction. The current time schedule remains provisional and will be developed by the contractors. The overall goal would be to complete the project within a time frame of approximately 8 years, commencing when the first contract being signed.

The complexity of the project and the risk associated with the long tunnel boring, combined with the large diameters of the tunnels, give the bored tunnel project a
special risk profile, where isolated incidents such as fire or cutter head failure - however rare - may have dramatic impact on the total time schedule.

The critical part of the time schedule concerns the purchase of the six TBMs for boring from both north and south, the starting of the boring process and the installation of the permanent equipment.

### 3.8 Decommissioning and removal

Decommissioning and removing the tunnel structures and installations comprises the following actions for the bored tunnel solution:

› The tunnel tubes are stripped of equipment and cabling, etc. and flooded, after which the entrances are sealed to prevent unauthorised access

› Decommissioning and removal/demolition of tunnel entrance structures, portal buildings and road and railway structures

› As the intention of the land reclamation areas is to maintain or even improve the conditions for flora and fauna in the area, it is considered unlikely that, after 120 years of 'natural environmental development', these areas will be required to be returned to their original condition. For this, a comparison can made with the existing sea dikes on both Lolland and Fehmarn, which were established in the 1870s.

### 3.9 Environmental pressures

The environmental pressures arising from the bored tunnel solution are summarised in Table 3.6, Table 3.7 and Table 3.8.
Table 3.6  Environmental pressures from permanent structures

<table>
<thead>
<tr>
<th>Project Features</th>
<th>Comprising</th>
<th>Environmental pressure</th>
</tr>
</thead>
</table>
| Permanent project structures on Lolland | Access roads  
Motorway  
Toll station  
Railway  
Green areas & paths  
Cut & cover tunnel  
O&M facilities  
Portal and ramps  
Sea defences | Footprint area (=horizontal extension)  
Vertical profile (height distribution)  
Material composition (use of materials) |
| Permanent project structures on Fehmarn  | Access roads  
Motorway  
Railway  
Green areas & paths  
Cut & cover tunnel  
O&M facilities  
Portal and ramps  
Sea defences | Footprint area (=horizontal extension)  
Vertical extension (height distribution)  
Material composition (use of materials) |
| Permanent project structures offshore  | Reclaimed area at Lolland  
Vertical profile (height distribution)  
Material composition (use of materials) | Footprint area (=horizontal extension)  
Vertical profile (height distribution)  
Material composition (use of materials) |
|  | Reclamation area at Fehmarn  | Footprint area (=horizontal extension)  
Vertical profile (height distribution)  
Material composition (use of materials) |
<p>|  | Bored tunnel  | Material consumption (use of materials) |</p>
<table>
<thead>
<tr>
<th>Project Features</th>
<th>Comprising</th>
<th>Environmental pressure</th>
</tr>
</thead>
</table>
| Temporary construction sites on Lolland | Temporary structures (facilities & buildings)                                  | Footprint area (=horizontal extension)  
Vertical profile (height distribution)  
Material composition                               |
|                                     | Construction works on land (earthworks, drainage, O&M facilities, construction traffic) | Disturbance  
Noise  
Solid and liquid waste  
Dust  
Light emission  
Accidental spills  
Spills of materials  
Energy consumption  
Water consumption |
| Temporary construction sites on Fehmarn | Temporary structures (facilities & buildings)                                  | Footprint area (=horizontal extension)  
Vertical profile (height distribution)  
Material composition                               |
|                                     | Construction works on land (earthworks, drainage, O&M facilities, construction traffic) | Disturbance  
Noise  
Solid and liquid waste  
Dust  
Light emission  
Accidental spills  
Spills of materials  
Energy consumption  
Water consumption |
| Temporary construction areas offshore | Offshore construction sites, including temporary work harbours and storage areas | Footprint area (=horizontal extension)  
Vertical profile (height distribution)  
Material composition                               |
|                                     | Offshore activities, including vessels and plants                              | Disturbance  
Restricted work zones  
Noise  
Accidental spills (including oil, chemicals, solid and liquid waste), collisions leading to oil spills |
|                                     | Deposition of excavated material                                              | Spill of fine sediments                                                             |
Table 3.8  Environmental pressures from Operation and Maintenance activities

<table>
<thead>
<tr>
<th>Project Features</th>
<th>Comprising</th>
<th>Environmental pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic</td>
<td>Vehicles, trains</td>
<td>Fuel consumption, Air emission, Noise, Vibrations, Light</td>
</tr>
<tr>
<td>O&amp;M activities</td>
<td>General activities</td>
<td>Energy consumption, Other resources (water, chemicals, etc)</td>
</tr>
<tr>
<td></td>
<td>Activities at ramp areas</td>
<td>Disturbance, Noise, Light</td>
</tr>
<tr>
<td></td>
<td>(Lolland and Fehmarn)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rainfall runoff and snow clearing at portals and ramps. Washing of road in tunnel. Seepage.</td>
<td>Contaminated discharges</td>
</tr>
</tbody>
</table>
4 Construction Costs and Risks

It is not normal practice to include a description of construction costs and risks in an EIA. However, in the present situation where there is only a small overall difference in the environmental impacts of the immersed tunnel and bored tunnel, it is pertinent to outline the reasons why the immersed tunnel has been selected as the preferred solution.

The following text is extracted directly from Femern A/S 2012.

4.1 Construction costs and programme

A cost estimate and a construction programme have been prepared for both the immersed tunnel and the bored tunnel solutions. The total construction cost includes all expenses necessary to realise the project including the cost to construct the tunnel itself, the owner’s costs including all planning costs, all additional works and estimates of risks.

Immersed tunnel
Total construction cost (price level 2008): € 5.5 billion.
Construction programme: 78 months to commissioning.

Bored tunnel
Total construction cost (price level 2008): € 6.8 billion.
Construction programme: 96 months to commissioning

The bored tunnel is thus 24% more expensive and takes 18 months longer to construct.

4.2 Construction risks

4.2.1 Immersed tunnel
Immersed tunnels of the proposed segmented concrete tunnel type have been widely used in Western Europe, but only in water depths of up to 25 m. Recently,
for the Busan Geoje tunnel in South Korea a similar concept has been applied successfully in a water depth of 45 m while the Bosphorus immersed tunnel in Istanbul, Turkey, has been successfully installed in 60 m water depth.

In terms of length, the Fehmarn tunnel will be by far the longest immersed tunnel. However, it will be constructed by using known technology for dredging, production of elements and transport and immersion of the elements.

4.2.2 Bored tunnel

Concept
Ten bored tunnels with diameters in the range 14.5 m to 15.5 m have been successfully constructed in recent years. It has been possible to resolve the problems encountered during construction of these large diameter TBMs and bored tunnels. Accordingly, a bored tunnel in the range 15 to 16 m diameter can be considered proven technology for distances up to 4 km. New upcoming tunnel projects in Seattle and St. Petersburg requiring TBMs of 17.5 m and 19.2 m diameter respectively have recently been awarded to TBM contractors; these tunnel drives are of the order 2.7 km and 1.0 km respectively. The performance of TBMs of this diameter has yet to be proven. In addition, there is no evidence available as to the performance of TBMs of over 10 m diameter in the difficult geological conditions which are present in Fehmarnbelt.

The TBMs will need to be designed as a technical compromise to cope with the variety of geological conditions that will be encountered along the alignment. All together approximately 60 km of tunnel has to be bored by six very large diameter TBMs.

In comparison, the immersed tunnel consists of 18 km tunnel constructed by proven technology.

TBM design challenge
For the bored tunnel the investments costs of the TBMs amount to less than 10% of the total construction costs, but the performance of each of the TBMs in the variety of conditions encountered is critical to the success of the project. TBM functionality has to take into account the specific conditions such as high water pressure, the large diameter tunnel, the length to be bored, the abrasive nature of the soil, the properties of the unique Palaeogene clay and the presence of boulders. Although each individual condition can be, and has been, addressed in the design on other projects, no TBM is known to have been designed to deal with the diameter and the length required for the Fehmarnbelt fixed link with the prevailing geological conditions. To design and build such a machine would be to extend the art of boring well beyond the existing boundaries of technology.

Limited number of qualified TBM suppliers
The tunnel boring machines are fabricated outside the construction site by a specialist manufacturer. The number of manufacturers who have previously produced TBMs approaching the size and quality required is limited to the
European mainland, Japan and North America. Only few manufacturers will be able to produce the six TBMs simultaneously which is required to fulfil the construction programme.

Geological hazards

Mixed soil conditions present a significant risk for the TBM method since the TBM design must be sub-optimal in order to accommodate a range of conditions. Once launched, the flexibility to adapt to unforeseen adverse conditions is severely limited.

Soil investigations indicate that the nature of the soil represents a high risk for any bored tunnelling technique due to the following aspects:

› The potential hazard of encountering large boulders imbedded in an unstable or plastic soil matrix presents a risk with high consequences. This will be a challenge particularly in connection with the high face pressures. Typically, boulders will be broken down by the cutter head, and any residual large pieces of boulders will be dealt with by the stone crusher. If boulders are found in soft or very soft ground, they can be problematic to break down into smaller pieces by the cutter head and would require intervention at the face by personnel.
› Hydraulic instability, which could cause inflow of soil and water into the boring chamber during maintenance, may present a hazard.
› Sudden changes in soil characteristics and mixed-face conditions present a risk because of the large tunnel diameter.
› Controlling the TBM direction can be difficult in the poor soil conditions.
› The highly abrasive nature of the soil will require high maintenance frequency for the cutter head and the cutter tools under difficult hyperbaric conditions.

Techniques to mitigate most of the risks to some degree do exist. However, boring a tunnel in a medium that is inherently variable means that there is always a risk of encountering conditions that are outside the design parameters of the TBM and outside the experience of the operators.

4.3 Conclusion

The immersed tunnel has been chosen as the preferred solution due to the lower cost, shorter construction time and the high risks associated with construction of a bored tunnel. Such aspects override the fact that the bored tunnel, overall, has a slight advantage from an environmental point of view.
5 Assessment of impacts on the Marine Environment

5.1 Introduction
This chapter addresses the impacts of the bored tunnel alternative solution on the marine environment in Fehmarnbelt and the Baltic Sea.

5.1.1 Environmental components
The marine environment is sub-divided into its various environmental components, each of which is addressed in a section of this chapter:

› Hydrography
› Water quality
› Seabed morphology
› Coastal morphology
› Plankton and jellyfish
› Benthic flora
› Benthic fauna
› Fish ecology
› Marine mammals
› Birds
› Migrating bats
› Commercial fishery
› Material assets
› Recreation
› Cultural heritage and archaeology
› Shipping

5.1.2 Background reports
A brief summary of the existing environmental situation is given for each component. The objective is to present the reader with the essential information, i.e. the results of the baseline studies. Reference is made to the background reports for a full, detailed description of the baseline studies, see Table 5.1
Specific impact assessment studies for the bored tunnel are reported directly in this chapter, i.e. there are no background reports on the specific studies with the exception of the report on sediment spill due to dredging activities (FEHY 2012k). In some cases the impact assessments are based on the immersed tunnel because of a number of similarities, especially the impacts due to the land reclamations. The immersed tunnel impact assessment reports are listed in Table 5.1.

### Table 5.1 Background reports on the marine baseline studies and immersed tunnel impact assessment.

<table>
<thead>
<tr>
<th>Environmental component</th>
<th>Baseline reports</th>
<th>Impact assessment reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrography</td>
<td>FEHY 2012a (Baltic Sea) FEHY 2012b (Fehmarnbelt)</td>
<td>FEHY 2012f (Baltic Sea) FEHY 2012g (Fehmarnbelt)</td>
</tr>
<tr>
<td>Water quality</td>
<td>FEHY 2012c (Suspended sediment) FEMA-FEHY 2011 (Fehmarnbelt) FEMA 2012a (Seabed chemistry)</td>
<td>FEHY 2012h (Sediment spill – immersed tunnel) FEHY 2012k (Sediment spill – bored tunnel) FEMA 2012f</td>
</tr>
<tr>
<td>Seabed morphology</td>
<td>FEHY 2012d</td>
<td>FEHY 2012i</td>
</tr>
<tr>
<td>Coastal morphology</td>
<td>FEHY 2012e</td>
<td>FEHY 2012j</td>
</tr>
<tr>
<td>Plankton and jellyfish</td>
<td>FEHY 2012a (Baltic Sea) FEMA-FEHY 2011 (Fehmarnbelt)</td>
<td>FEMA 2012f (Fehmarnbelt)</td>
</tr>
<tr>
<td>Benthic flora</td>
<td>FEMA 2012b</td>
<td>FEMA 2012d</td>
</tr>
<tr>
<td>Benthic fauna</td>
<td>FEMA 2012c</td>
<td>FEMA 2012e</td>
</tr>
<tr>
<td>Fish ecology</td>
<td>FeBEC 2012a</td>
<td>FeBEC 2012d</td>
</tr>
<tr>
<td>Marine mammals</td>
<td>FEMM 2012a</td>
<td>FEMM 2012b</td>
</tr>
<tr>
<td>Birds</td>
<td>FEBI 2012a</td>
<td>FEBI 2012b</td>
</tr>
<tr>
<td>Migrating bats</td>
<td>FEBI 2012c</td>
<td>FEBI 2012d</td>
</tr>
<tr>
<td>Commercial fishery</td>
<td>FeBEC 2012b</td>
<td>FeBEC 2012e</td>
</tr>
<tr>
<td>Recreation</td>
<td>FeBEC 2012c (Fishing)</td>
<td></td>
</tr>
<tr>
<td>Cultural heritage and archaeology</td>
<td>Viking Ship Museum 2012</td>
<td>Viking Ship Museum 2012</td>
</tr>
<tr>
<td>Shipping</td>
<td>Rambøll 2011</td>
<td>Rambøll 2011</td>
</tr>
</tbody>
</table>

#### 5.1.3 Assessment methodology

To ensure a uniform and transparent basis for the EIA, a general impact assessment methodology for the assessment of potential impacts of the Fixed Link Project on the environmental has been prepared. The methodology is defined by the impact assessment methods described in the scoping report (Femern and LBV-SH-Lübeck 2010, section 6.4.2). In order to give more guidance and thereby support comparability, the assessment method has been further specified.
Since the impact assessments cover a wide range of terrestrial and marine environments and environmental factors, the general methodology is further specified and in some cases modified for the assessment of the individual environmental factors (e.g. the optimal analyses for migrating birds and relatively stationary marine benthic fauna are not identical). These necessary modifications are explained in the individual sections of this chapter.

Two principal types of impacts are defined, “loss” and “impairment”.

“Loss” refers to the loss of part of an environmental component due to the project’s marine structures. A loss can be temporary (construction phase) or permanent (operation phase). An example of a permanent loss is the benthic flora and fauna covered by the land reclamations at the Lolland and Fehmarn coasts. However, the benthic flora and fauna covered by the breakwaters of the work harbours is a temporary loss because the breakwaters will be removed at the end of the construction phase. The environment will eventually recover from temporary impacts.

“Impairment” refers to partial damage inflicted on an environmental component by the project, particularly the construction activities. For example, sediment spilled during dredging activities creates a temporary increase in suspended sediment in the water and increased sedimentation, which in turn can impact water quality, benthic flora and fauna, fish etc. Impairments can also be temporary or permanent. However, for the bored tunnel alternative there are few permanent impairments in the marine environment.

The procedures for the assessment of the two types of impacts are sketched in the flow charts in Figure 5.2 and Figure 5.2.

Assessment of loss
The assessment of loss starts with the calculation of the magnitude of the pressure, e.g. the area of the land reclamation at the Lolland coast.

The second step is to calculate the magnitude of the impact, e.g. - continuing the example - the area of a specific benthic flora community, say red algae, under the reclamation.

In the third step the magnitude of impact is combined with the importance of the environmental component to give the “severity of loss”. The importance of the environmental component to the marine ecosystem is expressed relatively, i.e. “very high”, “high”, “medium” and “minor”, and is determined via a set of criteria. For example, redlisted species are of “very high” importance. The “severity of loss” is also expressed relatively in the same four categories “very high”, “high”, “medium” and “minor”.

The final step is to classify the significance of the impact as either “significant” or insignificant”. This is done by comparing the actual magnitude of the loss with the total area or population or biomass etc. of the component (e.g. red algae) in the
Fehmarnbelt or other relevant area. The significance is assessed both without and with the implementation of mitigation and compensation measures.

![Diagram](image)

**Figure 5.1 Procedure for assessment of the loss type of impact**

**Assessment of impairment**

In a similar way, the assessment of impairment starts with the calculation of the magnitude of the pressure, e.g. for benthic flora, a pressure is the increase in the concentration of suspended sediment due to dredging activities. The area, magnitude and duration of the increase are calculated.

The impact on benthic flora is a reduction in biomass since the increased suspended sediment reduces the light intensity at the seabed and thereby retards the growth of, e.g. red algae. The magnitude of the impact is then calculated as a reduction of biomass of red algae using the magnitude of the pressure and the sensitivity of red algae to light intensity.

A set of criteria are used to convert the magnitude of impact into a relative degree of impairment. The criteria are typically related to the importance of the component to the marine ecosystem, the natural variability and the recovery time of the component. For example, the degree of impairment could be “very high” if the reduction of biomass of a benthic flora community is much greater that the standard deviation of the biomass (the biomass will vary from year to year due to varying meteorological and hydrographic conditions) and the recovery time is long.

The final step is to classify the significance of the impact as either “significant” or insignificant”. This is done by comparing the actual magnitude of the impairment
with the total area or population or biomass etc. of the component (e.g. red algae) in the Fehmarnbelt or other relevant area. The significance is assessed both without and with the implementation of mitigation and compensation measures.

![Diagram]

**Figure 5.2 Procedure for assessment the impairment type of impact**
5.2 Hydrography

This section addresses the hydrographic conditions in Fehmarnbelt and the Baltic Sea and the possible impacts of the bored tunnel project on the conditions.

The hydrographic issues concerned fall under the environmental factor “water” and the sub-factor “marine water”. The relevant environmental “components” and “sub-components” under marine water are listed in Table 5.2.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sub-factor</th>
<th>Component</th>
<th>Sub-component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Marine water</td>
<td>Hydrography</td>
<td>Bathymetry</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water levels</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Waves</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Currents</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Salinity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Temperature</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stratification</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water and salt exchange at Darss Sill</td>
</tr>
</tbody>
</table>

5.2.1 Project pressures and potential impacts

The marine structures of the bored tunnel project may affect the hydrographic conditions through three mechanisms:

› The marine structures may cause a slight blocking of the exchange flow of water and salt between the North Sea and the Baltic Sea and thereby may impact the salinity and water quality in the Baltic Sea.

› The project structures may change local water level, wave and current conditions.

› The project structures may cause additional mixing between the lower (high salinity) and upper (low salinity) layers of water in Fehmarnbelt and thereby may have an effect on the salinity and stratification in both Fehmarnbelt and in the Baltic Sea.

Changes to the salinity and stratification can potentially affect the ecosystem. Later sections of this chapter address the potential impacts on water quality and on the ecosystem.

5.2.2 Study area and bathymetries

The bathymetry of the Baltic Sea is characterized by contractions and sills that influence the currents and mixing between the water masses.
There are three basins in the south-western Central Baltic Sea, namely the Arkona, Bornholm and Gotland Basins, see Figure 5.3. To the north there are three local deeps, Landsort Deep, Farö Deep and Karlsö Deep. The shallow sill which separates the Central Baltic Sea from the Bothnian Sea contains a local deepening, the Aland Deep. Another sill separates the Bothnian Sea from the Bay of Bothnia. On the other hand, a deep channel connects the northern Central Baltic Sea and the Gulf of Finland.

![Figure 5.3](image-url)

**Figure 5.3** Bathymetry and geographical structures of the Baltic Sea. Acronyms indicate some basins and connecting channels: Arkona Basin (AB), Bornholm Channel (BC), Bornholm Basin (BB), Stolpe Channel (SC, also called Slupsk Furrow), Gdansk Depression (GD), Eastern Gotland Basin (EGB), Landsort Deep (LD), Färö Deep (FD), Karlsö Deep (KD) and Aland Deep (AD)

The Baltic Sea transition area is the relatively shallow, contracted connection between the North Sea and the Central Baltic Sea, see Figure 5.4. It comprises the sea areas Kattegat, northern part of Sound, Great Belt, Little Belt and Fehmarnbelt. The border between the Baltic Sea transition area and the Central Baltic Sea are the Darss and Drogden Sills. The maximum depth at the two sills is only about 18 m and 7 m respectively. The transition area limits the inflow of high salinity water from the North Sea into the Central Baltic Sea.
5.2.3 Hydrography of the Baltic Sea

The most important aspects of the hydrography of the Baltic Sea are briefly summarised here. For more details refer to the baseline report FEHY 2012a.

The hydrography of the Baltic Sea is governed by two principal driving forces, viz. the inflow of freshwater from rivers and the meteorological conditions where storms from west force high salinity water from the North Sea to pass over the Darss and Drogden Sills and into the lower layers of the Baltic Sea waters. The processes are illustrated in Figure 5.5.

The river and diffuse freshwater inflows to the Baltic Sea are estimated to be $14,136 \pm 1,545 \text{ m}^3/\text{s}$ HELCOM (2009a). The difference of direct precipitation and evaporation (P – E) to and from the surface of the Baltic Sea is estimated to range from around 700 m$^3$/s (Lindau, 2002) to 1,300 m$^3$/s (HELCOM, 1986), which corresponds to 5%-10% of the river runoff.

The freshwater surplus to the Baltic Sea creates a low salinity water mass in the upper part of the water column.
High and low air pressures fields pass Scandinavia on a weekly time-scale and raise or depress the water levels in the North Sea and Baltic Sea, respectively. The water level difference it causes between the North Sea and the Central Baltic Sea drives an exchange flow between the two seas that either transports low salinity waters from the Central Baltic Sea out to the North Sea or high salinity water masses from the North Sea into the Central Baltic Sea. The pressure and wind driven exchange in the Danish Straits is an order of magnitude larger than the net outflow generated by the freshwater. Furthermore the wind shear stress on the sea surface produces wave turbulence that mixes the water masses.

When high salinity water originating from the North Sea passes the two sills it is trapped inside the Central Baltic Sea and propagates further into the Baltic Sea along the seabed. The high salinity water masses eventually leave the Baltic Sea again by being entrained upwards into the surface layers which flow out of the Baltic Sea.

During summer the water masses are heated and during winter they are cooled by the heat exchange with atmosphere. The heating creates a warm low-density layer at the surface with a thermocline located at 20-30 m depth, both in the North Sea and in the Baltic Sea.

![Figure 5.5 Sketch of water exchange in the Baltic Sea (redrawn after Lass and Matthäus, 2008)](image-url)
5.2.4 Hydrography of Fehmarnbelt

The most important aspects of the hydrography of the Fehmarnbelt area are briefly summarised here. For more details refer to the baseline report FEHY 2012b.

The meteorological conditions over the North Sea and the Baltic Sea are the dominating force in driving the flows through Fehmarnbelt. Low pressure systems over Scandinavia with a cyclonic wind field create high water levels in the Kattegat which drive flows into the Baltic Sea. High pressure systems over Scandinavia with anti-cyclonic winds reverse the situation and give low water levels in the Kattegat which allows water to flow out of the Baltic Sea.

The local meteorological conditions over Fehmarnbelt have little effect on the flows in the belt but the local wind determines the wave climate.

The high salinity in the North Sea and the freshwater input to the Baltic Sea causes the stratified, estuarine flow conditions which are particularly strong in the Danish waters and central and southern Baltic Sea.

Tides in Fehmarnbelt are small and are not a significant driving force. Similarly, freshwater inflows to the Belt Sea are small and only have very local effects on the stratification close to the mouths of the streams.

Baseline measurements

The baseline data on hydrography was collected through a combination of continuous measurements at 13 stations and monthly cruises covering the entire study area throughout 2009 and 2010, see Figure 5.6 and Figure 5.7.

Vertical profiles of current, salinity, temperature, turbidity, dissolved oxygen and chlorophyll $a$ along with waves were measured at the main stations MS01, MS02 and MS03. Turbidity was monitored at the near shore stations NS01 to NS10. A number of the near shore stations were moved to shallower water (4-5 m depth, marked with suffix "a") during the study to record turbidity where the wave turbulence increased re-suspension.

Data collection cruises were performed to obtain a wider spatial coverage of hydrographic and biological data. A total of 21 cruises were carried out on a monthly basis between February 2009 and December 2010. The measurements included vertical profiles of temperature, salinity, oxygen, chlorophyll $a$, turbidity together with water sampling for nutrient analyses. Plankton and jellyfish were sampled with nets.

Water levels

Long term observed time series of water levels in the Fehmarnbelt area are available at three stations, viz. Warnemünde, Gedser and Kiel-Holtenau. An example of the measurements at Warnemünde is shown in Figure 5.8. The rapid variations are due to the changing wind fields, seiching and tides. The water levels vary at the same time-scale as the air pressure fields and tides, i.e. from 6 hours to several days.
The measured water levels typically stay within the range from -0.5 m to +0.5 m. The tide has an amplitude of 7.5 cm at Gedser and therefore contributes little to the observed variations in level.

Figure 5.6   Location of fixed stations in the Fehmarnbelt monitoring programme
Waves

Waves in the Fehmarnbelt area are governed primarily by the local wind conditions and the fetch limitations defined by land boundaries. Wave measurements made during the baseline period at the main stations showed that in general 25% of the waves are under 0.5 m and 98% under 2 m. A study of maximum wave heights
shows that heights in the belt can reach 4m near the coasts and 5 m in the centre can occur at westerly wind speeds of 24 – 28 m/s.

The dominant wave direction is WNW, i.e. more or less perpendicular to the link corridor. However, a significant fraction of waves occurs also from the SSE direction.

Examples of wave patterns in Fehmarnbelt for the two dominant directions are shown in Figure 5.9 and Figure 5.10. Going from deep water to shallow water the waves turn towards the coast due to shoaling and reduce in height due to bottom friction.

Figure 5.9 Example of westerly wave pattern in Fehmarnbelt. Date: 8 Jan 2005.

Figure 5.10 Example of easterly wave pattern in Fehmarnbelt. Date: 28 Dec 2005.
Currents

Figure 5.11 and Figure 5.12 illustrate the two main flow patterns, outflow and inflow from/to the Baltic Sea at the surface as calculated in the hydrodynamic model. The main flows clearly pass through Fehmarnbelt and Great Belt. During outflow the low salinity Baltic Sea water is carried up Great Belt and Øresund at the surface while during inflow the high salinity North Sea water passes the Darss and Drogden Sills into the Baltic Sea, even at the surface.

The flows in the lower layer near the seabed are more complicated and can be in either direction in Fehmarnbelt during both outflow and inflow.

Historical data for the period 1950-1986 is available from the German Fehmarn Belt Light Vessel (BSH). The current near the surface (6 to 10 m depth) shows inflow during 47% of time and outflow during 54% of time, while the current near the bottom (24 m to 28 m depth) show inflow during 67% of time and outflow during 33% of time. The inflow is thus more frequent in the lower layer.

Most inflow situations at the surface at the light vessel have durations of less than 3 to 5 days, while outflow situations tend to last 1 or 2 days longer. The longest inflow situation lasted 14 days, and the longest outflow 17 days. Near the bottom the inflow has a typical duration of 3 to 5 days, with the longest situation observed lasted 21 days. Long outflow periods are rare but have occurred with durations up to 5 to 7 days.

A typical vertical profile of currents with outflow at the surface and inflow at the bed is shown in Figure 5.13. It also shows the relationship of the currents to the stratification.

Figure 5.11 Model simulated outflow current and salinity pattern at 5 m depth on 14 October 2004 at 15:00 UTC
Figure 5.12  Model simulated inflow current and salinity pattern at 5 m depth on 9 January 2005 at 00:00 UTC

Figure 5.13  Outflow at surface and inflow at bed at MS02 on 10 Jan 2012 at 14:50 (blue line) and daily mean (red line). On this day the daily average does not differ significantly from an instantaneous profile which indicates a stable stratification.

Salinity and temperature
The distribution of salinity, temperature and density at station MS02 during the baseline period is shown in Figure 5.14. Stratification develops during the calmer periods which occur mostly in spring and summer, with also an example in autumn, November 2009. Storms mix the layers and can give an almost vertically homogeneous density such as in October 2009 and January and December 2010.
The October 2009 event was a medium saline inflow to the Baltic Sea with a salinity of 22 psu from surface to bed.

![Salinity hourly means at M02](chart1)

**Figure 5.14** Measured salinity and temperature at MS02 in Fehmarnbelt during the baseline monitoring

5.2.5 Pressures on hydrography from the bored tunnel

The marine structures in the form of the permanent reclamations and the temporary work harbours and access channels create the environmental pressures on hydrography. These project features are described above in Chapter 3.

The footprint of the bored tunnel with the harbour breakwaters and access channels during the construction phase and reclaimed areas for the operation phase is presented in Figure 5.15.

A total length of 7,470 m of the coastline is integrated into the planned reclaimed area along the southern coastline of Lolland, as for the immersed tunnel. The reclamation west of Rødbyhavn extends approximately 3,720 m from Rødbyhavn to Sandholm. East of Rødbyhavn, the reclamation extends to Hyldtofte Østersøbad 3,750 m from Rødbyhavn. The areas of the reclamation are 130 ha west of Rødbyhavn and 200 ha to the east giving a total of 330 ha.
East of Puttgarden a total length of 700 m of the coastline is integrated into the planned reclamation, which consists of a landfill protected by a dike and a revetment facing the north-northeast. The reclamation area is 23 ha.

The footprints of the immersed tunnel and the bored tunnel during the operation phase are compared in Figure 5.16 and Figure 5.17.

The areas of the seabed occupied by the various marine structures and excavations are listed in Table 5.3.

Figure 5.15 Footprint of bored tunnel showing harbour breakwaters and access channels during the construction phase and reclaimed areas for operation phase
Figure 5.16 Footprint of reclaimed areas and dredged channels at Lolland for bored tunnel compared with similar footprints of immersed tunnel, operation phase

Figure 5.17 Footprint of reclaimed areas at Fehmarn for bored tunnel compared with similar footprints of immersed tunnel, operation phase
Table 5.3 Areas of the seabed affected by the construction and operation of the bored tunnel

<table>
<thead>
<tr>
<th>Feature</th>
<th>Areas affected (ha)</th>
<th>Construction phase</th>
<th>Operation phase</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lolland</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reclamation</td>
<td>330</td>
<td>330</td>
<td></td>
</tr>
<tr>
<td>West work harbour breakwaters</td>
<td>Included in reclamation area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West work harbour access channel</td>
<td>9.7</td>
<td>9.7</td>
<td></td>
</tr>
<tr>
<td>East work harbour breakwaters</td>
<td>7.1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>East work harbour access channel</td>
<td>19.7</td>
<td>19.7</td>
<td></td>
</tr>
<tr>
<td>East work harbour inside breakwaters</td>
<td>21</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(excluding access channel)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fehmarn</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reclamation</td>
<td>23.5</td>
<td>23.5</td>
<td></td>
</tr>
<tr>
<td>Breakwaters and quay areas</td>
<td>11.3</td>
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</tr>
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<td>Work harbour basin</td>
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</tr>
<tr>
<td>Work harbour access channel</td>
<td>6.1</td>
<td>6.1</td>
<td></td>
</tr>
</tbody>
</table>

5.2.6 Methodology

The key tools used for the assessment are 3D hydrodynamic and water quality models referred to as regional models for the Baltic Sea and local models for Fehmarnbelt. A description of the set up, calibration and validation of the models is found in FEHY 2012g.

For the studies of the tunnel alternatives only the local MIKE 3 model was applied because it showed that the exchange of water and salt with the Baltic Sea was affected only to a negligible degree so that there would be no impacts on the Baltic Sea. Therefore modelling of the impacts on the Baltic Sea is not required.

The degree of impairment to the individual sub-components in the Central Baltic Sea is assessed on the basis of the quantitative impact criteria quoted in Table 5.4. The basic concept in the impact criteria is to relate the degree of impairment to natural variability of the baseline conditions, where the natural variability is characterised by the standard variation (Table 5.5).

Therefore the impact classification is based on changes of the mean values of the state variables compared to the standard variation of the parameters in the baseline condition.

A change in the mean value of 100% of the standard deviation is defined to give a very high degree of impairment, e.g. the standard deviation (SD) for surface salinity at stations in the Central Baltic Sea is 0.34 psu and the criteria for a very high degree of impairment is a change of more than 0.34 psu. Changes below 5%
are below the uncertainty level of the measurement and thus cannot be detected in practice.

Similarly, changes of 5 - 10%, 10 - 20% and 20 - 100% of the SD define the levels low, medium and high degrees of impairment.

For the maximum water level (to be used for potential flooding assessments) the assessment criteria classes are given by predefined fractions of the difference between a 50 and a 20 year return period level.

The criteria apply to both the construction and operation phases.
### Table 5.4: Impact criteria used for the degree of impairment in relation to the hydrography sub-components in the Central Baltic Sea and Fehmarnbelt

<table>
<thead>
<tr>
<th>Component</th>
<th>Project pressure</th>
<th>Impact criteria</th>
<th>Duration</th>
<th>Degree of impairment</th>
</tr>
</thead>
</table>
| Hydrography | Project structures and construction activities | › Water level of events with a return period of about 20 years increases by 10cm or mean water level change exceeds 5cm, or  
› At least for one of the other sub-components the change in the indicator value will exceed 100% of the natural temporal standard deviation. | Permanently or for construction period | Very high |
| | | › Water level of events with a return period of about 20 years will increase by 5-10cm and/or mean water level change by 2-5cm, or  
› At least for one of the other sub-components the change in the indicator value will be 20-100% of the natural temporal standard deviation and the other components less. | Permanently or for construction period | High |
| | | › Water level of events with a return period of about 20 years increases 2.5-5cm, or mean water level change by 1-2cm, or  
› At least for one of the other sub-component the change in the indicator value will be 10-20% of the natural temporal standard deviation and the other components less. | Permanently or for construction period | Medium |
| | | › Water level of events with a return period of about 20 years increases by 1cm or mean water level change exceeds 0.5cm, or  
› At least for one of the other sub-components the change in the indicator value will be 5-10% of the natural temporal standard deviation and the other components less. | Permanently or for construction period | Low |
| | | › Below above threshold levels | Negligible/imperceptible |
Table 5.5  SD values of the sub-components, based on baseline study

<table>
<thead>
<tr>
<th>Sub-component</th>
<th>Fehmarnbelt Station N01 (1990-2007) or MS02 (2009-2010)</th>
<th>Central Baltic Sea Station K02 Bornholm Basin (1990-2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard deviation</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>Water level</td>
<td>0.24m (Gedser 2004-2009)</td>
<td>0.24m (Gedser 2004-2009)</td>
</tr>
<tr>
<td>Surface salinity</td>
<td>3.2psu (NO1)</td>
<td>0.34psu (Baltic Sea stations)</td>
</tr>
<tr>
<td>Bottom salinity</td>
<td>3.5psu (NO1)</td>
<td>1.1psu</td>
</tr>
<tr>
<td>Surface temperatures</td>
<td>5.7°C (NO1)</td>
<td>5.8°C</td>
</tr>
<tr>
<td>Bottom temperature</td>
<td>3.6°C (NO1)</td>
<td>1.5°C</td>
</tr>
<tr>
<td>Stratification (bottom - surface density)</td>
<td>4.0kg/m³ (MIKE model)</td>
<td>0.8kg/m³ (MIKE model)</td>
</tr>
</tbody>
</table>

5.2.7  Impact on the hydrography of the Baltic Sea

Permanent impacts in the operation phase

The assessment of the impacts of the bored tunnel on the hydrography of the Baltic Sea is based on the results for the immersed tunnel. This is possible because the footprints of reclaimed areas and access channels for the immersed tunnel and for the bored tunnel are very similar as described above. The only actual difference is the reclamation east of Puttgarden, which for the bored tunnel extends 200 m further offshore. However, the reclamation still does not protrude further out in the sea than the present Puttgarden Harbour breakwaters.

The immersed tunnel layout was assessed as having practically no effect on the water exchange and the salt flux in and out of the Central Baltic Sea across the Darss Sill. The actual magnitude of the impact was modelled to 0.01% reduction of water exchange and a zero change in the salt flux.

The following effects were assessed to apply for the immersed tunnel and it is furthermore assessed that they will also apply for the bored tunnel:

- **Impact magnitude:** There is no permanent effect on the Baltic Sea with respect to any of the hydrographic (and also water quality, cf. section 5.3) sub-components, including Central Baltic Sea water levels, currents, salinity, temperature and stratification, (and oxygen, transparency, chlorophyll $a$ and blue-green algae).

- **Severity of loss and degree of impairment:** There is no loss of area in the Baltic Sea. Since the magnitude of the impacts on the hydrographic and water
quality sub-components are negligible or zero, the degree of impairment is also negligible or zero everywhere in the Baltic Sea.

> **Impact significance:** With no areas of impairment or loss in the Central Baltic Sea the assessment is that after the construction period none of the tunnel alternatives will have any significance for the hydrography (and thus also water quality and plankton in the Baltic Sea) in any way.

**Impacts in the construction phase**

The permanent structures in the form of land reclamation perimeters are implemented as one of the first construction activities and completed relatively quickly. The possible impacts during the construction period of these permanent structures are thus very similar to the impact of these structures in the operation phase. As described above, the impacts are assessed to be negligible.

There are also some temporary marine structures during construction which can have possible environmental impacts. The temporary structures are:

- Breakwaters for the two work harbours on Lolland
- Two access channels for the Lolland work harbours
- Work harbour with breakwater east of the Fehmarn reclamation
- Access channel for the Fehmarn work harbour

These temporary structures are very similar to those for the immersed tunnel (see Figure 5.16 and Figure 5.17) and the temporary impacts for the bored tunnel will therefore be very similar to those for the immersed tunnel.

The model studies for the immersed tunnel showed that the temporary structures caused only local changes to the current pattern and did not change the results concerning the Baltic Sea. The conclusion also applies for the bored tunnel.

**5.2.8 Impacts on the hydrography of Fehmarnbelt during operation**

The impacts of the bored tunnel on the hydrography of Fehmarnbelt have not been assessed directly by modelling but are based on the assessment for the immersed tunnel. As described above, this is justified by the similarity of the permanent reclamations for the two tunnel alternatives.

Assessment for the immersed tunnel was focused on the “tunnel+ferry” scenario but this is a very good approximation for the isolated effect of the tunnel because the effect of the ferry regarding hydrography, e.g. enhanced vertical mixing, is minimal.

The assessment of hydrographical effects covers various scales:

- The immediate near zone of the project, defined as 500m on either side of the project footprint
- The local Fehmarnbelt scale (10 km on both sides of the alignment)
In addition, the calculation has been undertaken for the part of the total impact area situated within Danish waters, German national waters and German waters inside the EEZ zone. The different scales and zones are displayed in Figure 5.18.

Figure 5.18    Western Baltic area and zones for sub-division of impacts

Magnitude of impacts on hydrodynamics
Model simulations with the immersed tunnel showed the following impacts:

- Water level changes are negligible.
- The blocking of the exchange flow with the Baltic Sea is an effect indicator which to some extent integrates many other effects. For the tunnel scenarios the effect is a reduction of 0.01% of the water exchange flow which is a minimal value, and 0.00% of the salt exchange.
- Lolland: Reduced current speeds at the ends of the Lolland reclamation, in front of the ferry harbour, and near the protection reef with reduced mean
speeds from 0.02-0.06 m/s. In the vicinity of the access channel both increased (surface) and reduced (bottom) current speeds of up to 0.08 m/s are seen. See Figure 5.19.

› Fehmarn: Reduction of surface and bottom currents immediately north and east of the small reclamation of down to -0.1 m/s, but at 500 m from the reclamation the reductions are less than 0.03 m/s. See Figure 5.20.

› Outside the vicinity of the reclamation the current effects are negligible, and the same applies for other hydrographic sub-components everywhere.

› The estimated maximum changes for salinity, temperature and stratification are very low and considered negligible.

Table 5.6 summarises the maximum effects calculated in the underlying modelling. These have been computed for the immersed tunnel (“tunnel + ferry”) and are considered to apply also for the bored tunnel except for a slight spatial relocation of the effects related to the access channel on the Lolland side and slightly larger changes in current at the Fehmarn side due to the extended reclamation.
Figure 5.19  Impacts of permanent marine structures for the immersed tunnel at the Lolland coast on currents. Top: surface currents. Bottom: currents at seabed. Similar impacts apply for the bored tunnel.
Figure 5.20  Impacts of permanent marine structures of the immersed tunnel at the Fehmarn coast on currents. Top: surface currents. Bottom: currents at seabed. Similar impacts apply for the bored tunnel.
Table 5.6  Summary of magnitude for permanent key effects in the Fehmarnbelt and nearby areas for immersed and bored tunnels.

<table>
<thead>
<tr>
<th>“Tunnel+ferry” (immersed and bored)</th>
<th>Upper limit for estimated change in local model area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean water level</td>
<td>Everywhere less than 0.0001 m</td>
</tr>
<tr>
<td>Max water level</td>
<td>Locally up to 0.0002 m, elsewhere much less</td>
</tr>
<tr>
<td>Blocking of water exchange over Darss Sill</td>
<td>~0.01%</td>
</tr>
<tr>
<td>Blocking of salt exchange over Darss Sill</td>
<td>0.00%</td>
</tr>
<tr>
<td>Surface currents (annual mean)</td>
<td>Locally off reclamation stretches down to ±0.08 m/s, elsewhere less than ±0.01 m/s</td>
</tr>
<tr>
<td>Bottom currents (annual mean)</td>
<td>Locally off reclamation stretches down to -0.06 m/s, elsewhere less than ±0.005 m/s</td>
</tr>
<tr>
<td>Mean surface salinity (annual mean)</td>
<td>Locally off reclamation up to ±0.1 psu, elsewhere less than ±0.05 psu</td>
</tr>
<tr>
<td>Mean bottom salinity (annual mean)</td>
<td>Locally off reclamation up to ±0.2 psu, elsewhere less than ±0.05 psu</td>
</tr>
<tr>
<td>Surface temperatures (annual mean)</td>
<td>Less than 0.05°C everywhere</td>
</tr>
<tr>
<td>Bottom temperature (annual mean)</td>
<td>Less than 0.05°C everywhere</td>
</tr>
<tr>
<td>Summer bottom temperature (mean)</td>
<td>Less than 0.05°C everywhere</td>
</tr>
<tr>
<td>Stratification (annual mean)</td>
<td>Less than ±0.04 kg/m³ everywhere</td>
</tr>
<tr>
<td>Stratification summer (mean)</td>
<td>Less than ±0.04 kg/m³ everywhere</td>
</tr>
</tbody>
</table>

Magnitude of impact on waves
The permanent marine structures result in only very minor effects on the waves in Fehmarnbelt. This is based on the model studies for the immersed tunnel and applies as well for the bored tunnel. Changes are only seen in the immediate vicinity of the reclamation areas and appear mostly as lee effects on the eastern side of the reclamation. Adjacent to access channels a slight tendency to increased as well as decreased wave heights can be expected due to depth changes.

Severity of loss of marine water bodies
“Severity of loss” is a qualitative ranking of impacts concerning loss, in this case loss of marine water bodies. The reclamation areas cause the loss of water bodies at the coasts of Lolland and Fehmarn. The level of severity is found by combining the magnitude of the loss and the importance of the water body.

The concepts of severity and importance are described earlier in this report. The importance levels for seawater are graded into “special” and “general” importance and results in the same levels for severity.
The following assessments of severity of loss for the immersed tunnel are considered valid also for the bored tunnel. For the immersed tunnel Figure 5.21 illustrates the severities in the areas affected and Table 5.7 shows the areas affected within the project defined zones (Figure 5.18).

› Loss areas of “special” severity occur due to the reclamation in front of present bathing beaches west of Rødbyhavn (58 ha) and east of Puttgarden (6 ha). However, these beach areas are planned to be compensated by new bathing beaches, see Chapter 4.3.

› The remaining reclamation areas are characterized as loss areas of “general” severity for seawater, with 271 ha at the Lolland coast and 17 ha at the Fehmarn coast.

Degree of impairment of hydrography

“Degree of impairment” is a qualitative ranking of impacts which impair the value and/or function of a component or sub-component. The concept and process of evaluation is described earlier in this report.

First the impacted areas for each sub-component are divided into “very high”, “high”, “medium” and “minor” degrees of impairment according to a set of specific criteria (see FEHY 2012g for the criteria). Then the areas of each category for each sub-component are aggregated to give the degree of impairment for the component.

The degree of impairment is classified as minor and medium in the vicinity of the reclamations due to the lee effect on currents and waves and due to the open access channel. The dredged area of the access channel is assigned a “high” severity as the depth here is more than 10 m, and thus the area is characterised as being important for the general water exchange. However, the modelling has revealed that the actual blocking effect is negligible. See Figure 5.21 for an illustration of the degree of impairment in the affected areas.

The actual impact areas for the bored tunnel will be very similar to the immersed tunnel figures, which is summarised in Table 5.7. In total the areas with “minor” to “high” impairment amounts to 985 ha for the immersed tunnel. Half of this falls inside the near zone of the project.

As for the immersed tunnel all of the impacted area lies inside the defined local area (±10 km around link alignment, excluding the near zone). The impacted area, both loss and impaired, for the immersed tunnel constitutes 34% of the near zone and only 1.3% of the local area. Most of the impacted area is within Danish waters.
Tunnel Alternative E-ME (August 2011): Permanent impacts

Degree of Impairment for Seawater Hydrography

Severity of Loss for Seawater Hydrography

Figure 5.21: The degree of impairment and severity of loss distribution for permanent impacts of the immersed tunnel on hydrography. A similar distribution applies for the bored tunnel.
Table 5.7 The degree of impairment and severity of loss areas for permanent impacts on hydrography after implementation of the immersed tunnel. A similar distribution applies for the bored tunnel.

<table>
<thead>
<tr>
<th>Permanent impacts</th>
<th>Hydrography for Immersed Tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Various subpart areas (ha)</td>
</tr>
<tr>
<td></td>
<td>Near zone</td>
</tr>
<tr>
<td>Total area (ha)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>343</td>
</tr>
</tbody>
</table>

Severity of loss

| Special | 64¹ | 64¹ | 0 | 58¹ | 6¹ | 0 |
| General | 279 | 279 | 0 | 271 | 8  | 0 |

Total severity of loss | 343 | 343 | 0 | 329 | 14 | 0 |

Degree of impairment

| Very high | 0   | 0   | 0   | 0   | 0   | 0 |
| High      | 136 | 65  | 71  | 114 | 22  | 0 |
| Medium    | 274 | 199 | 75  | 235 | 40  | 0 |
| Low       | 575 | 211 | 364 | 497 | 78  | 0 |

Total degree of impairment | 985 | 475 | 510 | 845 | 140 | 0 |

Total permanent | 1,329 (0.2%) | 819 (34%) | 510 (1.3%) | 1.174 | 154 | 0 |

Reference area | 770,000² | 2,440 | 39,006 | - | - | - |

Note 1: New project beaches will replace these lost beaches, so the net effect for beach water will become about 0 ha

Note 2: Area of the Western Baltic Sea

Significance of permanent impacts

The permanent impacts on the hydrography are assessed to be of no significance for the general hydrography in the Fehmarnbelt and the Belt Sea (and also for the Baltic Sea), due to the minimal extent of the impacted area.

The local loss of beach areas is planned to be compensated by new beach areas and will thus not become a net loss.

Finally, the tendency to reduced currents at the harbour entrances will not have any adverse effect on navigation in and out of the present ferry terminals.

5.2.9 Impacts on the hydrography of Fehmarnbelt during construction

Impacts due to construction activities are classified as temporary since they will cease when construction finishes and, in all cases for the present project, the environment will recover from the impacts.

The impacts on hydrography during construction are due to the temporary structures which are described in section 5.2.5 above. The temporary structures are:
The two work harbours, their breakwaters and access channels on Lolland.
The work harbour, its breakwaters and access channel on Fehmarn.

Magnitude of impacts on hydrography
The following impacts were calculated for the immersed tunnel and are assumed to apply in general for the bored tunnel.

The magnitude of the impact on hydrodynamics is a local large area of reduced current speed in the lee of the temporary breakwaters at the Lolland production facility, and elsewhere the impacts on currents are similar to those for the permanent structures. Figure 5.22 shows the changes in surface current speeds near the work harbours for the immersed tunnel. The picture is similar for the bored tunnel but of course with a second harbour and access channel on the Lolland coast.
Figure 5.22  Close-up of estimated temporary effects to mean surface current speed for the immersed tunnel case during the construction period. Similar impacts apply for the bored tunnel.

The effect on local salinity, temperature and stratification is also negligible in this phase.

The magnitude of the impact on sea state (waves) has not been estimated separately for the construction period. The wave effect from the permanent impact assessment can be applied as a proxy.

Severity of loss and degree of impairment
The loss of water bodies during construction is the same as the permanent losses during operation.

The aggregation of the degree of impairment for the individual sub-component indicators in the construction period results in the distribution of degree of impairment for the immersed tunnel shown in Figure 5.23. The degree of
impairment reaches the “very high” level inside the area sheltered by the breakwaters at both temporary facilities, due to the nearly stagnant water here. The “high” level area is increased in the lee zone outside the breakwaters at Lolland, and also slightly at Puttgarden.

Outside the above areas all sub-components indicator changes are negligible.

A similar pattern of the severity of loss and degree of impairment applies for the bored tunnel, of course with an additional area at the second Lolland work harbour.

The quantification of the impact areas is shown in Table 5.8 and illustrates that the areas impacted are very marginal compared to the overall size of Fehmarnbelt.

---

Figure 5.23 The degree of impairment and severity of loss distribution in the construction period for hydrography impacts of the immersed tunnel. A similar distribution applies for the bored tunnel.
Table 5.8 The degree of impairment and severity of loss areas for temporary impacts on hydrography during construction of the immersed tunnel. A similar distribution applies for the bored tunnel.

<table>
<thead>
<tr>
<th>Temporary impacts</th>
<th>Hydrography for Immersed Tunnel</th>
<th>Various subpart areas (ha)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total area (ha)</td>
<td>Near zone</td>
<td>Local area (excl. n.z.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Total severity of loss</td>
<td>359</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Degree of impairment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very High</td>
<td>23</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>High</td>
<td>212</td>
<td>136</td>
<td>69</td>
</tr>
<tr>
<td>Medium</td>
<td>416</td>
<td>179</td>
<td>240</td>
</tr>
<tr>
<td>Low</td>
<td>636</td>
<td>170</td>
<td>466</td>
</tr>
<tr>
<td>Total degree of impairment</td>
<td>1,287</td>
<td>505</td>
<td>775</td>
</tr>
<tr>
<td>Total temporary</td>
<td>1,645 (0.2%)</td>
<td>863 (35.4%)</td>
<td>775 (2.0%)</td>
</tr>
<tr>
<td>Reference area</td>
<td>770,000¹</td>
<td>2,440</td>
<td>39,006</td>
</tr>
</tbody>
</table>

Note 1: Area of the Western Baltic Sea

Significance of temporary impacts

The temporary impact area is almost the same as the permanent impact area and is similarly evaluated as being of no significance for the general hydrography in the Fehmarnbelt and the Belt Sea (and also for the Baltic Sea).

The two working harbour areas without any through flow will not be fully stagnant, but will exchange water slowly with tide and wind generated circulation. Thus they are not considered a problem in relation to hydrography.

The local loss of beach areas will be fully compensated by new beach areas relatively late in the construction period, thus there will be some temporary net loss during the construction period.

Regarding effects on navigation in and out of the present ferry terminals the tendency to a reduced cross current will be present as soon as the outer perimeter of the reclamations is in place and will be slightly beneficial to the navigation.
5.2.10 Significance of impacts – summary
The impact assessment above concludes that the impacts of the bored tunnel on the hydrography of the Baltic Sea and of Fehmarnbelt are insignificant. The conclusion applies to both the construction and operation phases of the project.

5.2.11 Mitigation and compensation measures
In general the impacts of the bored tunnel project on the hydrography are local and of no significance.

An integrated part of the project design is the establishment of two new beaches at the western part of the Lolland reclamation and at the eastern end of the Puttgarden reclamation. These new facilities will result in no net loss of the high importance amenity seawater areas in front of beaches.

Backfilling of the access channels is not considered to be a necessary mitigation measure because the hydrographic impacts are insignificant.

5.2.12 Decommissioning
Decommissioning which may take place in the year 2140 at the end of the design lifetime of 120 years will comply with the following:

› Any structure on the seabed must be levelled with the seabed in order not to impede ship traffic, fishery and similar activities at sea.

› The decommissioning will leave the reclaimed areas untouched. The reclaimed areas of the tunnel project are designed to maintain or even improve the conditions for flora and fauna. Several habitats for rare species are foreseen in the reclaimed areas. Therefore Femern A/S foresees that it will not be desirable or in some cases not even legal to change the status of the reclaimed areas.

› The bored tunnel will stay in place after removal of internal installations and filling the inside.

Therefore there will be no impacts to the marine environment from the decommissioning activities, and the Fehmarnbelt hydrography will not sense the remaining project structures after the decommissioning.
5.3 Water Quality

This section addresses the water quality conditions in Fehmarnbelt and the possible impacts of the bored tunnel project on the conditions.

Water quality is a component under the environmental factor "water" and the sub-factor "marine water". The relevant sub-components are shown in Table 5.9.

Table 5.9 Water quality sub-components

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sub-factor</th>
<th>Component</th>
<th>Sub-component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Marine water</td>
<td>Water quality</td>
<td>Transparency</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nutrients</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Toxic substances</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dissolved oxygen</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bacteria</td>
</tr>
</tbody>
</table>

5.3.1 Project pressures and potential impacts

The project pressures which can potentially impact water quality are:

› Sediment spill from dredging and reclamation works during construction will affect water transparency.

› Release of nutrients from sediment spill which could enhance eutrophication.

› Release of toxic substances from sediment spill with potential impacts on marine organisms.

› Release of organic material from sediment spill which can impact dissolved oxygen conditions.

› Reduction of light penetration (resulting from a reduction of transparency) can reduce oxygen due to reduced photosynthesis by plankton and benthic flora.

› Discharge of wastewater during construction and operation can affect concentrations of nutrient, toxic substance and bacteria.

The spill of sediments during construction is a key issue in the assessment of water quality, and for impacts on benthic flora and fauna, fish, marine mammals and birds. Therefore the study of sediment spill is treated in detail in this chapter.

All wastewater will be treated according to regulations in Denmark and Germany before being discharged to Fehmarnbelt. The impacts will principally be local near the outfalls and will not be addressed further in this chapter.
5.3.2 Existing water quality in Fehmarnbelt

The most important aspects of the existing water quality in Fehmarnbelt are described here. Refer to FEMA-FEHY 2011 and FEHY 2012h for full details.

**Suspended sediment**

Turbidity was recorded continuously at the main stations and the nearshore stations (described in section 5.2) during 2009 and 2010. The turbidity was converted to suspended sediment concentrations with correlations developed by laboratory analysis of water samples taken at the sensors under a variety of current and wave conditions.

An example of the measured suspended sediment concentrations (SSC) at the main station MS01 is shown in Figure 5.24. For the great majority of the time SSC is under 10 mg/l at the seabed and under 3 mg/l at the surface. These are very low values. It is only during storms which generate strong currents at the seabed that the fine sediments on the bed are re-suspended. Waves in Fehmarnbelt are never large enough to cause significant re-suspension at water depths over 15 m.

![Figure 5.24 Suspended sediment concentrations at MS01 in 2010](image)

Much higher SSCs during storms were recorded at the nearshore stations due to the effect of the waves causing re-suspension of fine sediments deposited on the seabed. Figure 5.25 shows the results at the Lolland coast stations with concentrations reaching almost 200 mg/l during the January storm. Similarly the recordings in the shallow Rødsand Lagoon, which has a high natural deposit of fine sediments, showed SSC over 200 mg/l (Figure 5.26).

SSC at the Fehmarn coast (Figure 5.27) are generally lower, but did exceed 150 mg/l at NS08 on one occasion.
Figure 5.25 Suspended sediment concentrations recorded at mid-depth at nearshore stations NS01 to NS03 in approximately 6 m water depth on the Lolland coast

Figure 5.26 Suspended sediment concentrations recorded at mid-depth at stations NS04 and NS05 in Rodsand Lagoon

Figure 5.27 Suspended sediment concentrations recorded at mid-depth at nearshore stations NS06 to NS08 in approximately 8 m water depth on the Fehmarn coast

Figure 5.28 shows a statistical summary of the continuous measurements of SSC in the form of the 50% (median) and 95% percentiles at all the fixed stations. The figure also shows the seabed level, the height of the sensor above the seabed and the data coverage in % for the period of measurement. It is clearly seen that the SSC level is generally low but increases as the water depth reduces. For example, SSC exceeds 330 mg/l for 5% of the time (the 95% percentiles) at 3 meters depth at station NS03a near the Lolland coast.
Water transparency

The variation of light intensity with water depth was measured during the baseline monthly cruises. The data on the light attenuation was converted to Secchi depth which is the normal parameter for water transparency. Water transparency is dependent on the SSC, plankton and light absorbing pigments in the water.

Secchi depth within Fehmarnbelt itself varied between 4.5 and 9 m, see Figure 5.29. The depth was low during the spring plankton bloom in February 2009 and March 2010 and highest 1-2 months after the spring bloom. During autumn the Secchi depth was between 6 and 7.5 m. The lowest depth was measured in January 2010 (outside the belt itself) a few days after a storm with high wind speeds, currents and wave heights which caused an increased concentration of suspended matter in the water.
Nutrients

The seasonal variation in dissolved inorganic nitrogen (DIN), phosphate and dissolved silicate in the four areas Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill area is shown in Figure 5.30. Averaged over 2009 and 2010 the concentration of all inorganic nutrients peaks in January and February as a result of accumulated mineralisation during late autumn-winter and land run-off, combined with a low insolation preventing phototrophic production and uptake of nutrients by algae. Nutrients, in particular DIN, decreased in March due to the spring bloom and DIN remained exhausted until November. In contrast, phosphate was still available at the end of April and the concentration was varying between 2 and 5 mg PO4-P m$^{-3}$ from May through August. From September through December the concentration of phosphate increased gradually reaching peak winter values in January.

Concentration of silicate decreased from February to April in a 1:1 molar ratio with nitrogen (2:1 in weight) strongly indicating that the spring bloom was dominated by diatoms. From April onwards to January the concentration of silicate increased to reach peak winter values.

Compared to the seasonal variation, the spatial variation in nutrient concentrations is small. Notable patterns are lower winter concentrations of DIN in the Darss Sill area reflecting a larger influence from the Baltic Sea being lower in inorganic nitrogen, and higher nutrient concentrations in April in the Darss Sill and Fehmarnbelt areas caused by a delayed spring bloom compared to Great Belt and Mecklenburg Bight.
Dissolved oxygen

High concentrations of oxygen are required to support a healthy and diverse benthic system. When oxygen becomes reduced to below 4-5 mg O₂ l⁻¹ (i.e., oxygen deficiency) conditions become detrimental to aquatic organisms living in and on the seabed.

The depth and stratification in Fehmarnbelt leads to frequent oxygen deficiency at the bed in late summer and autumn.

During the baseline investigation, dissolved oxygen was measured continuously from late March 2009 through March 2011 at the 3 mooring stations located in the...
Fehmarnbelt area (see Figure 5.6). Oxygen concentration at the shallow northern Fehmarnbelt (MS01) was generally good, while the southern Fehmarnbelt (MS02) and Mecklenburg Bight (MS03) experienced oxygen deficiency during late summer, especially in 2010.

The oxygen situation differed between 2009 and 2010 (Figure 5.31). In 2009 the oxygen minima at MS02 was reached in late September, but the concentration never fell below 1 mg O$_2$ l$^{-1}$. In 2010 the bottom water experienced extended periods of severe oxygen deficiency. At MS02 the oxygen concentration fell below 1 mg O$_2$ l$^{-1}$ in beginning of September 2010 and reached anoxic conditions in late September persisting until 3rd October when a low pressure front passed. The better oxygen conditions in 2009 compared with 2010 were due to stormy winds from varying directions which prevailed at the end of August/beginning of September.

Bathing water quality

The Bathing Water Directive sets the standards for microbial water quality at popular beaches that have been designated as bathing waters because they attract large numbers of bathers. Discharges from the bored tunnel project construction and operation phases are will not alter the microbial conditions and official status of the beaches.

Another parameter affecting bathing water quality is turbidity. The dredging and reclamation works near the coasts of Lolland and Fehmarn can affect the turbidity at the beaches and the impact is addressed below.
5.3.3 Methodology

The assessment methodology for water quality and plankton biology is based on dynamic numerical models, including hydrodynamic models, sediment models and water quality models.

The important pressures related to construction and operation period of the tunnel scenario (e.g. concentration of spilled sediment) are modelled dynamically in 3 dimensions. The concentrations of spilled sediments are used to assess impacts at bathing beaches while the release of nutrients and organic material from the sediments is used to assess impacts on nutrient levels (and thereby eutrophication) and dissolved oxygen.

The principles used to define the criteria for determining the degree of impairment of water quality are listed in Table 5.10.

Table 5.10 Assessment criteria for water quality in the local Fehmarnbelt area and the regional area which includes the Western Baltic Sea

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Criteria for degrees of impairment</th>
<th>Duration</th>
<th>Range</th>
<th>Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended sediment (construction-related)</td>
<td>High to very high reduction in Secchi depth</td>
<td>Temporary</td>
<td>Regional (also outside local zone)</td>
<td>Very high</td>
</tr>
<tr>
<td></td>
<td>Medium to high reduction in Secchi depth</td>
<td>Temporary</td>
<td>Regional (also outside local zone)</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Minor to medium reduction in Secchi depth</td>
<td>Temporary</td>
<td>Regional (also outside local zone)</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Only minor reduction in Secchi depth</td>
<td>Temporary</td>
<td>Regional (also outside local zone)</td>
<td>Minor</td>
</tr>
<tr>
<td>Toxic substances (construction-related)</td>
<td>Concentration must not exceed Environmental Quality Standards (EQS) or national water quality criteria</td>
<td>Temporary</td>
<td>Local</td>
<td>Case-by-case related</td>
</tr>
<tr>
<td>Oxygen consuming substances</td>
<td>Reduction in oxygen concentration should not lead to impacts on benthic organisms</td>
<td>Temporary</td>
<td>Regional (also outside local zone)</td>
<td>Case-by-case related</td>
</tr>
<tr>
<td>Hydrographical regime (structure-related)</td>
<td>Change in oxygen concentration should not lead to impacts on benthic organisms (increase in DO is not regarded as a negative impact)</td>
<td>Permanent</td>
<td>Regional (also outside local zone)</td>
<td>Case-by-case related</td>
</tr>
</tbody>
</table>

The principle behind the assessment criteria concerns the ability of marine flora and fauna to adapt to changes in the physical, chemical and geological elements in the water column. These elements vary over a broad range from year to year due to changes in run-off, land use (changes in nutrients), climate and meteorology. The marine flora and fauna of Fehmarnbelt are adapted to such variability, but large
deviations outside the natural range may affect vegetation biomass and animal populations.

The natural variability is quantified as the standard deviation based on: 20 years of monitoring data from 2 - 3 stations in the Fehmarnbelt and data from the Baltic Sea basins. Data analyses include temperature, salinity, different indices of water column stratification, Secchi depth, chlorophyll-a and bottom water oxygen. The standard deviations are listed in Table 5.11.

Table 5.11  Standard deviation values of the water quality sub-components based on the baseline study

<table>
<thead>
<tr>
<th>Sub-component</th>
<th>Fehmarnbelt Station N01 (1990-2007) or MS02 (2009-2010)</th>
<th>Central Baltic Sea Station K02 Bornholm Basin (1990-2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom oxygen (annual minimum)</td>
<td>3.7 mg/l</td>
<td>2.3 mg/l</td>
</tr>
<tr>
<td>Surface chlorophyll a (annual mean)</td>
<td>2.1 µg/l</td>
<td>1.8 µg/l</td>
</tr>
<tr>
<td>Surface bluegreen carbon (annual mean)</td>
<td>-</td>
<td>30 - 60 µg/l</td>
</tr>
<tr>
<td>Secchi depth (annual mean)</td>
<td>1.9 m (1984-97)</td>
<td>3.2 m (1910-1999)</td>
</tr>
</tbody>
</table>

5.3.4 Sediment spill during construction

The construction activities generating sediment spill are:

› Dredging of work harbours and access channels
› Construction of containment dikes around reclamation areas
› Placement of dredged material and dewatered slurry in reclamations and as overburden, including landscaping
› Backfilling of work harbours
› Filling artificial beaches with sand

The construction of the bored tunnel is planned to take place between the 13 October 2014 and the 12 October 2020. The bulk of the spill will occur during the first 10 months (before the 13 August 2015) and the last 3 months (after the 29 June 2020).

Table 5.12 gives an overview of the activities that generate spill in the bored tunnel scenario. The table shows work sections and activity names, volumes and output rates, duration and spill in percentage, total spill in tons, starting/ending dates, locations, and equipment types. The total spill amounts to 96,000 m³ (169,000 tons).
<table>
<thead>
<tr>
<th>Work section</th>
<th>Activity</th>
<th>Quantity [m³]</th>
<th>Production [m³/week]</th>
<th>Duration [weeks]</th>
<th>Spill [%]</th>
<th>Total spill [Tons]</th>
<th>Starting date [y-m-d]</th>
<th>Ending date [y-m-d]</th>
<th>Area [_]</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Works harbour Fehmarn</td>
<td>Dredging Work harbour</td>
<td>794000</td>
<td>90000</td>
<td>8.82</td>
<td>0.7</td>
<td>8304</td>
<td>2014-12-15</td>
<td>2015-02-14</td>
<td>F8</td>
<td>BHD</td>
</tr>
<tr>
<td>Works harbour Fehmarn</td>
<td>Dredging Access channel</td>
<td>135000</td>
<td>90000</td>
<td>1.50</td>
<td>3.50</td>
<td>7089</td>
<td>2014-10-13</td>
<td>2014-10-23</td>
<td>T3</td>
<td>BHD</td>
</tr>
<tr>
<td>Works harbour Lolland East</td>
<td>Dredging Work harbour</td>
<td>688000</td>
<td>90000</td>
<td>7.76</td>
<td>0.70</td>
<td>9723</td>
<td>2015-02-16</td>
<td>2015-04-11</td>
<td>F5</td>
<td>BHD</td>
</tr>
<tr>
<td>Works harbour Lolland East</td>
<td>Dredging Access channel</td>
<td>477000</td>
<td>90000</td>
<td>5.30</td>
<td>3.50</td>
<td>33223</td>
<td>2014-10-27</td>
<td>2014-12-03</td>
<td>T5</td>
<td>BHD</td>
</tr>
<tr>
<td>Works harbour Lolland West</td>
<td>Dredging Work harbour</td>
<td>362000</td>
<td>90000</td>
<td>4.02</td>
<td>0.70</td>
<td>5043</td>
<td>2015-04-13</td>
<td>2015-05-11</td>
<td>F2</td>
<td>BHD</td>
</tr>
<tr>
<td>Works harbour Lolland West</td>
<td>Dredging Access channel</td>
<td>124000</td>
<td>90000</td>
<td>1.38</td>
<td>3.50</td>
<td>3637</td>
<td>2014-12-08</td>
<td>2014-12-17</td>
<td>T4</td>
<td>BHD</td>
</tr>
<tr>
<td>Containment dikes</td>
<td>Fehmarn East (750m)</td>
<td>158640</td>
<td>23000</td>
<td>6.90</td>
<td>0.80</td>
<td>2526</td>
<td>2014-10-13</td>
<td>2014-11-30</td>
<td>D4</td>
<td>BHD</td>
</tr>
<tr>
<td>Containment dikes</td>
<td>Fehmarn East (750m)</td>
<td>168640</td>
<td>23000</td>
<td>6.90</td>
<td>0.70</td>
<td>1766</td>
<td>2014-04-10</td>
<td>2014-11-30</td>
<td>D5</td>
<td>BHD</td>
</tr>
<tr>
<td>Containment dikes</td>
<td>Fehmarn East (750m)</td>
<td>79320</td>
<td>12500</td>
<td>6.35</td>
<td>0.10</td>
<td>126</td>
<td>2014-10-13</td>
<td>2014-11-25</td>
<td>D/D/D</td>
<td>G01,2,3</td>
</tr>
<tr>
<td>Lolland - East - Section 1 (1,250m)</td>
<td>Dredging Work harbour</td>
<td>102247</td>
<td>23000</td>
<td>4.36</td>
<td>0.80</td>
<td>9723</td>
<td>2014-10-13</td>
<td>2014-11-12</td>
<td>D1</td>
<td>BHD</td>
</tr>
<tr>
<td>Lolland - East - Section 1 (1,250m)</td>
<td>Dredging Access channel</td>
<td>123194</td>
<td>23000</td>
<td>5.36</td>
<td>0.70</td>
<td>1716</td>
<td>2014-10-13</td>
<td>2014-11-19</td>
<td>D1</td>
<td>BHD</td>
</tr>
<tr>
<td>Lolland - East - Section 1 (1,250m)</td>
<td>Dredging Access channel</td>
<td>64136</td>
<td>7500</td>
<td>8.55</td>
<td>0.10</td>
<td>102</td>
<td>2014-10-13</td>
<td>2014-12-11</td>
<td>D1</td>
<td>G01,2,3</td>
</tr>
<tr>
<td>Lolland - East - Section 2 (1,250m)</td>
<td>Dredging Work harbour</td>
<td>146739</td>
<td>23000</td>
<td>6.35</td>
<td>0.80</td>
<td>3867</td>
<td>2014-10-13</td>
<td>2014-11-26</td>
<td>D2</td>
<td>BM8</td>
</tr>
<tr>
<td>Lolland - East - Section 2 (1,250m)</td>
<td>Dredging Access channel</td>
<td>191962</td>
<td>23000</td>
<td>8.35</td>
<td>0.70</td>
<td>2674</td>
<td>2014-10-13</td>
<td>2014-12-10</td>
<td>D2</td>
<td>BHD6</td>
</tr>
<tr>
<td>Lolland - East - Section 2 (1,250m)</td>
<td>Hydrolane</td>
<td>96380</td>
<td>12500</td>
<td>7.87</td>
<td>0.10</td>
<td>156</td>
<td>2014-10-13</td>
<td>2014-12-07</td>
<td>D2</td>
<td>G01,2,3</td>
</tr>
<tr>
<td>Lolland - West (1700m)</td>
<td>Dredging Work harbour</td>
<td>107370</td>
<td>23000</td>
<td>4.67</td>
<td>0.80</td>
<td>1366</td>
<td>2014-11-17</td>
<td>2014-12-19</td>
<td>D3</td>
<td>BHD</td>
</tr>
<tr>
<td>Lolland - West (1700m)</td>
<td>Dredging Access channel</td>
<td>140490</td>
<td>23000</td>
<td>6.11</td>
<td>0.70</td>
<td>1957</td>
<td>2014-11-17</td>
<td>2014-12-29</td>
<td>D3</td>
<td>BHD</td>
</tr>
<tr>
<td>Lolland - West (1700m)</td>
<td>Dredging Access channel</td>
<td>71805</td>
<td>12500</td>
<td>5.76</td>
<td>0.10</td>
<td>114</td>
<td>2014-11-24</td>
<td>2015-01-03</td>
<td>D3</td>
<td>G01,2,3</td>
</tr>
<tr>
<td>Redamnment dredged material</td>
<td>Fehmarn - East - Dredged material out of harbour</td>
<td>96160</td>
<td>6900</td>
<td>13.86</td>
<td>0.90</td>
<td>7143</td>
<td>2014-12-01</td>
<td>2015-03-08</td>
<td>F8</td>
<td>BHD</td>
</tr>
<tr>
<td>Redamnment dredged material</td>
<td>Fehmarn - East - Place overburden</td>
<td>486000</td>
<td>3000</td>
<td>16.00</td>
<td>0.90</td>
<td>3568</td>
<td>2014-12-01</td>
<td>2015-03-19</td>
<td>F8</td>
<td>BHD</td>
</tr>
<tr>
<td>Redamnment dredged material</td>
<td>Lolland - Dredged material out of Lolland</td>
<td>954384</td>
<td>6900</td>
<td>13.83</td>
<td>0.90</td>
<td>9456</td>
<td>2015-03-09</td>
<td>2015-06-13</td>
<td>F3</td>
<td>BHD</td>
</tr>
<tr>
<td>Redamnment dredged material</td>
<td>Lolland - Place overburden</td>
<td>1800000</td>
<td>10000</td>
<td>16.00</td>
<td>0.10</td>
<td>18070</td>
<td>2015-03-09</td>
<td>2015-06-04</td>
<td>F3</td>
<td>BHD</td>
</tr>
<tr>
<td>Redamnment dredged material</td>
<td>Lolland - Ramsay material out of Harbour Lolland West</td>
<td>583000</td>
<td>6900</td>
<td>8.45</td>
<td>0.90</td>
<td>5801</td>
<td>2015-06-15</td>
<td>2015-08-13</td>
<td>F1</td>
<td>BHD</td>
</tr>
<tr>
<td>Landscaping redamnment area</td>
<td>Backfilling WH - Lolland East</td>
<td>120000</td>
<td>9230</td>
<td>13.00</td>
<td>0.90</td>
<td>8964</td>
<td>2020-06-29</td>
<td>2020-09-28</td>
<td>F5</td>
<td>Dumpe</td>
</tr>
<tr>
<td>Landscaping redamnment area</td>
<td>Backfilling WH - Lolland West</td>
<td>500000</td>
<td>35452</td>
<td>13.00</td>
<td>0.90</td>
<td>3735</td>
<td>2020-06-29</td>
<td>2020-09-28</td>
<td>F2</td>
<td>Dumpe</td>
</tr>
<tr>
<td>Landscaping redamnment area</td>
<td>Backfilling WH - Fehmarn</td>
<td>135000</td>
<td>108346</td>
<td>13.00</td>
<td>0.90</td>
<td>10835</td>
<td>2020-06-29</td>
<td>2020-09-28</td>
<td>F8</td>
<td>Dumpe</td>
</tr>
<tr>
<td>Landscaping redamnment area</td>
<td>Beach - Lolland East</td>
<td>70000</td>
<td>34000</td>
<td>2.06</td>
<td>2.00</td>
<td>2226</td>
<td>2020-09-28</td>
<td>2020-10-12</td>
<td>P6</td>
<td>TSHD</td>
</tr>
<tr>
<td>Landscaping redamnment area</td>
<td>Beach &amp; Dunes - Lolland West</td>
<td>440000</td>
<td>34000</td>
<td>12.94</td>
<td>2.00</td>
<td>13992</td>
<td>2020-06-29</td>
<td>2020-09-27</td>
<td>P4</td>
<td>TSHD</td>
</tr>
</tbody>
</table>
Sediment characteristics
Table 5.13 presents an overview of the different standard soil types found in the Fehmarnbelt area together with dry densities and distribution over the five fractions f0-f4 where:

› f0: sand
› f1: fine sand/coarse silt
› f2: medium silt
› f3: fine silt
› f4: clay

For the bored tunnel each activity is carried out in a specific soil which is represented by a combination of the different standard soil types. Table 5.14 shows the soil type distribution for each activity.

Table 5.13  Soil types and fraction distributions

<table>
<thead>
<tr>
<th>Material</th>
<th>Density [kg/m³]</th>
<th>f0 [%]</th>
<th>f1 [%]</th>
<th>f2 [%]</th>
<th>f3 [%]</th>
<th>f4 [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain size [mm]</td>
<td>-</td>
<td>0.147</td>
<td>0.065</td>
<td>0.028</td>
<td>0.010</td>
<td>0.007</td>
</tr>
<tr>
<td>Settling velocity [mm/s]</td>
<td>-</td>
<td>15.00</td>
<td>2.90</td>
<td>0.56</td>
<td>0.07</td>
<td>0.03</td>
</tr>
<tr>
<td>Glacial Melt Water Sand</td>
<td>1820</td>
<td>90</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Post Glacial Sand</td>
<td>1660</td>
<td>50</td>
<td>15</td>
<td>22</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Late Glacial Sand Silt</td>
<td>1660</td>
<td>63</td>
<td>14</td>
<td>17</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Gytje</td>
<td>670</td>
<td>12</td>
<td>10</td>
<td>16</td>
<td>31</td>
<td>32</td>
</tr>
<tr>
<td>Paleogene Clay</td>
<td>1330</td>
<td>15</td>
<td>11</td>
<td>14</td>
<td>14</td>
<td>47</td>
</tr>
<tr>
<td>Late Glacial Clay</td>
<td>1330</td>
<td>23</td>
<td>12</td>
<td>11</td>
<td>35</td>
<td>19</td>
</tr>
<tr>
<td>Clay Till</td>
<td>1990</td>
<td>45</td>
<td>17</td>
<td>9</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Avg</td>
<td>1494</td>
<td>39</td>
<td>15</td>
<td>11</td>
<td>18</td>
<td>17</td>
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<tr>
<td>Sand</td>
<td>1590</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rock</td>
<td>1590</td>
<td>50</td>
<td>45</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Armour</td>
<td>1590</td>
<td>50</td>
<td>45</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Gravel</td>
<td>1590</td>
<td>50</td>
<td>25</td>
<td>25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gravel Sand</td>
<td>1590</td>
<td>50</td>
<td>25</td>
<td>25</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 5.14: Overview of soil type distribution for each activity for the bored tunnel.

<table>
<thead>
<tr>
<th>Work section</th>
<th>Activity</th>
<th>Material (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GMWS</td>
</tr>
<tr>
<td>Works harbour Fehmarn</td>
<td>Dredging Work harbour</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Dredging Access channel</td>
<td>0</td>
</tr>
<tr>
<td>Works harbour Lolland East</td>
<td>Dredging Work harbour</td>
<td>0</td>
</tr>
<tr>
<td>Works harbour Lolland West</td>
<td>Dredging Access channel</td>
<td>0</td>
</tr>
<tr>
<td>Containment dikes</td>
<td>Fehmarn East (750m)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Fehmarn East (750m)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Fehmarn East (750m)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lolland - East - Section 1 (1,250m)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lolland - East - Section 1 (1,250m)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lolland - East - Section 1 (1,250m)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lolland - East - Section 2 (2,350m)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Fehmarn - East-Dredged material out</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Fehmarn - East-Place overburden</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lolland -Dredged material out</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lolland -Place overburden</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lolland -Remains out of Harbour</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Backfilling WH - Lolland East</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Backfilling WH - Lolland West</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Backfilling WH - Fehmarn</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Beach - Lolland East</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Beach&amp;Dunes - Lolland West</td>
<td>0</td>
</tr>
</tbody>
</table>
Spill locations

During dredging activities, dredgers will move along the access channels on each side (Fehmarn and Lolland). Spill locations are listed in Table 5.12 and shown in Figure 5.32.

Figure 5.32  Spill locations for the bored tunnel marine works. See Table 5.12 regarding activity at each location
Key spill figures

An overview of the amounts of sediment spilled in terms of total volume and total mass for each activity and per year is presented in Table 5.15 (volume) and Table 5.16 (mass). From the tables it is seen that 2014 and 2015 are the years with most spill.

Table 5.17 shows the total spill per fraction per year from the coarsest fraction (f0, sand) to the finest fraction (f4) (see Table 5.13 for fraction description). It is seen that a little bit less than half of the spilled material (44%) is sand (74 tons). Fractions f1 and f2, the most likely ones to settle in the Rødsand Lagoon, represent a total of 30% of the material spilled into the environment (49 tons).

### Table 5.15 Total volume spilled per work section per year (work harbours include access channels)

<table>
<thead>
<tr>
<th>Year</th>
<th>Work harbour Fehmarn</th>
<th>Work harbours Lolland</th>
<th>Containment dikes</th>
<th>Reclamation</th>
<th>Landscaping</th>
<th>TOTAL (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>6,255</td>
<td>21,035</td>
<td>8,714</td>
<td>2,192</td>
<td>0</td>
<td>38,196</td>
</tr>
<tr>
<td>2015</td>
<td>4,028</td>
<td>7,420</td>
<td>4</td>
<td>20,676</td>
<td>0</td>
<td>32,128</td>
</tr>
<tr>
<td>2016</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2019</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2020</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>39,002</td>
<td>39,002</td>
</tr>
<tr>
<td>TOTAL (m³)</td>
<td>10,283</td>
<td>28,455</td>
<td>8,718</td>
<td>22,868</td>
<td>25,450</td>
<td>95,773</td>
</tr>
</tbody>
</table>

### Table 5.16 Total mass spilled per work section per year (work harbours include access channels)

<table>
<thead>
<tr>
<th>Year</th>
<th>Work harbour Fehmarn</th>
<th>Work harbours Lolland</th>
<th>Containment dikes</th>
<th>Reclamation</th>
<th>Landscaping</th>
<th>TOTAL (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>9,345</td>
<td>41,860</td>
<td>15,638</td>
<td>3,275</td>
<td>0</td>
<td>70,117</td>
</tr>
<tr>
<td>2015</td>
<td>6,018</td>
<td>14,766</td>
<td>7</td>
<td>38,670</td>
<td>0</td>
<td>59,460</td>
</tr>
<tr>
<td>2016</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2019</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2020</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>39,002</td>
<td>39,002</td>
</tr>
<tr>
<td>TOTAL (tons)</td>
<td>15,363</td>
<td>56,625</td>
<td>15,644</td>
<td>41,945</td>
<td>39,002</td>
<td>168,579</td>
</tr>
</tbody>
</table>
Results from spill simulations

Results from the simulations of spreading and deposition of spilled sediments are presented in this section and compared to similar results for the immersed tunnel FEHY (2012a).

The locations of the stations where measurements of suspended concentrations have been undertaken are shown in Figure 5.6 (hydrography section). Stations NS03 (Lolland), NS04 (Rødsand Lagoon) and NS08 (Fehmarn) have been selected for comparison of the suspended sediment concentrations from the bored tunnel and immersed tunnel.

Simulated suspended sediment concentrations are shown for the first two years of construction (2014 and 2015) and compared with the immersed tunnel scenario with production facility in Rødbyhavn (Figure 5.33 to Figure 5.35). After 2015 bored tunnel operations are carried out underground and no spill will occur.

Results for suspended sediment concentration are also compared for the last year of construction of the two alternatives (Figure 5.36 to Figure 5.38). For both alternatives the spilled sediment is caused mainly by reclamation and landscaping operations even though only half of those operations are carried out in the last year for the immersed tunnel. Note that time series of suspended sediment have been shifted in time by one year for the immersed tunnel scenario as the last year is 2019 for this scenario and 2020 for the bored tunnel scenario.

The figures show that during 2014 and 2015 the sediment concentration at the three locations for the entire water column is in general much lower in the case of a bored tunnel, except for the period October-December 2014 where the concentrations are slightly higher for the bored tunnel due to more intensive operations on containment dikes and work harbours with spill rates up to 14 kg/s from up to 10 concurrent activities. Concerning the immersed tunnel, intense activity is seen from April 2015 with a combination of trench dredging activities and reclamation disposal operations on both sides (Lolland and Fehmarn).

Maximum spill rates are about 15 kg/s for the bored tunnel and about 30 - 50 kg/s for the immersed tunnel. Only station NS08 at the bottom has a maximum value of

Table 5.17 Total mass spilled per fraction per year

<table>
<thead>
<tr>
<th>Year</th>
<th>f0</th>
<th>f1</th>
<th>f2</th>
<th>f3</th>
<th>f4</th>
<th>TOTAL (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>30,928</td>
<td>13,753</td>
<td>6,089</td>
<td>7,908</td>
<td>11,439</td>
<td>70,117</td>
</tr>
<tr>
<td>2015</td>
<td>25,768</td>
<td>9,723</td>
<td>5,736</td>
<td>7,514</td>
<td>0</td>
<td>59,460</td>
</tr>
<tr>
<td>2016</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2019</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2020</td>
<td>17,054</td>
<td>11,451</td>
<td>2,577</td>
<td>3,983</td>
<td>3,937</td>
<td>39,002</td>
</tr>
<tr>
<td>TOTAL (tons)</td>
<td>73,750</td>
<td>34,927</td>
<td>14,402</td>
<td>19,405</td>
<td>26,096</td>
<td>168,579</td>
</tr>
</tbody>
</table>
about the same intensity for the bored tunnel as for the immersed tunnel but only for a very short period of time.

During the last year of construction (i.e. 2019 for the immersed tunnel and 2020 for the bored tunnel) sediment concentrations are generally much lower than during the first years, note the different scales applied in Figure 5.36, Figure 5.37 and Figure 5.38 compared with Figure 5.33, and Figure 5.35.

Maps of exceedance of sediment concentrations of 2 mg/l at the surface in summer and 10 mg/l at the bottom in winter for 2015 (Figure 5.39 and Figure 5.41) show no values above 10 % of the time for the bored tunnel solution, whereas for the immersed tunnel solution exceedance times are expected to be much longer (Figure 5.40 and Figure 5.42).

Deposition maps at the end of the simulation show that deposition in the western part of Rødsand Lagoon is reduced by a factor 2 for the bored tunnel compared to the immersed tunnel. No deposition is observed along the alignment for the bored tunnel (Figure 5.43 and Figure 5.44).

The sediment flows are shown in Figure 5.45 and Figure 5.46. It appears that 45.6% of the material remains within a 10 km zone around the alignment. The rest of the material is split into 7.9% spreading towards west (13,267 tons) and 46.5% towards east (78,355 tons). 6.3% of the total spill flows into the Rødsand Lagoon (11,688 tons). For the immersed tunnel 2.5% of the total spill flows into the lagoon (29,707 tons). Note that all fractions are taken into consideration (the percentage is the actual percentage of the total material spilled that is passing through the line).

Table 5.18 shows the accumulated spill from dredging operations on the Danish side and accumulated spill that has entered the Rødsand Lagoon on the 1 September 2015 and 1 September of the last year of operations (2019 for the immersed tunnel scenario and 2020 for the bored tunnel scenario).
Figure 5.33  Total suspended concentration at station NS03 between 13 October 2014 and 31 December 2015 for bored tunnel and immersed tunnel. From top to bottom: top, middle and bottom layer

Figure 5.34  Total suspended concentration at station NS04 between 13 October 2014 and 31 December 2015 for bored tunnel and immersed tunnel. From top to bottom: top, middle and bottom layer
Figure 5.35  Total suspended concentration at station NS08 between 13 October 2014 and 31 December 2015 for bored tunnel and immersed tunnel. From top to bottom: top, middle and bottom layer

Figure 5.36  Total suspended concentration at station NS03 for the last production year for bored tunnel and immersed tunnel. From top to bottom: top, middle and bottom layer
Figure 5.37  Total suspended concentration at station NS04 for the last production year for bored tunnel and immersed tunnel. From top to bottom: top, middle and bottom layer

Figure 5.38  Total suspended concentration at station NS08 for the last production year for bored tunnel and immersed tunnel. From top to bottom: top, middle and bottom layer
Figure 5.39  Bored tunnel solution: Exceedance time of 2 mg/l, 1 May – 1 September 2015 for the surface (top layer in the numerical model results).

Figure 5.40  Immersed tunnel solution: Exceedance time of 2 mg/l, 1 May – 1 September 2015 for the surface (top layer in the numerical model results).
Figure 5.41  Bored tunnel solution: Exceedance time of 10 mg/l, 1 March – 1 October 2015 for the bottom (bottom layer in the numerical model results).

Figure 5.42  Immersed tunnel solution: Exceedance time of 10 mg/l, 1 March – 1 October 2015 for the bottom (bottom layer in the numerical model results).
Figure 5.43  Bored tunnel solution: Deposition after 2020 (end of simulation).

Figure 5.44  Immersed tunnel solution: Deposition after 2019 (end of simulation).
Figure 5.45  Bored tunnel solution: Sediment flows in percentage of the total spill and mass in tons across the cross section.

Figure 5.46  Immersed tunnel solution: Sediment flows in percentage of the total spill and mass in tons across the cross sections.
Table 5.18  Accumulated spill from dredging operations on the Danish side and accumulated spill that has entered the lagoon on the 01/09/2015 and 01/09 of the last year of operations (2019 for the immersed tunnel scenario and 2020 for the bored tunnel scenario)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Accumulated spill 1 Sept 2015 [tons]</th>
<th>Accumulated spill, which has entered the Rødsand Lagoon 1 Sept 2015 [tons]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bored tunnel, Danish side</td>
<td>99,068</td>
<td>8,225</td>
</tr>
<tr>
<td>Immersed tunnel, Danish side</td>
<td>487,260</td>
<td>33,867</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Accumulated spill 1 Sept 2020 for bored tunnel 1 Sept 2019 for immersed tunnel [tons]</th>
<th>Accumulated spill, which has entered the Rødsand Lagoon 1 Sept 2020 for bored tunnel 1 Sept 2019 for immersed tunnel [tons]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bored tunnel, Danish side</td>
<td>117,890</td>
<td>10,987</td>
</tr>
<tr>
<td>Immersed tunnel, Danish side</td>
<td>821,610</td>
<td>29,725</td>
</tr>
</tbody>
</table>

5.3.5 Impact of sediment spill on transparency

Magnitude of impact

The increased concentrations of suspended sediment originating from sediment spill in the water increase the turbidity and reduce light penetration in the water column, e.g. leading to reduction in Secchi depth. The increased turbidity may also affect bathers’ perception of bathing water quality.

As a result of dredging and sediment spill in 2014-2015 Secchi depth becomes reduced by up to 20% in an area of 9,060 ha along the Lolland coast and in Rødsand Lagoon (Figure 5.47 to Figure 5.49).

The reductions in Secchi depth is negligible in 2020 (below 10% reduction compared with baseline values) and close to zero during the intervening period 2016-2019.

In German waters, the reduction in the yearly averaged Secchi depths does not exceed 2-3% at any location and period, meaning that impacts are negligible.
Figure 5.47  Modelled Secchi depth under baseline conditions, average for 2015

Figure 5.48  Modelled percent reduction in average Secchi depth October 2014 to December 2015
Figure 5.49  Modelled percent reduction in Secchi depth, average for 2020

Degree of impairment
The reduction of Secchi depth by up to 20% along the Lolland coast in 2014-2015 is classified as a minor degree of impairment (see section 5.2 Hydrography above for the criteria defining the degree of impairment). A reduction of less than 10% in 2020 is classified as a negligible degree of impairment.

Similarly, the reductions of Secchi depth along the Fehmarn coast do not exceed 2-3% at any time and the degree of impairment is negligible.

Table 5.19  Degree of impairment on Secchi depth (areas in ha) caused by suspended sediments for the bored tunnel alternative.

<table>
<thead>
<tr>
<th>2014-2015</th>
<th>Total</th>
<th>DK national + EEZ</th>
<th>DE national</th>
<th>DE EEZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>High</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medium</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minor</td>
<td>9,060</td>
<td>9,060</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9,060</strong></td>
<td><strong>9,060</strong></td>
<td><strong>0</strong></td>
<td><strong>0</strong></td>
</tr>
</tbody>
</table>

For the bathing quality a set of criteria has been determined (FEMA 2012f). Table 5.20 below depicts a matrix to assess the degree of impairment for bathing water. As Danish, German and European studies were lacking, the New Zealand findings
were adopted and supplemented with the duration of impact, i.e. the % of beach days (1 June – 31 August) that Secchi depth is below 1.5, 2.75 and 5 m.

Table 5.20 Matrix to assess degree of impairment for water clarity (equivalent Secchi depth) along beaches in Fehmarnbelt. Duration refers to % of time during bathing season (1 June – 31 August) Secchi depth boundaries was exceeded.

<table>
<thead>
<tr>
<th>Criteria for degree of impairment of bathing beaches</th>
<th>Secchi depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of exceedance (%)</td>
<td>&lt;1.5</td>
</tr>
<tr>
<td>100 Very high</td>
<td>High</td>
</tr>
<tr>
<td>50 High</td>
<td>Medium</td>
</tr>
<tr>
<td>25 Medium</td>
<td>Minor</td>
</tr>
<tr>
<td>5 Minor</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

Predicted reductions in Secchi depth (based on intensity and duration during the bathing season) along beaches are way below the threshold levels defined by the criteria and accordingly impacts are negligible.

5.3.6 Impact of release of nutrients from sediment spill

The release of nutrients from disturbed sediments is a key issue to be investigated in projects involving major dredging activities since they may increase the level or risk of eutrophication.

Magnitude of impact

Core samples of seabed sediments were taken during the baseline studies at 17 locations near the immersed tunnel alignment. The cores were up to 3 m in length and representative samples were analysed in the laboratory. The nutrient contents was determined (dissolved inorganic nitrogen, phosphorus and silicate) along with the proportion actually released from the sediment to the seawater. It is noted that only one of the locations is near the dredging areas for the bored tunnel, however many of the samples are in the same geological formations as the bored tunnel dredging areas.

With a daily dredging intensity of 20,000 m³, the average release of nitrogen is approximately 0.5 kg DIN/day and the average release of phosphorus is approximately 2 kg P/day. These estimated releases are very low; especially considering the horizontal transports through the Fehmarnbelt.

For reference, the daily demand for nutrients by phytoplankton in the Fehmarnbelt within a 100m wide zone along the entire immersed tunnel alignment (18 km) are estimated at 553 kg N and 35 kg P. For nitrogen, the daily uptake is 3 orders of magnitude higher than the estimated average release. For phosphorus the demand is about 15 times higher than the average release. Given these figures, effects of nutrient release can be ruled out.
Significance of impact
The impact on eutrophication of the release of nutrients from the bored tunnel dredged sediments will be negligible.

5.3.7 Impact of release of toxic contaminants from sediment spill
The concentrations of heavy metals, PCB, PAH, DDT and TBT were determined for the seabed sediments.

Magnitude of impact
The concentrations of heavy metals are low and, with the exception of Cu and Ni, below the lower values of the Danish and German environmental quality standards. The highest Cu and Ni concentrations are equal to the Danish L Ac (Lower Action level) but still far lower than the H Ac (Higher Action level). The concentrations in the sediments from 30 – 100 cm are equal to or slightly lower than those in the surface layer 0 – 30 cm.

Below 1 m the concentrations reach background levels which are a factor of 10 lower than the surface sediments (COWI-Lahmeyer 1998).

Previous studies with sediment from the Fehmarnbelt showed that release of heavy metals from suspended sediments was low, typically 1% of the sediment concentration (COWI-Lahmeyer 1998). In a most comprehensive assessment based on laboratory and field studies of about 100 contaminated sediments from across the United States, it was shown that the release of heavy metals was insignificant.

It can be concluded that the heavy metals released during dredging in Fehmarnbelt will not affect benthic or pelagic organisms.

Except for one sample the concentration of PCB in surface sediments was well below the lower values of the Danish and German standards. One surface sample in the middle of Fehmarnbelt differed from the other 14 samples by exceeding the lower standard values and showing a concentration that was 85 times higher than the other samples. As concentration of PCB is low at the nearby stations it is very likely that the pollution is very localised and due to an object either lost or dumped at sea.

Overall, the concentration of PCBs is low and confined to the upper 10-12 cm of the sediment. This was determined by the analysis of centimetre slices of surface sediments at two central stations. Since only 1/100 of the sediment column to be dredged contains PCB concentrations above background, there will be no impacts related to release of PCB during dredging and subsequent settling of PCB on the seabed.

Significance of impact
There will be no impacts from the release of toxic contaminants from dredged sediments.
5.3.8 Impact of sediment spill on dissolved oxygen

The organic carbon content of the sediments is expressed through the parameters total organic carbon (TOC) and loss on ignition (LOI). The values along the link alignment are typical for the marine environment and vary from low values in clean sand to higher values in the organic sediments in the deeper areas.

Cumulated oxygen demand was determined for 5 hour and 22 hour exposure times. The demand varied between 0.02 and 0.35 mg O$_2$/ml sediment. The major part of the oxygen uptake was due to oxidation of reduced substances such as sulphides within the sediment. Analyses showed a good correlation between oxygen demand and organic content.

Magnitude of impact

Knowledge of the oxygen demand is needed when assessing the impact of the fine sediments spilled during dredging operations on the dissolved oxygen content of the marine waters. It is possible that there will be some impacts of a very local nature where dredging in organically rich sediments.

An evaluation of the potential impacts of oxygen uptake from suspended sediments under dredging operations is based on a calculated daily oxygen uptake. The average oxygen uptake is estimated at 93 kg O$_2$/day and identical for dredging in shallow and deep waters.

A daily uptake of 93 kg O$_2$/day during dredging can theoretically lead to lower concentrations of oxygen in the water column. For reference, the amount of dissolved oxygen within 0.1 km$^2$ near the coast (approximate area of a work harbour and access channel) can be estimated to approximately 5 ton O$_2$ (assuming an average depth of 7 m and a mean oxygen concentration of 7 mg/l), i.e. fifty times greater than the maximum daily demand due to dredging. Very local depressions in oxygen levels in the immediate vicinity of the dredger may occur but the levels will remain well above critical concentrations (4 mg/l).

Significance of impact

The conclusion is that the dredging will not have a significant impact on the oxygen content of Fehmarnbelt waters.

5.3.9 Impacts during the operation phase

During the operation phase the impacts on water quality can only be due to changes in the hydrographic conditions and discharges of wastewater.

As described above the changes in the hydrographic conditions are negligible, and the subsequent impact on water quality will also be negligible.

Also as mentioned above, all discharges of wastewater will be in accordance with regulations and licence conditions in both countries and the impacts on water quality are insignificant.
5.3.10 Significance of impacts on water quality - summary
In summary the assessment of all potential effects of the bored tunnel on the water quality of Fehmarnbelt shows that the impact is insignificant.

5.3.11 Mitigation and compensation measures
Mitigation and compensation measures are not considered necessary since the impacts are insignificant.

5.3.12 Decommissioning
Decommissioning of the bored tunnel will not involve any marine activities and therefore there will be no impacts on water quality.
5.4 Seabed morphology

This section addresses the seabed morphological conditions in Fehmarnbelt and the possible impacts of the bored tunnel on the conditions.

The seabed morphological issues fall under the environmental factor “soil” and the sub-factor “marine soil”. The relevant components and sub-components under marine soil are listed in Table 5.21. The impacts on each of the sub-components are assessed in this section if relevant and form the basis for the assessment of impacts on seabed morphology.

Table 5.21 Seabed morphology sub-components

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sub-factor</th>
<th>Component</th>
<th>Sub-component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Marine soil</td>
<td>Seabed morphology</td>
<td>Sand waves</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lunate bed forms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Other active bed forms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Seabed without bed forms</td>
</tr>
</tbody>
</table>

5.4.1 Project pressures and potential impacts

A summary of the pressures on the seabed morphology is given below:

› Permanent reclamations which cover the seabed and change the local current conditions
› Dredging of access channels to the temporary harbours at the Lolland and Fehmarn coasts
› Sedimentation of dredging spill

The pressures may potentially impact one or more of the sub-components. The potential impacts are loss of seabed with or without bed forms and changes of bed forms due to changes of current and sedimentation.

For the bored tunnel the current conditions are only slightly affected by the reclamations and the changes do not affect any seabed conditions. Therefore changes of current conditions are screened out as a pressure requiring assessment.

Sedimentation on the areas without active bed forms is of such a low thickness that it will not impact the geomorphological processes in any significant way. It is also screened out as a pressure requiring assessment.

5.4.2 Existing environment

The seabed morphology is based on a detailed mapping of the bathymetry using a multibeam echo sounder. The multibeam measurements are carried out for water depths greater than approximately 6 m. The horizontal resolution of the seabed measurements is 2m.
The study revealed three distinct types of regular bed forms in Fehmarnbelt:

› Sand waves
› Ribbons
› Lunate bed forms

*Sand waves* have heights in the range 3 – 15 m and occur at intervals of 30 – 500 m. They can be transverse to the flow direction in uniform flow fields and oblique if there is a transverse gradient in the flow velocities. Sand waves occur on the shallower shoulders of Fehmarnbelt.

*Ribbons* are straight to sinuous, thin bodies of sand, with a narrow width in relation to their length. They are found immediately northwest of Fehmarn and in an area off the Lolland coast about 20 km west of Rødbyhavn.

*Lunate bed forms* are isolated crescent shaped dunes similar to those seen in sandy deserts. They occur in the deep central basin of Fehmarnbelt.

The remainder of the seabed of Fehmarnbelt consists of an irregularly undulating surface with boulders and isolated anomalies. The origin of the anomalies in the seabed is unknown but may be related to varying resistance to erosion.

Figure 5.50 shows the distribution of sand waves, lunate bed forms and other active bed forms (e.g. ribbons) in Fehmarnbelt. As an example, a detailed plot of the bathymetry of the seabed in Figure 5.51 shows the large sand waves offshore from Rødbyhavn.

The migration rates for the sand waves near the Lolland coast have been estimated. To be in the order of 1-10 m/yr towards southeast depending on the size of the sand waves and location. Most movement will occur during individual peak flow events when the bed forms could migrate 1-5 m in either direction.
Figure 5.50 Areas of bed forms in Fehmarnbelt
5.4.3 Methodology

The impacts on the seabed morphology are assessed primarily on the basis of the areas covered by the land reclaims and the areas directly affected by dredging. Numerical models are used to estimate the sediment transport rates which determine the time for the seabed to recover after disturbance. Reference is made to FEHY 2012i for a detailed description of the models.

Seabed areas covered by reclaims are classified as a “loss”. The severity of loss of the area is dependent on the relative importance of the seabed forms in that area. Areas with actives bed forms in Natura 2000 areas are of “very high” importance, other areas with active bed forms have “high” importance, area without active bed forms have “medium” importance while areas heavily affected by anthropogenic activities are of “minor” importance.

The degree of impairment of the seabed morphology is evaluated on a 4-level scale ranging from very high to minor. The levels are allocated in relation to the disturbance of the bed forms such as removal or change of character, e.g. height and volume of the bed forms. In areas without prominent bed forms it is the depth of dredging which determines the degree of impairment. Table 5.22 shows the criteria chosen for determining the degree of impairment.
Table 5.22  Criteria for assessment of the degree of impairment of the seabed morphology

<table>
<thead>
<tr>
<th>Factor Sub-factor Component</th>
<th>Criteria for assessment of changes to seabed morphology</th>
<th>Criteria for assessment of changes</th>
<th>Duration</th>
<th>Degree of impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Marine soil Seabed morphology</td>
<td>Mobilisation of sediment, changed near bed currents, changed sediment transport and changes to areal use due to dredging or construction related structures below water</td>
<td>Permanent removal or permanent change of character of the bed forms</td>
<td>Permanent</td>
<td>Very high</td>
</tr>
<tr>
<td></td>
<td>Permanent removal or temporary change of character of the bed forms for cases where regeneration is expected within the lifetime of the project (120 years)</td>
<td>Temporary</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change of height of bed forms (sand waves, lunate bed forms and other bed forms) of more than 25%</td>
<td>Permanent/temporary</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>More than 25% change of volume of lunate bed forms</td>
<td>Permanent/temporary</td>
<td>Minor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lowering of seabed with more than 2 m below natural sea bed level in areas outside of areas with prominent bed forms</td>
<td>Permanent/temporary</td>
<td>Minor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temporary occupancy of seabed area by structures (construction period)</td>
<td>Permanent/temporary</td>
<td>Minor</td>
<td></td>
</tr>
</tbody>
</table>

5.4.4 Impacts of reclamations

Magnitude of impact
The reclamations on the Danish and German side permanently occupy a part of the seabed. The magnitudes of the impact are identical to the areas of the land reclamations which are shown in Figures 5.15 – 5.17 and Table 5.3.

The land reclamations take up to 353 ha out of 41,446 ha within the local 10 km zone corresponding to 0.9%.

The impact of the land reclamations is classified as a “loss”. Only areas within the sub-component "seabed without bed forms" are impacted by the reclamations.

Severity of loss
The reclamations occupy seabed areas categorized with medium importance level and the loss is therefore classified with medium degree of severity, see Figure 5.52.
5.4.5 Impacts of temporary work harbours

Magnitude of impact

The magnitude of the impacts from the temporary work harbours are identical to the area covered by the breakwaters. The work harbour breakwaters cover the following areas:

- Fehmarn: 11.3 ha
- Lolland 7.1 ha

Work harbour breakwaters thus cove a total of 18 ha. Only the areas of the work harbours, which are not integrated into the permanent structures are assessed. These areas are shown in Figures 5.15 and 5.16.
The breakwaters are all located within areas of the sub-component "seabed without bed forms".

Degree of impairment

The areas of the breakwaters are expected to recover after the structures are removed and the seabed re-established by active backfilling. The impact is therefore considered to be temporary impairment of the seabed. The seabed morphology will recover to a natural state within a time scale of about 5 years (FEHY 2012i).

The degree of impairment for these areas is classified as minor according to the assessment criteria in Table 5.22, see Figure 5.53.

Figure 5.53 Degree of impairment of seabed morphology
5.4.6 Impacts of all access channels and of excavation in work harbour on Lolland and Fehmarn

Magnitude of impact

The magnitude of the impact is identical to the area of the access channel west and access channel east off the reclamation area on Lolland plus the access channel and excavated area on Fehmarn, see Figures 5.15 to 5.17 and Table 5.3. The levels of the bottom of the channels (DVR90) and their areas are as follows:

› Access channel west, Lolland: Level: -7.5 m, area: 9.7 ha
› Access channel east, Lolland: Level: -9.5 m, area: 19.7 ha
› Access channel, Fehmarn: Level: -9.5 m, area: 6.1 ha
› Excavated work harbour, Fehmarn: Level: -9.5 m, area: 13.7 ha

The area of access channels at Lolland is 29.4 ha and the excavated area of access channel and the work harbour at Fehmarn is 19.8 ha.

The natural seabed level along the access channels is in the range -6 to -9.5 m. The dredged depths therefore vary between 0 and 3.5 m with 0 m at the offshore end of the channels and maximum at the inshore ends.

The natural seabed level in the excavated area inside the work harbour at Fehmarn is in the range of 0 to -6.0 m. It is assumed that the work harbour excavation will be backfilled when the work harbour is dismantled at the end of the construction period whereas the access channels are left for natural backfilling.

The dredging of the access channels leaves a relatively large channel/hole in the natural seabed at the end of construction. The access channels are located outside areas with prominent bed forms. Only the sub-component "seabed without bed forms" which is classified as being of medium importance will be affected.

The channels will block the small natural eastwards/westwards transport of granular seabed material (sand). This blockage does not have any significant impact on the morphology in the area. The seabed in the vicinity of the channels may experience a slight lowering (in the order of 0.1 m) of the seabed level due to erosion.

Recovery time

The recovery time for the access channels to fill in by the natural sediment transport along the seabed has not been calculated specifically for the bored tunnel channels but the backfilling times have been estimated on basis of the backfilling calculations performed for the immersed tunnel.

The recovery time varies along the channels since the depths and widths of the channels vary along the alignment as described above. The required volume of sediment to backfill the trenches to a natural seabed level therefore varies along the alignments. Furthermore, the rate of the natural sediment transport on the seabed varies along the channels.
The estimated time needed for the natural backfilling of the access channels are estimated on basis of similar estimates for the trench associated with the immersed tunnel alternative. The recovery times are consequently estimated to vary from up to 12 years near the reclamation, where the trench is deep and wide, to 1-2 years for the outer shallow part of the trench.

At the stage when the channel has completely filled in, the seabed surface has also recovered to its natural morphology due to the slow process of the backfilling. The overall recovery time is therefore identical to the time estimated for the channel to fill.

The estimated recovery times for access channels and degree of impairment and timescale are presented in Table 5.23.

Table 5.23 Summary of estimated recovery time for access channels to work harbours on the Danish and the German side as well as degree of impairment and timescale.

<table>
<thead>
<tr>
<th>Section</th>
<th>Sub-component</th>
<th>Territory and channel location</th>
<th>Water depth [m DVR90]</th>
<th>Dredging depth below natural seabed [m]</th>
<th>Infill time for trench [years]</th>
<th>Degree of temporary impairment</th>
<th>Timescale for recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner part</td>
<td>Seabed without bed forms</td>
<td>Danish west</td>
<td>5.5-7.5</td>
<td>0-2</td>
<td>0-5</td>
<td>Minor</td>
<td>Temporary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Danish east</td>
<td>5.5-7.5</td>
<td>2-4</td>
<td>5-12</td>
<td>Medium</td>
<td>Temporary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>German</td>
<td>5.5-7.5</td>
<td>2-4</td>
<td>5-12</td>
<td>Medium</td>
<td>Temporary</td>
</tr>
<tr>
<td>Outer part</td>
<td>Seabed without bed forms</td>
<td>Danish west</td>
<td>No outer part</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA Temporary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Danish east</td>
<td>7.5-9.5</td>
<td>0-2</td>
<td>0-5</td>
<td>Minor</td>
<td>Temporary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>German</td>
<td>7.5-9.5</td>
<td>0-2</td>
<td>0-5</td>
<td>Minor</td>
<td>Temporary</td>
</tr>
</tbody>
</table>

Degree of Impairment

The degree of impairment is classified as medium on the seabed where the channel causes lowering of the seabed by more than 2 m below the natural seabed. In areas where the dredging depth is 0.5-2 m deep the impairment is classified as minor (see Figure 5.53).

The impairment is temporary as all parts of the seabed in the area of the access channel are expected to recover to the normal seabed level within a maximum of 12 years, i.e. well within the lifetime of the project of 120 years.

5.4.7 Aggregation of impacts on components

Table 5.24 shows the impacted areas for the individual sub-components and are divided into the four levels for severity of loss and degree of impairment.

The impacts are quantified as areas (ha) and fractions (%) of the areas of the given sub-component within 10 km from the alignment (local area + near zone). The total
impacted area is also provided together with the fraction of the total seabed area (%)
within 10 km from the alignment.

The area of 413 ha without bed forms corresponding to 1.6% of the area without such
morphological features are impacted by the tunnel project. The impacts are primarily a loss of seabed (353 ha) where the new reclamations are planned.

The remaining 60 ha are temporarily impacted by temporary work harbour structures or dredging activities (access channel west and east at the Lolland side and the access channel and work harbour on Fehmarn). The natural seabed morphology will recover in these areas after the end of construction.

It is noted that the loss of beach area for recreational purposes and impacts related to the near-shore seabed morphology (morphological elements in water depths less than 6 m DVR90) are treated separately in section 5.5. Only the loss of seabed in the footprint area is included in this section.

The impacted areas are also subdivided into the various impact zones in Fehmarnbelt in Table 5.25.

Table 5.24 Summary of impacts from the bored tunnel on the seabed morphology. The impacted areas are also expressed as a percentage (%) of the reference area of the given sub-component within 10 km from the alignment (i.e. within near zone + local zone)

<table>
<thead>
<tr>
<th>Sub-component for Seabed morphology</th>
<th>Total</th>
<th>Sand waves</th>
<th>Lunate bed forms</th>
<th>Other active bed forms</th>
<th>Areas without bed forms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ha</td>
<td>%</td>
<td>ha</td>
<td>%</td>
<td>ha</td>
</tr>
<tr>
<td>Permanent impacts: Severity of loss</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very high severity</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>High severity</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medium severity</td>
<td>353</td>
<td>0.9</td>
<td>0</td>
<td>0</td>
<td>353</td>
</tr>
<tr>
<td>Minor severity</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total permanent</td>
<td>353</td>
<td>0.9</td>
<td>0</td>
<td>0</td>
<td>353</td>
</tr>
<tr>
<td>Temporary impacts: Degree of impairments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very high impairment</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>High impairment</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medium impairment</td>
<td>13</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Minor impairment</td>
<td>47</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td>47</td>
</tr>
<tr>
<td>Total temporary</td>
<td>60</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>Total, permanent + temporary impacts</td>
<td>413</td>
<td>1.1</td>
<td>0</td>
<td>0</td>
<td>413</td>
</tr>
<tr>
<td>Reference areas (ha)</td>
<td>41,446</td>
<td>1,261</td>
<td>14,789</td>
<td>244</td>
<td>26,046</td>
</tr>
</tbody>
</table>
### Table 5.25
Summary of severity of loss and degree of impairments from the bored tunnel solution on the impact zones of Fehmarnbelt. The impacted areas are also expressed as a percentage (%) of the reference areas of the near zone and the local 10 km zone.

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Impact zones (ha and % of reference area)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Near zone</td>
</tr>
<tr>
<td>Permanent impacts: Severity of loss</td>
<td></td>
</tr>
<tr>
<td>Very high severity</td>
<td>0</td>
</tr>
<tr>
<td>High severity</td>
<td>0</td>
</tr>
<tr>
<td>Medium severity</td>
<td>353 (11.7%)</td>
</tr>
<tr>
<td>Minor severity</td>
<td>0</td>
</tr>
<tr>
<td>Total permanent impacts</td>
<td>353 (11.7%)</td>
</tr>
<tr>
<td>Temporary impacts: Degree of impairment</td>
<td></td>
</tr>
<tr>
<td>Very high impairment</td>
<td>0</td>
</tr>
<tr>
<td>High impairment</td>
<td>0</td>
</tr>
<tr>
<td>Medium impairment</td>
<td>13 (0.5%)</td>
</tr>
<tr>
<td>Minor impairment</td>
<td>47 (2.0%)</td>
</tr>
<tr>
<td>Total temporary impacts</td>
<td>60 (2.5%)</td>
</tr>
<tr>
<td>Total permanent and temporary impacts</td>
<td>413 (14.2%)</td>
</tr>
<tr>
<td>Reference area (ha)</td>
<td>3,019</td>
</tr>
</tbody>
</table>

#### 5.4.8 Significance of impacts on seabed morphology
The bored tunnel solution has no impact on the bed forms.

The primary contribution to the impacts on the seabed morphology outside of the areas with bed forms is caused by the loss of seabed in the areas of the coastal reclamations. In total, they occupy 353 ha or 0.9% of the total seabed area within 10 km from the alignment. For the seabed morphology, this loss is insignificant.

In conclusion, it is assessed that the impacts from the bored tunnel solution have no significant impacts on the marine soil component seabed morphology.

#### 5.4.9 Mitigation and compensation
The bored tunnel has no impact on the special morphological seabed forms in Fehmarnbelt. Furthermore, it is assumed that the excavated areas of the temporary work harbours which are not integrated into the permanent reclamations are filled at the end of construction.
Possible mitigation measures to be considered in the final design are active backfilling of the two access channels east and west at Lolland and the access channel at Fehmarn. Active backfilling of the access channels would prevent the seabed from having a trench of up to 4 m below natural seabed level remaining after the end of construction.

However, the access channels do not lead to any significant impacts and active backfilling is therefore not deemed necessary.

5.4.10 Decommissioning
Decommissioning is foreseen to take place in the year 2140, when the fixed link has been in operation for the design lifetime of 120 years.

The decommissioning will leave the reclaimed areas untouched and the tunnel tubes will also remain in the ground. The decommissioning process is therefore not predicted to cause any impacts on the seabed morphology.
5.5 Coastal morphology

This section addresses the coastal morphology of the coasts of Lolland and Fehmarn and the possible impacts of the bored tunnel project on the coasts.

The coastal morphological issues fall under the environmental factor “soil”, the sub-factor “marine soil” and component “coastal morphology”. The relevant sub-components under coastal morphology are listed in Table 5.26. The impacts on each of the sub-components are assessed in this section and form the basis for the overall assessment of the impacts on coastal morphology.

Table 5.26 Coastal morphology sub-components

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sub-factor</th>
<th>Component</th>
<th>Sub-component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Marine soil</td>
<td>Coastal morphology</td>
<td>Beaches and other unprotected sections of the coastline</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coastal protection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Individual coastal structures</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Special morphological features</td>
</tr>
</tbody>
</table>

Coastal protection refers for example to revetments and the coast parallel breakwaters at Hyldtofte Østersøbad. Individual coastal structures are the harbours at Rødbyhavn and Puttgarden etc. The special morphological features are Hyllekrog and Grüner Brink.

5.5.1 Project pressures and potential impacts

The permanent structures associated with the bored tunnel project, such as reclamations and access channels, can impact the stability of the coastlines of Lolland and Fehmarn. The pressures and potential impacts are listed in Table 5.27.

Table 5.27 Environmental pressures on coastal morphology and potential impacts

<table>
<thead>
<tr>
<th>Project features</th>
<th>Environmental pressure</th>
<th>Potential impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent structures</td>
<td>Reclamations at the coasts of Lolland and Fehmarn</td>
<td>Increased erosion/ accretion along beaches/unprotected sections of the coastline.</td>
</tr>
<tr>
<td></td>
<td>Access channels to work harbours on Lolland and Fehmarn</td>
<td>Increased erosion in front of structures/ failure of structures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Changes to special morphological features</td>
</tr>
</tbody>
</table>
5.5.2 Lolland

Existing environment - Lolland coast

The status of the present shoreline was established by site inspections and aerial photography.

The coast of Lolland in the study area is protected by a dike constructed after the 1872 storm which flooded large areas.

Between Kramnitze and Rødbyhavn (Figure 5.54), a stretch of 8.4 km, the coast is characterised by sandy beach sections and sections where the sea dike is protected by revetments to prevent erosion. Sand is still accumulating west of the Kramnitze harbour breakwater and forms a good sandy beach. Erosion occurs east of the harbour and the coast is partly protected by a revetment.

The beach in front of the lake/wetland area Skarholm is characterised by having a sandy beach with some gravel and a narrow dune in front of the dike. Further east of Skarholm towards Bredfjed summerhouse area, the shoreline is again protected by a revetment. The 3 km stretch from the western part of Bredfjed to Lalandia has a wide sandy beach with some gravel. East of Lalandia there is a section protected by a revetment where after the sand accumulation west of Rødbyhavn commences.

Sand has accumulated west of Rødbyhavn ever since the first harbour was built. Since 1999 the beach has moved 35 m seawards along a 1 km stretch caused by an average accumulation of 10,500 m³/year. The littoral drift is still active with the sand moving along the western breakwater and depositing in the sediment trap reservoir beside the navigation channel of Rødbyhavn. The reservoir prevents sedimentation in the channel and in the harbour basin. An analysis of the maintenance dredging volumes between 1977 and 2008 shows that the net eastwards littoral drift at the harbour entrance is approximately 22,000 m³/year.

The coastline between Rødbyhavn and Hyllekrog, a stretch of about 8.2 km, is generally fairly straight. See Figure 5.55 for an overview of this section of the coastline and the coastal structures along the coast. This entire stretch is also protected by a dike apart from a small section at Bunddragene. The western part of the section between Rødbyhavn and Hyldtofte Østersøbad experienced severe erosion after the construction of Rødbyhavn and is characterised by a revetment without a beach in front of the revetment. The coast subject to erosion is still expanding towards east.

Ten coastal breakwaters were built in 1999 over a stretch of 760 m at Hyldtofte Østersøbad to protect the bathing beach from further erosion.

The coast between Hyldtofte Østersøbad and Hyllekrog varies between sections protected by a revetment (typically without a beach) and sections with sandy beaches.

The Hyllekrog shoreline is generally stable, but it is important for its continued stability that the supply of sand by littoral drift from the west is maintained.
Figure 5.54  Overview of coastline and coastal structures from Kramnitze to Rødbyhavn. Aerial photo 2009 ©COWI.
Figure 5.55 Overview of coastline and coastal structures from Rødby Ferry Harbour to Hylekrog. Aerial photo 2009 ©COWI.
The development of a coastline is primarily determined by the littoral drift, which is the transport of sand parallel to the coast. Almost all the transport occurs in the wave breaking zone and therefore the transport is mostly dependent on the wave conditions at each point on the coast, in particular the wave height and direction.

Erosion occurs when the rate of transport increases in the direction of the net transport from one point to the next along the coast. Conversely, accretion occurs when the rate of transport decreases. Therefore detailed knowledge of the littoral drift is required for an understanding of the existing coastal morphology and of the impacts of new constructions on the coast, e.g. the project's reclamations.

A full description of the existing coastal morphology is found in FEHY 2012e and a brief summary is presented here in the form of the rates of sand transport along the coast, see Figure 5.56 and Figure 5.57.

The littoral drift is calculated with the LITDRIFT model which was calibrated against the observed shoreline changes west of Rødbyhavn in the period 1999-2009. The model was then applied to calculate the average littoral drift over the 20 year period 1989-2008.

Starting from the west (Figure 5.56), the net littoral drift decreases from 31,500 m³/year at Bredfjord (D6) to 28,000 m³/year at Lalandia (D9) giving a tendency for small but persistent accretion of the shoreline by 0.5-1.0 m/year as observed. There is a little erosion in the bay east of Lalandia beach (D9B).

It is seen that the adjusted net annual littoral transport in the accumulation zone west of Rødbyhavn decreases from 27,500 m³/year at profile D9B to 17,000 m³/year at the tip of the western breakwater, thus giving a deposition of about 10,500 m³/year and a shoreline accretion of 30-40 m/year.

East of Rødbyhavn there is a constant increase in the net littoral drift from 1,500 m³/year at the eastern breakwater (D11) to 22,000 m³/year at Brunddragene (D17) indicating that the shore and coastal profile are in a state of persistent erosion. Most of the erosion occurs between the harbour and Hyldtofte Østersøbad.

No sand by-passes the harbour breakwaters. This, combined with the high eastward net annual transport capacities to the east has resulted in erosion of almost all lose sand for 2.5 km. This fits well with the fact that there are revetments and no sandy beaches along this stretch. Furthermore, the seabed in this area is hard with coarse sediments and scattered stones. The actual net littoral drift is only 1,500 m³/year at D11.

At Hyldtofte Østersøbad the littoral zone has increased in width again and the net littoral drift is 18,500 m³/year at D14. This increases only slightly along the next 4 km to 22,000 m³/year at Brunddragene (D17) so that the shore is almost stable with a slight tendency to erosion.
Figure 5.56  Average littoral drift transport rates west of Rødbyhavn

Figure 5.57  Average littoral drift transport rates east of Rødbyhavn
Magnitude of impacts on the Lolland coast

The impacts on the Lolland coastline are solely due to the reclamations and access channels west and east of Rødbyhavn. The structures interrupt the littoral drift along the coastline and thereby change the sediment budget from one section to the next.

A total length of 7,470 m of the coastline is integrated into the reclaimed area, the same as for the immersed tunnel. The reclamation west of Rødbyhavn extends approximately 3,720 m to Sandholm. East of Rødbyhavn, the reclamation extends to the western termination of the breakwater scheme at Hyldtofte Østersøbad 3,750 m from Rødbyhavn.

The impacts of the bored tunnel are in practice identical with those calculated for the immersed tunnel since the reclamation is the same for both projects. The impacts are assessed by modelling the changes to the transport of sediment (sediment budget) and evaluating the initial shoreline evolution on the basis of this sediment budget along the Lolland coast.

The impacts on the coastal morphology from the tunnel develop over time and the coast does not recover from the impacts. All impacts from the tunnel project are therefore assessed as permanent.

Impacts on the coastal morphology will start during the construction period since the outer revetment of the reclamation and the work harbours and access channels are the first features to be constructed. However, these impacts will be of the same character as the impacts caused at a later stage by the permanent structures. The impacts during the construction period on the coastal morphology are hence not assessed separately.

The impacts for the various sections of the coast are described below.

Skarholm to Sandholm/new beach. Dragsminde Sluice at Sandholm

The reclamation will block the net eastward sediment transport. The sediment will accumulate along the 1,100 m new beach at the western termination of the reclamation. The present coastline at the termination point is seen in Figure 5.58. The accumulation will build up and fill in the ‘corner’ between the reclamation and the existing coastline as a sand fillet starting from the western part of the new beach building up towards southwest. Calculations show that 31,500 m$^3$/year will deposit along the new beach and that the beach width will initially (first 1-2 years) increase by up to 20 m/year for the average year conditions.

Within the first 5 years, the accumulation of sand is predicted to progress rapidly towards the northwest in the order of 100 m/year. The accumulation will cause increasing beach widths from Mygfjed over Sandholm to the Bredfjed summerhouse area, see Figure 5.59. The shoreline will initially advance by up to about 8-12 m/year in the Sandholm area.

With time deposition will occur along a longer stretch and the rate of the shoreline advance as well as the progression rate towards the northwest will decrease. In the
period 5-30 years after the end of construction, the shoreline is predicted to advance and increase the width of the beach by about 3-9 m/year and progress towards the northwest at a rate of 100 m/year after 5 years, decreasing to about 40-50 m/year after 30 years. The beach width at Bredfjed summerhouse area will begin to increase approximately 5-10 years after end of construction of the reclamation west of Rødbyhavn. Thirty years after the construction of the reclamation, the accumulation zone is expected to reach the coastline between Bredfjed and Skarholm, see Figure 5.59. The build-up of the sand accumulation with time is estimated by an analytical solution (method by Pelnard and Considéré, see e.g. Deigaard and Fredsøe 1992).

As the shoreline advances along the western part of the reclamation, the water depth decreases at the offshore western ‘corner’ of the reclamation to a depth where sand can start by-passing and a sand bar can build up along the offshore part of the reclamation. The time period before by-pass starts may be (a few) decades. The accumulation of sand west of the reclamation is predicted to continue for the lifetime of the project similarly to the situation at the beach west of Rødbyhavn in the baseline situation. Initiation of by-pass around the reclamation and the long stretch where deposition occurs will reduce the rate of shoreline advance and progression towards the west.

The advance of the shoreline west of Rødbyhavn is not assessed as an impairment of the coast except at the outlet at Dragsminde Sluice located off Sandholm. The accumulation of sand in front of the outlet will block the outflow of water draining from the low-lying land behind the dike. An alternative solution for the outflow should be sought. The accumulation of sand in front of Dragsminde Sluice is estimated to cause an advance of the shoreline in the order of 160 m within the first 30 years. The functionality of the present structure in the future will be assured by the inclusion of a new solution for the outlet structure in the scope of the bored tunnel project.

Figure 5.58 Sandy beach with gravel at the outlet from Dragsminde Sluice - the location for the western termination of the reclamation
The impacts on the coast between Sandholm and the western breakwater of Rødbyhavn are restricted to the occupancy of the original coastline by the reclamation. The impacts in this area are therefore the loss of the original coastline which is composed of approximately 3.2 km of beach and 500 m of revetment.

Rødbyhavn

The sedimentation of sand in the reservoir at the western side of the access channel to Rødbyhavn was estimated to be in the order of 15,000-20,000 m³/year during the period 1999-2009 (FEHY 2012e). The sedimentation occurs primarily because of by-pass around the western breakwater.

The water depth at the offshore part of the reclamation (approximately 6 m DVR90) is initially too large to facilitate a significant transport of sediment around the offshore western ‘corner’ of the reclamation and further along the offshore part of the reclamation.

As described above a sand bar will start to build up along the offshore perimeter of the reclamation after 10-20 years. For sedimentation to occur in the harbour and access channel, this sand will theoretically build up along the ~2,800 m section of the reclamation and reach the access channel to Rødbyhavn in another approximately 10-20 years. The sand bar will build up along the reclamation with a layer thickness of 2-3 m reducing the water depth to an active depth for sediment transport to occur. It is assumed that the deposition will have a width of about 50 m and that 50-100% of the sediment supply from west will by-pass the reclamation starting about 20 – 40 years after construction. This is similar to the present situation at Rødbyhavn. Depending on the detailed design of the reclamation west of Rødbyhavn, parts of this sediment may deposit in the beach lagoon west of Rødbyhavn, which is part of the final design.
In summary, Rødbyhavn will benefit from the construction of the tunnel project for some decades. The costs for maintenance in the harbour basins and access channel are expected to decrease greatly for at least the first 30-40 years after the construction of the reclamation in the tunnel project.

**Rødbyhavn to Hyldtofte Østersøbad**

The new reclamation causes the loss of 3,750 m of the coastline with revetment between Rødbyhavn and Hyldtofte Østersøbad. Two small drainage outlets west of Rødbyhavn from wetland areas behind the dike will also be lost but will be replaced by new outlets by the project.

**Hyldtofte Østersøbad to Brunddragene**

The reclamation blocks the sediment supply from west. In the baseline conditions, the net sediment supply to the coast east of the eastern termination of the reclamation is estimated at 19,000 m³/year for the average year conditions. The tunnel project therefore causes a lack of sediment supply in the order of 19,000 m³/year.

Erosion will initially take place from the coastal section nearest the reclamation which is the beach in front of the summer house area Hyldtofte Østersøbad if no mitigation measures are introduced. The beach is already protected with 10 coast-parallel breakwaters (Figure 5.60) to stop the erosion caused by the blocking of the sediment transport by Rødbyhavn. The beach and the unprotected coast to the east will retreat by up to 6-7 m/year and the beaches will become narrower.

Where the coast is protected by revetments the erosion will occur at the seabed and the coastal profiles will become steeper. In such areas there will be a severe risk of failure of the revetments within 5-10 years after the end of construction.

The erosion will extend eastwards at the rate of about 40 m/year so that, in the 120 year lifetime of the project, the erosion will reach Brunddragene.

Since the assessment showed that severe erosion would occur east of the reclamation it has been decided to mitigate the impact with beach nourishment with 19,000 m³/year of sand at Hyldtofte Østersøbad. This will prevent the erosion described above.
No impacts on the coast between Brunddragene and Hyllekrog are predicted from the tunnel within the lifetime of the link.

Severity of loss and degree of impairment

A set of criteria was developed for classifying the importance of environmental issues and the impacts (loss and impairment) into four levels, see FEHY 2012j.

Shoreline areas covered by reclaims are classified as a “loss”. The severity of loss of the area is dependent on the relative importance of the coast in that area. Coastal sections within Natura 2000 areas and other protected coastal sections are of “very high” importance, other sandy beaches, forelands and coastal lagoons have “high” importance, all other coastal stretches not heavily affected by anthropogenic activities “medium” importance while areas heavily affected by anthropogenic activities are of “minor” importance.

The degree of impairment of the coastal morphology depends on the relative loss of functionality of the coast or coastal structures. For example, loss of a beach due to severe erosion is classifies with a “very high” degree of impairment while a little erosion of beach sand by 0.5 – 2.5 m³/m/year gives only a “minor” degree of impairment. Table 5.28 shows the criteria chosen for determining the degree of impairment.
Table 5.28  Criteria for assessment of the degree of impairment of coastal morphology

<table>
<thead>
<tr>
<th>Factor Sub-factor component</th>
<th>Impact by project</th>
<th>Criteria for assessment of changes</th>
<th>Duration</th>
<th>Degree of impairment</th>
</tr>
</thead>
</table>
| Soil                        | Blocking of sediment, changed sediment budget and erosion/ accretion along the coastline, changes of areal use due to structures related to project | Loss of beaches due to severe erosion Permanent loss of functionality of special morphological features such as Hyllekrog/Redsand and Grüner Brink Failure of coastal structures Increased erosion of beach material/seabed material of more than an average of 5 m³/m/year or More than 5 m³/m/year extra accretion adjacent to harbours and intakes/outlets, both of which for average year wave conditions Temporary loss of functionality of special morphological features such as Hyllekrog/Redsand and Grüner Brink Increased erosion of beach material/seabed material at an average of 2.5-5 m³/m/year or 2.5-5 m³/m/year extra accretion adjacent to harbours and intakes/outlets, both of which for average year wave conditions Changes in functionality of special morphological features such as Hyllekrog/Redsand and Grüner Brink Increased erosion of beach material/seabed material at an average of 0.5-2.5 m³/m/year or 0.5-2.5 m³/m/year extra accretion adjacent to harbours and intakes/outlets, both of which for average year wave conditions Changes in morphological elements of special morphological features such as Hyllekrog/Redsand and Grüner Brink | Permanent | Very high 
Permanent/ Temporary | High | Permanent | Medium | Permanent | Minor |

The severities of loss and degrees of impairment are illustrated in Figure 5.61.

Beaches are assigned with a ‘high importance level’ and the loss of beach is hence according to the assessment method assessed with a ‘high severity of loss’. Sections with coastal protection covered by the reclamations are assigned a ‘minor importance level’ and are correspondingly assessed with a ‘minor severity of loss’.
Drainage outlets from wetland areas behind the dike will be lost due to the reclamations. They are assigned a ‘very high severity of loss’.

The coastal protection structures at Hyldtofte Østersøbad are in danger of failure and losing their functionality and are therefore categorized with a ‘very high degree of impairment’. The width of the present beach to the vegetation line is about 10-20 m in the bays between the breakwaters. The retreat of the shoreline/failure of structures described above will reduce the beach widths to a degree, where they also lose functionality. The beaches are therefore also considered impaired with a ‘very high degree of impairment’.

Further east, according to the assessment criteria there is a ‘medium degree of impairment’ for the unprotected as well as the protected sections of the coast, as shown in Figure 5.61.
Table 5.29 shows the impacted lengths of shoreline for the individual sub-components. The impacts are given in lengths of the coastal sections occupied by the given sub-component and in parts (%) of the total length the given sub-component occupies along the Lolland coast within 10 km on either side of the landfall of the tunnel.

6,570 m of the beaches/unprotected coastline are impacted (3,180 m lost in the new reclamation and 3,390 m impaired).
4,290 m of coastal protection (breakwaters and revetments) are lost. 2,040 m coastal protection are impaired and may need mitigation. 400 m of these are classified with a very high degree of impairment.

Note that following this assessment, additional planned mitigation and compensation measures have been included. These are assessed to compensate for the loss of beaches and mitigate the impairments to the coast east of the projects, the outlet at Sandholm (Dragsminde Sluice) and the loss of two outlets east of Rødbyhavn,
Table 5.29 Summary of impacts before mitigation and compensation at Lolland from the bored tunnel project divided on sub-components. Impacts on unprotected and protected sections are provided in lengths (m) of impacted coast. Impacts on individual structures and special morphological features are provided as a number of impacted structures/features. All impacts are permanent. Parts of impacted sections of the coast (%) are provided as part of the coastline with the given sub-component (reference) within 10 km of the landfall.

<table>
<thead>
<tr>
<th>Impacts on coastal morphology</th>
<th>Coastal sub-components</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Beaches and unprotected coastline</td>
</tr>
<tr>
<td></td>
<td>m</td>
<td>%</td>
</tr>
<tr>
<td><strong>Severity of loss</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very high severity</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>High severity</td>
<td>3180</td>
<td>15.9</td>
</tr>
<tr>
<td>Medium severity</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minor severity</td>
<td>4290</td>
<td>21.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7740</td>
<td>37.3</td>
</tr>
<tr>
<td><strong>Degree of impairment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very high impairment</td>
<td>750</td>
<td>3.7</td>
</tr>
<tr>
<td>High impairment</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medium impairment</td>
<td>4280</td>
<td>21.4</td>
</tr>
<tr>
<td>Minor impairment</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5030</td>
<td>25.1</td>
</tr>
<tr>
<td><strong>Reference distance</strong></td>
<td>20035</td>
<td>12020</td>
</tr>
</tbody>
</table>

1 Includes 3,180 m of loss of beach west of Rødbyhavn which will be compensated by artificial beaches and a lagoon as part of the project design.

2 Impacts which will not occur following implementation of mitigation measures, please refer to text.

3 The 750 m of very high impairments to the coastline at Hyldtofte Østersøbad consists of 750 m of impaired beach fronted by ten 40 m long shore-parallel breakwaters (400 m impaired coastal protection). In the "Total" for impairments, this section is counted as only 750 m of very high impaired coastline due to the overlapping of beach and coastal protection. The length of the reference coastline (total of 20,035 m) deviates due the overlapping of beach and coastal protection also by 400 m from the sum of beaches and coastal protection, respectively.
Mitigation and compensation on the Lolland coast

Mitigation and compensation measures for the loss of beaches, loss and impairment of sluices and pump station outfalls and increased erosion east of the reclamation have been included in the bored tunnel project scope of work.

A new 1,100 m long beach will be established at the western end of the reclamation west of Rødbyhavn together with a beach lagoon. Part of the present beach west of the harbour breakwater will also be retained along the edge of a canal. These new beaches will fully compensate for the lost beaches.

The new beach at the western end will be ready for use by the public approximately one year into the construction period, i.e. one bathing season will be lost. The other beaches will be ready at the end of the construction phase.

The Dragholm Sluice and pump station outfalls will all be reconstructed by the project to ensure their effective function in the future.

Beach nourishment with 19,000 m$^3$/year of sand to the coast east of the reclamation has been included as a mitigation measures and will commence immediately after the containment dike for the reclamation is constructed.

The effect of the nourishment of 19,000 m$^3$/year is to prevent the increased erosion of the beaches and in front of the breakwaters at Hyldtofte Østersøbad and revetments further east of the reclamation due to the tunnel project.

It is noted that nourishment with 19,000 m$^3$/year does not prevent erosion from the shoreline that already takes place in the baseline situation. Further eastward towards Brunddragene and Hyllekrog, the present longshore sediment transport rate increases from 19,000 m$^3$/year to 22,000-25,000 m$^3$/year. Between Hyldtofte Østersøbad and Hyllekrog there is therefore in the existing situation a sediment deficit of about 3,000-6,000 m$^3$/year and this situation will remain the same with the planned mitigation measures.

Significance of residual impacts on the Lolland coast

Residual impacts are those which remain after implementation of mitigation and compensation measures.

The residual impacts on the coastal morphology of Lolland are classified as insignificant.

Without mitigation and compensation the impacts would have been significant.

5.5.3 Fehmarn

Existing environment – Fehmarn coast

The northwest coastal stretch from Markelsdorfer Huk to Puttgarden (Figure 5.62) is low-lying land characterised by storm beaches, sand spits, coastal lagoons, dune areas, meadows and salt marches, which have been formed by the natural coastal
dynamics. This stretch belongs to the most important coastal landscape in Schleswig-Holstein with Grüner Brink as the most prominent natural coastal formation.

The entire north coast of Fehmarn is protected by a dike constructed after the 1872-storm. The dike extends along the west- and north coasts from south of Markelsdorfer Huk to Puttgarden and along the northeastern coast from Ohlensborgs Huk to the cliff off the village Klausdorf (Figure 5.63).

The north-west corner of Fehmarn, Markelsdorfer Huk, is a marine foreland. Waves from SW-WNW directions cause erosion of the west coast of Fehmarn and a net littoral transport towards the north causes formation of Markelsdorfer Huk. The predominant waves from WNW - NW directions along the north coast of Fehmarn cause transport of some of the material deposited at Markelsdorfer Huk further eastward. This sediment is the main source for the formation of Grüner Brink.

Along the stretch from Markelsdorfer Huk to Gammendorf a series of irregular beach undulations is present.

Grüner Brink is a special coastal morphological feature, which stretches along the coast from 2.4 km to 4.7 km west of Puttgarden. The Grüner Brink is a system of coastal lagoons created by the formation of natural sand spits which have developed as a result of the special wave conditions in the area. The coastal morphological processes in the area are still active and new lagoon sections are under formation due to growth of new sand spits towards SE.

The shore from Grüner Brink to Puttgarden is characterised by a lack of supply of sand caused by the fact that sand transported from west is deposited in the deep water at the east end of Grüner Brink. However there is a 1 km long sandy beach used by the public for bathing between Grüner Brink and a long groyne (Figure 5.62).

The 350 m long groyne 1.4 km west of Puttgarden Harbour was constructed in 1960 at the same time as the construction of Puttgarden Harbour. The groyne is detached from the shoreline with a gap between the groyne and the shoreline of about 90 m. The groyne was built to prevent the eastward movement of Grüner Brink which would eventually cause sedimentation in the harbour entrance.

There is a very narrow shingle beach along the dike between the long groyne and Puttgarden harbour.

The coastline between Puttgarden and Klausdorf is in general characterised by low cliff formations. A grass-covered dike, however, protects the low lying land in the area off the village Presen from just south of Marienleuchte to the cliff east of Klausdorf.

A small sand accumulation is located southeast of the east breakwater of Puttgarden and has potential value as a bathing beach, but access to the beach is difficult.
There are three small groynes immediately north of Marienleuchte at Ohlenborgs Huk and a massive vertical seawall protects the Naval station. Aerial photos indicate some submerged groynes protecting cables in this area.

There is a sandy beach with some gravel in front of the dike between Marienleuchte and Presen.
Figure 5.62 Overview of coastline and coastal structures from Markelsdorfer Huk to Puttgarden. Aerial photo 2009 ©COWI.
Figure 5.63 Overview of coastline and coastal structures from Puttgarden and Klausdorf. Aerial photo 2009 ©COWI.
The littoral drift along the Fehmarn coast has been calculated using the same method as described above for the Lolland coast. The results of the calculations are shown in Figure 5.64 and Figure 5.65.

A net eastward transport of about 41,000 m$^3$/year occurs off Gammensdorferstrand. The entire amount accumulates around Grüner Brink since the net transport at Puttgarden is zero. About 11-15,000 deposits at the submerged front of Grüner Brink while the remainder is transported offshore and feeds sediment to the area of sand waves off Grüner Brink. The littoral drift is very low between Grüner Brink and Puttgarden.

The littoral drift budget for the coast southeast of Puttgarden is shown in Figure 5.65. The net transport is north-northwest and transport rates are small and vary between 500 and 2,000 m$^3$/year.

Just southeast of the eastern breakwater of the harbour the rate is about 1,000 m$^3$/year towards north-northwest and explains the accumulation of sand on the beach and underwater.

Between section G14 south of Presen and Marienleuchte the transport rates decrease from 2,000 to 500 m$^3$/year indicating that there is an accretion in the section and a slow build up of the beaches.

![Figure 5.64](image_url)  
**Figure 5.64**  Littoral drift budget along the coast west of Puttgarden. Aerial photo 2009 ©COWI.
Magnitude of impacts on the Fehmarn coast

The only potential impacts on the Fehmarn coastline from the bored tunnel project are caused by the reclamation, the work harbour and the access channel on the Fehmarn side.

An overview of the planned structures along the Fehmarn coast is provided in Figure 5.66 for the area east of Puttgarden Harbour together with the present structures. There are no changes relative to the immersed tunnel for the area west of Puttgarden Harbour.

A total length of 700 m of the coastline is integrated into the planned reclamation, which consists of a landfill protected by a dike, a revetment facing the north-northeast and a new curved beach facing southeast. Furthermore, the following temporary structures/excavations in the construction phase are anticipated:

› A work harbour SE of the reclamation
› A dredged area inside the work harbour, which will be backfilled as an integrated part of the project
› An access channel to a water depth of 9.5 m
Figure 5.66  New permanent and temporary structures along the Fehmarn coast in the bored tunnel project – east of Puttgarden
The impacts and the loss/degree of impairment for sections of the coast are described below. The magnitude of the impacts is based on the results for the immersed tunnel since the reclamation, work harbour and access channel are almost the same for the two tunnel projects.

Markelsdorfer Huk to Grüner Brink
The littoral drift budget and the shoreline evolution for this section are unchanged and no impacts are predicted. The morphological development and migration of the special morphological feature of Grüner Brink is therefore also unchanged by the tunnel project.

Grüner Brink to Puttgarden
The tunnel project has negligible impact on the sediment budget and shoreline along this section. The very small changes to the waves just west of Puttgarden from eastern directions caused by the reclamation and access channel are assessed to cause negligible impacts on the coastal morphology.

Puttgarden Harbour
The harbour presently does not experience any sedimentation in the entrance channel. The situation is expected to be unchanged after construction of the tunnel project and no impacts are predicted for Puttgarden.

Puttgarden Harbour to Ohlenborgs Huk
The impacts on the coast between the eastern breakwater of Puttgarden and Ohlenborgs Huk are permanent occupancy of the original coastline by the reclamation and temporary occupancy and impact of the work harbour. The present shoreline in this area consists of the eastern breakwater of Puttgarden and a small accumulation of sand in the transition between the harbour and the natural coast. The natural coast up to Ohlensborg Huk has a sandy beach in front of an active cliff. The beach is protected by three small groynes.

Ohlenborgs Huk/Marienleuchte
The additional potential erosion caused by the bored tunnel project is about 8,000 m³/year along a stretch of about 1,000 m. This is an estimated increase of 20 – 35%. The erosion is not expected to reach its potential rate due to the already existing coastal protection (sea wall, glacis and groynes). The finer fractions of the seabed material have been removed by years of erosion from this section already. However, some lowering of the seabed and increased erosion from the shoreline/beach in between the groynes can take place. The magnitude is difficult to predict. Monitoring of the structures is recommended and strengthening of the structures/new structures may be required with time (within 5-10 years after construction). The length of the stretch is 370 m.

Marienleuchte to Presen
The changes to the shoreline evolution caused by the tunnel alternative are very small south of Ohlensborgs Huk. The changes due to the tunnel project are less than ±0.1 m/year everywhere. The coast is presently nearly stable at this section...
with shoreline changes of less than 0.5 m/year in average and this is not expected to change.

The marine structures (a bathing bridge in front of Marienleuchte and a pumping station/water outlet at the coast in front of Presen) will not be affected.

Southeast of Presen
The coast southeast of Presen is not expected to experience any impacts related to the tunnel project within the lifetime of the project.

Severity of loss and degree of impairment
A total stretch of the Fehmarn coast of 1,070 m is impacted by the tunnel project. This consists of a section of 700 m of ‘lost’ coastline which is included in the reclamation and 370 m of coastline which is impaired. A total of 6 groynes (individual structures) are impacted.

The severities of loss and degrees of impairment are illustrated in Figure 5.67. The impacts distributed on sub-components are provided in Table 5.30.

The impacts in the area affected by the reclamation and work harbour (700 m of beach) are a ‘loss’. Beaches are assigned with a ‘high importance level’ and the loss of beach is hence according to the assessment method assessed with a ‘high degree of severity’.

135 m of beach between the groynes north of Ohlenborgs Huk and 235 m of coastal protection at Ohlenborgs Huk are impaired to a medium degree.

Five of the six smaller groynes protecting Ohlenborgs Huk are impaired with a medium degree of impairment. One groyne will be integrated into the reclamation or removed (i.e. lost).

The coastline and the marine structures south of Marienleuchte will not be impacted by the project and are classified with no impairment.

Note that following this assessment, additional mitigation and compensation measures have been included. These are assessed to compensate for the loss of the beach and to mitigate the possible impairment of the structures at Ohlenborgs Huk.
Figure 5.67  Degree of impairments and severity of loss assigned to sections of the coast of Fehmarn southeast of Puttgarden due to the bored tunnel before implementation of mitigation and compensation measures.
Table 5.30  Summary of impacts before mitigation and compensation at Fehmarn from the bored tunnel project divided on sub-components. Impacts on unprotected and protected sections are provided in lengths (m) of impacted coast. Impacts on individual structures and special morphological features are provided as a number of impacted structures/features. All impacts are permanent. Parts of impacted sections of the coast (%) are provided as part of the coastline with the given sub-component (reference) within 10 km of the landfall.

<table>
<thead>
<tr>
<th>Impacts on coastal morphology</th>
<th>Coastal sub-components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>m</td>
</tr>
<tr>
<td>Severity of loss</td>
<td></td>
</tr>
<tr>
<td>Very high severity</td>
<td>0</td>
</tr>
<tr>
<td>High severity</td>
<td>700(^1)</td>
</tr>
<tr>
<td>Medium severity</td>
<td>0</td>
</tr>
<tr>
<td>Minor severity</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>700(^1)</td>
</tr>
<tr>
<td>Degree of impairment</td>
<td></td>
</tr>
<tr>
<td>Very high impairment</td>
<td>0</td>
</tr>
<tr>
<td>High impairment</td>
<td>0</td>
</tr>
<tr>
<td>Medium impairment</td>
<td>370(^2)</td>
</tr>
<tr>
<td>Minor impairment</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>370(^2)</td>
</tr>
<tr>
<td>Reference distance (m)</td>
<td>22,680</td>
</tr>
</tbody>
</table>

1 Includes 700 m of loss of beach east of Puttgarden, which will be compensated by a new artificial beach in the new reclamation.

2 Impairments, which will not occur following implementation of mitigation measures, please refer to text.

Mitigation and compensation on the Fehmarn coast

Femern A/S has included the following mitigation and compensation measures in the project works.

A new beach of approximately 700 m length will be created along the eastern edge of the reclamation to compensate for the beach lost behind the reclamation. The new beach is shown in Figure 3.8 and is indicated in Figure 5.66. It attaches to the original coastline west of Ohlensborgs Huk which is protected by a number of small groynes. Very little sediment is expected to bypass Ohlensborg Huk from the southeast, so the accumulation of sand at the new beach is expected to be very limited.

The new beach will be ready for use by the public at the completion of the construction phase.
Regular monitoring of erosion at Ohlensborgs Huk together with strengthening of the groynes and sea wall if required are included in the project as an additional mitigation measures. With these measures the impairments are assessed as negligible.

Significance of residual impacts on the Fehmarn coast
Residual impacts are those which remain after implementation of mitigation and compensation measures.

The residual impacts on the coastal morphology of Fehmarn are classified as insignificant.

Without mitigation and compensation the impacts would have been significant.

5.5.4 Decommissioning
Decommissioning of the tunnel after its 120 year lifetime does not involve any marine activities. In addition, it is expected that the reclamations at the coasts will not be removed and therefore the decommissioning will not cause additional impacts to the coastal morphology.
5.6 Plankton

This section addresses the status of plankton in Fehmarnbelt at present and the potential impacts of the bored tunnel project on the biomass, biodiversity and recruitment.

Plankton is a component which falls under the environmental factor flora and fauna and the sub-factor marine flora and fauna. Plankton covers phytoplankton (flora), zooplankton (fauna) and jellyfish. See Table 5.31

<table>
<thead>
<tr>
<th>Table 5.31 Plankton sub-components</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factor</strong></td>
</tr>
<tr>
<td>Flora and fauna</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

5.6.1 Project pressures and potential impacts

The project pressures which can potentially impact plankton are summarised in Table 5.32. The pressures result mainly from the dredging activities which create increased suspended sediment concentrations and from the project structures and features.

<table>
<thead>
<tr>
<th>Table 5.32 Project pressures and potential impacts on plankton</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project activity or feature</strong></td>
</tr>
<tr>
<td>Sediment spill from dredging, landscaping etc.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Land reclamations</td>
</tr>
<tr>
<td>Wastewater discharges</td>
</tr>
</tbody>
</table>

The pressure with the potentially greatest impact is the sediment spilled during dredging works in the construction phase. The pressures are temporary and local (i.e. they do not extend to the Baltic Sea).
A number of the pressures can be screened out immediately since the baseline data and simple calculation shows that the impacts are negligible. The following pressures will not be considered further:

- Release of nutrients and toxic substances from the spilled sediment during dredging has been analysed in the laboratory and the amounts found to be negligible.
- The loss of pelagic habitat of special importance for plankton in the area of the reclamations is negligible compared with the volume of water in the Fehmarnbelt area.
- The predicted changes in the discharges of treated wastewater and the outfall locations are assessed to have no significant effect on plankton in Fehmarnbelt.

The result of the screening is that increased suspended sediment and sedimentation are the only pressures which will be assessed in detail.

### 5.6.2 Existing plankton conditions in Fehmarnbelt

The description of the existing plankton conditions is based on historical data and data collected during the baseline studies in 2009-10 during which water samples were taken and analysed during the monthly cruises at the stations shown in Figure 5.68.

**Phytoplankton**

The field studies confirmed the expected seasonal variations with a short spring bloom of phytoplankton which stops when the nutrients are exhausted. This is followed during summer by a low but active phytoplankton biomass which is mainly controlled by zooplankton grazing. During autumn there is a longer bloom period which starts when the zooplankton concentration decreases. Figure 5.69 shows the measured seasonal variation of phytoplankton expressed by chlorophyll $a$. Despite the year-to-year variation, there is no trend in the summer concentration of phytoplankton over the past 20 years.

The spatial variation in chlorophyll $a$ at the offshore stations was modest compared to the seasonal variation (Figure 5.69). However, there is a tendency for a gradient in concentrations from Great Belt to Darss Sill reflecting a reduction of inorganic nutrients from west towards east. A higher biomass in Mecklenburg Bight area was observed during autumn 2009 and spring bloom 2010 compared to the other three areas. Among the four areas the Fehmarnbelt area showed the least spatial variation with respect to chlorophyll $a$. 
Figure 5.68  Plankton stations sampled in the Fehmarnbelt

Figure 5.69  Spatial and seasonal variation in chlorophyll a calculated from fluorescence in Great Belt, Fehmarnbelt, Mecklenburg Bight and Darss Sill areas. Bars represent averaged concentrations (with ±SD error bars) over depth (5-15m) and subsequently over stations sampled within each of the four areas.
The results from the baseline study and the historical data underlined the important influence of the exchange of water and plankton between the western Baltic Sea and the Great Belt/Kattegat. In the eastern part of the study area (Darss Sill area) the influence from the Baltic Sea was most prominent with delayed spring bloom, higher proportion of cyanobacteria and cladocerans and a lower phytoplankton production and biomass, while in the western part of study area phytoplankton biomass and primary production were higher. This was caused by higher nutrient concentrations so that the spring bloom occurred earlier and copepods vastly dominated the zooplankton community also during summer.

Zooplankton
The zooplankton community was dominated by holoplanktonic taxa with *calanoid Copepoda* as the most common group, and *Acartia bifilosa, Pseudocalanus spp.*, *Temora longicornis, Acartia longiremis* and *Centropages hamatus* as the five most dominant zooplankton species.

The seasonal variation of zooplankton biomass was quite large in the baseline period with a maximum in summer (May to July/August) of 500 g wet weight per m³ over the whole study area (Figure 5.70). The concentration fell suddenly in August 2009 and remained low until May 2010. In 2010 the reduction in biomass in autumn was more gradual. The difference between years cannot be explained by differences in grazing pressure from the ctenophore *Mnemiopsis leidyi* as the abundance of this species was identical in 2009 and 2010 (Figure 5.71).

Jellyfish
The scyphozoan species *Cyanea capillata* (lion’s mane jellyfish) and *Aurelia aurita* (moon jellyfish) dominated the gelatinous plankton community in the baseline investigation area besides the invasive ctenophore *Mnemiopsis leidyi*. The invasive species *M. leidyi* was the most abundant species, with a proportion of more than 90% on total annual jellyfish abundance in this region.

The three species showed a seasonal succession, with a different annual phenology in their appearance and their maximum abundance (Figure 5.71). *C. capillata* reached the highest abundance in early summer. In the same period a continuous increase of the *A. aurita* was observed. Whereas the abundance of *A. aurita* peaked in summer, the maximum abundance of *M. leidyi* occurred in early autumn, after the scyphozoan medusae had disappeared (Figure 5.71). In late winter and early spring, an increasing abundance of *A. aurita* ephyrae was observed across the whole investigation area, indicating an indigenous reproduction in the southwestern Baltic Sea.
Figure 5.70  Biomass of zooplankton during the baseline study (GB = Great Belt, FB = Fehmarnbelt, MB = Mecklenburg Bight, DS = Darss Sill)

Figure 5.71  Abundance of Aurelia aurita, Cyanea capillata and Mnemiopsis leidyi between June 2009 and December 2010 as mean number of individuals (+SD) of the whole baseline investigation area
5.6.3 Methodology

The impacts on plankton are predicted using hydrodynamic and ecological modelling, quantitative assessment and expert knowledge.

The impacts from the bored tunnel project are inferred from the results of the assessment of the immersed tunnel project. It was found that the impacts from the immersed tunnel were without noticeable effect on the pelagic ecosystem. Furthermore, the sediment spill from the bored tunnel project is much lower and the impacts will therefore also be much smaller. For these reasons a detailed assessment of the bored tunnel impacts is not made.

The assessment methodology relies extensively on dynamic models, including hydrodynamic models, sediment models and water quality models.

Important pressures related to construction and operation period of tunnel and bridge (e.g. concentration of spilled sediment) are modelled dynamically in 3 dimensions. Concentrations of spilled sediments are then used to calculate light attenuation dynamically (i.e. dose-response between sediment concentrations and light attenuation), which in turn affects the growth of phytoplankton (i.e. dose-response between light intensity and growth rate) and biomass (i.e. impact of dredging on phytoplankton), benthic vegetation biomass (impact of dredging on seagrass and macroalgae) and indirectly, oxygen concentration at seabed.

For potential impacts that cannot be modelled directly, i.e. when dose-response relationships are less well documented, appropriate model outputs are overlaid (time-step by time-step), to identify areas and duration where and when 2-to-several criteria were fulfilled. Such approaches are used in the assessment of direct effects of suspended sediments on phytoplankton sedimentation and on zooplankton growth and survival.

The principles used to define criteria for the assessment of degree of impairment of water quality are listed in Table 5.33.

Phytoplankton production is important for the planktonic and benthic grazing food webs. Reduction in phytoplankton production can have immediate effects on the dominant mussel population along Lolland and around Fehmarn (and cascading effects on population of wintering eiders) and on zooplankton (important food for planktivorous fish).

Plankton organisms have short generation times and, except for vertical migration of copepods and some phytoplankton, plankton organisms are transported passively with water. Therefore and in contrast to sessile benthic organisms, plankton organisms will not be exposed to sudden changes in salinity (and temperature), except for vertically migrating plankton.
Concentrations of chlorophyll $a$ have varied between 1 and 3.5 mg/m³ over the past 20 years with a standard deviation of 0.5 mg/m³, or about 25 – 30% of the average (HELCOM 2010). The degree of impairment (Table 5.33) is related to the standard deviation expressed as a percentage of the average.

Considering the rather large variation in summer concentration during the past 20 years it seems reasonable to assume that a temporary deviation in chlorophyll $a$ concentration of 5% in the construction period hardly will be important for the higher trophic levels. Hence, in the modelling of degree of impairment a deviation of ± 5% from the baseline will be regarded as negligible.

Minor level of impairment is defined as a concentration reduction of 5 - 10% compared to baseline levels. Assuming a ‘baseline level’ of 1.8 mg chlorophyll $a$/m³ the growth rate in copepods (i.e. *Acartia tonsa*) will be reduced by up to 10% assuming that phytoplankton constitutes the only food source.

Medium level of impairment is defined by the interval of 10 – 20% reduction of baseline chlorophyll $a$ concentration. The growth rates of *Mytilus* will potentially be reduced between 10% and 25% and copepod growth rates may be reduced by up to 40%.

### Table 5.33  Assessment criteria for plankton in the local Fehmarnbelt area and in the regional area including the western Baltic Sea

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Criteria for degrees of impairment</th>
<th>Duration</th>
<th>Range</th>
<th>Degree of impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended sediment</td>
<td>&gt;50% reduction in phytoplankton (Chl-a) and/or zooplankton due to reduction in light</td>
<td>Temporary</td>
<td>Regional (also outside local zone)</td>
<td>Very high</td>
</tr>
<tr>
<td></td>
<td>20 – 50% reduction in phytoplankton (Chl a) and/or zooplankton</td>
<td>Temporary</td>
<td>Regional (also outside local zone)</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>10 – 20% reduction in phytoplankton (Chl a) and/or zooplankton</td>
<td>Temporary</td>
<td>Regional (also outside local zone)</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>5 – 10% reduction in phytoplankton (Chl a) and/or zooplankton</td>
<td>Temporary</td>
<td>Regional (also outside local zone)</td>
<td>Minor</td>
</tr>
<tr>
<td></td>
<td>&lt;5% reduction in phytoplankton (Chl a) and/or zooplankton</td>
<td>Temporary</td>
<td>Regional (also outside local zone)</td>
<td>Negligible</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>Quantitative/qualitative assessment based on available data</td>
<td>Temporary</td>
<td>Regional (also outside local zone)</td>
<td>Case-by-case related</td>
</tr>
<tr>
<td>(construction-related)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrographical regime</td>
<td>Quantitative/qualitative assessment based on available data</td>
<td>Permanent</td>
<td>Regional (also outside local zone)</td>
<td>Case-by-case related</td>
</tr>
<tr>
<td>(structure-related)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Solid substrate           | Jellyfish and plankton  
Quantitative/qualitative assessment based on available data                                   | Permanent    | Local                          | Case-by-case related |
| (structure-related)       |                                                                                                  |              |                               |                      |
High level of impairment is defined as a reduction of 20 - 50% compared to baseline concentrations. In this interval, individual *Mytilus edulis* can maintain a positive energy balance, but growth rates will be very low and condition (meat content) will approach 'point of no return’. Copepods such as *Acartia tonsa* have a higher maintenance food concentration at 0.85 mg Chl-a/m³ (Kiørboe at al. 1985), and populations are expected just to be sustained at this level of impairment.

A very high level of impairment of the mussel populations will occur if chlorophyll *a* concentrations below 0.85 mg chlorophyll *a*/m³ persist for extended periods (one or more months). Copepods will starve at phytoplankton concentrations below approximately 0.85 mg Chl-a/m³ and because of limited storage copepods such as *Acartia* will not be able to survive for more than 4-8 days without food (Calbet and Alcaraz 1997), while *Pseudocalanus* probably can survive for weeks due to larger storage capacity. However, recruitment of copepods will take place continuously by advection from non-affected areas, therefore impacts caused by reductions in food will be much less important than for mussels, because they can only be replenished by the yearly reproduction.

### 5.6.4 Impacts of sediment spill on phytoplankton

#### Magnitude of impact

Chlorophyll *a* is an important light-harvesting pigment that occurs in all phytoplankton and therefore chlorophyll *a* is a much used surrogate measure of phytoplankton biomass.

Under baseline conditions, the concentration of chlorophyll *a* during the main primary production period (March through November) varied in the Fehmarnbelt from 1.6-2 µg chlorophyll *a*/l in the central part, to less than 0.5 µg/l in the Rødsand Lagoon (Figure 5.72). Along the Lolland coast concentration of chlorophyll *a* was slightly lower than in the central part of Fehmarnbelt due higher influence of Baltic Sea water (which has a lower chlorophyll *a* concentration), but also due to filtration by the population of blue mussels. The highest concentrations were found southeast of Fehmarn caused by influence from the more nutrient-rich Mecklenburg Bight.

The assessment of the magnitude of the impacts for the immersed tunnel showed that the effects are insignificant.

During 2015 when dredging activities are most intense concentration of chlorophyll *a* will be reduced with up to 8-10% in Rødsand Lagoon, while reductions will be lower along the Lolland coast (max reduction 3-4%, Figure 5.72). Reductions in chlorophyll *a* are much lower than impacts on the sedentary eelgrass and macroalgae because plankton is continuously replenished by advective transports mainly from the western Baltic Sea. The water with reduced plankton concentration is advected westwards with minor increases in chlorophyll *a* towards the Great Belt. In 2016 and 2017 reductions in chlorophyll *a* will gradually decrease (Figure 5.72) and baseline conditions are restored in 2018.
Based on long-term monitoring data a deviation in chlorophyll $a$ larger than 5% from baseline conditions was considered to reflect a minor impairment, a deviation larger than 10% a medium impairment etc. (Table 5.33). The modelled reductions in chlorophyll $a$ correspond to a low and negligible degree of impairment, because reductions in waters of special importance for plankton (depths > 6m) are below 5% in all years during construction (Figure 5.72).

High concentration of suspended sediments ($> 10$ g/m$^3$) can lead to increased sedimentation of phytoplankton provided that phytoplankton cells are “sticky” (primarily diatoms) and they occur in high concentrations ($> 300$ mg/m$^3$). Such situations only occur during the spring bloom in the Fehmarnbelt.

The simultaneous exceedence of the two thresholds for impact by sedimentation occurs along Lolland coast for a 6-7 day period in late March. Assuming that all phytoplankton biomass in these areas aggregate with suspended sediments and settle approximately 14 tons organic carbon will be taken out of the water column and added to the seabed. Under baseline condition and no sediment spill 8.8 tons organic carbon will sediment in the same area, but summed over an entire year the difference in sedimentation is very small. For the entire assessment area the difference in accumulated sedimentation is below 0.01%.
Degree of impairment due to the bored tunnel

Overall, there is a negligible degree of impairment of phytoplankton caused by the immersed tunnel project. Since the sediment spilled by the bored tunnel is much less than that for the immersed tunnel (96,000 m³ compared with 750,000 m³) the degree of impairment of phytoplankton by the bored tunnel project can be considered to be negligible.

5.6.5 Impacts of spilled sediment on zooplankton

Magnitude of impact

Zooplankton production and biomass depend on the availability of food, primarily phytoplankton. Thus, reduction in food concentration caused by shading from suspended sediments can lead to reduction in zooplankton growth and biomass.

The biomass of zooplankton in the baseline situation varies 10-fold within the model area, lowest in Rødsand Lagoon and highest west of Fehmarn (Figure 5.73), overall reflecting the concentration of food. For the immersed tunnel the indirect effect of suspended solids on mesozooplankton is very low in 2015 where sediment spill is highest, not exceeding 1% reduction in average biomass (Figure 5.73). Reductions larger than 0.1% were confined to Rødsand Lagoon, along Lolland coast and Hyllekrog.

The behaviour, feeding activity and egg production can be affected in some zooplankton species at suspended sediment concentrations above 10-20 mg/l, while copepods that dominate the zooplankton biomass in Fehmarnbelt are less sensitive (50-100 mg/l). The direct impact of suspended solids on zooplankton will be very low since the water column concentration of additional suspended sediments from sediment spill in general is low (< 2 mg/l) in Fehmarnbelt, except in coastal waters along Lolland and in Rødsand.
Recruitment of mesozooplankton (especially copepods) can be impaired if resting eggs in sediments are covered with 20-40 mm sediment for extended periods. Permanent burial of resting eggs will take place in 60 ha in the western part of Rødsand lagoon. Compared to the total area of assessment (402,282 ha) the affected area is negligible at 0.01%. In addition, when resting eggs are produced in autumn the biomass of zooplankton is very low in Rødsand, indicating a very low production of resting eggs. Also, given the large exchange with the adjacent areas minor reductions in recruitment will be compensated by imports from Great Belt and the Western Baltic Sea.

Degree of impairment due to the bored tunnel

The degree of impairment due to impacts from the immersed tunnel project on zooplankton is insignificant, because reductions in biomass in all areas is below 1% of the baseline condition and, summed over entire model area reductions are below 0.1%. Similarly, the impacts related to direct burial of eggs have a negligible degree of impairment.

As for phytoplankton, the degree of impairment of zooplankton by the bored tunnel alternative project can be considered to be close to zero since the sediment spilled by the bored tunnel is much less than that for the immersed tunnel (96,000 m$^3$ compared with 750,000 m$^3$).

Potential impact on jellyfish relates to additional solid substrate that provides increased area for settlement of scyphozoan polyps and thereby potentially increases recruitment of jellyfish. Such impact was assessed to be insignificant for the cable stayed bridge alternative that provides a much larger increase in solid substrate than the bored tunnel. Therefore the degree of impairment will be negligible for the bored tunnel.

5.6.6 Significance

The impacts of the bored tunnel project on plankton have a degree of impairment of close to zero. The impacts are therefore insignificant.

5.6.7 Mitigation and compensation

Mitigation and compensation measures for plankton are not required.

5.6.8 Decommissioning

Decommissioning in the marine area consists only of removing certain parts of the contents of the tunnels and then filling them. These activities will not affect the marine environment in any way and there will be no impacts on plankton.
5.7  Benthic flora

This section describes the existing situation for benthic vegetation of Fehmarnbelt and the potential impacts of the bored tunnel project on the vegetation and distribution of communities.

Benthic flora comes under the environmental factor “flora” and contains the components “flowering plants” and “macroalgae”, each of which contains a number of sub-components (communities). The sub-components which have been chosen as indicators for the benthic flora communities in Fehmarnbelt are shown in Table 5.34.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sub-factor</th>
<th>Component</th>
<th>Sub-component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flora</td>
<td>Marine benthic flora</td>
<td>Flowering plants</td>
<td>Eelgrass, Eelgrass / macroalgae, Tasselweed / dwarf eelgrass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Macroalgae</td>
<td>Fucus, Furcellaria, Phycodrys Delesseria, Saccharina, Filamentous algae</td>
</tr>
</tbody>
</table>

5.7.1  Project pressures and potential impacts

Ten pressures have been determined to have a potential impact on benthic flora in the construction phase and in the operation phase. The magnitude of the impacts is analysed for each of the ten pressures in the report describing the impact assessment for the immersed tunnel (FEMA 2011d). For some of the pressures the magnitude is so small that impacts on the flora were excluded for the immersed tunnel and therefore can also be excluded for the bored tunnel. This is the case for the following pressures:

› Release of toxic substances and nutrients from the sediment
› Construction vessels and imported material
› Seabed morphology
› Changes in hydrographic regime
› Water quality and drainage.

Five pressures had a magnitude that needed further analysis for the immersed tunnel alternative. These pressures were (Table 5.35):

› Suspended sediments
› Sedimentation
› Footprint
› Additional solid substrate
› Coastal morphology.
The suspended sediment and the sedimentation derives from the sediment spill created by the establishment of reclamation areas, temporary working harbours and access channels in 2015 and from the removal of temporary works in 2020. The sediment spill from the bored tunnel will be approximately five times lower than the sediment spill from the immersed tunnel in the first year (2015) and seven times lower in the final year of the construction phase (2020 for the bored tunnel and 2019 for the immersed tunnel).

The pressures assessed for the bored tunnel alternative are presented in Table 5.35.

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Potential impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended sediment</td>
<td>Reduced growth rate and biomass due to light reduction at the seabed</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>Reduced growth rate and biomass due to sedimentation</td>
</tr>
<tr>
<td>Footprint</td>
<td>Benthic flora communities lost under structures and construction works</td>
</tr>
<tr>
<td>Solid substrate</td>
<td>New benthic flora communities can develop on new solid substrate</td>
</tr>
<tr>
<td>Coastal morphology</td>
<td>Benthic flora communities lost or impaired in near coast areas subject to changes in erosion and sedimentation</td>
</tr>
</tbody>
</table>

5.7.2 Existing benthic flora communities in Fehmarnbelt
The baseline studies in 2009 and 2010 identified two soft bottom communities consisting of flowering plants, one mixed algae-flowering plant community and five hard bottom macroalgae communities.

The field studies consisted of underwater video recording along a number of transects as shown in Figure 5.74 to determine coverage and depth distribution. Within predefined depth intervals the divers collected samples for species determination, biomass analysis and shoot density (only for eelgrass).
Flowering plants

The two soft bottom communities are an eelgrass community and a tasselweed/dwarf eelgrass community.

The eelgrass community was found at depths of 1–5 m and was widely distributed in most of the shallow soft bottom areas. The key species for this community is the common eelgrass (Zostera marina). Accompanying species are small tiny epiphytic growing algae (Aglaothamnion/Callithamnion and/or Ceramium tenuicorne).

The tasselweed/dwarf eelgrass community was more shallow and distributed at depths of 0.25–1.5 m and spatially restricted to the sheltered shallow water zones of Redsand Lagoon and Orth Bight. Key species are the narrow-leaf angiosperms tasselweed (Ruppia cirrhosa/maritima) and dwarf eelgrass (Zostera noltii). These angiosperms are accompanied by different characeans (Chara aspera, Chara baltica, Tolypella nidifica) and other angiosperms like the pondweeds Potamogeton pectinatus or Zannichellia palustris.
Mixed eelgrass/algae community
The mixed eelgrass/algae community was found at depths between 1 and 5–6 m and the distribution was scattered along the more exposed outer coastline. Contrary to the above mentioned communities, it was found both in sandy bottom areas and in areas with coarse sediments. Key species for this community are common eelgrass (Zostera marina), various perennial macroalgae and filamentous algae.

Hard bottom macroalgae communities
The five hard bottom (macroalgae) communities were: Fucus, Furcellaria, Phycodrys/Delesseria, Saccharina and filamentous algae species.

The Fucus community was found at depths of 1–5 m, but was spatially restricted to a few locations. Key species for this community were serrated wrack (Fucus serratus) and bladderwrack (Fucus vesiculosus). Accompanying species were the perennial red alga Ahnfeltia plicata and the filamentous alga Polysiphonia fucoides.

The Furcellaria community grows at depths of 2–8 m and was widely distributed along the Danish coast. The aggregated taxa group Coccotylus /Phyllophora was abundant and occurred mixed with Furcellaria stocks as well as with epiphytic growing algae of the genus Ceramium.

The Phycodrys/Delesseria community was found at depths of 5–19 m and had a large spatial distribution in the study area. Key species were the perennial red algae Phycodrys rubens and Delesseria sanguinea. These red algae were accompanied by various other red algae like Coccotylus/Phyllophora, Membranoptera alata, Brongniartella byssoides, Cystoclonium purpureum and/or Rhodomela confervoides.

The Saccharina community was found at depths of 12–19 m. Key species is the perennial brown alga Saccharina latissima. Accompanying species are rare and are mostly annual, filamentous algae (e.g. Desmarestia aculeata, Polysiphonia stricta) or a key species of other communities (e.g. Delesseria sanguinea).

Many sites within the study area showed a dominance of filamentous, opportunistic algae (the filamentous algae community). The species composition and abundance of this group is very variable between sites and depths. No single species can be listed as key species.

Species diversity
Six angiosperm (flowering plants) species and six charophyte species were recorded. Eight of these species are red listed in Germany. None of the species are red-listed in Denmark.

A total of 69 macroalgae species were identified, including 17 green algae, 25 brown algae and 27 red algae species. 15 of the species are listed in the German Red List of the Baltic Sea. None of the species are red-listed in Denmark.
Distribution and cover

Figure 5.75 shows the distribution and coverage of the benthic vegetation communities within the investigation area.

Figure 5.75  Distribution and coverage of the benthic vegetation communities within the investigation area
5.7.3 Methodology

The pressure from the immersed tunnel is considered as a worst case scenario because the sediment spill is much higher and the footprint is larger. Therefore an impact on the benthic flora for the bored tunnel will be insignificant if it is insignificant for the immersed tunnel.

If the magnitude of pressure is approximately the same as for the immersed tunnel or higher, the degree of impairment or severity of loss is determined and the impact significance assessed.

Biomass is used as the indicator of impact of suspended sediment on benthic flora. Changes in the biomass due to increased suspended sediments are calculated with the Ecolab module of the MIKE 3 modelling system which uses the results of the previous sediment spill simulations. The model simulations are executed for the years 2014, 2015 and 2020.

The impact of suspended sediment is described as changes in biomass (i.e. percentage of reference biomass modelled without sediment spill) at the end of the growth seasons (September) 2015 and 2020. Footprint areas are subtracted from the calculations. For the calculations in 2020 it is assumed in the model that the vegetation is fully recovered in the years 2016-2019, following the reduction in biomass in 2014-2015. This assumption is based on results from the impact assessment of suspended sediment on benthic vegetation from construction of the immersed tunnel. The model output is reduction in the light and vegetation biomass on which the degree of impairment is assessed.

The impact of sedimentation is assessed by evaluating the thickness of sediment layers persisting for at least 10 days and relating it to the same data as for the immersed tunnel. New calculations are made for the impact of footprints and additional solid substrate. The impacts of changes in coastal morphology are assessed by comparing with the results for the immersed tunnel.

5.7.4 Impacts of suspended sediments

Magnitude of pressure

An increase of concentrations of suspended sediment in the water reduces the light availability for photosynthesis and growth of benthic flora. Sediment is spilled in 2014, 2015 and 2020 during the construction of the bored tunnel. In the years 2016-2019 there is no sediment spill, and thus no reduction in light intensity.

Timing of the dredging is important for the degree of impairment. The assumption of this impact assessment is that dredging will start in October 2014. Should the dredging start at another time of the year the outcome of the impact assessment may change.

The overall spatial pattern in the reduction in light availability for the benthic flora during 2015 and 2020 is shown in Figure 5.76. Near the alignment at the Lolland coast, the spilled sediment is transported along the shoreline resulting in a
The average reduction of light in the growth season (March – September) is expected to be between 5 and 40% along the Lolland coast during 2015 and between 2 and 30% in 2020 (see Figure 5.76).

The model predicts that the impact gradually decreases with distance from the shore and the impact on the benthic flora communities outside the investigation area will be minor to negligible and insignificant.

In Rødsand Lagoon the reductions in light are between 5 and 40% in 2015 and between 0 and 20% in 2016.

Along the German coast, the reductions in light is limited to 0-2% reduction in 2015 and 5-10% in 2020. The low reduction in light is related to limited construction activities on the German coast.

The model simulations predict that the response of benthic flora to reduced light is highest in 2015. In 2020 there is also a decrease in the biomass of benthic flora, but the impact is smaller.

Along the Danish coast, the macroalgae biomass at the end of the growth season 2015 will be reduced by 0 to 30% compared to the reference conditions (Figure 5.77). The highest reductions (20-30%) occur in very small areas close to the reclamation area. Further away from the reclamation area, the biomass reductions are 10-20%. In a larger area east and west of the reclamation, the biomass is predicted to be reduced by maximally 10% but generally the reductions are 0-5%. Along the German coast the reductions in biomass are 0-5% and occur in limited areas.

The pattern of reduction of macroalgae biomass is similar in 2020, but with lesser impact as a consequence of the reduced dredging activity (Figure 5.77).

The deep growing benthic flora consisting of Phycodrys/Delesseria and Saccharina communities remains unaffected.

At the end of the growth season in 2015, the eelgrass biomass is predicted to be reduced by between 0 and 30% and in 2020 by between 0 and 10% in the Rødsand Lagoon. In the main part of the lagoon, the reduction in biomass is between 0 and 20% in 2015 and 0-5% in 2020.

In the tasselweed/dwarf eelgrass community the impact occurs in 5 ha in the Rødsand Lagoon in 2015. The impact is restricted to the shallowest eastern parts of the sheltered lagoon. Light is not the main limiting factor for growth in these shallow waters, where physical disturbance from waves or grazing by birds is more important for biomass variations.

Reductions in biomass near the Fehmarn coast do not exceed 5% at any time.
Figure 5.76  Reduction of light availability (%) for benthic flora in the Fehmarnbelt area during the growth season (May-September) 2015 (upper) and 2020 (lower)
Figure 5.77  Spatial distribution of reduction in benthic flora biomass at the end of the growth season 2015 (upper) and 2020 (lower)
Magnitude of impact and degree of impairment

The degree of impairment due to suspended sediment is related to the magnitude of impact which is the reduction in biomass at the end of the growth season compared to the reference biomass without sediment spill. The four degrees (very high, high, medium and minor) and the corresponding criteria are shown in Table 5.36.

Table 5.36  Degree of impairment used in the assessment of impacts on benthic flora due to suspended sediment from sediment spill

<table>
<thead>
<tr>
<th>Degree of impairment</th>
<th>Reduction in biomass at the end of growth season</th>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>75-100%</td>
<td>Even in years with otherwise favourable conditions a reduction in biomass of this size may affect the primary production, and the structure and function of the habitat. Low biomass is present to survive the winter and produce spores for maintaining the populations. The loss of biomass may result in some fragmentation of the habitat, and associated communities of epifauna, infauna or fish may be disturbed.</td>
</tr>
<tr>
<td>High</td>
<td>50-75%</td>
<td>Even in years with otherwise favourable conditions a reduction in biomass of this size may influence the primary production, and the structure and function of the habitat. Less biomass is present to survive the winter and produce spores for maintaining the populations. The loss of biomass may result in some fragmentation of the habitat, and associated communities of epifauna, infauna or fish may be disturbed.</td>
</tr>
<tr>
<td>Medium</td>
<td>25-50%</td>
<td>Reduction of this size is 0-25% above average level of natural variability. In average years the impact may be minor but under unfavourable circumstances where both natural variability will reduce the seasonal production and the suspended sediment concentrations will further deteriorate the conditions the resulting reduction in biomass may be larger.</td>
</tr>
<tr>
<td>Minor</td>
<td>10-25%</td>
<td>Within the level of average natural variability.</td>
</tr>
</tbody>
</table>

The spatial distribution of the degree of impairment is shown in Figure 5.78 with the actual areas impaired in Table 5.37.

In the impacted areas along the Danish coast, *Furcellaria* and filamentous species communities dominate the benthic flora. The biomass reduction in the *Furcellaria* community corresponds to minor to medium degree of impairment in 2015 and minor degree of impairment in 2020. The area affected by a medium degree of impairment is 56 ha in 2015. The filamentous species community is affected to a
medium degree of impairment in 2015 and a minor degree of impairment in 2020. The area affected by a medium degree of impairment is 1 ha in 2015.

In the main part of Rodsand Lagoon the reduction in biomass of the eelgrass community corresponds to a minor to a medium degree of impairment in 2015 and a minor degree of impairment in 2020 (Table 5.37). The area affected by a medium degree of impairment is only 4 ha in 2015 whereas the area with minor impairment is 574 ha.

In the tasselweed/dwarf eelgrass community a minor degree of impairment occurs in 5 ha in Rodsand Lagoon in 2015.

The degree of impairment in German waters is less than the defined scales since the reductions in biomass are less than 5%.

Depth limits

The temporary reduction in light availability is not expected to influence the general depth limit of benthic flora in the assessment area as light reductions are only small in areas where light is limiting depth distribution, and the flora in deep water should be adapted to considerable year-to-year variations in light availability.

The depth distribution of eelgrass is limited by light in the eastern part of the Rodsand Lagoon (4.3-5.2 m) and the deeper parts of Orth Bight (4.5-4.8 m). Light reduction in the eastern deeper part of the Rodsand Lagoon is expected to be 2-5% in 2015 resulting in a comparable reduction of biomass. In 2020 the light reductions are 0-2%.

The light climate in Rodsand Lagoon is variable as re-suspension events are frequent and of magnitudes higher than the predicted sediment spill. Thus, eelgrass in the lagoon is adapted to variable light climate. Eelgrass is able to store carbohydrate reserves and thereby survive periods of low light (Burke et al. 1996).

In Fehmarnbelt the deepest growing communities are Phycodrys/ Delesseria and Saccharina. The reduction of light in these communities is expected to be up to 5-10% resulting in a comparable reduction in biomass. The key species of these communities are adapted to grow at low light levels. They have low light requirements, thallus that are optimal for capturing light and/or they are able to grow in the dark using stored reserves (Kain 1984, Lüning and Schmitz 1988).

The predicted reduction in light availability is small and limited to one growth season, and the long-term light climate is not expected to change due to construction of the tunnel. The construction of the tunnel is therefore not likely to impact the general depth limit of eelgrass or macroalgae in the area.
Figure 5.78 Spatial distribution of the degree of impairment of benthic flora at the end of the growth season 2015 (upper) and 2020 (lower)
Table 5.37  Degree of impairment, i.e. affected areas in ha. per community caused by suspended sediment for the bored tunnel alternative for the years 2015 and 2020. Calculations are based on reduction of biomass at the end of the growth season (1st September) compared to the reference conditions with no extra concentrations of suspended sediment.

<table>
<thead>
<tr>
<th>Degree of impairment</th>
<th>Community area, ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2015</td>
</tr>
<tr>
<td><strong>Eelgrass</strong></td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>4</td>
</tr>
<tr>
<td>Minor</td>
<td>574</td>
</tr>
<tr>
<td><strong>Tasselweed/dwarf eelgrass</strong></td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>5</td>
</tr>
<tr>
<td>Minor</td>
<td></td>
</tr>
<tr>
<td><strong>Filamentous species</strong></td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>1</td>
</tr>
<tr>
<td>Minor</td>
<td>148</td>
</tr>
<tr>
<td><strong>Furcellaria</strong></td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>56</td>
</tr>
<tr>
<td>Minor</td>
<td>511</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>66</td>
</tr>
<tr>
<td>Minor</td>
<td>1,238</td>
</tr>
</tbody>
</table>

Significance of impact
The impact on benthic floral biomass of the suspended sediment is temporary and, in combination with an expectation of a relatively rapid recovery, impacts will not cause significant effects on the function of the local or regional ecosystem. No areas are impacted with high degree of impairment so that loss of benthic flora due to suspended sediment is not expected.
Macroalgae communities are temporarily impacted with minor to medium degree of impairment on the Danish coast near the construction sites. The benthic flora in the German national zone is not impacted with any degree of impairment.

The largest impacts are on the Danish side near the reclamation area. The impact is occurring in the *Furcellaria* community. The macroalgae communities recover rapidly in the shallow waters along the coast and full recovery of the biomass is expected. The *Furcellaria* communities are common along Danish and German coasts and widespread in the whole Baltic Sea. The reduction in biomasses in 2015 is not likely to cause significant effects on the function of the ecosystem (e.g. lower oxygen and detritus production).

The impact in areas dominated by the deep growing communities (*Phycodrys/Delesseria* and *Saccharina*) is below a minor degree of impairment.

For eelgrass, impact with medium to minor degree of impairment is predicted in 2015. The small temporary reductions in biomass cannot be expected to cause any significant impact on the function of the eelgrass ecosystem. Eelgrass populations are naturally variable over time because of physical disturbance by waves, currents, ice and variations in light availability in deeper populations. It is not likely that the predicted short-term reduction in light availability should cause any long term effect on the function of the ecosystem.

### 5.7.5 Impacts of sedimentation

**Magnitude of pressure**

The magnitude of impact depends on the amount of deposited sediment as well as the duration and timing of the sedimentation. The important indicator is thus the specific thickness of the settled sediment, which persists for a certain number of days during the growth or reproductive season.

The maximum thickness of sediment layers persisting for more than 10 days is 40 cm (Figure 5.79). This is expected in small areas in the close vicinity of the reclamation areas and the access channels (less than 500 m). In the largest part of the area, in Rødsand Lagoon and east and west of the reclamation area at Fehmarn, sediment layers that persist for more than 10 days are less than one cm.

A total area of approximately 240 ha is expected to be impacted by sedimentation: 166 ha with a minor, 34 ha with medium, 11 ha with high and 15 ha with very high magnitude of pressure.

The sedimentation is expected to be below any magnitude of pressure in the areas with flowering plants (Rødsand Lagoon and Orth Bight, see Table 5.38).

Minor to very high magnitude of pressure are expected in the macroalgae communities in the vicinity of reclamation areas and access channels on Lolland and Fehmarn (see Table 5.39). High and very high magnitude of pressure is
predicted in very small areas. Minor magnitude of pressure is expected in areas along the Fehmarn coast further away from the alignment.

### Table 5.38 Magnitude of pressure levels for flowering plant communities

<table>
<thead>
<tr>
<th>Magnitude of pressure</th>
<th>Thickness of sediment layer persisting for more than 10 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>&gt; 20.0 cm</td>
</tr>
<tr>
<td>High</td>
<td>10.0 to 20.0 cm</td>
</tr>
<tr>
<td>Medium</td>
<td>5.0 to 10.0 cm</td>
</tr>
<tr>
<td>Minor</td>
<td>1.0 to 5.0 cm</td>
</tr>
</tbody>
</table>

### Table 5.39 Magnitude of pressure levels for macroalgae communities

<table>
<thead>
<tr>
<th>Magnitude of pressure</th>
<th>Thickness of sediment layer persisting for more than 10 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>&gt; 10.0 cm</td>
</tr>
<tr>
<td>High</td>
<td>5.0 to 10.0 cm</td>
</tr>
<tr>
<td>Medium</td>
<td>1.0 to 5.0 cm</td>
</tr>
<tr>
<td>Minor</td>
<td>0.2 to 1.0 cm</td>
</tr>
</tbody>
</table>

The Furcellaria and the filamentous species community dominate along the Lolland coasts. In this area the levels of sediment persisting for more than 10 days correspond to minor to very high magnitude of pressure. However, only few smaller areas of these communities occur in areas with medium to very high magnitude of pressure.

A sedimentation of less than 1 cm occurs in the most of the area with macroalgae. In these areas the recruitment success of macroalgae may be reduced, as hard substrates will be covered with a thin sediment layer, reducing the area for settlement of propagules. Macroalgae is expected to recover from the temporary failure of recruitment success during the following reproduction periods. The impact is expected to be limited and recovered within two years after end of construction. The impact on the macroalgae communities due to sedimentation is expected to be insignificant.

In Rødsand Lagoon all sediment layers persisting for more than 10 days are less than 1 cm, and thus below minor magnitude of pressure for flowering plants.

Benthic vegetation is sparse near the reclamation area at Puttgarden where sedimentation up to 40 cm occurs, thus there will be negligible impact on benthic vegetation.
Figure 5.79 Magnitude of pressure caused by sedimentation for the bored tunnel (upper) and the immersed tunnel (lower) alternatives
Significance of impact
In conclusion, the extent of the area impacted by sedimentation is much smaller than for the immersed tunnel (Figure 5.79). Sedimentation is not expected to cause any significant impacts on the benthic flora.

5.7.6 Impacts of project footprint

Magnitude of impact
Several structures of the bored tunnel alternative will occupy areas (footprints). These can be related to construction and temporary or be related to structure and hence permanent. The footprint areas are presented in Table 5.40 and illustrated in Figures 5.15 to 5.17.

Table 5.40 Footprint area (in ha) with respect to type, tunnel structure and geographical zone

<table>
<thead>
<tr>
<th>Type</th>
<th>Structure</th>
<th>Footprint area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Structure-related</td>
<td>Reclamation areas</td>
<td>353</td>
</tr>
<tr>
<td>Construction-related</td>
<td>Access channels</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Work harbours</td>
<td>52</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>441</td>
</tr>
</tbody>
</table>

Overall, the tunnel footprints take up 441 ha. Structure-related, permanent footprints occupy most of the area (353 ha), whereas construction-related footprints take up 88 ha. Reclamation areas (structure-related footprints) occupy the largest area.

In Danish waters footprints cover a larger area (387 ha) compared to footprint areas in German waters. Most of the footprints are structure-related with no possibility of recovery.

In German national waters footprints occupy 54 ha. Most of the footprints in the German area (31 ha) are construction-related footprints with a possibility of recovery. Recoverability are discussed in the significance section below.

Overall, the tunnel footprints affect 255 ha of benthic flora of which 212 ha are affected by structure-related footprints and 43 ha by construction-related footprints. Most of the lost area occurs in Danish national waters (251 ha). In German national waters 4 ha are lost. The areas of each community lost are detailed below.

Severity of loss
The severity of loss was estimated by intersecting the footprint area (corresponds to very high magnitude of pressure) with the relative importance of the various
benthic flora communities. The criteria for determining importance and severity are described in FEMA 2011d. The results are presented in Table 5.41, Table 5.42, Figure 5.80 and Figure 5.81.

No very high severity of loss occurs due to footprints.

There is a high severity of loss of benthic flora in an area of 16 ha. High severity of loss appears exclusively along the Lolland coastline, where dense stands of the Furcellaria community occur (> 50% cover). The main part, 13 ha, is lost due to structure-related footprints and 3 ha is affected by construction-related footprints.

A medium severity of loss occurs in an area of 189 ha due to footprints, mostly by structure-related footprints (169 ha). An area of 20 ha are affected by construction-related footprints. Medium severity of loss appears exclusively along the Lolland coastline, where the Furcellaria community occurs with coverage between 10 and 50%.

A minor severity of loss occurs in an area of 50 ha due to footprints. 30 ha are covered by structure-related and 20 ha by construction-related footprints. Minor severity of loss appears along the Lolland coastline (46 ha) and only to a small extent along the Fehmarn coastline (4 ha). At the Fehmarn coastline it is the filamentous algae community which is affected while at the Lolland coastline the filamentous algae community as well as single vegetation stands (coverage 1–10%) are affected.

<table>
<thead>
<tr>
<th>Severity of loss</th>
<th>Footprint type</th>
<th>Area affected (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total DK national DE national</td>
</tr>
<tr>
<td>Very high</td>
<td>Structure Construction</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Structure Construction</td>
<td>13 13 3 3</td>
</tr>
<tr>
<td>Medium</td>
<td>Structure Construction</td>
<td>169 169 20 20</td>
</tr>
<tr>
<td>Minor</td>
<td>Structure Construction</td>
<td>30 30 20 16</td>
</tr>
<tr>
<td>Total</td>
<td>Structure Construction</td>
<td>212 212 43 39</td>
</tr>
</tbody>
</table>

Table 5.41 Severity of loss caused by footprints for the bored tunnel alternative
### Table 5.42 Severity of loss (in ha) per community caused by footprints for the bored tunnel alternative

<table>
<thead>
<tr>
<th>Severity of loss</th>
<th>Footprint type</th>
<th>Filamentous algae</th>
<th>Furcellaria</th>
<th>Vegetation stands (1-10%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>DK</td>
<td>DE</td>
</tr>
<tr>
<td>Very high</td>
<td>Structure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Structure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction</td>
<td>13</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Structure</td>
<td>169</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>Structure</td>
<td>16</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Structure</td>
<td>16</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Figure 5.80 Spatial distribution of severity of loss caused by footprints for the bored tunnel alternative along the Lolland coastline
Significance

Significance is determined by comparing the loss of specific vegetation communities (Table 5.42) with the inhabited area in the local zone (10 km on either side of the tunnel alignment) or the assessment area (from Langeland to Darss Sill, Figure 5.75) and the possibility and duration of the recovery from the impact. The results for the percentage of communities affected are listed in Table 5.43.

The loss of filamentous algae community (16 ha) or single vegetation stands (1–10% coverage, 34 ha) is assessed as minor severity of loss, as both communities are considered to be of minor importance and not protected by any international or national guidelines or legislation. The 16 ha of filamentous algae correspond to 1% of filamentous algae in the local zone and 0.22% in the assessment area. The 34 ha of single vegetation stands correspond to less than 1% (0.39%) of single stands in the local zone and 0.03% in the assessment area. The impact due to footprints is therefore insignificant for filamentous algae and single vegetation stands in terms of area loss on a local and assessment area scale.

Within most of the impacted area (205 ha) the *Furcellaria* community occurs with different coverage densities (>50% coverage, 10–50% coverage), which is reflected in the severity level: 16 ha with high severity of loss and 189 ha with medium severity of loss. The 205 ha correspond to 9% of *Furcellaria* in the local...
zone and to 5% in the assessment area. The loss is mainly caused by structure-related footprints (182 ha), for which the impact is permanent and therefore not reversible. The 182 ha of lost *Furcellaria* correspond to 8% in the local zone and to 5% in the assessment area.

*Furcellaria* is not protected by Danish legislation, whereas it is protected in German waters (§30 BNatschG). However, the loss occurs exclusively in Danish waters.

The *Furcellaria* community is a valuable part of benthic flora (medium to high importance). The permanent loss of the *Furcellaria* community is assessed to be significant for the functioning of the local ecosystem of Fehmarnbelt, as perennial coastal macrophytes are important as habitat structuring elements contributing to the coastal primary production, O₂ production and creating habitats for associated flora and fauna. However, the loss will not threaten the existence or function of the community in the Baltic Sea. The *Furcellaria* community is common in the whole Baltic Sea area and is dominant or occurring frequently from Skagerrak to the Gulf of Bothnia (Nielsen et al 1995). *Furcellaria* is red-listed in the HELCOM area (HELCOM 2007).

The construction-related part of *Furcellaria* loss (23 ha) is caused by the access channel to the Lolland work harbour and by the work harbour itself. The duration of the seabed re-establishment for the access channel is calculated to 5 to 12 years for the deepest trench sections near to the reclamation areas where the *Furcellaria* community occurs. The recovery time for *Furcellaria* is long (5–10 years). The duration of the impact for the access channel is therefore longer than 5-12 years.

For the work harbour the duration was calculated to less than 5 years. With a recovery time for *Furcellaria* between 5 and 10 years, the duration of those impacts varies between 5 as a minimum and 15 years as a maximum.

In conclusion the permanent loss of the *Furcellaria* community is considered to be significant. The temporary losses are not considered to be significant.

**Table 5.43** Severity of loss per community expressed as a % of the area of each community within the local zone and within the assessment area

<table>
<thead>
<tr>
<th>Severity of loss</th>
<th>Filamentous algae (%)</th>
<th><em>Furcellaria</em> (%)</th>
<th>Vegetation stands (1-10% cover) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local zone</td>
<td>Assessment area</td>
<td>Local zone</td>
</tr>
<tr>
<td>Very high</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>1</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>0.22</td>
<td>9</td>
</tr>
</tbody>
</table>
5.7.7 Impacts of solid substrate

Magnitude of impact

New solid substrate is provided by the rock armour on the containment dikes around the land reclamations on Lolland and Fehmarn. It is assumed that the cross-section of the dikes is identical with those for the immersed tunnel.

The surfaces of the new structures provide new substrate for macroalgae species requiring solid substrate for colonisation. The potential new area and biomass of new algae communities depend on the depth.

In the depth interval from 0 – 20 m an area of 9 ha in Danish waters and 1 ha in German water of solid substrate is added to the area (Table 5.44). Below 20 m no substantial algae growth is expected.

<table>
<thead>
<tr>
<th>Total area</th>
<th>Denmark National + EEZ</th>
<th>Germany National</th>
<th>Germany EEZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>9</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Possible impacts to the benthic flora are:

› Increased risk of introduction of non-indigenous species. Newly introduced solid substrates can be used by non-indigenous species if free substrate is limiting their dispersal. The species composition found on new structures of the Øresund and Great Belt Fixed links are comparable to the communities of the surrounding hard bottom communities and not dominated by non-indigenous species. Therefore, the risk is assessed to be marginal.

› New structures will increase the area of hard bottom macroalgae communities. Macroalgae from the surrounding hard substrates can use the additional solid substrate for settlement and increase their area of distribution, and the impact will be a positive increase in the abundance and distribution in the area.

Monitoring from other new structures like Øresund and Øland bridge (Qvarfordt & Kautsky 2006, Øresundsbroen 2005) as well as investigations from artificial reefs (Kraufelin et al. 2007) showed that new solid substrates are often dominated by opportunistic, filamentous algae. Comparison between artificial reefs of different composition showed that reefs built out of concrete are inhabited by fewer algae species and lower algae biomasses (Ambrose 1994).

Based on the calculated additional solid substrate and the relationship between depth and macroalgae biomass (FEMA 2011b) the additional algae biomass was estimated (Table 5.45).
Table 5.45 Estimated biomass of benthic macroalgae (kg DW) on new solid substrate in the depth layer between 0 and 20 m assuming similar distribution of biomass as under baseline conditions

<table>
<thead>
<tr>
<th>Total biomass</th>
<th>Denmark National + EEZ</th>
<th>Germany National</th>
<th>Germany EEZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>20,479</td>
<td>17,863</td>
<td>2,616</td>
<td>0</td>
</tr>
</tbody>
</table>

Significance

If the new solid substrate is colonised by macroalgae with the same biomass as found in the baseline study on natural rocks the new area constitutes 1.3% of the area and biomass of the existing communities in the near zone which is the area of the footprint plus 500 m on either side. (Table 5.46).

On larger scales (e.g. local zone which is the area of the footprint plus 10 km on either side), the potential new communities will not significantly change to the functioning of the ecosystem as they only make up 0.3% or less of the existing area and biomass. For the Fehmarnbelt area as a whole, the impacted biomass is only 0.1% and therefore insignificant.

Table 5.46 Percentages new solid substrate in relation to existing areas and biomass of macroalgae in the different zones (1-10% vegetation cover not included)

<table>
<thead>
<tr>
<th></th>
<th>Total area</th>
<th>Near zone</th>
<th>Local zone</th>
<th>Denmark National + EEZ</th>
<th>Germany National</th>
<th>Germany EEZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>0.1%</td>
<td>1.3%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>&lt;0.1%</td>
<td>0%</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.1%</td>
<td>1.3%</td>
<td>0.3%</td>
<td>0.2%</td>
<td>&lt;0.1%</td>
<td>0%</td>
</tr>
</tbody>
</table>

5.7.8 Impacts of coastal morphology

The impacts from the bored tunnel alternative on the coastal morphology on the Danish side west of the reclamation area will be the same as for the immersed tunnel alternative. This will cause a similar impact on the benthic flora as the impact of the immersed tunnel. This impact is assessed to be insignificant (FEMA 2011d). The impacts east of the reclamation area will be larger for the bored tunnel alternative as there is no active cliff to deliver material to the down drift coast. However, this extra impact will be compensated by increased beach nourishment, which compensates for the additional erosion imposed by the reclamation along the coast east of the project area. Thus, the impact on the benthic flora is the same as for the immersed tunnel: no or negligible impacts.

On the German side there will be no impacts west of Puttgarden. East of Puttgarden and there is a potential minor impact on the structure/coastline at Ohlenborgs Huk due to a small increase in erosion potential. The impact will be
mitigated (see section 5.5), giving the conclusion that the impact on the benthic flora is negligible.

In conclusion, as for the immersed tunnel, no significant impacts are expected for benthic vegetation due to changes in coastal morphology.

5.7.9 Significance of impacts - summary
The overall conclusion on the assessment of the environmental impacts from the bored tunnel alternative on the benthic flora is that impacts are expected to be significant due to lost areas of the *Furcellaria* community. An area of 182 ha with *Furcellaria* community are expected to be lost, corresponding to 8% of the community in the Fehmarnbelt local zone and to 5% in the assessment area. The areas are lost permanently.

Impacts from other pressures are assessed as insignificant.

5.7.10 Mitigation and compensation
Compensation is a legal requirement if protected habitats/species are lost or impaired significantly.

The footprint of the tunnel alternative causes significant habitat loss. The reclamation area along the Lolland coastline causes a significant loss of the *Furcellaria* community. However, *Furcellaria* is not protected in Denmark and compensation is not necessary, nor is an effective compensation possible.

The project has already included optimisation of the impact of the footprint along the Fehmarn coastline to reduce the loss of vegetation. The present footprints fulfil technical requirements of the project and further mitigation is not possible.

5.7.11 Decommissioning
It is assumed that the bored tunnel alternative will be decommissioned in the same way as the immersed tunnel alternative. The assessment conclusions are therefore similar: There will be no impact on the benthic flora.
5.8 **Benthic fauna**

This section describes the existing situation for benthic fauna of Fehmarnbelt and the potential impacts of the bored tunnel project on the biomass and distribution of communities.

The benthic fauna communities in Fehmarnbelt are important components of the marine ecosystem. Benthic fauna functions as a key link between primary producers and the higher trophic levels and many benthic fauna communities also act as ecosystem engineers that actively shape their surroundings. The benthic fauna communities of Fehmarnbelt have been categorised into nine infauna and epifauna communities (sub-components). Each particular benthic fauna community has been named after the main characteristic species of that community.

Benthic fauna comes under the environmental factor “fauna” and contains the components “infauna”, “epifauna” and “mussels”, each of which contains a number of sub-components. The sub-components which have been chosen as indicators for the benthic fauna communities in Fehmarnbelt are shown in Table 5.34.

**Table 5.47 Benthic flora communities in Fehmarnbelt**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sub-factor</th>
<th>Component</th>
<th>Sub-component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fauna</td>
<td>Marine benthic</td>
<td>Infauna, epifauna</td>
<td>Arctica (large bivalve mollusc)</td>
</tr>
<tr>
<td></td>
<td>fauna</td>
<td>and mussels</td>
<td>Bathyporeia (sand digging shrimp)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cerastoderma (common cockle)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Corbula (European clam)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dendrodoa (sea squirt)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gammarus (an amphipod crustacean)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mytilus (blue mussels)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rissoa (minute sea snail)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tanaissus (a marine cheliped)</td>
</tr>
</tbody>
</table>

5.8.1 **Project pressures and potential impacts**

In the impact assessment for the immersed tunnel alternative for the benthic fauna (FEMA 2011e), a number of pressures were screened out because the pressure itself was very low and/or not significant for benthic fauna. These pressures were:

- Release of toxic substances and nutrients from spilled sediments
- Construction material and imported material
- Changes in hydrographic regime and water quality
- Drainage
- Changes in seabed and coastal morphology.

Since the pressures from the bored tunnel alternative are lower than the pressures from the immersed tunnel alternative, the pressures are also screened out for the bored tunnel and will not be dealt with further in this EIA.
Four pressures could not be screened out and will consequently be dealt with in the present EIA. These pressures were (Table 5.35):

› Suspended sediments
› Sedimentation
› Footprint
› Additional solid substrate.

The suspended sediment and the sedimentation derives from the sediment spill created by the establishment of reclamation areas, temporary working harbours and access channels in 2015 and from the removal of temporary works in 2020. The sediment spill from the bored tunnel will be approximately five times lower than the sediment spill from the immersed tunnel in the first year (2015) and seven times lower in the final year of the construction phase (2020 for the bored tunnel and 2019 for the immersed tunnel).

The pressures assessed for the bored tunnel alternative are presented in Table 5.35.

Table 5.38 Project pressures and potential impacts on benthic fauna for the bored tunnel

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Potential impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended sediment</td>
<td>Abrasion and/or clogging of filtration organs of filter feeders leading to reduced viability and possible increased mortality rate. Reduced chlorophyll $a$ leading to reduced food supply and possible increased mortality rate of benthic fauna.</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>Reduced benthic fauna biomass due to reduced viability and possible increased mortality rate.</td>
</tr>
<tr>
<td>Footprint</td>
<td>Benthic fauna communities lost under structures and construction works.</td>
</tr>
<tr>
<td>Solid substrate</td>
<td>New benthic fauna communities can develop on new solid substrate.</td>
</tr>
</tbody>
</table>

5.8.2 Existing benthic fauna communities in Fehmarnbelt

Baseline studies
The baseline field studies between 2008 and 2010 consisted of sampling of benthic epi- and infauna at 325 stations at the locations shown in Figure 5.82. Sampling was done using van Veen grabs operated from a ship at deep stations and frame samples operated by divers at shallower waters. The area covered the greater Fehmarnbelt including shallow and deep waters, and seven NATURA 2000 areas.
Because of their patchy distribution, blue mussel had its own sampling programme that comprised video and diver surveys of mussel beds (> 5000 observations), as well as frame sampling by divers and quantitative dredge sampling.

The fauna was characterised by species abundance and biomass in terms of ash free dry weight (AFDW). For mussels, that play an important role as food for wintering Eider ducks, also length distribution was quantified.

![Geographical positions of the sampling stations for the benthic fauna baseline sampling campaign](image)

**Figure 5.82** The geographical positions of the sampling stations for the benthic fauna baseline sampling campaign

**Fauna communities**

Overall, nine infauna and epifauna communities were identified (Table 5.34). Two of them were found in both deep (below pycnocline) and shallow waters (above pycnocline). Four communities were unique to deep waters and three communities were only found in shallow waters. The distribution of communities in the Fehmarnbelt is shown in Figure 5.83. Each particular benthic fauna community has been named according to the main characteristic species of that community.
Table 5.49  Summary of the benthic fauna communities in the Fehmarnbelt: Distribution, number of species, biomass (AFDW) and key features. The biomass value of the Mytilus community stated in brackets is the mean total biomass without mussel biomass.

<table>
<thead>
<tr>
<th>Community</th>
<th>Area (ha)</th>
<th>Depth zone</th>
<th>Total species number</th>
<th>Mean total biomass (g/m²)</th>
<th>Key features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arctica</td>
<td>112,239</td>
<td>Deep</td>
<td>261</td>
<td>47</td>
<td>Infauna – muddy sediments</td>
</tr>
<tr>
<td>Bathyporeia</td>
<td>15,635</td>
<td>Shallow</td>
<td>61</td>
<td>1</td>
<td>Infauna – exposed sand</td>
</tr>
<tr>
<td>Cerastoderma</td>
<td>11,171</td>
<td>Shallow</td>
<td>87</td>
<td>32</td>
<td>Infauna – sheltered immobile soft bottom</td>
</tr>
<tr>
<td>Corbula</td>
<td>13,246</td>
<td>Deep</td>
<td>180</td>
<td>12</td>
<td>In-/epifauna – transitional along pycnocline</td>
</tr>
<tr>
<td>Dendrodoa</td>
<td>21,251</td>
<td>Deep</td>
<td>271</td>
<td>46</td>
<td>Epifauna – hard substrate/algae</td>
</tr>
<tr>
<td>Gammarus</td>
<td>74,243</td>
<td>Shallow/deep</td>
<td>196</td>
<td>7</td>
<td>Epifauna – hard substrate/algae</td>
</tr>
<tr>
<td>Mytilus</td>
<td>30,935</td>
<td>Shallow/deep</td>
<td>152</td>
<td>100 (8)</td>
<td>Epifauna – hard substrate</td>
</tr>
<tr>
<td>Rissoa</td>
<td>11,635</td>
<td>Shallow</td>
<td>42</td>
<td>6</td>
<td>Epifauna – eelgrass</td>
</tr>
<tr>
<td>Tanaissus</td>
<td>2,333</td>
<td>Deep</td>
<td>182</td>
<td>20</td>
<td>Infauna – exposed sand and gravel</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>292,688</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In terms of area the Arctica community is by far the most important, and in terms of species richness and biomass the Arctica community is the second most important in the Fehmarnbelt. The community occurs in muddy and sandy-muddy sediments in waters deeper than 25 m. The community features the second largest number of species after the Dendrodoa community, with a very clear decreasing trend in species richness from west to east.

The Bathyporeia infauna community occurs in exposed shallow (< 5 m) sandy areas, where mobile sands are exposed to wave action and the dynamics of the sand motion only allows deeply burrowing species such as the soft-shell clam *Mya arenaria* or fast-burrowing species such as the amphipod *Bathyporeia* to inhabit the environment. In the greater Fehmarnbelt the community is found south-east of the Rodsand Lagoon, at the north coast of Fehmarn and along the Flügge Sand spit off the Orth Bight. Overall, the community has low species richness and very low biomass underlining that mobile sand is a harsh environment.
The Cerastoderma infauna community is found predominantly in shallow waters above the seasonal separation between the brackish surface water and the more salty bottom water (the halocline). The Cerastoderma community is associated with soft bottom that is muddy to sandy. In the investigation area the community was mainly found in the eastern part of the Rødsand lagoon, off the north coast of Fehmarn, and on the Flügge Sand area off the south-western coast of Fehmarn. The community is rather species poor but with a high biomass (Mytilus excluded) dominated by the filter-feeding bivalves Cerastoderma and Mya, and Macoma.

The Corbula community constitutes a transition community between shallow and deep water communities in waters of 10–20 m depth. The typical sediments are mixed and consist of sand, muddy sand, coarse sand, boulders and small mussel beds. The Corbula community is localised as two relatively narrow ribbons off the coast of both Fehmarn and Lolland and smaller areas in the Langeland Belt, offshore Lolland and southwest of Fehmarn. The biomass is dominated by several polychaetes and a few bivalves including and Arctica islandica. Corbula gibba giving name to the community is less important in terms of biomass.

The Dendrodoa epifauna community is characterised by hard substrate (sandy, partially coarse sediments, sometimes accompanied by boulders) in deeper waters.
The community is named after the ascidian (sea squirt) *Dendrodoa grossularia* that lives as a filter-feeder attached to hard substrate. The Dendrodoa community is localised at the edges of the basin of the Kiel Bight offshore Fehmarn and Lolland. The Dendrodoa community has the highest species richness and high biomass due to many epibenthic species growing on the three dimensional habitat.

The Gammarus epifauna community covers large areas in shallow waters where the seabed is dominated by benthic vegetation and areas with *Mytilus* assemblages. This habitat provides a three dimensional habitat and feeding environment for epifauna. Species richness is high and third largest among the nine communities. Excluding blue mussels, the biomass is low and is dominated by amphipods, isopods and gastropods. The species composition shows large overlap with the *Mytilus* community.

The *Mytilus* epifauna community is characterized by the occurrence of aggregations of the blue mussel *Mytilus edulis* together with an associated fauna. It is mainly found off the coast of Lolland where it occurs in water depths down to approximately 10 m. Around Fehmarn the most important areas are off Staberhuk and at the west coast. Mussels occur all over Fehmarnbelt and often dominate in terms of biomass, but to ‘qualify’ as a community *Mytilus edulis* should be the dominant species forming also the spatial structure of the habitat to a degree that enables the associated fauna to develop. The associated fauna consists of species that utilize the hard substrate as settling and feeding ground (e.g. *Gammarus* spp., *Balanus* spp., *Corophium insidiosum*, *Littorina* spp.). Other species benefit from the presence of the mussels but are not dependent on it, like deposit feeders which live on detritus and other remains of the *Mytilus* community (e.g. the polychaetes *Heteromastus filiformis*, *Marenzelleria viridis*, *Polydora cornuta*).

The Rissoa community is a shallow water epifauna community that is associated with eelgrass meadows (*Zostera marina*). The community has its largest extent in the western part of the Rødsand lagoon and in the Orth Bight, where dense eelgrass meadows occur. The community has the lowest species richness of the nine communities and is also characterised by a low biomass of invertebrates. The snail genus *Rissoa* belongs to the family Rissoidae which contains a number of snails represented in the community: *Pusillina sarsi*, *Rissoa membra-nacae*, *Rissoa parva*, and *Rissoa violacea*. These snails typically sit on the leaves of eelgrass and feed on microalgae.

The Tanaissus infauna community named after the crustacean *Tanaissus lilljeborgi* has the least extent in the Fehmarnbelt. Habitats are characterised by sandy, partially coarse sediments in waters of around 15–22 m depth. The community features a moderate number of species that are most often present and a large proportion of infrequent species. Biomass is dominated by few filter feeding species and several large predators.
5.8.3 Methodology

The impact on the benthic fauna for the bored tunnel from the pressures footprint, suspended sediment concentration and sedimentation have been assessed.

The impact of suspended sediment is described by comparing the suspended sediment concentration with a set threshold value above which the benthic fauna is impacted. The impact of sedimentation is assessed by evaluating the thickness of the sediment layer and the duration of the sedimentation (the magnitude of pressure) and relating it to the same data as for the immersed tunnel. New calculations are made for the impact of footprints and additional solid substrate.

An exception to the general assessment scheme is the result for the pressure suspended sediments on the mussel population (*Mytilus edulis*). Impacts on the mussel population from the bored tunnel construction works are evaluated based on the predicted reduction in phytoplankton biomass (chlorophyll \( a \)) due to shading from spilled sediments and the relation between reduction in chlorophyll \( a \) and mussel biomass.

5.8.4 Impacts of suspended sediments

Magnitude of pressure

In connection with the assessment of the main alternatives for the fixed link, a set of suspended sediment threshold values for the benthic fauna was determined. The values are based on expert judgement (e.g. tunicates being more sensitive than bivalves), existing literature (e.g. Cranford and Gordon 1992, Hygum 1993, Last et al. 2011, Kiørboe and Møhlenberg 1981) and the sediment spill scenario data:

- At suspended sediment concentrations below 10 mg/l impacts will be negligible because 10 mg/l is the naturally occurring concentration and even the most sensitive organisms (tunicates) do not respond negatively.

- Irrespective of suspended sediment concentrations, continuous exposures lasting less than a week will not affect benthic invertebrates because mortality is very unlikely (all species can survive a week without food) and instant mortality has not been reported (Essink 1989, Lisbjerg et al. 2002). Growth rates of individuals may be affected, but as suspension feeders generally have a high growth rate, biomass will be restored quickly after the exposure to suspended sediments has stopped.

- An exposure to suspended sediments lasting between a week and a month leads to medium to very high impacts when the concentration is above 100 mg/l depending on duration (Purchon 1997). Physiological studies have shown a reduction in growth rates due to starvation and expenditures related to cleaning of filtering apparatus (Navarro and Widdows 1997, Velasco and Navarro 2002). Mortality is not expected at this level.
Model results of the suspended sediments for the bored tunnel alternative show that the magnitude of pressure is below the set threshold values (10 mg/l) (FEHY 2012h), and thus lies within the range of natural variability.

In the assessment of the impacts on the blue mussel population for the immersed tunnel alternative and the cable stayed bridge alternative, numerical modelling was used to quantify changes in biomass of blue mussels that occurs in dense populations along the Lolland coast and around Fehmarn (Figure 5.84). These changes (compared to baseline) were linearly related to the predicted change (compared to baseline) in concentration of phytoplankton which constitutes the main food for mussels (Figure 5.85).

Predicted reductions in chlorophyll $a$ (average for 1 March – 30 November 2015) varied between -0.006 to -0.012 mg/m$^3$ along the transect which is about three times lower than the reduction predicted for the immersed tunnel, and about two times larger than the reduction predicted for the cable stayed bridge (Figure 5.85). Using the relation between chlorophyll and mussel biomass reductions, an average reduction of -0.5 g mussel biomass (ash free dry weight) per m$^2$ can be expected for the bored tunnel alternative.

![Figure 5.84](image-url) Close view of modelled biomass of mussels under baseline conditions. Modelled concentrations (1 March – 30 November 2015) of chlorophyll $a$ was extracted at 25 positions along transect for the immersed tunnel, cable stayed bridge and bored tunnel solutions.
Figure 5.85  Relation between reduction (compared to baseline) in chlorophyll a (average over 1 March – 30 November 2015) and reduction in mussel biomass (30 November 2015) along transect depicted for the immersed tunnel solution (♦ average for 3-4 stations) and the cable stayed Figure 5.84 bridge (△ average for entire transect). Error bars show ± SD for reductions in chlorophyll a and mussel biomass. Range in predicted chlorophyll a reductions (2015) along transect for the bored tunnel solution is indicated by the curly bracket.

Significance of impact
Since the magnitude of pressure is below the set threshold values and within the range of natural variability, the impact on the benthic fauna communities for the pressure suspended sediments will be insignificant.

The impacts on mussel population related to dredging works were evaluated as insignificant for the immersed tunnel solution (FEMA 2012c). Since the predicted impact on mussels from the bored tunnel solution will be typically three times lower than predicted impact for the immersed tunnel, the impact will also be insignificant.

5.8.5 Impacts of sedimentation

Magnitude of pressure
The sediment spill scenario data forms the basis for estimating the magnitude of pressure for the sedimentation. The magnitude of pressure used here is defined as the “largest incidental net deposition that remains in place for a given time”. Thus, the magnitude of pressure is dependent on two parameters: the thickness of the sediment layer and the time it remains in place. The magnitude of pressure is
graded into four categories based on available literature (Figure 5.86) and Table 5.50.

Only sedimentation of 3 mm and above is considered, regardless of the time it remains in place and the corresponding sedimentation rate (Miller et al. 2002, Gibbs and Hewitt 2004).

**Figure 5.86** Magnitude of pressure of the pressure sedimentation with duration along the horizontal axis and intensity along the vertical axis. The minimum intensity is 3 mm as the lowest level of excess sedimentation with documented negative effect on viability of marine benthic fauna. The minimum duration is 2 hours, which is the minimum time-step of the output data from the sediment spill modelling. The intensity-duration envelopes for the four categories minor (Mi), medium (Me), high (Hi) and very high (VH) are given in different colours. Numbers refer to references used (please see details in FEMA 2011c).

**Table 5.50** Criteria for the assessment of pressures

<table>
<thead>
<tr>
<th>Phase</th>
<th>Pressure</th>
<th>Possible impact</th>
<th>Magnitude of pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>Suspended sediments</td>
<td>Very high change of viability and food availability, high mortality</td>
<td>Very high</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High change of viability and food availability, low mortality</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minor to medium change of viability and food availability</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minor change of viability and food availability</td>
<td>Minor</td>
</tr>
<tr>
<td>Construction</td>
<td>Sedimentation</td>
<td>Very high change of viability and food availability, high mortality</td>
<td>Very high</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High change of viability and food availability, low mortality</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minor to medium change of viability and food availability</td>
<td>Medium</td>
</tr>
</tbody>
</table>
**Figure 5.87** illustrates the estimated magnitude of pressure of sedimentation for the whole assessment area for the entire period of bored tunnel construction (2015 and 2020).

A total of 1,369 ha are impacted by sedimentation. No impact in the central part of Fehmarnbelt has been predicted. A magnitude of pressure in the minor and medium category is expected along the coast of Fehmarn, Lolland, in Rødsand Lagoon and small areas in the coastal areas north of Fehmarn. High (19 ha) and very high (38 ha) magnitude of pressure occurs around the reclamation areas, working harbours and access channels at the Lolland and Fehmarn side.

The extent of the pressure from sedimentation for the immersed tunnel (Figure 5.88) is much higher than for the bored tunnel alternative (Figure 5.87). For the immersed tunnel only minor-high magnitude of pressure is predicted.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Pressure</th>
<th>Possible impact</th>
<th>Magnitude of pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minor change of viability and food availability</td>
<td>Minor</td>
</tr>
<tr>
<td>Structure</td>
<td>Footprint</td>
<td>Habitat loss. The criteria correspond to the importance of the communities</td>
<td>Very high</td>
</tr>
<tr>
<td>Structure</td>
<td>Solid substrate</td>
<td>Case-specific criteria based on - the amount on existing solid substrate in a specific distance from the structure - water depth - local change of currents suitability of the solid substrate - potential for non-indigenous species</td>
<td>Case-specific</td>
</tr>
</tbody>
</table>
Figure 5.87  The estimated magnitude of pressure for sedimentation for the entire dredging period during bored tunnel construction.

Figure 5.88  For comparison: The estimated magnitude of pressure for sedimentation for the entire dredging period during immersed tunnel construction.
Significance of impact

Effects of sedimentation and subsequent recovery of benthic communities will vary depending on sedimentation rates, depth of deposition, previous life history of the community and structure of the habitat. The possible impacts of sedimentation on benthic fauna range from a decrease in the viability of species to lethal events that destroy the benthic communities.

The impacts from the bored tunnel alternative are very small compared to the impacts from the immersed tunnel, and the impact from the immersed was not assessed as significant.

The impacted area corresponds to 0.5% of the assessment area (292,688 ha for the fauna). Three fauna communities are partially lost due to very high magnitude of pressure (Cerastoderma, Gammarus and Mytilus communities). The total loss of these communities in the local zone corresponds to less than 1% of the communities, which is regarded as insignificant.

The extent of the impacted areas for the bored tunnel alternative is much smaller than for the immersed tunnel. Even though 55 ha of the benthic fauna communities are lost due to very high magnitude of pressure, the impact on the affected communities is small. Because the impact area is less than 1% of the assessment area, and because there was no significant impact for the immersed tunnel alternative, the impact for the bored tunnel is regarded as insignificant.

5.8.6 Impact of project footprint

Magnitude of impact

The pressure footprint is defined as areas that will be lost due to constructions like reclamation areas, access channel or work harbours. Footprint can be either structure-related or construction-related. The impact of footprint on the benthic fauna communities is habitat loss.

In total, 424 ha of footprint are used for the bored tunnel alternative, divided into the different types of footprint (Table 5.51). Table 5.52 lists the spatial distribution of the total footprint area into the different types. The magnitude of pressure for footprint compared to the immersed tunnel is different in the coastal areas and a full assessment is hence made for this pressure.

Most of the footprint is from the reclamation areas, where the reclamation area on Lolland is larger than the one on Fehmarn (Figure 5.89 and Figure 5.90).
Table 5.51  Tunnel footprint structures and corresponding footprint type and duration of the impact

<table>
<thead>
<tr>
<th>Tunnel footprint structure</th>
<th>Type</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reclamation areas at Lolland and Fehmarn</td>
<td>Structure-related</td>
<td>Permanent</td>
</tr>
<tr>
<td>Access channel to Lolland and Fehmarn work harbour</td>
<td>Construction-related</td>
<td>Temporary</td>
</tr>
<tr>
<td>Work harbours at Lolland and Fehmarn</td>
<td>Construction-related</td>
<td>Temporary</td>
</tr>
</tbody>
</table>

Table 5.52  Tunnel footprint types and their size (ha) in the different geographical regions

<table>
<thead>
<tr>
<th>Type</th>
<th>Structure</th>
<th>Footprint area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Structure-related</td>
<td>Reclamation areas</td>
<td>353</td>
</tr>
<tr>
<td>Construction-related</td>
<td>Access channels</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Work harbours</td>
<td>52</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>441</td>
</tr>
</tbody>
</table>

Severity of loss
The footprint assessment for the bored tunnel is made by intersecting the importance of the benthic fauna communities (FEMA 2011e) with the footprint. The level of importance (minor, medium, high, very high) of the benthic fauna that is present in the different regions of the footprint is identical to the severity of loss, see (FEMA 2011e).

All 441 ha of footprint are inhabited by benthic fauna communities. The severity of loss is shown in Figure 5.89 and Figure 5.90. Loss of high severity occurs in the Mytilus community (see also Table 5.53). It is mainly due to the reclamation area at Lolland (176 ha) and the access channel to the work harbour at Lolland (30 ha). Medium severity of loss occurs mainly in the Cerastoderma and Gammarus communities. The main area in this category is due to the reclamation area at Lolland (51 ha) and Fehmarn (13 ha), followed by the access channel and work harbour at Fehmarn (30 ha). Minor severity of loss occurs in the Bathyporeia community mainly due to the reclamation areas at Lolland (103 ha) and Fehmarn (10 ha).
Table 5.53  Severity of loss of the bored tunnel alternative for the pressure footprint

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Footprint</th>
<th>Severity of loss – area lost (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Footprint type</td>
<td>Total</td>
</tr>
<tr>
<td>Very high</td>
<td>Construction Structure</td>
<td>57</td>
</tr>
<tr>
<td>High</td>
<td>Construction Structure</td>
<td>30</td>
</tr>
<tr>
<td>Medium</td>
<td>Construction Structure</td>
<td>1</td>
</tr>
<tr>
<td>Minor</td>
<td>Construction Structure</td>
<td>88</td>
</tr>
</tbody>
</table>

Figure 5.89  Severity of loss (purple) of the bored tunnel alternative at Fehmarn for the pressure footprint.
Figure 5.90  Severity of loss (purple) of the bored tunnel alternative at Lolland for the pressure footprint

Significance of impact

Four communities are affected by the footprint. These are:

› 216 ha in the Mytilus community (high severity)
› 115 ha in the Bathyporeia community (minor severity)
› 57 ha in the Gammarus community (medium severity)
› 37 ha in the Cerastoderma community (medium severity)

The 216 ha of Mytilus community are lost at Lolland due to the reclamation area (176 ha), the access channel (30 ha) and the working harbour (10 ha). This corresponds to 3.5% of the Mytilus community in the local zone (10 km on either side of the alignment). The community cannot recover in the major part, because the reclamation area is part of the project structure. Recovery is possible for 40 ha (access channel and work harbour) within 5–10 years after construction, because the recovery time of Mytilus is estimated to be 5-10 years and the recovery of seabed morphology and substrates in the access channels and work harbours are 5-10 years. On the scale of the whole EIA assessment area, the impact is equivalent to 0.7% of the areas occupied by the Mytilus community. In terms of the ecological relevance, the impact is thus not significant, because no permanent effect for the community as a whole is expected. Also, the reclamation areas themselves will generate solid substrate and thus be new settling grounds for the species of the Mytilus community.
The loss of 115 ha of the Bathyporeia community corresponds to 8.9% of the Bathyporeia community in the local zone and is divided into the reclamation areas (113 ha) and the work harbour at Fehmarn (2 ha). Thus, the community cannot recover in the major part of the affected area. This loss is equivalent to 0.7% of the Bathyporeia community in the whole assessment area. Due to this minor loss on the assessment area scale and the fact that the severity is also minor (minor importance of the Bathyporeia community), the impact is also considered not significant.

The major part (51 ha) of the 57 ha impacted Gammarus community is due to the reclamation area at Lolland and cannot recover since it is part of the project structure. The remaining 6 ha are part of the work harbour and will recover within the time for the work harbour recovery (see below). The area of 57 ha corresponds to 1.0% of the Gammarus community area in the local zone. However, the ecological relevance on the scale of the whole assessment area is minor, since the impacted area is 0.1% of the total community area. Thus, the impact on the Gammarus community is regarded as insignificant.

An area of 37 ha of Cerastoderma community are impacted due to the reclamation area (13 ha) and the work harbour (24 ha). All these areas are located at Fehmarn. In total, this corresponds to 2.2% of the community area in the local zone. For 24 ha (work harbour), the seabed can recover within < 5 years and with a community recovery time of 2–5 years it is possible that recovery takes place within the construction phase + 2 years. The ecological relevance within the complete assessment area is minor, since the 37 ha Cerastoderma community correspond to 0.3% of the total community area. Thus, the impact on the community is regarded as insignificant.

In summary, no significant impacts are expected due to the footprint of the bored tunnel alternative.

### 5.8.7 Impacts of solid substrate

**Magnitude of impact**

Solid substrate is defined as all structure-related solid or hard structures (embankments) located underwater and available as potential settling ground for marine organisms. The areas of additional solid substrate have been calculated based on technical drawings provided by Femern A/S.

The magnitude of the pressure is determined by the area of the additional solid substrate. This is given per assessment zone and per community where the additional solid substrate is introduced. Since sensitivity cannot be applied in this case, the impact can only be quantified from the amount of the solid substrate as the magnitude of pressure as listed in Table 5.54. The magnitude of pressure from added substrate from the embankments from the immersed tunnel is approximately the same as for the bored tunnel (Fehmarn: 1 ha and Lolland 10 ha). The conclusion on the degree of impairment and the significance is hence the same as for the immersed tunnel.
Table 5.54  
Estimated areas (ha) of additional solid substrate for the bored tunnel alternative divided into the zones where the substrate is introduced

<table>
<thead>
<tr>
<th>Solid substrate</th>
<th>Total</th>
<th>DK</th>
<th>DE national</th>
<th>DE EEZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embankment Fehmarn</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Embankment Lolland</td>
<td>9</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>9</strong></td>
<td><strong>1</strong></td>
<td><strong>0</strong></td>
</tr>
</tbody>
</table>

The impact on the German side primarily is on the Cerastoderma and the Bathyporeia communities and on the Danish side the Mytilus community.

**Significance of impact**

In relation to the predicted community area both in the local zone and the assessment area, the introduced solid substrate is very limited and never reaches a significant amount in the affected three fauna communities. Thus, as for the immersed tunnel alternative a potential effect of the solid substrate is insignificant for the bored tunnel.

**5.8.8 Significance of impacts - summary**

The overall conclusion on the assessment of the environmental impacts from the bored tunnel alternative on the benthic fauna is that impacts will be insignificant. The primary impact is caused by the pressure footprint where 425 ha of communities will be lost. Furthermore, 55 ha of fauna will be lost due to very high magnitude of pressure from sedimentation. Compared to the distribution of communities the impact is low and will not have an impact on the biomass and distribution of communities.

**5.8.9 Mitigation and compensation**

Mitigation and compensation of benthic fauna is not necessary for the bored tunnel alternative since none of the pressures will cause significant loss or impairment of the benthic fauna communities or of the marine ecosystem in the area.

**5.8.10 Decommissioning**

It is assumed that the bored tunnel alternative will be decommissioned in the same way as the immersed tunnel alternative. The assessment conclusions are therefore similar: There will be no impact on the benthic fauna.
5.9 Fish ecology

This section describes the existing situation for fish in Fehmarnbelt and the potential impacts of the bored tunnel project on spawning, growth and disturbance.

Fehmarnbelt plays a key role in the water exchange system of the Baltic Sea, and the belt is an important passageway for migrating cod, herring and silver eel, as well as a spawning area for a number of fish species, including cod and flatfish species. Several key species were identified in the baseline studies as key species for the present assessment: Eastern and Western Baltic cod (*Gadus morhua*), Western Baltic herring (*Clupea harengus*), European eel (*Anguilla anguilla*), sprat (*Sprattus sprattus*), flatfish and shallow water species. For each species the level of importance of spawning, eggs and larvae, nursery, feeding and migration were assessed.

Fish come under the environmental factor “fauna” and the sub-factor marine fauna. The sub-components which have been chosen to represent the fish communities in Fehmarnbelt are shown in Table 5.34.

<table>
<thead>
<tr>
<th>Table 5.55 Fish in Fehmarnbelt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factor</strong></td>
</tr>
<tr>
<td>Fauna</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
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</tbody>
</table>

5.9.1 Project pressures and potential impacts

The environmental pressures that may affect fish species and fish communities are caused by specific activities during construction and operation and by physical structures. Levels of impact can be assessed according to e.g. species or community vulnerability, permanent or temporary environmental pressures, spatial coverage and the ability of species or communities to recover.

Short term direct or indirect pressures during construction are mainly related to dredging activities. Dredging directly affects the seabed and hence habitats for spawning, nursery or feeding for different fish species and fish communities.

Spill and spreading of marine sediments from dredging will affect water quality by increasing the concentration of suspended sediment followed by an increased sedimentation. Both increased suspended sediment and increased sedimentation can potentially affect pelagic and demersal fish communities, fish migration and suitable habitats for fish communities. Most fish species are generally more vulnerable to environmental pressures in their early life stages than as adults. Fish eggs and fish larvae are highly sensitive to increased
concentrations of suspended sediment which decreases the buoyancy of eggs and affects the feeding of fish larvae.

Physical structures and associated facilities induce permanent pressure and loss of seabed and hence habitats for various fish communities. The physical structures may change the hydrographic regime potentially affecting the distribution of fish eggs and fish larvae.

Emission of noise, vibration and light from construction activities may have short term affects on fish species and fish communities. This might cause a barrier effect on fish migrating from and to spawning or feeding areas/grounds avoiding areas with such disturbances. Cod, herring and the European eel are the most important migratory species in the Fehmarnbelt and they are known to migrate over large distances to feed or spawn.

Three pressures are not studied further due to the conclusions reached in previous sections in this chapter or other reasons. The release of toxic substances from sediment will not present any danger at all for marine organisms and electromagnetic fields from the tunnels in the operation phase are not found to be a significant pressure. Light is also found to be an insignificant pressure.

5.9.2 Existing fish ecology in Fehmarnbelt

Detailed baseline surveys were carried out in 2009/2010 to prepare inventories of the present fish ecology in Fehmarnbelt. The objectives of the inventories can be summarized as:

› To describe the fish habitats and fish communities in Fehmarnbelt and adjacent waters.
› To describe the development of life stages from egg to larvae, and the dynamics and transport in time and space of eggs and larvae of commercially important fish stocks
› To identify potential spawning grounds in Fehmarnbelt.
› To evaluate the significance of Fehmarnbelt as a migratory route and to investigate the behaviour and preferred migration routes for the important migrating species European eel, herring, cod and sprat.
› To describe the distribution of spring and autumn spawning herring in potential spawning grounds in Fehmarnbelt.
› To describe the importance of Fehmarnbelt for protected fish species.

The surveys included:

› A programme designed to catch fish eggs and larvae. This was performed with a bongonet along a 20 km coastline of Lolland including Rødsand and along the northern and eastern coastline of Fehmarn as far south as Mecklenburger Bight. The sampling was performed in all seasons to cover the spawning seasons of almost all fish species in the area.
Herring gill net surveys and video screenings of the sea bottom for herring eggs along the German and Danish coast in the autumn of 2008 and 2009, and spring 2009.

Investigations of fish communities in specific habitats based on monthly sampling from May 2009 to April 2010 with multi-mesh gill nets in Danish and German coastal waters, and trawl surveys in the deeper parts of Fehmarnbelt. The investigations of nursery areas in specific habitats were based on sampling by fyke nets and beach seine nets in the coastal waters of Fehmarn and Lolland. Furthermore the YOY-trawl was used in the shallow sandy areas in Rødsand and west of Rødbyhavn.

Hydro-acoustic surveys were performed from April 2009 to July 2010. The equipment consisted of two Simrad echo sounders, an EK60 mounted with a split beam echo sounder (120 kHz) and an ES60 system mounted with a single beam dual frequency transducer (38/200 kHz).

Tagging experiments on migrating silver eel were performed with both intelligent tags (DST) (logging depth, temperature and time), and T-bar tags. The surveys included tagging and release of eel captured in pound nets from the coastal areas of Lolland and Fehmarn in late autumn 2009, and the release of eel in the Arkona Basin in October 2010.

A small scale tagging experiment on spawning cod caught by local fishermen on the spawning grounds in the western part of Fehmarnbelt during spring 2010. The cods were tagged with T-bars or DSTs.

The essential results of the baseline surveys are illustrated in Figure 5.91 and described below. The existing situation is described in detail in FeBEC (2012a).

Cod

The deeper part of Fehmarnbelt is an important spawning area for the West Baltic cod stock, and the migration to and from the spawning areas as well as the drift of the eggs and larvae are of high importance. The belt is also a valuable cod feeding area particularly for juveniles feeding in the vegetated areas along the coasts of both Fehmarn and Lolland.

Whiting

Whiting do not spawn east of Skagerrak, but juvenile whiting move into waters all over in the Baltic, including the Baltic proper. In Fehmarnbelt whiting are particularly numerous in January and February, where the belt acts as a passageway for the mature whiting coming from the Baltic proper on their way back to spawn in Skagerrak and the North Sea. This migration is rated as being of medium importance.
Herring
Fehmarnbelt has little importance as a spawning, nursery and feeding area for the various herring stocks in the Western Baltic, but has high importance as a migration corridor particularly for spring-spawning herring. This includes the important Rügen herring stock, although Rügen herring to a greater extent uses the Sound as passageway to and from feeding areas in the Kattegat, Skagerrak and eastern North Sea.

Sprat
Fehmarnbelt functions as a spawning area for the ecologically important sprat and the drift of eggs and larvae of this pelagic species is of medium importance. The belt is however not particularly important as a nursery and foraging area for sprat.

Flatfish
Fehmarnbelt houses a number of flatfish species, of which especially dab, flounder, plaice and turbot constitutes a significant proportion of fish fauna in the area. The
belt is assessed to be of medium importance for flatfish as a spawning, nursery and feeding area.

Eel
Fehmarnbelt is one of the few corridors between the Baltic Sea and the Atlantic Ocean. Therefore a free passageway is of very high importance for arriving eel larvae and elvers and for migrating silver eels going back to the Sargasso Sea. However, the function of the belt as nursery and feeding area for yellow eel is of limited significance.

Shallow water fish community
A number of resident fish species occurs abundantly in the coastal areas of Fehmarnbelt, where they locally play an important ecological role as food source for several key fish species and for birds and marine mammals in the area. This comprises species such as sand eels, sculpins, gobies and eelpout on the exposed coasts, while sticklebacks and pipefish in addition to gobies dominate in more protected areas, such as in Rødsand Lagoon.

Protected species
Endangered species are per definition of very high importance if they are protected by international conventions. In addition to European eel, river lamprey was caught by local fishermen during the baseline study period. In recent years twait shad has also been registered a few times by local fishermen.

Redlisted species
Red listed species are per definition of high importance. In total, nine red listed species (according to the German and Danish Red lists) were recorded during the baseline studies. These were snakeblenny, sea stickleback, corkwing wrasse, ballan wrasse, sea trout, Atlantic salmon, greater weever, European eel and painted goby. In addition, autumn spawning herring is listed as critically endangered on the German red list. The majority of the listed species occurred in very low numbers. However, the seastickleback in particular, was frequently abundant in the autumn. Other species like corkwing wrasse, ballan wrasse and greater weever showed a significant seasonal distribution.

The baseline description also addressed the mapping of fish communities in important habitats in the coastal and open areas of the Fehmarnbelt. In total 57 different fish species were registered during the mapping of fish communities in the area. The coast along Fehmarn had 43 species and was the most species-diverse area, compared to the 37 species registered along the coast of Lolland. The lowest number of species was found in the deeper areas of Fehmarnbelt where 35 species were registered. Ten of these species were only registered in the deeper parts of Fehmarnbelt.

In general, the western and north-western sandy habitats off the coast of Fehmarn are dominated by flatfish species such as dab and flounder. In addition, the highest abundance of hooknose and whiting are found in these habitats. The highly structured habitats with vegetation, stones and boulders along the eastern and south-eastern coast of Fehmarn are dominated by cod, whereas almost no flatfish
species, except flounder, are present within these habitat types. Beside cod, species like sea stickleback, wrasses (mainly goldsinny wrasse) and gobies are also characteristic for these habitats.

Cod is the most numerous species along the coast of Lolland in habitats with vegetation, stones and mussels, while dab and whiting are more frequent in sandy habitats. In the lagoon of Rødsand, the extensive eelgrass habitat is home to small fish species like three- and nine-spined stickleback, eelpout and several species of gobies.

The pelagic fish community of Fehmarnbelt is in general dominated by sprat, herring, whiting and cod. Considerable seasonal variability in abundance and species composition occurs, and from time to time pelagic species like garfish (*Belone belone*) and Atlantic horse mackerel (*Trachurus trachurus*) are highly abundant. The density of pelagic fish in Fehmarnbelt is relatively low compared to other observations made in the region, including the Sound.

### 5.9.3 Methodology

The methodology used for the present assessment of impairment of the fish fauna has been based on a stepwise process including the following elements:

- Identification of environmental indicators and pressures.
- Defining sensitivity threshold values towards pressures.
- Quantifying magnitude of impact and the reduction of fish communities.

The last step is based on the modelling of the scenarios of specific pressures and the exceedance of the threshold values given in Table 5.56.

The identified pressures assessed are:

- Land reclamation
- Hydrographic regime
- Sediment spill
- Noise/vibration
- Indirect pressures caused by changes/impairments of fish habitats

For each of these specific pressures the construction and operation phases have been treated separately. The length of time that the temporary pressures exist is also a factor in determining the magnitude of impact.

The criteria used for determining the degree of impairment are given in Table 5.57. The criteria are based on the reduction of the environmental indicator relative to the level of the natural yearly variation. A short-term impairment less than the natural variation is assessed to be minor, while an impairment higher than the natural variation is assessed to be high (1-2 times the variation) or very high (> two times the variation). Thus, if sediment spill causes cod migration to decline one year by 10-20 %, this impairment is assessed to be medium, as the level for the natural variation is set to 20 %.
The method is described in detail in FeBEC 2011d.

**Table 5.56**  Threshold values used to assess the impact of hydrological parameters, sediment spill and noise and vibrations

<table>
<thead>
<tr>
<th>Environmental Component</th>
<th>Cod</th>
<th>Whiting</th>
<th>Herring</th>
<th>Sprat</th>
<th>Flatfish</th>
<th>Shallow water fish community</th>
<th>Eel</th>
<th>Legally Protected species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydrological parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Salinity, spawning, ‰</td>
<td>15</td>
<td>4</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity eggs, ‰</td>
<td>18.9</td>
<td>14</td>
<td>17.6-20.7</td>
<td></td>
<td></td>
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<td><strong>Sediment spill</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoidance reaction, mg/l</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>50</td>
<td>50</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>Silting of eggs, mm</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sinking of eggs, mg/l</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Noise and vibrations</strong></td>
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<td></td>
</tr>
<tr>
<td>Avoidance reaction 50%, dB</td>
<td>145</td>
<td>145</td>
<td>145</td>
<td>145</td>
<td>160</td>
<td>160</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>Avoidance reaction 100 %, dB</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Vibrations, m/s²</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

**Table 5.57**  Criteria used for determining the degree of impairment as a function of the reduction of the environmental indicator

<table>
<thead>
<tr>
<th>Species</th>
<th>Environmental indicator</th>
<th>Indicator reduction %</th>
<th>Degree of impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temporary</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>short-term</td>
<td>Temporary</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>long-term</td>
<td>Permanent</td>
</tr>
<tr>
<td>Cod, herring, silver eel, whiting, protected species</td>
<td>Migration</td>
<td>&gt; 40</td>
<td>&gt; 20</td>
</tr>
<tr>
<td></td>
<td>20 - 40</td>
<td>10 - 20</td>
<td>5 - 10</td>
</tr>
<tr>
<td></td>
<td>10 - 20</td>
<td>5 - 10</td>
<td>2 - 5</td>
</tr>
<tr>
<td></td>
<td>&lt; 10</td>
<td>&lt; 5</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>All species</td>
<td>Spawning, eggs and larvae, nursery and feeding</td>
<td>&gt; 60</td>
<td>&gt; 30</td>
</tr>
<tr>
<td></td>
<td>30 - 60</td>
<td>15 - 30</td>
<td>8 - 15</td>
</tr>
<tr>
<td></td>
<td>15 - 30</td>
<td>8 - 15</td>
<td>4 - 8</td>
</tr>
<tr>
<td></td>
<td>&lt; 15</td>
<td>&lt; 8</td>
<td>&lt; 4</td>
</tr>
</tbody>
</table>
5.9.4 Impacts during the construction phase

The construction of a bored tunnel may impact the fish communities and fish migration in Fehmarnbelt in various ways. Changes in the hydrological conditions, sediment spill and sedimentation, noise and vibration due to construction works and land reclamation could potentially impact the present fish fauna causing mortality or avoidance behaviour. The potential impact of the specific pressures and the sensitivity of the specific fish species are discussed in detail in FeBEC 2011b.

Hydrographic changes

The only physical structures which can affect the hydrography are the work harbours and the land reclamation areas. As shown in section 5.2 the impact on the hydrographic regime is negligible.

Seabed reclamation

Temporary seabed loss will occur in relation to the establishment of working harbours and breakwaters, while access channels and the reclamations on the coasts of Lolland and Fehmarn will result in permanent seabed loss. In all 10 ha of seabed is temporarily lost in Danish waters and 25 ha in German waters (Table 5.58).

<table>
<thead>
<tr>
<th>Footprint</th>
<th>Tunnel structures</th>
<th>Area loss (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary</td>
<td>Temporary working harbours and breakwater zones</td>
<td></td>
</tr>
<tr>
<td>(&lt; 8 years)</td>
<td></td>
<td>Danish waters 28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>German waters 25</td>
</tr>
</tbody>
</table>

The temporary loss of area due to working harbours and breakwaters will impact the habitats of shallow water fish communities, as well as the nursery areas of cod, flatfish and eel (Table 5.59). The impacted areas are related to the near zone which is the area between the present coastline and 500 m seawards of the reclamations, work harbours and access channels and the local zone which is 10 km on both sides of the middle of the alignment corridor (see Figure 5.18). The impacted areas are 2.5% of the Danish near zone and 19.0% of the German national near zone, and are thus very small compared to the extent of feeding areas and nursery areas for these species in the Fehmarnbelt area.

The seabed reclamation during the construction will exceed the temporary reclamation areas, as the filling of the permanent reclamation areas will occur during the construction period. The permanent seabed reclamation is dealt with separately.
Table 5.59  The degree of impairment of fish communities during construction (temporary) due to loss of seabed (%) for the near zone and the local zone

<table>
<thead>
<tr>
<th>Environmental sub-component</th>
<th>Degree of impairment due to temporary seabed loss during construction, bored tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DE 10 km Nat.</td>
</tr>
<tr>
<td>Cod</td>
<td>-</td>
</tr>
<tr>
<td>Whiting</td>
<td>-</td>
</tr>
<tr>
<td>Herring</td>
<td>-</td>
</tr>
<tr>
<td>Sprat</td>
<td>-</td>
</tr>
<tr>
<td>Flatfish</td>
<td>-</td>
</tr>
<tr>
<td>Shallow water species</td>
<td>-</td>
</tr>
<tr>
<td>Eel</td>
<td>-</td>
</tr>
<tr>
<td>Protected species</td>
<td>-</td>
</tr>
</tbody>
</table>

Sediment spill

During the construction of the bored tunnel sediment spill will occur in 2014 - 2015 and at the end of the construction after June 2020. The activities generating spill are the work harbours, containment dikes, reclamation and the landscaping of the reclamation areas.

Maximum spill is expected October-December 2014 due to intensive operations on containment dikes and work harbours with spill rates up to 14 kg/s while spillage during 2015 is not expected to exceed 5 kg/s (FEHY 2012h). For comparison the maximum spill rates for the immersed tunnel solution are expected to be 50 kg/s and during most of 2015 the rates exceed 30 kg/s.

The area impacted by sediment spill during the construction phase is illustrated in Figure 5.92. It is seen that, even during the most intensive dredging activity between November 2014 and March 2015, the suspended sediment concentrations only exceed 10 mg/l for 5-10% of the time in narrow areas close to the coast, mainly the Lolland coast and mainly within the near area zone around the reclamation area. With no exceedance of 10 mg/l more than 10% of the time as well as no exceedance of 2 mg/l more than 10% of the time the degree of impairment caused by suspended sediment is assessed as minor for all considered fish species.
In general, the background level of suspended sediment in Fehmarnbelt is much higher than the excess concentration from the bored tunnel solution or the immersed tunnel solution. Excess concentrations do not necessarily worsen impacts since impacts from suspended sediment on fish often are ruled by thresholds rather than increasing values.

The expected deposition is likewise much lower for the bored tunnel than the immersed tunnel. However, just outside the containment dikes and the working harbours in the near zone at Lolland the sedimentation caused by the dredging for the bored tunnel is expected to exceed the threshold value of 0.1 mm/d. In the worst case this might affect spawning areas for herring (14 ha), benthic spawning shallow water species (126 ha) as well as sea stickleback (39 ha). In no cases do the affected areas exceed 15% of the total spawning area of these species in the near zone. Thus, the degree of impairment from sedimentation directly affecting fish caused by the construction of a bored tunnel is assessed as minor for all considered fish species.

**Noise and vibration**

Noise and vibration at sea due to construction works would be restricted to noise from the increased shipping traffic and vibrations from the TBM action. The noise from the increased shipping traffic would most likely drown in the noise from the very frequent ferry departures. This issue is discussed in FeBEC (2012d).
The potential vibrations from the TBMss at the seabed have been analysed. When drilling occurs at a minimum depth of 16 m below the seabed, the vibration at the seabed for the worst case scenario of 50 Hz would be 0.01 m/s² (Hiller, 2011) which is the threshold value for avoidance behaviour by fish. For larger depths and lower frequencies the vibration level would be lower. This energy will only be partially transmitted into the water column, so the vibration experienced by fish will be comfortably less than 0.01 m/s².

Ramming of steel sheets and concrete piles in the construction area will produce severe noise. The production site requires harbour facilities for the delivery of materials which are transported by ship, and the required quay walls could be constructed using sheet piles installed from the sea side. At the time of writing there are no noise scenarios for this part of the construction of the bored tunnel. However, if the overall noise picture from pile driving activities does not exceed the worst case scenario for the immersed tunnel (FEMM 2011), impacts on fish will be restricted to areas less than 14 ha close to the ramming sites and the degree of impairment is expected to be minor.

No impacts from noise and vibration are thus expected during the construction phase.

Indirect pressures

The construction of a tunnel across Fehmarnbelt can affect the substrate, the zooplankton, the benthic flora and fauna (cf. previous sections) and subsequently the habitat suitability and food availability of the different fish species.

However, the conclusion on the assessment of the environmental impacts from the bored tunnel alternative on plankton is a degree of impairment close to zero, and on the benthic flora and fauna impacts are only expected to be significant due to lost areas. Impacts from other pressures are assessed as insignificant. Indirect pressures from the bored tunnel on the fish community are accordingly considered minor.

Other pressures

Other pressures related to the bored tunnel scenario are solely related to the construction phase. Neither artificial light, spill of hazardous materials or electromagnetic fields are believed to be of any significance to the fish populations.

5.9.5 Impacts during the operation phase

The operation of a bored tunnel will not impact the fish communities or the fish migration in Fehmarnbelt except for the impact due to seabed and fish habitats lost under the reclamations.

Reclamations

Seabed loss will occur in relation to access channels and permanent reclamation areas at the coast of Lolland and Fehmarn. In all 359 ha of seabed is permanently lost in Danish waters and 30 ha in German waters (Table 5.60).
Table 5.60 Permanent footprint areas planned for the bored tunnel

<table>
<thead>
<tr>
<th>Footprint</th>
<th>Tunnel structures</th>
<th>Area loss (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent (≥ 8 years)</td>
<td>Reclamation areas and access channels to work harbours</td>
<td>Danish waters 359, German waters 30</td>
</tr>
</tbody>
</table>

The permanent loss of areas due to seabed reclamation will impact the habitats of shallow water fish communities including the sea stickleback, as well as the nursery areas of cod, whiting, herring, sprat, flatfish and eel and potential spawning areas of herring (Table 5.61). In the German near zone 22.0% of the nursery areas for cod, flatfish, shallow water species and eel and 20.9% of the potential herring spawning areas are lost. In the Danish near zone 32.2% of the nursery areas for cod, flatfish, shallow water species and eel, 29.9% of the potential herring spawning area and 18.9% of the nursery area of whiting, herring and sprat are lost. Although the impact is substantial inside the near zone the impacted areas are small compared to the extent of the relevant spawning areas, feeding areas and nursery areas in the Fehmarnbelt area and the fish communities will not be affected.

Table 5.61 The degree of impairment of fish communities during operation (permanent) due to loss of seabed for the near zone and the local zone

<table>
<thead>
<tr>
<th>Environmental sub-component</th>
<th>Degree of impairment due to permanent seabed loss during operation, bored tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DE 10 km Nat.</td>
</tr>
<tr>
<td>Cod</td>
<td>-</td>
</tr>
<tr>
<td>Whiting</td>
<td>-</td>
</tr>
<tr>
<td>Herring</td>
<td>-</td>
</tr>
<tr>
<td>Sprat</td>
<td>-</td>
</tr>
<tr>
<td>Flatfish</td>
<td>-</td>
</tr>
<tr>
<td>Shallow water species</td>
<td>-</td>
</tr>
<tr>
<td>Eel</td>
<td>-</td>
</tr>
<tr>
<td>Protected species</td>
<td>-</td>
</tr>
</tbody>
</table>

5.9.6 Significance of impact – summary
The establishment and operation of a bored tunnel will only result in small impacts to the fish communities and fish migration in Fehmarnbelt. Although the loss of habitats due to the reclamations gives a medium to high degree of impairment in the near zone the extent of these areas are insignificant compared to the area of similar habitats in Fehmarnbelt and adjacent waters. Thus the impact of the bored
tunnel on the fish ecology during construction and operation is classified as insignificant.

5.9.7 Mitigation and compensation
Mitigation and compensation of fish fauna is not necessary for the bored tunnel alternative since none of the pressures will cause significant loss or impairment of the fish communities.

5.9.8 Decommissioning
Decommissioning of the bored tunnel will not involve any marine activities and therefore there will be no impacts on fish communities.
5.10 Marine mammals

This section describes the existing condition for marine mammals in Fehmarnbelt and the potential impacts of the bored tunnel project on their condition and population.

Three species of marine mammals occur regularly in the Fehmarnbelt area:

- The harbour porpoise, *Phocoena phocoena*, a small cetacean which is widely distributed in the western Baltic Sea and the North Sea
- The harbour seal, *Phoca vitulina*, with haul-out sites in the Rødsand lagoon where a substantial proportion of the small sub-population in the western Baltic Sea resides
- The grey seal, *Halichoerus grypus*, which occurs in low but growing numbers in Rødsand lagoon.

The Fehmarnbelt is believed to provide important habitats for these species (FEMM 2012a).

All three species are protected under various conventions and legislation. The harbour porpoise is listed in Annex IV of the Habitats Directive and is thus subject to an assessment of strictly protected species in relation to Article 12 of the directive.

Marine mammals appear under the environmental factor “fauna” and the sub-factor marine fauna. The three species are the sub-components as shown in Table 5.34.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sub-factor</th>
<th>Component</th>
<th>Sub-component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fauna</td>
<td>Marine fauna</td>
<td>Marine mammals</td>
<td>Harbour porpoise</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Harbour seal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Grey seal</td>
</tr>
</tbody>
</table>

5.10.1 Project pressures and potential impacts

The following pressure descriptions and the associated description of marine mammal sensitivity provide the foundation for this impact assessment. For a more detailed description please see Impact Assessment FEMM 2012b.

The three main pressures that have been identified from the construction and operation of the bored tunnel option are noise, habitat loss and habitat change. The pressures and potential impacts are shown in Table 5.63.
Table 5.63  Project pressures and potential impacts on marine mammals

<table>
<thead>
<tr>
<th>Project pressures</th>
<th>Potential impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise and vibrations:</td>
<td>Auditory injury. Avoidance of noisy areas.</td>
</tr>
<tr>
<td>› From dredging, backfilling and piling operations for construction of work harbours, access channels and land reclamations at Lolland and Fehmarn.</td>
<td></td>
</tr>
<tr>
<td>› From tunnel boring machines.</td>
<td></td>
</tr>
<tr>
<td>Habitat loss:</td>
<td>Displacement of animals to other areas and reduction of food resources thus reducing the local population</td>
</tr>
<tr>
<td>› Land reclamations</td>
<td></td>
</tr>
<tr>
<td>› Temporary work harbours</td>
<td></td>
</tr>
<tr>
<td>Habitat change:</td>
<td>Displacement of animals due to temporary habitat change and reduction of food resources thus reducing local population</td>
</tr>
<tr>
<td>› Due to sediment spill during dredging and backfilling for the temporary work harbours, access channels and land reclamation works.</td>
<td></td>
</tr>
</tbody>
</table>

A number of pressures have been screened out because of their low magnitude and the impacts are not assessed. These are:

› Possible noise emissions from the tunnel boring machines. Since the tunnel trench will be bored 15 m below the sea floor, no relevant noise emissions are predicted to travel into the water column.

› Possible impacts from the release of toxic substances from sediment spill during dredging since the concentrations are far below toxic levels (see section 5.3 on water quality above).

› For the bored tunnel there will be no barrier effect from construction vessels and construction works throughout the Fehmarnbelt (alignment area) since construction activities are concentrated on the working harbours close to the coastline.

› Possible habitat changes due to habitat structure change, sedimentation rate and hydrographic changes.

5.10.2 Existing populations of marine mammals in Fehmarnbelt

For the baseline study harbour porpoises were counted by aerial transect surveys between November 2008 and November 2010 at monthly intervals in a 4,800 km² study area (Figure 5.93). Surveys were conducted from 600 ft altitude for mammals only, and from 250 ft altitude for combined mammal and bird surveys. Densities were calculated by applying the Distance-Sampling methodology (Buckland et al., 2001). The results show a marked seasonal pattern with lowest numbers during the winter months and higher numbers from spring to autumn (Figure 5.94 and Figure 5.95). Highest densities in 2009 were recorded in April with 0.59 porpoises/km². In
2010, highest densities reached 0.94 porpoises/km² in May with densities in summer 2010 generally higher than in summer 2009.

Calf sightings made up 13.04% of all observed individuals (18 calves from 122 individuals) in 2009 but only 5.5% in 2010.

Figure 5.93  Aerial survey lines and locations of harbour porpoise sightings November 2008 – December 2009
Figure 5.94  Estimated density of harbour porpoise (individuals per km$^2$) for summer 2010

Figure 5.95  Estimated density of harbour porpoise (individuals per km$^2$) for winter 2010
Monthly visual surveys from the ferries operating between Rødbyhavn and Puttgarden provide evidence of year-round use of the alignment area by harbour porpoise with a higher sighting rate during spring and autumn.

Porpoise activity was also monitored using passive acoustic monitoring with autonomous porpoise click detectors (C-PODs). C-PODs were deployed at 27 locations in the wider Fehmarnbelt area in order to obtain high spatial and temporal resolution. An almost continuous presence of harbour porpoises in the Fehmarnbelt area was found over the whole study period (January 2009 – January 2011). A general west to east gradient with more recordings in the northwest and fewest recordings in the southeast is in line with former studies on the distribution of harbour porpoises in the western Baltic Sea.

Sandbanks and rocks in the Rødsand lagoon provide haul-out sites for both seal species which occur in high numbers in this area. Close to 200 harbour seals and a small but increasing number of grey seals are regularly observed in the lagoon. The Fehmarnbelt area forms the southern-most haul-out site for harbour seals in the Baltic Sea. Rødsand lagoon is home to about one third of the small sub-population of harbour seals in the Baltic Sea.

Seals were counted between January 2009 and September 2010 at the haul-out sites in Rødsand lagoon by aerial monthly surveys. Numbers obtained during the surveys were lower for harbour seals than those obtained during national surveys, but provided new maximum numbers for grey seals. Surveys indicate a seasonal pattern with highest numbers of seals hauled-out in summer and lower counts in spring and autumn. There was very limited survey coverage during the winter months. Grey seal counts reached a maximum of 57 animals in June 2010. The seasonal increase in seal numbers at haul-outs during summer coincides with pupping and moulting activity.

In October 2009 five harbour seals were tagged at Rødsand – four adult males and a juvenile female. All the recorded tracks are shown in Figure 5.96. The tracks from all four adult male harbour seals showed that the seals remained within 50 km of the two haul-out sites. The juvenile female harbour seal travelled much further. Overall the mean trip duration for the four adults was 66 hours (range 56 to 79 hours). Mean dive duration was 2.8 min (range 2.7 to 3.1 min). The overall mean maximum dive depth was 8.4 m (range 7.7 to 10.0 m). Feeding seals move slowly and dive regularly and there was a strong association of feeding behaviour with the substrate types ‘coarse sediment / boulders’ and ‘sand’.

In October 2009 two juvenile grey seals were tagged at Rødsand – one male and one female. Both individuals travelled over large distances and commuted between other haul-out areas in Denmark and Sweden. The analysis of seal movements in relation to environmental variables indicated that distance to haul-out, bottom current strength and surface temperature determined the feeding locations of the tagged seals.
5.10.3 Methodology

The sensitivity of marine mammals to noise is complex as it depends on a number of inter-related internal and external factors, e.g. effects change with varying sensitivities of individuals and effects at the population level are also possible. The sensitivity of marine mammals has been described according to available knowledge from literature. The defined assessment criteria for noise emissions refer to response types at different noise levels.

A standard assumption, unless evidence is provided for specific species, is that animal populations are likely to be limited by availability of suitable habitats so that any loss of habitat or reduction in habitat quality will lead to an equivalent reduction in the number of individuals living in this habitat. The sensitivity of marine mammals towards habitat loss or change is determined by a change in environmental key drivers which govern directly or indirectly the presence of the animals in a specific area. The presence is primarily driven by prey availability and distribution. Changes in important key drivers may lead to a negative impact on marine mammals.

The magnitude of impact describes a species response to the pressure, e.g. injury, behavioural change or mortality.

The degree of impairment or relative evaluation of the impact is assessed through the criteria and thresholds defined in Table 5.64.
### Table 5.64  Criteria for degree of impairment of marine mammals

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Impacts and Criteria</th>
<th>Duration</th>
<th>Range</th>
<th>Degree of Impairment</th>
</tr>
</thead>
</table>
| Noise and vibration (construction, impulsive sounds) | Porpoises: Received sound levels are high enough to cause injury or PTS, SEL exceeds 198 dB re1µPa²s (Southall et al., 2007)  
Seals: Received sound levels are high enough to cause injury or PTS, SEL 186 dB re 1 re1µPa²s (seals)) (Southall et al. 2007) | Temporary | Local | Very high |
| | Temporary | Local | High | (Very high)* |
| Noise and vibration (operational phase) | Sound levels are high enough to cause TTS, SEL exceeds 183 dB re1 µPa²s  
Seals: Received sound levels are high enough to cause TTS, SEL exceeds 171 dB re 1µPa²s (Southall et al. 2007)  
All species: Sound levels at 750 m distance to source exceed 160 dBSEL or 190 dBp* | Temporary | Regional | Medium |
| | Temporary | Regional | Minor |
| Noise and vibration (operational phase) | Sound levels are high enough that some minor behavioural reactions might be expected (received SEL exceeds 144 dB re 1µPa²s (porpoises and seals) (Brandt et al. 2011) | Temporary | Regional | Minor |
| Habitat change (construction activities) | Construction activity for the Fixed Link induces habitat changes that will lead to loss of habitat for a biologically important proportion of the Belt population of seals and | Permanent | Local | Very high |
Construction activity for the Fixed Link induces habitat changes that will lead to loss of habitat for a biologically important proportion of the Belt population of seals and porpoises

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Impacts and Criteria</th>
<th>Duration</th>
<th>Range</th>
<th>Degree of impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction activity for the Fixed Link induces habitat changes that will lead to</td>
<td>Temporary –</td>
<td>Local</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>loss of habitat for a biologically important proportion of the Belt population of</td>
<td>Long term</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>seals and porpoises</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction activity for the Fixed Link induces habitat changes that will lead to</td>
<td>Temporary –</td>
<td>Local</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>loss of habitat for a biologically important proportion of the Belt population of</td>
<td>Short term</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>seals and porpoises</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction activity for the Fixed Link induces habitat changes that will lead to</td>
<td>Temporary -</td>
<td>Local</td>
<td>Minor</td>
</tr>
<tr>
<td></td>
<td>loss of habitat for a biologically unimportant proportion of the Belt population of</td>
<td>Permanent</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>seals and porpoises</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The German Federal Agency of the Environment proposes a threshold value for offshore pile driving of 160 dBSEL or 190 dBpeak at 750 metres distance to the source in order to reduce disturbance and the risk of injury for all marine mammal species. The value is used to regulate underwater noise emissions from offshore pile driving. As demanded by the German authorities the thresholds are adopted as assessment criteria and noise levels above the values are assessed as a very high degree of impairment.

The following definitions of sound pressure level, sound exposure level, temporary threshold shift and permanent threshold shift are derived from Southall et al. (2007):

- The sound pressure level (SPL) is the expression of sound pressure which is described as a log ratio comparing the measured pressure (P) with the reference pressure, (P0): SPL (dB) = 20 log10 (P/P0). The reference pressure in underwater acoustics is defined as 1μPa. Using the logarithmic scale in dB, it results that doubling the pressure of a sound leads to a 6 dB increase in sound pressure level.

- The sound exposure level (SEL) is a measure of received sound energy and is proportional to the total energy of the signal. Specifically, it is the dB level of the time integral of the squared-instantaneous sound pressure normalized to a 1-s period (dB re 1μPa2s).

- Temporary threshold shift (TTS) is a temporary and reversible increase of the auditory thresholds following exposure to noise. At specific level, duration
and spectral characteristics, sound can cause hair cells of the inner ear to fatigue.

Permanent threshold shift (PTS) is considered to be auditory injury in which hearing does not fully return to normal after the noise exposure. Some of the apparent causes of PTS in mammals are severe extensions of effects underlying TTS (e.g., irreparable damage to the sensory hair cells). PTS is an irreversible elevation of the hearing threshold (i.e., a reduction in sensitivity) at a specific frequency (Yost, 2000). This permanent change following intense noise exposure results from damage or death of inner or outer cochlear hair cells. It is often followed by retrograde neuronal losses and persistent chemical and metabolic cochlear abnormalities (Saunders et al. 1991, Ward 1997, Yost 2000).

The relationship between TTS and PTS depends on a highly complex suite of variables concerning the study subject and the exposure.

An assessment of the overall significance was then applied using expert judgement and OSPAR EcoQO thresholds of 1.7% reduction for harbour porpoises and a 10% reduction in grey and harbour seals. The 1.7% was agreed to be the ‘total anthropogenic removal’ from the population, so removals caused by multiple activities should not exceed that limit when combined. Therefore, a removal of more than 1% by a single activity has been assessed in conjunction with losses from other anthropogenic activities because the combined activities could have a significant effect at the population level. With this in mind, ‘removal’ has been considered in terms of both 1% and 1.7% of the Fehmarnbelt study area population. The same assumptions can be applied to the 10% seal criterion.

5.10.4 Impacts from construction noise

Magnitude of pressure
For the bored tunnel some construction works are planned to take place in the coastal areas of the Fehmarnbelt. The pressure derives from the physical presence of construction vessels and activities creating noise and vibration as well as dredging and piling for construction harbours. Three construction harbours will be built and operated during the construction period of the bored tunnel: one east of Puttgarden on Fehmarn, and one east and west of Rødbyhavn, resulting in two harbours on Lolland. The construction works also include dredging of access channels to these harbours.

The land reclamations will require construction works in marine areas, such as the erection of containment dikes. Remaining reclamation works will mostly be conducted from land and dikes. Thus impacts on marine areas outside the reclamations will be reduced in the later part of construction.

Vessel traffic between the construction harbours will add to the overall vessel traffic intensity in the alignment area. It is estimated that about 10 barges (1,000 m³ capacity each) will be tugged from Fehmarn to Lolland and back every day for
transporting dewatered slurry. However, additional vessel traffic would mostly take place in an area which is already highly disturbed by shipping from the ferry line. Therefore, no relevant additional impact from increased shipping between the construction harbours is expected. Impacts from disturbance are only expected for areas where construction works are conducted in the marine areas.

Since the tunnel boring machines will drill the tunnel about 15 m below the seabed, no relevant noise emissions on marine mammals are expected from this construction activity.

Figure 5.97 shows the modelled noise magnitude for the scenario of construction works for harbours at the Lolland and Fehmarn coasts for the bored tunnel.

Figure 5.97 Sound Exposure Level for construction works of the bored tunnel

Figure 5.98 to Figure 5.101 show the density of harbour porpoises and the magnitude of the pressure during construction at the Lolland and Fehmarn coasts during summer and winter.
Figure 5.98  Density of harbour porpoises and magnitude of pressure due to construction works at the Lolland coast during summer

Figure 5.99  Density of harbour porpoises and magnitude of pressure due to construction works at the Lolland coast during winter
Figure 5.100  Density of harbour porpoises and magnitude of pressure due to construction works at the Fehmarn coast during summer

Figure 5.101  Density of harbour porpoises and magnitude of pressure due to construction works at the Fehmarn coast during winter
Magnitude of impact and degree of impairment

The resulting magnitude of the impact on harbour porpoises is shown in Table 5.65 and Table 5.66. Overlapping the sound pressure map with the occurrence map and taking the duration of the pressure into account shows that up to 11 porpoises will be affected in summer and 5 during winter, but none will suffer permanent injury. The porpoises will leave the area temporarily, thus reducing the local population but increasing it in other areas.

Seals do not occur in the areas affected by noise and therefore there are no impacts on seals.

Analysis of the pressure maps (Figure 5.98 to Figure 5.101) and comparison with the criteria for degree of impairment (Table 5.64) gives the sub-division of the degree of impairment into very high, high, medium and minor shown in Table 5.65 and Table 5.66.

**Table 5.65 Degree of impairment for harbour porpoises from the construction of the bored tunnel. Values show number of affected harbour porpoises during summer.**

<table>
<thead>
<tr>
<th>Degree of impairment</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of porpoises affected</td>
<td>5.110</td>
<td>5.735</td>
<td>0.257</td>
<td>0.7</td>
<td>11.105</td>
</tr>
</tbody>
</table>

0.41 to 0.79 % of the Fehmarnbelt summer population

**Table 5.66 Degree of impairment for harbour porpoises from the construction of the bored tunnel. Values show amount of affected harbour porpoises during winter.**

<table>
<thead>
<tr>
<th>Degree of impairment</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of porpoises affected</td>
<td>2.377</td>
<td>2.664</td>
<td>0.094</td>
<td>0.002</td>
<td>5.137</td>
</tr>
</tbody>
</table>

0.23 to 0.82 % of the Fehmarnbelt winter population

**Significance of impact**

The noise will not result in the death or permanent injury of any harbour porpoises or seals.

The number of porpoises affected by noise is less than 1% of the Fehmarnbelt population (Table 5.65 and Table 5.66) and the impact is therefore classified as insignificant.

Since no seals are affected the impact is also insignificant.
5.10.5 Impacts of habitat loss

Magnitude of pressure

Habitat loss caused by the coastal land reclamation will directly impact porpoises and seals. Harbour porpoises, harbour seals and grey seals are mobile predators and occupy a wide range of habitats. Physical loss will directly affect occurrence areas through the direct loss of water column and the seabed and may thus affect the food supply.

The reclamation areas at the Lolland and Fehmarn coasts cover mostly shallow water habitats (see Figures 5.15 to 5.17). The larger reclamation area at Lolland, extending up to 4 km east and west of the ferry harbour, affects shallow water areas dominated by macroalgae (mainly *Fucellaria*) and Mytilus communities. These coastal areas are important habitats for shallow water fish communities composed of smaller species like gobies or sand eels, but these areas are also suitable habitats for juvenile stages of other fish species, e.g. cod and flounder.

The bored tunnel footprint covers 442 ha of marine area during the construction period, of which the loss from land reclamations comprises the largest fraction with 80% (353 ha) and the remaining 20% is lost due to harbour infrastructure (Table 5.67). Two construction harbours at Lolland and the construction harbour at Fehmarn with dredged access channels are part of the construction footprint. The areas relevant for assessing the impacts on marine mammals are obtained by excluding the intertidal areas which are not relevant for harbour porpoises and are not recognised seal haul-out areas.

The footprint area in the operation phase is less than the area in the construction phase since the harbour structures will be removed and the harbour basins filled. A specific assessment for the operation phase is not made since the impacts will be less than for the construction phase.

**Table 5.67 Footprint of the bored tunnel during construction**

<table>
<thead>
<tr>
<th>Footprint area</th>
<th>Size (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land reclamation Lolland</td>
<td>330</td>
</tr>
<tr>
<td>Land reclamation Fehmarn</td>
<td>23.5</td>
</tr>
<tr>
<td>Dredged areas Lolland (harbours, access channels)</td>
<td>50.4</td>
</tr>
<tr>
<td>Dredged areas Fehmarn (harbour, access channel)</td>
<td>19.8</td>
</tr>
<tr>
<td>Harbour breakwaters Lolland</td>
<td>7.1</td>
</tr>
<tr>
<td>Harbour breakwaters and quay area Fehmarn</td>
<td>11.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>442.1</strong></td>
</tr>
</tbody>
</table>
Magnitude of impact and severity of loss

The resulting magnitude of impact on harbour porpoises is shown in Table 5.68 and Table 5.69. It is obtained by overlapping the footprint map with the occurrence map. The procedure showed that less than 1 porpoise will be affected. It will no longer be able to use the lost area and will relocate to another area.

No seals will be affected by the reclamations.

The severity of loss is assessed in accordance with the criteria defined in Table 5.64 and is shown in Table 5.68 and Table 5.69. The severity varies from high to minor but the number of porpoises displaced by the reclamations is assessed to be small.

The severity of loss for harbour and grey seals is assessed to be minor since the habitat areas lost do not coincide with areas of pupping (haul-out sites) and therefore will not impair the most important areas for seals.

Table 5.68  Severity of loss of harbour porpoises during summer due to habitat loss

<table>
<thead>
<tr>
<th>Severity of loss</th>
<th>Habitat loss (km²)</th>
<th>% of Fehmarnbelt region</th>
<th>No. of Porpoises affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>High</td>
<td>0.10</td>
<td>0.002</td>
<td>0.07</td>
</tr>
<tr>
<td>Medium</td>
<td>0.84</td>
<td>0.017</td>
<td>0.31</td>
</tr>
<tr>
<td>Minor</td>
<td>1.11</td>
<td>0.023</td>
<td>0.19</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2.05</td>
<td>0.042</td>
<td>0.564</td>
</tr>
</tbody>
</table>

0.02 to 0.04% of the Fehmarnbelt summer 2010 population

Table 5.69  Severity of loss of harbour porpoises during winter due to habitat loss

<table>
<thead>
<tr>
<th>Severity of loss</th>
<th>Habitat loss (km²)</th>
<th>% of Fehmarnbelt region</th>
<th>No. of Porpoises affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>High</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
</tr>
<tr>
<td>Medium</td>
<td>0.08</td>
<td>0.002</td>
<td>0.03</td>
</tr>
<tr>
<td>Minor</td>
<td>1.98</td>
<td>0.041</td>
<td>0.29</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2.05</td>
<td>0.042</td>
<td>0.321</td>
</tr>
</tbody>
</table>

0.02 to 0.06% of the Fehmarnbelt winter 2010 population

Significance of impact

The habitat loss caused by the reclamations will only affect 0.02 – 0.06% of the Fehmarnbelt population of harbour porpoises and the impact is therefore insignificant.
No seals will be affected by the habitat loss and the impact is therefore also insignificant.

5.10.6 Impacts of sediment spill

Magnitude of impact
A total of 95,773 m³ of sediments is estimated to be spilled from dredging the working harbours, constructing containment dikes, depositing material at land reclamation sites and landscaping of the reclamations. The overall construction period is scheduled to last 6 years, starting in October 2014, but sediment spill concentrations in the marine areas are only assessed in detail for the first two construction years and the last year of construction (2020). The total amount of spilled material will be highest in the first two construction years (38,196 m³ in 2014 and 32,128 m³ in 2015) and lower in 2020 during landscaping activities (25,450 m³).

The baseline data for suspended sediments (turbidity) and the modelling of the sediment spill (see section 5.3) show that the background concentrations are higher and the exceedence much greater than the excess concentrations from the sediment spill. The largest excess concentrations occur in the last months of 2014 and the first months of 2015 during dredging of the work harbours and access channels. The excess concentrations at mid-water in the western end of Rødsand Lagoon only exceed 20 mg/l in short events. At the same location the natural background concentration (measured) exceeds 20 mg/l for 9% of the time. Away from the Rødsand Lagoon and offshore of the coastal areas, excess concentrations are lower. Figure 5.102 shows that suspended sediment concentrations reach 10 mg/l between only 5% and 10% of the time along the coastal areas and in a small part of Rødsand Lagoon during the period November 2014 to end March 2015 when the majority of the spill takes place and the maximum excess concentrations occur.

In Rødsand Lagoon and in the nearshore zone concentrations are mainly caused by re-suspension driven by hydrodynamic conditions. The natural median concentration levels are above 2 mg/l. In windy periods the measurement stations in Rødsand Lagoon show background concentrations of 20-30 mg/l for more than 5% of the time. The nearshore measurement stations at water depths between 3 m and 8 m show that the background concentrations exceed 10 mg/l between 4% and 60% of the time. In shallow nearshore areas the suspended sediment is a natural part of the water environment.

*Direct impacts* on marine mammals due to suspended sediments could arise from sediment spill. The presence of surface and sub-surface elevated suspended sediment concentrations caused by dredging operations has the potential to reduce the ability of visual-feeding marine mammals to locate their prey resulting in an impact upon feeding success. However, harbour porpoise hearing and echolocation are adapted for navigation and foraging in conditions where vision is limited or absent (Kastelein et al., 2002), and seals successfully live and forage in turbid environment with their vibrissae (whiskers) playing an important role when faced with reduced visibility (Renouf, 1980).
It is therefore assessed that there will be no impact on the harbour porpoise and seal populations from the direct effects of the sediment spill.

Additionally, indirect impacts on marine mammals can arise from sediment spill. Harbour porpoises may indirectly be affected through reduced prey availability as a result of the sediment spill, which may impact the benthic fauna and also affect fish. Direct impacts of the sediment plume at the dredging sites are considered to be small and are assessed to be negligible for fish (see section 5.9 Fish ecology) and it is assessed that there is no associated pressures on harbour porpoise or seal food supplies.

Degree of impairment
The degree of impairment has been assessed following the criteria described in Table 5.64.
The degree of impairment of direct impacts due to suspended sediments and of indirect impacts due to reduced food supply for marine mammals is considered to be between no impact and minor.

Significance of impact
The impacts of sediment spill on marine mammals are classified as insignificant since populations will not be affected and impacts vary between minor and no impact.

5.10.7 Significance of impacts – summary
The degree of impairment for the considered pressures during construction and operation of the bored tunnel on marine mammals (harbour porpoises and seals) is assessed to be between minor and no impact.

Since all pressures do not affect more than 1% of the Fehmarnbelt area population of harbour porpoises, all impacts are considered to be insignificant.

Since all pressures do not affect more than 10% of the Fehmarnbelt area population of harbour and grey seals, all impacts are considered to be insignificant.

5.10.8 Mitigation and compensation
Specific mitigation or compensation measures are not recommended because of the relatively small spatial areas affected by the construction and operation of the bored tunnel, in combination with the relatively low importance of these areas for marine mammals. On the other hand, since the largest effect on marine mammals is related to noise associated with the construction activities, it is suggested that the construction works consider the use of techniques that minimise noise emissions.

5.10.9 Decommissioning
There will be no impacts on the marine area from decommissioning activities and therefore no impacts on marine mammals.
5.11 Birds

The Fehmarnbelt area is of considerable importance for many bird species. A large number of water-birds, such as wintering sea ducks, moulting swans and many other species spend their non-breeding season in the region. The area also provides suitable and important breeding habitats for several water-bird species. Large parts of the Fehmarnbelt area and adjacent inland habitats are protected as Natura 2000 sites, which have been designated to protect important areas for staging and breeding birds.

During spring and autumn large numbers of land-birds and water-birds pass the Fehmarnbelt area on migration. Land-birds such as birds of prey and other daytime migrating species concentrate in the area, using the relatively short distance between Fehmarn and Lolland to cross the Baltic Sea. Many species of daytime migrating land-birds try to minimise the distance they fly over water, therefore Fehmarnbelt has a channelling effect for these. Water-birds which prefer to fly over water pass the Fehmarnbelt in large numbers parallel to the coast line, most of them during daytime, but some also during night-time. Nocturnally migrating birds also pass the area on their broad-front migration. The large numbers of birds migrating through the area twice a year make the Fehmarnbelt an internationally important migration corridor between breeding areas in Fennoscandia, Eastern Europe and Siberia and wintering areas in Europe and Africa.

The impact assessment on birds in marine areas was conducted separately for breeding water-birds, non-breeding water-birds and migrating birds. These categories fall under the environmental factor fauna as shown in Table 5.34.

Table 5.70 Birds in Fehmarnbelt

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sub-factor</th>
<th>Component</th>
<th>Sub-component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fauna</td>
<td>Birds</td>
<td>Breeding water-birds</td>
<td>Individual species</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-breeding water-birds</td>
<td>Individual species</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Migrating birds</td>
<td>Individual species</td>
</tr>
</tbody>
</table>

With respect to breeding water-birds only impacts on birds breeding in marine habitats, and birds breeding in inland SPAs but using marine areas were assessed.

The impact assessment for each environmental component was conducted on the species level wherever possible.

5.11.1 Project pressures and potential impacts

Habitat loss from footprint

Marine habitats utilised by breeding and non-breeding water-birds would be lost through the temporary and permanent footprints of the bored tunnel, i.e. construction harbours and land reclamation areas on Lolland and Fehmarn. This pressure is relevant during construction and operation of the bored tunnel. The
potential impacts are the displacement of birds and the reduction of feeding areas / food supply.

Habitat change from sediment spill

The sediment spill from different activities during construction of the bored tunnel, i.e. construction harbours, containment dikes, reclamation and landscaping, would lead to increased sedimentation and increased levels of suspended sediments. This may impair fish and benthic flora and fauna communities, i.e. reduction in biomass, growth and productivity, and thus affect food resources of breeding and non-breeding water-birds in the area. This pressure is only relevant during the construction of the bored tunnel.

Reduced water transparency

The direct sediment spill as well as re-suspension of mobile sediments would decrease water transparency. Where this exceeds background levels the ability of birds to find food may be impaired and thus lead to a displacement of birds preferring clear water. This pressure would be relevant during the construction period only.

Disturbance from construction activities

The construction of the bored tunnel would require different construction activities in marine areas, which may cause disturbance to breeding and non-breeding water-birds through the physical presence of vessels and structures, noise and light emissions.

The pressures ‘hydrographical changes’, ‘barrier effect of construction vessels’ and ‘collision with construction vessels’ have been assessed to result in no or minor effects on birds in the impact assessment for the immersed tunnel alternative (FEBI 2012b). The effects on birds from these pressures for the bored tunnel solution are considered to be comparable to, or considerably reduced (far fewer construction vessels) compared with the immersed tunnel and are therefore not assessed further in this report.

5.11.2 Existing bird populations in Fehmarnbelt

The area of investigation for the bird studies stretches from a line between Kiel and Langeland in the west to a line between Gedser and Dahmeshöved in the east (Figure 5.103). The area is defined to include all Natura 2000 sites, namely the Special Protection Areas (SPAs) and areas of Sites of Community Interest (SCIs) designated for the protection of birds in the Fehmarnbelt and adjacent areas. In addition, the area of investigation covers the maximum area potentially influenced by suspended sediments as identified in earlier investigations.

The baseline investigations focused on the following items:

› Abundance, distribution and trends (from historical data) of water-birds and seabirds in the Fehmarnbelt area
› Feeding grounds for seabirds and water-birds in the sea
› Local flight patterns of land-birds, seabirds and water-birds
Migration of land-birds, seabirds and water-birds.

For the baseline investigations the following data have been consulted:

› Data from monthly aerial (Figure 5.103) and ship-based surveys of non-breeding water-birds along transects
› Data from modelled water-bird density
› Data about bird migration from studies using radar and visual observation as well as acoustic surveys
› Radio, satellite and GPS telemetric data about the foraging patterns, long-distance and local movements of specific water-bird species
› Analysis of ringing data regarding the origins of populations in Fehmarnbelt
› Other historical data from monitoring and scientific studies which have been carried out in Denmark, German and Baltic Sea countries and which contain information necessary for abundance analysis and for ascertaining population trends. Wherever possible, original data have been used in the analyses.

Breeding water-birds
Breeding birds which could be relevant for the environmental impact assessment of the bored tunnel across Fehmarnbelt are almost completely restricted to the Natura 2000 sites of the area, see Figure 5.104. SPAs and SCIs have been established in Germany and Denmark because of the importance of the bird fauna. This emphasizes that these areas are already of high importance for birds.
Table 5.71 shows the number of EU Birds Directive Annex I species and breeding pairs of birds in the most important Natura 2000 areas.

<table>
<thead>
<tr>
<th>SPA</th>
<th>No. of Annex I species</th>
<th>Breeding pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE 1530-491 Eastern Kiel Bight</td>
<td>17</td>
<td>357</td>
</tr>
<tr>
<td>DE 1633-491 Baltic Sea east of Wagrien</td>
<td>46</td>
<td>56</td>
</tr>
<tr>
<td>DK 006X083 Hyllekrog-Rødsand</td>
<td>6</td>
<td>75</td>
</tr>
<tr>
<td>DK 006X087 Maribo Lakes</td>
<td>4</td>
<td>100</td>
</tr>
</tbody>
</table>

Of the SPAs in the Fehmarnbelt area the SPA Eastern Kiel Bight has the highest number of Annex I species and the highest number of breeding pairs of Annex I species. This is mostly due to non-marine species. Of the species occurring in the marine environment colonies of four species of breeding terns are to be highlighted, because breeding sites for these species are rare in the southern Baltic. Similarly, the breeding colonies of different gull species need to be mentioned as well as the breeding colonies of the Avocet. In addition the high number of breeding Common Eiders and Red-breasted Mergansers, which rear their young in the marine environment, provides special value for the area as breeding ground for waterfowl.
Most breeding areas are located at some distance from the alignment of a fixed link. However, terns and gulls breeding at Grüner Brink on Fehmarn are likely to forage in the alignment area and also birds from the larger gull colonies in the Rødsand Lagoon might at least partly be utilising this part of the Fehmarnbelt.

Non-breeding water-birds

The approach to evaluate the importance of the study area or parts of it differs from classic approaches to the identification of areas of conservation interest. It has also to be taken into account that the study area covers only a small proportion of the bird species in the region. Parts of the study area, which only hold a low proportion of the population, might extend across the border of the study area and be part of a larger area of importance. For dispersed species the study area might simply be too small to hold 1% of a population, especially when considering the smaller area covered by ship-based surveys. In order to take this into account, the method proposed in BirdLife International (2004) for identification of marine Important Bird Areas is adopted. The 1% criterion can be regarded as fulfilled if 1% of a population occurs in an area smaller than 3,000 km².

As an example of the results of the baseline studies the densities of Common Eider determined from the aerial surveys in winter 2010 are shown in Figure 5.105. The densities are then converted into a map of the importance of various areas in Fehmarnbelt for the Common Eider in Figure 5.106.

The total number of Common Eiders in the Western Palearctic has been estimated at between 1.82 and 2.38 million, of which 760,000 belong to the Wadden Sea – Baltic Sea population (Wetlands International 2006). Up to 18% of the Western Palearctic winter population and up to 43% of the Wadden Sea – Baltic Sea population winters in the Fehmarnbelt. This renders the Fehmarnbelt to be probably one of the most important wintering regions for this biogeographic population of the Common Eider.

Details for all non-breeding water-bird species can be found in FEBI 2012a.
Figure 5.105  Spatial distribution model (numbers per km²) of Common Eider Somateria mollissima in the Fehmarnbelt in winter period November 2009 – early March 2010 based on baseline aerial surveys

Figure 5.106  Classification of the importance of Fehmarnbelt to Common Eider during winter (November – early March), based on modelled densities derived from aerial surveys (average values of seasons 2008/2009 and 2009/2010)
Table 5.72 provides an overview of maximum numbers of water-bird species estimated for the Fehmarnbelt study area and the respective importance level (light to dark green: minor to very high importance). Numbers are the maximum estimates based on the baseline investigations and supplementary datasets available.

**Table 5.72** Maximum estimate of non-breeding water-bird species in the Fehmarnbelt study area (the list represents only the most abundant relevant species). The three columns on the right indicate the derivation of the importance levels based on the combination of the conservation status of a species with its abundance in the Fehmarnbelt.

<table>
<thead>
<tr>
<th>Species</th>
<th>Annex I</th>
<th>1% level</th>
<th>Max. estimate in Fehmarnbelt</th>
<th>Conservation status</th>
<th>Abundance</th>
<th>Importance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divers</td>
<td>X</td>
<td>3,000</td>
<td>1,711</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Crested Grebe</td>
<td></td>
<td>3,600</td>
<td>1,540</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red-necked Grebe</td>
<td></td>
<td>510</td>
<td>1,100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slavonian Grebe</td>
<td>X</td>
<td>200</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Cormorant</td>
<td></td>
<td>3,900</td>
<td>&gt;10,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mute Swan</td>
<td></td>
<td>2,500</td>
<td>16,200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bewick’s Swan</td>
<td>X</td>
<td>200</td>
<td>&gt;200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whooper Swan</td>
<td>X</td>
<td>590</td>
<td>&gt;1,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bean Goose</td>
<td></td>
<td>6,000</td>
<td>&gt;2,200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greater White-fronted Goose</td>
<td></td>
<td>10,000</td>
<td>&gt;1,900</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greylag Goose</td>
<td></td>
<td>5,000</td>
<td>&gt;5,700</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barnacle Goose</td>
<td>X</td>
<td>4,200</td>
<td>&gt;8,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brent Goose</td>
<td></td>
<td>2,000</td>
<td>1,800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eurasian Wigeon</td>
<td></td>
<td>15,000</td>
<td>&gt;17,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gadwall</td>
<td></td>
<td>600</td>
<td>&gt;800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Teal</td>
<td></td>
<td>5,000</td>
<td>&gt;3,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mallard</td>
<td></td>
<td>45,000*</td>
<td>&gt;11,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoveler</td>
<td></td>
<td>400</td>
<td>&gt;1,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Pochard</td>
<td></td>
<td>3,500</td>
<td>&gt;3,500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tufted Duck</td>
<td></td>
<td>12,000</td>
<td>&gt;30,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greater Scaup</td>
<td></td>
<td>3,100</td>
<td>&gt;12,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Eider</td>
<td></td>
<td>7,600</td>
<td>327,505</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-tailed Duck</td>
<td></td>
<td>46,000*</td>
<td>23,800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Scoter</td>
<td></td>
<td>16,000</td>
<td>66,290</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velvet Scoter</td>
<td></td>
<td>10,000</td>
<td>3,050</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Goldeneye</td>
<td></td>
<td>11,500</td>
<td>6,400</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Migrating birds
Reference is made to FEBI 2012a for a description of the migrating bird populations and migration behaviour. No description is included here because the subsequent impact assessment showed that none of the project pressures were likely to cause any relevant impact on migrating birds.

5.11.3 Methodology
The assessment methodology described in section 5.1 was followed by FEBI adjusting it for specific needs in the assessment of birds. As a first step, the sensitivity of bird species to the different pressures was assessed using baseline data and literature information. The sensitivity of a species to a pressure and the magnitude of a pressure define the quantitative magnitude of the impact and thereby the qualitative degree of impairment. The magnitude of impact describes a species response to a particular pressure, e.g. the number of birds being displaced from the impairment zone. Criteria for assessing the degree of impairment due to the different pressures were defined on the basis of the proportion of birds impacted, see Table 5.73. A very high degree of impairment corresponds to loss of function within the impairment zone. The impairment zone is pressure-specific and
defines the spatial extent of a pressure. Birds are not affected outside the impairment zone.

Table 5.73  Criteria for assessing the degree of impairment of breeding and non-breeding water-birds based on the sensitivity of a species to a pressure

<table>
<thead>
<tr>
<th>Project pressures</th>
<th>Degree of impairment</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat changes due to sediment spill and reduced water transparency during construction</td>
<td>Very high</td>
<td>Habitat changes result in 50–100% reduction in bird numbers within the impairment zone, or the degree of reduction in bird numbers in not assessable.</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Habitat changes result in 25–50% reduction in breeding or non-breeding water-bird numbers within the impairment zone.</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>Habitat changes result in 5–25% reduction in breeding or non-breeding bird numbers in the impairment zone.</td>
</tr>
<tr>
<td></td>
<td>Minor</td>
<td>Habitat changes do not result in a detectable reduction in breeding or non-breeding bird numbers (&lt;5% displacement).</td>
</tr>
</tbody>
</table>

| Disturbance during construction                        | Very high            | 50–100% of breeding or non-breeding water-birds are expected to get displaced from the impairment zone, or the degree of displacement is not assessable. |
|                                                        | High                 | 25–50% of breeding or non-breeding water-birds are expected to get displaced from the impairment zone. |
|                                                        | Medium               | 5–25% of breeding or non-breeding water-birds are expected to get displaced from the impairment zone. |
|                                                        | Minor                | Disturbance does not lead to a detectable displacement of breeding or non-breeding water-birds (<5% displacement). |

It is generally assumed in the assessment that all birds in an impairment zone will be displaced, i.e. 100% are displaced, and the definitions in Table 5.73 imply that such displacement gives a very high degree of impairment. Such an assessment does not give a true picture of the impact since the number of birds displaced could be very small compared to the biogeographic population. Therefore this section on birds differs from other sections and reports the relative impact (very high, high, medium or minor) based on the number of birds affected.

For areas lost due to the project footprint the severity of loss was assessed. The severity of loss corresponds to the importance level of the areas lost to a species and the bird numbers being affected.

The importance of the Fehmarnbelt area was determined at the species level by accounting both for the numerical abundance of a species in the area in relation to its biogeographic population and the conservation status of that species (Table 5.74). This approach was also used for assessing the importance of the number of birds affected by a pressure in a particular impact area.
Table 5.74  Scheme of determination of the environmental sub-component’s (bird species’) importance: the importance level is the result of the combination of the species’ abundance in relation to its biogeographic population and the species’ protection/conservation status. For an explanation how abundance criteria and protection/conservation status are defined see Table 5.75 and Table 5.76.

<table>
<thead>
<tr>
<th>Abundance in % of the biogeographic population</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>Very high</td>
<td>Very high</td>
<td>Very high</td>
<td>Very high</td>
</tr>
<tr>
<td>High</td>
<td>Very high</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Minor</td>
</tr>
<tr>
<td>Minor</td>
<td>Minor</td>
<td>Minor</td>
<td>Minor</td>
<td>Minor</td>
</tr>
</tbody>
</table>

The abundance criteria for the determination of importance levels are based on the proportion of the respective biogeographic population registered in the area (Table 5.75).

Table 5.75  Classification of the environmental sub-component (bird species) based on species abundance in relation to its biogeographic population

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>≥ 1% of the relevant population, or ≥ 20,000 individuals of a water-bird species*</td>
</tr>
<tr>
<td>High</td>
<td>≥ 0.5%, but &lt; 1% of the relevant population</td>
</tr>
<tr>
<td>Medium</td>
<td>≥ 0.1%, but &lt; 0.5% of the relevant population</td>
</tr>
<tr>
<td>Minor</td>
<td>&lt; 0.1% of the relevant population</td>
</tr>
</tbody>
</table>

* For populations over 2 million birds, Ramsar Convention criterion 5 (20,000 or more water-birds) applies. This criterion only applies for non-breeding water-birds.

Two international conservation statuses were chosen for classification of a species importance based on its protection and conservation status: whether a species is listed in the Annex I of the EU Birds Directive or not, and the SPEC status according to BirdLife International (2004a) (Error! Reference source not found.). If a species is listed in Annex I of the EU Birds Directive, but is classified at a lower SPEC status, the higher classification applies (i.e. very high).
**Table 5.76**  
Classification of the environmental sub-component (bird species) based on the protection/conservation status of the species according to the EU Birds Directive and the SPEC status of a species according to BirdLife International (2004a).

<table>
<thead>
<tr>
<th>Criterion</th>
<th>EU Bird Directive</th>
<th>SPEC Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>Listed in Annex I</td>
<td>SPEC 1 or 2</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td>SPEC 3</td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td>Non-SPEC ≠</td>
</tr>
<tr>
<td>Minor</td>
<td></td>
<td>Non-SPEC</td>
</tr>
</tbody>
</table>

Explanations to Table 5.76 (BirdLife International 2004a):

**SPEC 1:** European species of global conservation concern, i.e. classified as Critically Endangered, Endangered, Vulnerable, Near Threatened or Data Deficient under the IUCN Red List Criteria at a global level (BirdLife International 2004a, IUCN 2004).

**SPEC 2:** Species whose global populations are concentrated in Europe, and which have an Unfavourable Conservation Status in Europe.

**SPEC 3:** Species whose global populations are not concentrated in Europe, but which have an Unfavourable conservation status in Europe.

**Non-SPEC ≠:** Species whose global populations are concentrated in Europe, but which have a Favourable conservation status in Europe.

**Non-SPEC:** Species whose global populations are not concentrated in Europe, and which have a Favourable conservation status in Europe.

As a final step of the impact assessment the significance of impact was assessed at the species level. An impact from the construction and operation of the project was considered significant if the following criterion was met:

- The total number of displaced individuals (resulting from different pressures) corresponds to more than 1% of the biogeographic population, unless it can be excluded that the displacement of >1% of the biogeographic population would result in a population effect for a species.

Criteria for degree of impairment and significance for barrier effects and collision were also developed but are not relevant for the bored tunnel solution.

When assessing the significance of the project impact, the durations of the different pressures (i.e. duration of significant impacts) were taken into account.
5.11.4 Impacts from habitat loss due to footprint

Magnitude of pressure
The footprint of the bored tunnel in the Fehmarnbelt would cover 442 ha of marine area during the construction period. The predicted loss from land reclamations accounts for the major part with 80% of this total area. Two construction harbours at Lolland and the construction harbour at Fehmarn with dredged access channels would be part of the construction footprint. Similar to the immersed tunnel, the reclamation areas are planned outside the breakwater constructions of the ferry harbours in Rødbyn haven (both sides of the harbour) and Puttgarden (only east of the harbour) and would replace mostly shallow water habitats (Figures 5.15 to 5.17).

A description of habitat types being lost is given above in sections 5.4 Seabed morphology, 5.7 Benthic flora, 5.8 Benthic fauna and 5.9 Fish ecology. Briefly, the seabed in the impacted areas is without bed forms, there is little loose sediments on the surface except near the coasts and large stones and boulders are imbedded in or lying on the relatively hard clay till surface. An area of 205 ha of Furcellaria community with varying degrees of cover would be lost and 50 ha of filamentous algae with low (< 10%) coverage. The benthic flora habitats support fish which are a food supply for piscivorous water-birds. With respect to benthic fauna, the construction footprint would cause the loss of 216 ha of Mytilus community (corresponding to 0.7% of such communities in the study area), 115 ha of Bathyporeia community, 57 ha of Gammarus community and 37 ha of Cerastoderma community.

The habitat loss from the tunnel footprint is predicted to affect different life stages of the studied fish species, i.e. spawning, egg-larvae drift, nursery, feeding and migration. The impacts on fish are predicted to result in up to 30% reduction in some life stages of different fish species within the near zone (500 m around the footprint). The highest impact is predicted for juvenile stages of cod and flatfish, and the shallow water fish species, such as sandeels, gobies, and sticklebacks, in the Danish coastal area. There are no impacts on fish predicted to occur from the tunnel footprint beyond the near zone area in the immediate vicinity of the footprint.

Breeding water-birds
Only the impacts of habitat loss of marine areas have been assessed. Consequently, any possible loss of breeding habitats on land from the tunnel footprint is not part of the present assessment, and will be covered elsewhere. Habitat loss in marine areas is expected to be relevant for breeding bird species which use marine habitats for foraging during the breeding season or rear their offspring in marine areas.

Within the Fehmarnbelt area Red-necked Grebes, Great Cormorants, terns and gulls conduct foraging flights to marine waters. Mute Swans, Red-breasted Mergansers, Common Eiders and partly also other duck species rear their offspring in sheltered coastal areas, but among these only Red-breasted Merganser breeds close to the alignment.
The impact of the habitat loss by the tunnel footprint is assessed to be only relevant for birds breeding in the northern part of Fehmarn, in the south of Lolland and partly for birds breeding in the western part of Rødsand Lagoon, which might commute between the impact zone and the breeding area (Table 5.77). Cormorants breeding in the west of Fehmarn and birds of other breeding colonies within the German SPAs are expected to mostly use marine areas close to their colonies and not regularly visit the affected alignment area. Therefore, these are not listed in Table 5.77.

Table 5.77 Breeding water-bird species potentially affected by the habitat loss due to a bored tunnel in the Fehmarnbelt during the construction phase. Listed are the numbers of breeding pairs for which use of the impact zone cannot be excluded.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of breeding pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fehmarn north coast (SPA Eastern Kiel Bight)</td>
</tr>
<tr>
<td>Red-necked Grebe</td>
<td>35</td>
</tr>
<tr>
<td>Red-breasted Merganser</td>
<td>26</td>
</tr>
<tr>
<td>White-tailed Eagle</td>
<td>1</td>
</tr>
<tr>
<td>Black-headed Gull</td>
<td>15</td>
</tr>
<tr>
<td>Common Gull</td>
<td>12</td>
</tr>
<tr>
<td>Herring Gull</td>
<td>-</td>
</tr>
<tr>
<td>Great Black-backed Gull</td>
<td>-</td>
</tr>
<tr>
<td>Sandwich Tern</td>
<td>-</td>
</tr>
<tr>
<td>Common Tern</td>
<td>33</td>
</tr>
<tr>
<td>Arctic Tern</td>
<td>-</td>
</tr>
<tr>
<td>Little Tern</td>
<td>10</td>
</tr>
</tbody>
</table>

* Red-breasted Merganser breeding in Rødsand Lagoon are not expected to use the impact area.

Red-necked Grebes breeding at Grüner Brink or further west on Fehmarn are unlikely to cross the highly disturbed area of the ferry harbour in Puttgarden and thus are not expected to be affected by the footprint area located east of the harbour. Therefore few birds are expected to be impacted by the tunnel. The same conclusion applies to the Red-breasted Merganser breeding at Grüner Brink.

The habitat loss from the tunnel footprint would affect mostly the shallow coastal areas along the coast of Lolland. The breeding Red-breasted Merganser of Rødsand Lagoon are expected to forage and rear their offspring within the lagoon, and therefore would not be affected by the habitat loss. The conclusion also applies to the breeding pairs of Arctic Tern and Little Tern in the SPA Hyllekrog-Rødsand.

White-tailed Eagles forage on a variety of prey including carrion, birds and fish, and the species uses different inland and coastal habitats for feeding. The coastal areas which are predicted to be lost from land reclamation represent potential foraging habitats of White-tailed Eagle, but are assessed to be of minor importance to the species, since these areas are already highly disturbed by the existing ferry
traffic and tourist activities. Therefore the impact of the tunnel footprint is assessed to be minor for White-tailed Eagles breeding in the area.

The different gull species breeding in the vicinity of the impact area are assessed as not being sensitive to habitat change due to their opportunistic foraging strategy, which allows them to feed on a variety of prey and use various habitats. Therefore the footprint area is assessed to be of minor importance to gulls breeding in the area and therefore the impact is also assessed to be minor.

Terns catch by plunge-diving mostly in shallow waters, where small prey fish are abundant. The loss of such shallow water habitats on the German side would be rather small and therefore the impact from the tunnel footprint for the Common Tern and Little Tern colonies at Grüner Brink and further west are expected to be minor.

In conclusion, the severity of loss due to the project construction footprint is assessed to be minor for all breeding water-birds.

The conclusion also applies to the operation phase since the footprint is only marginally smaller. However, depending on the development, management and natural succession of the land reclamation sites, these areas will likely provide new breeding habitats for different water-bird species.

Non-breeding water-birds
The total impact area of the tunnel footprint would be relatively small in relation to the Fehmarnbelt study area. The footprint would lie within an area of relatively low water-bird densities of most species due to the existing disturbance from the intense shipping, including the ferry traffic. However, some of the coastal water-bird species occur in high numbers in the coastal areas.

The magnitude of impact is represented by the number of birds displaced by the footprint and is obtained by overlaying the footprint on maps of bird densities. The results are shown in Table 5.78. Due to the resolution of the abundance maps and the small area of the footprint it was only possible to estimate actual numbers of birds displaced when densities were sufficiently high. For other species the number is estimated to be “low” (Table 5.78).

Table 5.78  
Assessment of magnitude of impact and the severity of loss of non-breeding water-birds from the footprint of the bored tunnel during the construction period

<table>
<thead>
<tr>
<th>Species</th>
<th>Estimated number of displaced individuals</th>
<th>Estimated maximum number in Fehmarnbelt</th>
<th>Severity of loss</th>
<th>Percentage of the biogeographic population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divers</td>
<td>low number</td>
<td>1,711</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Great Crested Grebe</td>
<td>low number</td>
<td>1,540</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Red-necked Grebe</td>
<td>low number</td>
<td>1,100</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Species</td>
<td>Estimated number of displaced individuals</td>
<td>Estimated maximum number in Fehmarnbelt</td>
<td>Severity of loss</td>
<td>Percentage of the biogeographic population</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------------------------------</td>
<td>----------------------------------------</td>
<td>------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Slavonian Grebe</td>
<td>low number</td>
<td>10</td>
<td>Minor</td>
<td>&lt;0.05%</td>
</tr>
<tr>
<td>Great Cormorant</td>
<td>500</td>
<td>&gt;10,000</td>
<td>Minor</td>
<td>0.13%</td>
</tr>
<tr>
<td>Mute Swan</td>
<td>low number</td>
<td>16,200</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Bewick’s Swan</td>
<td>low number</td>
<td>&gt;200</td>
<td>Minor</td>
<td>&lt;0.05%</td>
</tr>
<tr>
<td>Whooper Swan</td>
<td>low number</td>
<td>&gt;1,500</td>
<td>Minor</td>
<td>&lt;0.05%</td>
</tr>
<tr>
<td>Bean Goose</td>
<td>low number</td>
<td>&gt;2,200</td>
<td>Minor</td>
<td>&lt;0.05%</td>
</tr>
<tr>
<td>Greater White-fronted Goose</td>
<td>low number</td>
<td>&gt;1,900</td>
<td>Minor</td>
<td>&lt;0.001%</td>
</tr>
<tr>
<td>Greylag Goose</td>
<td>low number</td>
<td>&gt;5,700</td>
<td>Minor</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Barnacle Goose</td>
<td>low number</td>
<td>&gt;8,000</td>
<td>Minor</td>
<td>&lt;0.001%</td>
</tr>
<tr>
<td>Brent Goose</td>
<td>low number</td>
<td>1,800</td>
<td>Minor</td>
<td>&lt;0.001%</td>
</tr>
<tr>
<td>Eurasian Wigeon</td>
<td>low number</td>
<td>&gt;17,000</td>
<td>Minor</td>
<td>&lt;0.05%</td>
</tr>
<tr>
<td>Gadwall</td>
<td>low number</td>
<td>&gt;800</td>
<td>Minor</td>
<td>&lt;0.05%</td>
</tr>
<tr>
<td>Common Teal</td>
<td>low number</td>
<td>&gt;3,000</td>
<td>Minor</td>
<td>&lt;0.001%</td>
</tr>
<tr>
<td>Mallard</td>
<td>low number</td>
<td>&gt;11,000</td>
<td>Minor</td>
<td>&lt;0.02%</td>
</tr>
<tr>
<td>Shoveler</td>
<td>low number</td>
<td>&gt;1,000</td>
<td>Minor</td>
<td>&lt;0.05%</td>
</tr>
<tr>
<td>Common Pochard</td>
<td>710</td>
<td>&gt;3,500</td>
<td>High</td>
<td>0.20%</td>
</tr>
<tr>
<td>Tufted Duck</td>
<td>7,100</td>
<td>&gt;30,000</td>
<td>High</td>
<td>0.59%</td>
</tr>
<tr>
<td>Greater Scaup</td>
<td>130</td>
<td>&gt;12,000</td>
<td>Minor</td>
<td>0.04%</td>
</tr>
<tr>
<td>Common Eider</td>
<td>low number</td>
<td>327,505</td>
<td>Minor</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Long-tailed Duck</td>
<td>low number</td>
<td>23,800</td>
<td>Minor</td>
<td>&lt;0.001%</td>
</tr>
<tr>
<td>Common Scoter</td>
<td>low number</td>
<td>66,290</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Velvet Scoter</td>
<td>low number</td>
<td>3,050</td>
<td>Minor</td>
<td>&lt;0.001%</td>
</tr>
<tr>
<td>Common Goldeneye</td>
<td>low number</td>
<td>6,400</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Smew</td>
<td>low number</td>
<td>&gt;1,400</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Red-breasted Merganser</td>
<td>low number</td>
<td>7,800</td>
<td>Minor</td>
<td>&lt;0.05%</td>
</tr>
<tr>
<td>Goosander</td>
<td>low number</td>
<td>&gt;600</td>
<td>Minor</td>
<td>&lt;0.001%</td>
</tr>
<tr>
<td>White-tailed Eagle</td>
<td>low number</td>
<td>&gt;20</td>
<td>Minor</td>
<td>&lt;0.05%</td>
</tr>
<tr>
<td>Common Coot</td>
<td>low number</td>
<td>&gt;15,000</td>
<td>Minor</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Little Gull</td>
<td>low number</td>
<td>5,720</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Black-headed Gull</td>
<td>low number</td>
<td>8,250</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
</tbody>
</table>
Species | Estimated number of displaced individuals | Estimated maximum number in Fehmarnbelt | Severity of loss | Percentage of the biogeographic population
--- | --- | --- | --- | ---
Common Gull | low number | 6,700 | Minor | <0.01%
Lesser Black-backed Gull | low number | 9 | Minor | <0.001%
Herring Gull | low number | 10,600 | Minor | <0.01%
Great Black-backed Gull | low number | 1,200 | Minor | <0.01%
Sandwich Tern | low number | 350 | Minor | <0.01%
Common Tern | low number | 255 | Minor | <0.001%
Arctic Tern | low number | 150 | Minor | <0.001%
Common Guillemot | low number | 10 | Minor | <0.001%
Razorbill | low number | 1,180 | Minor | <0.01%
Black Guillemot | low number | 18 | Minor | <0.1%
Other species | | | | <0.1%

The severity of loss from the footprint of the bored tunnel for the impact zone corresponds in a spatial approach to the importance level of the lost area to the respective water-bird species. Regarding the entire study area the severity of loss is assessed quantitatively by comparing the number of displaced individuals with the size of the biogeographic population. The severity of loss is assessed to be high for Common Pochard and Tufted Duck and minor for all other non-breeding water-bird species (Table 5.78). This conclusion applies to both the construction and operation phases of the bored tunnel.

**Migrating birds**

This pressure is assessed as irrelevant for migrating birds. Therefore, no impact is predicted to result from ‘habitat loss from footprint’ for migrating birds in the Fehmarnbelt.

### 5.11.5 Impacts of habitat change due to sediment spill

**Magnitude of pressure**

During the construction of the bored tunnel a total 95,773 m³ of sediments would be spilled while dredging the working harbours, constructing the containment dikes, depositing the material at land reclamation sites and landscaping of the reclamation areas. The overall construction period is scheduled to last 6 years starting in October 2014. However, sediment spill to marine areas and thus impairments from habitat change are only predicted for the first two years (2014/2015) and the last year of construction (2020). The total amount of spilled material would be the highest in the first two construction years and lower in 2020 during landscaping activities.
The comparison of the predicted accumulated spill for the immersed and bored tunnel alternatives revealed that much less sediments would be spilled for the bored tunnel alternative, e.g. accumulated spill from the bored tunnel for the Danish side would be 14-20% of the predicted spill of the immersed tunnel construction (see section 5.3).

Impacts due to the sediment spill from construction of the bored tunnel on benthic vegetation in terms of reduced biomass are predicted for the years 2015 and 2020. No impact on benthic vegetation is predicted for the years 2016-2018. The eelgrass biomass in the Rødsand Lagoon is predicted to be reduced by 0-30% after the first growth season (2015) and by 0-20% in the last year of construction. In total 579 ha of eelgrass communities were assessed to be affected by minor degree of impairment and 4 ha by medium degree of impairment in 2015, and only 8 ha by minor degree of impairment in 2020. Compared to the predictions for the immersed tunnel, the bored tunnel alternative results in impairment in an area 13 times less than the immersed tunnel alternative.

The impact on the benthic fauna communities for the pressure suspended sediments is predicted to be insignificant, as the magnitude of pressure is below the set threshold values and within the range of natural variability.

A total of 1,506 ha of benthic fauna would be impacted by sedimentation. No impact in the central part of Fehmarnbelt has been predicted. A magnitude of pressure in the minor and medium category is expected along the coast of Fehmarn, Lolland, in Rødsand Lagoon and small areas in the coastal areas north of Fehmarn. High (36.5 ha) and very high (55 ha) magnitude of pressure occurs around the reclamation areas, working harbours and access channels at the Lolland and Fehmarn side. The impacted area corresponds to 0.5% of the assessment area (292,739 ha for the fauna). Parts of three fauna communities are lost due to very high magnitude of pressure (Cerastoderma, Gammarus and Mytilus communities). The loss of these communities in the local zone corresponds to less than 1% of the communities, which is regarded as insignificant (FEMA 2012e).

Impairment of fish communities due to direct and indirect effects of the sediment spill from the bored tunnel construction are predicted to result only in minor reductions of fish biomass below 5% where 5% was set as threshold above which a detectable effect on fish-eating water-birds would be predicted to result from this pressure; FEBI 2012b). Therefore, the degree of impairment from habitat change from sediment spill has been assessed to be minor for all fish-eating breeding and non-breeding water-bird species in the Fehmarnbelt and no birds would be displaced due to this pressure. Thus these species are not further considered in the assessment of this pressure.

Breeding water-birds
Mute Swan and Common Eider are breeding water-bird species identified as being potentially sensitive to the pressure ‘habitat change from sediment spill’.

Estimates suggest that up to 89 pairs of Mute Swans breed within Rødsand Lagoon. Breeding birds comprise a relatively small fraction of all swans present in Rødsand
Lagoon in spring and summer, and breeders were not separated from non-breeding individuals in the baseline investigations. Therefore, breeding birds of this species were accounted for when assessing possible impacts from sediment spill on non-breeding Mute Swans (see below), which is assessed to be minor.

Of 43 pairs of Mute Swans breeding within the SPA Eastern Kiel Bight, only 4 pairs possibly use marine areas that are expected to be affected by the sediment spill, while the majority of other pairs nest inland. Because biomass reduction of submerged vegetation is expected to be minimal in the Orth Bight and it would be centred in the deepest areas, the degree of impairment from habitat change from sediment spill is assessed to be minor for breeding Mute Swans in the Orth Bight. Minor food limitations would not result in displacement of breeding Mute Swans from affected areas.

Up to 389 pairs of Common Eiders breed within Rødsand Lagoon and 64 on the German side of the Fehmarnbelt (FEBI 2012a).

When tending their young, Common Eiders use shallow marine habitats where ducklings can feed on crustaceans and small molluscs. It was therefore assumed that all benthic communities found in Rødsand Lagoon could be potentially used by eiders: Bathyporeia, Cerastoderma, Gammarus, Mytilus and Rissoa. In the absence of specific information about habitat use by breeding Common Eiders, all benthic communities were assumed as being equally important. The numbers of birds being displaced were calculated considering the benthic community that was affected by the highest percentage within a particular category of degree of impairment.

For the immersed tunnel a medium degree of impairment of 2.34% of the Rissoa community in Rødsand Lagoon is the largest benthic impact predicted and is assessed to cause the displacement of 2 Common Eider individuals. The impacts from the bored tunnel alternative to benthic fauna are very small compared to the immersed tunnel alternative. Therefore it is predicted for the bored tunnel alternative that habitat changes in benthic fauna communities result in displacement of less than 2 Common Eiders.

Benthic fauna in the vicinity of Common Eider breeding places on the German side of the Fehmarnbelt would not be affected by the sediment spill. Therefore, it was concluded that none of these birds would be displaced due to habitat changes from sediment spill.

Within the Fehmarnbelt study area only small areas would be affected by medium degree of impairment due to habitat changes in benthic fauna communities. Numbers of displaced breeding Common Eiders due to this pressure would be very low, the impact to this species therefore regarded to be minor.

Non-breeding water-birds
For the immersed tunnel alternative it was assessed that the pressure ‘habitat change from sediment spill’ (medium degree of impairment) would result in displacement of minor or negligible numbers of the different non-breeding water-
bird species from the impaired areas (FEBI 2012b). Since for the bored tunnel solution in general considerably smaller areas are affected from impairments due to changes in benthic communities, it is predicted that considerably less birds would be displaced due to this pressure for the bored tunnel solution than described for the immersed tunnel alternative. Therefore actual calculations of the number of birds affected were not made. Only minor or negligible numbers of non-breeding water-birds are predicted to be displaced due to medium degree of impairment from relatively small impairment zones.

However, in order to justify the conclusion, a brief summary of the magnitude of the impacts for the immersed tunnel is given below. The number of birds displaced by the bored tunnel construction is expected to be considerably less than that for the immersed tunnel.

The number of non-breeding water-birds assessed to be displaced for the immersed tunnel solution is shown in Table 5.79 with the assessment briefly explained in the following.

Mute Swan and Whooper Swan: Swans occur predominantly in Rødsand Lagoon and, with smaller numbers, in Orth Bight south of Fehmarn. They feed on eelgrass and other submerged vegetation in shallow waters. The assessment of impacts on the benthic flora for the immersed tunnel showed that biomass in a 5 ha area of eelgrass will be reduced by 25-50%. Considering the total area and biomass of eelgrass available as food for swans this reduction does not result in any food limitation for swans and the impact is classified as minor. The biomass in 574 ha of eelgrass and 5 ha of tasselweed/dwarf eelgrass is reduced by less than 25% which is considered within natural variability and will not have any impact on swans.

Greylag Goose, Brent Goose, Eurasian Wigeon and Common Coot: These bird species feed on benthic vegetation in shallow areas where suspended sediments would not reduce light availability to critical levels and therefore vegetation growth would not change or would only be affected to a minor degree. The impacts to these species are therefore assessed to be minor for both the immersed and bored tunnels.

Common Pochard, Tufted Duck and Greater Scaup: These diving ducks typically roost during the day and forage on benthic organisms at night. Since only relatively small areas of relevant benthic fauna communities are predicted to be affected to a medium degree of impairment by sediment spill, only small numbers of ducks are affected, namely 7, 63 and 25 respectively are assessed to be displaced during the immersed tunnel construction. The impacts on these species are therefore assessed to be minor for both the immersed and bored tunnel alternatives.

Common Eider: Approximately 610 individuals are predicted to be displaced due to the pressure 'habitat change due to sediment spill' during construction of the immersed tunnel with the great majority (583) due to impacts on the Blue Mussel communities. Therefore only minor numbers of eiders are assessed to be affected by this pressure for the bored tunnel alternative as well.
Long-tailed Duck, Common Scoter and Common Goldeneye: As with the Common Eider, these bird species feed predominantly on blue mussels. It is assessed that approximately 33, 57 and 5 individuals would be displaced during construction of the immersed tunnel. Therefore only minor numbers of birds are predicted to be affected by this pressure for the bored tunnel alternative as well.

Velvet Scoter: This species feeds on infaunal bivalves and the impacts due to the pressure ‘habitat change due to sediment spill’ are predicted to cause the displacement of up to 3 individuals for the immersed tunnel. Therefore only minor numbers of birds are predicted to be affected by this pressure for the bored tunnel alternative as well.

In relation to the particular biogeographic populations for the immersed tunnel alternative only minor numbers of non-breeding water-birds have been predicted to be displaced from the impaired areas due to habitat change. With considerably smaller numbers of birds being affected by the bored tunnel alternative, the impacts from the pressure ‘habitat change from sediment spill’ are assessed as minor or negligible (Table 5.79).

Table 5.79 Numbers of non-breeding water-birds predicted to be displaced from areas affected by the pressure ‘habitat change due to sediment spill’ during the first year of construction of the immersed tunnel. Numbers of birds displaced by the bored tunnel alternative would be considerably smaller.

<table>
<thead>
<tr>
<th>Species</th>
<th>Displaced individuals</th>
<th>Impact</th>
<th>% of biogeographic population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mure Swan</td>
<td>Low number</td>
<td>Minor</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Whooper Swan</td>
<td>Low number</td>
<td>Minor</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Greylag Goose</td>
<td>Low number</td>
<td>Minor</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Brent Goose</td>
<td>Low number</td>
<td>Minor</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Eurasian Wigeon</td>
<td>Low number</td>
<td>Minor</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Common Pochard</td>
<td>7</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Tufted Duck</td>
<td>63</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Greater Scaup</td>
<td>25</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Common Eider</td>
<td>610</td>
<td>Minor</td>
<td>0.08%</td>
</tr>
<tr>
<td>Long-tailed Duck</td>
<td>33</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Common Scoter</td>
<td>57</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Velvet Scoter</td>
<td>Low number</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Common Goldeneye</td>
<td>5</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Common Coot</td>
<td>Low number</td>
<td>Minor</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Other species</td>
<td>Low number</td>
<td>Negligible/Minor</td>
<td>&lt;0.1%</td>
</tr>
</tbody>
</table>
Migrating birds

This pressure is assessed as irrelevant for migrating birds. Therefore, no impact is predicted to result from ‘habitat change from sediment spill’ for migrating birds in the Fehmarnbelt.

Significance of impact

The significance of the impact of sediment spill is assessed by comparing the number of birds displaced with their biogeographic population, see Table 5.79. In all cases the numbers affected correspond to far less than 1% of the respective biogeographic populations and the impacts are therefore assessed as insignificant.

5.11.6 Impacts of reduced water transparency due to sediment spill

Magnitude of pressure

The amounts of sediment spilled during the construction of the bored tunnel are described in the water quality section above. The spill material is suspended, settles and under given conditions is re-suspended from the seabed depending on the grain size of the material and a range of hydrodynamic factors.

The optical properties of the material dredged during the immersed tunnel construction activities have been used to calculate the potential impact of suspended spill material on the light conditions in Fehmarnbelt, quantified as a reduction of the Secchi depths (see water quality section above).

Fluctuations in Secchi depth, frequency and duration of different conditions are possibly more important characteristics to wintering water-birds than simple average seasonal value representing water transparency. Even under natural (baseline) conditions Secchi depth varies within a rather broad range. Occurrence of reduced water transparency relative to the baseline conditions is predicted to increase during the first two years and the last year of the bored tunnel construction. Considering the sensitivity of water-bird species to reduced water transparency, the assessment has been based on an assumed complete displacement of birds from the impairment zone (i.e. very high degree of impairment). The determination of threshold levels of water transparency and the resulting spatial extent of the pressure (impairment zone) for sensitive species are described in FEBI (2012b). It was assumed that birds would avoid areas where the Secchi depth would drop more than 5% of the time below a certain threshold value (defined as the lower limit of 95% confidence interval of mean Secchi depth under baseline conditions, see FEBI 2012b).

Considering the Secchi depth threshold of 3.74 m as defined in FEBI (2012b), the occurrence of reduced transparency relative to the baseline conditions would be most pronounced during the first winter of the tunnel construction (Figure 5.107). In both impact winters the impairment from decreased water transparency would affect mostly the southern and western part of Rødsand Lagoon and would stretch along the Lolland coast east and west of Rødbyhavn (Figure 5.107 and Figure
5.108). No impairment on water-birds is predicted for offshore areas and the German part of the study area (Figure 5.107).

Considering the Secchi depth threshold of 3.73 m as defined in FEBI (2012b) for summer season, the occurrence of reduced transparency relative to the baseline conditions would be more pronounced during the first summer of the tunnel construction (2015) compared to the last summer (2020, Figure 5.108). During the first impact season the impairment from decreased water transparency would affect mostly the southern and western part of Rødsand Lagoon and the stretch along the Lolland coast between Rødbyhavn and Hyllekrog (Figure 5.108). The affected area would be limited mainly to the western part of Rødsand Lagoon during the last summer of the tunnel construction. No impairment on water-birds is predicted for offshore areas and the German part of the study area in summer seasons (Figure 5.108).
Figure 5.107 Modelled difference in occurrence of Secchi depth below 3.74 m during winter 2014/2015 (upper) and winter 2019/2020 (lower) during the bored tunnel construction relative to the baseline conditions (calculated by subtracting baseline from the tunnel construction scenario).
Figure 5.108  Modelled difference in occurrence of Secchi depth below 3.73 m during summer 2015 (upper map) and summer 2020 (lower map) during the bored tunnel construction relative to the baseline conditions (calculated by subtracting baseline from the tunnel construction scenario).
Breeding water-birds

Reduced water transparency during the summer period is anticipated only on the Danish side of the Fehmarnbelt and only during the first and last years of construction works (Figure 5.108). Therefore, impacts due to reduced water transparency are only assessed for birds using the Danish part of the Fehmarnbelt.

Red-necked Grebes nest on inland lakes and ponds and adult birds often fly to forage in marine coastal waters during the breeding season. Twenty-one pairs of Red-necked Grebes were recorded nesting in the coastal area of Lolland in the vicinity of Rødbyhavn and could potentially be affected by reduced water transparency. Impacts are assessed in the chapter on Lolland.

Nine pairs of Red-breasted Mergansers bred in the SPA Hyllekrog-Rødsand in 2009, and no breeders of this species were recorded in other areas of Lolland. After hatching, the adults take their chicks to the sea and stay in shallow waters. Because 6 out of the 9 breeding pairs were recorded in the northern and eastern part of the lagoon where no major changes in water transparency are predicted (Figure 5.108) it was assumed that only pairs breeding in the turbid areas would be affected from the very high degree of impairment due to this pressure, i.e. 3 pairs in the first summer (2015) of the tunnel construction and 1-2 pairs in the last summer (2020). No impairment is predicted for the other seasons. Due to low numbers of affected birds, the impact on Red-breasted Mergansers is assessed as being minor in all breeding seasons during the tunnel construction.

For other water-bird species breeding in Natura 2000 areas only minor impacts from decreased water transparency are assessed, either due to low numbers of birds occurring in the predicted disturbance zone or due to minor sensitivity of the species to this pressure.

Non-breeding water-birds

For the two construction winters, for which decreased water transparency due to the sediment spill is predicted (2014/2015 and 2019/2020) up to 2,650 Common Eiders would be affected to a very high degree of impairment, i.e. would be displaced from the impaired areas, mostly coastal areas of Lolland and the Rødsand Lagoon (Figure 5.109, Table 5.80). Compared to the assessment result for this pressure from construction of the immersed tunnel (FEBI 2012b), the maximum estimate for displaced Common Eiders is lower by more than factor 3. Based on the number of birds predicted to be displaced, the impact from this pressure for the bored tunnel construction is assessed as medium for the Common Eider (very high for the immersed tunnel alternative).

Regarding the Red-breasted Merganser, in the year of the highest impact from the bored tunnel construction it is predicted that 444 birds would be affected to a very high degree of impairment, i.e. would be displaced from the impairment zone (Figure 5.110). The number was calculated on the basis of the distribution model from ship-based survey data and the distribution model from aerial survey data for areas not covered from the ship-based surveys. Based on the number of birds predicted to be displaced the impact from this pressure for the bored tunnel
construction is assessed as minor for the Red-breasted Merganser (medium for the immersed tunnel alternative) (Table 5.80).

For all other non-breeding water-bird species it is predicted that only low numbers would be displaced from the impairment zone. Therefore the impact from the pressure ‘reduced water transparency’ is assessed as minor for these species (Table 5.80).
Figure 5.109  Extent of the impairment zone of the pressure ‘decreased water transparency’ from the bored tunnel construction in the winter of the highest impact (first construction winter 2014/2015). Common Eider distribution for the winter 2009/2010. It is predicted that all birds within the impairment zone would be displaced from that area (very high degree of impairment).

Figure 5.110  Extent of the impairment zone of the pressure ‘decreased water transparency’ from the bored tunnel construction in the winter of the highest impact (first construction winter 2014/2015). Red-breasted Merganser distribution of the winter 2009/2010. It is predicted that all birds within the impairment zone would be displaced from that area (very high degree of impairment).
Table 5.80 Numbers of non-breeding water-birds predicted to be displaced from areas of very high degree of impairment (impairment zone) due to the pressure ‘reduced water transparency’ during the first and last construction winter of the bored tunnel

<table>
<thead>
<tr>
<th>Species</th>
<th>Season</th>
<th>Estimated number of displaced birds</th>
<th>Impact</th>
<th>% of the biogeographic population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divers</td>
<td>2014/2015</td>
<td>16</td>
<td>Minor</td>
<td>0.005%</td>
</tr>
<tr>
<td></td>
<td>2019/2020</td>
<td>13</td>
<td>Minor</td>
<td>0.004%</td>
</tr>
<tr>
<td>Red-necked Grebe</td>
<td>2014/2015</td>
<td>17</td>
<td>Minor</td>
<td>0.033%</td>
</tr>
<tr>
<td></td>
<td>2019/2020</td>
<td>13</td>
<td>Minor</td>
<td>0.025%</td>
</tr>
<tr>
<td>Common Eider</td>
<td>2014/2015</td>
<td>2,649</td>
<td>Medium</td>
<td>0.349%</td>
</tr>
<tr>
<td></td>
<td>2019/2020</td>
<td>1,991</td>
<td>Medium</td>
<td>0.262%</td>
</tr>
<tr>
<td>Long-tailed Duck</td>
<td>2014/2015</td>
<td>334</td>
<td>Minor</td>
<td>0.007%</td>
</tr>
<tr>
<td></td>
<td>2019/2020</td>
<td>273</td>
<td>Minor</td>
<td>0.006%</td>
</tr>
<tr>
<td>Common Scoter</td>
<td>2014/2015</td>
<td>81</td>
<td>Minor</td>
<td>0.005%</td>
</tr>
<tr>
<td></td>
<td>2019/2020</td>
<td>73</td>
<td>Minor</td>
<td>0.005%</td>
</tr>
<tr>
<td>Common Goldeneye</td>
<td>2014/2015</td>
<td>782</td>
<td>Minor</td>
<td>0.068%</td>
</tr>
<tr>
<td></td>
<td>2019/2020</td>
<td>662</td>
<td>Minor</td>
<td>0.058%</td>
</tr>
<tr>
<td>Red-breasted Merganser</td>
<td>2014/2015</td>
<td>444</td>
<td>Minor</td>
<td>0.261%</td>
</tr>
<tr>
<td></td>
<td>2019/2020</td>
<td>347</td>
<td>Minor</td>
<td>0.204%</td>
</tr>
<tr>
<td>Razorbill</td>
<td>2014/2015</td>
<td>1</td>
<td>Minor</td>
<td>&lt;0.001%</td>
</tr>
<tr>
<td></td>
<td>2019/2020</td>
<td>1</td>
<td>Minor</td>
<td>&lt;0.001%</td>
</tr>
<tr>
<td>Other species</td>
<td>all seasons</td>
<td>Minor</td>
<td>Minor</td>
<td>&lt;0.1%</td>
</tr>
</tbody>
</table>

Migrating birds
This pressure is assessed as irrelevant for migrating birds. Therefore, no impact is predicted to result from ‘decreased water transparency’ for migrating birds in the Fehmarnbelt.

Significance of impact
The significance of the impact of sediment spill is assessed by comparing the number of birds displaced with their biogeographic population, see Table 5.80. In all cases the bird numbers predicted to be affected are far less than 1% and the impacts are therefore assessed as insignificant.
5.11.7 Impact of disturbance from construction activities

Magnitude of pressure

For the construction of the bored tunnel some works are planned to take place in marine areas of the Fehmarnbelt and thus represent a source of potential disturbance on breeding and non-breeding water-birds using these areas. The construction activities would cause disturbance to a number of water-birds species described to be sensitive to these activities. The pressure is defined as the physical presence including noise, vibration and light emissions of construction vessels and machines involved in the construction activities.

There would be three construction harbours built and operated during the construction period of the bored tunnel: one east of Puttgarden on Fehmarn, and one east and one west of Rødbyhavn on Lolland. The construction works for the harbours would also include the dredging of access channels to these harbours.

The construction of the land reclamations would require construction works in marine areas, such as the erection of containment dikes and dikes within the reclamations. Other activities following the reclamation works would mostly be conducted from land and dikes, thus presumably reducing the impact on marine areas outside the reclamations in the later construction years.

Vessel traffic between the construction harbours would increase the overall vessel traffic intensity in the alignment area. It is estimated that about 10 barges (1,000 m³ capacity each) would be tugged from Fehmarn to Lolland (and back) every day for transporting the slurry. However, additional vessel traffic would mostly take place in an area, which is already highly disturbed by shipping from the ferry line. Therefore, no relevant additional impact from additional shipping between the construction harbours is expected. Impacts from disturbance are only expected for areas where construction works are conducted in marine areas. The project footprint (i.e. the area where construction activities take place) plus a 3 km buffer zone around it was defined as disturbance zone, within which displacement of all birds of sensitive species is assumed (very high degree of impairment) (Figure 5.111).
Breeding water-birds

Red-necked Grebe is an abundant breeding bird on Fehmarn with 30 pairs breeding in the reserve Grüner Brink. Since the disturbance zone would not affect the adjacent coastal waters of Grüner Brink and the impairment area is already highly impaired by intense ferry traffic, the impact of the disturbance zone on these birds is assessed to be minor. The impacts on Red-necked Grebe breeding on Lolland are assessed in the chapter on Lolland.

The nature reserve Grüner Brink on Fehmarn is the closest reported breeding site of Red-breasted Mergansers to the disturbance zone. Red-breasted Mergansers use shallow marine areas to rear their offspring. Since the disturbance zone would not affect the adjacent coastal waters of Grüner Brink and the area east of Grüner Brink is already highly disturbed from the ferry traffic between Puttgarden and Rødbyhavn, the predicted impact on these birds is assessed as minor. Birds breeding in the Rødsand Lagoon are not expected to be affected by the pressure.

White-tailed Eagles forage on a variety of prey including carrion, birds and fish, and the species uses different inland and coastal habitats for feeding. The coastal areas of the predicted disturbance zone are possible foraging habitats of White-tailed Eagle, but are assessed to be of minor importance to the species, since these areas are already highly disturbed by the existing ferry traffic and tourist activities. Therefore the impact from disturbance from construction vessels is assessed to be minor for White-tailed Eagles breeding on Fehmarn and Lolland.
Gulls and terns are not sensitive to disturbance from ships while foraging at sea. Therefore the impact from disturbance due to construction vessels is assessed to be minor for these species.

**Non-breeding water-birds**

The shallow waters along the coasts of Lolland and Fehmarn are frequented by different non-breeding water-bird species for foraging and resting, some also use existing marine structures (e.g. breakwaters of the ferry harbours) for roosting. Intersecting species distributions with the predicted disturbance zone gives an estimate of the number of birds which would be displaced by the construction activities. For most species the numbers of displaced birds would be low compared to the size of the respective biogeographic populations, thus the impact of the pressure is assessed as minor (Table 5.81).

The predicted impact in terms of numbers of displaced birds is higher than minor for four species:

**Eurasian Wigeon**: Maximum counts indicate that, with up to 1,500 birds (0.10% of the biogeographic population), medium important numbers of Eurasian Wigeon use the area of the disturbance zone in winter time. Therefore, it is assumed that similar numbers would be displaced from that area. The impact from disturbance from construction vessels for the Eurasian Wigeon is assessed to be medium.

**Common Pochard**: Maximum daytime counts indicate that, with more than 700 birds (0.20% of the biogeographic population), highly important numbers of Common Pochard use the alignment area in winter time. It is assumed that similar numbers of night-time active Common Pochard would be displaced from the disturbance zone in winter. Thus, the impact from disturbance from construction vessels for the Common Pochard is assessed to be high.

**Tufted Duck**: Maximum daytime counts indicate that, with more than 7,000 birds (0.58% of the biogeographic population) using the area, highly important numbers of Tufted Duck use the alignment area in winter time. It is assumed that similar numbers of night-time active Tufted Ducks would be displaced from the disturbance zone in winter. Thus, the impact from disturbance from construction vessels for the Tufted Duck is assessed to be high.

**Common Eider**: The Fehmarnbelt area is a very important wintering area for the species holding up to 40% of the biogeographic population. Consequently, also large proportions of the alignment area have been evaluated as being of very high importance, though clearly not being an area of high densities within the Fehmarnbelt study area. Considering the maximum estimate for Common Eiders in the Fehmarnbelt study area (as it was recorded in winter 2009/2010), a maximum number of 4,739 birds (0.62% of the biogeographic population) would be displaced from the disturbance zone. Therefore the disturbance from construction vessels is assessed to result in a medium impact for the Common Eider.
Figure 5.112 Extent of the impairment zone of the pressure ‘disturbance from construction activities’ from the bored tunnel construction. Common Eider distribution of the winter 2009/2010. It is predicted that all birds within the impairment zone would be displaced from that area (very high degree of impairment).

Table 5.81 Numbers of non-breeding water-birds predicted to be displaced from areas of very high degree of impairment (disturbance zone) due to the pressure ‘disturbance from construction activities’ during the construction of the bored tunnel.

<table>
<thead>
<tr>
<th>Species</th>
<th>Estimated number of displaced birds</th>
<th>Impact</th>
<th>Percentage of the biogeographic population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divers</td>
<td>9</td>
<td>Minor</td>
<td>0.003%</td>
</tr>
<tr>
<td>Red-necked Grebe</td>
<td>26</td>
<td>Minor</td>
<td>0.05%</td>
</tr>
<tr>
<td>Great Cormorant</td>
<td>500</td>
<td>Minor</td>
<td>0.12%</td>
</tr>
<tr>
<td>Eurasian Wigeon</td>
<td>1,500</td>
<td>Medium</td>
<td>0.10%</td>
</tr>
<tr>
<td>Common Pochard</td>
<td>710</td>
<td>High</td>
<td>0.20%</td>
</tr>
<tr>
<td>Tufted Duck</td>
<td>7,100</td>
<td>High</td>
<td>0.59%</td>
</tr>
<tr>
<td>Greater Scaup</td>
<td>130</td>
<td>Minor</td>
<td>0.04%</td>
</tr>
<tr>
<td>Common Eider</td>
<td>4,739</td>
<td>Medium</td>
<td>0.62%</td>
</tr>
<tr>
<td>Long-tailed Duck</td>
<td>98</td>
<td>Minor</td>
<td>0.002%</td>
</tr>
<tr>
<td>Common Scoter</td>
<td>378</td>
<td>Minor</td>
<td>0.02%</td>
</tr>
<tr>
<td>Velvet Scoter</td>
<td>low number</td>
<td>Minor</td>
<td>&lt;0.01%</td>
</tr>
<tr>
<td>Common Goldeneye</td>
<td>94</td>
<td>Minor</td>
<td>0.008%</td>
</tr>
<tr>
<td>Red-breasted Merganser</td>
<td>210</td>
<td>Minor</td>
<td>0.12%</td>
</tr>
<tr>
<td>White-tailed Eagle</td>
<td>low number</td>
<td>Minor</td>
<td>&lt;0.10%</td>
</tr>
</tbody>
</table>
Species | Estimated number of displaced birds | Impact | Percentage of the biogeographic population
--- | --- | --- | ---
Common Coot | 340 | Minor | 0.02%
Razorbill | 4 | Minor | <0.001%
Black Guillemot | low number | Minor | <0.10%
Other species | | Minor | <0.10%

Migrating birds
This pressure is assessed as irrelevant for migrating birds. Therefore, no impact is predicted to result from ‘disturbance from construction activities’ for migrating birds in the Fehmarnbelt.

Significance of impact
The significance of impact from the pressure ‘disturbance from construction activities’ is assessed by comparing the number of birds displaced with their biogeographic population, see Table 5.81. In all cases the number predicted to be affected are less than 1% of the respective biogeographic population of a species and the impacts are therefore assessed as insignificant.

5.11.8 Significance of impacts – summary
The percentage of the biogeographic population predicted to be displaced by the aggregated effects of the different pressures of the project corresponds to less than 1% of the respective biogeographic populations for all water-bird species. This conclusion applies to the impacts during the construction and operation phases and by structures. It also applies to all species of breeding and non-breeding water-birds. For migrating birds it is assessed that the project will have no relevant impacts.

Therefore the overall conclusion is that the project impacts on birds in the marine area are insignificant.

5.11.9 Mitigation and compensation
Mitigation and compensation measures other than those already included in the project design are not found to be necessary due to the low level of impact.

However, it is mentioned that the new land reclamations will provide suitable habitats for roosting and breeding by some bird species.

5.11.10 Decommissioning
There will be no impacts on the marine area from decommissioning activities and therefore no impacts on water-birds or migrating birds are predicted.
5.12 Migrating bats

It is well known that bats from some European populations migrate between their summer and winter areas (Vauk 1974, Gerell 1987, Ahlén 1997, Skiba 2007). The winter is spent in Southern and Eastern Europe and they migrate north to Denmark and Scandinavia for breeding in summer. The knowledge about bat species, which are supposed to be migratory, their flyways, flight altitudes and distances is very limited. Although some species like the Nathusius’ Pipistrelle and the Noctule have been studied for years, no reliable flyways or population sizes can be defined. The current state of research lacks detailed information on migration corridors, flight altitudes during migration and total population sizes leading to uncertainties in assessing impacts on bat migration.

Bats occur regularly in the Fehmarnbelt coastal area and some species have been proven to migrate across Fehmarnbelt (FEBI 2012c). In particular during autumn bats were observed crossing Fehmarnbelt. There is no indication that bats would use specific migration corridors and the direction of migration is not clear (FEBI 2012c). It is assumed that bats cross Fehmarnbelt on a broad front and that the alignment area of a planned fixed link does not play a special role for bat migration. Fehmarnbelt has thus been considered to be of general importance for bat migration (FEBI 2012d).

All bat species are protected through their listing in Annex IV of the EU Habitats Directive.

Bats are within the environmental factor “fauna” as shown in Table 5.82 which lists the species observed over Fehmarnbelt. The baseline studies registered both migrating and local bats offshore Fehmarnbelt. Impact assessments are made in this section for the migrating bats while the local bats are addressed in the chapters on Lolland and Fehmarn.

Table 5.82 Bats registered over Fehmarnbelt

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sub-factor</th>
<th>Component</th>
<th>Sub-component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fauna</td>
<td>Bats</td>
<td>Migrating bats</td>
<td>Nathusius’ Pipistrelle</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soprano Pipistrelle</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Noctule</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local bats</td>
<td>Serotine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(bats which were registered</td>
<td>Common Pipistrelle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>offshore but which do not</td>
<td>Pond Bat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>migrate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>between south/east Europe and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scandinavia)</td>
<td></td>
</tr>
</tbody>
</table>

5.12.1 Project pressures and potential impacts

The present report describes the pressures of the bored tunnel solution and assesses the potential effects on migrating bats during construction, due to the permanent physical structures and in the operation phase.
The pressures from the bored tunnel project which potentially could impact migrating bats are listed in Table 5.83.

<table>
<thead>
<tr>
<th>Project pressure</th>
<th>Potential impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disturbance due to construction activities*:</td>
<td>Displacement or death of bats thus reducing the local population.</td>
</tr>
<tr>
<td>› Collision with construction vessels</td>
<td></td>
</tr>
<tr>
<td>› Barrier effect of construction vessels</td>
<td></td>
</tr>
<tr>
<td>› Temporary habitat change or loss</td>
<td></td>
</tr>
<tr>
<td>Permanent physical structures</td>
<td>Reduction of population</td>
</tr>
<tr>
<td>› Habitat change or loss</td>
<td></td>
</tr>
<tr>
<td>Operation of fixed link:</td>
<td>Reduction of population</td>
</tr>
<tr>
<td>› Collision with vehicle traffic</td>
<td></td>
</tr>
</tbody>
</table>

* Noise excluded because no passive listening species were detected in the baseline studies (FEBI 2012c)

All pressures ‘related to construction and the permanent physical structures were assessed to result in no or minor effects on bats in the impact assessment for the immersed tunnel alternative (FEBI 2012d). The effects on bats from these pressures for the bored tunnel solution are considered to be comparable to, or considerably reduced (far fewer construction vessels) compared with the immersed tunnel and are therefore not addressed further in this report.

5.12.2 Existing bat populations over Fehmarnbelt

The general knowledge about migratory bat species, their flyways, flight altitudes and distances is very limited. Only few studies have been undertaken on land and even fewer over the sea. The baseline studies over Fehmarnbelt were carried out in 2009 and 2010 both from coastal stations and in the marine area of the link alignment. The coastal stations were used to observe bats crossing between land and sea while the presence of bats along dikes, bushes and other natural commuting paths was also investigated. The studies provided sufficient data to describe the activity of the bats, their species diversity and abundance.

Several techniques were used to collect data on migration intensity, species diversity and migratory behaviour of bats over Fehmarnbelt. A range of investigation methods were developed and tested during the autumn migration period in 2009 (13 August to 19 October 2009) and continued in 2010 covering the spring to autumn period (1 April to 1 November 2010).

Bat calls were recorded at fixed stations and during manual surveys using two different ultrasound detector types: the Pettersson 240x and the AnaBat SD1. The two Scandlines ferries in regular service between Rødby and Puttgarden and the research vessel used for the bird baseline studies were also equipped with AnaBat SD1 detectors. To investigate possible migration at greater heights an AnaBat SD1 detector was attached to a kite and raised to a height of 60 m at night on four occasions.
The locations of the baseline study stations are shown in Figure 5.113. The five stations on the Lolland and Fehmarn coasts were used to study the species diversity during the migration period. In addition a number of manual surveys were carried out on the Lolland and Fehmarn coasts and at Gedser.

Studies were also carried out at the Øresund Bridge with the purpose of determining the species of bats which occur at existing links.

Leisler’s Bat, Noctule, Nathusius’ Pipistrelle and the Parti-coloured Bat are known as long-distance migrating bats which cover 3,000 – 4,000 km between their breeding areas and their hibernation roosts. Another category is the group of the “regional migrants” which migrate distances of up to 800 km, e.g. Barbastelle, Northern Bat, Common Pipistrelle and Pond Bat.

Bats were registered at different localities along the coasts and along the entire link alignment. In total six species (Nathusius’ Pipistrelle *Pipistrellus nathusii*, Soprano Pipistrelle *Pipistrellus pygmaeus*, Noctule *Nyctalus noctula*, Serotine *Eptesicus serotinus*, Common Pipistrelle *Pipistrellus pipistrellus* and Pond Bat *Myotis dasycneme* were recorded over the Fehmarnbelt during migration periods. The species composition during the migration phases is dominated by Nathusius’ Pipistrelle, Soprano Pipistrelle and Noctule which are therefore considered to be
relevant for the EIA regarding the marine environment of the Fehmarnbelt (Figure 5.114).

![Graph showing species composition over Fehmarnbelt as registered at the anchor positions AP5 and AP8 in 2009 and 2010]

Most bat activity (95%) was observed under conditions of wind speeds under 7 m/s and temperatures over 10°C. Virtually no activity was observed during rain.

Most of the bat species observed over Fehmarnbelt were also observed over Øresund where Nathusius’ Pipistrelle, Soprano Pipistrelle and Noctule were also the most common.

Near the coasts the most frequently observed species were Nathusius’ Pipistrelle (32%) and Soprano Pipistrelle (35%). The Common Pipistrelle was also reasonably frequent at 18%. The largest proportion of the observations was made at Hyllekrog (58%). The marshes, bush areas, dikes and a large concentration of insects are expected to be the reasons for the high occurrence of bats at Hyllekrog. The largest proportion of the observations (27%) on Fehmarn was made at Waldpavillon east of Puttgarden.

Of the six observations of Leisler’s Bat, four of these were at Waldpavillon. Daubenton’s Bat was registered six times at Rødbyhavn and once at Hyllekrog. Both species were therefore rarely observed in the study area.

### 5.12.3 Methodology

The impact assessment for the bored tunnel is based on the same data sets and follows the same methodological approach as used and described in the impact assessment on bats for the main project alternatives (FEBI 2012d).
The baseline provides detailed information on activity, distribution and habitat use of bats in the project area, as well as a review of the current state of knowledge concerning bat migration and flight patterns during migration at the location of the Fehmarn link. Different investigation methods were developed and tested during the baseline investigations (FEBI 2012c). Up to now no international standard for bat studies in offshore areas exists and only few studies have been conducted in offshore areas of the Baltic Sea. The importance of the study area for migrating bats is assessed in the baseline report (FEBI 2012c).

The methodology applied for the assessment of impacts is similar to that used for birds and other biological issues.

The sensitivity of migrating bats to the project pressures was assessed using baseline data and literature information. The magnitude of the pressure and the sensitivity to that pressure are used to estimate the magnitude of the impact. The magnitude of the impacts is expressed as, e.g. the proportion of migrating bats being displaced from the impairment zone or the proportion of bats colliding with traffic. The proportion can only be assessed qualitatively (very high, high, medium, minor) due to the lack of definitive studies allowing quantification of impacts.

The degree of impairment is then related directly to the magnitude of impact or, in other words, the proportion of bats affected. A very high degree of impairment corresponds to a very high proportion of bats being affected and means that there is a loss of function of the impairment zone for bats.

The criteria are defined in Table 5.84 for the pressure ‘collision with vehicle traffic’. The criteria are not shown for other pressures since they have already been screened out as relevant for further assessment. However, the criteria are available in the detailed background report FEBI 2012d.

**Table 5.84 Criteria for assessing the degree of impairment for migrating bats**

<table>
<thead>
<tr>
<th>Project pressure</th>
<th>Degree of impairment</th>
<th>Magnitude of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collision with vehicle traffic</td>
<td>Very high</td>
<td>A high proportion of migratory bats collide with the traffic on a regular basis</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>A small proportion of migratory bats collide with the traffic on a regular basis</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>Collisions with traffic are infrequent and the risk is limited.</td>
</tr>
<tr>
<td></td>
<td>Minor</td>
<td>Collisions between migrating bats and traffic are unlikely and limited to single individuals.</td>
</tr>
</tbody>
</table>

Finally, the significance of the impacts is assessed by considering the overall effect on the respective migrating bat populations.
5.12.4 Impacts during the construction phase
The assessment of the immersed tunnel (FEBI 2012d) showed that all pressures resulting from the construction works did not cause any detectable impacts/losses/impairments on migrating bats.

For the bored tunnel there will be far fewer construction vessels involved, in fact only vessels delivering construction materials and a few barges each day delivering the dewatered slurry from Fehmarn to the Lolland reclamation area. Therefore collision with, and barrier effects of the construction vessels will be negligible.

The disturbance from activities at the reclamation areas will be the same for both solutions.

Therefore the impacts on migrating bats from construction of a bored tunnel are assessed to the same or less than those for the immersed tunnel and are therefore also insignificant.

5.12.5 Impacts during the operation phase
Following the assessment of the immersed tunnel (FEBI 2012d) only the pressure ‘traffic related collision risk for migrating bats’ is predicted to potentially result in relevant impacts on bats in the area of tunnel ramps and tunnel portals. All other pressures related to structures and the operation of the immersed tunnel are assessed as not having any detectable impact on migrating bats. Due to the large degree of similarity between the two tunnel solutions it is assessed that the conclusion also applies to the bored tunnel. Therefore, pressures other than ‘collision risk’ are not addressed further here.

In the area of the tunnel ramps and portals the traffic gives rise to a permanent collision risk between bats and traffic. This risk is enhanced by the illumination of tunnel ramps and portals which attracts insects leading to an attraction of bats to the food resource. The pressure is a collision risk for bats due to the physical presence of vehicles (volume of traffic and speed) and light emission during operation conditions.

The total road traffic consisting of cars, buses and trucks is predicted to amount to about 11,723 vehicles per day in 2025. The traffic during the night is estimated at 2,110 vehicles and 30 trains. Only the periods of twilight and night-time are of interest for assessing the impacts of collision between bats and traffic.

The degree of impairment is assessed for the three relevant species on the basis of the estimated proportion of migratory bats colliding with traffic.

Nathusius’ Pipistrelle and Soprano Pipistrelle
These two species are known to forage next to illuminated areas and might use the illuminated tunnel portal and ramp areas. It cannot be excluded that Nathusius’ Pipistrelle and Soprano Pipistrelle would use these areas as a hunting habitat, which includes hunting next to or even within the risk area. This would result in an increased risk of collision with traffic and therefore might cause bat fatalities.
A medium risk of collision is assessed for Nathusius’ Pipistrelle and Soprano Pipistrelle in the area of tunnel portals and ramps. Therefore the degree of impairment regarding this pressure is assessed to be medium for the two species.

Noctule
On land the Noctule is known to fly at high altitudes which would be above the risk area (traffic space). The probability of being affected by vehicles using the fixed link is therefore low. Additionally, the traffic space at the tunnel entrances will be below the ground level in the surrounding area, which would reduce the risk of collision of traffic with the generally high flying Noctule.

A minor risk of collision is assessed for the Noctule in the area of tunnel portals and ramps. Therefore the degree of impairment regarding this pressure is assessed to be minor for this species.

5.12.6 Summary and assessment of significance of impact
All pressures resulting from the construction of the bored tunnel are assessed to have no detectable impacts on migrating bats. Therefore the impacts on migrating bats during construction are insignificant.

Regarding the permanent structures and the operation of a bored tunnel, only the pressure ‘traffic related collision risk’ is predicted to result in relevant impacts on migrating bats. The assessment of degree of impairment for this pressure is summarised for the three relevant migrating bat species in Table 5.85. The degree of impairment is assessed as medium for Nathusius’ Pipistrelle and Soprano Pipistrelle, and minor for Noctule.

Since the tunnel ramps and portals would be below the surrounding ground level, the risk of collision with bats would be reduced. Also, the impairment zone of the tunnel ramp and portal areas at Rødbyhavn and Puttgarden would be relatively small and the main part of the tunnel structure would be located under the seabed and not within the sphere of action of bats. Furthermore, bat migration is expected to occur on broad front and no important flyways were identified in the Fehmarnbelt area during the baseline investigations (FEBI 2012c). Thus, it can be expected that only a small proportion of the bats migrating across the Fehmarnbelt would be affected from a potential collision risk with traffic. Therefore, the impact from structures and operation of a bored tunnel in the Fehmarnbelt is assessed as insignificant for migrating bats.

Table 5.85 Degree of impairment and significance of impact for migrating bats

<table>
<thead>
<tr>
<th>Species</th>
<th>Degree of impairment</th>
<th>Significance of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Traffic collision risk</td>
<td>All other pressures</td>
</tr>
<tr>
<td>Nathusius’ Pipistrelle</td>
<td>Medium</td>
<td>No/Minor</td>
</tr>
<tr>
<td>Soprano Pipistrelle</td>
<td>Medium</td>
<td>No/Minor</td>
</tr>
<tr>
<td>Noctule</td>
<td>Minor</td>
<td>No/Minor</td>
</tr>
</tbody>
</table>
In conclusion the overall impact of the construction and operation of the bored tunnel project on migrating bats is assessed as insignificant.

5.12.7 Mitigation and compensation
Mitigation and compensation measures for migrating bats are not necessary due to the insignificance of the impacts.

5.12.8 Decommissioning
There will be no impacts predicted for the marine area from decommissioning activities and therefore no relevant impacts on migrating bats.
5.13 Commercial Fishery

This section deals with the impacts of the bored tunnel construction and operation on commercial fishery in Fehmarnbelt.

The primary catch of commercial species in Fehmarnbelt over the last decade has been sprat by weight and cod by value. However, there are a number of other important species for commercial fishery such as herring, flatfish species (flounder, dab, plaice, turbot, brill and sole), whiting, horse mackerel, European eel, garfish, salmon and sea trout, which are at times the primary fish targeted or are an important supplement to the overall landings.

Denmark and Germany are, almost without exception, the only countries that undertake commercial fishing in Fehmarnbelt and its regional area. Trawls are used in deeper waters (>10 m) with soft bottoms, gill nets are used in all types of seabed habitats, pound nets are placed near the coastlines and Danish seine nets are typically used in deeper open waters. Landings in recent years (1998-2008) from the Western Baltic, which includes Fehmarnbelt, have annually amounted to approximately 18,000 tons with a value of 14.7 million euro in the Danish fishery and 10,600 tons with a value of 10.5 million euro in the German fishery. Denmark undertakes the greater part of the commercial fishing in the fishery statistical area ICES 38G1 that contains the majority of Fehmarnbelt and the proposed Fehmarnbelt Fixed Link.

Commercial fish comes under the environmental factor socio-economy, see Table 5.86.

Table 5.86 Fishery sub-components for the Fehmarnbelt region

<table>
<thead>
<tr>
<th>Factor</th>
<th>Component</th>
<th>Sub-component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socio-economy</td>
<td>Commercial fishery</td>
<td>Trawl fishery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gill net fishery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pound net fishery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Danish seine net fishery</td>
</tr>
</tbody>
</table>

5.13.1 Project pressures and potential impacts

The project pressures which can potentially impact commercial fishery are primarily related to the establishment of marine structures and the sediment spill during the construction phase. These are described in Table 5.87.
Table 5.87  Project pressures and potential impacts on commercial fishery

<table>
<thead>
<tr>
<th>Project pressure</th>
<th>Potential impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction phase: Permanent and temporary marine structures (land reclamations, work harbours and access channels)</td>
<td>Possible reduction of catch due to loss of fishing area</td>
</tr>
<tr>
<td>Construction phase: Sediment spill</td>
<td>Possible reduction of catch due to avoidance of sediment plumes by commercial fish species thereby affecting their location, distribution and density.</td>
</tr>
<tr>
<td></td>
<td>Possible reduction of catch due to impairment of the habitats for commercial fish species.</td>
</tr>
<tr>
<td>Operation phase: Land reclamations</td>
<td>Possible reduction of catch due to loss of fishing area</td>
</tr>
</tbody>
</table>

The pressures due to change in hydrographic conditions, release of toxic contaminants from dredged sediment and electromagnetic fields are screened out as having no effect on commercial fishery.

5.13.2 Present commercial fishery in Fehmarnbelt

The smallest spatial unit for which comprehensive commercial fishery data from Fehmarnbelt is available is an ICES rectangle (30 × 30 nautical miles). This is therefore the primary spatial unit used to present the fleet and fishery statistics. ICES rectangles 38G1 and 37G1 were chosen to represent the areas where the near field fishery in Fehmarnbelt is described. Because there is a risk of impacts to the fishery extending beyond these ICES rectangles, the fleet statistics and fishery were also described in the regional areas to the west (ICES 37G0 and 38G0) and east (ICES 37G2 and 38G2) of Fehmarnbelt. See Figure 5.115.

The Danish and German commercial fishery and fleet statistics for the ICES rectangles and the harbours in the near field and regional area of Fehmarnbelt and the Western Baltic were obtained from the Danish Directorate for Fishery (FD) in Denmark, and from the Bundesanstalt für Landwirtschaft und Ernährung (BLE) in Germany. The statistics include vessel lengths, gear use, home-based harbours and the number of small vessels (<8 m).

Consultation meetings and surveys were held with both German and Danish vessel owners, fishermen and their representatives around Fehmarnbelt to supplement official fishery statistics and to gather more specific income data.
Figure 5.115 The six ICES rectangles representing the near field (38G1 and 37G1) and regional area (38G0, 37G0, 38G2 and 37G2) of Fehmarnbelt and the location of the Danish and German harbours in the Western Baltic.

Landings and value of commercial fishery in Fehmarnbelt

The average annual Danish and German fishing fleet landings (tons) and value (euro) from the near and regional field of Fehmarnbelt from 1998-2008 are given in Table 5.88 and Table 5.89.

The combined regional landings and value of the Danish fleet (Table 5.88) ranged from 10,429 to 26,776 tons and from 10.5 to 20.5 million euro during the period 1998-2008. In general, these values have decreased in recent years (since 2006) with the lowest amount of landings and value being recorded in 2008. The annual average over the 11 year period was about 18,000 tons with a value of about 14.7 million euro. In the ICES rectangle 38G1 which covers the fixed link alignment the annual average landing was about 1,800 tons with a value of about 1.25 million euro.

The catch of the German fleet (Table 5.89) did not show the same variation over the period 1998 – 2008. The annual average regional landing was about 10,600 tons (8,699 – 13,239) with a value of about 10.5 (8.1 – 14.1) million euro. In ICES rectangle 38G1 the annual average was 259 tons corresponding to a value of 0.284 million euro.
Table 5.88  The total landings (tons) and value (1,000 euro) of the Danish fishery in the near field of Fehmarnbelt (ICES 38G1 and 37G1) and regional area of the Western Baltic (ICES 37G0, 38G0, 37G2 and 38G2)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>37GO</td>
<td>20</td>
<td>27</td>
<td>330</td>
<td>374</td>
<td>12</td>
<td>25</td>
<td>24</td>
<td>129</td>
<td>433</td>
<td>99</td>
<td>63</td>
</tr>
<tr>
<td>38G0</td>
<td>7,624</td>
<td>7,984</td>
<td>8,510</td>
<td>9,078</td>
<td>3,908</td>
<td>6,955</td>
<td>6,160</td>
<td>8,896</td>
<td>7,376</td>
<td>4,354</td>
<td>3,087</td>
</tr>
<tr>
<td>37G1</td>
<td>2,826</td>
<td>1,174</td>
<td>1,806</td>
<td>2,701</td>
<td>863</td>
<td>491</td>
<td>1,043</td>
<td>658</td>
<td>3,574</td>
<td>2,495</td>
<td>1,739</td>
</tr>
<tr>
<td>38G1</td>
<td>1,551</td>
<td>1,260</td>
<td>1,540</td>
<td>2,859</td>
<td>1,121</td>
<td>975</td>
<td>671</td>
<td>1,702</td>
<td>4,160</td>
<td>2,071</td>
<td>2,092</td>
</tr>
<tr>
<td>37G2</td>
<td>434</td>
<td>629</td>
<td>496</td>
<td>706</td>
<td>270</td>
<td>122</td>
<td>935</td>
<td>247</td>
<td>508</td>
<td>142</td>
<td>117</td>
</tr>
<tr>
<td>38G2</td>
<td>8,101</td>
<td>8,514</td>
<td>9,619</td>
<td>11,058</td>
<td>7,929</td>
<td>5,732</td>
<td>8,635</td>
<td>6,867</td>
<td>5,392</td>
<td>3,684</td>
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<tr>
<td>Total</td>
<td>20,556</td>
<td>19,588</td>
<td>22,299</td>
<td>26,776</td>
<td>14,099</td>
<td>14,300</td>
<td>17,468</td>
<td>18,498</td>
<td>21,443</td>
<td>12,844</td>
<td>10,429</td>
</tr>
</tbody>
</table>

Table 5.89  The total landings (tons) and value (1,000 euro) of the German fishery in the near field of Fehmarnbelt (ICES 38G1 and 37G1) and regional area of the Western Baltic (ICES 37G0, 38G0, 37G2 and 38G2)

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<tbody>
<tr>
<td>37GO</td>
<td>936</td>
<td>1,228</td>
<td>1,104</td>
<td>958</td>
<td>790</td>
<td>709</td>
<td>764</td>
<td>660</td>
<td>620</td>
<td>629</td>
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<tr>
<td>38G0</td>
<td>2,662</td>
<td>3,407</td>
<td>3,003</td>
<td>2,678</td>
<td>2,686</td>
<td>2,763</td>
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<tr>
<td>37G1</td>
<td>4,364</td>
<td>6,068</td>
<td>5,889</td>
<td>4,560</td>
<td>6,314</td>
<td>5,502</td>
<td>4,662</td>
<td>4,796</td>
<td>6,591</td>
<td>5,355</td>
<td>5,339</td>
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<td>38G1</td>
<td>241</td>
<td>453</td>
<td>260</td>
<td>156</td>
<td>85</td>
<td>188</td>
<td>93</td>
<td>181</td>
<td>885</td>
<td>178</td>
<td>127</td>
</tr>
<tr>
<td>37G2</td>
<td>349</td>
<td>660</td>
<td>1,429</td>
<td>594</td>
<td>558</td>
<td>711</td>
<td>812</td>
<td>438</td>
<td>683</td>
<td>647</td>
<td>612</td>
</tr>
<tr>
<td>38G2</td>
<td>148</td>
<td>521</td>
<td>198</td>
<td>221</td>
<td>390</td>
<td>453</td>
<td>68</td>
<td>652</td>
<td>1,434</td>
<td>1,785</td>
<td>808</td>
</tr>
<tr>
<td>Total</td>
<td>8,699</td>
<td>12,337</td>
<td>11,885</td>
<td>9,169</td>
<td>10,823</td>
<td>10,326</td>
<td>9,447</td>
<td>10,562</td>
<td>13,239</td>
<td>11,071</td>
<td>9,315</td>
</tr>
</tbody>
</table>

Table 5.89  The total landings (tons) and value (1,000 euro) of the German fishery in the near field of Fehmarnbelt (ICES 38G1 and 37G1) and regional area of the Western Baltic (ICES 37G0, 38G0, 37G2 and 38G2)

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>37GO</td>
<td>1,194</td>
<td>1,586</td>
<td>1,621</td>
<td>1,550</td>
<td>1,364</td>
<td>1,085</td>
<td>1,175</td>
<td>903</td>
<td>862</td>
<td>938</td>
<td>640</td>
</tr>
<tr>
<td>38G0</td>
<td>2,749</td>
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<td>3,811</td>
<td>3,952</td>
<td>2,913</td>
<td>2,481</td>
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<td>2,541</td>
<td>2,490</td>
<td>2,360</td>
<td>1,652</td>
</tr>
<tr>
<td>37G1</td>
<td>4,761</td>
<td>6,809</td>
<td>6,531</td>
<td>5,697</td>
<td>5,336</td>
<td>4,027</td>
<td>3,816</td>
<td>4,794</td>
<td>5,480</td>
<td>5,550</td>
<td>4,538</td>
</tr>
<tr>
<td>38G1</td>
<td>319</td>
<td>655</td>
<td>392</td>
<td>240</td>
<td>158</td>
<td>236</td>
<td>122</td>
<td>110</td>
<td>478</td>
<td>218</td>
<td>197</td>
</tr>
<tr>
<td>37G2</td>
<td>504</td>
<td>559</td>
<td>626</td>
<td>662</td>
<td>603</td>
<td>693</td>
<td>676</td>
<td>485</td>
<td>520</td>
<td>625</td>
<td>585</td>
</tr>
<tr>
<td>38G2</td>
<td>193</td>
<td>306</td>
<td>202</td>
<td>187</td>
<td>220</td>
<td>118</td>
<td>36</td>
<td>371</td>
<td>919</td>
<td>883</td>
<td>476</td>
</tr>
<tr>
<td>Total</td>
<td>9,718</td>
<td>14,090</td>
<td>13,183</td>
<td>12,288</td>
<td>10,595</td>
<td>8,639</td>
<td>8,395</td>
<td>9,203</td>
<td>10,748</td>
<td>10,574</td>
<td>8,087</td>
</tr>
</tbody>
</table>
Commercial fish species
A general description of the most important fish species for the commercial fishing industry in the Fehmarnbelt region is given below.

**Cod** is the most important commercial species with respect to value and represents a large part of the value of the catch from trawl, gillnet and pound net fishery.

**Sprat and herring** form the largest part of the catch in tons, but the value is less than cod due to low prices per kilogram on the market.

**Flat fish** (plaice, flounder, dab, turbot, brill and sole) are important both in terms of landings and value. Plaice, flounder and dab make up the largest part of the flatfish catch, but turbot, brill and sole are periodically important target species due to their high value (kilogram price).

**Eel** is the primary target species for pound net fishing in Fehmarnbelt. The regional collapse in the abundance of eel and the introduction of fishing restrictions have had serious consequences for this form of fishing.

**Whiting** is periodically caught in large quantities in Fehmarnbelt and can be of significant economic importance for part of the trawl fishing activities.

Other species such as salmon and sea trout are not target species for commercial fishery in Fehmarnbelt and are only caught in small quantities. Garfish is an important supplement for pound net fishery in the spring. Horse mackerel is caught occasionally in large amounts but their economic value is low.

Figure 5.116 and Figure 5.117 summarize the 11 year (1998-2008) average annual landings and value of the landings of the Danish fleet for the most important commercial species according to logbooks. The species sprat, herring and cod make up the largest landings for all 6 ICES rectangles, with landings of sprat dominating in the area west of Fehmarnbelt and landings of herring dominating in the area to the east. Economically, the landings of cod have been the most valuable in all 6 ICES rectangles. Comparisons between the ICES rectangles show landings (and their value) are greatest in the rectangles 38G0, 38G1 and 38G2, which are those closest to the Danish coast.

Similarly, an overview of the annual average landings and the annual average value of the landings of the most important commercial species for the German fishing industry is given in Figure 4.4 and Figure 4.5. Overall in the region, cod is quantitatively the species with the largest landings in four ICES rectangles (38G0, 37G0, 38G1 and 37G1) representing Fehmarnbelt and the region to the west, whereas landings of herring dominated the catch in German fishery catch to the east of Fehmarnbelt (ICES 38G2 and 37G2). ICES 37G1 located to the southeast of Fehmarnbelt is the most important fishing area with respect to both landings (averaging landings of 5,400 tons a year) and value (annual average of 5.2 million euro).
Figure 5.116  The average annual landings (tons) from 1998-2008 of the most important commercial species in the Danish fishery.

Figure 5.117  The average annual value (euro (€)) from 1998-2008 of the most important commercial species in the Danish fishery.
Figure 5.118  The average annual landings (tons) of the most important commercial species in the German fishery

Figure 5.119  The annual average value (euro) of the landings of the most important commercial species in the German fishery

Fishing seasons

The average monthly landings (1998-2008) by Danish fishery for the most important commercial species for ICES rectangle 38G1 in the near field of
Fehmarnbelt are given in Figure 5.120. The pattern for German fishery is very similar.

The overall pattern in the seasonality shows landings are largest during the winter months and predominately in the first 3 months of the year. The landings data show that cod is caught almost exclusively from January-March while herring and sprat are caught in relatively high quantities during much of the year, except for the late spring and summer months (May-August). The seasonal pattern for the landings of the flatfish species flounder and dab follow the landings of cod, most probably because these species are typically a bycatch of the cod fishery. Other flatfish species (plaice, sole, turbot and brill) are caught in varying amounts during most of the year as these species are more directly targeted, especially during the warmer summer months and into the autumn/winter.

Geographic distribution of trawl fishery

Trawl fishing is the dominant form of fishery in Fehmarnbelt as well as in the western Baltic Sea. The main species caught by weight are sprat and cod.

The distribution of trawl fishery based on Vessel Monitoring System (VMS) data supplemented with interviews shows a concentration of fishing effort in the central, deeper part of Fehmarnbelt and in a broad belt towards east and west as well in ICES 37G1 southeast from Fehmarnbelt. Examples of the distribution of trawl fishery for the main fishing months of January to March for the Danish and German fleets are shown in Figure 5.121.
Figure 5.121 The seasonal distribution of the fishing activity of Danish (upper) and German (lower) trawlers as derived from VMS data. The number of individual VMS position plots for each vessel actively fishing was summed into 1 nm² quadrants to depict relative plot densities as a proxy for fishing intensity.
In the period 1998 – 2008 the number of Danish trawlers varied from 27 to 90. The average annual landing was 1,670 tons (554 – 3,980 t/year) corresponding to a value of 954,000 euro (426,000 – 1,678,000 euro). The main species caught were sprat (average annual landings of 959 tons with a value of 148,000 euro) and cod (average annual landings of 320 tons with a value of 621,000 euro).

The German trawling fleet varied between 7 and 21 vessels over the same period 1998 – 2008. The average annual landing was 209 tons (26 – 872 t/year) with an average value of 196,000 euro (40,000 – 464,000 euro). Cod dominated the catch in both weight and value with an average of 100 tons (20 – 305 t/year) at a value of 150,000 euro (30,000 – 458,000 euro). Flat fish landings averaged 26 tons (6 – 56 t/year) with a value of 22,000 euro (4,600 – 43,000 euro).

**Geographic distribution of gill net fishery**

Results from interviews of Danish fishermen and local fishery organisations indicate the location and greatest intensity of the Danish gill fishery in Fehmarnbelt and region appears to be mostly along an area that stretches across the western part of Fehmarnbelt from the southwestern part of Lolland to the western coast of Fehmarn, see Figure 5.122. The primary species targeted in these areas are cod and valuable flatfish species such as plaice, turbot, brill and sole. There is also a moderate amount of gill net fishery along the southern coast of Lolland and along the eastern coast of Langeland, which is to the northwest of Fehmarnbelt.

The number of Danish gill net fishing vessels with registered landings in ICES 38G1 varied between 10 and 24 in the period 1998 – 2008 (≥10 m until 2005, thereafter ≥8 m). There are also a number of smaller vessels but their landings are not registered at ICES rectangle level and their catch is only 2.6% of the value of the total gill net landings. The average of the total gill net landings was 94 tons (43 – 183 t/year) with a value of 180,000 euro (81,000 – 327,000 euro). Cod is the most important species with an average catch of 64 tons (31 – 107 t/year) with an average value of 123,000 euro (60,000 – 211,000 euro).

The distribution of the German gill net fishery was based on interviews with German fishermen (Figure 5.123). Results indicate gill net fishery effort is distributed along most of the shoreline of Fehmarn Island and much of the coastline of Schleswig-Holstein. Areas of high gill net fishery intensity appear to be along the northeastern coast of Fehmarn Island where cod is the main target species. Valuable flatfish such as plaice, turbot and brill are the main species targeted in other areas. German gill net fishing occurs primarily close to their coastline.

The number of German gill net fishing vessels with registered landings in ICES 38G1 varied between 1 and 4 in the period 1998 – 2008. The average annual landing was 41 tons (4 – 95 t/year) with a value of 62,000 euro (7,000 – 148,000 euro). As in Denmark, the most important species is cod with an average catch of 39 tons (3.6 – 95 t/year) and an average value of 95,000 euro (6,100 – 282,000 euro).
Figure 5.122  Danish fishing areas for passive gear (gill net and pound net) in Fehmarnbelt derived from interviews with Danish fishermen in 2009 and 2010.

Figure 5.123  German fishing areas for passive gear (gill net and pound net) in Fehmarnbelt derived from interviews with German fishermen in 2009 and 2010.
Geographic distribution of Danish seine net fishery

Fishing with Danish seine nets is only practised by Danish fishermen. The seasonal distribution of seine fishing activity according to VMS density plots shows that the greatest activity is, similar to trawling activity, in the colder months of the year (October-March). The plots (Figure 5.124) show that the location of this fishing activity is primarily to the east of Fehmarnbelt in ICES 37G1, 37G2 and 38G2. However VMS plots also suggest that there is some seining activity directly in Fehmarnbelt from January to March. These plots, however, originate from a few vessels (1-3) fishing here in 2005 and 2006 and not in more recent years. Except for some seining activity in the east (ICES 38G2) there appears to be almost no seine fishery in Fehmarnbelt and its regional area from April-September.

The number of seine net vessels decreased from 18 in 1998 to 3 in 2007 and only 1 in 2008. The average annual landings from ICES 38G1 in the period 1998 – 2008 was 45 tons (5 -125 t/year) with a value of 82,000 euro (10,000 – 232,000 euro). Cod is by far the most important catch (95%) with average weight and value of 38 tons and 74,000 euro respectively.

![Figure 5.124 Distribution of Danish seine net fishing activity (2005-2008). The number of individual VMS position plots for each vessel actively fishing was summed into 1 nm² quadrants to depict relative plot densities as a proxy for fishing intensity.](image)
Geographical distribution of pound net fishery

The Danish pound net fishery in the Fehmarnbelt area of southern Lolland are represented by 7 fishermen who have licenses (BBD numbers representing their firms) to fish at 82 pound net positions distributed along the southern and southwestern coast of Lolland (Figure 5.125) and in the local coastal areas with other passive gear (gill nets and fyke nets). Not all 82 licensed positions are in use every year.

Landings from the pound net fishery primarily include landings from pound nets, but also other passive gear such as fyke nets, traps and gill nets. It is therefore not entirely possible to distinguish which commercial species are specifically landed by pound nets and which species are landed by other gear. It is, however, assumed that European eel (silver and yellow) is caught in pound nets and to a certain extent in fyke nets due to the inability to catch this species in gill nets.

A considerable amount of eel and shrimp fishery is undertaken with fyke nets and traps in Nysted Nor (circled area in Figure 5.125).

The annual average Danish landings for the period 2000 – 2009 were between 94 and 323 tons with values between 221,000 and 569,000 euro. The most important species are cod and eel with values ranging between 53% and 91% (117,000 – 518,000 euro) of the total value of the catch. The remainder of the catch was made up of garfish (6.4 – 39 tons corresponding to 6,600 – 22,500 euro), flatfish (13 – 32 tons corresponding to 20,000 – 82,000 euro) and prawns (1 – 6 tons in Nysted Nor corresponding to 700 – 18,000 euro average for the period 2000 – 2005).

The total number of German pound nets is approximately 13 if the pound nets along a short section of the eastern coast of the mainland, across from Fehmarn Island are also taken into consideration, see Figure 5.126.

Data on the landings from German pound nets was not available from the fishery authorities. However data from two fishermen showed an annual average catch of 2,650 eels with a value of 2,350 euro from 3 – 5 pound nets in the period 1998 – 2008.

Pound net fishing is strongly seasonal with eel being caught between September and November when they migrate out of the Baltic Sea on their way to breeding grounds in the Sargasso Sea. Herring, cod and garfish are caught in the spring and summer. Prawn fishing takes place from April to August.
Figure 5.125  The distribution of the Danish pound net positions (82 positions) representing 7 pound net fishing firms (BBD numbers). Fyke nets and traps targeting eel and shrimp are primarily used in Nysted Nor – the area within the circle.

Figure 5.126  The distribution of the German pound net fishery represented by 13 pound nets positioned along the coast of Fehmarn, and the eastern coast of the mainland just south of Fehmarn
5.13.3 Methodology

The methodology for assessing the project’s impacts on fishery consists of the following steps:

› Mapping of fishery activity in Fehmarnbelt (see above).

› Defining the sensitivity of fishery to the project pressures, viz. sensitivity to loss of fishing areas, avoidance of suspended sediment plumes by commercial fish species and reduction of fish stocks.

› Calculating the magnitude of the pressures and combine with the sensitivity to estimate the magnitude of the impact, i.e. the reduction of catch.

› Classifying the degree of impairment through use of a defined set of criteria.

› Finally, assessing the overall significance of the impacts on fishery in the construction and operation phases by combining the degree of loss or impairment with the importance of the fishery components (see below).

Sensitivity, magnitude of impact, severity of loss and degree of impairment

The ability of the individual types of fishery (trawl, gill nets, pound nets and seine nets) to move and fish in alternative areas is a key characteristic in determining their sensitivity to a temporary or permanent loss of fishing areas.

The Danish and German pound net fishery are those that have the potential to be impacted the most due to loss of area. Fishermen are given licenses to set pound nets along specific sections of the coastline and are thus bound to set their gear within these areas, i.e. pound net fishery is not very mobile. Pound nets in the Danish and German fishery activity extends from 200 m to 1,500 m from the coastline. If some or all of this area is lost due to reclamation areas or other physical structures then this will lead to a direct loss in their landings.

Although the trawl, gill net and seine nets are more mobile they still rely on the quality of the fishing areas that they utilize and are bound by the way the fishing is performed. For example, trawlers often take long hauls where they fish along specific tracks depending on the bottom topography, especially avoiding seabed with stones and boulders which make fishing with bottom gear impossible or very difficult and full of risk for gear damage. As is observed from the distribution of the trawl fishery in Fehmarnbelt, trawl hauls are taken through the central deeper parts of Fehmarnbelt (Figure 5.121). For the bored tunnel project it is primarily the fishing which occurs in the land reclamation areas that will be affected.

The sensitivity of landings of commercial fish to the loss of fishing area cannot be directly defined quantitatively except for pound net fishing. A loss of fishing area does not necessarily mean a corresponding reduction of landings for trawl, gill net and Danish seine net fishery since the fish are displaced to other fishing areas and not necessarily lost. Only if the loss of specific habitats is associated with specific commercial interests will there be a corresponding reduction of landings. However,
since the lost area is the only thing which can be quantified, it is conservatively assumed in this assessment that the magnitude of the impact (% reduction in landings) is equal to the % loss of fishing area.

The severity of loss is, by definition, equal to the importance, see below.

Fish may avoid sediment plumes from dredging activity if the concentrations are too high. The threshold concentrations for the avoidance behaviour of the various fish species represent the sensitivity of the fish to this pressure. The thresholds are listed in Table 5.90. Areas with concentrations greater than the thresholds are assumed to be lost to the commercial fishery within the estimated time frame of the impact.

<table>
<thead>
<tr>
<th>Sediment spill</th>
<th>Cod</th>
<th>Whiting</th>
<th>Herring</th>
<th>Sprat</th>
<th>Flat fish</th>
<th>Eel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended sediment concentration (mg/l)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

The criteria for assessing the degree of impairment for the different fishery sub-components (i.e. trawl, gill net, pound net and seine net) due to sediment spill was based on the variation (Standard Deviation, SD) in the official landings of the fishery for each sub-component in Fehmarnbelt (ICES 38G1).

The criteria are defined on the basis of the SD but with the SD expressed as a % of the mean. For example, for trawl, the variation (SD) of the annual landings over an 11 year period has been found to be approximately ± 50% of the mean.

Because temporary impairments during the construction phase are limited in duration, a larger reduction of landings was accepted as giving the same degree of impairment in comparison with landings for permanent impacts during the operation phase. However, in some cases, impairment may be so intensive that the fishery function is lost. In these cases the impairment is then considered as a loss or permanent impact and assessed accordingly.

Table 5.91 shows the foundation for setting the criteria for degree of impairment, while Table 5.92 shows that actual criteria adopted.
Table 5.91 The foundation for establishing the criteria used to obtain the Degree of impairment when assessing temporary and permanent impacts

<table>
<thead>
<tr>
<th>Temporary</th>
<th>Permanent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of landings</td>
<td>Degree of impairment</td>
</tr>
<tr>
<td>≥ SD</td>
<td>Very high</td>
</tr>
<tr>
<td>SD/2 to SD</td>
<td>High</td>
</tr>
<tr>
<td>SD/4 to SD/2</td>
<td>Medium</td>
</tr>
<tr>
<td>≤ SD/4</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 5.92 Criteria for determining the degree of impairment of trawl, gill net, pound net and seine net fishery

<table>
<thead>
<tr>
<th>Fishery gear</th>
<th>Reduction in landings (= reduction in fishing area) in %</th>
<th>Degree of impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction (temporary)</td>
<td>Operation (permanent)</td>
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<td>Trawl</td>
<td>&gt; 50</td>
<td>&gt; 25</td>
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<tr>
<td></td>
<td>25 - 50</td>
<td>12 - 25</td>
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<tr>
<td></td>
<td>12 - 25</td>
<td>6 - 12</td>
</tr>
<tr>
<td></td>
<td>&lt; 12</td>
<td>&lt; 6</td>
</tr>
<tr>
<td>Gill net</td>
<td>&gt; 40</td>
<td>&gt; 20</td>
</tr>
<tr>
<td></td>
<td>20 - 40</td>
<td>10 - 20</td>
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<tr>
<td></td>
<td>10 - 20</td>
<td>5 - 10</td>
</tr>
<tr>
<td></td>
<td>&lt; 10</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Pound net</td>
<td>&gt; 25</td>
<td>&gt; 12</td>
</tr>
<tr>
<td></td>
<td>12 - 25</td>
<td>6 - 12</td>
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<tr>
<td></td>
<td>6 - 12</td>
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<tr>
<td></td>
<td>&lt; 6</td>
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<tr>
<td>Danish seine net</td>
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<tr>
<td></td>
<td>30 - 60</td>
<td>15 - 30</td>
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<td></td>
<td>15 - 30</td>
<td>7 - 15</td>
</tr>
<tr>
<td></td>
<td>&lt; 15</td>
<td>&lt; 7</td>
</tr>
</tbody>
</table>

Reduction of fishing area
The reduction of fishing area is obtained by overlapping the map of the area impacted by the project with the map of the area used for each type of fishery (i.e. trawl, gill net, pound net and seine net).
The area impacted by the project is mainly of two types:

- The land reclamation and other construction phase marine structures (work harbours and access channels) plus a 500 m wide near zone outside the perimeters of the reclamation and structures where it is assumed that fishing will be prohibited.

- The area where suspended sediment concentrations exceed the threshold levels.

Other impacts on commercial species are dealt with in more detail in the section on the assessment of fish. The overall significance of these impacts on fish and thus indirectly on fishery is included in the overall conclusions of the significance of impacts on fishery.

Importance of the fishery components

The importance of the sub-components representing the commercial fishing in Fehmarnbelt according to gear types are determined by their importance and value to the fishery in the local and regional areas of Fehmarnbelt as described in Table 5.93.

<table>
<thead>
<tr>
<th>Importance</th>
<th>Criteria for assessment of importance of fishery</th>
<th>Sub-component (Gear)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>Fehmarnbelt is specific for commercial fishery and is of high importance and value</td>
<td>Pound nets</td>
</tr>
<tr>
<td>High</td>
<td>Fehmarnbelt is the primary area for commercial fishery and/or this area is of regional importance and value</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Fehmarnbelt is an area used for commercial fishery and is of some local and regional importance and value</td>
<td>Trawling, gill nets</td>
</tr>
<tr>
<td>Minor</td>
<td>Fehmarnbelt is an area only seldom or not used for commercial fishery, or is of little local or regional importance and value</td>
<td>Danish seine nets</td>
</tr>
</tbody>
</table>

Significance of the impacts

The impact assessment is finalised with an overall assessment stating the significance of the predicted impacts. This assessment of significance is based on expert judgement. The reasoning for the conclusion on the significance is explained. Aspects such as degree of impairment, recovery time and the importance of the environmental factor are taken into consideration.

5.13.4 Impacts on trawl fishery

There is no loss of Danish or German trawl fishing areas in ICES rectangle 38G1 of in the Fehmarnbelt region due to the temporary and permanent footprints along the Lolland and Fehmarn coasts, see Table 5.94. The degree of impairment is
therefore classified as no impact. Temporary and permanent footprints from the bored tunnel solution are only near the coast of Lolland and Fehmarn, while the majority of the Danish and German trawling occurs in the central parts of Fehmarnbelt. Trawling activity near the coast is very limited and does not occur in water less than 10 m, see Figure 5.121.

The area impacted by sediment spill during the construction phase is illustrated in Figure 5.127. It is seen that, even during the most intensive dredging activity between November 2014 and March 2015, the suspended sediment concentrations only exceed 10 mg/l for 5-10% of the time in narrow areas close to the coast, mainly the Lolland coast. Comparisons of the trawling areas overlapping with sediment plumes indicate that sediment spill does not affect either Danish or German trawling areas. Thus there is no impact on trawl fishery due to sediment spill.

Figure 5.127  Exceedence time (%) of 10 mg/l (depth averaged) excess concentrations from sediment spill, November 2014 - March 2015
**Table 5.94**  Magnitude of impact and degree of impairment of trawl fishery according to the criteria presented in Table 5.92.

<table>
<thead>
<tr>
<th>Trawl fishery</th>
<th>Construction</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project pressure</strong></td>
<td><strong>Reduction of fishing area (ha). % of ICES 38G1. % of Fehmarnbelt region.</strong></td>
<td><strong>Severity of loss (for permanent loss of area) / Degree of impairment (temporary loss of area and sediment spill)</strong></td>
</tr>
<tr>
<td><strong>Trawl fishery</strong></td>
<td><strong>Construction</strong></td>
<td><strong>Operation</strong></td>
</tr>
<tr>
<td>Denmark</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of area (reclamations, work harbours, access channels, near zone)</td>
<td>0 ha</td>
<td>0 %</td>
</tr>
<tr>
<td>Maximum impact due to sediment spill (area affected)</td>
<td>0 ha</td>
<td>0 %</td>
</tr>
<tr>
<td>Germany</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of area (reclamations, work harbours, access channels, near zone)</td>
<td>0 ha</td>
<td>0 %</td>
</tr>
<tr>
<td>Maximum impact due to sediment spill (area affected)</td>
<td>0 ha</td>
<td>0 %</td>
</tr>
</tbody>
</table>

### 5.13.5 Impacts on gill net fishery

During construction the work harbours and their breakwaters will cause a temporary loss of 23 ha on the Lolland coast and 56 ha along the Fehmarn coasts, respectively. This is less than 1% of the gill net fishing area and leads to a minor degree of impairment according to guidelines given in Table 5.92. During operation of the bored tunnel there will be no loss of either Danish or German gill net fishing areas due to reclamations, work harbours or access channels at the Lolland and Fehmarn coasts. The results are listed in Table 5.95.

Sediment spill during the most intensive dredging activity between November 2014 and March 2015 will result in increased suspended sediment concentrations above 10 mg/l for 5-10% of the time in a narrow band of shallow water along the southeastern coast of Lolland and the northern coast of Fehmarn, see Figure 5.127. This will affect approximately 840 ha or 2.4% of the Danish gill net fishery in Fehmarnbelt and 968 ha (1.2%) of the total Danish gill net fishing in the Fehmarnbelt region. Sediment spill during the same period will affect a total of 176 ha (170 ha in Fehmarnbelt) or approximately 1.4% of the German gill net fishing area along the northern coast of Fehmarn (Table 5.95).

According to criteria for temporary impacts to the gill net fishery (Table 5.92) the impact of sediment spill during the construction phase of the bored tunnel is considered to be minor for both the Danish and German fishery.
Table 5.95  Magnitude of impact and severity of loss/degree of impairment of gill net fishery

<table>
<thead>
<tr>
<th>Gill net fishery</th>
<th>Construction</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project pressure</strong></td>
<td><strong>Reduction of fishing area (ha). % of ICES 38G1. % of Fehmarnbelt region.</strong></td>
<td><strong>Severity of loss (for permanent loss of area) / Degree of impairment (temporary loss of area and sediment spill)</strong></td>
</tr>
<tr>
<td><strong>Denmark</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of area (work harbours, access channels, near zone)</td>
<td>23 ha 0.064 % -</td>
<td>Minor 0 ha 0 % -</td>
</tr>
<tr>
<td>Maximum impact due to sediment spill (area affected)</td>
<td>968 ha 2.4 % 1.2 %</td>
<td>Minor N/A N/A</td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of area (work harbours, access channels, near zone)</td>
<td>56 ha 0.23 % 0.05%</td>
<td>Minor 0 ha 0 % 0 %</td>
</tr>
<tr>
<td>Maximum impact due to sediment spill (area affected)</td>
<td>176 ha 1.4% 0.3%</td>
<td>Minor N/A N/A</td>
</tr>
</tbody>
</table>

The low percentages of gill net fishing areas affected justify the classification of the degree of impairment as minor for both Danish and German gill net fishery.

5.13.6 Impacts on Danish seine net fishery

Danish seine net fishery does not take place in areas affected by reclamations or sediment spill, see Figure 5.124. Therefore there will be no impacts on fishery with this gear.

5.13.7 Impacts on pound net fishery

The reclamations at the Lolland coast during the construction phase will directly remove 6 of the 82 pound nets along the Lolland coast, see Figure 5.128. This corresponds to a reduction in the Danish pound net fishing area of 387 ha which is 6.4% of the total fishing area. After construction 29 ha of access channels will not be restored and the area is permanently lost for pound fishing.

According to the criteria the severity of permanent loss is, by definition, equal to the importance of the fishery, see Table 5.93. Thus, the severity of loss of 387 ha of the Danish pound net fishery is assessed to be very high.

The loss of the German pound net fishing area due to land reclamation and working harbours along the Fehmarn coast will be 55 ha or approximately 2.4 % of the total pound net fishing area. After construction 6 ha of access channel will not be
restored and the area is permanently lost for pound fishing. The severity of loss of these fishing grounds to the German pound net fishery is therefore assessed to be very high.

According to baseline information this will potentially affect 1 German pound net fisherman.

![Figure 5.128 The location of the reclamation areas and footprints from the bored tunnel solution and their affects on the Danish pound net fishery in Fehmarnbelt.](image)

Sediment spill from the construction of the bored tunnel will at its worst affect approximately 331 ha or 5.6% of the Danish pound net fishing area and at least an additional 9 pound nets west of the Lolland reclamation and the remaining 11 pound nets to the east, see Figure 5.125 and Figure 5.127. The impact occurs for only 5 - 10% of the time between November 2014 and March 2015 (which, with the exception of November and early December, is generally outside the pound net fishing season). According to Table 5.92 the degree of impairment of this temporary impact is minor.

Similarly, the sediment spill along the northern coast of Fehmarn (see Figure 5.126) will affect up to 7.7% (178 ha) of the German pound net fishing area, which should lead to a medium degree of impairment (Table 5.92). This will affect up to 7 pound nets (Figure 5.127) for a limited part (5 – 10%) of the time between November 2014 and March 2015. As mentioned above, this period is primarily outside the pound net fishing season with the exception of November and early December when eels are the target species.
Table 5.96 summaries the magnitude of impact and severity of loss / degree of impairment of the bored tunnel project on pound net fishery.

**Table 5.96  Magnitude of impact and severity of loss/degree of impairment of pound net fishery**

<table>
<thead>
<tr>
<th></th>
<th>Construction</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pound net fishery</strong></td>
<td><strong>Reduction of fishing area (ha), % of Fehmarnbelt region.</strong></td>
<td><strong>Severity of loss (for permanent loss of area) / Degree of impairment (for sediment spill)</strong></td>
</tr>
<tr>
<td><strong>Project pressure</strong></td>
<td><strong>Construction</strong></td>
<td><strong>Operation</strong></td>
</tr>
<tr>
<td>Denmark</td>
<td>Loss of area (reclamations, work harbours, access channels, near zone)</td>
<td>387 ha 6.4 %</td>
</tr>
<tr>
<td></td>
<td>Maximum impact due to sediment spill (area affected)</td>
<td>331 ha 5.6 %</td>
</tr>
<tr>
<td>Germany</td>
<td>Loss of area (reclamations, work harbours, access channels, near zone)</td>
<td>55 ha 2.4 %</td>
</tr>
<tr>
<td></td>
<td>Maximum impact due to sediment spill (area affected)</td>
<td>178 ha 7.5 %</td>
</tr>
</tbody>
</table>

* See text

Overall, the impact on Danish and German pound net fishery from the loss of fishing area is regarded as significant for the local area, but insignificant on a regional scale.

### 5.13.8 Significance of impacts – summary

The effect of the construction and operation of the bored tunnel project on the fish resource in the Fehmarnbelt region is assessed as being small. Some fishing areas will be lost under the reclamations and the sediment spill during dredging may cause avoidance behaviour by commercial fish species as well as a temporary reduction of biomass of benthic flora in fish habitats.

Conservatively, the reduction of fish landings is assumed to be proportional to the fishing areas lost under reclamations, areas of high suspended sediment concentrations (> 10 mg/l) and areas of impacted benthic flora. Even under such a conservative assumption, the degree of impairment for trawl, gill net and Danish seine net fishery is assessed as minor or no impact.

Only for the pound net fishery is the severity of loss along the Lolland and Fehmarn coasts assessed as being very high because of the permanent loss of fishing grounds due to land reclamations, access channels and work harbours and medium due to temporary sediment spill during the construction phase.
On this basis, the impacts are classified as insignificant for trawl, gill net and Danish seine net fishery of both the Danish and German fleets. The impacts on pound net fishery are significant for the local area but insignificant on a regional scale.

Table 5.97 summaries the significance of the impacts.

<table>
<thead>
<tr>
<th>Fishery</th>
<th>Danish fishing fleet</th>
<th>German fishing fleet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction</td>
<td>Operation</td>
</tr>
<tr>
<td>Trawl</td>
<td>No impact</td>
<td>No impact</td>
</tr>
<tr>
<td>Gill net</td>
<td>Insignificant</td>
<td>No impact</td>
</tr>
<tr>
<td>Danish seine net</td>
<td>No impact</td>
<td>No impact</td>
</tr>
<tr>
<td></td>
<td>Insignificant - regional</td>
<td>Insignificant - regional</td>
</tr>
</tbody>
</table>

5.13.9 Mitigation and compensation

The Danish pound net fishermen will be compensated for the losses in the Lolland reclamation areas. Although the impact on Danish trawl, gill net and seine net fishery is assessed as insignificant, it is normal practice that some compensation can be considered and will be negotiated at the appropriate time with the fishermen’s organisation.

In Germany there is no law or practice to compensate fishermen for the impacts of infrastructure projects.

5.13.10 Decommissioning

Decommissioning of the bored tunnel will not involve any marine activities and therefore there will be no impacts on commercial fishery.
5.14 Material assets

This section deals with the material assets in the marine area of Fehmarnbelt. Such assets include windmill parks, sand mining areas, disposal sites for dredged material and submarine cables.

Material assets are an environmental component under the factor “material assets and cultural heritage” as defined in the EU EIA Directive 97/11/EC. The sub-components are listed in Table 5.98.

Table 5.98 Sub-components of material assets in Fehmarnbelt marine area

<table>
<thead>
<tr>
<th>Factor</th>
<th>Component</th>
<th>Sub-component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material assets and cultural heritage</td>
<td>Material assets</td>
<td>Windmill parks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sand mining areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disposal sites for dredged material</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Submarine cables</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Harbours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ferry traffic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Navigation aids</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Military areas</td>
</tr>
</tbody>
</table>

5.14.1 Project pressures and potential impacts

The pressures of the bored tunnel project are essentially those caused by the reclamations and the marine construction works. Table 5.99 lists the potential impacts of the pressures. These are all considered in the assessment of the impacts in the sub-sections below.

Table 5.99 Pressures and potential impacts of the bored tunnel project on material assets

<table>
<thead>
<tr>
<th>Project pressures</th>
<th>Potential impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction phase:</td>
<td>Damage to material assets. Disturbing marine activities.</td>
</tr>
<tr>
<td>› Reclamations covering seabed</td>
<td></td>
</tr>
<tr>
<td>› Dredging</td>
<td></td>
</tr>
<tr>
<td>› Activities of vessels and marine plant including anchoring</td>
<td></td>
</tr>
<tr>
<td>› Reclamations covering seabed</td>
<td></td>
</tr>
</tbody>
</table>

5.14.2 Existing material assets

The existing material assets in Fehmarnbelt are illustrated in Figure 5.129 and described below.
Windmill parks

Two windmill parks exist approximately 20 km and 30 km southeast of Rødbyhavn:

- Rødsand I consists of 72 turbines reaching a height of 69 m and with a wing span of 40 m. Each mill can generate up to 2.3 MW and together they produced 552,112 MWh in 2009.

- Rødsand II is a larger installation with 90 turbines and covers an area of 35 km². Each mill has a capacity of 2.3 MW which, together with some test turbines, gives a total capacity of 215 MW. The park was commissioned in October 2010.

The cables carrying the power to land are shown in Figure 5.129 and it is seen that they are far from the fixed link alignment.

A windmill park is planned in German waters (GEOFRee) approximately 30 km east of Fehmarn (Planungsbüro Ostholstein 2009). It is far from the bored tunnel alignment and will not be affected by the project.
Sand mining areas

There are three legally approved sand mining areas in Danish waters, viz. 568-CA Gedser, 568-BA Vindholme and 568-AA Rødbyhavn, (see Figure 5.129 and http://www.naturstyrelsen.dk/Vandet/Havet/Raastoffer/Raastoffer_paa_havet/Indvindingstilladelser/). There are none in German waters.

As of August 2011 four companies were approved to extract sand in 568-CA Gedser where permission allows for extraction of up to a total 200,000 m$^3$ of stone and gravel. There are no mining activities in 568-BA Vindholme at present but the area has been reserved for Femern A/S if it is needed.

Three companies carry out mining at 568-AA Rødbyhavn with a permitted total removal of 200,000 m$^3$ of sand. The northwest corner of the area lies over the bored tunnel.

Disposal sites for dredged material

There are four approved disposal sites for dredged material in Danish waters, of which only two are in use, see Figure 5.129. One is southwest of Rødbyhavn (No. 4.1) and the second is southeast of Gedser. They are both far from the tunnel alignment and marine construction works. Approximately 750,000 m$^3$ of clean material from the Rødbyhavn and Gedser access channels have been deposited at the sites since 1987 along with about 200,000 m$^3$ of moderately polluted harbour sediment (Regionalplan 2005 – 2017).

In German waters there are three disposal sites, one near the west coast of Fehmarn and one on each side of the Wargriens peninsula (Figure 5.129). All three are far from the bored tunnel alignment and will not be affected by the project (see http://www.bsh.de/de/Meeresnutzung/Wirtschaft/CONTIS-Informationssystem/index.jsp).

Submarine cables

Three telecommunication cables cross Fehmarnbelt from just west of Puttgarden to just west of Rødbyhavn. The cables will be covered by the reclamation at the Lolland coast.

There are also a number of cables from Marienleuchte supplying the German military area with, among other things, electricity. They are just east of the reclamation area and work harbour and outside the marine works area.

As mentioned above cables connect the two Danish windmill park to land but these are far from the marine works and will not be affected by the project.

Harbours and ferry traffic

The two major harbours, Rødbyhavn and Puttgarden together with the ferries represent a major investment in the region. Although they are immediately adjacent to the reclamations at both coasts, the project design and construction activities are specially planned to avoid any significant impacts on their operation. The plan will allow the ferries to operate unhindered throughout the construction phase.
Navigation aids
There are a number of buoys and other navigation aids in the project area both near the coast and in the belt itself. The main shipping route, the T-route, lies along the centre of Fehmarnbelt and is marked with buoys. Three buoys marking hydrographic recording stations are established close to the Rødsand windmill parks.

Military areas
There is a German military area (16.3 km2) east of Puttgarden and 750 m east of the tunnel alignment (Figure 5.129). A small area is closed to all non-military vessels and is marked with buoys.

5.14.3 Methodology
All the material assets described above are considered of special importance due to the importance for the society in general and are therefore be included in the impact assessment. The assessment is based on an evaluation of the actual risks that the project pressures could result in damage to the material assets or in impairment of their operation.

5.14.4 Impacts on material assets in the construction phase
In general it is assessed that all material assets - both existing and planned - situated more than 10 km from the tunnel alignment and construction activities will not sustain any damage from the project.

The Rødsand windmill parks are far from the tunnel alignment and the construction works. There will not be any activities of construction vessels, dredgers, barges or marine plant which could result in damage to the windmills.

The northwest corner of sand mining area 568-AA Rødbyhavn lies over the tunnel alignment. Removal of the sand in this area could affect the tunnel since there is a requirement that the tunnels should be at least one diameter under the seabed to counteract buoyancy. The sand waves are up to 3 m high in the area but the full depth of sand which can be removed is not presently known. However, it has already been established for the immersed tunnel that the sand mining area will be closed if it poses any threat to the construction and operation of the tunnel. This is assumed to apply also to the bored tunnel and the project impact could therefore be a closure of a part of this sand mining area. The degree of impact is minor.

None of the disposal sites for dredged material will be impacted by the project since they are far from the alignment and construction works.

The land reclamations along with the work harbours and access channels will be established during the first years of the construction phase. The land reclamation west of Rødbyhavn will cover the three telecommunication cables which have their landfall immediately west of the harbour. The owner of the cables has been contacted and has no objection to the cables being covered.
The electricity and telecommunication cables to the German military area will not be affected by the project.

With respect to the harbours and ferry traffic, as mentioned above, the construction activities will be specially planned to avoid any significant impacts on their operation.

Similarly the planning of the construction works and marine traffic will respect the restrictions of the German military area.

5.14.5 Impacts on material assets in the operation phase.
Two of the potential impacts of the bored tunnel project on material assets during the operation phase would be due to the land reclamations at the Lolland and Fehmarn coasts.

The second impact is that the reclamations make it impossible to implement future developments along the coastline behind the reclamations. No such developments are included in regional plans for Lolland and Fehmarn and the impact is therefore not significant.

The only other potential impact could be due to the application of restrictions on the development of offshore activities over the tunnel alignment. However, the impact is not considered significant since the area affected is small compared with Fehmarnbelt and there are no special marine or seabed features which could attract development of material assets.

5.14.6 Significance of impacts
The assessment is that the project pressures on marine material assets result in degrees of impairment in the range minor to no impact and are therefore insignificant.

5.14.7 Mitigation and compensation
Mitigation and compensation measures are not necessary.

5.14.8 Decommissioning
Decommissioning of the bored tunnel will not involve any marine activities and therefore there will be no impacts on marine material assets.
5.15 Recreation

This section deals with the recreational activities in the marine area of Fehmarnbelt. Such activities include bathing, boating, fishing and hunting.

Recreation is a component under the environmental factor “humans” as defined in the EU EIA Directive 97/11/EC. The sub-components are listed in Table 5.98.

<table>
<thead>
<tr>
<th>Table 5.100</th>
<th>Sub-components of recreation in Fehmarnbelt marine area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factor</strong></td>
<td><strong>Component</strong></td>
</tr>
<tr>
<td>Humans</td>
<td>Recreation</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.15.1 Project pressures and potential impacts

The project pressures which potentially can affect recreational activities in Fehmarnbelt are the reclamations, work harbours, areas with restricted access during construction and increased turbidity (suspended sediment from sediment spill during dredging). Table 5.99 shows that the potential impacts are loss of recreational areas and impairment of bathing waters.

<table>
<thead>
<tr>
<th>Table 5.101</th>
<th>Pressures and potential impacts of the bored tunnel project on material assets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project pressures</strong></td>
<td><strong>Potential impacts</strong></td>
</tr>
<tr>
<td>Construction phase:</td>
<td>Loss of recreational areas</td>
</tr>
<tr>
<td>› Reclamations</td>
<td></td>
</tr>
<tr>
<td>› Restricted zones around construction sites</td>
<td>Increased turbidity of bathing waters</td>
</tr>
<tr>
<td>› Sediment spill during dredging</td>
<td></td>
</tr>
<tr>
<td>Operation phase:</td>
<td>Loss of recreational areas</td>
</tr>
<tr>
<td>› Reclamations</td>
<td></td>
</tr>
</tbody>
</table>

Impacts from construction noise and visual disturbance are screened out since recreational activities will be prohibited near construction works.

5.15.2 Existing recreational activities

Data on the existing recreational activities in Fehmarnbelt has been obtained from available literature, reports and plans for development of the area and site inspections. In particular, data on boating (sailing and motor boats) was obtained from HELCOM and from the German N.I.T. FFL Einflussanalyse Tourismus which also contains data on recreation on Fehmarn island.
Bathing and water sports

Bathing beaches within the study area along the Lolland coast are found at Bredfjed, Lalandia, a wide 800 m long beach immediately west of Rødbyhavn and at the summerhouse area Hyldtofte Østersøbad, see Figure 5.130.

The beach at Hyldtofte Østersøbad is artificial and consists of a series of small semi-circular beaches behind short coast parallel breakwaters, see section 5.5. The original beach was eroded away after construction of the ferry harbour Rødbyhavn.

Bathing within the study area on Fehmarn occurs along much of the coast where there are sand and shingle beaches. The island receives more than 1 million guests each year and activities on the water and along the coast are the main attraction.

Water sports are practised at or near the bathing beaches. Fehmarn is a popular location for wind and kite surfing due to the favourable wind conditions and three areas near Puttgarden are allocated to these sports. Orth Bight at the south side of Fehmarn is also ideal for wind and kite surfing. There are no specific surfing areas on the Lolland coast but wind and kite surfing do occur regularly at some of the beaches.

There are sea kayak clubs in Maribo, Guldbergssund and Nysted which potentially could use the Lolland coastal waters.

Figure 5.130 Coastal recreational areas on Lolland and Fehmarn
Boating

There are five marinas along the Lolland coast at Kramnitse, in Rødbyhavn (35 moorings), Lundehøje, Errindlev and Stubberup (Figure 5.130). The last three are small and located in Rødsand Lagoon.

Fehmarn has six marinas all of which are on the south coast of the island.

There were 170,000 registered overnight stays in 2007 in the five Lolland marinas and 52,000 in the six Fehmarn marinas. The percentage of foreign guests in the marinas was 11% for Lolland (20,000 from Germany) and 8% for Fehmarn. There are no precise observations of the number of sailing and motor boats passing through Fehmarnbelt, but the number of overnight stays indicates that there is a considerable amount of recreational boating traffic in Fehmarnbelt. It is known that most of the traffic is national and along the coast and therefore does not cross Fehmarnbelt. However data shows that there is an increasing tendency over the recent years for recreational traffic to cross into international waters (HELCOM 2010).

For comparison, there are 850,000 registered recreational boats in the Baltic Sea as a whole (HELCOM 2010).

Fishing

Fishing on the Lolland coast occurs either from boats or from land, especially from the two breakwaters of Rødbyhavn. On land there are a number of fishing lakes. Rødby Sport Fishing Association has about 250 active members and sold about 150 fishing licences in 2011.

There are three fishing areas in the study area on the Fehmarn coast, one just west of the harbour and two to the southeast at Marienleuchte and Presen (Figure 5.130).

The extent of sport fishing activity in Fehmarnbelt was established from the authority’s official statistics together with interviews with fishermen. The data includes the seasonal distribution of fishing from boat and coast, the species and amount caught and the geographical distribution. On both sides of Fehmarnbelt the primary catch includes sea trout, cod, garfish and flat fish depending on the season.

On Fehmarn there are 21 registered commercial angling vessels which take guests out to deeper waters to catch mainly cod. These vessels catered for 67,500 sport fishermen in 2008, mostly from Germany. About 70% of the vessels have registered a reduction in the number of guests over the last 10 years. There are no corresponding Danish vessels operating in Fehmarnbelt.

On both the Lolland and Fehmarn sides there are a few private boats which troll for sea trout, jig for cod and herring and in some areas use bait to catch flatfish.

Figure 5.131 shows the areas used for sport fishing in Fehmarnbelt and surrounding waters.
5.15.3 Methodology
The assessment of the impacts of the project on recreation is based on a subjective evaluation of the area affected by the pressures and the duration of potential impacts.

5.15.4 Impacts on recreation during construction

Bathing and water sports
The impacts of the bored tunnel project on bathing conditions are addressed in detail in the chapters on Lolland and Fehmarn. 1.5 km of bathing beaches will be lost on Lolland due to the reclamations and this is assessed to give a high severity of loss. One new beach will be available at the western end of the reclamation within 2 years after start of construction. It provides some compensation but the beach is further away from residential areas of Lalandia and Rødbyhavn and the impact is still regarded as significant.

On Fehmarn the beach southeast of Puttgarden harbour will also be lost during construction. The severity of loss is classified as minor. A new beach established
along the reclamation but will not be available to bathers until the end of the construction phase.

Section 5.3 on Water Quality (see above) shows that the sediment spill during construction will only impact the water turbidity at bathing beaches to a minor degree and the impact is insignificant. This applies to the beaches on both Lolland and Fehmarn.

Water sports will be prohibited in a 500 m wide area around the reclamations and construction works on both Lolland and Fehmarn. However, this is assessed as having little impact on the possibilities for practising water sports since this type of sport is not so dependent on the availability of good beaches.

Boating
It is assessed that the project will have a minor and insignificant impact on boating in the construction phase. This is due to the fact that the sailors in the area are used to the existing intense commercial shipping traffic in Fehmarnbelt and the 52 daily ferry crossings. The project will not give any significant increase in the shipping activity (see section 5.17 on shipping).

Fishing
The Lolland reclamation will cause the loss of about 7.7 km of coastline where recreational fishing occurs as well as the popular Rødbyhavn breakwaters. However, on Fehmarn, the reclamation will have little or no impact on recreational fishing. Furthermore, the construction activities are assessed as having no impact on recreational fishing from boats, hobby fishing or fishing from the German commercial angling vessels.

The severity of loss on Lolland is assessed to be minor since the number of fishermen affected is small.

Hunting
The project activities during the construction phase will not impact hunting since very little, if any, occurs along the coasts.

5.15.5 Impacts during the operation phase

Bathing and water sports
The bathing beaches lost in the operation phase are the same as those lost in the construction phase. However, the project will provide compensation in the form of new beaches along the edges of the reclamations.

On Lolland there will be a new beach at the western end of the reclamation and a new bay with beach west of Rødbyhavn. There will also be a wading beach in an internal lagoon connecting the bay with Rødbyhavn. These new beaches will provide part compensation, but the impact is still assessed to be high and significant because of the longer distance to the beaches from residential areas.
The bay and internal lagoon will also provide opportunities for water sports.

On Fehmarn the new beach on the reclamation will provide full compensation for the lost beach.

**Boating**
The finished project will not present any difficulties to boating activities.

**Fishing**
Similar to the construction phase, the fishing areas along the Lolland coast behind the reclamations and on the Rødbyhavn breakwaters will be lost. On the other hand, the containment dikes around the reclamation will provide even greater opportunities for recreational fishing and the overall impact is assessed as positive.

**Hunting**
Similar to the construction phase, the finished project will have no impact on hunting.

### 5.15.6 Significance of impacts - summary
Table 5.102 summaries the severity of loss or degree of impairment and the significance of the impacts of the bored tunnel project on the recreational activities in Fehmarnbelt. Only one of the sub-components, viz. bathing on the Lolland coast, is assessed to be impacted to significant level. This is simply due to the fact that the new, compensatory beaches will be further away from residential areas than the existing beaches.

The impacts on fishing in the operational phase are positive since the project provides long sea dikes around the reclamations on which fishermen can stand.

All other impacts are classified as insignificant or no impact.

**Table 5.102  Summary of severity of loss/degree of impairment and significance of impacts of the bored tunnel on recreational activities in Fehmarnbelt**

<table>
<thead>
<tr>
<th>Sub-component</th>
<th>Severity of loss / Degree of impairment</th>
<th>Significance</th>
<th>Construction</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lolland</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bathing</td>
<td>High</td>
<td>High</td>
<td>Significant</td>
<td>Significant</td>
</tr>
<tr>
<td>Water sports</td>
<td>Minor</td>
<td>Minor</td>
<td>Insignificant</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Boating</td>
<td>Minor</td>
<td>No impact</td>
<td>Insignificant</td>
<td>No impact</td>
</tr>
<tr>
<td>Fishing</td>
<td>Minor</td>
<td>Positive</td>
<td>Insignificant</td>
<td>Positive</td>
</tr>
<tr>
<td>Hunting</td>
<td>No impact</td>
<td>No impact</td>
<td>No impact</td>
<td>No impact</td>
</tr>
<tr>
<td><strong>Fehmarn</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bathing</td>
<td>Minor</td>
<td>Minor</td>
<td>Insignificant</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Water sports</td>
<td>No impact</td>
<td>No impact</td>
<td>No impact</td>
<td>No impact</td>
</tr>
<tr>
<td>Boating</td>
<td>Minor</td>
<td>No impact</td>
<td>Insignificant</td>
<td>No impact</td>
</tr>
<tr>
<td>Fishing</td>
<td>No impact</td>
<td>Positive</td>
<td>No impact</td>
<td>Positive</td>
</tr>
</tbody>
</table>
### 5.15.7 Mitigation and compensation

The mitigation and compensation measures are already described above and include:

- In the Lolland reclamation, a new beach at the western end, a bay with beach and a lagoon with beach connecting the bay with Rødbyhavn which will partly compensate for the loss of bathing beaches.
- The bay and lagoon in the Lolland reclamation will provide opportunities for water sports.
- A new beach along the southeast side of the Fehmarn reclamation will compensate fully for the lost bathing beach.
- The seadikes around the reclamations will provide new opportunities for recreational fishing.

All these measures are included in the design for the project and will therefore be implemented.

### 5.15.8 Decommissioning

Decommissioning of the bored tunnel will not involve any marine activities and therefore there will be no impacts on marine material assets.
5.16 Cultural heritage and archaeology

This section deals with the cultural heritage and archaeology in the marine area of Fehmarnbelt and the potential impacts of the bored tunnel upon object and sites of archaeological interest. For Fehmarnbelt this consists of ship wrecks and other objects more than 100 years old on the seabed.

Cultural heritage and archaeology is an environmental component under the environmental factor “material assets and cultural heritage” as defined in the EU EIA Directive 97/11/EC.

5.16.1 Project pressures and potential impacts

The pressures of the bored tunnel project are essentially those caused by the reclamations and the marine construction works. Table 5.99 lists the potential impacts of the pressures. These are all considered in the assessment of the impacts in the sub-sections below.

<table>
<thead>
<tr>
<th>Project pressures</th>
<th>Potential impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction phase:</td>
<td>Damage to cultural or archaeological objects and sites</td>
</tr>
<tr>
<td>› Reclamations covering seabed</td>
<td></td>
</tr>
<tr>
<td>› Dredging and sediment spill</td>
<td></td>
</tr>
<tr>
<td>› Activities of vessels and marine plant including anchoring</td>
<td></td>
</tr>
<tr>
<td>Operation phase:</td>
<td>Damage to cultural or archaeological objects and sites</td>
</tr>
<tr>
<td>› Reclamations covering seabed</td>
<td></td>
</tr>
</tbody>
</table>

5.16.2 Existing cultural heritage and archaeology

Ship wrecks from all historical periods are found almost everywhere in Danish and German territorial waters. There are also pre-historical items in the form of settlements, fishing sites, cultural objects and discarded waste such as bones from the time of the hunter-gatherer tribes. These sites are underwater because sea water levels were approximately 70 m lower than today at the end of the last ice age about 10,000 BC. The level rose gradually until about 3,500 BC and in that period the climate was warmer leading to the stone age settlements along earlier coastlines.

A series of baseline studies have been carried out with the purpose of mapping the marine cultural heritage and archaeology in Fehmambelt:

› Geophysical surveys with multibeam echo sounder, side scan sonar, sub-bottom profiler and magnetometer in a 2 km wide corridor from coast to coast along the tunnel corridor at depths > 6 m.
Geophysical surveys with side scan sonar, sub-bottom profiler and magnetometer in a 5 km wide zone along the coast east and west of Rødbyhavn.

Diver inspections and ROV video (Remotely Operated Vehicle) of selected anomalies with the purpose of locating possible stone age settlements east of Rødbyhavn and east of Puttgarden.

Geotechnical borings in the 2 km wide corridor were also studied to identify possible stone age settlements and earlier coastlines.

These studies located two ship wrecks and an anchor near the tunnel alignment, see Figure 5.132. No evidence of pre-historical settlements was found.

![Figure 5.132 Locations of the wrecks of “Lindormen, another warship (Kanonvraget) and an anchor.](image)

The Viking Ship Museum, Roskilde, Denmark carried out archaeological studies of the two wrecks. The Danish warship Lindormen which during the Battle of Fehmarn 13 October 1644 and lies 370 m west of the tunnel alignment. Divers have robbed many objects and parts of the ship.
The second ship, temporarily called the “canon boat wreck”, lies in Danish waters about 200 m from the tunnel alignment. It is probably a Dutch ship and may also have sunk during the Battle of Fehmarn. However, some evidence suggests that it is older and it is not possible to identify it by name. Figure 5.133 is a photo of part of the wreck.

Figure 5.133   Photos of parts of the canon boat wreck

A ship’s anchor from about 1850 was also identified and lies 180 m from the tunnel alignment.
Legal situation

In Denmark historical ship wrecks and ancient monuments on the seabed are protected under the Museums Law §28 and 29 and must not be disturbed or removed without the permission of Kulturstyrelsen (the Agency of Culture). Kulturstyrelsen maintains a database of ancient monuments and archaeological sites (www.kulturarv.dk/fundogfortidsminder). The Museums Law protects all ancient and cultural monuments and archaeological objects and sites on the seabed even if they are not yet registered in the database. This means that any new finds are also protected by the law.

In Schleswig-Holstein a new law passed in January 2012 stipulates a similar protection of all cultural and archaeological objects and monuments. The law, Denkmalschutzgesetz des Landes Schleswig-Holstein (Law on Protection of Cultural Monuments), also protects such finds from any changes in their state due to any construction works.

The administrating authority on Fehmarn and in the sea is Archäologisches Landesamt Schleswig-Holstein (ALSH) (Slesvig-Holstein’s Agency for Archaeology). The agency coordinates excavations and is responsible for registering finds in a database (Archäologische Landesaufnahme).

All marine construction works or activities on the seabed are to be approved by the agencies in Denmark and Schleswig-Holstein before work starts. The agencies assess their own national area involved with respect to known finds and may request that geophysical studies be made along with subsequent archaeological studies of objects and sites identified on the seabed. The studies for Fehmarnbelt were carried out by the Viking Ship Museum in Danish waters and by ALSH in German waters.

5.16.3 Methodology

The impact assessment methodology consists basically of determining if there is an overlap between the project pressures and the identified ship wrecks and anchor on the seabed. For the present project this means determining:

› If the reclamations will cover the ship wrecks or anchor.
› If dredging or construction works occur over or close to the sites.
› If sediment spill from the dredging can adversely impact the sites.

The severity of loss or degree of impairment is assessed if there is any impact and environmental significance is determined.

5.16.4 Assessment of impacts during the construction phase

Figure 5.132 shows that the reclamations, work harbours and access channels will not impact either of the ship wrecks or the anchor.
Similarly, marine construction works will be restricted to areas close to the reclamations, work harbours and access channels and will not impact the ship wrecks or anchor.

The area affected by sedimentation from the sediment spilled during dredging works for the work harbours and access channels is described in section 5.3 Water Quality above. It is seen that sediment will not settle at the sites of the wrecks or anchor.

5.16.5 Assessment of impacts during the operation phase
It is only the land reclamations at the Lolland and Fehmarn coasts which can have any impacts on marine cultural heritage and archaeological assets. As shown in the section above the reclamations will not impact either of the two wrecks or the anchor.

5.16.6 Significance of impacts
It is shown above that the bored tunnel project will not impact any of the known cultural heritage or archaeological objects on the seabed. The significance of the impacts is therefore classified as “no impact”.

5.16.7 Mitigation and compensation
Mitigation and compensation measures are not necessary since there will be no impacts. However, as a security measure in connection with the chosen immersed tunnel solution, the Danish Kulturstyrelsen has required that the canon boat wreck should be covered with sand and an armouring layer of stone to reduce decay and prevent robbing by divers. Femern A/S has already covered the wreck as required.

Femern A/S will specify the areas around the wrecks and anchor to be avoided by construction vessels in the construction contracts.

Normal construction management procedures require that construction works shall stop immediately if new cultural or archaeological finds are made. The responsible agency shall be contacted and the agency will decide on further action, i.e. which investigations should be made and when construction can recommence. Femern A/S will include the specification of such procedures in the construction contracts.

5.16.8 Decommissioning
Decommissioning of the bored tunnel will not involve any marine activities and therefore there will be no impacts on marine material assets.
5.17  Shipping

This section describes the present shipping traffic in Fehmarnbelt and the studies
carried out to ensure safe conditions for shipping during construction and operation
of the bored tunnel alternative for the fixed link.

The studies carried out were specified and coordinated by the Danish and German
maritime navigation authorities.

Shipping differs from the other marine environmental issues described in previous
sections of this chapter. Therefore the method of investigation and reporting also
differs from the previous sections.

5.17.1 Project pressures and potential impacts

The project pressure on the existing shipping traffic in Fehmarnbelt consists
entirely of the activity of construction vessels and marine plant with the potential
impact being an increased risk of collision.

The bored tunnel does not present any pressure on shipping in the operational
phase since there are no permanent structures in the shipping routes.

5.17.2 Shipping studies

Femern A/S initiated the process of obtaining approval from the Danish and
German Maritime Authorities in 2006. At that time the project alternatives were
the immersed tunnel and the cable-stayed bridge.

A steering committee formed by the authorities from the two countries identified
the analyses and investigations which Femern A/S should carry out in order to
define the risk control options which would be necessary to ensure safe conditions
for shipping in Fehmarnbelt during construction and operation of the preferred
immersed tunnel solution and the alternative cable stayed bridge solution for the
fixed link. The committee has not considered the requirements for a bored tunnel
solution. The authorities will follow and coordinate activities until then end of
construction and commissioning of the link.

The baseline data for the studies was a one year record of shipping in the period
2006/2007, its composition, intensity and sailing pattern. The data was used to
develop predictions of the traffic in 2020 and 2030. The maritime authorities
selected these two years as the reference scenarios for analysis of safety for
passage through Fehmarnbelt. For the construction phase it was conservatively
chosen to use 2020 which is towards the end of construction when shipping traffic
is more intense than earlier. For the operation phase the year chosen was 2030
which is approximately 10 years after the originally planned commissioning of the
link.

A comprehensive and quantitative accident risk analysis was made for the
immersed tunnel and the cable stayed bridge as the basis for the maritime
authorities’ assessment of shipping safety. The risk analyses included the
commercial shipping traffic, construction vessels and stationary marine plant and the proposed risk control measures.

The experiences obtained during the marine geotechnical borehole investigations in 2009 – 2010 were useful in the risk analyses. In that period a drilling rig protected by a safety zone and buoys took samples of the seabed along the link alignment. Observations during the drilling gave useful information on how ships react to stationary marine plant operating in a safety zone marked by buoys.

It is noted that specific risk analyses for the bored tunnel alternative have not been performed. Specific analyses have not been considered necessary since construction of the bored tunnel only involves very limited traffic across Fehmarnbelt. The results of the studies for the immersed tunnel are used for the present assessment of impacts on the bored tunnel project on shipping.

5.17.3 Navigation routes and shipping intensity

Route T which passes through Fehmarnbelt is used by the major part of the commercial shipping between the Baltic Sea and the North Sea. In addition there is intense ferry traffic between Rødbyhavn and Puttgarden, local commercial traffic and smaller vessels for fishing and recreation.

The international commercial traffic (excluding ferries) amounted to 48,000 ships per year in 2006/2007 but the intensity has since fallen to 38,000 in 2010, most probably due to the global financial crisis. The navigational route used by the vessels, the sailing pattern and intensity are quite constant throughout the year. The traffic is dominated by cargo vessels (50%) followed by tankers (25%) and container ships (15%). The length of the vessels is typically 50 m – 300 m.

The local traffic in Fehmarnbelt is dominated by the ferries with 34,000 crossings per year and a present maximum in summer of 104 per day. The ferries are 150 m long.

The remaining local traffic consists of smaller vessels used for commercial fishery and recreation (sailing boats and motor boats). This traffic is rather evenly distributed in the Fehmarnbelt area and doesn’t follow the routes used by the international shipping. The intensity of this local traffic varies over the year with the highest intensity in summer and lowest in winter. It is estimated that this part of the local traffic accounts for about 9,000 movements per year.

Figure 5.134 shows the shipping routes and intensity in 2010 in the Fehmarnbelt area. It is seen that the shipping uses Route T through Fehmarnbelt and generally maintain a directional separation even although there is not a requirement for separation. Towards west the route divides into Route H, Route T and the Kiel – Baltic Sea Route. Routes H and T lead up into Great Belt while the Kiel – Baltic Sea Route is the connection to Kiel and the Kiel Canal. Route T is for the largest ships, e.g. tankers, with drafts of up to 17 m.
The figure also clearly shows the ferry traffic routes between Rødbyhavn and Puttgarden and between Gedser and Rostock. The apparent route east from Rødbyhavn and close to land was due to the construction activities at the Rødsand 2 windmill park which is now completed.

The remaining medium and low intensity routes are due to shipping outside the main routes and do not contribute significantly to the overall traffic in Fehmarnbelt.

Traffic predictions for the international commercial shipping show that the intensity in Fehmarn will rise to 70,000 – 80,000 per year in 2020 and 80,000 – 110,000 per year in 2030 depending on the general economic development in the Baltic Sea countries. The predictions are based on the 2006 data and it has been chosen to ignore the recent reduction in intensity because of the possibility of a return to “normal” traffic if the global economic crisis is resolved.

5.17.4 Risk assessment
The risk assessment starts with modelling the risk of accidents on Route T in the present situation. Such accidents include encounters between two ships, accidents during overtaking manoeuvres and collisions with ferries. The risks are evaluated in terms of fatalities, property damage (as a cost) and environmental damage (principally oil spills).
The subsequent steps are assessments of the risks in the construction phase and in the operation phase with or without the ferries.

The risk assessment for the immersed tunnel is briefly summarised below because it is the basis for the assessment of the bored tunnel.

**Immersed tunnel**

For the immersed tunnel the maritime steering committee specified that the following risk control measures should be implemented in the construction phase:

- Coordination through the maritime steering committee (continuous monitoring and improvement of risk control options).
- Implementation of a Vessel Traffic Service (VTS) which will monitor traffic and provide information to ships in the area.
- Guard ships in the work areas to warn vessels on collision courses.
- Coordination of work vessel traffic by the marine contractor.
- Marking of safety zones around work sites with buoys and lights.
- Limited number of simultaneous work sites and adequate spacing between them.
- Official warnings (international maritime navigation rules) for commercial shipping, fishery and recreational boating.
- Restrictions on operation of work vessels, e.g. all movements to be on east of the link alignment away from the ferry traffic.

The VTS would be the coordinating authority commercial shipping in the area including the guard vessels at the work sites. Femern A/S will establish a coordinating body for the work vessel traffic.

It was assumed that these risk control measures would be discontinued in the operation phase.

The work vessel traffic during the four year marine construction period is estimated to be 130,000 movements, or about 90 per day which is of the same order as the ferry traffic. About half the movements would cross Route T.

In addition, at any one time, there would be a maximum of two marine work areas along the alignment. These areas would be moved every 2 – 3 weeks as construction progresses. The activity in these areas would first be dredging of the tunnel trench, then temporary storage and immersion of the tunnel elements and finally backfilling of the trench. The maximum size of the work areas would be 1,900 m × 950 m.

The risks of collisions and other accidents were modelled for four scenarios:

- **Reference scenario (2020)**
  No construction works, no risk control measures.
Construction phase (2020)
Construction in progress, risk control measures implemented, with ferry service.

Operation phase (2030) – with ferries
No risk control measures, continued ferry service.

Operation phase (2030) – without ferries
No risk control measures, no ferry service.

The results of the quantitative risk analysis of the four scenarios are shown in Figure 5.135. The risk is measured in million euro per year.

![Figure 5.135 Average risk per year for the four scenarios for the immersed tunnel](image)

Figure 5.135 shows that the risk during construction is greater than the reference scenario. The largest part of the construction risk is due to accidents involving work vessels and collision with tunnel elements. The possible collisions with the floating tunnel elements is the greatest risk in terms of cost since a damaged element will be very expensive to repair. Therefore even a small risk of collision gives a large contribution to the cost.

The risk of damage to the property of Femern A/S and its contractors during construction is 6 million euro per year.

The risk due to accidents which do not involve work vessels or tunnel elements is less during construction than in the reference scenario. This is due to the implementation of the risk control measures.
During the operation phase in 2030 the risk raises above the risk during construction due the increased international ship traffic and the cessation of the risk control measures. The risk will fall by about 10% if the ferry service stops.

The Danish and German Maritime Authorities have concluded that the level of safety for shipping in Fehmarnbelt during construction of the immersed tunnel is acceptable provided that the risk control measures are implemented.

Bored tunnel
The construction of the bored tunnel alternative only requires limited traffic by work vessels.

A maximum of 10 barges per day (20 crossings) will deliver dewatered slurry from the tunnel boring machines on Fehmarn to the reclamation on Lolland in the 45 month period from April 2016 to December 2019. The barges will be self propelled. This corresponds to 20% of the present ferry traffic and only 10% of the combined ferry and work vessel traffic for the immersed tunnel.

Approximately two ships per day will deliver construction materials to the main work harbour on Lolland and another two ships per day to the work harbour on Fehmarn. This can be compared with the expected 200 ships per day on Route T in 2020.

Construction of the bored tunnel does not involve any stationary marine plant in the shipping routes or in most of the Fehmarnbelt as is the case with the immersed tunnel.

Dredgers will work at the work harbours and access channels and some marine plant will be involved in the construction of the containment dikes around the reclamation. However, this is the same for the immersed tunnel where the risk of accidents with shipping was excluded from the overall analysis because the activities are not near any of the shipping routes. Furthermore, they are in shallow water where ships will not enter.

It is therefore assessed that the construction of the bored tunnel will pose only a negligible increase in shipping accident risks in Fehmarnbelt.

5.17.5 Conclusion
The overall conclusion is that construction and operation of a bored tunnel solution will not cause any significant change in the safety for international commercial shipping in Fehmarnbelt.
6 Assessment of Impacts on Lolland

6.1 Introduction
This chapter addresses the impacts of the bored tunnel alternative solution on the terrestrial environment on Lolland.

6.1.1 Environmental components
The terrestrial environment is sub-divided into various environmental factors and components, each of which is addressed in a section of this chapter.

› Landscape and soil
› Flora and fauna
› Cultural heritage and archaeology
› Recreation
› Water
› Noise and vibrations
› Air quality and climate
› Material assets
› Population and health
› Derived socio-economic effects

6.1.2 Background reports
A brief summary of the existing environmental conditions is given for each component. The objective is to present the reader with the essential information, i.e. the results of the baseline studies which are needed for an understanding of the impact assessment. Reference is made to the background baseline report, COWI 2012a for the full, detailed description of the baseline studies.

The impact assessment studies for the bored tunnel are reported directly in this chapter, i.e. there are no background reports on the specific assessment studies. In a few cases the impact assessment is based on the immersed tunnel because of the similarities to the bored tunnel. COWI 2012b is the background impact assessment report for the immersed tunnel.
6.1.3 Assessment methodology

Reference is made to the Introduction section of Chapter 5 where the assessment methodology for the marine environment is described. For Lolland the methodology is adjusted to comply with standard practice in Denmark for EIAs of projects on land.

The flow chart for the procedure adopted for Lolland is shown in Figure 6.1.

The first step is to calculate the magnitude of the pressure, e.g. the area and location of the construction work site, of the corridors for the motorway and railway and of the toll plaza etc.

The second step is to calculate the magnitude of the impact, e.g. continuing the example, the area of salt meadow, marsh, dry grassland etc. affected by the construction work site etc.

Finally the significance of the impact is assessed. This is done by expert judgement based on:

› Importance of the sub-component (e.g. salt meadow).
› Comparison magnitude of impact with natural variability where relevant.
› Recovery time.
› Comparison magnitude of impact with the total area or population or availability of the sub-component in the study area or on Lolland as relevant.
› Implementation of mitigation and compensation measures.

“Importance” refers to the value of the sub-component to the terrestrial ecosystem and is categorised relatively as “very high”, “high”, “medium” and “minor”. The final step classifies the impact as “significant” or “insignificant”.

The significance is assessed assuming the implementation of the recommended mitigation and compensation measures.
Figure 6.1  Procedure for assessment of impacts on Lolland
6.2 Landscape and soil

Lolland's landscape and soil have been formed by the last Ice Age, by the weather and by human activity over millennia.

6.2.1 Method

The landscape and soil have been analysed and divided into landscape areas using the method Landscape Character Assessment (Landskabskaraktermetoden) (Danish Ministry of the Environment 2007). The division is based on an overall assessment of the landscape values, including aesthetics, recreational opportunities, history, landscape creation and soil conditions. The mapping provides an overview of the types of landscape in an area and how vulnerable they are to external pressures.

The landscape and soil are protected by a number of commitments. Information on these was obtained from the Municipality of Lolland (the local authority) and other sources.

The importance of the landscape and soil has then been assessed on a four-step scale as very high, high, medium or minor. The importance of the landscape areas is assessed on the basis of criteria including an assessment of the landscape's character as well as designations and legislation for soil and landscape. The criteria are indicated in the environmental mapping report (COWI 2012a).

6.2.2 Legal framework

A review of the legal framework considered to be relevant for landscape and soil is presented below.

An area at Saksfjed Inddæmning is protected under the Danish Nature Protection Act on account of its nature and landscape. This area must not be changed without an exemption or a new protection case.

The Danish Nature Protection Act includes building and protection lines. These ensure that no structures are built within a specific distance from rivers, lakes, forests and beaches. Among others, there is a lake protection line around Stengård Sø east of Rødbyhavn and a river protection line around Rødby Kanal north-west of Rødby.

The Danish Planning Act protects the so-called coastal proximity zone, i.e. mainly land areas less than 3 km from the coast. The coastal proximity zone protects coastal landscapes against construction works.
Lolland Municipality’s 2010-2022 Municipal Plan has also designated three landscape types that should be protected:

› Larger undisturbed landscapes must be kept free of technical installations that disturb the experience of the landscape, including noise. In the north-eastern corner of the study area, there is a small part of such a larger undisturbed landscape.

› Structures or installations in lowland areas must be designed so that subsequent natural restoration is possible. There are lowland areas in the drained fjord and lagoon areas east of Rødbyhavn and the former Rødby Fjord.

› On farmland with special nature and landscape values, establishing installations or making other interventions that may cause deterioration of
landscape and nature or disturbance to flora and fauna are normally not permitted. The fjord arms in the former Rødby Fjord and Saksfjed Inddæmning are designated in this category.

6.2.3 Existing landscape and soil conditions
The analysis of the existing condition covers 'landscape creation and soil' and 'the cultural landscape's development and land use'. The landscape areas have been described and characterized on the basis of these factors.

Landscape creation and soil
The landscape of Lolland was primarily formed during the last Ice Age. The terrain was levelled off by the ice which, when melting, left the landscape relatively flat with slightly wavy landscape forms. The shape of the landscape forms close to the coast is elongated and clearly oriented in the direction of the movement of the ice.

The soil in the wavy landscape shapes is primarily clay, mixed with stone, gravel and sand.

Before the coastal dike was built in 1873, the coast consisted of barrier islands and spits in front of shallow lagoons and fjords. After the drainage in the 19th century, the lagoons and fjords were reclaimed. Today they are flat lowland areas below sea level and lying behind the dike, which is over 60 km long. The soil in the drained areas is primarily sand.

The cultural landscape's development and area use
As early as in the mid-19th century, the drainage of the shallow lagoons and fjords began. The storm surge dike on Lolland's southern coast was built in 1873 after a severe storm caused destructive flooding. After the construction of the dike the rest of the low-lying areas were drained and cultivated.

The good agricultural soil allowed the establishment of many farms and small holdings in the landscape. There are also several large estates in and around the study area complete with forests, fields, avenues and small holdings. Most of the area is still used for agriculture.

The landscape is characterised by a high degree of human activity. This is seen in the straight canals, the coastal dike and the marl pits that are now small, overgrown lakes or ponds.

Landscape areas
The coastal dike, the lowland area behind the dike and the agricultural landscape further inland are the landscape areas most likely to be affected by a fixed link east of Rødbyhavn.

The coastal dike forms a straight coastline on both sides of Rødbyhavn. With a height of 4 m, the dike appears as a striking landscape element in relation to the flat landscape behind the dike. The dike generally follows the barrier islands that
The inland boundary of the lowland area behind the dike is the former coastline of the lagoon and fjord. The area, which is artificially drained, contains meadows, lakes and reed forest, plus industrial installations, a sewage treatment plant and a wind farm. The soil is marine sand.

The agricultural landscape, which extends inland behind the lagoon, was created during the last Ice Age. It is characterised by scattered farms and a few manors and estates between intensively cultivated fields. The terrain is relatively flat with straight drainage ditches and hedges, plus many ponds - previously marl pits. The soil is clayey.
6.2.4 Importance

The importance of the landscape areas is assessed on the basis of criteria including an assessment of the landscape's character and designations and legislation for soil and landscape.

The map (Figure 6.6) shows that just one protected area, at Hyldtofte Østersøbad, has been assessed as being of very high importance. The dike and the former fjord bed are assessed as having high importance. This is on account of the striking appearance and the special formation history. The sandy lowland soil also offers good potentials for nature. The landscape within the beach and lake protection line is also of high importance. Finally, an area towards the north-east is designated as a larger undisturbed landscape and is therefore also assessed as being of high importance.

The agricultural area is of medium importance. This is because the landscape does not contain special landscape elements and the soil is common for the area. The agricultural value (quality) of the soil is discussed in section Material assets.

It is assessed that the importance of the landscape in the 0-alternative (2025) will be roughly as today. However, it is be possible that the coastal areas that are currently zoned as industrial areas, will be developed and in operation. The importance of the landscape within the industrial areas will be lower than today. The coastal area is also zoned for recreational purposes in the Municipal Plan. If the areas develop towards more recreational purposes in the future, this may mean an improvement of the present situation, provided that the current industry disappears. The rest of the land use is expected to correspond to the situation today.
6.2.5 Potential impacts

The impacts potentially caused by the bored tunnel can generally be divided into:

- Area expropriation
- Division of the landscape
- New land reclamation
- Impact on the experience of the landscape (noise, light, visual disturbance)
- Groundwater lowering and contamination, compaction and erosion of soil.

Access to agricultural areas, expropriation of agricultural land and contamination of soil are considered in the section on Material assets. Barrier effects in relation to recreational use of the landscape are discussed in the section on Recreation.
6.2.6 Assessment of impacts during the construction phase

During the 8 years of the construction phase, an area of 72 ha will be appropriated as a worksite on land and for use during the construction work itself. The areas appropriated in the construction phase will subsequently be re-established.

Coastal dike

Approximately 1 km of coastal dike will be appropriated as a worksite in connection with the construction phase. The section will be demolished to create part of the work harbour. The reclamation work for the new land area will start early in the construction phase. Therefore, the impact on the coast during the construction phase will be significant. The consequence is assessed as significant because an 8 km section of the dike will be appropriated and affected by the reclamation work. However, the impact is limited in time because the dike will be re-established and opened to the public again after end of construction.

The visual consequences for the experience of the dike and of the area from the dike are assessed as significant. This is because the straight coastline will be broken and traffic in the area will cause increased noise, light and visual disturbance to the experience of the landscape. The reclaimed land will be built as the material is excavated. The coastline seen from the sea will also be affected by the construction work, as the working harbour, the growing reclaimed land and traffic at sea will dominate the stretch. The construction work will expropriate a significant area on land and will make the area look like an industrial site. The visual impact of the worksite will, however, be limited to the construction period.

Illustrations can help increase understanding of a project. For example, an installation can be shown from a bird's eye view, which gives a good idea of the project as a whole (Figure 6.7). However, illustrations are less suitable as a basis for specific assessment of consequences. This is partly because it can be difficult to distinguish between the actual elements of the landscape and the additions in the illustration. Furthermore, the landscape is shown at an angle different from that experienced from a bike, car or when walking in the surrounding landscape.
Lowland area

In the construction phase, approximately 45 ha of lowland area behind the dike will be expropriated. The entire worksite is in the coastal proximity zone, and a part is also protected by the beach protection line (13 ha). The coastal proximity zone and the beach protection line that both aim to keep the coastal landscape free of unnecessary construction, will be temporarily rescinded during the construction phase. The worksite is dependent on a location by the sea in order to transport materials for the tunnel. Moreover, the lowland area is already disturbed by wind turbines and industrial activities.

The worksite will expropriate a section of the coastal landscape approximately 1 km long. The view within the lowland area is assessed as being greatly affected by the large industrial plants and facilities in the worksite.

There will also be drainage, erosion and soil compaction as a consequence of the construction work. This will, as far as possible, be limited through an environmental management plan and through the detailed project planning. Overall, it is assessed that the consequences of the construction phase are significant, as 45 ha of an important landscape area is expropriated for 8 years. However, the area will be re-established after the construction phase and the characteristics of the sandy soil will not change since the structures are mainly built on minimum 1 m of fill which will be removed.

Agricultural landscape

The landscape and soil in the agricultural landscape east of Rødbyhavn will be affected by the area expropriation and the increased traffic during the construction phase. The tunnel mouth for the railway will be located further from the coastal dike than the tunnel mouth for the motorway and will thus be in the agricultural landscape at Færgevej. However, the consequences of this impact are assessed as insignificant. This is because the landscape and soil where the new alignments will
be located are already influenced by proximity to the existing motorway and railway.

6.2.7 Assessment of impacts during the operational phase
When the construction works have been completed, the impact will be limited to the use and presence of the motorway and railway tracks and the associated toll facilities, tunnel portal and land reclamation.

Coastal dike
The tunnel portal crosses the dike and expropriates 1 ha, which does not, in itself, have significant consequences for the landscape and soil. A section of 8 km of the dike will, however, be more than 0.5 km inland behind a land reclamation area. This means that the section will lose its direct contact with the sea permanently and thus, one of the dike's special features as a landscape element. In addition, the sandy beach and the dune area west of Rødbyhavn will be lost, as well as the long coastal section of sandy beach from Rødbyhavn to Bredfjed. This is overall assessed to be a significant consequence for the coastal landscape and the associated soil.

Land reclamation
The coastal land reclamation will be a major new feature in the landscape and will have an influence on a number of environmental issues, e.g. landscape, new nature areas including ponds, new habitats for birds, animals, amphibians, insects and new recreational possibilities.

Chapter 3 describes that, after dewatering, 36% of the tunnel slurry to be deposited in the Lolland reclamation will be clay with a high water content. Under normal circumstance it is expected that it will take 4 – 15 years before the land reclamation
The land reclamation will be sufficiently consolidated to allow the development of nature areas and recreational facilities. Chapter 3 also describes that it is expected that a technical solution can be found to ensure that the land reclamation is ready for development at the end of construction. However, for the assessment of impacts, the precautionary principle is invoked and the assessment is based on the assumption that it will be 4 – 15 years before the area is ready. This means that the first part of the reclamation which is filled may be ready at the end of construction while the last part, at worst, will not be ready for up to 15 years.

The impact of the land reclamation on landscape value is assessed as being significant because:

› The earth surface of the reclamation will be partly bare and visually unattractive for some years.

› Although an attractive landscape will eventually be developed, it will be up to 15 years before this can be achieved.

› The reclamation has a detrimental impact on the existing coastal landscape, as described above.

The project will also change the coastline seen from the sea. This is mainly due to the change of the current straight coastline to a more varied coastline. The portal will blend in with the vegetation on the land reclamation area while the terrain of the constructed embankments possibly can be seen from the sea.

The new land area will potentially affect the beach protection line. The dike and part of the lowland area behind the dike are currently included in the beach protection line. Depending on the development of the landscape area, it is expected that the future protection line will be moved, based on the new land area. The beach protection line is determined by the vegetation line, and therefore the protection line can not be determined until vegetation is established.

Lowland area

Approximately 14 ha will be expropriated for the motorway and railway, which will constitute striking new structures in the landscape. The consequences of the area expropriation and the barrier are, however, assessed as being rather insignificant, because artificial embankments will be constructed in the section between the tunnel portals and the land area. These embankments will cross the existing structures and will, with their contours, stand out in the flat, low-lying lowland area. In relation to the visual impact on the eastern part of the lowland area, the artificial embankment for the railway tunnel will screen off traffic on a section of approximately 500 m of the motorway.

The sea is not visible from the low-lying drained areas east and west of Rødbyhavn because of the 3.5 m high coastal dike, and the land reclamation area will not affect the local landscape experience. The portal will not be visible from west of Rødbyhavn, and the impact is therefore considered to be limited in the lowland area. None of the consequences are assessed as significant.
Agricultural landscape
The landscape and soil in the agricultural landscape east of Rødbyhavn will be affected by the area expropriation and increased traffic during the operational phase. In addition, part of the artificial embankment constructed above the railway's alignment south of the tunnel portal, will be located within the agricultural landscape. Like the lowland area, the embankment will be a new type of landscape element. The consequences of this impact are assessed as insignificant. This is because the landscape and soil are already influenced by proximity to the existing motorway and railway, and the embankment has a flat gradient when seen from the land.

6.2.8 Mitigation and compensation measures
To reduce the tunnel's significant consequences, a number of mitigation and compensation measures have been incorporated for the landscape and soil. The measures cannot prevent the impacts on the landscape and soil, but they may contribute to limiting the consequences. The measures are as follows:

Construction phase
› During the construction work, landslides and erosion of uncovered soil surfaces and slopes may occur. An environmental management plan will be prepared, describing how landslides and erosion will be limited.

› The slopes on the artificial embankments will be constructed so that erosion and landslides are limited. This will be ensured during the detailed project planning of the project.

› Top soil will be removed from construction sites and stored. At the end of construction the land surface will be restored and the top soil replaced.

› Construction vehicles will cause soil compaction. At the end of construction the compacted soil will be loosened by ripping and the top soil replaced to restore the land for agriculture.

Operational phase
› A technical solution should be developed to ensure that the land reclamation is ready for development as soon as possible and not later than the end of construction.

› The coastal dike will be re-established in accordance with its original character at the end of the construction phase.

6.2.9 Conclusion
The approach and ramp area with the motorway and railway, tunnel portal and toll facilities are, in relation to landscape and soil, best located east of Rødbyhavn. The landscape and soil are already characterised by small industrial installations and wind turbines. The toll facilities and new planted areas will be established on the old moraine area, far from the former lagoon area with landscape and soil values.
The tunnel portals and the artificial embankments of up to 12 m will, however, will be striking new elements in the mainly flat landscape.

In the construction phase, a large and valuable coastal area will be expropriated for more than 8 years as a worksite for the tunnel work and to establish the land reclamation. This has significant consequences for the landscape and soil at the coastal dike and for the landscape experience.

After construction, the lowland area will be re-established and a new natural environment will be constructed. The old coastal dike will be affected for an 8 km section by the land reclamation, which will be 500 to 700 m wide. It may not be possible to develop the land reclamation for up to 15 years. Therefore, it has been assessed that the construction of the land reclamation has significant consequences for the landscape and soil. The other impacts in the operational phase concern the coastal dike and the lowland area behind it, which will lose contact with the sea.

Landscape loss will be partly compensated by new landscapes on the land reclamations.
6.3 Flora and fauna

Most areas of interest for flora and fauna in the study area are found along the coast in coastal grasslands (protected as the nature type salt meadow) and inland in lakes, freshwater meadows, marshlands and forests. Many of these nature areas are protected under Section 3 of the Danish Nature Protection Act.

Various plant species live here, as well as mammals, birds, amphibians, reptiles and insects. Some of the animal species and their habitats are strictly protected under the EU Habitats Directive (Annex IV species), while the EU Birds Directive protects all birds against disturbance and prohibits destruction of nests.

It has been investigated whether a bored tunnel can cause damage to or destroy the habitats of these plants and animals and affect the ecological cohesion of the area. Ecological cohesion is equally important to strictly protected species, threatened species on the Danish red list, protected species and more common species.

6.3.1 Method

The current conditions are described on the basis of information from various sources and new mappings and fieldwork carried out in 2009, 2010, 2011 and 2012.

The sources are shown in the list of references and include databases of public authorities and private associations, literature, Municipality of Lolland, the Danish Nature Agency and local specialists. New biotope registrations have been made for sites, and searches for species groups have been carried out at selected sites.

Biotope registration

All areas that were assessed as potentially having biological value were registered as biotopes. This means areas covered by Section 3 of the Danish Nature Protection Act, forests/stands, hedges, stone and earth dikes, fallow fields and possible habitats for species in Annex IV to the Habitats Directive or birds in Annex I to the Birds Directive, plus threatened (red-listed), rare or protected species.

The sites were described and species lists for observed animals and plants were made. For bats, amphibians, dragonflies, ground beetles and butterflies, observed individuals were counted, while birds were counted as number of pairs. No estimates of population sizes were made.

Assessment of biological value

All localities were valued on a scale from 1 to 5 (very high to very low biological value). The biological value of a site includes its natural value and the indicator value of observed species, while the protection status of an area or the species found in it is not included. The valuation is based on the plant community found at the site, for example whether there are many indicator species, rare species, threatened species and species which Denmark has a special responsibility to protect (responsibility species). Moreover, an assessment was made of the importance of the site for the dispersal of species (for example, whether the site is
isolated, functions as a stepping stone between habitats or is a dispersal corridor), its importance for rare species, whether it is unique in a local context and whether it may be difficult to restore.

Mapping of species groups
As a supplement to the registration of localities, targeted searches were made for species within selected species groups. The selected species groups were bats, birds, reptiles, amphibians, dragonflies, grasshoppers, ground beetles, butterflies, fungi, vascular plants, mosses and reindeer lichens. The targeted searches cover all potentially occurring, strictly protected species (species from Annex IV to the Habitats Directive).

Impact assessment
The assessment of how nature is impacted by the establishment of a bored tunnel is primarily based on expert judgement. Experiences from previous road and railway projects are drawn upon. If a significant impact on nature cannot be ruled out, mitigation and compensation is carried out to the extent assessed as necessary.

6.3.2 Legal framework
The planning factors that are relevant to flora and fauna in the study area are shown in Figure 6.9.

Habitats Directive and Birds Directive
Denmark has designated areas in which habitat types and species are specially protected (Natura 2000) on the basis of the EU Habitats Directive and Birds Directive. Saksfjed Inddæmning in the south-eastern corner of the study area is the only designated area in the study area. It is both a habitat (Site of Community Interest, SCI) and bird (Special Protection Area, SPA) protection area.

The Habitats Directive also requires strict protection of a number of animal and plant species, regardless of where they occur. The species are listed in Annex IV of the Directive. 13 such species (6 amphibians, 6 bats and 1 insect) were found in the study area.

Danish Nature Protection Act
Section 3 of the Danish Nature Protection Act protects a number of habitat types against intervention: Lakes and ponds with an area of over 100 m², heath, freshwater meadows, salt meadows, marshlands and dry grasslands of over 2,500 m² and designated watercourses. The study area contains coastal grassland and reed beds (both protected as salt meadow) along the coast, many lakes and ponds, several watercourses and small areas of marshland, freshwater meadow and dry grassland.

Other planning restrictions
The Danish Forest Act regulates areas with protected forest. Byhave, Rødby Lystskov in Rødby, a forest in Saksfjed Inddæmning, a forest east of Rødbyhavn and several stands in Rødby and Rødbyhavn are protected.
The study area contains one protected area created in respect of the natural environment and landscape (Saksfjed Inddæmning and Hyllekrog). This protects the bird life, the botanic values and the landscape.

8 amphibian species, 2 reptile species, 6 bat species and 5 plant species that are protected were found in the study area.

The 2010-2022 urban area development plan specifies two guidelines with relations to flora and fauna (ecological corridors and special local nature areas) that apply to subareas within the study area.

Red list
The Danish red list is a list of Danish plant and animal species that are at risk of extinction in Denmark. The list's guidelines were prepared by the International
Union for Conservation of Nature, IUCN, and contain different categories based on the degree of threat to the species. Several national red list species live in the study area.

### 6.3.3 Existing flora and fauna

**Sites**

There are 9 sites with very high biological value within the study area, see Figure 6.10.

These include the railway terrain in Rødbyhavn which is habitat for the Annex IV insect willowherb hawkmoth and a number of rare species of insects, many of which do not exist elsewhere in Denmark. The locality is rated as valuable at a national level.

On the coastal dike both east and west of Rødbyhavn the habitat type coastal grassland (protected as salt meadow) is found. This area is habitat for many rare plant species such as white sticky catchfly and field cow-wheat and several species of butterfly. Despite its interruption at Rødbyhavn, the dike is important for the dispersal of plants and animals.

In the eastern part of the study area (directly west of Hyldtofte Østersøbad), a freshwater meadow with a very large population of the red-listed plant lesser butterfly-orchid is found, and further to the east, valuable nature areas are located directly behind the dike in Saksfjed Inddæmning. These areas are designated as both habitat (SCI) and bird (SPA) protection areas, and are habitats for rare plants, fungi, birds, amphibians and insects. Byhave, a forest in the northern part of the study area, is a deciduous forest with long continuity and is a habitat for amphibians and bats.

There are 33 sites with high biological value. These are, in particular, the coastal salt meadows (sub types coastal grassland and reed forest) directly behind the dike. The salt meadows contribute to the dike's dispersal function at a regional level and are habitats for species of amphibians and butterflies. There are areas with high biological value further from the coast, for example several ponds with rarer amphibians, a large, locally important marshland area (Ringsebølle Mose) with amphibians, birds and butterflies, and a recreational path (railway path) that functions as a local dispersal corridor for animals.
Figure 6.10 Biological value of the registered biotopes within the study area.

Strictly protected species

13 protected species that are covered by Annex IV to the Habitats Directive were found: 6 amphibians (great crested newt, European green toad, moor frog, agile frog, common spade foot and natterjack toad), willowherb hawkmoth and 6 bats (Daubenton’s bat, Nathusius’ pipistrelle, common pipistrelle, soprano pipistrelle, noctule bat and serotine bat). In addition to these species, which were found during the fieldwork, barbastelle bats and sand lizards have been reported in the study area. Sand lizard could however not be verified. See Figure 6.11.

Great crested newt is found throughout the study area, while agile frog is mostly found in ponds near deciduous forest. European green toad is found at 11 sites. The largest population is in a pond east of Rødbyhavn. Common spade-foot is found in 3 ponds west of Lalandia, natterjack toad in 1 pond in the same area, while moor frog is found near Saksfjed Inddæmning with isolated records around Rødbyhavn and Lalandia.
Few bats were found in the study area. The most important sites for bats are the railway terrain in Rødbyhavn and the forest immediately to the east, Byhave and a forest in Saksfjed Inddæmning. The area is generally poor in structures which bats can use as commuting routes (hedges, watercourses with rows of trees and forest edges) and is only of importance to the local population.

Figure 6.11  Records of Annex IV species

**Birds**

Four birds listed in Annex I to the Birds Directive are possibly breeding in the study area. Bittern and marsh harrier are associated with the reed beds along the coast, while red-backed shrike is believed to breed in the coastal grasslands around Syltholm Vindmøllepark (wind farm). Kingfisher has been registered at a potential breeding site in the lakes west of Strandholm Sø. Individuals of several other Annex I species were observed in the study area, but they were individuals
migrating through the area which is not considered to be of importance to the given species.

Red-listed (threatened) species
Several red-listed species were found in the study area. European brown hare is widespread in the uncultivated areas along the coast. Garganey breeds in a freshwater meadow east of Rødbyhavn in wet years (when the meadow is covered by water), while stonechat is believed to breed in Saksfjed Inddæmning.

Most red-listed insects live along the coast, either on the railway terrain, on the dike or directly behind it. Of these 5 are butterflies (grizzled skipper, dark green fritillary, Glanville fritillary, silver-washed fritillary and the white-letter hairstreak), 2 are burnet moths (forester moth and six-spot burnet moth), 21 are nocturnal moths and 3 are ground beetles. 4 red-listed plants (lesser butterfly-orchid, bur medick, wood betony and lance leaf water plantain) and 10 threatened fungus species were also found. The most important sites for fungi are Mygfjed, the dike west of Rødbyhavn, the dike at Syltholm Vindmøllepark, the dike at Hyldtofte Østersøbad and Saksfjed Inddæmning.

Protected species
All species of amphibians and reptiles are protected in Denmark. In addition to species covered by Annex IV, these are common newt, common toad and edible frog, which are found in many ponds in the area, and common lizard and grass snake, which live near and on the dike.

The protected plant, royal fern is found behind the dike both east and west of Rødbyhavn, while 4 orchid species (all orchids are protected) have large populations both along the coast and further inland.

Other species
All species found in the groups studied were mapped and included in the assessment of biological value. Many of the species found are widespread in Denmark. However some rarer species were also found. A species total of 24 dragonflies, 11 grasshoppers, 60 ground beetles, 31 butterflies, 2 burnet moths, 200 fungi, 70 mosses and 19 reindeer lichens were found. The most interesting records include blue sand grasshopper, which lives on the railway terrain in Rødbyhavn and is found nowhere else in Denmark, and Swartz’s polytrichum moss, which grows on a meadow between Syltholm Vindmøllepark and Hyldtofte Østersøbad. There is also a dune area dominated by reindeer lichens behind the dike just west of Hyldtofte Østersøbad. This nature type is rare locally and 11 species of reindeer lichens were found.

6.3.4 Existing pressures
› The highway and railway to Rødbyhavn fragment the area and cause increased noise and nitrogen deposition.
› The ferries cause increased noise and nitrogen deposition.
› Rødbyhavn creates a disruption of the coastal dike thereby decreasing its value as a dispersal corridor.

› Intensive farming in large parts of the study area causes fragmentation of habitats for plants and animals, increased nitrogen deposition and possibly increased supply of pesticides to bordering nature areas and surface waters.

› Generally the study area only contains few hedges which can serve as guiding structures for animals along the cultivated fields.

› Absence of natural watercourses, since the history of drainage means that the majority of watercourses are created by man.

› A background deposition of 13.48 kg nitrogen/ha/year.

› Buildings in the coastal area occupy areas which could otherwise develop into nature areas.

› Hunting (especially for birds), fishery and derived impacts caused by feeding and stocking with ducks in ponds.

The impacts due to these pressures are included in the assessment of the current conditions of the study area.

6.3.5 Importance

The importance of the study area for flora and fauna is shown on a four-point scale (Figure 6.12). The importance includes both statutory protection and biological value of species and habitats.

Figure 6.12 shows that there are areas with very high importance close to the coast. These are protected salt meadows on and near the coastal dike and habitats for Annex IV species. Dispersal corridors along watercourses and other nature areas are of high importance. Areas with the potential for a good natural environment have been given medium importance, while remaining areas have low importance.
Figure 6.12  Importance of the study area for flora and fauna

An example of an area with very high importance is the railway terrain in Rødbyhavn, which is habitat for many rare insects, including the Annex IV species willowherb hawkmoth. The occurrence of these species is due to the very warm and dry micro-climate at the site which makes it similar to areas much further south, where the species are more common. Another example is a shallow pond created by industrial activities directly east of Rødbyhavn, where the Annex IV species European green toad breeds in very large numbers. A third example is a temporary wetland on a meadow west of Syltholm Vindmøllepark, which in some years is a valuable habitat for the Annex IV species agile frog and European green toad and for the red-listed garganey. Between Syltholm Vindmøllepark and Hyldtofte Østersøbad there is a fourth example, which is a freshwater meadow with a very large population of the red-listed plant lesser butterfly-orchid. Finally the coastal dike is assessed as having very high biological importance due to the widespread occurrence of rare plants such as white sticky catchfly and field cow-wheat and its value as a dispersal corridor. Behind the dike, just west of
Rødbyhavn, there is a heterogeneous area where both moor frog and European green toad as well as the red listed grizzled skipper live.

There are also several ponds in which the Annex IV species moor frog, agile frog and great crested newt breed. In some years bittern, marsh harrier and possibly kingfisher breed in the reed beds along the coast west of Rødbyhavn. Red-backed shrike breeds around Strandholm Lake, on a site east of Syltholm Vindmøllepark and near the coast west of Rødbyhavn. These 4 bird species are Annex I species. All the areas mentioned have been given very high importance Figure 6.12.

Areas with high importance are, e.g. nature areas along the coast, located on old reclaimed land which is poor in nutrients, meaning that it has only been cultivated to a limited extent. These areas are home to a large population of the protected western marsh orchid which has become rarer in Denmark.

0-alternative
No major changes to the biological values are expected to occur in the 0-alternative since it is assumed that the current land use and drainage pattern will continue as at present.

6.3.6 Potential impacts
It has been investigated whether a bored tunnel can impact animals and plants by means of:

› Loss of area
› Fragmentation of nature areas
› Groundwater lowering
› Contamination of water, soil and air with nutrients and anthropogenic substances
› Disturbance caused by noise, light, vibrations and human traffic
› Changes in salt content or other factors in the coastal nature areas due to the new land reclamations
› Dispersal of invasive species

The impacts may occur due to temporary pressures in the construction phase and the more permanent pressures during operation.

Assessment of impacts on nature areas
Approximately 72 ha, of which parts are protected nature areas (specified below), will be lost during the 8 year construction phase of a bored tunnel. There is no loss of area in Natura 2000-area, protected area, protected forest, regional nature protection area or biotope network area (see Figure 6.9).

Of the nature areas lost only during construction, it is primarily the dike east of Rødbyhavn that is of value to flora and fauna (Figure 6.13). The dike is habitat for many rare plant species (among others field cow-wheat, white sticky catchfly and sea holly) and is also important for the dispersal of animals and plants.
Coastal grassland and reed beds (protected as salt meadow) around and east of Strandholm Sø (Lake) (Figure 6.13) will also be lost, as well as a small part of freshwater meadow west of Syltholm Vindmøllepark (windfarm) (some years covered by water and then of value to amphibians and birds) and a small marshland east of Strandholm Lake. In total, the following protected nature areas will be lost during the construction phase:

› 6.6 ha salt meadow (coastal grassland and reed beds)
› 0.5 ha marshland
› 1.75 ha freshwater meadow
› 4 lakes
› 700 m watercourse.

All the protected nature areas that are temporarily lost during the construction phase will be replaced with new nature areas, which are established prior to construction and with the same extent as the areas which are lost. In addition, the areas which are lost temporarily will be re-established to a condition, which will enable nature to re-establish after the construction period.

In addition to the 72 ha lost only in the construction phase, approximately 78 ha will be lost permanently for the bored tunnel's future structures, for example motorway, railway, tunnel portal and toll facilities.
The 78 ha include parts of the dike east of Rødbyhavn near the tunnel portal and parts of the dike east and west of Rødbyhavn, where there will be land reclamation. The land reclamation causes loss of approximately 10 ha.

Finally, valuable coastal grassland (protected as salt meadow) around Strandholm Lake will be lost. The protected nature areas that will be permanently lost are:

- 6 ha salt meadow
- 4 lakes (including Strandholm Lake of 8.2 ha)
- 350 m watercourse.

Areas that are lost permanently will be replaced with new nature areas on an area twice as large (1:2) before the present areas are occupied. Strandholm Lake and watercourses will be replaced 1:1. Coastal grassland and reed beds will develop on the land reclamation area in the future but it is uncertain when this process can start (assessed as between 4 and 15 years).

During the construction phase there will be temporary groundwater lowering, which can potentially lead to significant impacts on nearby wet nature areas. The necessary measures to prevent groundwater lowering outside the construction area will be implemented (e.g. cut off walls).

Addition of harmful, anthropogenic substances due to accidents is not assessed to cause a significant impact in nature areas. This is due to the low risk of it happening, which is further minimized by regulations in the environmental management plan for the construction phase. In the operation phase there are no sensitive nature areas in the immediate surroundings of the highway or railway, and therefore an increased level of salt in winter and pesticides in these areas will not cause a significant impact.

During construction there will be an increased nitrogen deposition in a sensitive nature area. Since the increased deposition will only occur temporarily (8 years) and is below the amount which is assessed as causing measurable changes (DMU 2005), the impact is not assessed as significant. There will not be increased deposition during the operation phase.

During the construction phase, soil containing seeds from invasive species will be moved around, potentially causing them to be spread. To ensure against a significant impact, the surface soil from areas with invasive species will be stored separately and not be reused as surface soil.

The establishment of the land reclamations can mean a decreased addition of salt to the salt meadows found along the coast today. Eventually this can lead to change in the vegetation. Potentially the land reclamations can also lead to changes in vegetation due to changes in hydrology and absence of coastal dynamics (e.g. wind), but the extent of this is difficult to predict.

The protected areas along the coast that are lost are shown in Figure 6.14. Note that the map shows that in addition to registered protected nature areas, there are other
areas which may be protected. In the calculations of lost protected areas, the additional areas are included as if they were protected.

Figure 6.14 Protected areas that are lost along the coast

6.3.7 Assessment of impacts on animal species

A large infrastructure installation can cause direct loss of habitats for species, impact through noise, light and discharge of substances, but it can also impact through fragmentation, by acting as a barrier to the free movement of animals. Fragmentation will cause the area between Rødbyhavn and the bored tunnel to become isolated. The area is small and there is a risk that the species living in the area today will die out.

The consequences of these impacts for the strictly protected Annex IV species, bird species in Annex I, red-listed species, protected species and other species are reviewed in the following.

The necessary mitigation will be carried out to reduce the impacts and risks.

Bats
All bats are Annex IV species. No breeding or resting areas for bats have been found and therefore no breeding or resting areas will be destroyed or damaged. There are however a few potential breeding or resting areas which will be affected (see FF).
A few foraging areas for bats will be lost, but they are all considered to be of little importance to the species in the area, and the impact is thus insignificant.

No important commuting routes for bats (hedges, forest edges and tree-lined watercourses) will be intersected. The structures present which will be affected are watercourses without bordering trees, narrow hedges which do not connect nature areas and there are no forest edges. The coastline is not considered to be an important bat commuting route because of wind exposure. Since no important commuting routes will be intersected a significant impact due to traffic kills can be ruled out.

Light and noise will not affect bats significantly, neither in the construction phase nor when the link is in operation. This is because none of the bats in the area are particularly sensitive to noise or light and since the area is generally of less importance to bats.
To ensure there is no impact on ecological cohesion for bats due to impacts on resting or breeding areas, all trees and buildings that may contain bats will be reinvestigated before they are removed. Bats are very mobile animals and even though the potential resting or breeding areas did not contain bats when field investigations were carried out, it is possible that bats will be present when the trees are removed many years later. If at all possible, the sites will be conserved if bats are found. Alternatively the bats will be removed from the site before it is destroyed and new breeding or resting sites will be established.

Overall, the bored tunnel is not considered to have an impact on ecological cohesion for bats.

**Sand lizard**

Sand lizard is an Annex IV species. It is uncertain whether sand lizards have ever been found in the study area or on Lolland. The last confirmed sighting from Falster is 30-40 years old. A possible sighting has been reported from Rødbyhavn, in an area which will become isolated by the bored tunnel. There is also a possible observation of tracks from sand lizard at Hyllekrog. Neither of the sightings can be confirmed. The species was not found during the field investigations despite a focussed search. Based on this, it is assessed that the species is not found in the study area and that it will therefore not be impacted.

**European green toad**

European green toad is an Annex IV species. A small part (the driest and least valuable to the species) of a freshwater meadow where the green toad breeds in wet years will be temporary lost and a possible resting area on the dike will be destroyed. Also an important breeding site will become isolated in the construction phase and to some degree in the operation phase. The degree of isolation in the operation phase will depend on the development of the land reclamation, but it is assessed that European green toad will be able to pass south of the tunnel portal.

During the construction phase, there is a risk of the species' dispersal paths being intersected by work roads, and in the operation phase by the new highway. These roads increase the risk of traffic kills.
To secure the population five of the ponds established before the construction phase will be made suitable for the species. Of these three new ponds will be placed near the existing pond with access to the railway terrain and two ponds will be placed north of Hyldtofte Østersøbad, securing the population there. After the construction phase, two more ponds will be established in the area affected by construction works.

From the new ponds, access to suitable resting and foraging areas with sparse or very short vegetation will be secured. 1 km of amphibian fence will be erected along the motorway to prevent road kills.

It is assessed that the mitigation measures incorporated (seven new ponds and 1 km of amphibian fence) will ensure that the population in the area can be maintained and that the area's ecological cohesion is intact.

**Great crested newt**

Great crested newt is an Annex IV species. A breeding pond used by great crested newt will be lost. To avoid an impact on the ecological cohesion of the species, three of the ponds that are established before the construction phase will be made suitable for great crested newt. It is assessed that the ecological cohesion for the species will thus be maintained.

**Moor frog**

Moor frog is an Annex IV species. A small population of moor frog will be isolated during the construction phase and to some degree in the operation phase. The degree of isolation in the operation phase will depend on the development of the land reclamation, but it is assessed that moor frog to some extent will be able to pass south of the tunnel portal.

To secure the isolated population during the construction phase, three ponds will be made suitable for the species in the forest east of the railway terrain. After the construction phase, another two ponds will be established in the area used for construction works. It will be ensured that the ponds established for great crested newt north of Hyldtofte Østersøbad are also suitable for moor frog. The amphibian fence erected along the motorway will prevent the species from being killed by road traffic. On this basis, it is assessed that ecological cohesion for the species will be maintained.

**Agile frog**

Agile frog is an Annex IV species. A small part (the driest and least valuable) of a freshwater meadow in which agile frog breeds some years will be used as a worksite. A total of three of the ponds established before the construction phase will be made suitable for agile frog. Dispersal paths will be destroyed by new roads both in the construction and operational phase and individuals of the species might be killed by traffic. The amphibian fence erected along the motorway will prevent the species from being killed by road traffic. It is therefore assessed that ecological cohesion for the species will be maintained.
Common spade foot and Natterjack toad
These two species (both in Annex IV) breed west of Rødbyhavn and it is assessed that they will not be impacted by the project.

Willowherb hawkmoth
Willowherb hawkmoth is an Annex IV species. When the rail service to Rødbyhavn is shut down, the railway terrain may become overgrown. This will have a negative impact on the breeding and resting areas of the willowherb hawkmoth. This is assessed as being outside the impacts of the assessed project and no mitigation measures will be carried out.

Marsh harrier
The Annex I bird species marsh harrier can be disturbed by noise and human activity, but since the species does not breed permanently in the study area, this impact is not assessed as being significant.

Construction work in or near a likely breeding site must be avoided to the extent possible to avoid scaring a breeding couple away. Marsh harrier forages over large areas and has a relative high tolerance towards human activity, including vehicles. It is therefore assessed that the species is not affected by traffic in the operation phase.

Red-backed shrike
The Annex I bird species red-backed shrike breeds in areas west of Strandholm Lake, parts of which will be lost in the construction phase. Remaining breeding areas (including areas west of Rødbyhavn and east of Syltholm windfarm) will be affected visually and by noise and light in the construction phase and parts also in the operation phase. The species breeds at scattered locations in the coastal area where there are several likely breeding sites in the form of coastal grassland with scattered hawthorn. The local population of the species is therefore not assessed as being significantly impacted during construction, despite the impacts on likely breeding sites. Operation will not impact the species significantly since it is
expected that the compensation areas will develop into suitable habitat for the species.

**Bittern**

The Annex I bird species bittern is likely to breed in reed beds west of Rødbyhavn at least in some years. They have been registered once in the breeding season near Stengård Sø (Lake) east of Rødbyhavn. It is assessed that the sites are less suitable as breeding sites and therefore the impact due to noise and disturbance during construction is not assessed as being significant for the species. The species is not affected during operation.

*Figure 6.18 Records of birds breeding in the study area*
Kingfisher
The Annex I bird species kingfisher are registered as a possible breeder near Stengård Lake and the nearby small lakes east of Rødbyhavn. The lakes are potentially impacted by noise and disturbance, but the impact is not assessed as significant for the species. This is because it can tolerate humans at the breeding site as long as there is no permanent disturbance exactly at the nest. The species is not affected during operation.

Stonechat
The red-listed stonechat breeds in Saksfjed Inddæmning at such a distance from the project that impacts can be excluded.

Garganey
The red-listed garganey breeds occasionally in a freshwater meadow west of Syltholm Vindmøllepark. The most western part of this area will be temporary lost but it is the least valuable to the species since it is the driest part which is seldom under water. Therefore it is assessed that the impact will not affect the population of the species.

Glanville fritillary
The red-listed butterfly Glanville fritillary will lose part of its habitat on the coastal dike. The construction works and the bored tunnel will also act as a barrier between habitats on the railway terrain and at Saksfjed Inddæmning, which are currently connected by the coastal dike. Parts of the dike will be re-established after the construction phase and the railway terrain will be selectively cleared of shrubs to compensate the impact in the construction phase. New nature areas at Saksfjed Inddæmning will develop into suitable habitat for the species.

Ground beetles
Two red-listed species of ground beetle will lose a small part of their habitat on the coastal dike as a consequence of the establishment of the bored tunnel. Parts of the dike will be re-established after the construction phase and new nature areas at Saksfjed Inddæmning will develop into suitable habitat for the species.

European brown hare
The red-listed hare will lose a small part of its habitat on the coastal dike and in the uncultivated areas behind the dike, because the areas will be lost in the construction phase. A smaller part will also be lost during operation. The population is not assessed as being affected by this loss and the re-established dike and the new
nature areas in Saksfjed Inddæmning will develop into suitable habitat for the species.

Figure 6.19 Records of red-listed species and western marsh orchid

Moths
Three species of moths which are Danish species of national responsibility (Chortodes brevilinea, Chortodes extrema og Chortodes elymi), will loose smaller parts of their current and potential habitats. Habitats for the species are widespread along the south coast of Lolland and due to the reestablishment of the dike and the new nature areas in Saksfjed Inddæmning the populations are assessed not to be significantly affected.
Western marsh orchid

The western marsh orchid will lose part of its habitat behind the dike as a consequence of area loss, and some of the individuals will be damaged. There will still be large populations of the species in the local area, e.g. in Syltholm Vindmøllepark and the species is assessed to quickly colonise the new nature areas in Saksfjed Inddæmning.

Common lizard, common toad, common newt and edible frog

Habitats for common lizard on the dike will be destroyed, and ponds where common toad, common newt and edible frog live will be lost. There is also an increased risk of individuals being killed and the new roads acting as barriers both during construction works and when the bored tunnel enters into use. To prevent an impact on the populations, the dike will be re-established and the new ponds and nature areas will benefit the species.

Other species

The plant species field cow-wheat is regionally yellow-listed. The dike along the southern coast of Lolland has the largest population in Denmark and parts of it will be lost. Especially the area lost at the dike west of Rødbyhavn can impact the population significantly. To secure the population, it will be sought to minimize the impact on the dike during establishment of the new land reclamations. Where the dike is impacted, the top soil will be removed and stored separately until it can be used on the re-established dike or possibly on the land reclamations. This will increase the likelihood of reestablishment of the species.

In addition, the new motorway and the new railway will act as a barrier in the landscape for roe deer and other animals potentially leading to a significant impact on these species. Fauna passages in both structures will mitigate and compensate for these impacts and thus secure the populations.

6.3.8 Mitigation and compensation measures

To mitigate and compensate the significant impacts on flora and fauna that are unavoidable, the following measures have been incorporated into the project and are illustrated in Figure 6.20.

New nature areas will be established to compensate for the nature areas lost. Before the construction phase, permanently lost areas will be compensated 1:2 and temporary lost areas 1:1. This means that 14 ponds, 0.5 ha marshland, 1.75 ha freshwater meadow and 18.6 ha salt meadow will be established. In addition a watercourse channelled through a pipe will be restored and Strandholm Lake will be

Protected species

Protected species are protected against killing, collection, capture and damage. Among other species, all bats, amphibians and reptiles and several plant species are protected.
be relocated. The replacement compensation nature areas will be established, at the latest, a year before the construction of the bored tunnel starts. After the construction phase, temporarily affected areas will be restored, including 0.5 ha marshland, 1.75 ha freshwater meadow and 6.6 ha salt meadow. A further four ponds will be established in the construction area. The new nature areas will be suitable for amphibians, birds, butterflies, ground beetles and hare as well as other species. The establishment of new nature areas will be detailed in cooperation with the Danish Nature Agency and Municipality of Lolland.

It is assessed that the criteria for being a protected biotope can be met in the compensation areas within 5-10 years (for meadow, marshland, salt meadow and dry grassland). For lakes it is anticipated to take 1-2 years.

It can not be guaranteed that values for flora and fauna will be exactly the same as in the present areas, but it is expected that similar values will develop within 10-25 years. However, it is likely that an even longer time may be required before the areas achieve high or very high biological value. It is a prerequisite that compensation areas have suitable soil conditions and are located close to existing nature areas without significant barriers between them.

Where the dike is impacted, the topsoil will be removed and stored separately until it can be reused as topsoil on the new dike or the land reclamation. This will increase the likelihood that vegetation similar to that currently present on the dike will develop.

Three fauna passages with berms along the banks of Næsbæk will be established to secure the passage of the watercourse and animals under the motorway, railway and Ottelundvej. These passages will be 0.5 m high and 5 m wide. There will be one additional fauna passage under the railway (0.5 x 0.5 m) and one under the motorway (0.5 x 1.5 m). There will also be a combined fauna passage and foot path in front of the tunnel mouth. Guiding structures leading to the passages as well as fences along the road near the passages will be installed as required.

1 km of amphibian fence will be established along the motorway to prevent road kills.

Sea buckthorn will be selectively cleared once in selected parts of the railway terrain to secure the population of Granville fritillary

All trees and buildings which can be used by bats will be reinvestigated prior to removal in order to avoid an impact on localities used temporarily by the species.

Lighting in both construction phase and operation phase will be adjusted to avoid unnecessary light pollution which can cause impacts on animals. There will not be permanent lighting along the highway in open country and where lighting is necessary, e.g. near the payment facility yellow light will be used which does not attract insects.

Ponds and lakes will be removed outside the breeding season of amphibians (meaning the period 1 October - 1 February). Construction work in the coastal area
will, to the extent possible, be initiated outside the breeding season of birds (meaning the period 15 July - 1 April).

Temporary amphibian fences will be placed around the construction area and approach roads. After further consideration fences also will be put up around the coastal dike to prevent impacts on European green toads hibernating in the dike.

Before the construction of a bored tunnel is initiated, an environmental management plan will be made. Femern A/S will ensure that the conditions for the construction phase are met by carrying out internal control of the contractors.

Figure 6.20 Proposed locations for the mitigation and compensation measures

6.3.9 Conclusion

The study area is valuable for a number of plant and animal species. Therefore there will be significant impacts on biological values due to the construction and
operation of a bored tunnel, construction of the land reclamation, a temporary work harbour, a drying plant for slurry and a tunnel segment factory.

Mitigation and compensation measures for significant impacts have been incorporated into the project. With the uncertainties that are always associated with these kinds of measures, it is assessed that the ecological cohesion of Annex IV species, other species and biological values as a whole are ensured throughout all phases of the project. The nature compensation areas will however not develop a high or very high biological value until many years into the future.
6.4 Cultural heritage and archaeology

Mapping of cultural heritage and archaeology covers both visible and invisible elements, structures and entire features in the landscape. Culture-historical relics show how people have used and affected the landscape from early history until today.

Cultural heritage includes protected ancient monuments, buildings that are listed or worth preserving, protected stone and earth dikes, hedgerows, valuable cultural environments, churches and church surroundings, cultural heritage areas and archaeological sites.

6.4.1 Method

To map cultural heritage and archaeology, information has been used from sources including the Danish Agency for Culture's two databases, 'Listed buildings and buildings worthy of preservation' (Fredede og Bevaringsværdige Bygninger) and 'Sites and monuments' (Fund og Fortidsminder). Information has also been obtained from the Municipality of Lolland, Lolland-Falster Museum, the topographical archives of the National Museum of Denmark and relevant literature. The general culture-historical development has been analysed using old maps. The culture-historical and archaeological areas and finds were mapped on the basis of the information obtained.

Six particularly valuable cultural environments have been identified and prioritized by Lolland-Falster Museum in cooperation with COWI. The prioritisation is based on the history, architecture, state of preservation and importance to the local area of the cultural environments.

For a more detailed description, please see (COWI 2012a).

The study focuses in particular on the area east of Rødbyhavn, where the most substantial impacts from the project are expected.

6.4.2 Legal framework

The planning and legislative commitments relevant to the culture-historical values of the area are existing legislation and guidelines form the Municipality of Lolland.

They include the following:

Protected ancient monuments

Protected ancient monuments, such as burial mounds, fortifications and ruins are protected against changes. Most protected ancient monuments are also covered by a 100 metre protection line within which no changes may be made.

Stone and earth dikes

Stone and earth dikes are covered by the Danish Consolidated Act on Museums, which states that no changes may be made to their state.
Listed buildings
Listed buildings (typically characteristic examples of building types or periods) are assessed as important at regional and national level under the Danish Preservation of Buildings Act.

Cultural heritage areas
Cultural heritage areas are designated by the Danish Agency for Culture in cooperation with Lolland-Falster Museum. These areas are not protected, but finds of non-protected ancient monuments are expected. Therefore, construction should, preferably, be avoided in these areas.

Buildings worth preserving
The Municipality of Lolland has, in cooperation with the Danish Agency for Culture, assigned a preservation value (SAVE value) between 1 and 9, where 1 is...
the highest value, to several buildings in the area. Values between 1 and 4 indicate that a building has an above-average preservation value.

Churches and church surroundings
Churches and church surroundings are protected against construction within a distance of 300 metres from the church. In addition, when planting forest, constructing buildings, locating technical installations, etc., it is necessary to assess whether the visual interaction between the church and the landscape suffers.

Valuable cultural environments
The valuable cultural environments are designated by Lolland-Falster Museum. Some are particularly important and are therefore selected as prioritized cultural environments based on their history and importance to the local area. The storm surge dike and Rødbyhavn are examples of prioritized cultural environments.

6.4.3 Existing cultural heritage and archaeology
Historically, Lolland is dominated by agriculture. Small farm houses and buildings, estates and manors, stone and earth dikes and hedges marking field and property boundaries are culture-historical elements that show how people have lived off the land and left their mark on the landscape.

Figure 6.22 The protected ancient monument Hyldehøj is surrounded by fields

Protected ancient monuments, cultural heritage areas and other archaeological sites
There are two protected ancient monuments with protection lines in the area: a fortification west of Lalandia and Hyldehøj north of Syltholm Vindmøllepark, which is a Stone Age round barrow with a passage grave.

The three cultural heritage areas designated in the study area are located in Rødby at Ringsebølle Mose and at an area south-west of the marsh.

The non-protected archaeological locations are sites with traces of human activity: settlements, graves and burial sites, building groups, structures, objects, etc. 95 archaeological finds have been registered in the study area, both individual finds and larger areas such as ancient fields or contours of embankments.
In addition, the Lolland-Falster Museum has designated areas of archaeological interest where one or more finds have been made, but where it is uncertain what is to be found beneath the ground. For example, the museum has designated a large area of archaeological interest east of the railway which includes a protected burial mound and relics from 30 small burial mounds from the Bronze or Stone Age. These areas are cultivated.

Listed buildings and buildings worthy of preservation

There are 9 listed buildings distributed over 4 locations in the area, some in Rødby and more in connection with the manors Højbygård and Lungholm at the eastern boundary of the area.

Most buildings worthy of preservation are in Rødby (144) and Rødbyhavn (73) and are included in the designated cultural environments. Others are dispersed.
throughout the area. The Strandholm farm, built in 1825, is situated near the coast east of Rødbyhavn. The farmhouse is worth preserving and has a SAVE value of 4.

Protected stone and earth dikes and hedges
There are 23 protected stone and earth dikes in the area, the majority in the eastern part between Hylldtofte Østersøbad in the south and Højbygård in the north. There are also hedges, which, to some extent, coincide with or are extensions of the stone and earth dikes. The hedges are not protected by legislation, but may be important to the appearance of the landscape.

Cultural environments
The six prioritized cultural environments in the study area are: Rødby as a market town and station town, the Fugleflugtslinje (bee line), the storm surge dike, Rødbyhavn, the sugar industry cultural environment as well as Rødby Fjord and Lidso.

The Fugleflugtslinje covers the railway section and the motorway which meet at the ferry harbour in Rødbyhavn. The structures in the cultural environment (for example the bridges over the motorway and railway and the ferry port buildings) offer a certain experience value. They were built in 1963 in a consistent functionalist style representative of its time. The Fugleflugtslinje is important and identity-forming for the local population, because the area and its structures represent the ferry link to Germany.

![Figure 6.24 Industrial structures in the port and the ferry terminal for the Rødby-Puttgarden link](image)

The storm surge dike was built after 1872, when a destructive flood affected the south coast of Lolland. The dike is 63 km long and a striking element in the landscape. The dike is a historical source of knowledge about the storm surge and how the dike was built. The dike is an element created by people and has changed the natural landscape dramatically. The dike continues to protect against flooding in the low-lying landscape behind the dike and is important to local identity.
Rødbyhavn is approximately 100 years old and grew up around the shipyard with associated workers' houses, officials' houses and industrial buildings. The first harbour was built in 1908 outside the dike. In the 1920s, a small harbour basin was excavated inland. The current ferry harbour was built in 1962-1963. There are 73 buildings worthy of preservation within the Rødbyhavn cultural environment. They bear witness to the various phases in the development of the area.

**Churches and church surroundings**
The study area contains three churches with building lines. None of them are expected to be affected by the project.

### 6.4.4 Importance

The importance of cultural heritage and archaeology has been assessed on a four-step scale as very high, high, medium or low. The assessment was based on protection status, architectural/historical value, rarity and authenticity. The criteria are indicated in a separate environmental mapping report (COWI 2012a).

The map (Figure 6.25) shows that the culture-historical elements of very high importance include a protected burial mound (Hyldehøj), Rødbyhavn Kirke and a protected fortification at Lalandia.

Five prioritized cultural environments are assessed as having high importance. They are Rødbyhavn, the storm surge dike, the sugar industry cultural environment as well as Rødby Fjord and Lidsø. They are all well-preserved and representative of the time in which they were created. They also have high authenticity and narrative value. The storm surge dike, which was built in the 1870s after destructive flooding, is one of them. After the construction of the dike, the lagoon and fjord area behind it were drained and Rødbyhavn was constructed. The dike and Rødbyhavn are part of local cultural history. Protected stone and earth dikes, cultural heritage areas and the churches' protection areas (remote effect) are also assessed as having high importance.

The following are of medium importance: the remaining cultural environments, the buildings worth preserving that are not included in the five prioritized cultural environments, the remaining non-protected stone and earth dikes, the areas of archaeological interest and the other archaeological sites.

It is assessed that the importance of the cultural heritage in the 0-alternative (2025) will be roughly as today. The coastal areas are currently zoned as industrial areas and may be developed and in operation. It is possible that in 2025 new knowledge has been obtained about ancient finds in the areas. This may give reason to change the assessment of the importance of the archaeological interests. Finally, it is likely that in the future there will be even more focus on developing recreational interests in coastal areas. If this happens in southern Lolland, the importance of the culture-historical interests will probably be preserved.
6.4.5 Potential impacts
The tunnel project may cause the following impacts on cultural heritage on land:

› Loss of cultural heritage/archaeology
› Temporary and permanent expropriation of cultural landscapes and cultural environments
› Visual impact and other disturbance of the experience of authenticity (noise, emissions)

6.4.6 Assessment of the impact during the construction phase
During the construction phase, which may last for up to 8 years, an area will be expropriated as a worksite. No protected stone and earth dikes or listed buildings
will be affected by the project. Nor will churches and church surroundings be affected.

Protected ancient monuments, cultural heritage areas and other archaeological sites
No protected ancient monuments or cultural heritage areas will be affected by the work in the construction phase. The distance to the protected burial mound ensures that although the experience of it may be affected by light, noise and increased traffic, this will not be a significant consequence.

Part of the temporary structure is located in an area designated by Lolland-Falster Museum as an area of archaeological interest. Before the construction work starts, the archaeologists will carry out studies of the area where the fixed link and the tunnel lining factory are to be built. In this way, the possibility of encountering ancient finds during the construction work itself is minimized. If ancient finds are discovered during the earthworks, the construction work will be stopped, and the find will be reported to Lolland-Falster Museum. The state of preservation of ancient finds can deteriorate if they are removed from the find site. On the other hand, archaeological finds can contribute new information on how people have lived and worked in the area.

Hedges
The size of the area expropriated in the construction phase and the artificial embankments means that one hedge east of Rødbyhavn and Stengård Lake will be removed. The hedge indicates how part of the field structure looked around 100 years ago, with many small plots in the lowland area. The consequence is assessed as insignificant.

Cultural environments
The construction phase will have significant consequences for the historical storm surge dike, because approximately 1 km of the dike will be removed temporarily. In addition to this, the land reclamation will affect an 8 km section of the dike for up to 8 years in total.

6.4.7 Assessment of impacts during operational phase
The operational phase will require the expropriation of areas where the motorway, railway, buildings and land reclamation are located. No protected ancient monuments, listed buildings, protected stone and earth dikes or hedges occur in the areas and therefore will not be affected by the project. This also applies to churches and church surroundings and to archaeological sites.

Building worth preserving
A building worth preserving must be removed to make way for the new motorway. The building is a detached single-family house built in 1936 and has been assessed as representative of its type in terms of architecture, craftsmanship and cultural history. Although removal of the house is a major impact, the consequence is not assessed as significant as the house is not part of a cultural environment.
Cultural environments
The dike is affected by the land reclamation area as 8 km of the 63 km long dike will no longer be in contact with the sea. However, the dike will still have an important function in relation to protection against flooding. This primary function will no longer be obvious along the 8 km stretch due to the land reclamation and therefore affects the culture-historical value of the dike. It will make it difficult to explain why the dike is located where it is, and what the area looked like in times past.

![Image](image_url)

Figure 6.26 The storm surge dike along the coast of southern Lolland was built in 1873 after a destructive storm surge. The dike is approximately 4 m high and a total of 63 km long

On the other hand, the land reclamation can be seen as just another man-made element in the distinct cultural landscape. However, there will be a delay of 4 to 15 years before the land reclamation becomes an integrated part of the cultural environment and therefore the consequence is assessed to be significant.

The artificial embankments on top of the tunnel portals will change the visual experience of the dike dramatically, partly because they cross the dike, but also because they are striking elements. It will not be possible to see the tunnel portals and the embankments from the dike west of Rødbyhavn.

The closure of the ferry service could have significant consequences for the cultural environments Rødbyhavn and Fugleflugtslinjen. The town's role in relation to providing the link between Denmark and Germany will be dramatically different. The port environment in Rødbyhavn is linked to a certain level of shipping traffic and therefore partly depends on the ferry service being maintained. The construction of a fixed link allows the buildings to be used for other purposes in the future, as it is seen in a number of port cities across the country.
6.4.8 Mitigation measures

The bored tunnel's impact during the operational phase is limited and cannot be avoided through mitigation measures. However, a series of mitigation measures are incorporated to limit the tunnel project's impact on cultural heritage and archaeology during the construction phase:

› Before the construction phase, archaeological studies will be carried out in the area that may be affected by the project. The studies will be carried out by the Lolland-Falster Museum. The Danish Agency for Culture is aware of the studies and will be kept informed during the work.

› If ancient finds are discovered during the earthworks on land the construction work will be stopped and the find will be reported to Lolland-Falster Museum and relevant authorities.

› Most of the storm surge dike will be re-established to its original state when the construction work ends.

6.4.9 Conclusion

In terms of the actual loss of culture-historical and archaeological values, the impact is limited to the storm surge dike. For the storm surge dike, the land reclamation area will mean that the dike's direct connection with the sea will disappear along an 8 km section of the total 63 km. Without the coastal proximity, it will be difficult, at first glance, to understand and explain why the dike is located where it is, and what the area looked like before the storm surge dike was constructed. In addition, it will be some years before the land reclamation achieves its final cultural value. The consequence is assessed to be significant due to the land reclamation and the loss of coastal proximity on an 8 km stretch.

The port environment in Rødbyhavn is linked to a certain level of shipping traffic and partly depends on the ferry service being maintained. If the ferries stop sailing between Rødbyhavn and Puttgarden, it may have indirect consequences for the cultural environments Rødbyhavn and Fugleflugtslinjen.

The consequences of the loss of cultural values are limited. It is rather the tunnel project’s visual and physical fragmentation of cultural heritage sites that may affect the existing values.
6.5 Recreation

Outdoor leisure activities include a range of activities in which the aim may be recreation or exercise. The outdoor leisure activities in the study area are mapped and described in this section.

6.5.1 Method

The facilities relating to outdoor leisure activities are protected via a number of planning and protection restrictions. Information on these comes from Lolland’s Municipal Plan.

The recreational values have been mapped and assessed with inspiration from the method for recreational experience assessment (Caspersen and Olafsson 2006).

6.5.2 Legal framework

The most important guidelines from the Municipal Plan on outdoor leisure activities are reviewed below.

Cycle paths
Extension and improvement of cycle paths and cohesion between local, regional and national cycle routes are required. The Lolland dike and the road between Rødbjerg and Rødbyhavn are important cycle and walking routes.

Golf courses
New golf courses may be built. They should preferably be near urban or holiday areas and on land less suited for agriculture. A golf course west of Lalandia has been closed.

Marinas
Construction on harbour areas must be coordinated to limit the extent, and the highest possible consideration must be shown to the visual impacts on the coast and the existing harbour environment. There are 35 moorings for yachts and sailing boats in the study area, all in Rødbyhavn.

Camp sites
It is permitted to extend existing camp sites unless specific conditions determine otherwise. The camp sites must be shielded from open land and existing buildings. There is a camp site at Rødbjerg, and it is possible to create one at Hyldtofte Østersøbad.

Outdoor leisure areas
The existing gravel roads and paths in the open landscape must be preserved and extended, and access to outdoor leisure areas must be improved provided this does not conflict with restrictions. Primitive camp sites may be established unless this disturbs the local area, the nature interests and the local fauna and flora. An outdoor leisure area that covers the dike from Rødbyhavn to Hyllekrog and
Osteraabodet has been designated. There are currently primitive camp sites in Rødby and Rødbyhavn.

Figure 6.27 Recreational outdoor leisure interests and facilities in the coastal area

6.5.3 Existing recreational facilities

The area has some basic characteristics which are attractive for recreation. There is almost no light pollution except a minor amount from the urban areas and the motorway to Rødbyhavn. It is not significant. There is noise around the motorway, railway and ferry harbour, while the rest of the study area is largely unaffected by noise.

The area contains a number of outdoor leisure opportunities. These are divided into forest, viewpoints, hunting and fishing, nature observations, cultural observations,
outdoor activities in nature and recreational facilities. They are described briefly in the following:

Forest
There are only a few small forests in the area (Byhave, Rødby Lystskov, woodland in Rødbyhavn and east of Rødbyhavn), and they are all private. The largest forest is private and situated in the south-eastern part of the area, but is surrounded by agriculture and not very accessible.

View points
There are few view points. The most important is the coastal dike, with a height of just 4 metres, but with a fine view. There are two other elevated locations, the Søren Thomas Høj and Hyldehøj burial mounds, but they are covered by bush and forest.

Hunting and fishing
Hunting and fishing have not been mapped separately as hunting is possible in most parts of the area and fishing is possible along most of the coast. Angling in Fehmarnbelt takes place from either boats or the shore (in particular from the two breakwaters at Rødbyhavn and the dike on the eastern breakwater). There are also two put-and-take lakes east of Rødbyhavn with surrounding paths, and tables, benches and rubbish bins.

Nature observation
There are several opportunities for experiencing nature in the area. The railway terrain is home to many rare insect species, and there are many amphibian species and rare plants along the dike. Saksfjed Inddæmning is protected and part of a larger Natura 2000 site. Bird watching is possible throughout the area, in particular near the harbour in Rødbyhavn. Migrating birds can be watched mostly in the south-eastern part of the area.

Cultural observation
The entire coast and the reclaimed area are protected by a dike that is 4 metres high and 63 km long and was built in the late 19th century. Monuments and memorials to the storm surge in 1872 are found in Rødby and in Mindelunden west of Rødbyhavn. The Søren Thomas Høj and Hyldehøj burial mounds also bear witness to activity in earlier times.

Activities in the nature – paths
There are many paths in the area, including the dike, which is used intensively for walking, running and cycling, and the railway path, a 20 km path on a disused railway track between Rødbyhavn and Maribo. A hiking and cycle route, Munkeruten, also runs through Rødby and Rødbyhavn.

Activities in the nature - beach and sea
There are only a few good sandy beaches, as most of the coast is protected with granite boulders. However, it is possible to walk close to the coast and sea along the paths mentioned above. The two most important beaches are west of
Rødbyhavn. They are child-friendly, have good water quality and nearby facilities such as paths, parking, toilets, tables and benches. There is also a narrow sandy beach at Hyldtofte Østersøbad with a toilet and parking.

There are several recreational areas along the coast, including the salt meadows behind the dike. However, some are inaccessible on account of reed forest growth or wet soil. The sea is accessible by sailing boat, kayak, etc. from, among other places, Rødbyhavn.

**Entertainment and holiday facilities**

The most important tourist attraction in the area is the Lalandia holiday centre, which has a water park and holiday homes. There are three summer cottage areas: Bredfjed to the north-west, Hyldtofte Østersøbad to the south-east and the holiday homes in connection with Lalandia between Bredfjed and Rødbyhavn. There are also three hotels, a camping area with 53 sites (Rødby Lystskov Camping), some primitive camp sites, a marina with 35 moorings, a go-kart track and a local airfield which offers gliding and sky diving/parachute jumping.

**Importance**

The importance of outdoor leisure activities is assessed on a four-step scale as very high, high, medium or low. However, no recreational facilities or areas are assessed as being of very high importance. The importance map (Figure 6.28) was made on the basis of a number of criteria including recreational values and planning commitments. All criteria are indicated in the baseline report (COWI 2012a).

As the map shows, the most important recreational areas and facilities are located along the coast. They include beaches, the storm surge dike with the cycle route and the accessible nature areas behind the dike, the marina in Rødbyhavn, Lalandia and the summer cottage areas. These facilities are assessed as being of high importance. Having access to the beach and being able to go for a swim, fish, go kayaking and take a walk on the beach, are also of high recreational importance for the residents, summer cottage owners/tenants and visitors in the area. There are no areas and facilities of very high importance.

A primitive camp site in Rødbyhavn, two fishing lakes (the Hirbo lakes), Strandholm Sø and a forest east of Rødbyhavn are assessed as having high importance because of their accessibility and the facilities around them.

Further inland there is only minor opportunity for outdoor leisure activities. However, Munkeruten and the railway path (Jernbanestien) constitute the primary opportunities for walking and biking in the agricultural landscape away from the roads and are classified as of high recreational importance.

It is assessed that the opportunities for outdoor leisure activities and thus the importance of the recreational areas and facilities in the 0-alternative (2025) will be roughly as today. However, it is possible that the areas zoned as industrial areas in the Municipal Plan will be developed and in operation. The Municipal Plan also offers the opportunity to increase accessibility and develop facilities, which would
be an improvement of the current situation. The rest of the land use is expected to correspond to the situation today.

**Figure 6.28**  The map shows the importance of the recreational areas and facilities and the footprint of the tunnel structure, motorway, railway, land reclamation and tunnel lining production site

### 6.5.4 Potential impacts

The effects that may be caused by the bored tunnel project in the construction and operational phases are generally divided into the following:

- Expropriation and land use change
- Physical and visual barrier effects and fragmentation
- Impact on recreational areas from pollution, noise, light and coastal erosion.
6.5.5 Assessment of impacts during the construction phase

During the 8 years of the construction phase, a significant area (72 ha) will be expropriated for the production of tunnel elements and for use during the construction work itself. The areas expropriated in the construction phase will be re-established after construction.

A 1 km section of the storm surge dike and the coastline in front will be temporarily removed because of the worksite and work harbour. At the same time, a total of 8 km of coastline will be closed during construction of the land reclamation. This also means that the national cycle route, which currently follows the path on the dike, must be rerouted while the construction work is taking place. The rerouted cycle route will probably follow existing roads since it is a temporary measure.

Particularly east of Rødbyhavn, the construction work will obstruct the view and movement on 8 km of the dike during the construction phase. In general, the experience will be degraded by noise and the view of a construction site. Conversely, some may consider the construction site and activities to be an attraction.

It is assessed as a significant consequence for outdoor leisure activities that the construction phase lasts 8 years and expropriates a total of 8 km of coast near facilities including summer cottage areas (Hyldetofte Østersøbad and Bredfjed) and Lalandia, where access to the coast will be severely limited.

As a consequence of the construction work, the shallow sea area along the coast will not be accessible for recreational fishing. Noise will affect the area at the Hirbo lakes during construction work, and the recreational fishing activities will be affected.

Two of the three good bathing beaches in the area (Rødbyhavn and Lalandia) will be affected during the construction phase, and approximately 2.5 km of bathing beach will be lost. It will be possible to use the beach at Hyldtofte Østersøbad throughout the construction phase.

6.5.6 Assessment of impacts during the operational phase

When the road, railway, tunnel and land reclamation are constructed, there will be a number of significant consequences in relation to recreational activities.

The view from the main sea dike over the sea will be reduced because of the project since the land reclamation will increase the distance to the sea by 500 to 700 m along a section of approximately 8 km. Depending on the design of the land reclamation, the terrain may block the view from parts of the dike. In other places, there may still be a view of the sea. New view points will become available when it is possible to walk on the land reclamation area and its perimeter dike. These potential views are, however, assessed as more difficult to access for residents and visitors than the dike is today as the distance to the new paths will be longer.
Around the tunnel portals and the toll facilities, there will be light, air pollution, turbulence and noise. This is assessed as a local but significant consequence for the potential to achieve outdoor leisure experiences during the construction phase.

2.5 km of beach and the dunes west of Rødbyhavn, will be lost permanently. However, the plan is to establish a new beach at the western end of the land reclamation. The loss of these sandy beaches is assessed as a significant consequence for outdoor leisure activities. The land reclamation can, at best, compensate for some of these losses through a new sandy beach, a bay with beach, a lagoon and a large new recreational coastal landscape. This will potentially benefit residents and visitors in the area. Bathers, kayakers and windsurfers will, however, have to face a longer distance to the sea than they do today.

![Figure 6.29 The lagoon east of Rødbyhavn is illustrated here with two kayakers (RAT 2011)](image)

### 6.5.7 Mitigation and compensation measures

To minimize the tunnel project’s significant impacts, mitigation and compensation measures have been incorporated for outdoor leisure activities. The measures cannot prevent the impacts on the outdoor leisure activities, but they can help limit their consequences. The following measures have been incorporated:

**Construction phase**

- It will be ensured that national cycle route 38 will be maintained and the rerouting of the route will be marked with signs.

- Sedimentation waste will be minimized to, as far as possible, avoid any deterioration of in depth visibility and bathing water quality.

**Operational phase**

- The coastal dike and the cycle route/footpath on the top of the dike will be re-established when the construction work ends. The same surface and width as for the path today will be used. This also ensures access for wheelchair users.

- Two new beaches and a lagoon are included in the plan for the reclamation as compensation for the lost beaches.
The tunnel portal, toll facilities and access area will be designed so that artificial light does not dazzle cyclists and walkers around the tunnel portal and unnecessary light pollution will be avoided.

A new lake will be established to replace Strandholm Lake. The location and size will be agreed between the Municipality of Lolland and Femern A/S.

The land reclamation around Rødebyhavn will be established so it will still be possible to see the sea from the marina.

6.5.8 Conclusion
The approach and ramp area with the motorway and railway, tunnel portal, toll facilities and land reclamation cause changes for the existing outdoor leisure activities. The location east of Rødebyhavn is the most appropriate in many aspects, as there are fewer recreational interests here than west of Rødebyhavn, and the area is presently dominated by small industrial installations and wind turbines.

The most striking impacts will be in the construction phase.

During the construction phase, an 8 km section of coast will be expropriated for construction activities. On account of the impact, which may last up to 8 years, it is assessed that the construction work linked to the bored tunnel will have significant consequences for outdoor leisure activities.

Residents in Rødebyhavn and guests in Lalandia and in the nearby summer cottage areas will not have access to this section of the coast. There will be pollution from light, emissions and noise close to the construction area and the tunnel element facility. It will not prevent recreational activities but may impair the experience.

The construction area and the coastal dike will be re-established after the construction phase. There will be a delay of 4 to 15 years in the development of new recreational facilities for residents and visitors on the new land reclamation.
6.6 Water

This section deals with groundwater, watercourses and large lakes. Small lakes, ponds and other wet nature areas such as marshland are described from a biological perspective in the section on Flora and fauna.

6.6.1 Method

Watercourses and lakes are mapped on the basis of literature and data, supplemented with observations from field studies in 2009. Environmental objectives laid down in the state’s Water Plans (Danish Ministry of the Environment, Danish Nature Agency 2011) and the background material used for preparing the Water Plan have also been added.

The description of the groundwater conditions is based on a summary for the construction works (Femern 2010), supplemented with existing literature and data.

For a more detailed description of the method for mapping, please see the baseline report (COWI 2012a).

The significance of the impact on the surface water is assessed on the basis of the importance of the areas for drainage of water and the importance as a habitat for fauna and flora. In relation to the local impacts, importance has been attached to the objectives and requirements in the 2010-2015 Baltic Sea Water Plan - Vandplan Østersøen (Danish Ministry of the Environment, Danish Nature Agency 2011).

For groundwater, the assessment is based on the suitability of the groundwater occurrence for water catchment and drinking water and in relation to its importance to wet nature areas.

For a more detailed description of the assessment criteria and method and the environmental consequences described below, please see the baseline report of the Danish approach and ramp area (COWI 2012b).
6.6.2 Legal framework

Major watercourses and lakes as well as groundwater and coastal waters are included in the 2010-2015 Baltic Sea Water Plan, Main water catchment area 2.6. Water district: Zealand (Danish Ministry of the Environment, Danish Nature Agency 2011).

The Danish Nature Agency is the public authority responsible for the water plan, and the Municipality of Lolland must prepare action plans and ensure the implementation of the plan.
Water plan

The water plan defines an objective for the ecological and chemical state of watercourses, large lakes and coastal waters. As a general rule, all water in the water plan must achieve at least a 'good ecological state' or 'good ecological potential'. For all groundwater occurrences, the objective is a 'good chemical state' and a 'good quantitative state'.

The water plans show the need for initiatives and requirements to be made to reduce impacts. For some water occurrences, the requirements are in this plan period (up to 2015), and for others they are deferred to a later water plan period.

Regardless of the object, no changes may be made that have a detrimental impact on the state and/or obstruct achievement of the environmental objective.

Lakes over 100 m² and a number of designated watercourses are covered by Section 3 of the Danish Nature Protection Act, and any changes require an exemption from the Act. The watercourses are also protected by the Danish Watercourse Act, and any changes must be approved by the municipality.

The Water Plan designates near-surface, regional and deep groundwater occurrences. The designated groundwater occurrences are shown in Figure 6.31. In addition to these groundwater occurrences, there is groundwater in layers of sand close to the surface which were deposited on the bed of a fjord that is now reclaimed. This groundwater is of significant importance to the water balance in wet habitat types in the area.

Areas with drinking water interests or special drinking water interests have also been designated (Figure 6.32).

Extracting water and significant lowering of groundwater require permission under the Danish Water Supply Act. The municipality is the public authority responsible for granting permission.
Figure 6.31 Regional and near-surface groundwater occurrences in the study area. There are no deep groundwater occurrences in the area.
6.6.3 Existing conditions

A major part of the study area is reclaimed and drained fjord bed. Drainage is led via a network of ditches to pumping stations at the Lolland dike and thence into Fehmarnbelt.

Lakes, watercourses, watercourse catchment areas and pumping stations are shown on the map Figure 6.30.

The watercourses belong to four different catchment areas that all lead to pumping stations. The watercourses are within Strandholm Landvindingslag (polder board),
Some of the watercourses are fully or partially channelled through pipes. The physical state of the open watercourses is poor to medium, as a consequence of low gradient (and thus low water flow), poor maintenance, etc. The water quality and biodiversity fluctuate between poor and medium.

Næsbæk 40L, 41L and watercourse 17RØ are protected under Section 3, but no watercourse that can potentially be subject to direct impact is included in the Water Plan. The background material for the Water Plan shows that Næsbæk 40L has a moderate ecological state/potential.

There are two large lakes, Strandholm Lake and Stengård Lake, in the study area. Both were created by excavating raw materials. Both lakes are included in the Water Plan, and Strandholm Lake is already assessed as having a good ecological state.

Geologically, the area consists primarily of clay-till, and the groundwater exists in local layers of sand inside the clay-till. There is also groundwater in layers of marine sand deposited on the clay-till in areas of the former fjord bed.

The regional groundwater occurrences in the area have a good chemical state, but a poor quantitative state. This is due to extraction of drinking water on Lolland which is too intensive. However, no drinking water is extracted in the area.

The near-surface groundwater occurrences in the area have a good quantitative state, but a poor chemical state. This is due to the general impact from the ground surface of nitrate, pesticides and xenobiotics.

### 6.6.4 Importance

The importance of watercourses and lakes is assessed on a four level scale. The importance is based on the observed physical and biological factors and the water plans' background, objectives and assessment of state. For a further description of the method for assessment of importance, please see the baseline report's sections on surface water and groundwater (COWI 2012a).

Figure 6.33 shows that Strandholm Lake has high importance, even though the lake was established artificially by excavation for raw materials. In its present form, Strandholm Lake has a good ecological state, despite its slightly brackish water.

The three watercourses protected under Section 3, Næsbæk 40L, 41L and a section of watercourse 39L, are assessed to be of medium importance. On inspection, Næsbæk and part of 39L were assessed to have a better physical state and higher biodiversity on the bed and the cliff sides than the other watercourses in the area. The remaining watercourses are assessed to have low importance and no watercourse or lake within the study corridor is assessed to be of very high importance.
The importance of groundwater is assessed in relation to the natural environment on a two-point scale as special or general importance. This is shown in Figure 6.34. A three level scale with high, medium or low importance is used in relation to extraction of drinking water. In most of the study area, the groundwater is of low importance in relation to water extraction as it has a naturally high salt content.

All near-surface groundwater occurrences in the area are less than 2 metres below the surface and are assessed to be of special importance to the water balance in the area's habitat types. This applies to the entire former Rødby Fjord and any other near-surface groundwater occurrences.

Figure 6.33 Importance of watercourses and lakes.
6.6.5 Possible impacts
The environmental state of watercourses, lakes and groundwater can be affected directly or indirectly by the following factors:

› Expropriation and closure
› Changes in the size or use of the catchment area, including increased surface covering (asphalting)
› Physical barriers in or fragmentation of watercourses
› Permanent or temporary lowering of the groundwater in near-surface and regional occurrences
› Discharge of water to the water environment, for example road water and extracted groundwater, including water with a potential content of xenobiotics
› Spillage of xenobiotics
› Increased water consumption and creation of waste water
The effects can occur both during the construction phase and the operation phase of the fixed link.

6.6.6 Assessment of impacts during the construction phase

Strandholm Lake will be closed and a new lake will be established at a scale 1:1 as replacement in a location that has not yet been settled. The new lake is assessed as being able to achieve a good ecological and physical state. It will be fresh water and hence differ from the existing brackish lake.

Over 0.5 km of watercourse 17RØ will run through the construction area and it may be necessary to lay pipes for an indefinite period.

During the construction period, it will be necessary to lower the groundwater in the ramp area to a level below the bed of the excavation. This may lead to the lowering
of the water level in the upper groundwater aquifer. Lowering of the near-surface groundwater that is in direct contact with watercourses, lakes and wet nature areas is assessed as a serious impact. The mitigation measures described are assessed as being able to ensure that the water balance in the wet habitat types will not be affected.

Extraction of groundwater for drinking water supply is not expected to occur because of the limited reserves and therefore is not a threat to groundwater.

Lolland Vand A/S has undertaken to supply 500,000 m$^3$ of water of drinking quality per annum for the tunnel lining production and for operation of the construction site. For slurry production, it is assumed that brackish water from Fehmarnbelt will be used.

The sanitary waste water from the production area, including from camp sites, will be channelled to the municipal sewage treatment plan for treatment. Femern A/S has stated that waste water can be handled within the parameters of the existing discharge licence.

In addition, for all open watercourses and lakes, there is a risk of chemical impact in connection with spillages and hydraulic impact throughout the construction phase. Accordingly, there is a risk of impact on the groundwater from spills. The mitigation measures described mitigate this risk.

6.6.7 Assessment of impacts during the operational phase

Strandholm Lake will be closed permanently and the new lake will be established as a replacement in a location that has not yet been settled. The new lake is assessed as being able to achieve a good ecological and physical state. It will be fresh water and hence differ from the existing brackish lake.

For watercourses, the bored tunnel is assessed to result in the loss of two small sections of watercourse, changes in catchment area sizes in the drained area and new underpass pipelines.

Precipitation that falls on areas with paved surfaces (motorway, ramps and toll facilities) runs to retention basins via sumps. Soil particles and xenobiotics are precipitated here before the water is channelled in small doses to watercourses. Despite this, there will be a minor impact of substances including heavy metals and PAHs in three watercourses in Strandholm Landvindingslag and two watercourses in the Rødby Fjord system (Næsbæk and tributaries).

It is assessed that, depending on the design, there may be an impact on Stengård Lake because of changes in tributaries and inflow of xenobiotics.

It is assessed that there will be no significant impact on the groundwater in the operational phase.
6.6.8 Mitigation and compensation measures

Construction phase
The measures below have been incorporated to mitigate or compensate for the consequences that a bored tunnel will have for the water environment:

› A lake will be established instead of Strandholm Lake (scale 1:1) in accordance with public authority directions.

› An environmental management plan will be prepared in which surface water and groundwater will be handled to ensure that there is no impact on the water environment. The plan will include restrictions on discharges of soil into the watercourse, directions for re-establishing the bed and sides of watercourses after the end of construction work and directions for handling spillages of xenobiotics.

› Retention basins will be established to collect surface water from construction areas. The basins will be dimensioned to collect 1 mm rain per 10,000 m², have a retention time of at least 72 hours, oil separators/submerged outlets and sand traps.

› Water will be discharged into the sea from the tunnel lining production site via oil separators and sand traps.

› Groundwater lowering will be limited by technical means.

Operational phase
› Retention basins established in the construction phase are permanent installations.

› The section of 17RØ channelled in pipes will be compensated by improving the physical state of the existing section elsewhere in the watercourse.

› A subsection of Næsbæk will be adjusted, a tributary to Næsbæk that is currently channelled in pipes will be opened and subsections of watercourse (16RØ) will have less steep slopes.

› Drainage of water from pumping stations and sluices to the sea through the land reclamation area will be ensured.

6.6.9 Conclusion
The most significant consequence for the surface water environment is assessed to be the filling of Strandholm Lake. This loss will be compensated by the establishment of a new lake or lakes.

In addition, the bored tunnel is assessed to result in the loss of two small sections of watercourse, small changes in catchment area sizes and new culvert pipe lines. These impacts will be compensated by measures including reopening sections
channelled in pipes and improving the physical state of the watercourse by means of watercourse adjustment.

The excavations and groundwater lowering implemented in the construction phase will not be important to the water balance in the wet nature areas that are in contact with the groundwater. This is because measures will be established to restrict lowering along the excavations. The groundwater in the area is not important to extraction of drinking water.

The impacts are assessed as being insignificant provided that the mitigation and compensation measures are implemented.
6.7 Noise and vibrations

Noise is propagated through the air or water, while vibrations are propagated through solid materials, typically the ground. Low-frequency noise is a special form of noise pollution that is assessed separately.

Noise affects people who live and stay in areas that are exposed to noise. Noise may also affect the experience of the countryside and animal behaviour.

The 0-alternative is defined as the situation where a fixed link is not built. The 0-alternative shall be used to compare a situation with or without a fixed link. Therefore, a year must be chosen that is later than the fixed link’s completion date. In this EIA report, the year 2025 has been chosen.

The 0-alternative includes noise from the current road and rail link to Rødbyhavn and from the ferries when they dock in the harbour.

There are also a number of other noise sources in the area (wind turbine farm, industrial plants, airport and go kart tracks). The noise from these sources are regulated by environmental approvals. Their noise contribution does not dominate compared to traffic noise, and it is expected that they will not change due to a fixed link. Therefore, noise impact from these sources is not assessed and has not been calculated.

The construction of a bored tunnel has an impact; with noise and vibrations originating from the construction and operation of the prefabrication of the tunnel segments, excavations and construction machinery and transportation of materials to/from the construction area.

When the fixed link with a new motorway and railway is finished, road and rail traffic will generate noise and vibrations. Today, road and rail traffic extends to the ferry in Rødbyhavn. A proportion of the traffic will use the bored tunnel instead of the ferries. Therefore, there will be less noise and vibrations along the approach road and the existing railway line to Rødbyhavn than there is today. This will be reduced even more if the ferry services are closed.

In summary, the following noise scenarios are addressed:

- 0-alternative (2025): Noise from existing railway, motorway and ferries.
- Construction phase noise.
- Operation phase noise: Noise from railway and motorway without ferries

Details of the calculations of the noise levels and impacts can be found in Atkins (2012).
6.7.1 Limit values, traffic data and method

Noise indicators and limit values
The Danish Environmental Protection Agency’s recommended noise limits for different noise sources have been used in the assessment of noise.

Table 6.1 and Table 6.2 show the limit values for noise generated by road and rail traffic and from industry.

**Table 6.1** The Danish Environmental Protection Agency recommended limit values for noise generated by road and rail traffic (The Danish Environmental Protection Agency 2007a and b)

<table>
<thead>
<tr>
<th>Type of area</th>
<th>Limit value Railway traffic</th>
<th>Limit value Road traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreational areas in the open countryside, summer cottage areas, camp sites, etc.</td>
<td>$L_{den} = 59\text{ dB}$</td>
<td>$L_{den} = 53\text{ dB}$</td>
</tr>
<tr>
<td>Residential areas, kindergartens, crèches, schools and educational buildings, senior care facilities, hospital etc. Additionally, allotments, outdoor public areas and suburban parks</td>
<td>$L_{den} = 64\text{ dB}$; $L_{A_{\text{max}}} = 85\text{ dB}$ (at residences)</td>
<td>$L_{den} = 58\text{ dB}$</td>
</tr>
<tr>
<td>Hotels, offices, etc.</td>
<td>$L_{den} = 69\text{ dB}$</td>
<td>$L_{den} = 63\text{ dB}$</td>
</tr>
</tbody>
</table>

$L_{den} =$ A-weighted day, evening, night noise
$L_{A_{\text{max}}}$ = A-weighted maximum noise level (fast)

**Table 6.2** The Danish Environmental Protection Agency’s recommended limit values for noise from industry, including ferries in harbours (Danish Environmental Protection Agency 1984)

<table>
<thead>
<tr>
<th>Type of area</th>
<th>Limit value, $L_{A_{\text{eq},Xh}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 7:00 - 18:00 (Saturday 7:00 - 14:00)</td>
<td>Evening 18:00 - 22:00 (Saturday 14:00 - 22:00 Sunday 7:00 - 22:00)</td>
</tr>
<tr>
<td>Areas for mixed residential and commercial properties, centre areas (city centres)</td>
<td>55 dB</td>
</tr>
<tr>
<td>Multi-storey residential areas</td>
<td>50 dB</td>
</tr>
<tr>
<td>Residential areas for open and low-rise residential properties</td>
<td>45 dB</td>
</tr>
<tr>
<td>Holiday cottage areas and public recreational areas</td>
<td>40 dB</td>
</tr>
</tbody>
</table>

$L_{A_{\text{eq},Xh}}$ = A-weighted equivalent noise within 8 hours during day, 1 hour in the evening and $\frac{1}{2}$ hour during night

The noise assessment shows the total number of residences and other forms of noise-sensitive buildings where the level of noise is greater than the recommended limit values for each of the three types of noise sources: rail, road and ferry traffic. Noise from the different sources have not been added to a cumulative figure due to different limit values and indicators depending on the type of noise source.
The limit values for noise in Denmark are recommended limits and describe the level at which a significant part (approx. 10%) of people feel highly annoyed. The limit values are different for railway traffic, road traffic and ferry traffic, because the noise level is experienced differently. The number of exposed dwellings are therefore calculated separately in relation to the noise from various sources.

When the noise impact is below the recommended limit values, no health effects are to be expected.

Vibration standards
The Danish recommended limit values for vibrations and low frequency noise are shown in Table 6.3 and Table 6.4 respectively for various building types. The German norm DIN 4150 (part 3) “Erschütterungen im Bauwesen” is applied for assessment of possible structural damage to buildings (Table 6.5).

Table 6.3 Danish Environmental Agency’s recommended limit values for vibrations

<table>
<thead>
<tr>
<th>Building area</th>
<th>Weighted acceleration level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential areas (24 hours)</td>
<td>$L_{an} = 75$ dB</td>
</tr>
<tr>
<td>Mixed residential/commercial areas (18:00 – 07:00)</td>
<td>$L_{an} = 80$ dB</td>
</tr>
<tr>
<td>Institutions</td>
<td>$L_{an} = 85$ dB</td>
</tr>
<tr>
<td>Mixed residential/commercial areas (07:00 – 18:00)</td>
<td></td>
</tr>
<tr>
<td>Offices, schools</td>
<td></td>
</tr>
<tr>
<td>Commercial areas</td>
<td>$L_{an} = 85$ dB</td>
</tr>
</tbody>
</table>

$L_{an} = \text{KB weighted acceleration vibration level}$

Table 6.4 Danish Environmental Agency’s recommended limit values for low frequency noise

<table>
<thead>
<tr>
<th>Building area</th>
<th>Indoor noise level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residences incl. child institutions etc.</td>
<td>$L_{PA,LF} = 20$, $L_{PG} = 85$ dB</td>
</tr>
<tr>
<td>07:00 – 18:00</td>
<td>$L_{PA,LF} = 25$, $L_{PG} = 85$ dB</td>
</tr>
<tr>
<td>Offices, schools and other noise sensitive rooms in</td>
<td></td>
</tr>
<tr>
<td>commercial buildings</td>
<td>$L_{PA,LF} = 30$, $L_{PG} = 85$ dB</td>
</tr>
<tr>
<td>Other rooms in commercial buildings</td>
<td>$L_{PA,LF} = 35$, $L_{PG} = 90$ dB</td>
</tr>
</tbody>
</table>

$L_{PA,LF} = \text{low frequency noise (10 – 160 Hz)}$

$L_{PG} = \text{infra-noise (5 – 20 Hz)}$

Table 6.5 Requirements for avoidance of vibration induced damage to buildings expressed as peak oscillation speed in the foundations

<table>
<thead>
<tr>
<th>Building type</th>
<th>Limit value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial and industrial buildings</td>
<td>$V_{\text{peak}} = 20$ mm/s</td>
</tr>
<tr>
<td>Residences</td>
<td>$V_{\text{peak}} = 5$ mm/s</td>
</tr>
<tr>
<td>Protected buildings</td>
<td>$V_{\text{peak}} = 3$ mm/s</td>
</tr>
</tbody>
</table>
Railway traffic

All future traffic volumes are provided by Femern A/S. The expected railway traffic in the 0-alternative is given in Table 6.6, where traffic is divided into periods; day 7:00 - 19:00, evening 19:00 - 22:00 and night 22:00 - 7:00.

Table 6.6 Traffic basis for railway traffic in the 0-alternative

<table>
<thead>
<tr>
<th>0-alternative 2025 (total length during the periods mentioned)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rail type</strong></td>
</tr>
<tr>
<td>IC3 train length (m)</td>
</tr>
<tr>
<td>Regional train length (m)</td>
</tr>
</tbody>
</table>

The night train is presumed to be an ICE-TD train from Germany, with a noise level assessed as being equivalent to an IC3 train.

Table 6.7 shows the expected railway traffic in 2025 with the bored tunnel. This is the same for the cases with and without ferries since all rail traffic will pass through the tunnel.

Table 6.7 Traffic basis for railway traffic for the bored tunnel (2025)

<table>
<thead>
<tr>
<th>Bored tunnel 2025</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rail type</strong></td>
</tr>
<tr>
<td>IC3 train length (m)</td>
</tr>
<tr>
<td>Regional train length (m)</td>
</tr>
<tr>
<td>Night train length (m)</td>
</tr>
<tr>
<td>Freight train length (m)</td>
</tr>
</tbody>
</table>

The maximum length for an IC3 train is 400 m. The maximum length for a freight train is assumed to be 835 m.

Motorway traffic

The motorway traffic data source is Femern A/S, see Table 6.8 for the 0-alternative traffic. Traffic periods are the same as for railway traffic.

Table 6.8 Traffic basis for motorway traffic in the 0-alternative (2025)

<table>
<thead>
<tr>
<th>0-alternative in 2025</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category</strong></td>
</tr>
<tr>
<td>Light vehicles</td>
</tr>
<tr>
<td>Heavy two-axle vehicles</td>
</tr>
<tr>
<td>Heavy multiple-axle vehicles</td>
</tr>
</tbody>
</table>

For the bored tunnel operation phase only the case without ferry operation has been considered. The year 2025 has been used in order to be able to make direct comparisons with the 0-alternative, see Table 6.9.

Table 6.9 Traffic basis for motorway traffic for bored tunnel without ferry operation (2025)
Bored tunnel in 2025

<table>
<thead>
<tr>
<th>Category</th>
<th>Day</th>
<th>Evening</th>
<th>Night</th>
<th>Speed [km/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light vehicles</td>
<td>6,468</td>
<td>1,274</td>
<td>2,058</td>
<td>110</td>
</tr>
<tr>
<td>Heavy two-axle vehicles</td>
<td>99</td>
<td>20</td>
<td>32</td>
<td>80</td>
</tr>
<tr>
<td>Heavy multiple-axle vehicles</td>
<td>1,155</td>
<td>228</td>
<td>368</td>
<td>80</td>
</tr>
</tbody>
</table>

Ferry traffic

The ferries M/V Schleswig-Holstein, M/V Prins Richard, M/V Deutschland, M/V Prinsesse Benedikte sail on the Rødby-Puttgarden route. The 4 ferries each have a present capacity of 364 cars. They are expected to be increased in length to accommodate the larger traffic volumes in the case of the 0-alternative. The 2010 sailing schedule for the route has 40 daily departures from Rødby.

Car speed in the ferry area is presumed to be 20 km/h. The traffic volumes are shown in Table 6.10.

Table 6.10  Traffic with ferry in the 0-alternative (2025)

<table>
<thead>
<tr>
<th>Category</th>
<th>Day</th>
<th>Evening</th>
<th>Night</th>
<th>Speed [km/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light vehicles</td>
<td>4,422</td>
<td>871</td>
<td>1,407</td>
<td>20</td>
</tr>
<tr>
<td>Heavy two-axle vehicles</td>
<td>99</td>
<td>20</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Heavy several-axle vehicles</td>
<td>990</td>
<td>195</td>
<td>315</td>
<td></td>
</tr>
</tbody>
</table>

Noise calculation model

The calculation of noise is done in a 3D model of the local area including terrain, buildings, the highway and railway line and the port area based on elevation data.

The Nord2000 predictions method has been used for the noise from road and rail traffic, while the general Nordic prediction model for industrial noise has been used for the other sources.

Calculation model for vibrations

There is no official method for calculating vibrations. The calculation of vibrations in this project are done in a model that is based on a general propagation method and utilising results from measurements at other railway projects and known source levels from trucks and ships.

6.7.2 Traffic noise and vibrations in 2025 for the 0-alternative

As mentioned above the limit values are different for railway traffic, road traffic and for ferry traffic, because the same sound pressure level is perceived differently by people.
The noise impact is therefore calculated separately. Figure 6.36, Figure 6.37 and Figure 6.38 show the noise levels for the noise generated by the railway, the motorway and the ferries.

Figure 6.36 Noise propagation from railway traffic in the 0-alternative (2025)
Figure 6.37  Noise from highway traffic in the 0-alternative (2025)
The number of buildings with an estimated noise impact above the limit values is listed in Table 6.11.

Table 6.11  The total number of buildings where noise above the limit value may be experienced in 2025 for the 0-alternative

<table>
<thead>
<tr>
<th>Building Application</th>
<th>Railway line</th>
<th>Motorway</th>
<th>Ferry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$L_{den}$</td>
<td>$L_{Amax}$</td>
<td>Day</td>
</tr>
<tr>
<td>Single-family and terraced houses, farmhouses, etc.</td>
<td>1</td>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td>Multi-storey residences and student residences</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other institution</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total number of residences</td>
<td>1</td>
<td>1</td>
<td>60</td>
</tr>
</tbody>
</table>
Noise from the railway line affects just one residence while the motorway affects 60 residences in the 0-alternative.

Noise from the ferries and associated traffic affects 325 residences during the night time period where the limit value is lowest (most exposed ½ night hour).

**Vibrations for the 0-alternative**

The vibration conditions are reported as a calculation of the total number of residences where vibrations and structure-borne sound limit values are expected to be exceeded (Table 6.12).

**Table 6.12 Numbers of buildings with vibrations above limit value for the 0-alternative**

<table>
<thead>
<tr>
<th>Vibration limit values</th>
<th>Railway line</th>
<th>Highway</th>
<th>Ferry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibrations, $L_{BA} &gt; 75$ dB</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Low-frequency noise, $L_{A(,LF)} &gt; 20$ dB</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Infrasound, $L_{FG} &gt; 85$ dB</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total number of residences impacted</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Only few residences are affected by vibrations from the railway and none from the motorway or ferries. It is expected that vibrations will not exceed the limit value for structurally-damaging vibrations.

### 6.7.3 Assessment of impacts during the construction phase

**Noise during the construction phase**

Assuming that some of the construction activities for the bored tunnel will take place primarily during daytime, construction activities in the case of the establishment of work harbours, worksites and the motorway will not cause significant noise pollution.

Separate assessments of the impact of underwater noise on marine mammals and fish have been carried out. See sections 5.9 and 5.10 above.

However, when constructing the railway line, the piling of catenary supports will create noise. In order to reduce noise from piling, a solution to utilise pre-boring or tamping shall be considered.

The production facilities; the slurry treatment plant and prefabrication of the tunnel segments take place continuously around the clock over a 3-year period, where only residences very near to the production facilities and transportation of materials will be affected by noise. By establishing noise barriers around the production areas, it is expected to be possible to comply with a noise limit value of 40 dB during night time for the respective residences.
Vibrations during the construction phase
The calculations show that structurally-damaging vibrations are not expected during the construction phase, because no residences are located close to the construction area.

6.7.4 Assessment of impacts during the operational phase

Noise during operation phase
The calculations of noise during the bored tunnel's operational phase are calculated for each noise source (railway line, road and ferry) because different limit values and noise indicators apply. The results of the noise propagation calculations are shown in Figure 6.39 and Figure 6.40.

Figure 6.39 Noise from the new railway line
The ferry traffic to/from Rødbyhavn may be decommissioned when a fixed link is established. In terms of noise, this will mean that residents that are affected by ferry traffic and road traffic to/from the ferries in the 0-alternative will experience a significant reduction in noise.

The numbers in Table 6.13 state how many residences will experience noise that is above the limit values.

**Table 6.13**   Residences where noise above the limit values will be experienced in the 0-alternative, with an immersed tunnel and with a bored tunnel (2025)

<table>
<thead>
<tr>
<th>Noise impact in 2025</th>
<th>Rail traffic noise</th>
<th>Road traffic noise</th>
<th>Ferry traffic noise - night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limit value</td>
<td>(L_{\text{den}} = 64,\text{dB}) and (L_{\text{max}} = 85,\text{dB})</td>
<td>(L_{\text{den}} = 58,\text{dB})</td>
<td>(L_{\text{Aeq,1/2h}} = 40,\text{dB})</td>
</tr>
</tbody>
</table>
Noise from the railway line affects four residences in the 0-alternative. When a fixed link opens, all of the railway traffic will use the fixed link and the ferries will only transport cars. Moreover, railway traffic will increase in relation to the 0-alternative and freight trains will now use the fixed link.

Nonetheless, the railway traffic will only result in a limited increase in the number of noise-impacted residences. Noise above the limit value \( L_{den} = 64 \text{ dB} \) will be experienced in 9-8 residences in total, because the railway will pass significantly further away from the residences.

In the 0-alternative 60 residences will experience noise levels that exceed the limit value for residences \( L_{den} = 58 \text{ dB} \). After the construction of an immersed tunnel, the impact from noise will be reduced to five noise-impacted residences and 18 noise-impacted residences for a bored tunnel, if the ferry operation is stopped. No residences along the roads in Rødbyhavn will experience noise levels above the limit value.

The impact of noise from the ferry traffic will be reduced with a fixed link and will, naturally, cease altogether, if the ferry operation is shut down.

**Vibrations during the operational phase**

Vibrations derive from the rail service, while road traffic and ferries do not cause vibrations. The calculations show that vibrations are a completely marginal issue.

In the 0-alternative vibrations will not exceed the limit of \( L_{aw} = 75 \text{ dBA} \) at any residence. With the fixed link as an immersed tunnel or a bored tunnel just one residence will be affected by vibrations.

In the 0-alternative the highest vibrations are generated by passenger trains while, in the case of a fixed link, the freight trains will operate and they will generate the highest vibrations.

In the 0-alternative a level of low-frequency noise greater than \( L_{PA,LF} = 20 \text{ dB} \) will be experienced in three residences, while in the case of an immersed tunnel 5 residences will be affected by low-frequency noise, and in the case of a bored tunnel, 4 residences will be affected.
6.7.5 Mitigation measures

Construction phase
If it is desired that construction activities are carried out during the evening and night, the contractor will be required to adjust the working methods and duration.

Because the production facilities; the slurry treatment plant and prefabrication of the tunnel elements take place continuously around the clock, noise barriers will have to be established around the production areas to ensure the nearby residents do not experience noise levels above 40 dB. Noise barriers will be provided by the 8 – 10 m high embankments of soil around the production site.

In the case of the piling of foundations for the power lines, the noise will be reduced where possible, for example by pre-boring or ramming the ground before piling close to residences.

Operational phase
There are no plans for noise mitigation measures in the operation phase.

6.7.6 Conclusion

In the case of the establishment and operation of the fixed link as an immersed tunnel or as a bored tunnel, the impact of noise and vibrations is assessed as being of the same magnitude on Lolland.

The impacts during the construction phase will be insignificant provided the mitigation measures are implemented. Special care has to be considered in order to achieve acceptable conditions for workers living in the temporary campsite.

The impacts during the operation phase are classified as insignificant due to the small number of residences affected.
6.8 Air quality and local climate

Rødbyhavn is located in an area with very limited sources of large air emissions. The local air quality is only affected to a limited degree by local sources such as the ferries and road traffic.

Good air quality is important for people's well-being and health, and for plant and animal life.

People's well-being and health may be adversely affected by harmful substances in the air. The harmful substances can lead to both long-term effects such as cancer and cardiovascular diseases and acute effects such as allergy and irritation of the nasal and respiratory passages.

About 1,800 people live in Rødbyhavn, primarily along Havnevej and side roads to Havnevej. Residences and farms are scattered in the area where the tunnel construction is planned. Furthermore, the holiday resort Lalandia is located west of Rødbyhavn, while the summer cottage area Hyldtofte Østersøbad is located to the east of the town. Both the holiday resort and the summer cottage area are located more than two kilometres from the bored tunnel. However, the summer cottage area lies less than one kilometre from the temporary tunnel production site.

Nature areas can be affected by air that has been polluted with nutrients and xenobiotics. The substances can change or adversely affect the habitats of plants and animals.

Flora and fauna around Rødbyhavn are more commonly found along the coast on salt meadows and inland in lakes, meadows, marshlands and forests. Many of the nature areas are protected under Section 3 of the Danish Nature Protection Act.

The local climate is also important for people's well-being and for plants and animals. It is determined by the overall climatic conditions of the region. Locally, special factors determine warming or cooling of the ground-level plant cover via sheltering, turbulence and wind conditions, shadows and reflections, etc.

6.8.1 Method

The study method applied consisted of the following steps:

› Determination of existing background air quality.
› Extrapolation to 2025 for the 0-alternative.
› Calculations of emissions during construction and operation of the bored tunnel.
› Dispersion modelling of local air quality for 0-alternative and for the bored tunnel.
› Assessment of impacts by comparison with air quality standards.
› Assessment of impacts of increased nitrogen deposition.
› Assessment of impacts on local climate
For the air quality assessment dispersion modelling was carried out for the operation phase of the bored tunnel. The German dispersion model Austal2000 was used with meteorological data from Gedser.

Emission sources included in the model are road traffic and rail traffic.

Denmark has adopted the EU air quality standards (Table 6.14). The standards express a range of limit values for each pollutant depending on the averaging time (1 hour, 8 hours, 24 hours and 1 year). The thresholds are values above which adverse effects on human health are likely. For example, for NO₂ exceedence of 200 µg/m³ for 1 hour on more than 18 occasions during a year may be dangerous to health. Similarly, an exceedence of 40 µg/m³ for a whole year is also dangerous.

### Table 6.14 EU air quality standards

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Concentration</th>
<th>Averaging period</th>
<th>Legal nature</th>
<th>Permitted number of exceedences each year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen dioxide (NO₂)</td>
<td>200 µg/m³</td>
<td>1 hour</td>
<td>Limit value entered into force 1.1.2010</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>40 µg/m³</td>
<td>1 year</td>
<td>Limit value entered into force 1.1.2010*</td>
<td>n/a</td>
</tr>
<tr>
<td>Sulphur dioxide (SO₂)</td>
<td>350 µg/m³</td>
<td>1 hour</td>
<td>Limit value entered into force 1.1.2005</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>125 µg/m³</td>
<td>24 hours</td>
<td>Limit value entered into force 1.1.2005</td>
<td>3</td>
</tr>
<tr>
<td>Fine particles (PM₂.₅)</td>
<td>25 µg/m³</td>
<td>1 year</td>
<td>Target value entered into force 1.1.2010</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>20 µg/m³ (AEI)</td>
<td>Based on 3 year average</td>
<td>Legally binding in 2015 (years 2013,2014,2015)</td>
<td>n/a</td>
</tr>
<tr>
<td>Particles (PM₁₀)</td>
<td>50 µg/m³</td>
<td>24 hours</td>
<td>Limit value entered into force 1.1.2005</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>40 µg/m³</td>
<td>1 year</td>
<td>Limit value entered into force 1.1.2005</td>
<td>n/a</td>
</tr>
<tr>
<td>Benzene</td>
<td>5 µg/m³</td>
<td>1 year</td>
<td>Limit value entered into force 1.1.2010</td>
<td>n/a</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>10 mg/m³</td>
<td>Maximum daily 8 hour mean</td>
<td>Limit value entered into force 1.1.2005</td>
<td>n/a</td>
</tr>
<tr>
<td>Ozone (O₃)</td>
<td>120 µg/m³</td>
<td>Maximum daily 8 hour mean</td>
<td>Target value entered into force 1.1.2010</td>
<td>25 days averaged over 3 years</td>
</tr>
</tbody>
</table>

* Under the new Directive the member State can apply for an extension of up to five years (i.e. maximum up to 2015) in a specific zone.

### 6.8.2 Existing background air quality

The background level describes the air quality which, in the low atmospheric layers, arises from the remote transport of air pollution and without any significant contribution from local sources. The background level and contributions from new sources are summed up to assess whether the air quality complies with the current air quality standards.

The development of the air quality is monitored through measurements, which are supplemented with models. The modelling is carried out by the DCE - Danish Centre for Environment and Energy (formerly the National Environmental Research Institute (DMU)), based on the national monitoring programme (LMP) and the background monitoring programme (BOP).
Measurements carried out at measuring stations Keldsnor on southern Langeland, Lille Valby and in Copenhagen were used to describe the air quality at Rødbyhavn.

The measurements from Keldsnor are assessed as being the most representative for a background level at Rødbyhavn. The other measuring stations are included to qualify the assessment and also because there are no measurements for SO2 and benzene at Keldsnor.

The measurement data from Keldsnor for NO2 and PM10 for the period 1995-2010 (DMU 2011) is shown in Figure 6.41 and Figure 6.42.

As the figures show, the values for particulates and NO2 are well below the current thresholds, for the entire period.

The annual average of NO2 is stable at 5-10 µg/m³.

The annual average of PM10 is between 20-30 µg/m³ and shows a slightly decreasing trend.

The levels for NO2 and PM10 for the measuring station at Keldsnor are low in comparison to other Danish measuring stations, whereas the ozone level is high, primarily because of the long distance transport from the European continent.

For benzene, SO2 and PM2.5, of which there are no measurements at Keldsnor, the background level is based on measurements from other stations in Denmark.

Figure 6.41 Measurement results from Keldsnor 1995-2010, annual average of NO2 (µg(NO2)/m³)
6.8.3 0-alternative – background level
To be able to compare air quality and local climate with and without a fixed link, the current situation has been extrapolated to a 0-alternative.

In terms of traffic, the 0-alternative is defined as the situation where the fixed link is not built, and the infrastructure subsequently adapts to this. In this EIA report, the year 2025 has been chosen as the 0-alternative. It is expected that the traffic is adapted and the users have become accustomed to the new option. The other factors (local emissions, etc.) are presumed to be unchanged.

Towards 2025 new and more stringent requirements for road traffic and vessel traffic will be implemented and mean that emissions of polluting substances to the air from individual vehicles and vessels will fall. This especially applies to emissions of particulates and NOx. However, at the same time it is expected that traffic will increase, which may cancel out the positive trend.

In the dispersion calculations, the background level for 2025 has been set to a conservative level on the basis of the above measurements for (NOx: 9 µg/m³, NOy: 11 µg/m³, PM10: 24 µg/m³, PM2.5: 15 µg/m³, benzene: 1 µg/m³, SO2: 3 µg/m³).

6.8.4 0-alternative – local air quality
The assessment of the 0-alternative has primarily focussed on the areas where people live and stay and on sensitive nature areas.

Rødbyhavn is located in an area with only a few large emission sources, and the local air quality is only affected to a limited degree by local sources such as the ferries and road traffic.
Sources of local air pollution in the 0-alternative include:

- Ferries in the year 2025.
- Traffic emissions from the south motorway E47.
- Traffic emissions from other primary roads in Rødbyhavn.
- Rødbyhavn Fjernvarme a.m.b.a (local district heating public limited company) and other small heating plants.

An assessment of the local air quality in the area around Rødbyhavn for the 0-alternative has been carried out to be able to compare the project alternatives.

The assessment is based on the dispersion calculations where emissions from ferries, traffic from the existing motorway and other primary roads are included. Other sources are not included, because they are assessed as having a marginal effect on the local air quality level and furthermore, it is expected that the difference between the 0-alternative and the project alternative will not be significant. The traffic is extrapolated to 2025, and the ferries' capacity has been adjusted in relation to the expected capacity requirements. Both exhaust-related emissions and diffuse dust from re-suspension, brakes etc. are included in the calculations.

In terms of the ferries, both emissions in the harbour and emissions from sailing/manoeuvring are included.

The determination of ferries in the future and emissions from the ferries has been carried out by Hans Otto Holmegaard Kristensen, Senior Researcher at the Technical University of Denmark, incorporating the latest knowledge related to technology and forthcoming legislation.

The exhaust-related emission factors from road traffic are based on the Danish Ministry of Transport's emission model TEMA2010, and dust from braking, re-suspension, etc., from road and rail traffic is based on Swiss figures. The dispersion calculations have been carried out using a dispersion model Austall2000 (Lairm 2012) and with meteorological data from the station at Gedser Odde, which is assessed as being the most representative for Rødbyhavn.

The results of the dispersion calculations for 2025 are shown in Figure 6.43, Figure 6.44, Figure 6.45 and Figure 6.46.

As the figures show, the ferries and traffic along the roads included in the model only make a very limited contribution to the background level of NO₂, NOₓ, PM₁₀ and SO₂ and no threshold is exceeded.

In terms of small particulates PM₂.₅ and benzene, the calculations show that the contributions are marginal and no thresholds are exceeded.

Furthermore, the calculations show that the traffic on the motorway only causes slightly deteriorated air quality very locally along the road.
Figure 6.43  Average annual NO$_2$ concentration $\mu$g/m$^3$ for the 0-alternative in 2025. A background concentration of 9 $\mu$g/m$^3$ has been factored in. The EU threshold: 40 $\mu$g/m$^3$. 
Figure 6.44 Average annual NO\textsubscript{x} concentration µg/m\textsuperscript{3} for the 0-alternative in 2025. A background concentration of 11 µg/m\textsuperscript{3} has been factored in.
Figure 6.45  Average annual PM$_{10}$ concentration $\mu$g/m$^3$ for the 0-alternative in 2025. A background concentration of 24 $\mu$g/m$^3$ has been factored in. The EU threshold: 40 $\mu$g/m$^3$
6.8.5 0-alternative – nitrogen deposition

Nitrogen is an airborne nutrient that, when it is deposited on the ground surface, may cause over-fertilisation of nutrient-poor habitats. Over-fertilisation can lead to the destruction of a habitat when nutrient-demanding species outcompete the nutrient-poor species. Agriculture is a significant source of nitrogen, but small volumes of nitrogen can also be generated by traffic, etc. Therefore, calculations for the magnitude of nitrogen deposition from the 0-alternative have been carried out.

The deposition calculations are made on the basis of the dispersion calculations and the assessed deposition speeds (Lairm 2012). The sources used are the same as the ones used in the dispersion calculations for the air quality.
Figure 6.47 shows the calculated N-deposition for the 0-alternative assuming forest deposition speeds everywhere.

The deposition for forests is shown since this type of habitat gives the largest deposition of nitrogen due to the roughness of the leaves and the ability to make the nitrogen deposit.

As shown, deposition occurs primarily along the road's alignment at a distance of up to 100 m and around the ferry port. The deposition is assessed as limited.

At greater distances, the sources do not contribute to nitrogen deposition in the 0-alternative.
6.8.6 0-alternative – local climate

The nearest station that records wind and weather data is located in Gedser at the southern tip of Falster.

As the Gedser wind rose shows (Figure 6.48) wind directions are primarily from west and southwest, followed by the east and south east.

![Wind rose for Gedser, based on wind data from 1993-2002, source DMI](http://www.dmi.dk/dmi/GEDSERstor10.gif)

The average temperature, rainfall and hours of sunshine in the period 1961–1990 are shown in Figure 6.49. The area is, along with Bornholm, known as having the greatest number of hours of sunshine and the highest average temperature in Denmark. Furthermore, the area has the lowest average annual rainfall in the period.

For the 0-alternative it is assessed that there are no special factors that would give rise to significantly different local climatic conditions.
6.8.7 Project pressures and potential impacts

Both the construction and operation of a bored tunnel may have an impact on the local air quality. This can happen with the emission of polluting substances from machines during the construction phase or from the traffic on the new motorway or railway. The new fixed link may also mean that in some areas the air quality will improve because the cars and trains are on new alignments and because the ferry operations may be discontinued.

The study is focused on the areas where people live and stay and sensitive nature areas.

During the construction phase, the following potential sources of local air pollution exist:

- Existing emissions.
- Emissions from the contractor's machines on land and at sea, lorries and tug boats, and traffic to/from the construction area and the tunnel element factory, including facilities for the workforce.
- Emissions from the tunnel lining factory, e.g. smoke from welding, dust from cutting processes and concrete mixing, flue gas from the energy plant.
- Dispersion of dust from the handling of materials and vehicles driving on gravel roads.
- Emissions of VOC (volatile organic compounds) from refuelling and from any fuel depots.

During the operational phase, two scenarios have been studied:

- Bored tunnel without ferries.
Bored tunnel with continued ferry operations at the current level. Passenger car traffic in 2025 will be evenly divided between the ferries and the bored tunnel.

During the operational phase, the following potential sources of local air pollution exist:

- Existing emissions.
- Emissions from the tunnel opening, where pollution from traffic in the tunnel will be concentrated.
- Emissions from traffic along the motorway and railway line.
- Deducting emissions from the ferries (only in Scenario 1).

In addition, the energy used to operate the bored tunnel will create more air pollution where the power stations are located.

6.8.8 Assessment of the impact on local air quality during the construction phase

The construction of the bored tunnel will lead to emissions of polluting substances that can affect the local air quality. The most significant elements are:

- Establishment and operation of the tunnel lining factory.
- Establishment of land reclamation area.
- Establishment of motorway and railway on land.
- Transport of materials by ship and by lorry.

A qualitative assessment of the local air quality in the area around the most significant construction activities has been carried out.

The emissions, particularly from the marine activities including the excavation of the temporary harbour and establishment of the reclamation area, i.e. from excavation machinery, tug boats, transport vessels, etc., are significant, and the air quality very locally around the work area may be affected by the marine construction activities.

However, the activities will take place over a large area, where the air circulation is good, consequently it is expected that in the long term, the thresholds for air quality on land will not be exceeded during the construction phase.

Furthermore, mitigation measures could limit air pollution from both dust and exhaust emissions.

On this basis, air pollution during the construction phase is assessed as being insignificant.
6.8.9 Assessment of the impact on nitrogen deposition during the construction phase

The assessment of nitrogen deposition during the construction phase has been made on the basis of a screening of a "worst-case construction scenario". Calculations have been made for the construction work, which is assessed as resulting in the largest emission during a year and, at the same time, the emission will occur close to sensitive nature areas, specifically the Natura2000 site at Hyldtofte.

The "worst-case construction scenarios" are identified on the basis of machinery and fuel consumption stated by the design groups. The "worst-case construction scenarios" are identified to be the construction activities connected to excavation of the immersed tunnel trench. The calculations of this scenario show that the most significant deposition will occur immediately next to the construction area, and that the deposition on sensitive nature areas is limited.

During the construction, the bored tunnel will result in fuel consumption which is around half of what is expected during construction of the immersed tunnel. Furthermore, the location of the activities is the same. Based on these facts, it can be concluded that the bored tunnel will not result in a higher deposition in the sensitive nature areas around Rødbyhavn that what is found in the above mentioned deposition calculations for the immersed tunnel.

6.8.10 Assessment of the impact on local climate during the construction phase

The effects on local climate in the form of wind, rainfall, sunshine, etc., are expected to be minimal. The buildings may, during a limited period, have a shadow/shading effect, which at a local level increases the potential for increased turbulence.

The project's influence on the local climate during the construction phase is assessed as being insignificant.

The assessment of the construction's impact on the global climate in the form of emissions of greenhouse gases is given in a separate section.

6.8.11 Assessment of impacts on local air quality during the operational phase

Dispersion calculations have been made for the operational phase of the bored tunnel both for Scenario 1 and Scenario 2. The traffic is extrapolated to 2025.

Compared to the immersed tunnel, the bored tunnel opening is positioned differently, the opening for the railway line and road respectively are separated, and the emissions from traffic will differ slightly because of the longer distance and the change in the incline of the section.
In terms of the ferries, both emissions in the harbour and emissions from sailing/manoeuvring are included.

The emissions from future ferries have been determined in cooperation with the Technical University of Denmark, incorporating the latest knowledge related to technology and forthcoming legislation. (DTU 2011).

The exhaust-related emission factors are from TEMA2010. Dust from brakes, re-suspension, etc., are based on Swiss empirical data. The dispersion calculations have been carried out using a dispersion model Austall2000 (Lairm 2012) and with meteorological data from the station at Gedser Odde, which, in consultation with the Danish Meteorological Institute (DMI), is assessed as being the most representative for the local climate in Rødbyhavn.

The dispersion calculations for Scenario 1 for the bored tunnel show that the concentration of particulates and NO₂ will exceed the current annual average thresholds for air quality immediately around the tunnel openings and a maximum distance of 200 m on each side (Figure 6.50). Even the 1 hour thresholds will be exceeded in a somewhat smaller area. There will also be an increased concentration of NO₂ along the new motorway.

The area where the threshold for the PM₁₀ concentrations is exceeded is larger around the tunnel mouth for the railway line than from the road (Figure 6.51). Furthermore, there will be an increased concentration of PM₁₀ along the railway, caused by re-suspension of dust and dust from brakes etc. Despite the tunnel being slightly longer and the incline of the section is greater, the concentration at the tunnel mouth is not significantly different from that for the immersed tunnel.

The calculations show that the concentration of PM₂.₅ will be highest at the tunnel mouths and that the area where the threshold is exceeded is limited (Figure 6.52).

Regarding areas with residences, air quality is not expected to deteriorate significantly, and the thresholds will not be exceeded here.

The concentration of benzene will increase slightly around the tunnel opening, but no concentrations above the current thresholds were found in the model results.

Moreover, the calculations show that the traffic on other roads on Lolland only causes slightly deteriorated air quality very locally along the roads.
Figure 6.50  Average annual NO$_2$ concentration µg/m$^3$ for the bored tunnel in 2025, Scenario 1. A background concentration of 9 µg/m$^3$ has been factored in. The EU threshold: 40 µg/m$^3$. 
Figure 6.51  Average annual PM$_{10}$ concentration $\mu g/m^3$ for the bored tunnel in 2025, Scenario 1. A background concentration of 24 $\mu g/m^3$ has been factored in. The EU threshold: 40 $\mu g/m^3$
Figure 6.52  Average annual PM$_{2.5}$ concentration $\mu g/m^3$ for the bored tunnel in 2025, Scenario 1. A background concentration of 15 $\mu g/m^3$ has been factored in. The EU threshold: 25 $\mu g/m^3$. 
As with the immersed tunnel, it will also apply to the bored tunnel that if the ferry operations are stopped (Scenario 1), there will be a fall in the concentration of polluting substances (particularly nitrogen dioxides and oxides) compared to the 0-alternative. However, this does not apply at the tunnel opening and along the new motorway. However, the difference from today is very limited. See Figure 6.53.

Figure 6.53  Difference in average annual NO$_2$ concentration µg/m$^3$ between bored tunnel Scenario 1 and the 0-alternative in 2025. A background concentration of 9 µg/m$^3$ has been factored in. The EU threshold: 40 µg/m$^3$. 

Map: © Kort & Matrikelstyrelsen
In Scenario 2, the ferries continue to operate and the old motorway continues to be used. Compared to Scenario 1, this results in increased emissions locally in Rødbyhavn and along the old motorway and a lower contribution around the tunnel opening for the road and along the new motorway.

However, the dispersion calculations show that the concentration level around the tunnel opening also exceeds the thresholds for particulates and NO\textsubscript{2} (Figure 6.54). The area with critical values is less than in Scenario 1, where 100% of the traffic uses the tunnel.

In Scenario 2, the ferries are smaller than in the 0-alternative, which explains the reduction in concentration of NO\textsubscript{2} when comparing Scenario 2 to the 0-alternative (Figure 6.55).
6.8.12 Assessment of impacts on nitrogen deposition during the operational phase

The deposition calculations are made on the basis of the dispersion calculations and the assessed deposition speeds. The sources are the same as the ones used in the dispersion calculations for the air quality.

Figure 6.56 shows the difference in the calculated N-deposition between the bored tunnel alternative (Scenario 1) and the 0-alternative for forest. It shows the main deposition is just around the tunnel opening in a radius of up to 500 m and along the motorway’s route at a distance of up to 100 m.
There will be a larger reduction in nitrogen deposition immediately around the ferries and the old motorway than in the rest of the area.

Over greater distances there is no significant difference between the 0-alternative and the tunnel's contribution to nitrogen deposition.

Figure 6.56  Calculated difference in nitrogen deposition between the bored tunnel alternative (Scenario 1) and the 0-alternative (g/ha per year) for forest

It is the same for Scenario 2. However, in the area where there will be a reduced nitrogen deposition, the reduction will be diminished because of the continued ferry operation.
6.8.13 Assessment of impacts on local climate during the operational phase

The effects on local climate in the form of wind, rainfall, sunshine, etc., are expected to be minimal. The ramp and approach area may have a very local shadow effect, which in the immediate vicinity of the buildings may lead to areas with less rainfall, sheltering or increased turbulence.

The assessment of the construction's impact on the global climate in the form of emissions of greenhouse gases is given in a separate section.

6.8.14 Mitigation measures

Construction phase

To minimise the environmental consequences, the following mitigation measures will be incorporated into the project:

› The contractors will be required to minimise dust pollution as much as possible and prepare a management plan for covering and watering earth deposits. The plan must cover normal operating conditions including dry and windy periods.

› The contractors will be required to prepare a management plan for the purpose of reducing emissions from lorries and construction plant. The plan must also include the regulation of driving and work, of idle running of vehicles and engines, regular maintenance, etc.

› Femern A/S will set emission requirements for contractor's machines and transport equipment for the purpose of reducing the emissions. The set requirements will be based on what is practicable.

Operational phase

No measure are planned for the operation phase.

6.8.15 Conclusions

The construction of the bored tunnel is expected to lead to an increase in the concentration of polluting substances (especially particulates and nitrogen dioxides) in the area around Rødbyhavn. Because the activities will take place over a large area, where the air circulation is good, it is expected that the thresholds for air quality on land will not be exceeded.

The assessment of the air quality during the operational phase is based on dispersion calculations for the bored tunnel. Unsurprisingly, the calculations show that the largest concentration of polluting substances will be immediately around the road tunnel opening and along the new motorway. The annual average concentration of particulates and NO2 exceeds current thresholds for air quality in a 200 m radius area just around the tunnel opening. The model results show that even the 1 hour thresholds will be exceeded near the tunnel entrance. However, people
will only remain in the area for short periods so their health will not be affected and the impact is insignificant.

Thresholds are not exceeded in areas with permanent residences and the impact is consequently assessed as insignificant.

As long as ferry services continue there will be traffic to the ferries. The concentration of polluting substances around the tunnel mouth will therefore be less than in Scenario 1, but still will exceed thresholds. Instead, there will be a larger concentration around the harbour and the current motorway. The difference for the local air quality is assessed as being marginal.

The nitrogen deposition will primarily occur immediately around the tunnel opening in a radius of up to 500 m and along the motorway at a distance of up to 100 m. In addition to the distance, there is no great difference between the 0-alternative and the tunnel’s contribution to nitrogen deposition. The impacts of nitrogen deposition are assessed as insignificant.
6.9 Material assets

The material assets include an airfield, ferry port and ferry traffic, road and rail connections, wind turbines, sewage treatment plants, pumping stations, industrial plant, a deposit for raw material and the soil’s cultivation value (soil quality). In addition, potentially contaminated soil within the construction area will also be described.

6.9.1 Method

The material assets and contaminated soil are mapped based on information in the Municipal Plan, literature, Region Zealand and the Danish Nature & Environment Portal.

6.9.2 Legal framework

Airports, wind turbines, utility supply lines, industrial plants, contaminated soil and raw materials recovery area are handled in the Municipal Plan. The guidelines are not stated here because they are primarily about the requirement for the future positioning and installation of new facilities.

6.9.3 Existing material assets

In terms of technical facilities and infrastructure in the area, there is the road and rail connection, an airfield, wind turbines, high-voltage power line along the highway, industrial plants, sewage treatment plants and pumping stations. Two corridors are reserved east and west of Rødbyhavn for a future gas pipeline according to a national planning directive (Landsplandirektiv) from 1979. The reservation is not included in the assessment. The railway terrain is not reviewed further as no impacts are expected to this as a material asset.

Additionally, there is farmland with high soil quality (cultivation value) and a known raw materials area for the recovery of bentonite. Finally, there are several contaminated or potentially contaminated areas.

The existing material assets are illustrated in Figure 6.57.

The highway and railway lines cut through the area and end in Rødbyhavn, where there is a ferry port with ferry connections to Germany. The airport, Lolland Falster Airfield, is located in the north-eastern part of the study area and is operated by Municipality of Lolland and the Municipality of Guldholmsund. A wind farm, Syltholm Vindmøllepark, is located on the south coast and consists of 35 wind turbines.

The industrial plant BG Elements, which manufactures products such as reinforced concrete piles and the soil decontamination plant RGS 90 are both located near the coast between Rødbyhavn and the wind farm. The industrial plant Klimafisk, which is not operating, is located in the same area. There are two sewage treatment
plants, one east of Rødbyhavn and one at Hyldtofte Østersøbad. There are pumping stations located along the dike used for draining the reclaimed land.

The majority of the area has clayey soil, which is well-suited for agricultural use. The reclaimed areas, which were previously seafloor and bottom of the fjord, are less well-suited to agricultural use, but are valuable in terms of nature and landscape. In the eastern part of the area there is a bentonite deposit (a type of clay used in the construction industry, etc.) at depths of between 13 and 26 m. The deposits are identified as a potential for raw materials recovery, but the bentonite is not mined today. According to the Raw Materials Plan for Region Zealand, a new and smaller demarcation of the raw material recovery area is in public hearing.

The municipality has identified areas where the soil is classified as potentially contaminated. This concerns the older parts of the towns Rødbyhavn and Rødby, the industrial areas around the port area at Rødbyhavn and the area east of there. In

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**Figure 6.57 Material assets and mapping of potentially contaminated soil**

The majority of the area has clayey soil, which is well-suited for agricultural use. The reclaimed areas, which were previously seafloor and bottom of the fjord, are less well-suited to agricultural use, but are valuable in terms of nature and landscape. In the eastern part of the area there is a bentonite deposit (a type of clay used in the construction industry, etc.) at depths of between 13 and 26 m. The deposits are identified as a potential for raw materials recovery, but the bentonite is not mined today. According to the Raw Materials Plan for Region Zealand, a new and smaller demarcation of the raw material recovery area is in public hearing.

The municipality has identified areas where the soil is classified as potentially contaminated. This concerns the older parts of the towns Rødbyhavn and Rødby, the industrial areas around the port area at Rødbyhavn and the area east of there. In
addition, sites have been identified and mapped after the knowledge levels 1 and 2 (V1 and V2). V2 areas are documented as being contaminated, whereas V1 areas are potentially contaminated.

6.9.4 Importance

The material assets within the study area are mapped and the subjects' importance is assessed. Their assessed importance is based on criteria that are divided into four categories: Very high, high, medium and low. However, no material asset was classified as having a very high importance. See F.

The map shows that the pumping stations and the sewage treatment plant near the coast are assessed as being high importance assets. Also the infrastructure facilities
(highway, railway line, ferry port and airport) are classed as being of high importance as they are of regional importance.

The wind farm Syltholm Vindmøllepark, the high-voltage power line and bentonite deposit are classed as being of medium importance. The two industrial plants RGS 90 and BG Element are assessed as being of medium importance because they can be relocated. There may be costs associated with this and a new location may mean that a new EIA report would have to be carried out.

The importance of the company Klimafisk has not been assessed because it is no longer in operation.

Today, some areas are already contaminated or potentially contaminated. They are assessed as having medium importance. This is because the construction work may be expensive if the contaminated soil must be removed and cleaned.

The remaining areas are farmland and are assessed as having low importance. This is because similar soil conditions exist throughout the greater part of east Denmark. This means there is no special agricultural factors within the project area, even though the soil is classed as having a high agricultural soil quality.

The importance of the material assets in the 0-alternative (2025) is expected to be the same as today. However, it is expected that the wind farm Syltholm Vindmøllepark will have been replaced or decommissioned. This is because the wind turbines were installed in 1996 and a wind turbine has a normal working lifetime of 20 years.

6.9.5 Potential impacts
The effects caused by the tunnel project are divided into the following:

› Temporary or permanent expropriation, which entails that an industrial plant or element has to be removed, relocated or have its function changed.

› Change in land use, which may limit mining and use of raw materials and soil.

› Management of polluted soil during the construction phase

› Heavy machinery traffic, which can lead to soil compaction and impairment of the cultivation value of the farmland.

6.9.6 Assessment of impacts during the construction phase
The construction phase for the bored tunnel is estimated to last for 8 years. This covers construction of the new highway and railway, toll facilities, construction and operation of the work area and reclamation of new land.

The consequences for the airfield, ferry port, highway and railway are estimated to be minimal. This is because the functionality of the infrastructure facilities is
maintained throughout the construction phase. The impact on the high-voltage power line is also assessed to be limited, as the function will be maintained. The wind turbines at Syltholm are not affected by the construction work. The consequences for the bentonite clay deposits are assessed as not being significant, because any subsequent mining has been assessed as being uneconomic and will only be affected to a small degree.

Sewage treatment plant
During the construction phase, sanitary wastewater from the production facility and labour camp will be directed to the sewage treatment plant east of Rødbyhavn. The plant will be upgraded to sufficient capacity to handle road run-off etc. in the future. Furthermore, land reclamation means that the discharge from the sewage treatment plant will be relocated. This will not result in a loss of the sewage treatment plant or its function because the sewage treatment plant can handle the extra volume of wastewater. On the basis of this assessment, the consequence is not significant.

Pumping stations
The pumping station at Strandholm Pumpelag (east of the construction site) can maintain its function, and therefore the consequences are assessed as not being significant. The outlet from the pumping station west of Lalandia will be relocated as a consequence of the land reclamation, and, at the same location, the outlet from the lock at Bredfjed may be changed.

Industrial plants
BG Element manufactures products such as reinforced concrete piles and is located immediately west of the highway's tunnel portal. About 1/3 of the company's total area will be expropriated for the construction of the portal and artificial hills. The soil decontamination plant RGS 90 is not affected during the construction phase. The disused buildings from the plant "Klimafisk" will be removed as agreed with the owner.

Farmland
If soil contamination occurs in the farmland areas, the soil will be cleaned so the area can continue to be used for agricultural purposes. The limiting of soil compaction and contamination and the need for the sorting of soil will be dealt with in an environmental management plan. As the farmland is expected to be used for agricultural purposes after the construction phase, the impact will not be significant. The construction work may lead to cleaning of contaminated soil which will have a positive impact.

Classified soil area
If the classified soil has to be removed or excavated, it is necessary to examine the soil for contamination, the type of contamination and the degree of contamination. However, there is no immediate need to remove the soil from the area.
6.9.7 Assessment of impacts during the operational phase

When the construction works are completed, in comparison to the 0-alternative, some permanent structures will remain east of Rødbyhavn – a new highway, a new railway line, toll facilities, tunnel portals, embankments over the tunnels and land reclamation.

The airfield and air traffic will not be affected by the tunnel. The highway will be maintained as a local route into Rødbyhavn. The new railway line and highway will take over the function as the link to Germany. The old railway line and station will be closed down and replaced by a new one at Holeby (not part of this project). The high-voltage power line is not affected by the operation of the new structures. The wind farm Syltholm Vindmøllepark is not affected and neither the distance to the new motorway or the land reclamation will prevent the area from continuing to be used as an area for wind turbines.

Ferry port

When the fixed link is connected, the need for a ferry port will be greatly diminished. It is not yet clarified if the ferry route from Rødbyhavn to Puttgarden will be shut down. This will be a change to the existing situation, but does not constitute a negative consequence for the material assets because the fixed link will take over the function. It is not clarified who will take over the buildings, ferries, etc.

Sewage treatment plant and pumping stations

Today, the sewage treatment plant east of Rødbyhavn and the three pumping stations are located close to the coast. Outlets will be extended by approx. 500 m, so the cleaned wastewater can continue to be discharged into the sea. Lolland Municipality has planned that sewage from Hyldetofte Østersøbad will be led to the sewage plant at Rødbyhavn after 2013. The road run-off will also be treated at the plant. The load does not entail a loss as such of the sewage treatment plant, the pumping stations or their function, but it probably requires new pumps, etc. The upgrading of the sewage plant will be implemented in the construction phase. The consequences are assessed as not being significant.

Industrial plants

The industrial plant at Klimafisk will be removed and a smaller corner of the BG Element's site will be expropriated. The soil decontamination plant RGS 90 will not be affected.

Farmland

During the operational phase, 55 ha of farmland will be expropriated for the new highway and railway line. The construction will also have a barrier effect in relation to access between farmland areas located east and west of the road lanes and the railway. New local roads will be established. The consequence is assessed as not being significant.

The farmland's financial value is dealt with specifically in the subsequent planning through compulsory acquisition businesses and agreement about land division.
Bentonite deposits

The tunnel project will be constructed on 26 ha of an area where deposits of bentonite clay have been identified. Bentonite can be used for building projects etc., but the deposits at Rødbyhavn are of doubtful quality. A large part of the mapped deposits will continue to be accessible and therefore the consequence is assessed as not being significant.

Area classified soil

If the area continues to be classified as an industrial area, the area will in all probability be area classified during the operational phase. Any contamination from construction work will be cleaned up.

6.9.8 Mitigation and compensation measures

A few essential mitigation and compensation measures have already been incorporated in the project to ensure that the consequences are not significant:

› The new solutions in relation to the sewage treatment plant and the pumping stations will be established before the existing facilities are removed.

› In the environmental management plan, guidelines will be included to ensure that the farmland areas can be used for agricultural operations after the construction phase. The plan will deal with, for example, soil compaction, contamination and any need for the sorting of the soil.

› Owners of all areas expropriated will be compensated.

6.9.9 Conclusion

Increased volumes of sanitary wastewater from the production area will be released into the treatment plant during the construction phase. Both the sewage treatment plant and the pumping station's functions will be maintained.

The material assets' functions will continue to be maintained after the tunnel project is constructed. A part of the area of the industrial plant BG Element will be appropriated, but apart from this, the expropriation of the farmland and bentonite deposit will be limited. The consequences are therefore assessed as being insignificant. Moreover, the new fixed link will be seen as a new material asset.

When the fixed link is complete, the need for a ferry port will be greatly diminished. This will be a change to the existing situation, but does not constitute a negative consequence for the material assets because the fixed link will take over the function of the ferry port and operate as the road and rail link between Denmark and Germany.

The overall conclusion is that the impacts on material assets are insignificant.
6.10 Population and health

The term 'population' refers to the people who live in or visit the study area.

6.10.1 Method

The assessment of the consequences for the resident population and visitors in the study area caused by the environmental impacts is based on the survey of the area's values and their importance for the population.

For a more detailed description of the survey, please refer to (COWI2012a).

Furthermore, the assessment is based on the environmental assessments in this report and on a series of interviews with residents, employees and visitors related to the study area. Specifically, a total of 17 couples or residents from the area were interviewed, three visitors, three sector managers and two directors in the Municipality of Lolland, two business owners in the tourist industry, a real estate agent and a representative of the Femern Belt Development Fund.

The focal point of the interviews was the impact of the fixed link, including the interviewee's expectations about the consequences of the choice of alternative (bridge or tunnel).

This assessment is mainly based on information in following chapters: 6.4 Cultural heritage and archaeology, 6.5 Recreation, 6.6 Water, 6.7 Noise and vibrations, and 6.8 Air quality and local climate. Knowledge from these topics is used where there are environmental impacts affecting the population's quality of life (living conditions) and health.

The present situation is projected to 2025 to enable the comparison of impacts with or without a fixed link.

6.10.2 Legal framework

The legal framework relevant for the population is regulated through municipal plans and Local Plans.

According to the municipal plan for 2010–2022 an area east of Rødbyhavn is reserved for the fixed link.

Furthermore, a number of Local Plans apply to the area. A Local Plan can be modified by a waiver or by adopting new Local Plans.

6.10.3 Existing population and health conditions

Population

The study area is located in the Municipality of Lolland, with approximately 50,000 residents of which 70% live in urban areas. Figure 6.59 shows that the study area does not cover all of the Municipality of Lolland, but only the area
located closest to the site where the tunnel is to be constructed and which is affected by the construction phase and the operation phase.

The majority of the population in the study area is concentrated in the two smaller towns Rødby and Rødbyhavn, with populations of around 2,200 and 1,800 respectively. The nearest larger town located 13 km from Rødby is Maribo, with 6,000 residents. The study area also includes three holiday cottage areas, of which Lalandia is the largest.

Housing in the area is shown in Figure 6.59.

The municipality is sparsely populated and has lately experienced a significant depopulation, especially among the young. This depopulation has caused the population's age composition to differ compared to eastern Denmark in general.

Figure 6.59 Residential units and holiday cottages in the study area. Source: Bygnings- og boligregistret (Danish Buildings and Housing registry).
Compared to eastern Denmark, the proportion of the population of an employable age (16–66 years) is small, and with a larger proportion of older people. This means that the proportion of the labour force is relatively smaller in Lolland compared with eastern Denmark. Given the small proportion of younger people, the labour force will continue to be proportionally smaller than in eastern Denmark in the coming years.

The population in the Municipality of Lolland differs from the population in eastern Denmark by having a shorter average lifespan (74.8 years compared to 76.9 years in eastern Denmark) and in having the lowest self-assessed health.

Two of the external factors impacting the population's health could be noise and air pollution derived from road, rail and ferry traffic. Air pollution may irritate eyes, respiratory tract, mucous membranes and skin and may lead to serious respiratory disorders and heart disorders. However, no thresholds are exceeded in the current situation or in the 0-alternative (2025 without a fixed link) meaning that air quality is not the reason for the shorter lifespan.

The railway line, ferry and motorway are also sources of noise. There are no residences in the area where the threshold for railway noise is exceeded. For 62 residences, the threshold for motorway noise is exceeded and in 180 cases the threshold for ferry noise is exceeded at night. In terms of health, noise can lead to increased blood pressure, disturbed heart rate and stress.

6.10.4 Importance

In connection with the mapping (COWI 2012a), individual subareas have been categorised according to the importance for the population using one of four categories: Very high, high, medium and low.

The two towns Rødby and Rødbyhavn and the holiday resort Lalandia are categorized as areas of very high importance because of the concentration of the population in Rødby and Rødbyhavn and partly because Lalandia is an important centre for the local population, providing access to the cinema, swimming pool, etc.

The other two holiday cottage areas (Bredfjord and Hyldtofte) are categorized as areas of high Importance.

Based on noise levels, etc., buffer zones of 500 m and 50 m have been designated around the towns and individual residential properties. The buffer zones are defined as having medium importance for the population and cover approx. 330 houses in the open countryside, primarily along main roads.

The remaining areas are assessed as having low importance for the population. However, they can have importance in terms of recreational use. This theme is looked at in section Outdoor leisure activities.
The importance criteria are described in detail in the Environmental Survey (COWI 2101a).

Figure 6.60 The importance of individual areas for the population and for the business community and areas that will be affected during the construction phase and the operation phase in relation to a bored tunnel

6.10.5 Potential impact
For the population, the most significant effects from a bored tunnel are:

› Area expropriation.
› The physical fragmentation of areas with detours and barrier effects as a consequence.
› Increased population causing reduced accessibility and more life in the local community.
› Visual fragmentation of the landscape (addressed in section 6.2 Landscape and soil)
Increased water consumption during the construction phase (addressed in section 6.6 Water)
Increased risk of water pollution (addressed in section 6.6 Water)
Noise, air and light emission (addressed in more detail in sections 6.7 Noise and vibrations, 6.8 Air quality and local climate and 6.2 Landscape and soil).

The effects may occur both during the construction and operation phase.

6.10.6 Assessment of the impact during the construction phase

During the construction phase, that is expected to last eight years, an area of 72 ha will be designated as a worksite and used during the construction work; of which 45 ha is low lying areas behind the dike (see the section 6.2 Landscape and soil).

The land use will not affect the town or the holiday cottage areas but only a number of houses in the open countryside. This specifically concerns

- Two detached single-family homes on Humlegårdsvej and Færgevej
- A farmhouse on Gl. Badevej
- Four buildings for commercial production or offices, trade, storage on Gl. Badevej
- Three buildings for sporting activities or other leisure activities on Gl. Badevej.

The expropriation of these properties and buildings is considered to have no significant consequences for the population as a whole, while having a large impact for the individual affected people.

In relation to the construction phase, neither the town nor the holiday cottage areas will be separated. In the open countryside, the fragmentation of the areas and subsequent barrier effects will as far as possible be compensated by alternative routes and by establishing new roads and paths across the construction.

Traffic as well as noise and air pollution levels will increase on the approach roads to the work and construction area in Rødbyhavn. This may be inconvenient at the local scale in periods but it unlikely to pose a significant impact on the population at large.

The population during the construction will increase by up to 2,000 workers who will, to some extent, make use the nearby towns and areas during their leisure time. This will lead to increased congestion and traffic in the area but also an increased turnover at local businesses. The extent of this impact is not known.

The holiday cottage area Hyldtofte Østersøbad may be periodically affected by noise, dust and visual disturbances when filling up the work site west of the cottage area. Generally the area west of Hyldtofte Østerbad will be characterised by the industrial area during the construction period, but it is assumed that the holiday cottage area will primarily be affected by the land fill, located near the area. The
land fill is carried out early in the construction phase; resulting in a shorter and temporary impact. Furthermore, the impact is expected only to be visual because the current noise levels will not be exceeded.

During the establishment of the land fill west of Rødbyhavn, the holiday cottage areas Bredfjord and Lalandia may also experience an equivalent impact, and likewise the current noise thresholds will not be exceeded.

The noise from the slurry treatment plant and from the prefabrication of the tunnel segments will not exceed the current noise thresholds, because noise barriers will be installed around the affected areas. Here too, the impact will be purely visual.

However, the piling of masts for the railway line will cause noise pollution for the housing located along the railway. To reduce noise from piling, pre-boring orramming can be used.

Finally, the residences along the motorway will experience noise during construction. Because the activities will primarily take place during the daytime and that the activities will continuously be relocated, this impact is assessed as not being significant.

The other residential areas will not be significantly affected by noise because the various activities, including the establishment of the working harbours, will primarily take place during the daytime, when the permissible noise threshold for the construction work is 70 dB. If construction work takes place at night, the noise threshold is 40 dB.

Since there are relatively many older residents and unemployed residents in the Municipality of Lolland, there are relatively many at home during the daytime who will experience noise that exceeds the thresholds applicable to construction work at night. One way to reduce the discomfort is to give the residents detailed information about the construction work and in this way give them the option of moving away to other sites during those periods when the noise level is at its most disruptive.

Establishing the land fill will prevent access for Rødbyhavn residents to a section of eight kilometres of the coast east and west of Rødbyhavn during the eight years of construction work. This is assessed as a significant but temporary consequence for residential areas and for the holiday cottage areas in Rødbyhavn and its environs.

The beach west of Rødbyhavn and at Lalandia will be closed throughout the construction period. In total, 3.5 km of beach will be lost. As compensation, a new beach will be established at the end of the land fill (west of Lalandia) within the first two years. Throughout the entire construction period, the resident population and the areas' visitors will be able to use the beach at Hyldtofte Østerbad.

When the bored tunnel is constructed, the work area east of Rødbyhavn will be re-established. Furthermore, there will be access to a large new area with the potential
for recreation and experiencing nature if possibly such an area on the reclaimed land area is established.

It has been demonstrated that access and distance to green areas affects the population’s self-assessed health (University of Copenhagen 2011). The shorter the distance to the green areas for the population, the better is their self-assessed health.

The fact that the population’s access to various recreational areas in the study area will be limited during certain periods during the construction phase may have an impact on the populations perceived quality of life and health.

The most important recreational areas and facilities are located along the coast, including bathing beaches, the dike for flood protection with its cycle route and the accessible nature areas behind the dike, the marina in Rødbyhavn, Lalandia and the holiday cottage areas. When the population is asked in this regard, they specifically point out the beach, the nature trails (the old railway line and especially the dike), the go-kart track and Lalandia as the most important areas. See section 6.5 Recreation for an assessment of the consequences for outdoor leisure activities.

6.10.7 Assessment of the impact during the operation phase

There will be no expropriation of areas in the towns and in the holiday cottage area during the operation phase. The area of expropriation during the operation phase will temporarily affect:

› Three detached single-family houses on Færgevej, Strandholmsvej and Ottelundevej, respectively
› Two sheds at the same address on Strandholmsvej.

The expropriation of these properties and buildings is assessed as not entailing any significant consequences for the population as a whole.

In the open countryside, the permanent fragmentation caused by the new motorway and railway will, as much as possible, be compensated by indicating alternative routes and by establishing new roads and paths.

When the link is completed, Rødbyhavn will experience significantly reduced levels of noise and air pollution from vehicles to and from the ferry, including the train. The levels of noise and air pollution will be reduced even further if the ferry operations cease as the ferries are significant sources of noise and air pollution in Rødbyhavn. Overall, this as a positive impact on residential areas and for people's health in Rødbyhavn. However, the ferry operations create life in the town and are seen by many as a benefit rather that a disadvantage.

Noise and air pollution during the operation phase will primarily occur along the motorway and the railway and around the area by the toll plaza and the tunnel portals.
In total, 9–13 residences will experience noise that exceeds the threshold for residences ($L_{den} = 64$ dB) as a consequence of the railway, while 18 residences will experience noise that exceeds the threshold ($L_{den} = 58$ dB) as a consequence of road traffic, given that ferry operations cease. If ferry operations are not discontinued, a total of 46 residences will experience noise that exceeds the threshold as a consequence of road traffic, see section 6.7 Noise and vibrations.

Finally, it is expected that within a radius of 200 m from the tunnel openings air pollution by particulates and nitrogen dioxide will exceed the current thresholds for air quality (see section 6.8 Air quality and local climate). This is unlikely to have significant health consequences for persons passing by the tunnel opening on the path. This reason is that the path will be constructed at some distance from the opening and persons are not expected to stay at the site for longer periods.

Furthermore, an increased concentration of NO$_2$ will occur along the new motorway and a slightly increased concentration of PM$_{10}$ (fine particles) will occur along the railway. This is assessed as having no health-related consequences.

After the tunnel has been constructed, the area that has been used for pre-cast internal structure element storage, tunnel segment storage, separation plant and soil depot will be re-established to its current condition. However, there will be commercial properties that are located in the area which will not be re-established at the same site (see section about the derived socio-economic effects).

### 6.10.8 Mitigation measures

The following mitigation measures have been incorporated in the project to limit the effects on most of the people who live and use the area:

**Construction phase**
- Establishment of temporary paths and roads during the construction phase
- Noise, vibrations and air pollution during construction of the bored tunnel will be reduced as much as possible
- Unnecessary light pollution will be avoided.

**Operation phase**
- The establishment of new paths and roads across the permanent construction.
- Unnecessary light pollution will be avoided.

### 6.10.9 Conclusion

No significant consequences have been identified for the residential areas in relation to the construction and operation of a bored tunnel to the appropriation and fragmentation of the area. However, individual properties will be affected by noise, vibrations and some will be expropriated. During the construction phase, the holiday cottage areas will also experience increased noise and there will be a visual impact. Traffic noise from the new motorway and railway may affect individual detached residences during the operation phase.
The construction work will create up to 2,000 new jobs. Many temporary workers are expected to live next to the factory while others will stay in the nearest residential area. In their leisure time they will seek out nearby attractions, including cinemas, restaurants, recreational facilities and shops.

This is assessed as a significant consequence for the local area, although it may be considered both positive and negative, because it provides greater revenue and more jobs in the local area but leads to greater crowding in the form of more traffic and more people in the area.

The limited access to the coast during the entire construction phase and for a long period after the construction phase may have significant consequences for the population and visitors using the local recreational areas and beaches. This may affect their quality of life and future health.

The population's health is not significantly affected by noise pollution or air pollution during the construction phase. The same applies to the operation phase where the overall effect is expected to be positive with reduced noise and reduced air pollution if the ferry operations are discontinued.

There will be an increased concentration of air pollution around the tunnel openings at a distance of 200 m. However, people will only remain in the area for short periods so their health will not be affected and the impact is not significant.

There will also be an increased level of air pollution along the new motorway and along the railway. This is assessed not having consequences for the population's health because they are not expected to be present beside the motorway and railway for longer periods of time.
6.11 Derived socio-economic effects

The derived socio-economic effects of the project's environmental impact are described in this section. The legal framework and current conditions are not described. Those that may be relevant are found in the sections Population and Material assets.

6.11.1 Method

The derived socio-economic effects include the impact on larger social or commercial groups.

Focus is given to the effects on the following six social or commercial groups:

› Residents in Rødbyhavn (addressed in the section on Population and health and is not further considered here).
› Farming and fishing industry.
› Energy and water supply.
› Industry.
› Trade and transport.
› Tourism.
› Private and public services.

The socio-economic effects for commercial groups can be derived from the following environmental effects:

› Area expropriation and change in land-use.
› Barrier effect and changed accessibility.
› Work accidents and traffic accidents.
› Pollution of water, soil and air.
› Disturbance through noise, light and vibrations.

The effects can occur both during the construction phase and the operation phase.

6.11.2 Existing conditions

Compared to eastern Denmark, Municipality of Lolland has comparatively more residents employed in agriculture and fishery, industry and social institutions. In the last ten years, the growth in employment in Municipality of Lolland has primarily been in service businesses and in social institutions, i.e. in the service sector. In the same period there has been a major decline in employment in industry, energy and water supply sector and in public administration.

In general, the business community in Municipality of Lolland is made up of small and medium size enterprises. The most important sectors are agriculture, industry, building and construction, trade and transport, service, education and social institutions.
The fishing industry is an important sector and is therefore subject to a more detailed study in the section on Commercial fishery. It will not be addressed further here.

Tourism is also an important sector for the area and is regionally important. This is due primarily to Lalandia with 700,000 overnight stays annually. Lalandia's business activity is equivalent to almost 80% of the total activity in Municipality of Lolland.

The educational level is lower in Municipality of Lolland than the average for eastern Denmark and the average income is significantly lower. The Municipality of Lolland has an unemployment rate of 4.3%, which is almost one percentage point higher than in eastern Denmark.

6.11.3 Assessment of derived effects

The most significant consequences of the immersed tunnel for the agriculture and the fishery will arise from the expropriation of area, change in use of area and barrier effects.

The establishment of the motorway, railway, toll plaza and the construction work site will cause loss of farmland east of Rødbyhavn. However, the consequences are assessed as not being significant because it is only a small fraction of the total area of farmland on Lolland.

During operation the traffic load on the motorway will increase, leading to increased pollution in the area, affecting farming. The increased air pollution is expected to only affect the farmland located close to the motorway. The impact is assessed as not having any significant consequences for agriculture as a whole.

Regarding the energy and water supply sector, the construction phase will lead to an increase in demand for electricity and drinking water. The reasons are partly that the slurry treatment plant, the boring machines and pumps that will be used to bore the three tunnels require a lot of electricity and partly because the total number of residents in the area will increase significantly during the construction phase as a consequence of the presence of up to 2,000 workers.

The project's environmental impact is not expected to have any significant derived socio-economic consequences for the industry. However, companies may potentially be affected by reduced accessibility during the construction phase as a consequence of increased traffic in the area.

Any derived socio-economic consequences for trade and transport are also expected to be the result of reduced accessibility during the construction phase. The consequences are not significant. No derived socio-economic consequences are expected during the operation phase for either trade or transport industry.
During the construction and operation phase, tourism may be affected by the lack of access to the coast, including access to the two bathing beaches (the beach west of Rødbyhavn and the beach at Lalandia).

Furthermore, tourists may be discomforted by noise, air pollution and light emission during the various construction processes. Watching the construction progress can also be an attraction. Finally, people employed at the different worksites that are directly related to the tunnel construction and their relations will make use of the available tourist attractions.

On this basis, the consequence for the tourist industry is assessed as being significant during construction and operation. However, it cannot be determined on the present basis if the consequence will be negative or positive. The land fill will have positive consequences for the tourist industry when it becomes accessible after the construction. The impact depends on accessibility, other recreational facilities and the accommodation in the local area.

Finally, it may be expected that during the construction phase there will be an increased demand for public and private services within the health sector. Experience shows that there is an increased incidence of work-related and traffic-related accidents in major building and construction projects. The reasons for this may include that workers frequently work longer consecutive hours to enjoy longer periods of time away from work. The long working days may lead to more work-related and traffic-related accidents because people are tired. Some workers will work under a very large pressure in connection with the boring and this may also lead to health-related consequences. However, none of these derived consequences are assessed as being essential for the profession. There is not expected to be similarly derived socio-economic effects for the public and private service sector after the tunnel is opened.

6.11.4 Mitigation measures
To limit as much as possible the negative derived socio-economic effects of the impact, following mitigation measures have been incorporated into the project:

Construction phase
- Special attention will be paid to avoiding work-related and accident-related accidents in connection with the construction phase.
- Special attention will be paid to minimising hazards related to working under high pressure, which will be the case with the boring of the tunnels.

6.11.5 Conclusion
The tourist industry is the only social or commercial group that may experience significant derived socio-economic effects in relation to the bored tunnel.
During the construction phase and the operation phase, there may be a fall in the total number of tourists because of the environmental consequences, including the lack of access to the coast and local bathing beaches.

However, number of tourists may increase if the construction works becomes an attraction and because employees in the different worksites directly related to the tunnel construction and their families will make use of available tourist attractions.

After the construction, the total number of tourists may increase as a consequence of more people travelling between Central, Southern and Northern Europe and locally because of the new recreational options available on the landfill.
6.12 Decommissioning

No specific plans have been made for the decommissioning of the fixed link or with what it would be replaced at the end of its design lifetime of 120 years. For the EIA it is assumed that the decommissioning of the land works on Lolland would involve:

› The land reclamation at the coast would be left in place.
› The motorway and railway would be removed or rerouted.
› The toll plaza, customs and administration facilities would be removed if the link is discontinued or retained if a new link is established.
› The tunnel ramps would be filled and the land surface generally restored or reshaped in some way.

The decommissioning works would cause temporary on noise and local air quality and some general disturbance in the area due to traffic etc. Such impacts are not expected to be worse than those during the construction phase.

It is not expected that there will be any adverse impacts on landscape, soil, flora and fauna, cultural heritage, archaeology, surface water, groundwater, material assets and derived socio-economic aspects. Flora and fauna species are expected to re-colonise the restored areas. The streams and drainage canals will remain and still function as required.

The decommissioning is expected to have a positive effect on recreation possibilities if some barriers to movement are removed and since there may be less noise and pollution from traffic.
7 Assessment of Impacts on Fehmarn

7.1 Introduction

This chapter addresses the impacts of the bored tunnel alternative on the terrestrial environment on Fehmarn.

The study area on Fehmarn is shown in Figure 7.1 along with the names of the towns and the geographical features on the island. The study area covers 31 km$^2$ east, west and inland from Puttgarden. It covers all the area of possible link alignments and where impacts could potentially occur.

This chapter is structured in accordance with normal practice for EIAs in Germany and therefore differs from the structure in the previous chapter on Lolland.

7.1.1 Environmental factors

The terrestrial environment is sub-divided into the environmental factors as defined in the EIA Directive from EU. Each factor is addressed in a separate section in this chapter.

- Population and health (noise, visual and sensory impacts, air pollution, fragmentation and barrier effects, light, vibrations and recreation)
- Soil
- Water
- Flora
- Fauna
- Biodiversity
- Landscape
- Cultural heritage and material assets
- Local climate and air quality
- The interaction among the above factors
7.1.2 German EIA

The German EIA of the Fehmarnbelt Fixed Link forms the basis for the present chapter. The German EIA is called the Umweltverträglichkeitsstudie (UVS) and contains the baseline studies and the impact assessment study. In order to correspond to the Danish and international EIA practice it is necessary to include also the Landschaftspflegerischer Begleitplan (LBP), the landscape management plan where the mitigation and compensation measures are described.

The UVS is a detailed assessment of the various alternative solutions for the project, in this case the immersed tunnel, the cable stayed bridge and the bored tunnel. It includes both the baseline and the impact assessment. In the German system there are no background reports so that the UVS must contain all the details which are found in the background reports produced by the environmental consultants (see Chapter 2).

The UVS carries the impact assessment through to the definition of the “severity of loss” and “severity of impairment” for each factor and component (see Assessment...
methodology below). It then compares the impacts of the various solutions and concludes with a ranking of the various solutions.

The environmental ranking is combined with considerations of economy, technical feasibility and risk to make the recommendation of the preferred solution.

The LBP considers only the preferred solution, the immersed tunnel. It, among other things, defines the mitigation and compensation measures. The environmental law in Germany requires that all unavoidable impacts on nature shall be compensated where possible. When compensation measures cannot be implemented, the law gives the possibility for payment of monetary compensation by the project owner. The monetary compensation can be used in other projects where the impacts on natural values or nature types are different to those of the fixed link project.

In the German methodology the first objective is to avoid significant impact by mitigation. Then, on plan approval level (LBP) only the remaining significant impacts (impairments) have to be addressed and only the significant impacts have to be compensated. The assumption in the German methodology is that after implementation of the mitigation and compensation measures no significant impact will remain.

The present chapter draws heavily on the UVS, especially for the sections on assessment of impacts. The LBP cannot be used directly since it only deals with the immersed tunnel. However, because of the many similarities between the immersed and bored tunnels it is possible use the mitigation and compensation measures from the LBP, adjusted as appropriate for the bored tunnel.

7.1.3 Assessment methodology

The assessment methodology applied in the UVS corresponds in general with that described in the Scoping Report (Femern and LBV-SH-Lübeck 2010, section 6.4.2) and also with the methodology used for the marine environment (chapter 5) and on Lolland (chapter 6). It is however adjusted to correspond with German procedures as described above. See the UVS for the full details of the assessment methodology.

This report describes the most important steps in the full German methodology supplemented with an assessment of the significance of the impacts. As described above, German practice does not include an assessment of the overall environmental significance of the impacts. However, in order to conform with Danish and international practice and with the assessments for the marine area and Lolland, the overall significance is addressed in this chapter.

The two principal types of impact are the same, viz. “loss” and “impairment”, see section 5.1. The flow charts with the procedure for assessment of these two types of impact are shown in Figure 7.2 and Figure 7.3.
Loss
The first step is, as usual, to identify and calculate the magnitude of the project pressures which potentially have impacts on the environment. For example, one pressure magnitude is the area and location of the construction work site, another is the area needed for the motorway and railway corridors.

The second step is to calculate the magnitude of the impact as a loss of a component. For example, a loss could be the number of buildings which lie within the motorway and railway corridors and have to be permanently removed, or the area of farmland to be bought up or rented in agreement with the landowners for the construction work site.

The third step is to classify the severity of loss on a relative scale of “very high”, “high”, “medium” and “minor”. The severity of loss is determined by combining the magnitude of the impact with the importance of the component.

Importance expresses the value of the component for the ecosystem or the society. It can also express the protection status of the component, e.g. a species on the red list or a protected biotype. Importance is a relative concept ranging from very high to minor and is classified through a set of pre-defined criteria. See the UVS for details of the criteria.

The fourth step is to classify the significance of impact by subjectively assessing the residual impacts after mitigation and compensation and comparing the loss with the total area or population of the component in a representative area.

Figure 7.2 Procedure used in the present report for assessment of the loss type of impacts of the bored tunnel project on Fehmarn. The procedure differs from that used in the German UVS and LBP.
An LBP has not been written for the bored tunnel since it is not the preferred solution for the fixed link. Therefore there is no background report where the mitigation and compensation measures on Fehmarn are described for the bored tunnel. However, due to the many similarities of the impacts of the immersed and bored tunnels, it is possible to propose the “in kind” compensation measures for the bored tunnel on the basis of those for the immersed tunnel. “In kind” compensation means compensating for, e.g. lost nature by establishing similar nature areas in the immediate vicinity of the project.

However, without an LBP for the bored tunnel it is neither possible to list the quantities of certain “in kind” compensation measures required nor the requirements for monetary compensation.

Impairment

Similar to the loss procedure, the first step is the identification of the pressures and calculation of the magnitude of pressure.

The second step is to calculate the magnitude of the impact as an impairment of a component e.g., the number of birds displaced by noise from the construction site.

The third step is the classification of the severity of impairment for each impacted component on a relative scale from very high to minor. The severity of impairment is derived from the magnitude of impact and the sensitivity of the component to the pressure being considered.

Sensitivity expresses the reaction of a component to a given magnitude of pressure, e.g. the reaction of people, birds or animals to a given noise level. A predefined set of criteria defines the level of sensitivity from very high to minor. See the UVS for details.

The fourth step is to classify the significance of impact. This is done by subjectively assessing the residual impacts after mitigation and “in kind” compensation and comparing the impacts with some physical and biological factors such as:

- **Natural variability**, e.g. the variation of the population of a particular bird or animal species due to the changing meteorological and climatic conditions from year to year. For example, the displacement of a very small percentage of the roe deer population on Fehmarn compared with the natural variability would be an insignificant impact.

- **Recovery time**, e.g. if the population of a bird or animal species recovers within one season or requires several years, this will affect the classification of the significance of impact.

- **Total area/population/biomass/availability etc. of the component in the study area or in the region**. The impairment of a component is compared with the total amount of that component in the study area or the region. For example, if 100 birds of a particular species are displaced due to noise and the
biogeographic population is one million, then the impact could be insignificant. On the other hand, if the bird is on the red list, the impact could be significant.

Regarding compensation, see the section above on assessment of “loss”.

![Diagram](image)

**Figure 7.3** Procedure used in the present report for assessment of the impairment type of impact of the bored tunnel project on Fehmarn. The procedure differs from that used in the German UVS and LBP.

**Presentation**

German practice is to present the assessment of impacts principally in the form of tables which combine the magnitudes of impact, importance or sensitivity, severity of loss or impairment and explanatory text.

### 7.1.4 Legal background

The German regional planning which form the background for the environmental studies on Fehmarn are:

- Landschaftsprogramm Schleswig-Holstein (1999) (Schleswig-Holstein Landscape’s Programme)
- Generalplan Küstenschutz Schleswig-Holstein (2001) (Schleswig-Holstein Coastal Protection Plan)

The following local plans for Fehmarn have also been used in the study:
Flächennutzungsplan der Stadt Fehmarn (1973-2009) (Fehmarn preparatory land-use plan)
Bebauungspläne der Stadt Fehmarn (1972-2009) (binding land-use plans)
Landschaftsplan der Stadt Fehmarn (2008) (Fehmarn Landscape Plan)

These plans for Fehmarn specify details of planned land-use including areas which can be developed for residential, commercial and industrial purposes. They also include detailed plans for protection of nature and landscape management.

Figure 7.4 shows the most important areas covered by the plans for the development of Fehmarn. Most of the areas important for plants and animals are found at the north coast and in the south-east and south-west corners of Fehmarn where there is least human activity.

Figure 7.4 Most important protected areas, land-uses as well as other areas covered by local and regional plans (Digitale Topografische Karte 1:25.000 – Permission of Landesvermessungsamt Schleswig-Holstein 12.01.2009, Permission Number S 20/09).
7.2 Population and health

This section addresses the impacts of the bored tunnel project on the population and health of the people on Fehmarn.

The environmental components included under the factor “population and health” are:

› Loss of residential and settlement areas and residential surroundings
› Noise
› Visual and sensory impacts
› Air pollution
› Fragmentation and barrier effects
› Light
› Vibrations
› Recreation

The Fehmarn Municipality has a population of approximately 13,000 of which there are about 6,650 in Burg, 2,485 in Landkirchen, 2,170 in Bannesdorf and 1,780 in Westfehmarn. The built-up areas consist mainly of villages spread out in the open landscape with individual farms. Only Burg has the characteristics of a town. Villages such as Hinrichsdorf, Todendorf and Presen consist of a mixture of individual homes and farm buildings while Burg, Puttgarden, Landkirchen, Marienleuchte and Bannesdorf also have normal residential areas.

Marienleuchte also has mixed-use areas (residential and commercial), a summer house area and military barracks. The local industry is concentrated mainly in Burg, the southwest part of Puttgarden and in the southern part of Bannesdorf.

The public institutions are found mainly in Burg and in the study area there are a school, a health facility and several institutions including kindergardens and administration buildings. A school with sports ground and child care centre is found at the southern edge of Puttgarden. There is a church in Bannesdorf.

The largest, planted green areas, sports grounds parks and gardens are in Puttgarden, Bannesdorf and Burg.

Tourism is an important source of income on Fehmarn. In addition to guests staying overnight there are many day trippers from the rest of Germany and from Scandinavia. Hotels, summer houses and holiday apartments take care of most of the guests staying overnight. In 2009 there were 800,000 – 900,000 guests staying overnight.

7.2.1 Project pressures and potential impacts

The potential impacts on population and health on Fehmarn and their causes are listed below:

› Loss of residential areas and settlement areas as well as residential surroundings due to expropriation of land.
Impairment of residential areas and settlement areas as well as residential surroundings due to noise.
Visual and sensory impact on areas of importance for living.
Impairment of residential and settlement areas as well as residential surroundings due to air pollution.
Impairment of residential and settlement areas as well as residential surroundings due to light emissions.
Impairment of residential and settlement areas as well as residential surroundings due to vibrations.
Fragmentation of and barrier effects in residential and settlement areas as well as residential surroundings due to motorway and railway.
Loss of recreation areas due to expropriation of land.
Impairment of recreation areas due to noise.
Visual and sensory impact on recreation areas.
Impairment of recreation areas due to air pollution.
Impairment of recreation areas due to light emissions.
Impairment of recreation areas due to vibrations.
Fragmentation of and barrier effects in recreation areas due to motorway and railway.

Most of the potential impacts listed above are assessed during both the construction phase and the operation phase.

7.2.2 Importance of areas for the population
The distribution of the population within the study area and the land-use is described above.

The existing conditions for the population in the study area are expressed through the importance classification. The importance of the residential areas and their surroundings is classified on a four level scale as shown in Figure 7.5. The classification is based on laws and the local development plans and includes factors such as land-use, use for recreation and the length of time people use the areas.

The permanent residential areas are classified as of very high importance and include Puttgarden, Marienleuchte, Bannesdorf, Presen, Todendorf and Johannisberg (see Figure 7.5). Facilities with social functions, e.g. schools, kindergartens, churches and health facilities, especially in Bannesdorf and partly in Puttgarden, also have very high importance due to their essential functions for the local society.

Camping grounds and summer houses have high importance due to their temporary residential function. Green areas such as sports grounds, play grounds, gardens and parks near residential areas have high importance due to their recreational functions.

The other areas within 500 m of residential areas and which are not crossed by roads or other dominating disturbances are of medium importance since they are also used by the people. There are such green areas in Burg, Puttgarden and
Bannesdorf. Similarly, the area around the ferry harbour is only of medium importance since people mostly travel through the area and do not reside there.

Commercial areas such as industry parks, business areas and infrastructure are of minor importance since they are work places rather than residential areas.

Figure 7.5 Importance map for the population in the study area
7.2.3 Loss of residential and settlement areas and residential surroundings

The losses and explanatory text are given in Table 7.1 and the areas affected are shown in Figure 7.6.

Table 7.1 Loss of residential and settlement areas as well as residential surroundings

<table>
<thead>
<tr>
<th>Importance</th>
<th>Construction related</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Impact</td>
<td>Impact</td>
</tr>
<tr>
<td>Very high</td>
<td>0.25 ha</td>
<td>0.08 ha</td>
</tr>
<tr>
<td></td>
<td>***** Temporary loss at the edge of green areas in the residential district of Marienleuchte during the construction phase</td>
<td>***** Permanent loss of a partial area of an individual farm near Puttgarden</td>
</tr>
<tr>
<td>High</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>Medium</td>
<td>37.78 ha</td>
<td>3.50 ha</td>
</tr>
</tbody>
</table>
|            | **- Temporary loss of areas of residential surroundings due to construction, especially in Marienleuchte, but also in Puttgarden | **- Permanent loss of residential surroundings near Puttgarden. 
**- Permanent loss of residential surroundings near Marienleuchte due to a new agricultural road to Marienleuchte |
| Minor      | 0.00 ha              | 0.00 ha           |
| Total      | 38.03 ha             | 3.57 ha           |

Qualitative description

- Due to the new agricultural road to Marienleuchte, there will be temporary and permanent loss of small areas at the edge of the residential areas.
- Large parts of the residential surroundings of Marienleuchte will be used for construction site facilities.
- There will be losses of small areas of very high importance.

Severity of loss

<table>
<thead>
<tr>
<th>*** Very high</th>
<th>*** High</th>
<th>** Medium</th>
<th>• Minor</th>
</tr>
</thead>
</table>
Compensation
The owners of the land and property that will be expropriated by the project, either
temporarily or permanently, will be compensated by Femern A/S. The areas
temporarily affected during construction will be re-established to original condition
at the end of construction. They will be returned to their original land-use where
relevant.
Conclusion
The compensation measures will ensure that there will be no residual impacts from the loss of residential and related areas.

7.2.4 Noise impacts on residential and settlement areas and residential surroundings
This section concerns the impairment of residential and settlement areas and residential surroundings due to noise during both the construction and operation phases of the bored tunnel project.

Methodology
The determination of the impairment due to noise was based on the total noise level at the sensitive receptors consisting of street, motorway and railway noise for the entire road and rail network and on 100% of the car traffic being directed across the Fehmarnbelt Fixed Link.

The impact assessment distinguishes between the six types of land-use as different noise levels apply as limit or guideline values. The maximum allowable noise levels from the 16th Federal Emission Control Ordinance (BImSchV) are applied in impact zones 1, 2 and 3, while the guideline values of DIN 18005 are considered for impact zones 4, 5 and 6.

The German noise standards are shown in Table 7.2.

The bored tunnel has no zone 5 in the study area and therefore no assessment of impacts in that zone.

Table 7.2 German noise standards

<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
<th>Noise limit and guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Residential areas</td>
<td>49 dB(A)</td>
</tr>
<tr>
<td>2</td>
<td>Mixed-use areas incl. hotels and individual farms</td>
<td>54 dB(A) (day)</td>
</tr>
<tr>
<td>3</td>
<td>Sensitive shared community facilities, e.g. churches, schools</td>
<td>57 dB(A) (day)</td>
</tr>
<tr>
<td>4</td>
<td>Residential-only areas</td>
<td>40 dB(A) (night)</td>
</tr>
<tr>
<td>5</td>
<td>Residential areas and general residential districts</td>
<td>45 dB(A) (night)</td>
</tr>
<tr>
<td>6</td>
<td>Villages and mixed-use areas</td>
<td>50 dB(A) (night)</td>
</tr>
</tbody>
</table>

The quantitative assessment was performed with consideration of the 0-alternative forecast, i.e. only residential and settlement areas beyond the 0-alternative forecast were quantitatively assessed.

It is noted that when limit or guideline values are exceeded in the assessment below, this is nearly exclusively due to railway noise as it is the greater noise
source. With one exception (a small part of mixed-use area in Puttgarden), the traffic noise from the road does not result in exceedence of the limit value.

The intensity of noise at the sources was taken from well established guidelines (Richtlinien für den Lärmschutz an Straßen, RLS-90 and Richtlinie zur Berechnung der Schallemissionen von Schienenwegen, SCHALL 03) and the modelling of noise levels was carried out with the software CADNA/A. The calculation of sound propagation is based on the two guidelines mentioned above. For the model of propagation different factors are considered:

› The existing and planned topography, especially the planned excavations and embankments of the footprints.

› The screening due to existing and planned developments and the reflection from buildings.

› The height of sensitive receptors in existing buildings.

Existing noise sources
The principal existing noise sources around Puttgarden and in the area to the east are the railway, the motorway, other roads, the ferries, a few smaller industries and the windmill park. The contribution of the ferries to the noise levels occurs during the period from arrival to departure.

0-alternative
The 0-alternative is taken to be the situation in the year 2025. The forecasted traffic in 2025 assuming that there is no fixed link is the basis for the modelling of the noise levels.

The noise levels for the combined rail and road traffic in 2025 is shown in Figure 7.7.
The noise limits and guideline values in the 0-alternative are only exceeded at a few buildings in Puttgarden and not anywhere else in the rest of the study area. The legal limits are exceeded at two buildings at the intersection of Strandweg and Fährhafenstrasse. The guideline values are exceeded at Hotel Dania in Puttgarden, at an individual farm east of Puttgarden and a few residences along Dorfstrasse also in Puttgarden.

Impairment of residential and settlement areas due to construction-related noise

The construction site for the bored tunnel contains a range of noise sources. The tunnel boring machines (TBM) require permanent power supply plus cooling and ventilation. Several cement plants and a separator will be used. The material excavated from the tunnel is a slurry and will be pumped through pipes to the separators on shore where the soil is separated from the slurry for subsequent reuse. The slurry separation plant, the electrical power plant (moored on a barge offshore) and the cooling and ventilation plants will operate on a 24/7 basis.

For other operations on the construction site, it was assumed that the noise-intensive construction times will be largely limited to the daytime hours between 7 a.m. and 8 p.m., in accordance with the German guideline for management of construction noise (Die allgemeine Verwaltungsvorschrift zum Schutz gegen Baulärm, or AVV Baulärm). By contrast, it is to be assumed that during the night time (8 p.m. to 7 a.m.) the construction activities will be considerably less busy. The present case was based on the operation of a few pieces of construction equipment for cement work as well as a cement plant during the night time.
The AVV Baulärm construction noise guidelines are listed in Table 7.3.

**Table 7.3** German guideline limits for noise from construction sites (AVV Baulärm)

<table>
<thead>
<tr>
<th>Land-use</th>
<th>Noise guideline values (dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day</td>
</tr>
<tr>
<td>Commercial and industrial areas</td>
<td>70</td>
</tr>
<tr>
<td>Dominantly commercial and industrial areas</td>
<td>65</td>
</tr>
<tr>
<td>Mixed-use areas</td>
<td>60</td>
</tr>
<tr>
<td>Dominantly residential areas</td>
<td>55</td>
</tr>
<tr>
<td>Residential-only areas</td>
<td>50</td>
</tr>
<tr>
<td>Social institutions (e.g. schools)</td>
<td>45</td>
</tr>
<tr>
<td>Recreation areas</td>
<td>49</td>
</tr>
</tbody>
</table>

All land-use types have very high sensitivities towards construction related noise. Consequently, any impairment will have a very high severity. Three construction phase scenarios are examined below and compared with one another.

**Scenario 1 (daytime operation without the use of pile drivers):**
Generally speaking, if no pile drivers are employed during the daytime operation, the noise levels will be within the requirements of AVV Baulärm. The noise guideline values will not be exceeded.

**Scenario 2 (consisting of daytime operation during the setup phase and daytime operation of the construction site):**
During the setup phase of the construction site, it is to be expected that the use of pile drivers in the construction of the work harbour will cause considerable exceedence of the noise limit and guideline values at buildings in Puttgarden and Marienleuchte. Especially in Marienleuchte, it is not impossible that limits will be exceeded by >5 dB(A) in a residential-only area. In addition, without mitigation measures, the noise guideline value of 55 dB(A) will be exceeded by more than 5 dB(A) during the day in a general residential area in Marienleuchte.

If pile drivers are used in construction, this may result in very high impairments near the construction work, especially at the planned elevated crossing in the area of the individual farm near Puttgarden. Without any mitigation measures, the noise guideline value of 60 dB(A) will be exceeded by more than 5 dB(A).

**Scenario 3 (night-time construction from 8 p.m. to 7 a.m.):**
The noise guidelines values will be exceeded by up to 4 dB(A) during the night in the area of Marienleuchte. According to AVV Baulärm no measures for mitigating the noise will be required because the noise level exceedence is less than the permitted 5 dB(A).

**Conclusion**
The pile-driving work will cause impairments at the sites of Marienleuchte and Puttgarden, including the vicinity of an individual farm at the outskirts of
Puttgarden. The area-specific noise guideline values will be considerably exceeded. The values will also be exceeded by up to 4 dB(A) during the night time in Marienleuchte.

Implementation of a number of mitigation measures will reduce the impacts from construction noise. During the construction phase it is suggested to reduce the pile driving to 2.5 hours a day. Considering this timing the area-specific noise guideline values will not be exceeded over the permissible value of 5 dB(A). During the installation of the construction sites, especially for the sheet pilings in the work harbour, this mitigation measure probably will not be enough to satisfy the guideline value in Marienleuchte. It is suggested to use low-noise procedure techniques for installation of sheet piling. For the area of concrete production it is suggested to reduce the operation to 2.5 hours at night if possible.

Impairment of residential and settlement areas due to noise in the operation phase

The noise levels in the residential and settlement areas during the operation phase of the fixed link were assessed for the combination of the motorway and railway traffic along with the traffic on the access roads in the hinterland, the extension of the railway and the B207. However, ferry operation was not included in the results presented here. Noise modelling was also carried out for the situation where half the traffic uses the bored tunnel and the other half uses the ferries (i.e. continued ferry operation). Refer to Lairm Consult (2012) for the results.

The noise levels for the combined road and rail traffic are shown in Figure 7.8 for the immersed tunnel solution and will be quite similar for the bored tunnel alternative.
Figure 7.8 Noise from road and rail traffic in the operation phase (immersed tunnel)

The results of the assessment of noise impact are given in the following tables and figures (Table 7.4 to Table 7.8 and Figure 7.10 to Figure 7.13)
Table 7.4  **Bored tunnel: impairments due to noise in Zone 1, residential areas**

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>Operation related: 1.30 ha (significant impairment of living function)</td>
</tr>
<tr>
<td></td>
<td>Exceedance of the noise limit of 49 dB(A) by 1 dB(A):</td>
</tr>
<tr>
<td></td>
<td>- Partial areas of Bannesdorf (1.3 ha) - they are only affected because the hinterland</td>
</tr>
<tr>
<td></td>
<td>infrastructure (extension of the railway/B207) is taken into account</td>
</tr>
<tr>
<td>High, Medium, Minor</td>
<td>- Not affected</td>
</tr>
<tr>
<td>Total</td>
<td>1.30 ha</td>
</tr>
</tbody>
</table>

**Qualitative description**

- The bored tunnel alternative does not result in the noise limit for residential districts being exceeded.
- Due to the construction of the hinterland access roads, very high impairments of residential areas due to noise are to be expected in Bannesdorf.

```
Severity of impairment  | ***** Very high | *** High          | ** Medium        | * Minor
```

**Figure 7.9**  **Bored tunnel: impairments due to noise in Zone 1, residential areas**
### Bored tunnel: impairments due to noise in Zone 2, mixed-use areas including hotels and individual farms

#### Mixed-use areas incl. hotel and individual farms

Impact zone noise 2 [zone > 54 dB(A) (night time)] – Magnitude of pressure: very high

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation related</td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>0.01 ha</td>
</tr>
<tr>
<td></td>
<td>(significant impairment of living function)</td>
</tr>
<tr>
<td>Exceedance of the noise limit of 54 dB(A) by 1–2 dB(A):</td>
<td></td>
</tr>
<tr>
<td>- in a partial area of mixed-use village areas in Puttgarden</td>
<td></td>
</tr>
<tr>
<td>High, Medium, Minor</td>
<td>- Not affected</td>
</tr>
<tr>
<td>Total</td>
<td>0.01 ha</td>
</tr>
</tbody>
</table>

#### Qualitative description
- In the entire impact zone 2, only a very small very sensitive area (0.01 ha) near Puttgarden is exposed to noise.

### Figure 7.10

Bored tunnel: impairments due to noise in Zone 2, mixed-use areas including hotels and individual farms
Table 7.6  Bored tunnel: impairments due to noise in Zone 3, sensitive shared community facilities such as schools, churches etc.

<table>
<thead>
<tr>
<th>Sensitive shared community facilities, e.g. schools, churches etc.</th>
<th>Impact zone noise 3 [zone &gt; 57 dB(A) (daytime)] – Magnitude of pressure: very high</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
<td><strong>Impact</strong></td>
</tr>
<tr>
<td>Operation related</td>
<td>Operation related</td>
</tr>
<tr>
<td>Very high*</td>
<td>0.10 ha</td>
</tr>
<tr>
<td>- Impairment of the school/kindergarten in Puttgarden</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.10 ha</td>
</tr>
<tr>
<td>Qualitative description</td>
<td>The school/kindergarten in Puttgarden is within the impact zone and is a shared community facility of very high sensitivity.</td>
</tr>
<tr>
<td>Severity of impairment</td>
<td>Very high</td>
</tr>
<tr>
<td></td>
<td>****</td>
</tr>
</tbody>
</table>

*Since all shared community facilities have very high sensitivity, no other sensitivity levels are listed.

Figure 7.11  Bored tunnel: impairments due to noise in Zone 3, sensitive shared community facilities such as schools, churches etc.
Table 7.7 Bored tunnel: impairments due to noise in Zone 4, residential areas and residential-only areas

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation related</td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>1.66 ha</td>
</tr>
<tr>
<td></td>
<td>- Exceedance of the guideline value of 40 dB(A) by up to 8 dB(A):</td>
</tr>
<tr>
<td></td>
<td>- a residential-only area in Bannesdorf (1.66 ha) (for information)</td>
</tr>
<tr>
<td>Total</td>
<td>1.66 ha</td>
</tr>
</tbody>
</table>

Qualitative description
- Residential areas of very high sensitivity are mainly impaired in Bannesdorf (for information) because the guideline value is exceeded there. In Bannesdorf a residential-only area is impaired by noise in this impact zone. In Bannesdorf these are new impairments when compared to the zero-alternative forecast.

Severity of impairment
- **** Very high
- *** High
- ** Medium
- * Minor

Figure 7.12 Bored tunnel: impairments due to noise in Zone 4, residential areas and residential-only areas
Table 7.8  Bored tunnel: impairments due to noise in Zone 6, village and mixed-use areas

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
<th>Magnitude of pressure: high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>Exceedance of the guideline value of 50 dB(A) by 1–3 dB(A): sections of mixed-use areas in Puttgarden and a mixed-use area in Bannesdorf (for information)</td>
<td>0.69 ha</td>
</tr>
<tr>
<td>High</td>
<td>Sports ground in the residential surrounding of Puttgarden</td>
<td>0.41 ha</td>
</tr>
<tr>
<td>Medium</td>
<td>Residential surroundings of Bannesdorf (for information) and Puttgarden as well as on the eastern edge of Todendorf (for information)</td>
<td>31.91 ha</td>
</tr>
<tr>
<td>Minor</td>
<td>Not affected</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>33.01 ha</td>
</tr>
</tbody>
</table>

Qualitative description: Within this impact zone, mostly residential surroundings of medium sensitivity as well as mixed-use areas in Puttgarden and Bannesdorf (for information) will be impaired. Noise guideline values are presently exceeded in parts of the areas in Puttgarden and Bannesdorf. The areas in Todendorf (for information) are subject to new impairments.

Severity of impairment: **** Very high, *** High, ** Medium, * Minor

Note: According to § 2 para. 2 16th BlmSchV, structures in undeveloped outskirt areas such as the individual farm near Puttgarden (marienleuchter Weg) or structures at facilities which are not subject to legally binding arrangements must be assessed depending on their need of protection according to § 2 para. 1 cl. 1, 3 and 4 of 16th BlmSchV. Therefore the same noise limit as for mixed-use areas is applied.
As seen in the tables and figures, noise limits are exceeded in smaller area (0.11 ha) of very high sensitivity in Puttgarden and Bannesdorf. An area of 1.3 ha in Bannesdorf will also be affected by the hinterland infrastructure. The night guideline values are exceeded in a small area (2.76 ha) of very high and high sensitivity in Puttgarden and Bannesdorf and in a larger area (31.91 ha) of medium sensitivity in the same two towns plus the eastern edge of Todendorf.

The impacts in Bannesdorf are attributed to the hinterland infrastructure and the calculated results are only a first reference value. The specific calculation for Bannesdorf and corresponding mitigation measures will be determined in the investigation of the hinterland infrastructure.

Mitigation measures
There are no limit values for the residential surroundings and the guideline values can be exceeded without requiring mitigation measures. The exceedence of noise limits and guideline values occurs mainly in the surrounding of residential and settlement areas not in buildings. Therefore mitigation measures are not necessary for residential and settlement areas.

Severity of impairment

<table>
<thead>
<tr>
<th>Severity of Impairment</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
</tr>
</thead>
</table>

Figure 7.13  Bored tunnel: impairments due to noise in Zone 6, village and mixed-use areas
Conclusion
Relative small areas will be impacted significantly due to noise from the operation of the bored tunnel. The largest area affected (32 ha) is of medium sensitivity.

It is assessed that the implementation of the mitigation measures will reduce the impacts to an insignificant level.

7.2.5 Visual and sensory impacts on residential and settlement areas and residential surroundings
The temporary structures during construction and the permanent structures during operation can have visual and sensory impacts.

Method
Visual and sensory impairments are assessed by calculating the residential and settlement areas and the area of their surroundings which are likely to be affected to various degrees by:

› Construction works.
› Structures in the constructions sites (esp. height).
› Permanent structures in the operation phase.

As an example, the visual impairment is assessed according to the following principle: The area which is affected increases with the height of the structures since higher structures can be seen from greater distances. The sensitivity of the population to the impacts uses the four level scale of very high, high, medium and minor. The criteria used to set the sensitivity are almost the same as used for importance. Therefore the importance of areas for the population shown in Figure 7.5 can also be used for sensitivity.

The impacts are considered in zones. Zone 1 is the area within 200 m of the source of disturbance, e.g. the construction site or the completed motorway and railway. Zone 2 is the area from 200 m to 1,500 m.

Visual and sensory impairments during construction and operation
The impacts of the project are principally visual.

In impact zone 2 (altitude of 10–30 m) there will only be construction-related impairments, as the bored tunnel does not exceed a height of 10 m. However, there are some construction site facilities or construction machines with a height of up to 20 m. The impacts in zones 1 and 2 are shown in Table 7.9 and Figure 7.14.

In zone 1 approximately 19 ha and 40 ha are impacted during construction and operation respectively, the great majority of which is residential surroundings of Marienleuchte, Puttgarden and Bannesdorf of medium sensitivity.

In zone 2 there are only impacts during construction. About 104 ha will be impacted, of which 100 ha is residential surroundings of Marienleuchte, Presen and Bannesdorf.
Table 7.9 Bored tunnel: visual and sensory impairments of residential and settlement areas

Visual impact zone 1: width of up to 200 m, depending on altitude of up to 10 m – Magnitude of pressure: high, temporarily medium

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
<th>Construction related</th>
<th>Structure and operation related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td></td>
<td>1.20 ha</td>
<td>0.23 ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Temporary impact on residential areas in Marienleuchte</td>
<td>- Impact on a farm near Puttgarden and on residential construction areas in Marienleuchte to a small extent</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td>0.07 ha</td>
<td>- Not affected</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Temporary impact on green corridors near Marienleuchte</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td>17.70 ha</td>
<td>39.93 ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Temporary impact on residential surroundings near Marienleuchte and at the edge of Puttgarden and Bannesdorf</td>
<td>- Impact on residential surroundings near Puttgarden and Marienleuchte</td>
</tr>
<tr>
<td>Minor</td>
<td></td>
<td>- Not affected</td>
<td>- Not affected</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>18.97 ha</td>
<td>40.16 ha</td>
</tr>
</tbody>
</table>

Qualitative description: Mainly residential surroundings of medium sensitivity will be subject to sensory and visual impact during both construction and operation. To a considerably smaller extent, areas of very high and high sensitivity will also be impacted.

Impact zone 2: width of 200 to 1,500 m, depending on altitude of 10 to 30 m – Magnitude of pressure: minor, with temporary impairment

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction related</td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>3.30 ha</td>
</tr>
<tr>
<td></td>
<td>- Temporary impact on mixed-use village areas in the north of Presen</td>
</tr>
<tr>
<td>High</td>
<td>- Not affected</td>
</tr>
<tr>
<td>Medium</td>
<td>100.44 ha</td>
</tr>
<tr>
<td></td>
<td>- Temporary impact on residential surroundings south of Marienleuchte, west of Presen and north of Bannesdorf</td>
</tr>
<tr>
<td>Minor</td>
<td>- Not affected</td>
</tr>
<tr>
<td>Total</td>
<td>103.74 ha</td>
</tr>
</tbody>
</table>

Qualitative description: Only residential and settlement areas east of the railway track will be subject to sensory and visual impact during the construction phase. Essentially, residential surroundings of medium sensitivity will be impaired, but also a mixed-use village area in Presen.
Mitigation and compensation measures

The following mitigation measures will be implemented to reduce the visual impacts:

- Construction sites will be re-established at the completion of the construction phase.
Trees and bushes will be planted along various sections of the new motorway and railway to screen the view of the traffic. Grass will be planted on embankments and in the road and rail corridors.

In the sense of multifunctional compensation, the mitigation and compensation measures to be implemented for fauna and flora (see sections 7.5 and 7.6 below) are considered to also compensate for the visual and sensory impairments of residential and settlement areas. Further mitigation and compensation is not necessary.

Conclusion

The visual aesthetics of a total area of about 120 ha will be affected temporarily by the construction activities and there is little that can be done to directly mitigate the impacts.

The impacts during the operation phase will be mitigated by planting of trees, bushes and grass and further compensation is not necessary.

7.2.6 Air quality impacts on residential and settlement areas and residential surroundings

There are only a few sources of air pollution on Fehmarn and the local air quality is little affected by the local sources such as the ferries and road traffic. The combination of a flat landscape, the wind conditions and proximity to the sea gives a rapid refreshment of the air masses over the island. The importance of the air quality and local climate is assessed to be “special” for the whole area (on a two level scale of “special” and “general”) because the present level of pollution is low and it is not possible to distinguish different conditions in different areas.

Good air quality is important for the population’s well-being and health and also for plant and animal life.

Method

Reference is made to section 6.8 Air and climate on Lolland for a description of the procedure, model and standards for the air quality study. The German standards are defined in 39th Verordnung zum Bundesemissionsschutzgesetz and the statutory order Technische Anleitung Luft.

The pollutants nitrogen dioxide (NO₂), sulphur dioxide (SO₂), suspended particulate matter (PM₁₀), particulate matter (PM₂.₅) and benzene were investigated.

The additional pollution is calculated as the difference between the forecasted air quality and the existing air quality.

The impacts are considered in zones. Zone 1 is the area within which 90 to 100% of the respective air quality standard is reached. Zone 2 is the area within which 50 to 90% of the respective air quality standard is reached.
Existing background air quality
The background air quality is based on measurements from a measuring station in Schleswig-Holstein. On Fehmarn there is only measured data for ozone available so the measured data from an representative station in Bornhöved were used.

The existing air quality conditions are:

- NO₂: 12.1 µg/m³
- SO₂: 3 µg/m³
- PM₁₀: 18 µg/m³
- PM₂.₅: 16 µg/m³
- Benzene: 1 µg/m³

0-alternative
The 0-alternative is defined as the case in 2025 without the fixed link. Even although the traffic intensity will increase, the stricter requirements to the quality of vehicle exhaust gases will reduce the impact to some degree. It is therefore assessed that the air quality in the 0-alternative will be more-or-less the same as today.

Project pressures and potential impacts
The project pressures and potential impacts on Fehmarn are the same as those described for Lolland, see section 6.8.7.

Only the scenario without ferries has been considered on Fehmarn.

Assessment of impacts on air quality during construction
A qualitative assessment of the impacts of the construction phase on air quality has been made. The impacts can come from the works on the construction sites, vessels at sea delivering and removing materials, the floating power plant and construction traffic.

It is expected that 50 to 150 trucks per day will be involved in construction and will mainly use the main road B207 and the ring road K49. The largest part of the construction materials will be delivered by ship.

It is assessed that, during construction, there will not be any exceedence of the air quality standards in sensitive areas due to the rapid refreshment of the air by the prevailing wind, the large area over which the pollution sources are spread and the distance from permanent residential areas, see Table 7.10 and Figure 7.15.

Assessment of impacts on air quality during operation
Dispersion modelling was carried out for the operation phase of the bored tunnel (Lairm 2012). The pollution sources included in the calculations were the road and rail traffic.

The results are shown in Table 7.10 and Figure 7.15.
### Table 7.10  Bored tunnel: impairment of air quality of residential and settlement areas as well as residential surroundings

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction related</td>
<td></td>
</tr>
<tr>
<td>Very high to minor</td>
<td>Due to the good supply of fresh air in the area of the construction site, the large distance between route and residential area, and the small number of construction machines, no increase in the emission of pollutants is to be expected during the construction phase which is relevant for the assessment.</td>
</tr>
</tbody>
</table>

#### Impact zone 1: 90 to 100% of the respective air quality standard (Magnitude of pressure: high)

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation related</td>
<td></td>
</tr>
<tr>
<td>Very high to minor</td>
<td>- Not affected, as impact zone 1 does not include any permanently built-up areas where the standards for PM$<em>{10}$, PM$</em>{2.5}$ and NO$_2$ apply. In the immediate vicinity of the tunnel portal, 90–100 % of the standards for these pollutants are exceeded, especially particulate matter (up to 100 $\mu$g/m$^3$).</td>
</tr>
</tbody>
</table>

#### Impact zone 2: 50 to 90% of the respective air quality standard (Magnitude of pressure: medium)

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation related</td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>Not affected</td>
</tr>
<tr>
<td>High</td>
<td>Not affected</td>
</tr>
<tr>
<td>Medium</td>
<td>Impairment of residential surroundings west of Marienleuchte in the vicinity of the tunnel portal due to NO$<em>2$, PM$</em>{1.5}$ and PM$<em>{10}$. This means an additional pollution by NO$<em>2$ of 6–8 $\mu$g/m$^3$, by PM$</em>{2.5}$ of 1 $\mu$g/m$^3$ and by PM$</em>{10}$ of 2 $\mu$g/m$^3$. Impairment of residential surroundings south of Puttgarden by PM$<em>{10}$ with an additional pollution by PM$</em>{10}$ of 1–2 $\mu$g/m$^3$. A major part of the impaired area is inside the permanently built-up sections, so these have already been taken into account in the loss assessment. Only the affected areas of residential surroundings are included in this quantitative assessment which is not going to be built up anyway.</td>
</tr>
<tr>
<td>Minor</td>
<td>Not affected</td>
</tr>
</tbody>
</table>

**Total** 0.31 ha

#### Qualitative description

- No impairments by the emission of pollutants due to construction are to be expected and an assessment is not relevant.
- The operation-related pollutants are concentrated around the two tunnel portals (road/ railway) and along the railway track.
- Outside of the permanently built-up areas, impact zone 1 (90–100% of the standards) was not reached for any of the pollutants which were examined. Consequently, residential areas will not be affected.
- The pollutants benzene and SO$_2$ do not reach the respective standard values in impact zone 2 (50–90% of the standards). They are therefore not included in the detailed analysis. The above remarks refer to the pollutants NO$_2$, PM$_{10}$ and PM$_{2.5}$. In impact zone 2 (due to operation), only residential surroundings of medium sensitivity west of Marienleuchte and south of Puttgarden will be permanently impaired.
- No residential and settlement areas of very high or high sensitivity will be impaired by pollutants.

<table>
<thead>
<tr>
<th>Severity of impairment</th>
<th>***** Very high</th>
<th>*** High</th>
<th>** Medium</th>
<th>* Minor</th>
</tr>
</thead>
</table>
A small area of residential surrounding of Marienleuchte and Puttgarden will have impaired air quality, but the air quality standards will not be exceeded.

The air quality standards will be exceeded at the tunnel portals in an area with radius 200 m, but there are no permanent residences within the affected area.

Mitigation and compensation measures

No specific mitigation or compensation measures are required due to the very low level of impact on air quality. However, the normal environmental management of the construction site will help to reduce impacts, e.g. watering of earth stock piles and unsealed areas in dry periods to reduce dust and regular maintenance of engines to reduce emissions.

Conclusion

Air quality standards in built-up areas are not expected to be exceeded during either the construction or operation phases of the bored tunnel.
For the future, buildings or facilities where people can remain for longer periods should not be constructed near the tunnel portals in the area where air quality standards are exceeded.

7.2.7 Fragmentation and barrier effects on residential and settlement areas and residential surroundings

Fragmentation refers to the splitting of areas which previously had a common function which barrier effects refers to the impairment of access by the population to or between areas due to construction works and new roads and railways.

Method

Assessment of fragmentation and barrier effects in areas of importance for the population is based on expert judgement for each specific case. The assessment includes factors such as the frequency with which people will be affected and the role of the new roads in the road network.

Assessment of fragmentation and barrier effects

The fragmentation and barrier effects during construction and operation are collected in Table 7.11.

Table 7.11 Bored tunnel: Fragmentation and barrier effects for residential and settlement areas as well as residential surroundings

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
</tr>
<tr>
<td>1</td>
<td>Parts of the residential surroundings (medium sensitivity) of Marienleuchte will be separated by the construction site areas in front of the working harbour and can therefore temporarily not be used.</td>
</tr>
<tr>
<td>2</td>
<td>The work harbour will produce a temporary barrier effect between the residential surroundings of Marienleuchte and Puttgarden (medium sensitivity).</td>
</tr>
</tbody>
</table>

Qualitative description

- The working harbour will constitute a temporary barrier effect. Fringe areas around the residential districts north-west of Marienleuchte will be temporarily and permanently separated. The area around the residential section in Puttgarden will also be fragmented. The loss of these areas has already been taken into account in the criterion of the same name.

Severity of impairment

- - - - - Very high
- - - High
- - Medium
- Minor
As described in Table 7.11 the bored tunnel will unavoidably result in fragmentation of areas and in barrier effects particularly during construction.

Mitigation and compensation
As described elsewhere in this report, temporary footpaths and roads will be established during the construction phase to ensure the continued movement of people in the area. Permanent new roads and footpaths will also be established for the operation phase.

Conclusion
The bored tunnel project will have some unavoidable fragmentation and barrier effects during both construction and operation phases. However, the implementation of the mitigation and compensation measures will ensure that the effects will not have a significant impact on the population of Fehmarn. It is noted that the area is already impaired by the fragmentation and barrier effects of the existing main road B207 and railway.

7.2.8 Light pollution
There is presently little light pollution on Fehmarn. The sources are the ferry harbour, the towns and villages and the road traffic and do not give rise to any adverse impacts on the population or on tourists.

Method
The assessment of light pollution by the bored tunnel project is based on expert judgement in relation to the threshold values in the German guidelines in Licht-Richtlinie des LAI, Landesausschuss für Emissionsschutz. Factors such as the duration and intensity of the artificial light are included in the guidelines. They are also categorised according to the time of day and according to the activities in the areas impacted. Refer to the UVS for more details.

Assessment of impairments due to light pollution
The potential impairments due to light pollution are assessed in Table 7.12.
Table 7.12  Bored tunnel: impairment of residential and settlement areas as well as residential surroundings due to light emissions

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
</tr>
<tr>
<td>Very high to minor</td>
<td>- Due to sufficiently large distances between construction site and residential area, it is highly unlikely that the area will become too bright because light guideline values are exceeded.</td>
</tr>
<tr>
<td>Qualitative description</td>
<td>- It is not to be expected that the light guideline values are exceeded during construction because there is a sufficient distance to the nearest residential section.</td>
</tr>
</tbody>
</table>

Severity of impairment

<table>
<thead>
<tr>
<th>Severity of impairment</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
</tr>
</thead>
</table>

Conclusion
Light pollution during construction and operation phases will not be a significant impact on the population of Fehmarn.

7.2.9  Vibration impacts on residential and settlement areas and residential surroundings

Vibrations typically spread from the source through the earth to distant locations. However, low frequency noise can also cause vibrations, e.g. low frequency noise from machinery can cause windows and furniture to vibrate.

The sensitive receptors for vibrations are principally the areas where people live and work. These areas and their general importance are shown in Figure 7.5. Excessive vibrations can also cause structural damage to buildings located close to the source.

Sources of vibrations
The vibration sources in the construction phase are:

› Present vibrations from traffic, railway and local industry.
› Vibrations from construction machinery, trucks, general traffic, earth works, vibration compaction of earth, pile driving etc.

In the operation phase the sources are:

› Present vibrations from existing local traffic and industry.
› Vibrations from the new motorway and railway
Method

There are no binding thresholds for vibrations. There is, however, a set of guidelines (Erschütterungs-Leitlinie DIN 4150) which recommend threshold values for vibration intensity at high and low frequencies and for durations of impact. The frequencies lie between 0.05 and 6 Hz depending on whether it is day or night and on the use of the built-up area impacted. Residential areas are generally assessed as being very sensitive to vibrations whereas the surroundings are medium sensitive.

Experience has shown that milder vibrations seldom spread more than 100 m from the source.

Specific modelling of vibrations was not found to be necessary and the assessment is based on expert judgement.

Assessment of impacts due to vibrations

The assessment during both the construction and operation phases is described in Table 7.13.

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction related</td>
<td>Operation related</td>
</tr>
<tr>
<td>Very high</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>- Vibrations due to construction machines at the individual farm near Puttgarden</td>
</tr>
<tr>
<td></td>
<td>- There will be vibrations at the individual farm near Puttgarden due to traffic, but they will not exceed the admissible guide value.</td>
</tr>
<tr>
<td>High</td>
<td>- Will probably not be affected</td>
</tr>
<tr>
<td>Medium</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>- Due to the construction activities (e.g. pile driving) on a large area east of the railway, there may be temporary impairments of residential surroundings west of Marienleuchte.</td>
</tr>
<tr>
<td></td>
<td>- Minor impairments of residential surroundings east of Puttgarden due to road construction work are possible.</td>
</tr>
<tr>
<td></td>
<td>- Possible operation-related vibrations at the edge of the residential surroundings west of Marienleuchte due to the traffic, specifically freight trains</td>
</tr>
<tr>
<td>Minor</td>
<td>- Will probably not be affected</td>
</tr>
<tr>
<td>Qualitative description</td>
<td>- Not affected</td>
</tr>
</tbody>
</table>

- For an individual farm of very high sensitivity as well as residential surroundings of medium sensitivity, impairments on account of the construction work cannot be excluded.
- Vibrations caused by the operation are possible in the area of an individual farm. All other buildings are at a sufficiently large distance (> 100 m) from the routes, so no relevant vibrations are to be expected for the residential areas. Vibrations are only possible at the outskirts of the area around the residential area (medium sensitivity) of Marienleuchte.
In general it is assessed that the guideline thresholds for vibrations will not be exceeded during either the construction or operation phases. The individual farm near Puttgarden is likely to experience some disturbance due to vibrations during construction and during operation due to traffic.

Some residential surroundings of Marienleuchte and Puttgarden may experience a low level of vibrations during construction. During operation there could be some vibrations from freight trains in the residential surroundings west of Marienleuchte.

Conclusions
The general conclusion is that vibrations are unlikely to be a significant impact on the population of Fehmarn in general. One farm near Puttgarden may be affected, but the guideline thresholds will not be exceeded.

7.2.10 Recreation
This section gives a general introduction to recreation facilities on Fehmarn. It sets the background for the subsequent sections on impacts of the bored tunnel project on recreation.

Recreation includes a wide range of outdoor activities and facilities which are used by the local population, guests and tourists for enjoyment and exercise. The areas used for recreation are mainly found in environments dominated by natural values particularly near the northern coast. There are also some attractions in the town of Burg.

![Bathing beach between Puttgarden and Grüner Brink](image)

**Figure 7.16**  Bathing beach between Puttgarden and Grüner Brink

Existing recreation facilities
The existing possibilities for recreational activities are shown in Figure 7.17.

Camping grounds are found mainly around the coasts of the island with a few inland in the northwest corner. Holiday apartments, summer houses, private
pensions and bed & breakfast homes are spread around the entire island. An eight storey hotel is placed east of Puttgarden and is mostly used by ferry passengers for one night stays.

Bathing beaches are found along almost all the coastline of Fehmarn with wind- and kite-surfing sites on the north, west and south coasts. Attractive fishing spots are also found on most parts of the coast.

There is a quad-bike track east of Landkirchen and a view point on the west breakwater at Puttgarden.

The island has more than 170 km of bicycle, horse riding and walking tracks. There are nature attractions in the form of a garden centre, an information centre for the protected nature area Wallnau and a geological beach walk at Presen.

![Recreation attractions on Fehmarn](image)

**Figure 7.17 Recreation attractions on Fehmarn**

**Importance**

The importance of recreation is assessed on the four level scale of very high, high, medium and minor. The criteria for classifying the importance are:
› The quality of the recreation area (e.g. the attractiveness of the landscape).
› The distance to other areas.
› Ease of access (e.g. distance to residential areas and infrastructure).
› Use of the area (frequency and duration).

The importance of the study area for recreation is shown in Figure 7.18.
Figure 7.18 Importance of recreation areas
The bathing beaches with high landscape quality, easy access and many guests are assigned very high importance. These are found west of Puttgarden and east of Presen (Figure 7.18). They are also used for wind- and kite-surfing.

Other coastal stretches with narrow beaches and dikes are less attractive for bathing and are mainly used for cycling and walking. They are classified as being of high importance particularly because of their location close to residential areas and camping grounds and frequent use by the population and guests. The viewpoint from the Puttgarden breakwater is also of high importance.

Residential surroundings (500 m) are characterised by easy access and views of farmland, and are given medium importance. The regional coastal cycle path (Ostseeküstenradweg) and parts of areas reserved for recreational purposes in the landscape plan are also of medium importance. Medium importance is also given to entertainment and tourist attractions such as Meereszentrum in Burg, the quad-bike track near Landkirchen and the planned recreation park in Burg.

Other areas have minor importance for recreation. These include parking areas in recreation areas, restaurants, beaches with no or very limited access for the public and those parts of the cycle, horse riding and walking routes using public roads.

Potential impacts
The potential impacts of the bored tunnel project on recreation areas and activities are similar to those on residential areas and their surroundings:

› Loss of areas due to expropriation
› Noise
› Visual and sensory disturbances
› Air pollution
› Vibrations
› Fragmentation and barrier effects

These impacts are addressed in the following sections of this chapter.

Mitigation and compensation measures
A number of mitigation measures have been introduced to reduce the impacts of the project on recreational activities and areas. They are listed at this stage since they are common to a number of the impacts described below and unnecessary repetition can be avoided.

› Screening by planting bushes and trees along the motorway and railway corridors.
› Maintaining or re-routing of pathways of importance for recreation.
› Establishing a new beach along the reclamation edge.
› Dust control during construction works.
› Implementation of an environmental management plan to ensure that the mitigation measures function as intended.
0-alternative

It is assessed that the possibilities for recreation in the 0-alternative will be more-or-less the same as today. The present plans for further development of tourism can result in an increase in the use of the important recreation areas.

7.2.11 Loss of recreation areas

Land will be temporarily expropriated during the construction phase for the construction work sites and the work harbour. These areas will be re-established at the end of construction. The new motorway and railway corridors will be permanently expropriated also during the construction phase.

The impacts on recreation are listed and described in Table 7.14 and Figure 7.19.

Table 7.14  Bored tunnel: loss of recreation areas

<table>
<thead>
<tr>
<th>Importance</th>
<th>Construction related</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>High</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>Medium</td>
<td>0.68 ha</td>
<td>0.01 ha</td>
</tr>
<tr>
<td></td>
<td>** Temporary loss of areas especially suited for recreation (according to Landscape framework plan – LRP) in Marienleuchte due to areas required for setting up the construction site</td>
<td>** Permanent loss of an area especially suited for recreation (according to LRP) north of Marienleuchte because of land reclamation area</td>
</tr>
<tr>
<td>Minor</td>
<td>0.37 ha</td>
<td>0.61 ha</td>
</tr>
<tr>
<td></td>
<td>- Temporary loss of sections of a natural beach south-east of the existing ferry port due to the work harbour and temporarily used construction areas</td>
<td>- Permanent loss of sections of a natural beach of minor importance south-east of the existing ferry port due to structure (land reclamation area) of the Fehmarnbelt Fixed Link</td>
</tr>
<tr>
<td>Total</td>
<td>1.05 ha</td>
<td>0.62 ha</td>
</tr>
</tbody>
</table>

Qualitative description
- During the construction work, small recreation areas of minor to medium importance near Marienleuchte as well as part of the natural beach will be (temporarily) lost.
- Largely the permanent structures will affect sections of the natural beach of minor importance.
Conclusion
Only small recreational areas of medium and minor importance will be lost. The lost beach will be compensated by the creation of a new beach. The loss of recreation areas is not considered to be a significant impact.

7.2.12 Noise impairment of recreation areas
Table 7.15 lists the impairments of recreational areas due to noise. During construction a narrow part of a recreation area near the coast at Marienleuchte will be affected by noise, especially due to pile driving at the work harbour. This will only occur for a short time. The little used beach in the same area will also be affected.

There will be no impacts on recreation areas by traffic noise in the operation phase.

Conclusion
Noise impacts on recreation areas on Fehmarn are not significant.
### Table 7.15  Bored tunnel: impairments of recreation areas due to noise

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Construction related</th>
<th>Operation related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>- Not affected</td>
<td>- Not affected</td>
</tr>
<tr>
<td>High</td>
<td>- Not affected</td>
<td>- Not affected</td>
</tr>
<tr>
<td>Medium</td>
<td>- Setting up the construction site (especially pile driving for the work harbour) and the construction activities along the new agricultural road will result in temporary impairments of narrow areas which are especially suited for recreation at the western edge of Marienleuchte</td>
<td>- Not affected</td>
</tr>
<tr>
<td>Minor</td>
<td>- The section of the natural beach north of Marienleuchte will be impaired by the construction noise.</td>
<td>- Not affected</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Qualitative description**
- Due to the construction, areas which are especially suited for recreation (medium sensitivity) near Marienleuchte will be impaired.
- No recreation areas will be impaired by noise >49 dB(A) caused by operation related traffic.

### 7.2.13 Visual and sensory impairments of recreation areas

The visual and sensory impacts on recreation areas are listed and described in Table 7.16 and Figure 7.20.

Visual and sensory impairments are assessed by calculating the residential and settlement areas and the area of their surroundings which are likely to be affected to various degrees by structures.

As an example, the visual impairment is assessed according to the following principle: The area which is affected increases with the height of the structures since higher structures can be seen from greater distances. The sensitivity of the population to the impacts uses the four level scale of very high, high, medium and minor. The criteria used to set the sensitivity are almost the same as used for importance. Therefore the importance of areas for the recreation shown in Figure 7.18 can also be used for sensitivity.

The impacts are considered in zones. Zone 1 is the area within 200 m of the source of disturbance, e.g. the construction site or the completed motorway and railway. Zone 2 is the area from 200 m to 1,500 m.
### Table 7.16  Bored tunnel: visual and sensory impairments of recreation areas

#### Impact zone 1: width of up to 200 m, depending on altitude of up to 10 m – Magnitude of pressure: high, temporarily medium

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
<th>Construction related</th>
<th>Structure related and operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>- Not affected</td>
<td>- Not affected</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Not affected</td>
<td>- Not affected</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>6.00 ha</td>
<td>- 0.10 ha</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temporary impact on the area with special</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>suitability for recreation west and south of</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marienleuchte due to construction site</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>elements with a height of up to 10 m (e.g.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>silos, buildings, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>0.18 ha</td>
<td>0.90 ha</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Natural beach section south-east of the</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>breakwater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6.18 ha</td>
<td>1.0 ha</td>
<td></td>
</tr>
</tbody>
</table>

**Qualitative description:**
- No areas of very high sensitivity will be impacted.
- Fairly large areas of special suitability for recreation will be impaired due to the construction.

#### Impact zone 2: width of 200 to 1,500 m, depending on altitude of more than 10 m – Magnitude of pressure: Medium

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
<th>Construction related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>0.46 ha</td>
<td>0.46 ha</td>
</tr>
<tr>
<td></td>
<td>- Bathing beach east of Presen</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.67 ha</td>
<td>1.67 ha</td>
</tr>
<tr>
<td></td>
<td>- Beach sections not used for swimming</td>
<td></td>
</tr>
<tr>
<td></td>
<td>between Marienleuchte and Presen</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>74.24 ha</td>
<td>74.24 ha</td>
</tr>
<tr>
<td></td>
<td>- Areas with special suitability for</td>
<td></td>
</tr>
<tr>
<td></td>
<td>recreation in and south of Marienleuchte</td>
<td></td>
</tr>
<tr>
<td></td>
<td>as well as north-west of Presen</td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>- Not affected</td>
<td>- Not affected</td>
</tr>
<tr>
<td>Total</td>
<td>76.36 ha</td>
<td></td>
</tr>
</tbody>
</table>

**Qualitative description:**
- Mainly areas of special suitability for recreation, which are of medium sensitivity, near Marienleuchte and Presen will be impacted. There will also be visual and sensory impacts on small areas of high and very high sensitivity, such as beach sections.

**Total area (all impact zones):**

<table>
<thead>
<tr>
<th>Construction related</th>
<th>Structure and operation related</th>
</tr>
</thead>
<tbody>
<tr>
<td>82.54 ha</td>
<td>1.0 ha</td>
</tr>
</tbody>
</table>

**Severity of impairment:**
- **** Very high
- *** High
- ** Medium
- * Minor
Figure 7.20 Visual and sensory impairments of recreation areas

The impacts are primarily visual and occur mostly during the construction phase with 6 ha affected in zone 1 and 76 ha in zone 2. The impairment is due to the fact that silos, cranes and other high structures in the construction work site can be seen over larger distances.

About 2 ha of beach area between Presen and Marienleuchte with very high and high sensitivity are impacted.

Conclusion
Despite the classification in various levels of severity of impairment, the recreation areas affected will not be rendered unusable. Therefore there is no need for mitigation and the impacts are not significant. It is noted that it is the same areas where there are impacts on flora and fauna and the compensation for those impacts will also compensate for the visual and sensory impacts.
7.2.14 Air quality impacts on recreation areas

Reference is made to section 7.2.6 (Air quality impacts on residential and settlement areas and residential surroundings) above for a description of the present air quality, the method of assessment, project pressures and potential impacts.

The results of the assessment for recreation areas is listed and described in Table 7.17.

Table 7.17  Bored tunnel: impairment of recreation areas due to the emission of pollutants

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction related</td>
<td></td>
</tr>
<tr>
<td>Very high to minor</td>
<td>- It is to be assumed that a relatively small number of construction machines and ships will be used. The recreation areas are &gt;100 m away from the construction site areas. Moreover, supply of fresh air in the study area is good, so no impacts on air quality are to be expected during the construction phase.</td>
</tr>
<tr>
<td>Impact zone 1: 90 to 100% of the respective air quality standards and guideline values (Magnitude of pressure: high)</td>
<td></td>
</tr>
<tr>
<td>Operation related</td>
<td></td>
</tr>
<tr>
<td>Very high to minor</td>
<td>- Not affected</td>
</tr>
<tr>
<td>Impact zone 2: 50 to 90% of the respective air quality standards and guideline values (Magnitude of pressure: medium)</td>
<td></td>
</tr>
<tr>
<td>Qualitative description</td>
<td>- No impacts on air quality due to construction are noted in recreation areas. The operation-related pollutants are concentrated around the railway track and in the area of the tunnel portals, but no recreation areas will be impaired.</td>
</tr>
<tr>
<td>Severity of impairment</td>
<td>***** Very high</td>
</tr>
</tbody>
</table>

Conclusion

There will be no impacts on air quality in recreation areas during either construction or operation of the bored tunnel project.

7.2.15 Fragmentation and barrier effects on recreation areas

Reference is made to section 7.2.7 (Fragmentation and barrier effects on residential and settlement areas and residential surroundings) for an introduction to the fragmentation and barrier effects.

For this section on recreation areas the impacts are divided into areas with importance for landscape-related recreation (Table 7.18) and landscape related recreation paths (Table 7.19 and Figure 7.21).
Table 7.18  Bored tunnel: barrier effects and fragmentation of areas with importance for landscape-related recreation

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
</tr>
<tr>
<td>1</td>
<td>•</td>
</tr>
<tr>
<td></td>
<td>Because of the bored tunnel (reclamation area and route structure), part of the natural beach between Marienleuchte and the ferry port (minor sensitivity) will be permanently cut off the southernmost section of the beach. The permanent deprivation of use has already been taken into account in the investigation of losses. The new agricultural road west of Marienleuchte will impair an area of special suitability for recreation. The area will be fragmented inside.</td>
</tr>
<tr>
<td>2</td>
<td>•</td>
</tr>
<tr>
<td></td>
<td>Exacerbation of the existing barrier effect (railway, B207, ferry port) west of Marienleuchte (functional relationship between Marienleuchte and Puttgarden). Due to the already existing impairments caused by traffic infrastructure facilities, the additional impairment of Marienleuchte must be regarded as minor.</td>
</tr>
<tr>
<td>Qualitative description</td>
<td>- Minor functional impairment with respect to Marienleuchte (small increase of the existing barrier effect between Marienleuchte and Puttgarden)</td>
</tr>
<tr>
<td>Severity of impairment</td>
<td>***** Very high</td>
</tr>
</tbody>
</table>

Table 7.19  Bored tunnel: fragmentation of landscape-related recreation paths

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
</tr>
<tr>
<td>Medium</td>
<td>1 path</td>
</tr>
<tr>
<td></td>
<td>•</td>
</tr>
<tr>
<td></td>
<td>- Potential construction-related impairment of the Baltic Sea coast bicycle path (Ostseeküstenradweg)</td>
</tr>
<tr>
<td>Minor</td>
<td>2 paths</td>
</tr>
<tr>
<td></td>
<td>•</td>
</tr>
<tr>
<td></td>
<td>- Potential construction-related impairments for the signposted bicycle path between Niendorf and Puttgarden as well as the bridleway between Marienleuchte and Puttgarden</td>
</tr>
<tr>
<td>Total</td>
<td>3 paths</td>
</tr>
<tr>
<td>Qualitative description</td>
<td>- The three trails listed above will not be permanently fragmented but may be temporarily impaired during the construction phase due to construction site traffic or temporary blocking. A sufficient number of optional detours and alternative routes exist.</td>
</tr>
<tr>
<td>Severity of impairment</td>
<td>***** Very high</td>
</tr>
</tbody>
</table>
Severity of impairment

| Medium | Minor |

Fragmentation

Figure 7.21  Fragmentation of landscape-related recreation paths

Conclusion

The fragmentation and barrier effects on landscape-related recreation areas are minor and considered insignificant. Three bicycle and horse riding paths will be affected but alternative routes will be established and signposted as compensation.
7.3 Soils

7.3.1 Existing soil conditions
The soil which dominates the surface of Fehmarn is moraine clay from the last ice age. It consists of an unsorted mixture of clay, silt, sand and coarser material with a high content of chalk. The original ice age layers are typically 1 – 2 m deep. Topsoil which is partly organic covers the clay so that the surface soil of large areas of the island and nearly all the study area is black (the Fehmarn Schwarzerde). The black soil is very fertile and valuable for farming because of the high content of nutrients, chalk and clay. This soil type is the one of the most productive for agriculture in Schleswig-Holstein. There are small areas of more normal brown soil (Parabraunerde) with less organic content than the black soil.

Around Bannesdorf the soil is more moist due to the higher groundwater table. Wetland soil occurs in the hinterland of the north coast where there is also a high groundwater table. Such areas were typically drained in earlier times and used for agriculture.

Sandy beaches occur around most of the coast and some coastal cliffs show the different geological layers.

All town areas, roads, railways, railway yards and the harbour are generally considered to be polluted. The main road B207 is expected to be more affected than other roads in the study area due to the more intense traffic.

The occurrence of proven polluted soil areas is assessed from the mapped soil pollution in the public database called Atlastenkataster. There are three registered areas in the study area: Northeast of the railway yard in Landkirchen and two localities in the industry area in Burg.

7.3.2 Importance
The importance of the soil conditions is assessed on a two level scale, special and general. The criteria for classifying the importance include consideration of the rarity of the soil type, its fertility and natural state (degree of human disturbance). Other parameters included are the biological function of the soil, the geomorphological history and its role in the hydrological cycle.

The black soil, the wetland soil and post-glacial marine deposits are given special importance (Figure 7.22). The coastal cliffs are also of special importance due to their cultural and natural value.

The brown soils are classified as of general importance.
Figure 7.22  Importance map for soil on Fehmarn
7.3.3 0-alternative
It is assessed that the soil conditions and importance in the 0-alternative (2025) will be more-or-less the same as today. The main land-use will continue to be farming.

7.3.4 Potential impacts
The assessment of impacts on soil is considered under the following headings which also represent the potential impacts:

› Loss of soils and geological formations (due to construction and the facilities)
› Impairments of soils because of soil compaction (due to construction)
› Impairment because of the emission of pollutants and nutrients (due to construction and operation)

7.3.5 Loss of soils and geological formations
The losses are calculated as the areas which are affected during construction and operation. These are listed in Table 7.20 and illustrated in Figure 7.23.

<table>
<thead>
<tr>
<th>Importance</th>
<th>Bored tunnel</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
<td>Structure related</td>
</tr>
<tr>
<td>Special</td>
<td>82.40 ha</td>
<td>61.92 ha</td>
</tr>
<tr>
<td></td>
<td>- Mainly &quot;Fehmarn black soil&quot; (80.59 ha)</td>
<td>- Mainly &quot;Fehmarn black soil&quot; (61.01 ha)</td>
</tr>
<tr>
<td></td>
<td>- Plus storm-beaches and coastal cliff in sections east of the ferry port</td>
<td>- Plus storm-beaches and coastal cliff east of the ferry port</td>
</tr>
<tr>
<td>General</td>
<td>0 ha</td>
<td>0.38 ha</td>
</tr>
<tr>
<td></td>
<td>- Parabrown earth west of Bannesdorf</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>82.40 ha</td>
<td>62.30 ha</td>
</tr>
</tbody>
</table>

Table 7.20 Bored tunnel: loss of soils and geological formations

- The construction will essentially result in the loss of areas of special importance for the environmental factor soil along the entire route and, especially, in the area where the construction site is set up.
- The proportion of parabrown earth which will be lost is small.
Mitigation and compensation measures
The black top soil will be removed from the affected areas and stored for later use on the construction and work areas to be re-established at the end of construction.

It is noted that the area of soil lost is the same as the area of landscape lost (see below). The owners of the land, and thereby also the soil will be compensated for the loss by Femern A/S.

For the immersed tunnel additional compensation is proposed through the re-establishment of the soil conditions in areas affected by human activities in other parts of Fehmarn and Schleswig-Holstein (the so-called Ökokontofläche or eco-account). It is assumed that a similar compensation would be applied for the bored tunnel project.

Conclusion
The project will result in the loss of areas of Fehmarn black soil of special importance in both the construction and operation phases, viz. 81 and 61 ha.
respectively. The area affected during construction will be re-established at the end of the construction phase including the replacing of the black top soil. The area will become useable for farming again.

Comparing the area lost with the total farming area on black soil on Fehmarn and taking into account the proposed mitigation and compensation measures, the impact is considered insignificant.

### 7.3.6 Impairment of soils due to compaction

Compaction of soils will inevitably occur on all construction sites and on temporary access roads. The soils affected will be those under the top black soil layer which will be removed and stored at the start of construction.

The areas affected are listed in Table 7.21.

<table>
<thead>
<tr>
<th>Impairment of soils due to soil compaction (Magnitude of pressure: depends on specific instances)</th>
<th>Bored tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
<td><strong>Construction related</strong></td>
</tr>
<tr>
<td>Special</td>
<td>80.59 ha</td>
</tr>
<tr>
<td>- &quot;Fehmarn black soil&quot; sites will be affected by compaction on the area of the construction site.</td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>1.76 ha</td>
</tr>
<tr>
<td>- Storm-beach areas by part of the construction site near the coast</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>82.35* ha</td>
</tr>
<tr>
<td><strong>Qualitative description</strong></td>
<td>- Areas of soil compaction will be created, especially at sites of “Fehmarn black soil” in the construction site areas west of Marienleuchte.</td>
</tr>
</tbody>
</table>

#### Mitigation and compensation measures

The top black soil will be removed and stored at the start of construction so that it will not be affected by compaction.

The underlying soil layers in the areas to be re-established at the end of construction will be loosened to remove the compaction and the top black soil replaced.

#### Conclusion

The impairment of soil by compaction is not significant since the soils will be loosened again at the end of construction. No top black soil will be compacted.
7.3.7 Impairment of soils due to pollution and nutrients

The air pollution from traffic in the operation phase will give deposition of nutrients nearby the motorway and railway.

There may also be accidental spills of polluting substances on the construction sites, but the increase in impairment is not regarded as relevant for inclusion in the assessment.

The results of the assessment are shown in Table 7.22 and Figure 7.24.

Table 7.22 Bored tunnel: impairment of soils due to the emission of pollutants and nutrients

<table>
<thead>
<tr>
<th>Impact zone 1 (up to 50 m from the edge of the railway/road) – Magnitude of pressure: high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>- Increased concentration of pollutants in strips of land parallel to the road and railway track on “Fehmarn black earth” and parabrown earth</td>
</tr>
<tr>
<td>- Increased concentration of nutrients in storm-beach sections south-east of the ferry port</td>
</tr>
<tr>
<td>General</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

**Qualitative description**

- No increases in the emission of pollutants and nutrients which are relevant for a decision are to be recorded as a consequence of the construction activities.
- Soils of special sensitivity will be impaired along the entire railway track, mostly due to increased concentrations of particulate matter. Pollution by concentrations of NOₓ will occur on soils of special sensitivity along the planned road.
- Due to the new developments in engine technology and the electrification of the railway, no increased concentrations of benzene are to be expected for the forecast year 2025. Metals such as zinc and lead will also decrease.
- Along the railway track, the grit from rails and pipes constitute sources of emission which may lead to increased concentrations of metals (e.g. iron and copper) on a 10 m wide area.
- The construction- and operation-related emission of pollutants and nutrients will be slightly above the already existing levels of pollution.
Mitigation and compensation
The top black soil will be removed from all construction and work sites and stored before work commences. This will reduce the impairment of the top soil due to nutrients during construction.

The construction site environmental management plan will include provisions for the clean-up of any accidental spills and thereby avoid any permanent impairment of the underlying soil by polluting substances.

Conclusion
The impairment of soil due to pollution during the construction phase is assessed to be a minor and insignificant impact.

In the operation phase, the fact that the pollution of soil by nutrients will only be slightly above the existing levels of pollution renders the impact insignificant.
7.4 Water

This section addresses the surface and groundwater conditions on Fehmarn and the potential impacts of the bored tunnel project on the conditions.

7.4.1 Methodology

The methods for mapping the existing surface and groundwater on Fehmarn and the assessment of impacts follow the German practice for such issues. Geotechnical borings carried out by Femern A/S during 2009 – 2010 also revealed the presence of aquifers and the general groundwater conditions. Surface water occurrence was determined in connection with the mapping of biotypes in 2009. The field data was combined with data from literature including local studies on groundwater formation and in connection with the widening of the main road B207. Data was also gathered from the authorities’ databases on soils, coastal protection, water supply, flooding, soil pollution and environment. Maps of water quality, hydrogeology and information from the water management plan, groundwater protection plan and municipal development plans were also used.

Assessment of the impacts (loss and impairment) is based on a combination of the actual areas of surface water and groundwater water affected and the importance or sensitivity of the water in each area.

7.4.2 Legal framework

Fehmarn is included in the water management plan for the Trave-Schlei area (MLUR-SH & LU-MV, 2009). Only the two water courses Bannesdorfer Graben and Kopendorfer Au are covered by the plan but none of the lakes are in the study area. The EU Water Framework Directive specifies that all water resources shall achieve “good ecological state” or a “good ecological potential” by 2015.

Coastal lakes and ponds are “protected biotypes” according to the German nature protection law (BNatSchG). The surface water in the study area does not fulfil the requirements for protection by the lake and water course protection lines. Only the area within 100 m of the coast is protected by the requirements of the Schleswig-Holstein nature protection law (LNatSchG). There are no areas in the study area covered by the drinking water protection requirements.

7.4.3 Existing water environment

Lakes and ponds

There are 250 protected lakes and ponds (protected under the nature protection law, not the water protection law) in the study area evenly distributed over the agricultural land areas and most are the result of earlier excavations of marl. The largest lakes on the island are Kopendorfer See, Fastensee, Salzensee, Nördliche Binnensee and Sarensdorfer Binnensee.
Most of the ponds contain water during rainy periods and dry out during longer dry periods. Only the lakes and ponds in contact with groundwater are wet all the year round.

Most of the lakes and ponds in the study area are found near the coasts and especially near Presen. Here the water courses are broader and surrounded by more plants and, behind the dike, form a row of small lakes. There are also two brackish coastal lakes in the Grüner Brink nature area part of which is in the study area.

Most of the lakes and ponds on Fehmarn are affected by nutrient runoff from the surrounding farmland.
Water courses

The surface water on Fehmarn flows typically in drainage canals and ditches around the fields. In general the water courses flow from west to east and are often dry in the summer months. The water courses in the study area flow to either the north or east coasts where they are pumped up to the sea.

The water quality shows clear signs that the water courses do not have the same physical conditions as natural streams and that they are also affected by the runoff of nutrients from the farmland. The water courses near the main road B207 and the railway are affected by increased runoff from sealed areas and are piped in certain sections, especially under roads and railway.

The only originally natural stream in the study area is Kopendorfer Au which flows to the west coast of Fehmarn. It is now heavily regulated in straight, excavated ditches.

The main drainage ditches affected by the project are the Drohngaben and Nielandsgraben which cross the study area to the east coast near Presen (Figure 7.25).

The dikes, drainage canals and ditches and pump stations are operated and maintained by Wasserverband Fehmarn Nord-Ost.
Groundwater
The groundwater table on Fehmarn is generally high due to the high clay content of the soil which limits percolation of rainfall and due to the flat nature of the surface and its low height above sea level. The groundwater table is only a few meters below the surface in most areas and reaches the surface in the wetlands near the north coast.

There is no large groundwater aquifer on Fehmarn due to the geological conditions which only allow the occurrence of isolated lenses of groundwater in small sandy deposits on top of moraine clay. The annual replenishment of groundwater is estimated to be only 1 mm since most of the rainfall evaporates or runs off. The existing groundwater is not suited for drinking.

The groundwater table in most areas is significantly lowered by drainage of the fields and the water is affected by the use of fertilizers and pesticides on the agricultural land. Soil pollution particularly in Burg and Landkirchen can be a local threat to groundwater quality. The deeper bodies of groundwater, according to the water management plan, are in a good state as regards both quantity and quality.

7.4.4 Importance

Surface water
The importance of water courses, lakes and ponds are assessed on a two level scale (special and general). The assessment is based on criteria including the protection status, the contribution to the landscape value and the function of the water in the
hydrological cycle and as a habitat. The criteria are defined through parameters such as rarity, water quality, present degree of impact, sensitivity, drainage function, catchment area and retention of pollutants.

Coastal lakes, ponds, dams and other protected wetlands are given special importance (Figure 7.28). This also applies to the protected zone within 100 m of the shoreline.

Drainage canals and ditches and Kopendorfer Au (excavated to resemble a canal) are assessed to be of special importance for the water balance in the study area despite their state of pollution by nutrients from agriculture. Low areas under 3.5 m above sea level are classified as being of general importance due to the small risk of flooding because of the coastal dike. Artificial water areas like retention basins are of general importance due to their low natural value.

Groundwater

The importance of groundwater is also assessed on the two level scale. The assessment is based on criteria including protection status, present state of the water and the indirect function as a habitat. The criteria are defined through parameters such as water quality, geological protection layers, proximity of the groundwater table to the surface, size of the groundwater body, catchment area, percolation rate, drainage and possibilities for use.

Areas where the groundwater is in contact with the surface are of special importance for the flora and fauna in the area. This applies to the wetlands in the Blankenwisch area (Figure 7.28). All other areas are of general importance except sealed and built-up areas which are not assessed.

As a source of drinking water the groundwater in the study area is of general importance because it is not used for that purpose on Fehmarn nor is any area protected for that purpose.
Figure 7.28 Importance map for surface water and near-surface groundwater
7.4.5 0-alternative
The groundwater conditions in the 0-alternative (2025) are assumed to be more-or-less the same as today. However, the water courses Bannesdorfer Graben and Kopendorfer Au included in the water management plan are expected to be improved to fulfil the requirements of good ecological potential. In 2014 the goals of the water management plans will be re-assessed to determine if the requirements for some water courses can be changed from good ecological potential to good ecological status because of changed land-use.

7.4.6 Potential impacts
The assessment of impacts on soil is considered under the following headings which also represent the potential impacts:

› Loss of and changes in bodies of surface water
› Loss of areas of the Gewässerschutzstreifen (water protection area)
› Fragmentation of bodies of flowing water
› Impairment of bodies of surface water due to the emission of pollutants and nutrients. The impairments will be generally considered within a 50 m wide marginal strip.

7.4.7 Loss of and changes in bodies of surface water
The loss and changes of surface water bodies are listed in Table 7.23 and illustrated in Figure 7.29.

The assessment shows that eight ponds and several sections of drainage ditches of special importance will be lost during construction and due to permanent structures in the operation phase. Table 7.23 does not differentiate between the two types of loss.

Mitigation and compensation
Compensation for the losses of ponds will be achieved by the establishment of new ponds in suitable nature areas. They will be excavated before the existing ponds are filled or impaired, planted with similar vegetation and amphibians will be moved from the existing ponds to the new ponds where relevant. The number and location of the ponds are to be agreed with the authorities.

Culverts will be constructed under the new motorway and railway and other new roads to ensure the continued function of the Drohngraben and Nielandsgraben as drainage ditches in both the construction and operation phases. Sections of the ditches will also be rehabilitated to improve their function.

Conclusion
The implementation of the mitigation and compensation measures will effectively counteract the adverse impacts on ponds and water courses and the residual impacts become insignificant.
### Table 7.23  Bored tunnel: loss of and changes in bodies of surface water

<table>
<thead>
<tr>
<th>Importance</th>
<th>Bored tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction related</td>
<td>0.34 ha</td>
</tr>
<tr>
<td>Structure related</td>
<td></td>
</tr>
<tr>
<td>Special</td>
<td></td>
</tr>
<tr>
<td>- Construction and structure related loss of two ponds south-east of the ferry port</td>
<td></td>
</tr>
<tr>
<td>- One pond will be lost between the B207 and the &quot;Windpark Presen&quot; wind farm due to a storage area.</td>
<td></td>
</tr>
<tr>
<td>- Construction on the edge of a pond at the western edge of Marienleuchte</td>
<td></td>
</tr>
<tr>
<td>- Sections of the Drohngraben near the B207 as well as small sections of the Nielandsgraben next to the road between Hinrichsdorf and Presen near the B207 will be affected during construction and structure related losses.</td>
<td>0.21 ha</td>
</tr>
<tr>
<td>General</td>
<td>0 ha</td>
</tr>
<tr>
<td>Total</td>
<td>0.34 ha</td>
</tr>
<tr>
<td></td>
<td>8 ponds and several drainage ditch sections</td>
</tr>
<tr>
<td>Qualitative description</td>
<td></td>
</tr>
<tr>
<td>- A total of eight ponds will be lost. One of them (AS Puttgarden) will be completely covered by the structure. Four more will be lost to areas where the construction site is set up. The edges of three ponds will be impaired due to construction or the structure. Several small sections of the drainage ditches Drohngraben and Nielandsgraben will be covered.</td>
<td></td>
</tr>
<tr>
<td>- Four ponds are completely inside the temporary loss zone and must be considered permanent losses. Another small body of water, which will only be impaired at its edge, could be kept exempt.</td>
<td></td>
</tr>
</tbody>
</table>

#### 7.4.8  Loss of areas of the Gewässerschutzstreifen (coastal protection area [according to § 61 BNatSchG])

This section concerns the loss of areas within the 100 m wide coastal strip which is protected under the nature protection law § 61 BNatSchG.

The losses are listed in Table 7.24 and illustrated in Figure 7.29.

The work harbour and construction site will cause the temporary loss of 4.41 ha of the protected coastal strip while the final reclamation will cause the permanent loss of only 0.52 ha.
Table 7.24 Bored tunnel: loss of areas of the Gewässerschutzstreifen (coastal protection area [according to § 61 BNatSchG])

<table>
<thead>
<tr>
<th>Importance</th>
<th>Construction related</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special</td>
<td>4.41 ha</td>
<td>0.52 ha</td>
</tr>
<tr>
<td></td>
<td>- Temporary use of the Gewässerschutzstreifen due to construction along the structure east of the ferry port</td>
<td>- Permanent excavations and structures on the Gewässerschutzstreifen near the coast east of the ferry port</td>
</tr>
<tr>
<td>General</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>Total</td>
<td>4.41 ha</td>
<td>0.52 ha</td>
</tr>
</tbody>
</table>

Qualitative description
- Temporary constructions make up the major part of the construction on the Gewässerschutzstreifen. The temporarily used areas at the edge can be restored once construction has been completed.
- There will be losses of a much smaller portion of the Gewässerschutzstreifen because of the structure-related land reclamation area.

Severity of loss
- Special
- General

Figure 7.29 Loss of and changes in bodies of surface water and loss of areas of the Gewässerschutzstreifen (protection area [according to § 61 BNatSchG])
Mitigation and compensation
The area affected during construction will be re-established at the end of the works.

Presumably the shoreline and the protected coastal strip will be redefined to correspond to the edge of the permanent land reclamation.

Conclusion
The implementation of the mitigation and compensation measures will result in the residual impacts being insignificant.

7.4.9 Fragmentation of water courses
The fragmentation of water courses due to the project consists of the new crossings of the Drohngraben and Nielandsgraben drainage ditches by the new motorway and railway, see Table 7.25 and Figure 7.30. The ditches are classified as of special sensitivity. Culverts will be constructed for 541 m of Drohngraben and 32 m of Nielandsgraben.

Conclusion
The drainage ditches and other water courses are already fragmented by the existing road and railway. The cause of the increased fragmentation is the same as that causing the loss of the ditches addressed above in section 7.4.7 and is an unavoidable consequence of the project. Although the fragmentation is increased, it has no impact on the functions of the water courses as drainage ditches and pathways for aquatic animals.

Table 7.25  Bored tunnel: fragmentation of water courses

<table>
<thead>
<tr>
<th>Magnitude of pressure: very high, temporarily high</th>
<th>Bored tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
<td><strong>Construction related</strong></td>
</tr>
<tr>
<td>Special</td>
<td>1 ditch (3 sections)</td>
</tr>
<tr>
<td>- Different sections of the Drohngraben (total length approx. 80 m) between Todendorf and Presen near the B207, which will be permanently fragmented because of the structure</td>
<td>- 4 partial sections (total length approx. 480 m) of the Drohngraben ditch north of the Puttgarden junction, temporary impairment appears to be permanent</td>
</tr>
<tr>
<td>- Fragmentation of the edge of the Nielandsgraben ditch between Hinrichsdorf and Presen near the B207</td>
<td>- Small part of the Nielandsgraben ditch east of Hinrichsdorf (32 m)</td>
</tr>
<tr>
<td>Total</td>
<td>2 ditches (3 sections construction related and 5 sections structure related)</td>
</tr>
<tr>
<td>Qualitative description</td>
<td>- Both affected ditches are already fragmented because of the existing B207 or are conducted underneath it through pipes. Because of the construction of the Fehmarnbelt Fixed Link, the piped sections must be extended accordingly, thus exacerbating the fragmentation.</td>
</tr>
<tr>
<td>Severity of impairment</td>
<td>***** Very high</td>
</tr>
</tbody>
</table>
7.4.10 Impairment of bodies of surface water due to the emission of pollutants and nutrients

The areas of surface water bodies affected by the emission and deposition of pollutants and nutrients from construction machinery and the traffic in the operation phase are listed in Table 7.26 and illustrated in Figure 7.31.

It is seen that only a very small area of 0.09 ha of water bodies is affected.

Conclusion

It is assessed that the concentration of pollutants and nutrients in the atmosphere during the construction will only be slightly above the existing situation and the impacts are therefore insignificant.

During operation of the fixed link the emission of pollutants and nutrients will be proportional to the increase in traffic. On the other hand, the expected stricter
requirements to the quality of exhaust gases in the future will counteract the emissions from the increase in traffic.

Table 7.26  Bored tunnel: impairment of bodies of surface water due to the emission of pollutants and nutrients

<table>
<thead>
<tr>
<th>Zone 2: 0 to 50 m from the edge of the railway track/ traffic lane (Magnitude of pressure: high)</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
<td><strong>Operation related</strong></td>
</tr>
</tbody>
</table>
| Special | 0.09 ha  
- Impairment of a small body of water in the vicinity of the Puttgarden junction (at the K49 due to the roads connecting Puttgarden)  
- Impairment of the Drohngraben ditch in several partial sections near the route  
- Pollution of section of the Nielandgraben ditch near the road |
| General | Not affected |
| Total | 0.09 ha |
| **Qualitative description** | - Impairments of bodies of surface water of special sensitivity are to be expected due to pollution by pollutants and nutrients.  
- Ditches will also be polluted by concentrations of pollutants and nutrients in the areas near the road |
| **Severity of impairment** | Very high | High | Medium | Minor |
Figure 7.31  Bored tunnel: impairment of bodies of surface water due to the emission of pollutants and nutrients
7.5 Fauna

The section deals with the impacts of the bored tunnel project on the fauna on Fehmarn.

Plants and animals play an important role in the ecosystem and exist in a close interaction with each other and with the soil, water, air, minerals and all physical and chemical factors. Observation of plants and animals is an important source of recreation for the population and guests on Fehmarn.

The purpose of the baseline studies was to determine the biological function of the area for both plants and animals and identification of species and their abundance. Factors such as the legal protection requirements and the presence of rare and threatened species on the German red list also enter into the assessment of the biological function of the area.

The Fehmarn landscape is of a generally uniform nature with large areas of intensive agriculture and a lack of forests, bushes, heath and fallow fields. This, together with the draining of the land by non-natural ditches and poor water quality, results in few areas which are suitable for animals to live. Other existing pressures are the windmills and infrastructure which isolate habitats, and traffic which gives noise and pollution and causes road deaths of animals. Tourists on the beaches also disturb plants and animals. On the other hand, some of the landscape elements created by humans provide habitats for some species.

7.5.1 Existing fauna and its importance

Mammals

Roe deer, hares and rabbits are common on Fehmarn and the number of roe deer killed in the traffic is above average. Hare is on the German red list and classified as vulnerable due to the fall in numbers. There are only few foxes on Fehmarn and none in the study area. Wild pigs are seen occasionally because a few individuals swim across from the mainland. However, they are shot if they don’t get killed on the roads first. Fallow deer are rare on Fehmarn and otters (an Annex IV species) are only registered about 10 km from the study area at Wallnau. Stoats have been seen on Grüner Brink.

The whole study area is of general importance for mammals since they are distributed evenly over the area.

Bats

Seven species of bats were found in the study area, but only in small numbers. The brown long-eared bat and the Nathusius’ Pipistrelle are on the German and/or the Schleswig-Holstein red lists as vulnerable species and the Serotine and Noctule can potentially be threatened. Baubenton’s bat and the Common Pipistrelle are not threatened but the availability of data is limited. The Common Pipistrelle is the most common species while the others are less frequent on Fehmarn. Only one Baubenton’s bat was observed.
Noctule and Soprano Pipistrelle are associated with built-up areas. Brown long-eared bats and Nathusius’ Pipistrelle are sometimes seen in the bushes and trees along roads since there is a general lack of forest areas. Bats use the vegetation along the main road as a commuting path which continues along the bushes on the eastern side of the railway yard. On the other hand the road and railway can be a barrier and bat presence was observed to increase at bridge overpasses which are used as passages. Roosting areas for bats are found especially near Blankenwisch and partly near Marienleuchte. Bannesdorf and Klausdorf are breeding areas for Soprano Pipistrelle while all the areas mentioned above are feeding areas. Outside the study area bats were observed at Grüner Brink and Katharinenhof.

Concentrated migration routes over Fehmarnbelt for bats were not observed in the study area.

The study area’s importance for bats is assessed by combining the observations with the number of each species one would expect to find on Fehmarn. Medium importance is given to areas where the observations correspond with the expected average. Other areas are of minor importance. No areas of very high or high importance were found, i.e. there are no areas where the abundance of bats exceeds the average.

Most of the study area is of medium importance for bats. The areas of minor importance are near Marienleuchte, Blankenwisch and four places along the main road B207, see Figure 7.32.

Breeding birds

The baseline study registered 74 breeding bird species, of which avocet and marsh harrier are in Annex 1 in the EU Birds Directive. They are also subject to strict protection under Section 7 of the German nature protection Act, as well as the barn owl, common buzzard, kestrel, sparrow hawk, lapwing, long-eared owl, moorhen and ringed plover. Germany's and/or Schleswig-Holstein's red lists have the ringed plover as critically endangered and the lapwing and common partridge as moderately endangered. The following bird species are considered to be vulnerable: skylark, teal, cuckoo, shoveler and barn owl. Another 13 species are registered as potentially endangered. The most frequently occurring species are house sparrow, rook, wood pigeon, blackbird, house martin, skylark, whitethroat and greenfinch. In general, the number of breeding bird species in the study area is average or small in relation to Schleswig-Holstein.

The most breeding birds are seen in the north-western part of the study area at wetlands, along the beach and at Grüner Brink. Other breeding bird locations are villages, the villages' green areas and parts of industrial areas and around the railway.

The criteria for assessing the importance of the breeding bird areas include consideration of:

› Bird abundance and density (Wilms 1997).
› Assessment of habitats (Flade 1994).
Presence of species on red and yellow lists of Schleswig-Holstein, Germany and the EU Birds Directive.
Assessment of local, regional, state and national aspects of importance

No areas are assessed as being of very high importance for breeding birds (Figure 7.32). The coastal area between Grüner Brink and the ferry harbour are of high importance due to the presence of a large population of the red-listed shylark. Large parts of the study area which are characterised by open farm land, lowlands, gardens, villages and some industry areas are of medium importance.

Resting birds
The baseline study registered 26 resting bird species among 8,541 individuals. Golden plover is in Annex 1 in the EU Birds Directive. The most frequently observed species are black-headed gull, grey lag-goose, common gull, mallard and tufted duck. To assess a species that occurs, the observed number of individuals per day within an area is compared with the total incidence at a higher level (for example internationally). Common gull and black-headed gull stand out here with observations of 780 and 900 individuals, respectively. In general, the number of resting bird species and individuals in the study area is small in relation to Schleswig-Holstein. However, there are other areas on Fehmarn outside the study area where more resting birds occur.

The criteria for assessing importance are mainly based on Burdorf (1997) who uses threshold values for the proportion of bird population which gives a local, regional, state and national importance.

Only the categories very high and high are considered. There are no areas of very high importance and only two areas of high importance for resting birds (Figure 7.32). They are agricultural fields southeast of Todendorf (regional importance) and northeast of Landkirchen (local importance) with presence of common gull and black-headed gull.
Figure 7.32 Importance for birds and bats on Fehmarn
Amphibians

In 208 of the 358 water areas studied (ponds, lakes, rivers, ditches), there are one or more amphibian species. Edible frogs and smooth newts are in 70% of the locations and occur frequently and evenly distributed. Crested newts also occur in a quarter of the locations. Five other amphibians (common toads, common frogs, natterjacks, moor frogs and green toads) are also seen. The latter three species are vulnerable according to Germany’s and/or Schleswig-Holstein’s red lists, and crested newts are protected as an Annex IV species in the Habitats Directive.

Edible frogs and smooth newts (and, in part, crested newts) have a high level of exchange of individuals between ponds. On the other hand, the other species are often found in isolated incidences consisting of individual or just a few ponds. In the north-eastern part of the study area at Grüner Brink and the damp forest area of Blankenwisch, all the species mentioned are found, as well as the only incidences of green toads and natterjacks. To this are added three out of four incidences of the moor frog. Other locations with several species and/or few rare species are found south-east of Presen, west of Burg, east of Puttgarden ferry port (a small pond) at Hinrichsdorf and Ostermarkelsdorf. The incidence of amphibians varies with time. Larger concentrations are generally seen in periods in which the amphibians migrate and lay eggs.

The criteria for assessing importance of areas for amphibians include:

- Dominance (each species proportion of the total amphibian population in the study area).
- Relative number (the number of a given species at each locality compared with the total number in the study area).
- Continuity (the number of localities where the species is found).
- Isolation (the number of localities connected by corridors).

There are eight localities of very high importance and six of high importance for amphibians (Figure 7.33). Six of the eight localities of very high importance are near Grüner Brink, Blankenwisch and some artificial ponds immediately to the east. These areas are the most important for amphibians which include Annex IV species natterjack toad, green toad, moor frog and crested newt. The two other localities of very high importance are southeast of Presen where there is an isolated group of moor frog and west of Burg where there is an isolated group of crested newt and smooth newt.

The six localities of high importance consist of ditches at Blankenwisch, a pond east of the ferry harbour, two ponds near Hinrichsdorf and two ponds near Ostermarkelsdorf.

There are also 25 localities of medium importance and 169 of minor importance.
Figure 7.33 Importance for amphibians, reptiles and dragonflies on Fehmarn
Reptiles

The common lizard is the only reptile on Fehmarn. 11 of them were registered in the field studies. Common lizards are not red-listed as an endangered animal species in Germany or Schleswig-Holstein.

The most common lizards in the study area occur around the abandoned railway track immediately east of the main road B 207 and the railway track between Puttgarden and Burg. Other individuals were registered in locations with trees around water areas in the fields, banks, bushes in the outskirts of urban areas and other disused railway tracks. These locations are along the main road B207, at Blankenwisch, north of Burg, at Landkirchen and at the Presen wind farm.

The importance of a locality for reptiles is determined from a consideration of the number of individuals at the locality and its suitability as a habitat. Only few areas and corridors are suitable for skovfirben in the study area. Those of medium importance consist of the main road B207, the railway, the road into Burg and some isolated localities near Blankenwisch and Burg. A disused railway section west of B207 is of minor importance (only one individual observed). See Figure 7.33).

Dragon flies

25 dragonfly species were registered in 140 out of 179 locations (ponds, watercourses, ditches, etc.). Germany's red list contains one species, the migrant spreadwing, indicated as moderately endangered, three species (hairy dragonfly, emerald spreadwing and yellow-winged darter) indicated as vulnerable and two as potentially endangered. Most species are common in Schleswig-Holstein.

The number of species per location is 1 - 11, but only approximately 8% of the locations have more than seven species. The most frequently occurring dragonflies include the ruddy darter, blue-tailed damselfly and common spreading, which are found in 66%, 59% and 54% of the locations, respectively. In a quarter of the locations (in part different locations), the following occur: migrant hawker, vagrant darter, black darter and common blue damselfly. These four species are not endangered and make few demands on their habitats. Nevertheless, the water quality on Fehmarn is often inadequate to maintain stable populations of these species. Many ponds and ditches dry out at irregular intervals and this prevents the propagation of species with single-year or multi-year larva development such as the emperor dragonfly.

All other species are rare in the study area with only a few incidences. The number of species is over seven in only 12 locations. Most of these species-rich locations are in the north-western part of the study area in the immediate surroundings of Puttgarden, Ostermarkelsdorf, Grüner Brink and Blankenwisch. One location is further to the east between Klausdorf and Presen. In these locations, there are dragonflies that make greater demands on their habitats, for example migrant spreadwing and common darter.
The criteria for assessing the importance of area for dragonflies are based on the number of species and which localities fulfil the requirements for specific species which need special conditions.

There are four localities of very high importance (Figure 7.33) consisting of two ponds near Puttgarden, a pond east of Ostermarkelsdorf and a pond beside the ditch between Klausdorf and Presen. There are eight localities of high importance, seven of which lie north of the line Presen-Todendorf. Generally, most of the localities valuable for dragon flies are in the northwest part of the study areas. There are also 33 localities of medium importance and 95 of minor importance.

Grasshoppers and crickets
10 grasshopper species were found in the study area, which is equivalent to a third of the species occurring in Schleswig-Holstein. Two of the species (short-winged conehead and mottled grasshopper) may potentially be endangered, according to Germany's and Schleswig-Holstein's red lists.

The composition of species in the study area is characterised by a lack of suitable habitats. The incidence of mottled grasshopper in the coastal areas west of Puttgarden indicates that there was previously greater variety of species. Lesser marsh grasshopper and common field grasshopper which can tolerate the hard conditions are relatively widespread. Grasshoppers that otherwise occur commonly in Schleswig-Holstein, also in areas characterised by agriculture, have only a few incidences in the study area, for example meadow grasshopper, upland green bushcricket and great green bushcricket. The latter occurs only in the Grüner Brink/Blankenwisch area. This area is also preferred by the short-winged conehead, which is also seen in the wet areas south of Presen and along the coast at Marienleuchte. Roesel's bushcricket occurs along the railway. Dark bushcrickets and speckled bushcrickets are generally seen in trees and bushes and are therefore not as sensitive to environmental impacts from agriculture.

The criteria for assessing the importance of localities for grasshoppers are based on number of species and individuals. The existing pressures in the study area are such that the occurrence of grasshoppers is limited compared with the rest of Schleswig-Holstein. Therefore only areas of medium importance (west of Puttgarden and near Presen) and of minor importance (26 localities) were identified.

Butterflies and moths
There are 18 butterfly species in the study area, which is only equivalent to just under a quarter of the species registered in Schleswig-Holstein. None of the species is endangered and all are widespread in Schleswig-Holstein. The only specialised butterfly is the Queen of Spain fritillary. The others make fewer demands on their environment.

The following species are generally widespread in the study area: small white, small tortoiseshell, ringlet, peacock, meadow brown, green-veined white, red admiral and painted lady. The large white and small heath are found in approximately half of the study area, where they prefer small unused areas and the sections along the railway/main road and coast, respectively. The other species
observed are seen more rarely. There are only eight species in the intensively
cultivated fields, which is few, even for agricultural areas. The locations for the
other species include the areas along the railway/main road, the fallow areas at the
car park for Grüner Brink, the eastern beach areas and the fallow areas at the wet
areas between Klausdorf and Presen.

The criteria for assessing the importance of localities for butterflies are based on
the number of species and individuals. The existing pressures in the study area are
such that the occurrence of butterflies is limited compared with the rest of
Schleswig-Holstein. There are no localities of very high or high importance in the
study area. Six localities of medium importance are found near the railway and in
fallow fields in the northwest and between Klausdorf and Presen. In addition there
are 21 localities of minor importance.

The occurrence of moths was investigated in four smaller areas in Blankenwisch,
near Marienleuchte and north and south of the railway yards. The study did not
allow the classification of localities on the four-level importance scale. The largest
proportion of typical and specialised species was found near Blankenwisch which
is therefore assessed as the most important of the investigated localities. The
Annex IV species, willow-herb hawk moth, was not found in the study area.

Beetles
A total of 5,441 beetles of 67 species were found in the study area, which is a fifth
of the species occurring in Schleswig-Holstein. Two species are regarded as
moderately endangered, five species as vulnerable and three species as potentially
endangered, according to Germany's and/or Schleswig-Holstein's red lists. A few
species are less sensitive to their environment and dominate the observations in
terms of both numbers of individuals and locations. *Pterostichus melanarius* occurs
in 40 out of 45 locations and accounts for 54% of the individuals. *Pterostichus
niger* occurs in 38 locations and accounts for 8% of the individuals. *Anchomenus
dorsalis, harpalus latus, nebría brevicollis* and *notiophilus biguttatus* together
account for 12% of the beetles and are found in 55 - 60% of the observations.

The studies were carried out along the railway/main road and at the car park at
Grüner Brink. Some species prefer specific environments. These are, for example,
wet areas, bushes and trees, fallow areas, roadsides, disused railways, rush areas
and the drained birch and alder areas at Blankenwisch.

The importance of localities for beetles was based on the occurrence of the
individual species on the red and yellow lists of threatened species. The railway
embankment and the railway yard at Puttgarden are of high importance due to the
presence of red-listed species. The intersection of roads B207 and K49 is of
medium importance.

7.5.2 Potential impacts on fauna
The potential impacts on the environmental factor fauna are listed below. They are
addressed in the impact assessment. The following impacts will be examined for
the animal species listed below and their functional elements:
Loss of animal habitats:
- Areas of greater relevance for bats compared to the surroundings
- Breeding bird habitats
- Resting sites for resting birds
- Bodies of water for amphibians
- Amphibian habitats (aquatic/terrestrial) with importance during the spawning period
- Reptile habitats
- Bodies of water for dragonflies
- Moth habitats

Fragmentation of animal habitats and collision hazard (risk of traffic deaths):
- Medium-sized and large mammals
- Bats
- Breeding birds
- Resting birds
- Amphibians (aquatic/terrestrial habitats)
- Reptiles
- Moths (in connection with impairments due to light emissions, as both project pressures act jointly here)

Impairment of animal species in their habitats due to noise and other disturbances:
- Breeding bird habitats
- Resting bird habitats

Impairment of animal species due to light emissions
- Bats

The assessment of the impacts is described in the following sections. The magnitude of the impacts and the severity of loss or impairment is first listed in a table and then illustrated in a figure if relevant. The table includes a qualitative assessment of the impacts as a summary and further text description is not needed. An overall summary is given at the end of the section on fauna together with a description of the mitigation and compensation measures and the overall significance of the impacts.

7.5.3 0-alternative
The situation in the 0-alternative is assessed to be more-or-less the same as the present situation. The Nature Agency for Schleswig-Holstein (Landesamt für Natur und Umvelt) is considering declaring the north and northwest coast a protected area to improve the protection of the natural coast with lagoons and the immediate surroundings. A large part of the area which would be protected is already protected as a Natura 2000 area.
### 7.5.4 Loss of areas of greater relevance for bats compared to the surroundings – impact assessment

**Table 7.27 Bored tunnel: loss of areas of greater relevance for bats compared to the surroundings**

<table>
<thead>
<tr>
<th>Importance</th>
<th>Construction related</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>High</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>Medium</td>
<td>0.25 ha **</td>
<td>5.25 ha **</td>
</tr>
<tr>
<td></td>
<td>- Temporary loss of areas of greater relevance for bats along the B207; only area FL4 (hunting ground) will be affected</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Loss of areas in the sections of greater relevance for bats along the B207; most areas in FL5 will be lost, which serves as a hunting and mating ground, as well as in FL4, a hunting ground; there will be permanent structures on a small part of the area FL6 (hunting and mating ground).</td>
</tr>
<tr>
<td>Minor</td>
<td>0.03 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td></td>
<td>- Temporary use of areas near Marienleuchte during the construction phase; area FL3 (hunting ground) will be affected.</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.27 ha</td>
<td>5.25 ha</td>
</tr>
</tbody>
</table>

**Qualitative description**
- Mainly three areas of greater relevance for bats will be affected by loss. The areas comprise only structures at the edge of the B207 and at the edge of the railway, all of which can be restored or rebuilt in a similar manner in the course of the project.
- The areas which will be lost near Marienleuchte are very small and concern only the edge of the bat area, plus these will only be temporary losses. While the Marienleuchte area also has a potential function as a habitat, no specific habitats in the sense of nursery roosts and winter quarters are to be expected in this border area.
- Building the bored tunnel will cause construction on a small part of a line of bushes east of the ferry port, which functions as a continuation of the route of B207 / railway and where one occurrence of one Daubenton’s bat was recorded.

**Severity of loss**
- ** Very high
- *** High
- ** Medium
- * Minor
Severity of loss: | Very High | High | Medium | Minor |

Figure 7.34  Bored tunnel: Loss of areas of greater relevance for bats compared to the surroundings
### 7.5.5 Loss of breeding bird habitats – impact assessment

**Table 7.28**  Bored tunnel: loss of breeding bird habitats

<table>
<thead>
<tr>
<th>Importance</th>
<th>Impacts</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>High</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>Medium</td>
<td>81.45 ha</td>
<td>50.48 ha</td>
</tr>
<tr>
<td></td>
<td>- Only habitat D4 “Fields with few wooded areas” of temporary use will be affected, on which the vast majority of construction will take place east of the existing B207 / railway.</td>
<td>- The major part of the areas will be lost in the breeding bird habitat D4 “Fields with few wooded areas” east of the B207 (ramp of the Fehmarnbelt Fixed Link and new agricultural road to Marienleuchte); structure related loss will also take place in another part of habitat D4, west of the B207.</td>
</tr>
<tr>
<td>Minor</td>
<td>3.04 ha</td>
<td>18.19 ha</td>
</tr>
<tr>
<td></td>
<td>- Mainly the traffic facility areas of the combined railway and road embankment will be subject to temporary use.</td>
<td>- The permanent losses mainly concern the combined road and street embankment.</td>
</tr>
<tr>
<td></td>
<td>- Only small areas of the habitat A3 “Beaches” east of the ferry port will be subjected to temporary use.</td>
<td>- Moreover, the habitats D5 “Richly structured fields and meadows” west of the B207 and A3 “Beaches” north-east of the ferry port will be affected.</td>
</tr>
<tr>
<td>Total</td>
<td>84.48 ha</td>
<td>68.67 ha</td>
</tr>
</tbody>
</table>

**Qualitative description**
- The use of large areas west of Marienleuchte for construction will cause major construction-related losses.
- Mainly affected by construction- and structure-related losses will be areas of the fields with few wooded areas (D4), which are of medium importance.
Figure 7.35  Bored tunnel: Loss of breeding bird habitats
### 7.5.6 Loss of sites for resting birds – impact assessment

Table 7.29  Bored tunnel: loss of sites for resting birds

<table>
<thead>
<tr>
<th>Importance</th>
<th>Impacts</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>High</td>
<td>0.00 ha</td>
<td>0.39 ha</td>
</tr>
<tr>
<td></td>
<td>- Small section of a resting bird area which is used by black-headed and common gulls</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>Minor</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>Total</td>
<td>0.00 ha</td>
<td>0.39 ha</td>
</tr>
<tr>
<td>Qualitative description</td>
<td>- The loss will occur only at the edge of the resting bird area and on a small scale.</td>
<td></td>
</tr>
</tbody>
</table>

Severity of loss: ⭐⭐⭐⭐ very high  ⭐⭐⭐ High  ⭐⭐ Medium  ⭐ Minor
### 7.5.7 Loss of ponds for amphibians and terrestrial habitats – impact assessment

**Table 7.30** Bored tunnel: loss of ponds for amphibians and terrestrial habitats

<table>
<thead>
<tr>
<th>Importance</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction related Structure related</td>
<td></td>
</tr>
<tr>
<td>very high</td>
<td>0.00 ha No ponds or terrestrial habitats affected</td>
</tr>
<tr>
<td>High</td>
<td>0.18 ha 2 ponds   Loss of two ponds east of the ferry port and one terrestrial habitat</td>
</tr>
<tr>
<td>Medium</td>
<td>0.06 ha 1 pond   Spawning pond between K49 and B207 in the latitude of Todendorf and Presen</td>
</tr>
<tr>
<td>Minor</td>
<td>0.06 ha 4 ponds   Loss of a spawning pond in the south-western section of the &quot;Windpark Presen&quot; wind farm Loss of a spawning pond west of Marienleuchte Loss of a small part of a spawning pond west of Marienleuchte, close to the town Loss of a small part of a spawning pond at the K49</td>
</tr>
<tr>
<td>Total</td>
<td>0.30 ha 5 bodies of water in their entirety and 2 bodies of water partially (= permanent loss; in other words, a total of 7 bodies of water)</td>
</tr>
</tbody>
</table>

**Qualitative description**
- Considering the extent of the construction work, it is to be assumed that in the case of the partially affected bodies of water, the losses will be complete and permanent.
Severity of loss

| Very High | High    | Medium | Minor | construction related |

Figure 7.36 Bored tunnel: loss of ponds for amphibians and terrestrial amphibian habitats
## 7.5.8 Loss of reptile habitats – impact assessment

**Table 7.31 Bored tunnel: loss of reptile habitats**

<table>
<thead>
<tr>
<th>Importance</th>
<th>Impacts</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>0.00 ha</td>
<td>0.0 ha</td>
</tr>
<tr>
<td>High</td>
<td>0.00 ha</td>
<td>0.0 ha</td>
</tr>
<tr>
<td>Medium</td>
<td>1.80 ha</td>
<td>2.96 ha</td>
</tr>
<tr>
<td></td>
<td>•• Temporary loss of areas in the functional area for reptiles along the combined railway and road embankment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>•• Temporary loss of part of the reptile habitat in the western part of the &quot;Windpark Presen&quot; wind farm</td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>0.00 ha</td>
<td>0.0 ha</td>
</tr>
<tr>
<td>Total</td>
<td>1.80 ha</td>
<td>2.96 ha</td>
</tr>
</tbody>
</table>

### Qualitative description
- Altogether, the fragmentation/danger of collision (see below) is more decisive for the habitats of reptiles than their loss, as the habitats lost to the structures at the edge of the railway embankment will be restored after the completion of the bored tunnel.

### Severity of loss
- •••• Very high
- ••• High
- •• Medium
- • Minor
Severity of loss

Very High  High  Medium  Minor  construction related

Figure 7.37  Bored tunnel: loss of reptile habitats
### 7.5.9 Loss of dragonfly habitats – impact assessment

#### Table 7.32 Bored tunnel: loss of dragonfly habitats

<table>
<thead>
<tr>
<th>Magnitude of pressure: very high</th>
<th>Importance</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very high</td>
<td>0.00 ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No ponds affected</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.06 ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 pond</td>
</tr>
<tr>
<td></td>
<td></td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- A pond between K49 and B207 in the latitude of Todendorf and Presen</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.00 ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No ponds affected</td>
</tr>
<tr>
<td></td>
<td>Minor</td>
<td>0.05 ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 ponds (2 ponds partially)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- A pond in the south-western section of the “Windpark Presen” wind farm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- A pond east of the ferry port</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- A narrow area of a pond west of Marienleuchte (= permanent loss)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- A small part of a pond at the K49</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>0.11 ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 ponds in their entirety and 2 ponds partially (= permanent loss; in other words, a total of 5 ponds)</td>
</tr>
<tr>
<td>Qualitative description</td>
<td></td>
<td>- Considering the extent of the construction work, it is to be assumed that the partially impacted ponds will also be lost in their entirety.</td>
</tr>
</tbody>
</table>

Severity of loss

<table>
<thead>
<tr>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
</tr>
</thead>
</table>
Figure 7.38  Bored tunnel: loss of dragonfly habitats
7.5.10 Loss of moth habitats – impact assessment

**Table 7.33**  Bored tunnel: loss of moth habitats

<table>
<thead>
<tr>
<th>Importance</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
</tr>
<tr>
<td>Qualitative description</td>
<td>- The location of the marshalling yard's northern part is in the direct vicinity (approx. 25 m) of the construction field. There will be no construction directly in areas of the switching station north. Therefore no loss is to be expected at this location.</td>
</tr>
<tr>
<td></td>
<td>- The location of the marshalling yard's southern part is in the direct vicinity (approx. 25 m) of the construction field. However, there will be no construction directly at this location, either.</td>
</tr>
<tr>
<td></td>
<td>- Both areas of the marshalling yard are already impacted and are special locations for exchanges among the moth fauna. The marshalling yard's southern part is considerably less valuable than the marshalling yard's northern part, which is the second-most valuable among the locations investigated.</td>
</tr>
<tr>
<td></td>
<td>- The location of Marienleuchte is in the direct vicinity (approx. 20 m) of the construction field. However, there will be no construction at the location.</td>
</tr>
<tr>
<td></td>
<td>- The area of Marienleuchte which the location represents is already impaired with respect to the moth fauna. Due to the highest occurrence of eurytopic species and the vastly reduced range of species, the location is of little value among the four locations investigated.</td>
</tr>
<tr>
<td></td>
<td>- The other location, Blankenwisch, as well as the associated habitats will not be affected by losses.</td>
</tr>
</tbody>
</table>

**Severity of loss**

- Very high
- High
- Medium
- Minor

7.5.11 Fragmentation and traffic collision risk for medium-sized and large mammals – impact assessment

**Table 7.34**  Bored tunnel: fragmentation of habitats and traffic collision risks for medium-sized and large mammals – impact assessment

<table>
<thead>
<tr>
<th>Magnitude of pressure: depends on specific circumstances</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualitative description</td>
<td>- There already exists fragmentation on Fehmarn, with the B207 / railway dividing the island into an eastern and western part for medium-sized and large mammals (more specifically, roe dear and brown hare) (existing impairment)</td>
</tr>
<tr>
<td></td>
<td>- The forecasted traffic volume is not expected to increase the already existing collision hazard and traffic death risk</td>
</tr>
<tr>
<td></td>
<td>- The same applies potentially to the European otter, which is especially sensitive to fragmentation/ collision hazard; It is theoretically already endangered by the existing fragmentation and the traffic on the B207 and the railway if it moves in this area at all. It has not been shown to occur in the area of investigation.</td>
</tr>
</tbody>
</table>
### 7.5.12 Fragmentation and traffic collision risk for bats – impact assessment

**Table 7.35** Bored tunnel: fragmentation of areas of greater relevance for bats compared to the surroundings and risk of traffic collision

<table>
<thead>
<tr>
<th>Magnitude of pressure: depends on specific instance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Special</td>
</tr>
<tr>
<td>General</td>
</tr>
<tr>
<td>- Areas of construction along the route during the construction phase will not generate a considerable collision hazard, as construction vehicles will not drive at a high speed.</td>
</tr>
<tr>
<td>- Only the edge of the area FL3 will be cut off by the construction field, which will not cause fragmentation or any significant collision risk.</td>
</tr>
</tbody>
</table>

**Qualitative description**

- FL4, FL5 and FL6 are areas of greater relevance for bats compared to the surroundings. They are already characterized by existing fragmentation (B207/ railway); bats use this structure, for instance as a guideline; the interesting vegetation structures which are useful for bats as hunting grounds will be generated as new developments at the edge of the route in the areas FL5 and FL6 as a consequence of the bored tunnel. Only in the area FL4 the guideline of the B207/ railway will be crossed and fragmented by the new route. The continuation of the guideline (line of bushes east of the railway system) will only be used to a minor extent by an access road in the northern section. However, this will not create a barrier effect, as the structures at the edge of the road can take over the function as guideline in this area. Moreover, the bats can use the underpass (for the former railway track) which is newly built. Furthermore, a Daubenton’s bat (special sensitivity towards fragmentation) was recorded here once, but its behaviour was indifferent (but hunting can be excluded, as the species does not find suitable hunting habitats in the area of investigation) and higher frequentation could not be observed.

- There will not be any significant barrier effect for the species, because theoretically it can move from the wooded structure at the newly built western vegetation structures of the bored tunnel further southwards, or vice versa; nor is any collision hazard to be expected for this species for the same reason (also because it does not regularly occur in the investigation area but only in exceptional instances).

- The collision hazard for the species which have been regularly recorded in the affected areas FL4 and FL5 is medium, because they are accustomed to the already existing impairment by B207/ railway and also have hunting grounds in the already impaired areas.

- No significant collision hazard can be established for the regularly recorded species in the area FL6, since only the edge of the area will be affected by fragmentation.

- The brown long-eared bat (special sensitivity to fragmentation, due to the structure) was only recorded as an exception in the area FL6, it does not occur regularly, because the area of investigation also lacks suitable habitats. Should the species use the B207/ railway as a guideline, this will not result in a collision hazard, as the guideline function will then be assumed by the newly developed vegetation structures of the bored tunnel.

<table>
<thead>
<tr>
<th>Severity of impairment</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Insignificant impairment</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Severity of impairment: **Medium**  

**Fragmentation**

*Figure 7.39*  
Bored tunnel: fragmentation of areas of greater relevance for bats compared to the surroundings and risk of traffic collision
### 7.5.13 Fragmentation and traffic collision risk for breeding birds – impact assessment

**Table 7.36 Bored tunnel: fragmentation of breeding bird habitats and traffic collision risk for breeding birds**

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
</tr>
<tr>
<td>Very high</td>
<td>Not affected</td>
</tr>
<tr>
<td>High</td>
<td>Not affected</td>
</tr>
<tr>
<td>Medium</td>
<td>- No fragmentation in the habitat “Fields with few wooded areas” (D4), as the construction site areas are directly connected to the existing traffic facilities and the planned structure.</td>
</tr>
<tr>
<td></td>
<td>- Fragmentation of the breeding bird habitat “Fields with few wooded areas” (D4)</td>
</tr>
<tr>
<td></td>
<td>- Three fairly large as well as smaller isolated areas will be created east of the B207/ railway.</td>
</tr>
<tr>
<td></td>
<td>- West of the B207/ railway there is a loss at the edge of the bird habitat (D4) but there is no fragmentation which creates isolated areas.</td>
</tr>
<tr>
<td></td>
<td>- The magnitude of pressure is medium.</td>
</tr>
<tr>
<td></td>
<td>- Medium traffic collision hazard in the breeding bird habitat “Fields with few wooded areas” (D4).</td>
</tr>
<tr>
<td></td>
<td>- The magnitude of pressure is medium because of the existing impacts.</td>
</tr>
<tr>
<td>Minor</td>
<td>- No fragmentation in the sense of isolation in the habitat “Beaches” east of the ferry port, as the construction site area will only be established at the edge of the habitat.</td>
</tr>
<tr>
<td></td>
<td>- There is loss of breeding habitats D5 west of the B207 and A3 east of the ferry port due to the new structure. Fragmentation of these areas is described above.</td>
</tr>
<tr>
<td></td>
<td>- The magnitude of pressure is medium because of the existing impacts.</td>
</tr>
<tr>
<td></td>
<td>- Minor traffic collision hazard in the breeding bird habitats “Richly structured fields and meadows” (D5) west of the B207 and ”Beaches” (A3) east of the ferry port</td>
</tr>
<tr>
<td></td>
<td>- The magnitude of pressure is medium because of the existing impacts.</td>
</tr>
<tr>
<td>Qualitative description</td>
<td>- The ferry port as well as the B207 and railway already cause a fragmentation of the breeding bird habitats, splitting them into a western and an eastern part.</td>
</tr>
<tr>
<td></td>
<td>- No isolation will occur as a consequence of the construction, as the construction site areas are either directly adjacent to the existing or planned traffic facilities or will only be set up at the edge of habitats.</td>
</tr>
<tr>
<td></td>
<td>- Moreover, the construction will not result in a significant traffic collision hazard, as the construction vehicles do not move fast.</td>
</tr>
<tr>
<td></td>
<td>- West of the existing B 207/ railway there is no fragmentation that leads to isolated areas. Only the breeding habitats at the edges are affected. East of the B207/ railway isolated area are created by fragmentation.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Severity of impairment</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>•••• Very high</td>
<td>••• High</td>
<td>•• Medium</td>
<td>• Minor</td>
</tr>
<tr>
<td></td>
<td>- Insignificant impairment</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Severity of impairment  Medium  Fragmentation

Figure 7.40  Bored tunnel: fragmentation of breeding bird habitats and traffic collision risk for breeding birds
# 7.5.13.1 Fragmentation and traffic collision risk for resting birds – impact assessment

Table 7.37 Bored tunnel: fragmentation of resting sites and traffic collision risk for resting birds

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Magnitude of pressure: depends on specific instance</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special</td>
<td></td>
<td>Construction related</td>
</tr>
<tr>
<td>General</td>
<td></td>
<td>- No construction-related traffic collisions</td>
</tr>
<tr>
<td>Qualitative description</td>
<td></td>
<td>- The structure-related use of areas will not result in the isolation of areas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Since the construction site vehicles move at a slow speed, no construction-related collisions are to be expected.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- There already exists a collision hazard for the registered black-headed and common gulls due to the operation of the B207/railway. An operation-related medium collision hazard is forecasted due to the project.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Severity of impairment</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*****</td>
<td>***</td>
<td>**</td>
<td>*</td>
</tr>
</tbody>
</table>
### 7.5.14 Fragmentation and traffic collision risk for amphibians – impact assessment

Table 7.38  Bored tunnel: fragmentation of amphibian habitats (aquatic and terrestrial) and traffic collision risk

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Construction related</th>
<th>Structure related</th>
<th>Operation related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>(No impairment)</td>
<td>(No impairment)</td>
<td>(No impairment)</td>
</tr>
<tr>
<td>High</td>
<td>- No fragmentation of habitats due to the construction-related use of areas, as respective habitats will be permanently lost anyway</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(No impairment)</td>
<td>(No impairment)</td>
<td>(No impairment)</td>
</tr>
<tr>
<td>Medium</td>
<td>(No impairment)</td>
<td>(No impairment)</td>
<td>(No impairment)</td>
</tr>
<tr>
<td></td>
<td>- No construction-related fragmentation of habitats east of the ferry port, as areas will lose their function anyway due to the loss of the respective spawning pond</td>
<td>- No fragmentation of habitats east of the ferry port due to the bored tunnel portal, as they will lose their function anyway due to the loss of the respective spawning pond</td>
<td>- No collision hazard must be examined east of the ferry port, as all terrestrial and aquatic habitats will be lost there.</td>
</tr>
<tr>
<td>Minor</td>
<td>(No impairment)</td>
<td>(No impairment)</td>
<td>(No impairment)</td>
</tr>
<tr>
<td>Qualitative</td>
<td>- The habitats east of the ferry port (two spawning ponds and terrestrial habitats) are already isolated due to traffic infrastructure (ferry port, railway) and intensive agriculture, and will now be lost in their entirety. No impairment due to fragmentation or collision hazard can actually occur any longer.</td>
<td>- The same applies to the two spawning ponds of minor importance west of Marienleuchte, between which exchange takes place.</td>
<td></td>
</tr>
<tr>
<td>description</td>
<td>- The same applies to the two spawning ponds of minor importance west of Marienleuchte, between which exchange takes place.</td>
<td>- In the southern area of the bored tunnel structure, ranges of action of the common newt, which engages in exchanges beyond the B207/ railway, will be fragmented. The sensitivity is minor and there is already existing impairment in the form of fragmentation and collision hazard because of the B207/ railway. The impact will not be exacerbated relative to the current situation.</td>
<td></td>
</tr>
</tbody>
</table>
| Severity of impairment  | ●●●● Very high | ●● High | ● Medium | ● Minor
7.5.15 Fragmentation and traffic collision risk for reptiles – impact assessment

Table 7.39  Bored tunnel: fragmentation of reptile habitats and traffic collision risk

<table>
<thead>
<tr>
<th>Magnitude of pressure: depends on specific circumstances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Special</td>
</tr>
<tr>
<td>General</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Qualitative description</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Severity of impairment

| Very high | High | Medium | Minor |

7.5.16 Fragmentation and traffic collision risk in connection with light emissions for moths – impact assessment

Table 7.40  Bored tunnel: Fragmentation and traffic collision risk in connection with light emissions for moths

<table>
<thead>
<tr>
<th>Magnitude of pressure: depends on specific circumstances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Very high</td>
</tr>
<tr>
<td>High</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>High</td>
</tr>
</tbody>
</table>
## Magnitude of pressure: depends on specific circumstances

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impacts</th>
<th>Operation related</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction related</strong></td>
<td><strong>Structure related</strong></td>
<td>beyond this connection have been documented.</td>
</tr>
<tr>
<td>crashing into them or by burning unless this is prevented by the design of the lamp.</td>
<td>- Since the ramp inclines towards the bored tunnel portal, its illumination will not cover as much of the surrounding area as lighting would that is mounted higher up. Consequently, the surrounding areas will be less affected by light emissions.</td>
<td>- In the area of up to 600 m before the ramp, the operation-related light emissions from the cars will be superseded by the impacts of the structure-related lighting of the route. As a result, no significantly increased operation-related collision hazard for moths can be established for this section, especially since no exchanges of moth species across the route are documented.</td>
</tr>
<tr>
<td><strong>Medium</strong></td>
<td>- The northern part of the marshalling yard (which is already light-impaired) is about 25 m away from the construction-related area west of the project route (magnitude of pressure is medium).</td>
<td>- The southern section of the marshalling yard is about 210 m away from the lighted ramp of the bored tunnel. The southern section of the marshalling yard is even further away. Due to the distances and the projected use of lamps with a minor attraction for moths, it is not to be assumed that there will be any relevant attraction effects on the moths. The severity of the impairment is altogether classified as insignificant.</td>
</tr>
<tr>
<td>- Given a maximum spotlight height of 10 m, it is likely that moths will be attracted from the area without finding their way back to their home habitat.</td>
<td>- The northern section of the marshalling yard is about 210 m away from the lighted ramp of the bored tunnel. The southern section of the marshalling yard is even further away. Due to the distances and the projected use of lamps with a minor attraction for moths, it is not to be assumed that there will be any relevant attraction effects on the moths. The severity of the impairment is altogether classified as insignificant.</td>
<td>- Considering the intensity of the future road and railway traffic compared to the existing road and railway traffic and the existing general mortal risk for moths, the severity of operation-related impairments is classified as insignificant.</td>
</tr>
<tr>
<td>- They may die at the hot spotlights by crashing into them or by burning unless this is prevented by the design of the lamp.</td>
<td>- The secondary structures are about 100 m away from the southern section of the marshalling yard. Due to the only sporadic lighting in this area, the impairment must be assessed as insignificant.</td>
<td>- The southern section of the switching station is about 80 m from the construction area.</td>
</tr>
<tr>
<td>- If the spotlights are turned away from the areas of medium sensitivity, the severity of the impact is going to be reduced accordingly.</td>
<td>- -</td>
<td>-</td>
</tr>
<tr>
<td>- Despite the intensive construction-related lighting in individual spots, altogether the severity of impairment at the location of the marshalling yard's northern part, where moths have been observed, is classified as medium because of the already existing impairment and the adjustment of the lighting to the respective construction activities.</td>
<td>- -</td>
<td>-</td>
</tr>
<tr>
<td>- The southern section of the switching station is about 80 m from the construction area.</td>
<td>- -</td>
<td>-</td>
</tr>
<tr>
<td>- The southern section of the switching station will be impaire by construction-related light for just a short time, since there will be no construction-related long-term lighting along the route as it is going to be in the area of the bored tunnel portal and the large construction-related area west of Marienleuchte. Consequently, the gravity of the impairment is considered to be insignificant.</td>
<td>- -</td>
<td>-</td>
</tr>
</tbody>
</table>
Magnitude of pressure: depends on specific circumstances

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
</tr>
<tr>
<td>Minor</td>
<td>Not classified</td>
</tr>
</tbody>
</table>

Qualitative description
- During the construction work for the bored tunnel, light will mainly be emitted in the area east of the tunnel portal as well as around the bored tunnel portal for an extended period.
- The tunnel ramp inclines gradually towards the tunnel portal. As a result, fewer light emissions in the immediate vicinity of the tunnel portal will be projected into the surroundings.
- The use of lamps with minor attraction for moths will mitigate the impact on moths. Moreover, the lighting will be generally adjusted to the pertinent conditions (weather, traffic, time of day). This will further reduce its potential impact on moths. Therefore no structure-related attraction will be exerted on highly sensitive moths from the area of Marienleuchte, the location where they have been observed.
- Compared to the construction-related light emissions, the structure-related impacts caused by the use of lamps with minor attraction for moths will be smaller.
- Compared to the status quo, the increase in traffic will not significantly worsen the already existing collision hazard with the road and railway traffic. The reason is that there are few exchanges between the different locations where moths have been recorded. An exchange takes only place between the two locations of the marshalling yard (northern and southern part). However, the interactions between the marshalling yard's northern part and the marshalling yard's southern part take place parallel to the route rather than crossing it.

Severity of impairment
- •••• Very high
- •• High
- • Medium
- • Minor

- Insignificant impairment

* With respect to moths there is a very close connection between the project pressures fragmentation and traffic collision hazard on the one hand and light emissions on the other. For this reason they are not examined separately for this species group but jointly.
7.5.17 Impairment of breeding bird habitats by noise and other disturbances – impact assessment

Preliminary remarks concerning operation-related impacts: The special sensitivity of the respective breeding pairs that will be affected was always taken as precautionary value to determine the severity of impairments in the three operation-related impact zones.

Table 7.41  Bored tunnel: impairment of breeding bird habitats and breeding areas due to operation-related noise and other disturbances

<p>| Permanent impairments near the route, impact zone 1 (0 to 100 m from the edge of the railway/road), Magnitude of pressure: high |</p>
<table>
<thead>
<tr>
<th>Qualitative description</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation related</td>
<td></td>
</tr>
<tr>
<td>52.70 ha</td>
<td></td>
</tr>
<tr>
<td>The following breeding pairs (BP) will probably be affected inside impact zone 1:</td>
<td></td>
</tr>
<tr>
<td>4 breeding pairs of specially sensitive species</td>
<td></td>
</tr>
<tr>
<td>4 breeding pairs of an endangered species</td>
<td></td>
</tr>
<tr>
<td>****</td>
<td></td>
</tr>
</tbody>
</table>

Predominantly the breeding bird habitat “Fields with few wooded areas” (D4) in impact zone 1 will be impaired:
- The major part of the affected areas is east of the B207, where there are only relatively few breeding pairs (already existing impairment by B207 and railway, intensive agriculture).
- Even so, there are occurrences, and there will be impairment, of the specially sensitive skylark (2 BP), which is furthermore on the Red List (D, S-H).
- South-west of the B207, areas of the habitat D4 will also be affected. Thanks to the already existing impairment, however, only few breeding pairs breed near the existing route there.
- One breeding pair of the skylark breeds there near the edge of the road.
- West of the B207 there are no breeding pairs in the affected areas in the habitat D4.

One breeding pair of the endangered skylark will be impaired in the breeding bird habitat “Richly structured fields and meadows” (D5), but the species currently already breeds near the impaired B207/ railway.

While other breeding bird habitats will also be affected by noise and other disturbances in this impact zone, no breeding pairs will be impaired in the affected areas:
- “Traffic facilities”

<p>| Permanent impairments near the route, impact zone 2 (100 to 300 m from the edge of the railway/road), Magnitude of pressure: medium |</p>
<table>
<thead>
<tr>
<th>Qualitative description</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation related</td>
<td></td>
</tr>
<tr>
<td>117.80 ha</td>
<td></td>
</tr>
<tr>
<td>The following breeding pairs will probably be affected inside impact zone 2:</td>
<td></td>
</tr>
<tr>
<td>9 breeding pairs of specially sensitive species</td>
<td></td>
</tr>
<tr>
<td>6 breeding pairs of generally sensitive species</td>
<td></td>
</tr>
<tr>
<td>5 breeding pairs of an endangered species</td>
<td></td>
</tr>
<tr>
<td>1 breeding pair of a strictly protected species</td>
<td></td>
</tr>
<tr>
<td>***</td>
<td></td>
</tr>
</tbody>
</table>

In impact zone 2, it is again mainly the habitat “Fields with few wooded areas” (D4) that will be affected:
- East of the B207/ railway, most areas will be affected.
- However, when looking at the fields and meadows, only relatively few individuals and, most importantly, few species will be affected; one breeding pair each of the skylark (Red list D/ S-H), whitethroat and chiffchaff will be impaired (all of special sensitivity).
- Contrary to the fields and meadows, considerably more breeding pairs and more species will be affected at the edge of the "Fields with few wooded areas" bordering on the ferry port.
- Here the following species were registered along the bush and hedge structure, all of which are already subject to existing impairment by noise and other disturbances from the nearby ferry port, and which are accustomed to it:
  - the generally sensitive species wood pigeon, dunnock and great titmouse
  - the especially sensitive species linnet (1 BP) and chiffchaff (1 BP)
- South-west of the B207, in the habitat "Fields with few wooded areas", only one breeding pair of the endangered skylark will be affected by noise and other disturbances.
- West of the B207, areas of the breeding bird habitat "Fields with few wooded areas" will also be affected, but only one breeding pair of the moorhen (strictly protected, of general sensitivity) at a pond; that no additional bird species will be affected is an indication of the already existing impairment of the area due to the operation of the current infrastructure.

As another breeding bird habitat in this zone, “Richly structured fields and meadows” (D5) west of the B207 will be affected by noise and other disturbances:
- Here three breeding pairs of the skylark exist which breed in the already impaired area of the B207 and railway (accustomed to existing impairment).
- Furthermore, the generally sensitive mallard can be found there.

Other breeding bird habitats in this zone are:
- "Industrial areas and railway systems (Puttgarden)“ (F9) – but here only the generally sensitive wood pigeon will be affected
- "Traffic facilities"

### Permanent impairments near the route, impact zone 3 (300 to 500 m from the edge of the railway/road),
Magnitude of pressure: minor

<table>
<thead>
<tr>
<th>Qualitative description</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operation related</strong></td>
<td></td>
</tr>
<tr>
<td>128.35 ha</td>
<td></td>
</tr>
<tr>
<td>The following breeding pairs will probably be affected inside impact zone 3:</td>
<td></td>
</tr>
<tr>
<td>5 breeding pairs of specially sensitive species</td>
<td></td>
</tr>
<tr>
<td>175 breeding pairs of generally sensitive species</td>
<td></td>
</tr>
<tr>
<td>3 breeding pairs of endangered species</td>
<td></td>
</tr>
<tr>
<td>1 breeding pair of a strictly protected species</td>
<td></td>
</tr>
</tbody>
</table>

Mainly the breeding bird habitat "Fields with few wooded areas“ (D4) will be affected by noise and other disturbances in this impact zone 3:
- The major part of the area will be impaired east of the existing B207 and railway.
- In the fields and meadows themselves only few breeding pairs will be affected:
  - particularly sensitive species: one breeding pair each of the skylark (endangered according to Red list D/ S-H), the lapwing (seriously) endangered according to Red list D/S-H, strictly protected) and the white wagtail
  - On the areas of the same habitat west of the B207, the specially sensitive species skylark (1 BP) and whitethroat (1 BP) as well as the generally sensitive blue-headed wagtail will be affected.
  - On the areas of the same habitat west of the B207, the especially sensitive species skylark (1 BP) and whitethroat (1 BP) as well as the generally sensitive blue-headed wagtail will be affected.

In the breeding bird habitat “Richly structured fields and meadows” (D5) west of the B207, only the generally sensitive blue-headed wagtail will be affected.

In the breeding bird habitat “Industrial areas and railway systems (Puttgarden)” (F9), which is characterized by already existing impairments, there are occurrences of the generally sensitive species wood pigeon and rook.

In the small affected area of the habitat "Villages“ (F6) (Puttgarden), no breeding pairs will be affected.
In the three zones there will be very high (impact zone 1), high (impact zone 2) and medium severity of impairment (impact 3, see above), because the especially sensitive breeding pairs are taken as the decisive precautionary value. However, it must be noted that the impaired areas are already subject to existing impairment by noise and disturbances caused by the B207 and railway (at least in the lower area of the alternatives), and, compared to the total area, only few (but especially sensitive) breeding pairs occur in the affected areas (cf. listing in the table above). This qualifies the evaluated severity of the impairments in this area.

**Preliminary remarks concerning construction-related impacts:** The impact zones subject to permanent noise and other disturbances and the construction-related impact zone largely overlie one another. Parallel to the road, the character of the construction-related impact zone is not essentially different from that of the permanent impact zones 1, 2 and 3 altogether. It is only where the connections of the side streets will be built and the work harbour takes up large areas of land that the construction-related impact zone reaches far beyond the permanent impact zones 1 to 3.

At the tunnel, the permanent impact zones end at the entrance to the tunnel and hence do not extend all the way to the coastline. In other words, the breeding pairs residing there will only be impaired by temporary noise and disturbances.

Though mostly the same species and habitats will be affected as those within the permanent impact zones 1 to 3, it must be noted that the impact of construction site noise and disturbances will be different to the operation-related impacts. Due to the discontinuous and non-directional movements at the construction site, only one impact zone (0–500 m) with one magnitude of pressure (high) has been designated rather than subdividing it into several impact zones and allocating different magnitudes of pressure to it.

Since the breeding pairs being affected by temporary impairment are often identical with permanently impaired breeding birds later on (in all three impact zones), only those breeding birds which occur additionally in the temporarily impaired areas beyond the permanent impact zones are discussed below.

As was done concerning the operation-related impairments, the special sensitivity of the respective breeding pairs that will be affected was always taken as precautionary value to determine the additional severity of the construction-related impairments.
### Table 7.42  
**Bored tunnel: impairment of breeding bird habitats and breeding areas due to construction-related noise and other disturbances**

<table>
<thead>
<tr>
<th>Temporary impairments, impact zone 0 - 500 m from the construction site, Magnitude of pressure: high</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualitative description</td>
<td>Construction related</td>
</tr>
<tr>
<td></td>
<td>207.54 ha (in addition to breeding bird habitats permanently impaired by noise, see above). In addition, the following breeding pairs are likely to be affected in the construction-related impact zone:</td>
</tr>
<tr>
<td></td>
<td>- 31 breeding pairs of specially sensitive species</td>
</tr>
<tr>
<td></td>
<td>- 143 breeding pairs of generally sensitive species</td>
</tr>
<tr>
<td></td>
<td>- 3 breeding pairs of strictly protected species</td>
</tr>
<tr>
<td></td>
<td>*****</td>
</tr>
</tbody>
</table>

Mainly the breeding bird habitat “Fields with few wooded areas” (D4) will be impaired by noise and disturbed by the construction site operation (approx. 136 ha).

- Especially the area east of the B207/ railway will be impaired in addition to the permanently impacted areas.
  - Aside from the permanently impaired breeding pairs, mainly generally sensitive species east of the existing B207/ railway (mallard, garden warbler, chaffinch, black redstart, magpie, lesser whitethroat, house sparrow, dunnock, great titmouse, wood pigeon and common blackbird) will be temporarily impaired.
  - The following temporarily affected species are specially sensitive: greenfinch (1 BP), song thrush (3 BP), icerine warbler (1 BP), whitethroat (1 BP), linnet (1 BP), white wagtail (1 BP), stock dove (1 BP) and common buzzard (1 BP).
- In addition, west of the B207/ ferry port, a breeding pair of the whitethroat (special sensitivity) and the generally sensitive blue-headed wagtail will be impaired.

Aside from these, only the generally sensitive mallard will be impaired in the habitat “Richly structured fields and meadows” (D5).

In the breeding bird habitat “Villages” (F6) in Puttgarden, next to generally sensitive species [collard dove, wood pigeon, chaffinch, blue tit, house martin, lesser whitethroat, mallard, common blackbird, great titmouse, European goldfinch, redstart and moorhen (strictly protected)] breeding pairs of the specially sensitive species whitethroat (2 BP), linnet (2 BP), chiffchaff (1 BP) and icerine warbler (1 BP) will be temporarily impaired. In the habitat “Villages” (F6) in Marienleuchte, generally sensitive species (collard dove, wood pigeon, magpie, house sparrow, great titmouse, common blackbird, blue tit, chaffinch, dunnock, spotted flycatcher and starling) as well as carrion crow (1 BP), sparrowhawk (1 BP; strictly protected), chiffchaff (3 BP), icerine warbler (1 BP), white wagtail (4 BP), greenfinch (1 BP) and stock dove (1 BP) (all with special sensitivity) will be temporarily impaired by noise and other disturbances.

Moreover, generally sensitive species (chaffinch, common blackbird, house martin, wood pigeon and lesser whitethroat) will be impaired on the ferry port ground [“Industrial areas and railway areas” (F9)]. The white wagtail is particularly sensitive (1 BP). No assessment of the sensitivity based on the general method applied here can be made for the species herring gull and common gull, which were found here; however, their occurrence in areas already affected by noise and other impairments rather indicates that they are of general sensitivity.

In addition to these, only generally sensitive species (starling, chaffinch, common blackbird, great titmouse, wood pigeon and tree sparrow) will be impaired on the ferry port ground [“Industrial areas and railway areas” (F9)].

Moreover, the generally sensitive species garden warbler and oystercatcher will be impaired in the habitat “Beaches” (A3 – ferry dock area up to Presen). As an especially sensitive species, 1 BP of the icerine warbler will be impaired.

**Summary qualitative description**

- The construction-related noise and disturbances will result in an impairment of very high severity, because the precautionary value that was applied was the special sensitivity of breeding pairs which will be affected. As in the operation-related impacts, so in the construction-related impairment at least the southern section is already impaired by noise and other disturbances at this point, which qualifies the severity of the impairment in this area.

<table>
<thead>
<tr>
<th>Severity of impairment</th>
<th>••• Very high</th>
<th>•• High</th>
<th>• Medium</th>
<th>• Minor</th>
</tr>
</thead>
</table>
Figure 7.41  Bored tunnel: impairment of breeding bird habitats and breeding areas due to operation and construction-related noise and other disturbances
7.5.18 Impairment of resting bird habitats by noise and other disturbances – impact assessment

Table 7.43  Bored tunnel: impairment of resting sites for resting birds due to noise and other disturbances

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impacts</th>
<th>Operation related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Construction related</strong></td>
<td></td>
</tr>
<tr>
<td>Special</td>
<td>Not affected</td>
<td>Not affected</td>
</tr>
<tr>
<td>General</td>
<td>0.65 ha</td>
<td>29.38 ha</td>
</tr>
<tr>
<td></td>
<td>- Northern part of an area which is used by common and black-headed gulls and is located west of the B207/ railway between Bannesdorf and Hinrichsdorf</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- The magnitude of pressure is medium because of the existing impacts</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.65 ha</td>
<td>29.38 ha</td>
</tr>
<tr>
<td></td>
<td>(Construction-related and operation-related impact zone largely overlie one another, therefore only the additionally impacted areas due to construction are listed here.)</td>
<td></td>
</tr>
<tr>
<td>Qualitative description</td>
<td>- The area is already impaired due to the traffic on the existing B207/ railway as well as intensive use of land. Even so, the gulls recorded here use the area as a resting site.</td>
<td></td>
</tr>
</tbody>
</table>

Severity of impairment: 
- Very high
- High
- Medium
- Minor
7.5.19 Impairment of bats due to light emissions – impact assessment

Only impairments of bats due to light emissions are considered in this section on fauna.

The impact of light emissions on moths is included in the section on fragmentation and traffic collision risk above due to the close connection with light emissions.
### Table 7.44  Bored tunnel: impairment of bats due to light emissions

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction related</td>
<td>Structure related</td>
</tr>
<tr>
<td>Special</td>
<td>Not affected (cf. qualitative description)</td>
</tr>
<tr>
<td>General</td>
<td></td>
</tr>
<tr>
<td>- Construction-related light emissions will have an impact on the Marienleuchte area (FL3). This is a minor magnitude of pressure.</td>
<td>- No area of greater relevance for bats will be affected by the lighting of the bored tunnel ramp (limited range of lamps with minor attraction for moths used).</td>
</tr>
<tr>
<td>- Scattered construction-related light emissions along the route being built will have an impact on two areas of greater relevance for bats (FL4, FL5) along the B207 / railway. This is a minor magnitude of pressure.</td>
<td>- The bats can also occur outside of the areas of greater relevance for bats; should they occur at additional sites affected by structure-related light, at worst only little impairment due to light would have to be expected.</td>
</tr>
<tr>
<td>- Due to the general sensitivity towards light emissions of the bat species occurring here and a minor magnitude of pressure, the severity of impairment is to be categorized as minor.</td>
<td>- The area FL4 is near the secondary structures; however, since it will be illuminated only sporadically, no significant impairments of the generally sensitive bat species recorded here will result.</td>
</tr>
<tr>
<td>Qualitative description</td>
<td></td>
</tr>
<tr>
<td>- There will not be any construction-, structure- or operation-related impairments of specially sensitive bat species, even if structures where they have been recorded will be touched by light emissions. The reason is that the observations of Daubenton's bat and Nathusius' pipistrelle individuals were exceptional and the possibility of their hunting in the area can be excluded; there are no suitable hunting grounds for either one of the two species. For the Nathusius' pipistrelle (wood species) there are no suitable hunting grounds in the entire study area where this species will react very sensitively with respect to light.</td>
<td></td>
</tr>
</tbody>
</table>

| Severity of impairment | •••• Very high | •• High | • Medium | • Minor |
7.5.20 Summary of impacts

Bats
There are three main areas of medium importance for bats (hunting and mating grounds) which will be affected by loss (about 5.5 ha). The areas comprise only structures at the edge of the B207 and at the edge of the railway, all of which can be restored or rebuilt in a similar manner in the course of the project. No specific habitats in the sense of nursery roosts and winter quarters are affected by the project. Only in two areas is there an additional traffic collision risk of medium severity for bats. There will not be any construction-, structure- or operation-related impairments of especially sensitive bat species by light emissions.

Birds
The permanent structures will cause the loss on about 69 ha of bird breeding areas while the temporary construction works will affect about 84.5 ha. Although the areas are relative large they are only of (mainly) medium or minor importance for birds and are mostly arable land. The project will cause medium additional fragmentation of bird habitats and minor to medium additional risks for road deaths of individuals. The area is already fragmented by the B207 and the railway. During construction phase there is no relevant traffic collision risk. Noise in the operation phase will impact an area of 298 ha in zones with various degrees of severity. However, it must be noted that the impaired areas are already subject to existing impairment by noise and disturbances caused by the B207 and railway and, compared to the total area, only few, but especially sensitive breeding pairs occur in the already affected areas – the birds have become accustomed to the noise. The impact zones subject to permanent noise and other disturbances and the construction-related impact zone largely overlap one another. The disturbance due to temporary construction noise is assessed to impair additionally an area of 208 ha. The area is already impaired by noise and other disturbances which qualifies the severity of impairment.

The loss of resting places for resting birds by the project is negligible.

Amphibians, reptiles and mammals
Amphibians will be impacted through the permanent loss of seven ponds suited for amphibians in areas of permanent structures and construction activities. Besides loss of habitat structures, additional fragmentation of amphibian habitats by the project is assessed as negligible. For reptiles the fragmentation/danger of traffic collision of medium severity is more decisive for the habitats of reptiles than their loss, as the habitats lost to the structures at the edge of the railway embankment will be restored after the completion of the bored tunnel. Deer and hare (red-listed) are common in the study area and are sensitive to fragmentation and traffic. However the area is already fragmented by the B207 / railway dividing the island of Fehmarn into an eastern and western part and the traffic prediction does not indicate any noticeable increase in road kills.

Insects
With respect to insects one pond of high importance and four of minor importance for dragonflies will be lost. The railway yard is important for moths but is not
affected by loss by the project. Lighting during construction will attract moths and the impairment is assessed medium to high. Damped lighting will be used at the tunnel portals during operation and considering that the project will only have a negligible impact on moths.

7.5.21 Mitigation and compensation measures
The following mitigation and compensation measures will be implemented:

› New ponds will be established to compensate for the losses which impact birds (breeding), amphibians and dragonflies. They will be constructed before the existing ponds are filled, vegetation will be planted and amphibians transferred from the existing ponds to the new ones. The number and location of the new ponds are to be agreed with the authorities.

› Clearing of vegetation will occur outside the bird breeding season.

› Restoration of construction areas and the road and railway corridors with trees and bushes at the end of construction will mitigate impacts on bats, birds and reptiles. It will provide commuting lines for bats.

› Hibernation habitats will be established for the Northern Crested Newt (compensation for lost areas).

› Amphibian fences will be established at required locations to mitigate impacts during construction and operation.

› Fauna passages will be established. The culverts which lead the drainage ditches under the motorway and railway will be wide enough and have paths at the side to function as fauna passages. Another new fauna passage will be established across a small stream.

› Lighting used at the construction sites and along the motorway and railway will be of a type which reduces the attraction of insects.

› Noise which can disturb fauna during construction will be regulated according to standards and guidelines and controlled by the site environmental management plan.

› Monetary compensation will be made through the eco-account for the residual impacts which are not negligible according to the German practice.

7.5.22 Conclusion – significance of impacts
The implementation of the comprehensive mitigation and compensation measures are assessed to render the project impacts on fauna as insignificant during both the construction and operation phases of the bored tunnel alternative.
7.6 Flora

The dominant biotope on Fehmarn is agricultural fields crossed by belts of trees and hedge rows of shrubs and bushes. A large number of small wetlands, especially ponds, are evenly distributed throughout the farmland.

Along the coasts, especially the north and west coasts, the biotope is characterised by brackish lagoons with reed forests, salt meadows and sandy dunes. Cliffs occur along parts of the east coast.

7.6.1 Existing flora

Plants

76 plant species which were found in the study area are on Schleswig-Holstein's and/or Germany's red lists. On Schleswig-Holstein's list one species is regarded as extremely rare, four species as critically endangered, nine as moderately endangered, 28 as vulnerable, 30 as potentially endangered and one has insufficient data. The endangered species (golden marguerite, meadow brome, dropwort and field gromwell) are found in only 1 or 2 places. The moderately endangered species (greater spearwort, fringed water-lily, bur chervil, briza, British yellowhead, wood sage, hairy smotherweed and black horehound) are found in only a few places, apart from the latter, which occurs more regularly.

13 species from Schleswig-Holstein's red list were found by the unused railway track south of Puttgarden's ferry port. Several of the species were not found elsewhere in the study area (field cottonrose, little cottonrose, pale toadflax, annual pearlwort and wood sage). South of Marienleuchte on the dunes between the water and the dike, 10 species were registered from the red list, of which dropwort was only found here. There are several examples of sites with red-listed species at Grüner Brink, in the dunes east of Presen and on the dike slope between Blankenwisch and Puttgarden. Other locations with red-listed species are additional sections of coast, hedges and some places in fields, in ponds, in groves and along roads.

Fungi

93 fungus species were identified in 22 locations in the study area. Two of the species are considered to be extremely rare, and eight of the species were registered for the first time in Schleswig-Holstein. However, this must also be seen in the light of the fact that no nationwide study of incidences of fungi has ever been carried out in Germany. One of the species studied is on the red list categorised as critically endangered (entoloma species) and three are categorised as moderately endangered (Alder bolete, Perenniporia fraxinea and a cup fungus (peziza domiciliana)). Three of the species are listed as vulnerable and 64 as species that are not endangered. Seven species were indicator species that indicate habitats with special environmental continuity and complexity.

The most fungus species were found at Grüner Brink (59 species), followed by Blankenwisch (45 species) and at the coastal dunes (16 species). Moreover, fung
were found in several small locations along the north coast and in green areas near the villages of Hinrichsdorf, Ostermarkelsdorf, Niendorf and Presen.

7.6.2 Importance
The importance of flora is assessed on the normal four-level scale (very high, high, medium and minor). Both the protection status and the biological value of the species are used in classifying the importance.

Biotopes / biotope types
The importance of biotopes is based on the botanical value of the area and its suitability for the plants species characterising the biotope. Schleswig-Holstein has a standard list of biotypes (Standardliste der Biotoptypen, LANU 2003) of which 87 types are found in the study area. These types cover the entire study area including built-up areas.

The areas of very high importance are mostly the coastal areas which are in near-natural condition (Figure 7.43). Reed forests, some ponds, birch and alder forests and part of the disused railway yard are of high importance. Medium importance is given to areas with some natural value even although they are affected by human activities, e.g. ditches, ponds, hedge rows, dikes etc. The areas of minor importance are those dominated by human intervention, e.g. farmland, residential areas, parks, camping grounds, industry areas etc.

Plants
The criteria for classifying the importance of plant areas are based on a point system which is derived from the red and yellow lists for threatened Schleswig-Holstein plants. Points are allocated according to the number of threatened species in the area and the degree of threat.

There are two areas of very high importance from a botanical point of view. These are the disused part of the railway yard south of the ferry harbour where 13 red- or yellow-listed species are found and the area with grey dunes south of Marienleuchte with 10 red- or yellow-listed species (Figure 7.43).

Four areas are classified as of high botanical importance, viz. two coastal sites with grey dunes and sand cliffs in the protected area of Grüner Brink, a grey dune area east of Presen and dry grassland on the dike west of Puttgarden harbour.

41 localities are of medium importance and 297 of minor importance. Areas without the presence of red- or yellow-listed species are not classified.
Figure 7.43  Importance of flora on Fehmarn
Fungi

The criteria for importance of fungus species also use the categories in the red list. Factors such as presence of indicators, first time finds and the area’s potential for fungi are also considered.

No localities of very high importance were found, but there are eight localities of high, seven of medium and seven of minor importance (Figure 7.43). The most valuable are near the coast in the northwest part of the study area including around Grüner Brink and Blankenwisch. There are also fungi localities near the villages in the western part of the study area, at Presen and at the coast near Marienleuchte. However, there are generally fewer suitable localities east of the main road B207.

7.6.3 Potential impacts

The project pressures and potential impacts which are addressed in this section on flora are:

› Expropriation of land areas giving loss of biotopes / biotope types
› Emission of pollutants giving impairment of habitats and flora

7.6.4 0-alternative

Please refer to the corresponding section under Fauna above.

7.6.5 Loss of biotopes/ biotope types, including protected biotopes/ biotope types

<table>
<thead>
<tr>
<th>Importance</th>
<th>Construction related</th>
<th>Impacts</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>1.21 ha ****</td>
<td></td>
<td>1.50 ha ****</td>
</tr>
</tbody>
</table>
|            | There will be temporary construction on the following habitats which are protected according to § 30 BNatSchG (in conjunction with § 21 LNatSchG):
|            | - Part of a field hedge with the typical vegetation of wooded areas along the B207, semi-dry grassland and perennial vegetation in the south-western part of the "Windpark Presen" wind farm
|            | - Coastal area east of the ferry port: grey dune, sand beach, coastal cliff, perennial vegetation of the beaches (0.49 ha).
|            | (Because of the very high importance of the biotypes the construction related loss is considered as a permanent loss.) |         | There will be permanent construction on the following habitats which are protected according to § 30 BNatSchG (in conjunction with § 21 LNatSchG):
|            | - Parts of the tree-lined street between Puttgarden and Bannesdorf
|            | - A small portion of a field hedge along the B207, plus semi-dry grassland and perennial vegetation in the south-western part of the "Windpark Presen" wind farm
|            | - A spit with the typical vegetation of wooded areas west of Marienleuchte
|            | - Loss of sand and pebble beach on the coast east of the ferry port (0.68 ha) |         |
## Loss of biotopes/biotope types. Magnitude of pressure: very high

<table>
<thead>
<tr>
<th>Importance</th>
<th>Construction related</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ponds</strong></td>
<td>Loss of five ponds because of construction sides (two east of the ferry port, two west of Marienleuchte and one north of the Puttgarden junction)</td>
<td>It can be assumed that the ponds will be permanently lost due to the construction work. For three ponds there is a permanent loss because of the structure.</td>
</tr>
<tr>
<td>0.01 ha</td>
<td>- Semi-dry grassland and perennial vegetation in dry locations by the B207 south-east of Puttgarden</td>
<td>0.32 ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.75 ha</td>
<td>- Three small partial areas of the Drohngraben pit, east of the B207 in the region north of the Puttgarden junction</td>
<td>4.76 ha</td>
</tr>
<tr>
<td></td>
<td>- One very small partial area of a group of trees east of the Puttgarden junction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Two areas of (semi-) dry grassland and perennial vegetation east of the ferry port as well as on the western edge of Marienleuchte</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Habitats of the traffic facilities (mesophile grassland, field hedges, other wooded field areas and (semi-) dry grassland and perennial vegetation in moist/ fresh locations) at the B207 north of the Puttgarden junction</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>81.03 ha</td>
<td>- Predominantly arable land (77.59 ha)</td>
<td>58.70 ha</td>
</tr>
<tr>
<td></td>
<td>- An area of intensively used grassland south-west of Marienleuchte</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- The rest consists of artificially impacted areas: railway and railway track systems as well as coastal protection structures</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>83.01 ha</td>
<td>65.28 ha</td>
</tr>
</tbody>
</table>

### Qualitative description
- Legally protected habitats (§ 30 BNatSchG in conjunction with § 21 LNatSchG) will only be lost to a small extent. About half of the losses will be of non-restorable coastal habitats.
- Most of the other legally protected inland habitats can be restored after the area has been used.
Loss of biotopes/ biotope types. Magnitude of pressure: very high

<table>
<thead>
<tr>
<th>Importance</th>
<th>Construction related</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>temporarily (e.g. field hedges and ponds).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Apart from that, largely areas of arable fields with little importance in terms of nature conservation will be lost.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>In addition to the arable land, mostly wooded structure of medium value as well as semi-dry grass and perennial vegetation will be lost.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A total of eight ponds will be lost.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The vast majority of the biotopes can be restored or compensated for after they have been used temporarily for construction.</td>
<td></td>
</tr>
</tbody>
</table>

Severity of loss

<table>
<thead>
<tr>
<th>Severity of loss</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction related</td>
<td>Very High</td>
<td>High</td>
<td>Medium</td>
<td>Minor</td>
</tr>
<tr>
<td>Structure related</td>
<td>Very High</td>
<td>High</td>
<td>Medium</td>
<td>Minor</td>
</tr>
</tbody>
</table>

Figure 7.44   Bored tunnel: Loss of biotopes/ biotope types, incl. biotopes and biotope types which are protected according to § 30 BNatSchG; in conjunction with § 21 LNatSchG
7.6.6 Impairment of habitats/flora due to the emission of pollutants and nutrients

The pollutant sulphur dioxide (SO₂) is almost exclusively emitted by the ferry traffic and therefore no increase in the emissions and the concentration in the air are to be expected on account of the Fehmarnbelt Fixed Link. In compliance with EU Directive 2005/33/EC of 6 July 2005 amending Directive 1999/32/EC limiting the sulphur content of fuels used by ships, it is planned to reduce the emission of sulphur dioxide of ship traffic. According to the directive, the sulphur content of fuel may not exceed 0.1% as of 2015. Therefore it is to be assumed that the SO₂ pollution by the ferry traffic will decline in the future, regardless of the construction of a Fehmarnbelt Fixed Link. For these reasons this pollutant is disregarded in the present impact assessment.

The impacts of nitrogen oxides (NOₓ) from the road traffic and construction site operation are explained below.

<table>
<thead>
<tr>
<th>Temporary impairment of biotopes because of nitrogen oxides (NOₓ) during the construction period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td>Special</td>
</tr>
<tr>
<td>Only very minor and insignificant impairments of biotopes are to be expected, as in comparison with the traffic, relatively few pollutants and nutrients will be deposited on account of the ongoing construction. Moreover, only generally sensitive and largely already impaired biotopes will be affected in the vicinity of the construction area and the work harbour (e.g. biotopes of arable land and at edges of roads). The biotopes in the construction areas themselves are classified as construction-related losses.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>General</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact zone 1: impairment because of nitrogen oxides (NOₓ) with exceedance of the critical emission values according to the 39th Federal Emission Control Ordinance (BImSchV) and the Technical Instruction for Air (TA-Luft)</td>
</tr>
<tr>
<td>Magnitude of pressure: very high</td>
</tr>
<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td>Special</td>
</tr>
<tr>
<td>General</td>
</tr>
<tr>
<td>In two sections of the road west and east of the tunnel portal the critical emission values for the vegetation (30 µg/m³ according to the 39th BImSchV and the Technical Instruction for Air – TA-Luft) will be exceeded (in the western sub-area up to 56 µg/m³ and in the eastern sub-area up to 33 µg/m³)*. In both cases only arable land biotopes will be affected.</td>
</tr>
</tbody>
</table>

| Impact zone 2: impairment due to nitrogen oxides (NOₓ) below the critical emission values (up to a maximum of 50 m on either side of the traffic lane) |
| Magnitude of pressure: medium |
| **Sensitivity** | **Impacts** |
| Special | 0.06 ha |

---

*Note: Values for NOₓ.
- A small area of (semi-) dry grassland and perennial vegetation in dry locations in the area of the edge of the B207 south-east of Puttgarden

<table>
<thead>
<tr>
<th>General</th>
<th>23.27 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Mainly arable field habitats along the entire route (west and east of the B207)</td>
<td></td>
</tr>
<tr>
<td>- In addition, predominantly biotopes of the various traffic facilities in the area of the &quot;Vogelfluglinie&quot; (B207 and railway system)</td>
<td></td>
</tr>
<tr>
<td>- To a small extent, also perennial vegetation and shrubbery as well as ditches and part of a tree-lined street around the B207/ railway system</td>
<td></td>
</tr>
</tbody>
</table>

| Total | 23.33 ha |

<table>
<thead>
<tr>
<th>Qualitative description</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Critical emission values will be reached or exceeded for the vegetation near the tunnel portal. Only fields are affected (1.34 ha).</td>
<td></td>
</tr>
<tr>
<td>- A very small ratio of biotope types which are particularly sensitive to the emission of pollutants and nutrients (0.06 ha)</td>
<td></td>
</tr>
<tr>
<td>- Almost exclusively affected will be generally sensitive habitat types (23.27 ha) in the vicinity of the &quot;Vogelfluglinie&quot; (B207 and railway system).</td>
<td></td>
</tr>
<tr>
<td>- Near the railway system in an area of no more than seven metres from the railway tracks, impairment due to railway-specific pollutant and nutrient depositions will be possible (emission of nutrients and herbicides). Accumulations of heavy metals as well as impairments of the vegetation due to dust and lime are not to be expected (Eisenbahn-Bundesamt 2004).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Severity of impairment</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
</tr>
</thead>
<tbody>
<tr>
<td>* According to 39. BimSchV/ TA Luft the exceedence of NOx is not relevant for the assessment of the impairment because the project is at a distance less then 5 km from settlements and routes. But according to a precautionary principle the exceedance is considered in the EIA.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.6.7 Summary of impacts

Legally protected habitats (biotopes) will only be lost to a small extent and about half can be restored at the end of construction. The eight ponds of very high importance will be compensated with new ponds. The other areas lost are almost all of minor importance (arable land) and the vast majority can be restored or compensated after they have been used temporarily for construction.

No critical emission values regarding pollutants and nutrients will be reached or exceeded for the vegetation.

7.6.8 Mitigation and compensation measures

The following mitigation and compensation measures will be implemented:

› Establish new ponds with suitable vegetation to compensate for those lost.

Figure 7.45 Bored tunnel: impairment of biotopes/flora due to the emission of pollutants and nutrients
Plant trees and shrubs along the marshalling yard and along the overpass over K49.

Develop natural coastal vegetation on the reclamation area.

Create new biotope types outside the project area on Fehmarn to compensate for those lost.

Create new biotope types in other areas of Schleswig-Holstein through the eco-account to compensate for those lost.

7.6.9 Significance of impacts

The impacts on flora are generally very limited and after implementation of the mitigation and compensation measures are considered insignificant.
7.7 Biodiversity

7.7.1 Existing biodiversity
On Fehmarn all protected areas like Natura 2000 areas and a nature conservation area are significant for biodiversity. They are situated near the coast and there are no other protected areas in the remainder of the investigation area. Since the main part of the investigation area is used intensively (e.g. agriculture) its importance is minor.

In the investigation area there are large areas of biotope complexes at the northern part of the coast. The areas reach from Grüner Brink in the West to the outskirts of Puttgarden. Other biotope complexes are situated close to Presen and reach from the coast to the Bannesdorfer ditch.

7.7.2 Importance
The importance of biotopes and habitats for biodiversity are assessed from the following criteria which contribute to the maintenance of biodiversity:

› Populations
› Interactions
› Ecosystems and habitats
› Habitats with special structures or geographical characteristics
› Naturally present dynamics in relation to given landscapes.

Biodiversity is assessed for larger contiguous areas each of which includes several different ecosystems.

The biotope complexes of the beach and dike areas of the north coast, the protected Grüner Brink and the nearby lowlands are of very high importance. The partly forested Blankenwisch wetland and the beach and cliff at Marienleuchte and to the south are assessed to be of high importance.

Medium importance is given to the varied farmland northwest of Puttgarden with permanent grass, ponds and hedge rows, to the beach and cliff between the ferry harbour and Marienleuchte, to the railway yard at Puttgarden and the areas along the railway and main road B207.

The ecological corridor consisting of the Bannesdorfer Graben and the lowlands south of Presen are of minor importance.

7.7.3 Potential impacts
The project pressures and potential impacts which are addressed in this section on biodiversity are:

› Expropriation of land areas giving loss of areas of importance for biodiversity
Fragmentation of areas of importance for biodiversity due to construction works and permanent structures

7.7.4 0-alternative
Please refer to the corresponding section under Fauna above.

7.7.5 Loss of areas with importance for the biodiversity

Table 7.47  Bored tunnel: loss of areas with importance for the biodiversity

<table>
<thead>
<tr>
<th>Importance</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction related</td>
</tr>
<tr>
<td>Very high</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>High</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>Medium</td>
<td>3.85 ha</td>
</tr>
<tr>
<td></td>
<td>- Mainly sections of functional area 6 (“Vogelfluglinie”) will be used temporarily (2.87 ha).</td>
</tr>
<tr>
<td></td>
<td>- The remaining areas (0.98 ha) concern the habitat complex 4a (beach between the Puttgarden ferry port and Marienleuchte).</td>
</tr>
<tr>
<td>Minor</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>Total</td>
<td>3.85 ha</td>
</tr>
</tbody>
</table>

Qualitative description
No high or very high important sections of conservation areas, habitat complexes or habitat networks will be lost.
In the area south of the Puttgarden junction up to the southern edge of the railway system, there will be losses in sections of the “Flying Bird Line” (functional area 6) with medium importance for the biological diversity and they will be used temporarily. However, their function as habitat network line will be restored in the short to medium term. The disused marshalling yard with very high importance for Red List plants will not be used.
At the beach section between the Puttgarden ferry port and Marienleuchte (habitat complex 4a) no specially significant animal species (Annex IV-species, strictly protected species, Red list species) will suffer loss, with the exception of a Red List plant species (Crambe maritima – sea kale, included in the list of near-threatened species). With respect to the ecosystem diversity, beach habitats and a coastal cliff section will be affected, with the latter to be categorized as non-restorable.
Severity of loss

- Very High
- High
- Medium
- Minor
- construction related

Figure 7.46  Bored tunnel: loss of areas with importance for the biodiversity
7.7.6 Fragmentation of areas with importance for the biodiversity

Table 7.48 Bored tunnel: fragmentation of areas with importance for the biodiversity

<table>
<thead>
<tr>
<th>Magnitude of pressure: depends on specific circumstances</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>Not affected</td>
</tr>
<tr>
<td>High</td>
<td>Not affected</td>
</tr>
<tr>
<td>Medium (qualitative description)</td>
<td>(No impairment, but see “Loss”)</td>
</tr>
<tr>
<td></td>
<td>No fragmentation of functional area 6 (&quot;Vogelfluglinie&quot;) which exceeds the losses described above. The areas at the edge of the bored tunnel structure which are going to develop in the short to medium term will re-create the habitat network line – with the already existing impairments and impacts of the fragmentation due to traffic and sealed areas at the B207/ railway – in a way that is going to be similar to the currently existing diversity of habitats and species.</td>
</tr>
<tr>
<td></td>
<td>No fragmentation of habitat complex 4a (beach section between the Puttgarden ferry port and Marienleuchte), as here the loss of biotopes and fauna habitats which was described above will result in no beach areas remaining west of the bored tunnel structure. The reduction of the habitat complex has already been covered by the discussion of the predicted loss. The already existing considerable limitation of habitat complex 4a as an area where species can thrive due to its fragmentation by Marienleuchte and the Puttgarden ferry port must also be taken into account.</td>
</tr>
<tr>
<td>Minor</td>
<td>Not affected</td>
</tr>
</tbody>
</table>

Severity of impairment | Very high | High | Medium | Minor

7.7.7 Summary of impacts

N areas of very high or high importance for biodiversity will be lost. The areas of medium importance along the existing main road B207 and railway which will be lost will be partly re-established at the end of construction. New, similar areas will be created along the new motorway and railway. Only the habitats of small areas of the beach between Puttgarden and Marienleuchte will be lost permanently and cannot be directly compensated.

All in all, the impact on biodiversity is minor due to the small affected areas which are only of medium importance.

7.7.8 Mitigation and compensation measures

The mitigation and compensation measures proposed for other factors such as fauna, flora, water, soil and landscape are also relevant measures for biodiversity.

7.7.9 Significance of impacts

The impacts on biodiversity are small and minor, and, with the implementation of the mitigation and compensation measures, they are considered insignificant.
7.8 Landscape

7.8.1 Existing landscape

Fehmarn’s landscape is categorised in Germany as Schleswig-Holstein hill landscape (Schleswig-Holsteinisches Hügelland) with its long, low hills in an east to west or east-south-east to west-north-west directions. There are two main landscape types, viz. the coast and the inner part of the island. These can be subdivided in smaller landscape areas with different character as described below.

The coastal landscape is characterised by the views of Fehmarnbelt, other coastal stretches, the harbour and the lighthouse. The landscape varies between natural coasts with beaches and varied plant and animal habitats, narrow beaches with coastal cliffs and stretches with dikes and coastal protection structures.

Figure 7.47 Coastal landscape at Marienleuchte towards southeast

Figure 7.48 Coastal landscape at Marienleuchte looking towards the ferry harbour
Wetlands near the coast together with the ponds and diverse vegetation contribute to a varied and natural landscape. This is seen particularly in the large Blankenwisch area and to a lesser degree in the small wetlands such as south of Presen. Ditches and drains mark the boundary to the farmland.

The intensive agriculture is the dominant characteristic of the landscape in the inner part of the island. The landscape is quite uniform, relatively flat, uniform land-use with only few stone fences and hedge rows. There are many ponds enclosed by dense vegetation, and some areas where a view of the sea increases the landscape value. The windmill park between Presen and Klingenberg dominates the visual impression in that area.

The farmland west of Puttgarden and around the villages is more varied with hedge rows and green areas. Trees along the K49 and K63 rods are strong landscape features in the open land particularly where the roads are higher that the surrounding fields.

The towns and new built-up areas with their uniform urban character are in contrast to the surroundings. This applies especially to the northern part of Burg and the southwest part of Puttgarden. On the other hand some of the villages contribute positively to the landscape with their cultural-historic character.

The ferry harbour and the railway yard and station are infrastructure related landscape units with a technical and dominating character. The main road B207 and the railway also dominate the landscape, but the vegetation along the alignments reduces this impact.

Figure 7.49 Agricultural landscape with a tree lined road as a prominent landscape feature
7.8.2 Importance
Landscape importance is classified on the normal four-level scale with focus on the aesthetic value. In general, a high importance is associated with areas in a more natural state, characterised for example by natural vegetation, surface water, natural dynamics and cultural-historic features such as land-use. The criteria for classification are based on three characteristics:

› The landscape’s special character as a combination of original nature, special structures in the landscape and rarity in the region.

› The landscape’s diversity which is greatest in a varying terrain with many changing structures and landscape elements.

› The beauty of the landscape, which is a subjective judgement.

The coastal landscapes at the north and east of the study area are of very high importance, together with the nature protected Grüner Brink and the landscape protected area “LSG Insel Fehmarn” (Figure 7.50).

High importance is given to low- and wetland areas, farmland with visually dominating tree-lined roads and older villages since these agrarian landscapes have special landscape elements compared to the remaining area.

The remaining landscape with fewer, but somewhat positive landscape values are of medium importance. This applies to both agrarian landscapes with less dominant tree-lined roads or views of the sea, some villages and the main road B207 which is lined with trees and bushes.

Minor importance is given to the uniform villages and farmland together with the industrial areas and the harbour area.

7.8.3 Potential impacts
The potential impacts on the environmental factor landscape are listed below and are assessed in detail in the following section:

› Loss of (partial) landscape units and landscape elements due to construction sites and permanent structures

› Visual and sensory impairment of landscape units including fragmentation due to structures in the construction and operation phases
Note: The study area is extended for landscape due to the potential visual impacts.

Figure 7.50 Importance of landscape on Fehmarn
7.8.4 0-alternative

It is assessed that the importance of the landscape in the 0-alternative (2025) will be more-or-less the same as at present. The dominant land-use will still be agriculture and no larger urban development projects are planned. An area near the main road B207 between Hinrichsdorf and Bannesdorf and an area south of the existing Presen wind farm are allocated for additional potential wind farms. Establishment of windmills in these areas will change the visual impression of the landscape at the localities.
### 7.8.5 Loss of (partial) landscape units and landscape elements

Table 7.49  Bored tunnel: loss of (partial) landscape units and landscape elements

<table>
<thead>
<tr>
<th>Importance</th>
<th>Construction related</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very high</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.57 ha</td>
<td>0.55 ha</td>
</tr>
<tr>
<td></td>
<td>••••</td>
<td>••••</td>
</tr>
<tr>
<td></td>
<td>- Parts of the coastal landscape east of the ferry port (K 3), some sections with low coastal cliff</td>
<td>- A partial area of the coastal landscape K 3 east of the ferry port, some sections with low coastal cliff</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td>0.00 ha</td>
<td>2.14 ha</td>
</tr>
<tr>
<td></td>
<td>••</td>
<td>•••</td>
</tr>
<tr>
<td></td>
<td>- Several partial areas of the landscape unit A 4.1 with typical lines of trees in the agrarian landscape, at the K49, south of the Puttgarden junction</td>
<td></td>
</tr>
<tr>
<td><strong>Medium</strong></td>
<td>55.57 ha</td>
<td>24.63 ha</td>
</tr>
<tr>
<td></td>
<td>••</td>
<td>••</td>
</tr>
<tr>
<td></td>
<td>- Predominantly (53.66 ha) areas of the agrarian landscape with visual connection to the Baltic Sea east of the ferry port and west of Marienleuchte (A 3.1 and A 3.2)</td>
<td>- Predominantly (12.19 ha) areas of A 3.1, and to a small degree also of A 3.2 between the ferry port and Marienleuchte</td>
</tr>
<tr>
<td></td>
<td>- Moreover, a small portion of the landscape unit of the traffic facilities (B207/ railway) of the &quot;Vogelfluglinie&quot; (V 2) in a partial area north of the Puttgarden junction</td>
<td>- Furthermore, A 4.2 in the vicinity of the Puttgarden junction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- V 2 in several partial areas</td>
</tr>
<tr>
<td><strong>Minor</strong></td>
<td>28.41 ha</td>
<td>41.18 ha</td>
</tr>
<tr>
<td></td>
<td>••</td>
<td>•</td>
</tr>
<tr>
<td></td>
<td>- Agrarian landscape units in the western (A 1.1) and eastern (A 1.2, A 1.3) vicinity of the B207/ railway and around the &quot;Windpark Presen&quot; wind farm (A1.3)</td>
<td>- Predominantly A 1.1 west and A 1.2 as well as A 1.3 east of the B207/ railway track and A 1.3 in the vicinity of the &quot;Windpark Presen&quot; wind farm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Two partial areas of the landscape unit which is marked by the ferry port (V 1) in the area of the marshalling yard south of the ferry port</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>84.55 ha</td>
<td>68.49 ha</td>
</tr>
</tbody>
</table>

**Qualitative description**
- The loss of highly to very highly important areas will be relatively small. Predominantly medium-to minor-important landscape units of the cleared agrarian landscape and of the agrarian landscape with visual connection to the Baltic Sea will be occupied or be temporarily used.
- The ratio of the construction-related (temporary) use of areas is considerably above the structure-related (permanent) loss.
- Large share of construction-related (temporary) loss in landscape units of medium importance, in particular near the B207 and in agrarian landscape units near the coast.
- The section of the coastal landscape with a coastal cliff near Marienleuchte cannot be restored, i.e. a temporary loss in this area must be considered to be permanent.
Severity of loss

- Very High
- High
- Medium
- Minor

<table>
<thead>
<tr>
<th>construction related</th>
</tr>
</thead>
</table>

**Figure 7.51**  Bored tunnel: loss of (partial) landscape units and landscape elements

### 7.8.6 Visual and sensory impairment of landscape units including fragmentation

Structure- and operation-related impacts are described jointly in the table below since they overlap spatially and for the same length of time.

#### Table 7.50  Bored tunnel: visual and sensory impairment of landscape units including fragmentation

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Construction related</th>
<th>Structure related and operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact zone 1 (0 to 200 m from the edge of the railway/road with a route altitude of up to 10 m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnitude of pressure: very high when permanently impaired, medium when temporarily impaired</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very high</td>
<td>0.49 ha</td>
<td>1.26 ha</td>
</tr>
<tr>
<td>- A strip of the coastal landscape unit K 3 north of Marienleuchte</td>
<td>****</td>
<td></td>
</tr>
<tr>
<td>- Parts of the coastal landscape unit K 3 directly east of the ferry port</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Sensitivity Impacts

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Construction related</th>
<th>Structure related and operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Since the area will be used for the construction starting with the section immediately east of the ferry port, there will be no fragmentation of landscape units in the coastal region. Rather, an area at the edge will be lost (cf. Table 7.49).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### High

<table>
<thead>
<tr>
<th>0.66 ha</th>
<th>7.12 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Several small areas at the western edge of Marienleuchte (O 2.1), in which vicinity there are no elements which obstruct the view (e.g. green corridors and wooded areas)</td>
<td></td>
</tr>
<tr>
<td>- A narrow strip of the landscape unit of the lines of trees along the K49 (A 4.1) east of the existing B207/ railway track west of Bannesdorf</td>
<td></td>
</tr>
<tr>
<td>- Landscape unit of the lines of trees along the K49 (A 4.1) south of the intersection with the existing B207</td>
<td></td>
</tr>
</tbody>
</table>

#### Medium

<table>
<thead>
<tr>
<th>20.99 ha</th>
<th>54.83 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Partial areas of the agrarian landscape unit A 3.1 with visual connection to the Baltic Sea on the coast north-west of Marienleuchte</td>
<td></td>
</tr>
<tr>
<td>- Partial areas of the agrarian landscape unit A 3.2 with visual connection to the Baltic Sea south of Marienleuchte</td>
<td></td>
</tr>
<tr>
<td>- A narrow section of the landscape unit of the lines of tree along the K49 north of the Puttgarden junction (A 4.2)</td>
<td></td>
</tr>
<tr>
<td>- Landscape unit of the lines of trees along the K49 (A 4.2) in the area north of the B207</td>
<td></td>
</tr>
<tr>
<td>- Landscape unit of the traffic infrastructure of the existing B207 and the railway system (V 2) from Puttgarden to Puttgarden junction (a narrow strip in the middle of the route)</td>
<td></td>
</tr>
<tr>
<td>- Units of the agrarian landscape with visual connections to the Baltic Sea in the area between the B207/ railway system and Marienleuchte. West (A 3.1) as well as east of the planned route (A 3.1, A 3.2)</td>
<td></td>
</tr>
</tbody>
</table>

Fragmentation of the agrarian landscape unit A 3.1 with visual connection to the Baltic Sea between Marienleuchte and the ferry port by the project route and secondary facilities (road to Marienleuchte). A partial area between the ferry port and the planned route will lose its visual connection to the Baltic Sea or will be permanently obstructed. Fragmentation effects will already occur during the construction phase due to the construction site operation and the construction work.

#### Minor

<table>
<thead>
<tr>
<th>22.20 ha</th>
<th>138.96 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Landscape unit of the ferry port and the connected road and railway systems (V 1): Part of the port basin in the south-eastern section of the harbour near the sewage plant and in the area of the road and railway system in the latitude of Puttgarden</td>
<td></td>
</tr>
<tr>
<td>- Narrow areas of the cleared agrarian landscape unit (A 1.1, A 1.2, A 1.3) along the planned railway track and road</td>
<td></td>
</tr>
<tr>
<td>- A fairly large area of the landscape unit A 1.3 east of the planned railway track</td>
<td></td>
</tr>
<tr>
<td>- The landscape unit of the ferry port and the connected road and railway systems (V 1) in the south-eastern section of the harbour near the sewage plant and in the area of the road and railway system in the latitude of Puttgarden</td>
<td></td>
</tr>
<tr>
<td>- Cleared agrarian landscape units (A 1.1, A 1.2, A 1.3) in areas west and east as well as between the railway track and the road from the latitude of Puttgarden and Marienleuchte to that of Bannesdorf</td>
<td></td>
</tr>
</tbody>
</table>

**Total**

| 44.34 ha | 202.16 ha |
**Sensitivity** | **Impacts**
--- | ---
**Construction related** | **Structure related and operation**

**Qualitative description** | - The areas which are temporarily impaired due to construction will be predominantly impacted by the large construction areas east of the planned route and west of Marienleuchte. The working port in the marine area as well as the construction areas along the planned railway track and road will also have a minor impact on the landscape.
- Very highly and highly sensitive landscape units will be relatively little affected by permanent and temporary impacts.
- Mainly landscape units with minor sensitivity, especially cleared agrarian landscape units and landscape units of the traffic infrastructure, will be affected.
- There will be fragmentation effects in the agrarian landscape near the coast, as a result of which some visual connections with the Baltic Sea will be disrupted and some will be lost.
- The impacts of noise and pollutants are described in detail in connection with the environmental factor population and health. Impairments due to smell as a result of emissions, however, will have hardly any impact on the perception of the landscape, except in the immediate surroundings of the planned route.

<table>
<thead>
<tr>
<th>Impact zone 2 (200 to 1,500 m from the edge of the railway/road with a route altitude of 10 m to 30 m)</th>
<th>Magnitude of pressure: minor when temporarily impaired</th>
</tr>
</thead>
</table>

**Sensitivity** | **Construction related impacts**
--- | ---
**Very high** | 11.33 ha
- Coastal landscape unit K 3 south of Marienleuchte (beach with state protection dyke behind it)

**High** | 12.24 ha
- Parts of the lowland landscape north and east of Presen (N 2)
- A small part of the northern edge of Presen (O 5) without any elements obstructing the view (e.g. green corridors/wooded areas)

**Medium** | 66.10 ha
- Agrarian landscape unit with visual connection to the Baltic Sea, along the Baltic Sea coast between Marienleuchte and Presen (A 3.2)
- A small section of the agrarian landscape unit with visual connection to the Baltic Sea, east of Presen (A 3.3)

**Minor** | 142.92 ha
- Cleared agrarian landscape units between the planned route and Presen (A 1.2, A 1.3)

**Total** | 232.59 ha

**Qualitative description** | - The visual impairment will be a result of large-scale construction areas between the planned route and Marienleuchte, the facilities and buildings, which will have a height of up to 30 m.
- Due to the obstructed view caused by the planned route, the green corridors and wooded areas along the route as well as the ferry port and the railway system, which will remain, no areas west of the planned route will be visually impaired.
- Compared to the landscape units with medium and minor sensitivity, only relatively few very highly and highly sensitive landscape units will be affected.
- The affected landscape units largely consist of the cleared agrarian landscape with minor sensitivity.

**Total area (all impact zones)**

<table>
<thead>
<tr>
<th>Construction-related (impact zones 1 and 2):</th>
<th>Structure- and operation-related (only impact zone 1):</th>
</tr>
</thead>
<tbody>
<tr>
<td>276.93 ha</td>
<td>202.16 ha</td>
</tr>
</tbody>
</table>

**Severity of impairment** | Very high | High | Medium | Minor
7.8.7 Summary of impacts

The project construction site will cause the temporary loss of 84.5 ha of the landscape. The area is mainly farmland which will be restored after end construction. A small area of 0.5 ha of coastal landscape with a segment of the cliff structure east of the work harbour will be lost and cannot be restored. Larger areas will be subject to visual and sensory impairment by the construction site and construction activities, namely about 277 ha, the great majority of which (about 250 ha) is farmland and is only affected to a medium or minor degree.
The permanent project structures (portals, motorway, railway and buildings as well as embankments) will cause the loss of 68.5 ha of the landscape. Except for 0.5 ha loss of coastal area, almost all of the area is farmland of medium to minor importance. An area of 202 ha is subject to visual and sensory impairment, 97 % to a medium or minor degree. Visual fragmentation effects occur in respect of visual connections from the agrarian landscape to the Baltic Sea, but are restricted to the coastal area between the ferry harbour and the project.

7.8.8 Mitigation and compensation measures
The following mitigation and compensation measures will be implemented. Note that some of the measures are implemented in the project design and are therefore not mitigation but avoidance of impacts.

› Compensatory landscape will be developed on the land reclamation including design to ensure visual connection with the sea.

› Coastal erosion is reduced in the design phase to avoid the possible loss of coastal landscape.

› The footprint of the construction sites, work harbour and permanent structures are minimised in the design to reduce impacts on landscape.

› The landscape in the construction sites will be restored at the end of construction.

› Compensatory, typical landscapes will be developed in other areas on Fehmarn. The number, area and type are to be agreed with authorities.

› Monetary compensation for the permanent loss and impairment of landscapes through the eco-account.

7.8.9 Significance of impacts
Although in the construction phase the bored tunnel impaires large areas in the landscape, all impacts are addressed with the implementation of the mitigation and compensation measures for fauna and flora. In the sense of multifunctional compensation there remain no significant impacts.
7.9 Cultural heritage, archaeology and material assets

7.9.1 Existing cultural heritage, archaeology and material assets

Cultural heritage and archaeology includes protected buildings, buildings worth preserving, monuments, churches and cultural environments such as cultural landscapes and villages and archaeological sites.

A series of archaeological studies have confirmed that Fehmarn has been inhabited since the early stone age (around 3,000 BC) and there are indications that there was an early iron age settlement at Puttgarden harbour. There are no burial mounds or dolmens in the study area. Neither are there any registered archaeological sites or individual finds.

Buildings protected under the German culture law (Denkmalschutzgesetz Schleswig-Holstein, § 5) are an old church in Bannesdorf and the historical lighthouse in Marienleuchte. In addition, a number of valuable buildings are protected under § 1 of the same law. These are found mainly around the villages Todendorf, Bannesdorf and in Burg. Fehmarn’s first church from 1198, Peter and Paul Chapel, west of Puttgarden is a cultural historical monument.

![Figure 7.53 The church in Bannesdorf](image)

Material assets include infrastructure as well as smaller public facilities and private buildings. One of the largest material assets in the study area is the infrastructure consisting of the railway station and the road and railway crossing the island in a south-westerly direction as well as the buildings associated with the infrastructure.
The Puttgarden harbour itself with its buildings, parking area and technical facilities are part of this large material asset.

Another important asset is the dike from Grüner Brink to Marienleuchte protecting the land from flooding. There is a radio tower west of Puttgarden and the light house at Marienleuchte. The towns of Burg, Puttgarden, Landkirchen, Bannesdorf and Niendorf have material assets in the form of waste water treatment plants, rain water retention basins, drainage facilities and electricity production and distribution facilities.

Finally there is the Presen wind farm with 23 windmills on an area of 108 ha. Fehmarn Municipality has tentative reservations on four new areas for development of sustainable energy.

![Presen wind farm](image)

**Figure 7.54** Presen wind farm

### 7.9.2 Importance

The importance of cultural heritage and archaeology is assessed on the normal four-level scale. The criteria used in classifying the importance are:

- Protection status
- Cultural and aesthetic value,
- History
- Value for regional identity
- Rarity
- State of maintenance
- Usefulness in relation to education
- Integral part of the local scene
- Contribution to the landscape value
Cultural historic buildings and part of their surroundings are assessed as of very high importance if they are protected under § 5 (strictly protected) in the culture law (Denkmalschutzgesetz DSchG S-H). There are two such buildings in the study area, viz. the lighthouse in Marienleuchte and the church in Bannesdorf (Figure 7.53). See Figure 7.55 for the importance map of the study area.

Similarly, cultural historic monuments, buildings and their surroundings which are protected under § 1 (worth preserving) of the culture law are assessed as being of high importance. These are found in Burg, Bannesdorf, Niendorf and Todendorf. The special fortified town structure (fortadorf) which characterises a number of villages on Fehmarn are also of high importance, e.g. Puttgarden, Presen, Bannesdorf, Niendorf, Ostermarkelsdorf and Hinrichsdorf.

Special sites or historical monuments which indicate the historical development of the island are of medium importance because they have often been ruined by the passage of time. Examples are places where there have been churches or there are the remains of churches. Thus the site of the Peter and Paul Chapel west of Puttgarden is of medium importance.

Areas of minor importance are the marl pits, areas with little cultural or landscape structure and the few archaeological sites.

There are no larger, contiguous historical cultural landscapes or cultural elements in the study area on Fehmarn.

The classification of importance of the material assets is based on the following criteria:

› The public security
› Ability to perform its function
› Production capacity
› Worthiness for preservation
› State of maintenance
› Intensity of use
› Requirements for its location
› Possibility for re-establishment
› Size
› Economical value

The coastal dike is of very high importance because it is protected by law and also protects the land against flooding from the sea, thereby performing a valuable function (Figure 7.56). The Puttgarden harbour and the railway and road network leading to the mainland are of high importance since they provide a valuable regional and local transport function.

The Presen wind farm, the radio tower west of Puttgarden and the new lighthouse in Marienleuchte provide public functions and are of medium importance. This also applies to areas reserved for sustainable energy development in the local plan. Other material assets and technical installations are of minor importance.
Figure 7.55  Importance of cultural heritage on Fehmarn
Figure 7.56 Importance of material assets on Fehmarn
7.9.3 Potential impacts

The impacts on the environmental factors cultural heritage, archaeology and material assets are listed below and addressed in the following sections:

› Loss of cultural assets and parts of cultural landscapes
› Visual and sensory impairments of cultural assets and parts of cultural landscapes
› Loss of material assets

7.9.4 O-alternative

The situation in the O-alternative is assessed to be more-or-less the same as at present with the possible addition of sustainable energy installations in the reserved areas. There is also a plan for strengthening the coastal dike between Puttgarden and Westermarkelsdorf.

7.9.5 Loss of cultural assets, archaeology and parts of cultural landscapes

Table 7.51  Bored tunnel: loss of cultural assets, archaeology and parts of cultural landscapes

<table>
<thead>
<tr>
<th>Magnitude of pressure: very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance</td>
</tr>
<tr>
<td>Very high</td>
</tr>
<tr>
<td>High</td>
</tr>
<tr>
<td>Medium</td>
</tr>
<tr>
<td>Minor</td>
</tr>
<tr>
<td>- Area with potential individual archaeological finds.</td>
</tr>
<tr>
<td>A total of eight marl pits (now ponds) will be lost. Construction-related loss is classified as permanent loss.</td>
</tr>
</tbody>
</table>

Qualitative description
- There is no loss of protected cultural assets
- Individual archaeological finds can be expected to be made in the entire area of the route (incl. Construction-related areas).

Severity of loss
- Very high
- High
- Medium
- Minor
Severity of loss

- Very High
- High
- Medium
- Minor

Figure 7.57  Bored tunnel: loss of cultural assets, archaeology and parts of cultural landscapes
7.9.6 Visual and sensory impairments of cultural assets and parts of cultural landscapes

The only cultural assets likely to be impaired are the historical lighthouse at Marienleuchte and the fortified town structure (fortadorf) of Puttgarden and Bannesdorf.

Table 7.52  Bored tunnel: visual and sensory impairments of cultural assets and parts of cultural landscapes

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Impacts</th>
<th>Structure related and operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high (qualitative description)</td>
<td>Historical Marienleuchte lighthouse [§ 5 Schleswig-Holstein Monuments Act (DSchG S-H)]</td>
<td>- Insignificant impairment</td>
</tr>
<tr>
<td></td>
<td>- Large construction areas between the planned railway track/road and Marienleuchte will be needed. The distance to the historic lighthouse will be approx. 140 m to the south of the monument and 180 m in the west, as well as approx. 250 m to the work harbour. Especially high and long-term noise emissions will originate from various sources in the construction area which are relatively close to the lighthouse. Moreover, the construction area will visually impair the surroundings of the lighthouse. Due to the temporary impairment and since the lighthouse is screened off by wooded areas the impairment will not be severe. - Temporarily it may be more difficult to reach the cultural monument during the construction phase. - Due to the actual distance between the planned structures to the cultural monument, the possibility of significant structure- and operation-related impairments on account of smell (e.g. because of emissions from the construction site traffic), reduction of groundwater levels, as well as damage to the material and substance on account of vibrations or chemicals can be excluded.</td>
<td>- The cultural monument will be subject to hardly any visual impairment or an impairment of its character as a cultural experience, as the facilities surrounding the lighthouse are not high and are located in road cuts. - Due to the distance to the road and railway system (approx. 500 m) and the already existing impairment due to the die B207/ railway, the operation-related noise and visual impairments will only be of minor importance. - Due to the actual distance between the planned structures to the cultural monument, the possibility of significant structure- and operation-related impairments on account of smell (e.g. because of emissions from the traffic) and vibrations or chemicals can be excluded.</td>
</tr>
<tr>
<td>High (qualitative description)</td>
<td>No impairment. The towns of Puttgarden and Bannesdorf which have the historic fortadorf structures lie in the extended surroundings of the planned route, but will not be impaired due to the distance of about 500 m or 700 m to the route of the Fehmarnbelt Fixed Link.</td>
<td>No impairment</td>
</tr>
<tr>
<td>Medium</td>
<td>No impairment</td>
<td>No impairment</td>
</tr>
<tr>
<td>Minor</td>
<td>No impairment</td>
<td>No impairment</td>
</tr>
</tbody>
</table>

Severity of impairment

- Very high
- High
- Medium
- Minor
### 7.9.7 Loss of material assets

**Table 7.53**  Bored tunnel: loss of material assets

<table>
<thead>
<tr>
<th>Importance</th>
<th>Construction related</th>
<th>Structure related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>High</td>
<td>1.50 ha</td>
<td>3.30 ha</td>
</tr>
<tr>
<td>- Areas of the existing B207/ railway</td>
<td></td>
<td>- Almost exclusively areas of the existing B207/ railway in the area of the Puttgarden junction as well as areas north and south of the Puttgarden junction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- A very small area next to the harbour (part of the eastern mole) due to reclamation areas</td>
</tr>
<tr>
<td>Medium</td>
<td>5.69 ha</td>
<td>9.63 ha</td>
</tr>
<tr>
<td>- Areas of the &quot;Windpark Presen&quot; wind farm, at its western edges, due to construction areas of the railway system and secondary facilities, plus in the northern edges due to construction areas</td>
<td></td>
<td>- Areas of the &quot;Windpark Presen&quot; wind farm, at its western edges, due to construction areas of the railway system and secondary facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Wind power plants will be affected (cf. discussion of construction-related impairments). Current plans provide for the dismantling of at least 5 WPP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- A small area at the edge of an individual farm east of Puttgarden (0.08 ha)</td>
</tr>
<tr>
<td>Minor</td>
<td>0.00 ha</td>
<td>0.00 ha</td>
</tr>
<tr>
<td>Total</td>
<td>7.19 ha</td>
<td>12.93 ha</td>
</tr>
</tbody>
</table>

**Qualitative description**

- No material assets of very high or minor importance will be affected.
- Most of the area losses of highly significant material assets concern the existing traffic infrastructure of the B207/ railway which will be replaced with new infrastructure.
- It is likely that at least five wind turbines of the "Windpark Presen" wind farm will be affected and must be dismantled.
- All material assets which will be affected can be easily restored or replaced. Some of them will already be restored as part of the project (connecting railway and road).
7.9.8 Summary of impacts

Cultural heritage and archaeology
The bored tunnel project will not result in the loss of any important or protected cultural or archaeological assets on Fehmarn. Eight marl pits in the construction site will be lost but are only of minor importance. There is always the potential that the construction works will reveal individual archaeological finds which will be assessed at that time.

The historical lighthouse at Marienleuchte will be slightly impaired during construction phase by noise and also visually due to its proximity to the construction site.

Material assets
The material assets on Fehmarn which will be affected by the project consist of the main road B207, the railway, some secondary roads, the windmill park at Presen, a
small area (0.25 ha) of green corridors at the western edge of Marienleuchte and a small area (0.08 ha) of a farm area east of Puttgarden.

The main road and railway will be improved by the project and the secondary roads will be re-routed so that all will maintain their function through both construction and operation phases. It is likely that up to five wind mills will be removed and it may be possible to re-erect them elsewhere.

**7.9.9 Mitigation and compensation measures**

The following mitigation and compensation measures will be implemented:

- The construction environmental management plan will include a “late finds protocol” for archaeology. It defines the procedures to be followed by contractors if excavations should find objects or sites of possible archaeological importance.

- Losses of material assets such as the wind turbines will be compensated by Femern A/S.

- Parts of the existing road and rail infrastructure will be lost, but it is the objective of the project to replace it with improved infrastructure.

**7.9.10 Significance of impacts**

The actual impacts on cultural heritage, archaeology and material assets are all small and, after implementation of the mitigation and compensation measures will be insignificant.
7.10 Local climate and air quality

The regional climate is characterized by the Baltic Sea.

There are no small-scale climates on Fehmarn because of its small size compared to the scale of the regional climate and the smooth relief. In the investigation area there is no big forest with its own climate and an area of fresh air production.

7.10.1 Existing local climate and air quality

There are only a few sources of air pollution on Fehmarn and the local air quality is little affected by the local sources such as ferries and road traffic. The combination of a flat landscape, the wind conditions and proximity to the sea gives a rapid refreshment of the air masses over the island. The importance of the air quality and local climate is assessed to be “special” for the whole area (on a two level scale of “special” and “general”) because the present level of pollution is low and it is not possible to distinguish different conditions in different areas.

Good air quality is important for the population’s well-being and health and also for plant and animal life.

Method

Reference is made to section 6.8 Air and climate on Lolland for a description of the procedure, model and standards for the air quality study. The German standards are defined in 39th Verordnung zum Bundesimmissionsschutzgesetz and the statutory order Technische Anleitung Luft.

The pollutants nitrogen dioxide (NO2), sulphur dioxide (SO2), suspended particulate matter (PM10), particulate matter (PM2.5) and benzene were investigated.

The additional pollution is calculated as the difference between the forecasted air quality and the existing air quality.

The impacts are considered in zones. Zone 1 is the area within which the respective air quality standards are exceeded. Zone 2 is the area within which 90 to 100% of the respective air quality standards are reached. Zone 3 is the area within which 50 to 90% of the respective air quality standards are reached.

Existing background air quality

The background air quality is based on measurements from a measuring station in Schleswig-Holstein. Only measured data for ozone is available on Fehmarn so the measured data from a representative station in Bornhöved were used.

The existing air quality conditions are:

- NO2: 12.1 µg/m3
- SO2: 3 µg/m3
PM10:  18 µg/m³
PM2.5:  16 µg/m³
Benzene:  1 µg/m³

0-alternative

The 0-alternative is defined as the case in 2025 without the fixed link. Even although the traffic intensity will increase, the stricter requirements to the quality of vehicle exhaust gases will reduce the impact to some degree. It is therefore assessed that the air quality in the 0-alternative will be more-or-less the same as today.
### 7.10.2 Impairment of air quality

The impacts on air quality are described in Table 7.54 and illustrated in Figure 7.59, Figure 7.60 and Figure 7.61.

#### Table 7.54  Bored tunnel: Impairment of air quality

<table>
<thead>
<tr>
<th>Constructed related impacts outside the zones which are considered for the operation phase</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td><strong>Construction related</strong></td>
</tr>
<tr>
<td>General</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zone 1: exceedance of respective air quality standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td><strong>Operation related</strong></td>
</tr>
</tbody>
</table>
| General | - Near the tunnel portal there is an exceedance of NO₂ up to 144 µg/m³ (limit value = 40 µg/m³) on an area of 1.19 ha.  
- In the area of the tunnel portal (railway) there is an exceedance of PM₁₀ (limit value = 40 µg/m³) up to 486 µg/m³ and up to 81 µg/m³ near the tunnel portal (motorway) on an area of 2.82 ha.  
- For PM₂,₅ there is an exceedance of the limit value (25 µg/m³) up to 108 µg/m³ near the tunnel portal (railway) and up to 42 µg/m³ near the tunnel portal (motorway) on an area of 1.83 ha.  
- The exceedences are only near the tunnel portals.  
- Because of the good supply of fresh air there is no loss of function but a high impairment. |

<table>
<thead>
<tr>
<th>Zone 2: 90-100% of respective air quality standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td><strong>Operation related</strong></td>
</tr>
</tbody>
</table>
| General | - In this zone the concentration of NO₂ near the tunnel portal (motorway) is reached (concentration about 36 up to 40 µg/m³) on an area of 0.26 ha.  
- The concentration of PM₂,₅ (22.5 bis 25 µg/m³) near to the tunnel portals is reached on an area of 0.90 ha.  
In an area of 0.59 ha there is a concentration of 36 to 40 µg/m³ near the tunnel portals. |

<table>
<thead>
<tr>
<th>Zone 3: 50-90% of respective air quality standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td><strong>Operation related</strong></td>
</tr>
</tbody>
</table>
| General | Concentrations of PM₁₀ (20 to 36 µg/m³) (existing impact = 18 µg/m³) within bands of 50m on both sides of the railway and around the tunnel portals on an area of 39.50 ha.  
Concentrations of NO₂ (20 bis 36 µg/m³) in the area of the tunnel portal (motorway) (existing impact = 12,1 µg/m³) on an area of 4.51 ha.  
Concentrations of PM₂,₅ about 17 bis 22,5 µg/m³ (existing impact = 16 µg/m³) on an area of 17,20 ha near the tunnel portal. |

| Qualitative description | |
|---|
| - No increase in the emission of pollutants is to be expected during the construction phase which is relevant for the assessment.  
- The limit values are reached near the tunnel portals (zone 1).  
- The zone 2 is reached near the tunnel portals, too.  
- In the zone 3 the air quality is impaired of PM₁₀. Half of the area is impaired of PM₂,₅, too. Only on a smart part there are concentrations of NO₂.  
- Because the gradient of the bored tunnel will disappear in front of the coast line and there is a good supply of fresh air there is no impact of air quality in the marine area. |

<table>
<thead>
<tr>
<th>Severity of impairment</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Minor</th>
</tr>
</thead>
</table>
Zones (PM$_{10}$)

Figure 7.59  Bored tunnel: Impairment of air quality (PM$_{10}$)
Zones (PM$_{2.5}$)

zone 1  zone 2  zone 3

Figure 7.60  Bored tunnel: Impairment of air quality (PM$_{2.5}$)
7.10.3 Mitigation and compensation measures
There are no specific mitigation or compensation measures due to the impact on air quality necessary. In the sense of multifunctional compensation these impacts are considered to be addressed by the mitigation and compensation measures for fauna and flora.

7.10.4 Significance of impacts
The air quality standards are exceeded during the operation phases of the bored tunnel near the tunnel portals. However, people will only remain in the area for short periods so their health will not be affected and the impact is insignificant.

There are no significant impacts on local climate expected because of the good supply of fresh air and the dominance of the local climate by the climate of the Baltic Sea region.
8 Climate

8.1 Introduction
Climate change on a global and regional scale is well-known in a geological time frame. Climate change interacts with the physical/chemical and biological environment and will cause changes to the environment from a global to a local scale.

There is growing recognition that human beings have a direct and indirect impact on the climate to a possibly growing extent and that emissions of greenhouse gases (including carbon dioxide, methane and nitrous oxide) probably play an important role in this impact.

Climate change can lead to changes to and destabilisation of the environment. Against this background, bodies including the UN Intergovernmental Panel on Climate Change (IPCC) have developed a number of scenarios for the climate development of Earth and for a number of its derived consequences, including changes to sea levels.

The increased focus on climate change and its anthropogenic components have resulted in a desire in the EU to cover the following subjects as far as possible in the context of an EIA:

› Assessment of the project's impact on the climate as a result of the project's specific emissions of greenhouse gases and the project's long-term impact on greenhouse gas accounting.

› Assessment of the significance of the expected climate change for the technical durability of the project.

› Assessment of the possible significance of the expected climate change for the project's impacts on the environment as assessed in the present EIA.
It is noted that the German regulations for EIAs do not require that climate change issues are addressed in EIAs (UVS in German). Therefore the assessments for the third bullet above are only made for Lolland in this report.

In addition to the above considerations, which are linked to overall climate change, the EIA contains an assessment of the project's potential direct impacts on the local climate. The latter impacts are covered separately in chapters 6 and 7.

This chapter gives an account of the emissions of greenhouse gases as a consequence of the construction and operation of the bored tunnel. In addition, it describes whether the expected climate change can cause a subsequent change in the impacts the project is assessed to have on the environment.

The latter considerations are based on an outline of the possible environmental changes that may occur as a result of the central (IPCC) scenarios for global emissions of greenhouse gases and climate development. The scenarios describe developments that are based on different assumptions concerning the factors that determine the development of human societies in the course of the next 100 years. The central scenarios selected are described below.

The A2 scenario describes a world with a high level of self-sufficiency and preservation of local distinctive features. The birth rate falls only slowly, resulting in the population continuing to increase. Economic development is primarily regional, while economic growth per capita and technological development are slower than in other scenarios.

The B2 scenario describes a world in which importance is attached to local sustainable solutions in the economic, social and environmental areas. This is a world in which the population continues to increase globally, although more slowly than in the A2 scenario.

There is great uncertainty in extrapolations of the global emissions of greenhouse gases and climate. One of the reasons for this is that the development of human society is difficult to predict, cf. IPCC's scenarios. To this is added the uncertainty in the climate models themselves.

Recommendations concerning the project's climate strategy

Femern A/S has involved a number of climate researchers to determine the strategy for dealing with climate change in relation to both the project's design and environmental considerations. The climate researchers come from the Hadley Centre in London, the Max Planck Institute in Hamburg, SMHI in Sweden, GKSS in Germany, the Niels Bohr Institute at Copenhagen University, Risø/DTU and DMI. The process has involved events including a workshop implemented by Femern A/S in 2009 entitled "Climate change and the Fehmarnbelt Fixed Link" (Risø DTU and DMI 2009). This has resulted in the following recommendations, which are incorporated in relation to dealing with climate change in connection with the life of the Fehmarnbelt Fixed Link:

- IPCC scenarios A2 and B2 are used.
The annual mean temperature may rise 1 - 4 °C.
The sea ice season may be reduced by 1 - 3 months and the extent of sea ice may be reduced by 30%.
The maximum wind strength that occurs once in 50 years may rise by 10% from 27 m/s to 30 m/s.
The freshwater supply to the Baltic Sea may rise by 5 - 20%, depending on the location in the Baltic Sea.
The intensity of rain may rise by 20% for the 10-year rain event.
The water level may rise by up to 1 m.
Changes in other parameters affected by climate, for example ice formation on ships and visibility, are not included in the recommendations.

8.2 Greenhouse gases

The emissions of greenhouse gases (GHG) during the construction and operation of a bored tunnel have been assessed. Greenhouse gases here are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF₆).

This section describes the calculated total emissions of greenhouse gases from the construction and operation of the fixed link. The most important sources of greenhouse gas emissions during construction and operation are included. It is assessed that the calculation includes the majority of greenhouse gas emissions and fairly illustrates the extent of the contributions from the various sources and alternatives.

The calculated greenhouse gas emissions from a fixed link are compared with the emissions in a zero alternative and Denmark's total emissions.

The project's impacts from greenhouse gases are caused by emissions from various activities in the construction and operation phases and can be divided into:

- Construction of the fixed link, including the link itself, construction works, temporary workplaces and links to the railway and roads.
- Operation and maintenance of the link, excluding traffic.
- Traffic.

Emissions of greenhouse gases from construction come from the production and transportation of building materials, power consumption, emissions from contractors' machines, etc.

Emissions of greenhouse gases from operation (excluding traffic) come from the use of electricity for lighting, ventilation, etc., emissions from the use of building materials and contractors' machines for maintenance and renovation.

Emissions of greenhouse gases from traffic are related to the expected changes in traffic, including operation of ferries and changed forecasts for rail and vehicle traffic as a consequence of the establishment of a fixed link, assessed in relation to the zero alternative.
A study of greenhouse gas emissions from the immersed tunnel, cable-stayed bridge and bored tunnel alternatives has been carried and reported in detail in COWI 2012c. The report forms the basis for the present section of the chapter on climate.

8.2.1 Greenhouse gas emissions during construction

Method

The greenhouse gas emissions from the most important building materials have been calculated on the basis of information on the quantities and origins of building materials, estimated by the design groups, and emission factors for the primary building materials.

Knowledge about the content of CO₂ emissions for building materials is, in most cases, given in CO₂ equivalents and will thus include emissions of all greenhouse gases.

The construction of the Fehmarnbelt Fixed Link includes the most important physical structures, construction activities, including temporary work sites on Lolland and Fehmarn, and links to roads and the railway.

The greenhouse gas emissions from the transportation of building materials are calculated on the basis of information on the probable origins of building materials, the possible destination for waste and the choice of means of transport.

For each means of transport, the emission factors were identified using data from TEMA (2010).

The calculations of greenhouse gas emissions from contractors' plant are based on existing knowledge of the fuel consumption of contractors' machines and an estimate of the machines to be used. The choice of use type, sizes, quantities, etc. of contractors' machines will ultimately be made by the contractors who construct the Fehmarnbelt Fixed Link.

In relation to contractors' machines, emissions from traffic and transportation of building materials, only the greenhouse effect of CO₂ emissions has been included. The effect of the other greenhouse gases, methane (CH₄) and nitrous oxide (N₂O), has not been included because the emission of greenhouse gases other than CO₂ is considered to be insignificant. The Danish Centre for Environment and Energy (formerly the National Environmental Research Institute (DMU)) estimates that 95 - 99% of the greenhouse effect from road transport comes from CO₂ (NERI 2011).

Where fuel consumption cannot be calculated accurately, estimates have been made based on the EMEP / EEA Emission Inventory Guidebook 2009 for non-road mobile sources and machinery (EMEP / EEA, 2010). CO₂ emissions from diesel are based on standard factors from the Danish Energy Agency (ENS 2011a).
Materials for the construction of the bored tunnel

The estimated amounts of materials for the construction of the bored tunnel are listed in Table 8.1.

Table 8.1 Main materials to be used for the construction of the bored tunnel and road and railway on both sides of the Belt

<table>
<thead>
<tr>
<th>Main materials</th>
<th>Ton</th>
<th>m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete mix 110</td>
<td>7,073,680</td>
<td>3,123,727</td>
</tr>
<tr>
<td>Carbon steel reinforcement</td>
<td>457,214</td>
<td></td>
</tr>
<tr>
<td>Concrete mix #200</td>
<td>602,905</td>
<td>274,422</td>
</tr>
<tr>
<td>Concrete (general)</td>
<td>270,206</td>
<td>123,028</td>
</tr>
<tr>
<td>Fill</td>
<td>2,438,000</td>
<td>1,060,000</td>
</tr>
<tr>
<td>Concrete for buildings</td>
<td>329,445</td>
<td>150,000</td>
</tr>
<tr>
<td><strong>Road construction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt</td>
<td>142,000</td>
<td></td>
</tr>
<tr>
<td>GAB I/II</td>
<td>60,000</td>
<td></td>
</tr>
<tr>
<td>Base course aggregates</td>
<td>300,000</td>
<td></td>
</tr>
<tr>
<td><strong>Railway construction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel bars</td>
<td>8,700</td>
<td></td>
</tr>
<tr>
<td>Crushed stone (Ballast)</td>
<td>79,000</td>
<td></td>
</tr>
<tr>
<td>Gravel (Sub ballast)</td>
<td>112,700</td>
<td>49,000</td>
</tr>
<tr>
<td>Concrete sleeper</td>
<td>8,850</td>
<td></td>
</tr>
<tr>
<td>Concrete slab track</td>
<td>165,000</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>199</td>
<td></td>
</tr>
<tr>
<td>Aluminium</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>3,725</td>
<td>1,490</td>
</tr>
<tr>
<td>Steel</td>
<td>899</td>
<td></td>
</tr>
<tr>
<td>Bronze II</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>
Construction machinery

The main equipment/activity for the construction of the bored tunnel is listed in Table 8.2 together with the associated diesel oil consumption (m³). The list is based on input from the design groups for the bored tunnel and the rail works.

Table 8.2 List of equipment and estimated fuel consumption (m³) during construction of the bored tunnel and road and railway on both sides of the belt.

<table>
<thead>
<tr>
<th>Machines/activity</th>
<th>Estimated diesel oil consumption (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthworks</td>
<td></td>
</tr>
<tr>
<td>Excavation by boring</td>
<td>None (see electricity consumption)</td>
</tr>
<tr>
<td>Total fuel consumptions incl. temporary harbour</td>
<td>54,228</td>
</tr>
<tr>
<td>Internal transport/placing of tunnel elements</td>
<td>11,974</td>
</tr>
<tr>
<td>Rail works</td>
<td>1,540</td>
</tr>
<tr>
<td><strong>Total estimated fuel consumption</strong></td>
<td><strong>67,750</strong></td>
</tr>
</tbody>
</table>

Electricity consumption during construction

The electricity consumption for light, ventilation, pumps, compressors etc. during construction has been estimated by the design group for the bored tunnel. The estimated consumption is listed in Table 8.3.

Table 8.3 Estimated electricity consumption during construction of the bored tunnel (kWh).

<table>
<thead>
<tr>
<th>Source to electricity consumption</th>
<th>Estimated electricity consumption (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation by boring, Fehmarn side*</td>
<td>637,000,000</td>
</tr>
<tr>
<td>Excavation by boring, Lolland side*</td>
<td>593,000,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,230,000,000</strong></td>
</tr>
</tbody>
</table>

* The figures include electricity consumption for tunnel boring machines (TBMs), pumps, ventilation, slurry treatment plant, batching plant, segment factory, other miscellaneous consumption at construction site, welfare and offices, etc.

Greenhouse gas emissions during construction

In total the GHG emission from construction of the bored tunnel amounts to 2.5 million ton CO₂ equivalents, see Table 8.4.

CO₂ embodied in concrete is the main contributor with 39 % of the total GHG emission from construction works for the bored tunnel. The high emission is because of very high energy consumption associated with the cement production. Another important source is CO₂ embodied in steel for reinforcement etc., which
contributes another 24%. Steel production also requires very high energy consumption. Electricity consumption for the tunnel excavation and related activities contribute 23% of the GHG emissions while machinery accounts for 7% and transport for 4%. Other contributors are relatively insignificant.

<table>
<thead>
<tr>
<th>Main contributors</th>
<th>CO₂ eq emission (ton)</th>
<th>Distribution %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>973,924</td>
<td>39%</td>
</tr>
<tr>
<td>Reinforcement and steel</td>
<td>589,806</td>
<td>24%</td>
</tr>
<tr>
<td>Other materials for main construction</td>
<td>20,520</td>
<td>1%</td>
</tr>
<tr>
<td>Asphalt etc.</td>
<td>11,290</td>
<td>0.5%</td>
</tr>
<tr>
<td>Materials for rail works</td>
<td>36,891</td>
<td>1.5%</td>
</tr>
<tr>
<td>Transport</td>
<td>96,213</td>
<td>4%</td>
</tr>
<tr>
<td>Machinery</td>
<td>179,819</td>
<td>7%</td>
</tr>
<tr>
<td>Electricity consumption</td>
<td>573,395</td>
<td>23%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,481,858</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

8.2.2 Greenhouse gas emissions during operation of the link (excluding traffic)

Method

Annual GHG emissions from the operation activities of the link (excluding traffic) originate from use of electricity for lighting, ventilation etc. and emissions from the use of materials and construction equipment for maintenance and for reinvestment.

The annual electricity consumption for lighting, ventilation etc. during the operation of the fixed link was estimated by the design groups. The consumption for the bored tunnel was assumed to be identical with that for the immersed tunnel.

The emission factor for electricity was based on the average Danish electricity production for the year 2025 projected by the National Danish Energy Agency, Energistyrelsen (ENS 2011b).

Maintenance and reinvestment are necessary to keep the fixed link in operation for the expected lifetime of 120 years. The design teams provided information on the use of material, equipment, electricity etc. for all planned maintenance works and reinvestments. It was assumed that the maintenance and reinvestment requirements would be identical for the bored and immersed tunnels.
Maintenance was defined as the routine (daily, weekly, monthly, annual) activities to keep the rail and the road on the link in operation. Reinvestments are the more infrequent activities, which demand a relatively large reinvestment, such as new asphalt or new rail tracks etc.

The information provided by the design groups was mainly related to the use of material for renewal of example asphalt road surface, rail tracks etc. In the current stage of planning, the design groups were unable to estimate the use of equipment and transport for maintenance and reinvestment activities during operation. The contribution to GHG emissions from these sources is considered marginal and is therefore disregarded.

The GHG emissions from maintenance and reinvestment activities were calculated as annual averages even though it is known that the activities will not be distributed evenly.

**GHG emissions**

The estimated annual electricity consumption for the operation of the bored tunnel is shown in Table 8.5.

<table>
<thead>
<tr>
<th>Source</th>
<th>Estimated electricity consumption per year (kWh/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>11,600,000</td>
</tr>
<tr>
<td>Ventilation</td>
<td>500,000</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>2,600,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14,700,000</strong></td>
</tr>
</tbody>
</table>

This results in CO₂ emissions of 3,900 tonnes annually.

Materials consumption for maintenance and replacement was estimated by the design group, and it is listed in Table 8.6.
Table 8.6  Main material used for maintenance and replacement during operation of the bored tunnel

<table>
<thead>
<tr>
<th>Material description</th>
<th>Estimated quantity per replacement</th>
<th>Unit</th>
<th>Replacement intervals (Years)</th>
<th>Estimated quantity (per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt - driving lanes and emergency lanes</td>
<td>43,000 T</td>
<td></td>
<td>40</td>
<td>1,075</td>
</tr>
<tr>
<td>Asphalt - portal ramps</td>
<td>20,000 T</td>
<td></td>
<td>25</td>
<td>800</td>
</tr>
<tr>
<td>Asphalt for the portal ramps</td>
<td>142,000 m³</td>
<td></td>
<td>60</td>
<td>2,367</td>
</tr>
<tr>
<td><strong>Rail</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crushed stone</td>
<td>2,700 T</td>
<td></td>
<td>1</td>
<td>2700</td>
</tr>
<tr>
<td>Steel bars</td>
<td>8,700 T</td>
<td></td>
<td>15</td>
<td>580</td>
</tr>
<tr>
<td>Crushed stone</td>
<td>79,000 T</td>
<td></td>
<td>25</td>
<td>3,160</td>
</tr>
<tr>
<td>Concrete sleeper</td>
<td>8,800 T</td>
<td></td>
<td>25</td>
<td>352</td>
</tr>
<tr>
<td>Concrete slab track</td>
<td>165,000 T</td>
<td></td>
<td>60</td>
<td>2,750</td>
</tr>
<tr>
<td>Concrete catenary</td>
<td>1,360 m³</td>
<td></td>
<td>60</td>
<td>23</td>
</tr>
<tr>
<td>Steel catenary</td>
<td>899 T</td>
<td></td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

It is estimated that the use of materials for maintenance and large replacements will result in CO₂ emissions of around 2,000 tonnes annually.

8.2.3  Greenhouse gas emissions from traffic

Method
The construction of a fixed link across the Fehmarnbelt will have significant implications for the traffic and travel pattern between Germany and Scandinavia. The fixed link will reduce travel time, thus making transport more attractive in the corridor. Therefore, a fixed link will, most likely, promote traffic and transfer transport from other routes and between modes of transport. The effects on traffic are assumed to be identical for all alternative fixed link solutions.

The specific changes in traffic and transport modes in a predefined influence area were analysed by the Fehmarnbelt Traffic Consortium in 2003. The analysis was made for a fixed link alternative and a reference alternative, i.e. the zero-alternative (FTC 2003a, FTC 2003b).

The use of the influence area implies that changes in transport between Scandinavia and Germany within the area were included in the analysis. Thus flight, vehicle and train transport and ferry transport on the routes Rødby-Puttgarden, Trelleborg-Rostock and Gedser-Rostock were considered. In particular,
there will be a large transfer of freight trains from the Great Belt Link to the Fehmarn Link.

It was assessed that the effect from the change in air transport was marginal, and consequently emissions from air transport were not included in the analysis.

For further description of the model, see the reports from the Femarnbelt Traffic Consortium (FTC 2003a and FTC 2003b) and a previous report from the Danish Ministry of Transport and Energy (COWI 2005).

The GHG emission inventory emissions were calculated for the year 2025 as determined by Femern A/S. Year 2025 represent the year when the traffic can be assumed to be phased-in and the related infrastructure projects finished.

The traffic volumes were projected using the 2015 traffic volumes (COWI 2005) as the basis assuming an annual increase in traffic of 1.7% for all traffic modes as assumed in the earlier studies (COWI 2005).

The emission factors for road traffic are based on assumptions for a Danish vehicle fleet composition in years 2025 and 2030, which draws on statistics and forecasts about age, size and fuel distribution. Emission factors derive from TEMA 2010 which is the official emission calculation model by the Danish Ministry of Transport (TEMA 2010).

The typical train type was defined by Femern A/S. All trains are assumed to be fully electric.

The basic source for the calculation of emission factors for trains is TEMA2010. As the values are related to today’s efficiency and the technology, they have been projected to year 2025 using a reduction factor, which considers improvements in train efficiency and electricity production.

The increase in traffic volume across the Fehmarnbelt will have a great influence on the potential future ferry capacity across the Baltic Sea. Predictions of emissions from ferries in 2025 were made by the Technical University of Denmark based on the latest knowledge of technology and future regulation (Kristensen, 2010).

In calculating the CO₂ emissions, the key information is the distances driven by the different traffic categories in the influence area. The interesting figure is not the absolute traffic volume, but the relative traffic volume compared with the zero-alternative.

The zero-alternative is the scenario without a fixed link, but with continued ferry operations as is the case today.

**Road and rail traffic**

The projected traffic volumes for 2025 with the fixed link are shown in Table 8.7. The volumes are expressed in terms of distances travelled between Scandinavia and Germany within the influence area.
Table 8.7 Distances driven between Denmark/Scandinavia and Germany, 2025, million km/year.

<table>
<thead>
<tr>
<th>Mode of traffic</th>
<th>Unit</th>
<th>The zero-alternative</th>
<th>The project alternative (fixed link)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger cars</td>
<td>Vehicle-km</td>
<td>4,277</td>
<td>4,399</td>
<td>2.9%</td>
</tr>
<tr>
<td>Buses</td>
<td>Vehicle-km</td>
<td>75</td>
<td>75</td>
<td>0.8%</td>
</tr>
<tr>
<td>Passenger trains</td>
<td>Passenger-km</td>
<td>1,236</td>
<td>1,479</td>
<td>19.7%</td>
</tr>
<tr>
<td>Lorries</td>
<td>Vehicle-km</td>
<td>4,344</td>
<td>4,319</td>
<td>-0.6%</td>
</tr>
<tr>
<td>Freight trains</td>
<td>Tonne-km</td>
<td>18,250</td>
<td>17,975</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Combi trains</td>
<td>Tonne-km</td>
<td>4,056</td>
<td>3,752</td>
<td>-7.5%</td>
</tr>
</tbody>
</table>

Table 8.7 shows that, for passenger transport, the distances driven increase for all modes of transport. For passenger cars and trains the increase is a result of an increase in the number of passengers transported, and the fact that the passenger cars and trains use the fixed link instead of the ferry. The buses also use the fixed link instead of the ferry, and this effect is stronger than the decrease in number of buses.

The tables also show a minor decrease in distances driven by the different modes of freight transport. For lorries, a reduction in number of tonnes is seen due to the transfer of freight to rail. At the same time, the lorries use the fixed link (implying longer distances driven), but the distances travelled are shorter due to the transfer of traffic from other routes. For trains, the effect from the increase in numbers is outweighed by the fact that the trains no longer travel through Jutland and thereby travel shorter distances

The calculation of the emissions from cars in the TEMA 2010 method require data on fuel type, Euro norm, engine size, road type and speed. For busses the data required is Euro norm and weight while for lorry and vans it is fuel type, weight, lorry type and Euro norm. Reference is made to COWI 2012c for the details of the data and the emission factors.

The basic source of the emission factors for trains was TEMA 2010. Reduction factors were applied for passenger and freight trains to take account of the expected improvements in efficiency and technology (COWI 2012c).
Ferry traffic

The number of ferry crossings per year for the three routes in 2025 is predicted to be:

- Rødbjerg-Puttgarden: 32,351
- Gedser-Rostock: 6,400
- Trelleborg-Rostock: 2,840

The CO₂ emissions were based on the fuel consumption data provided by the ferry companies, see COWI 2012c for details.

**CO₂ emissions in 2025**

For the present report the interesting result is not the total emissions but the reduction of emission due to the operation of the fixed link compared with the zero-alternative. The total emissions based on the data given here would be the emissions only from the Scandinavia-Germany traffic within the influence area and, as such, has little meaning.

The reductions in the CO₂ emissions for traffic are shown in Table 8.8.

<table>
<thead>
<tr>
<th>Mode of traffic</th>
<th>Changes in CO₂ emission per year (ton) compared with the zero-alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 2025 (tonne/year)</td>
</tr>
<tr>
<td>Passenger cars</td>
<td>19,740</td>
</tr>
<tr>
<td>Busses</td>
<td>406</td>
</tr>
<tr>
<td>Passenger train</td>
<td>8,727</td>
</tr>
<tr>
<td>Ferries</td>
<td>-201,422</td>
</tr>
<tr>
<td>Lorries</td>
<td>-16,235</td>
</tr>
<tr>
<td>Freight trains</td>
<td>-9,749</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>-198,533</strong></td>
</tr>
</tbody>
</table>

The largest saving will come from the expected closing down of the ferry route between Rødbjerg and Puttgarden and a reduction in the departures at the other ferry routes. However, emission reductions will also be achieved in road and rail freight transport due to the expected transfer of freight from road to rail and shorter travel distances for rail freight.

Calculations of traffic emissions have been based on a traffic analysis from 2003 and an average progression factor per year for all traffic modes of 1.7%, allowing
extrapolation of data to the 2025. This factor is highly dependent on the general economic growth and is thus subject to much uncertainty.

Calculations are based on a Danish vehicle fleet and TEMA2010 emission data. A previous sensitivity analysis using HBEFA emission factors and a German vehicle fleet found only minor differences compared to the final emission calculations (COWI 2005).

**CO₂ emissions in 2025 for the 50% scenario**

The second traffic scenario to be considered assumes that the Rødby-Puttgarden ferry service is still operational in 2025 and that 50% of the vehicle traffic uses the ferries. However, all trains are assumed to use the fixed link. The results of the calculations of the reduction of emissions are shown in Table 8.9.

<table>
<thead>
<tr>
<th>Mode of traffic</th>
<th>Changes in CO₂ emission per year (ton) compared with the 50% alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 2025</td>
</tr>
<tr>
<td></td>
<td>(ton/year)</td>
</tr>
<tr>
<td>Passenger cars</td>
<td>13.966</td>
</tr>
<tr>
<td>Busses</td>
<td>406</td>
</tr>
<tr>
<td>Passenger train</td>
<td>8,727</td>
</tr>
<tr>
<td>Ferries</td>
<td>-46,055</td>
</tr>
<tr>
<td>Lorries</td>
<td>-16,235</td>
</tr>
<tr>
<td>Freight trains</td>
<td>-9,749</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>-43,166</strong></td>
</tr>
</tbody>
</table>

As it appears, the scenario will result in a reduction in CO₂ emission compared with the zero-alternative. This is due to less ferry departures on the routes Trelleborg-Rostock and Gedser-Rostock, but also due to less kilometres driven by lorries and freight trains.

**8.2.4 Summary of greenhouse gas emissions**

The total greenhouse gas emissions for the bored tunnel are shown in Table 8.10. The results for the immersed tunnel and the cable stayed bridge are shown for comparison.
Table 8.10  Total greenhouse gas emissions compared with the zero-alternative (tonne)

<table>
<thead>
<tr>
<th>Emission source</th>
<th>Bored tunnel</th>
<th>Immersed tunnel</th>
<th>Cable Stayed Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>2,482,000</td>
<td>1,1816,000</td>
<td>1,235,000</td>
</tr>
<tr>
<td>Operation</td>
<td>5,900</td>
<td>5,900</td>
<td>2,900</td>
</tr>
<tr>
<td>Traffic 2025 (reduction per annum)</td>
<td>-198,500</td>
<td>-198,500</td>
<td>-198,500</td>
</tr>
<tr>
<td>Traffic 2025/50% (reduction per annum)</td>
<td>-43,000</td>
<td>-43,000</td>
<td>-43,000</td>
</tr>
</tbody>
</table>

Construction of a bored tunnel will result in emissions of approximately 2.5 million tonne CO₂ equivalents throughout the construction period. For comparison, the total Danish CO₂ emissions during the eight year construction period would be about 400 million tonne.

The most important contribution to CO₂ emissions in the construction phase is CO₂ from production of building materials, in particular concrete and steel, partly on account of the large quantities to be used and partly because production of cement and steel involves high energy consumption compared with other sources of emissions of CO₂ from construction.

During the operation of the fixed link, the annual CO₂ emissions from power consumption, maintenance and renovation will be approximately 6,000 tonne for the bored tunnel. Over the life of the fixed link (120 years), assuming the same emission level and emission factors, this totals 0.7 million tonne CO₂ for the tunnel.

If the Fehmarnbelt Fixed Link is compared with the zero-alternative, the establishment of a fixed link will entail an expected reduction in CO₂ emissions of approximately 200,000 tonne per annum in 2025.

If the Fehmarnbelt Fixed Link is compared with a situation with a fixed link and the ferry service being maintained, where the traffic is equally distributed between the two transport alternatives, the annual CO₂ saving is reduced to approximately 43,000 tonne.

From Table 8.10 it can be calculated that the bored tunnel will become CO₂ neutral after 9 years when compared with the zero-alternative and after 37 years when compared with the scenario of continued ferry operation.
8.3 Impact of climate change on project durability

Potential climate change has been taken into consideration in the design of the bored tunnel. The most important potential change is the sea level rise and the thereby an increase in the potential storm surge levels.

The portal areas on Lolland and Fehmarn are protected by dikes around the outer boundary of the portals and ramps to protect against the tunnel being flooded in the event of extreme high water situations (1 in 10,000 year storm surge level). The top of the dike will have an elevation of +5.75 m MSL with the possibility of raising it another 0.5 m if necessary (see Chapter 3).

The dike around the road portals and ramps will continue until the road level reaches the crest level of the dike. This is not possible for the rail due to low permissible gradients. In the event of an extreme storm surge rising above +2.5 m MSL, provision has been made for storm surge protection barriers to be placed across the railway at the end of the railway ramp.

Other potential climate changes are assessed as not giving rise to the need for design optimisation.
8.4 Significance of climate change for the project’s environmental impacts

With its proposal for an environmental study programme, Femern A/S wanted to incorporate possible climate-related changes to the environmental status in the assessment of the project's environmental impacts. The main question is how climate change will affect important environmental parameters and species and whether these impacts will change the project's probable main impacts on the environment.

This section is a description of how an expected climate development as outlined in IPCC scenarios A2 and B2 will affect the environment in the project's primary area of influence, with particular focus on the marine area, and how the project's impacts may be affected by this. Moreover, relevant EIA background reports’ conclusions concerning the individual environmental components have been incorporated to illustrate how these components are affected by climate change. For a more detailed description of methods and the data used for each environmental component, please see the respective sections for them in chapters 5, 6 and 7.

The significance of the climate changes for the project's total impacts is only described in general terms since the impact of the expected climate change on a number of the environmental conditions will largely be subject to possible specific local measures.

8.4.1 Hydrography, water quality and plankton

Climate change

The warming trend in the Baltic Sea has been at around 0.08°C per decade in the past century. This is higher than the global warming trend of 0.05°C per decade. The mean value of the average temperature in Denmark has been approximately 8.5°C since 1990, whereas the average temperature for the normal period 1961 - 1990 was 7.7°C. This indicates an average increase of 0.8°C in relation to the last normal period. This warming may be related to global warming.

Based on models carried out using the Baltic Sea Basin Regional Climate model, a trend towards rising temperatures in the Baltic Sea basin has been identified. In the north-eastern part of the Baltic Sea basin, the temperature increase will be highest in the winter and the spring, while the temperature increase is highest in the summer in the south-western part of the Baltic Sea basin.

In addition, the daily maximum temperature in the summer will increase by 3 to 10 °C. Models show an increased precipitation in the winter, while simulations for the summer period show a higher precipitation in the northern part of the Baltic Sea and a lower precipitation in the southern part of the Baltic Sea.

Precipitation during extreme events will increase in the winter half of the year. The sea ice season will be reduced by 1 - 2 months in the northern part of the Baltic Sea and 2 - 3 months in the central parts of the Baltic Sea. The temperature of the
surface of the sea will increase by 2 - 4 °C and increase most in May - June in the southern and central parts of the basin. Global sea level increases of up to 1 m will spread into the Baltic Sea basin.

The cumulative effect of climate change on factors including the salinity of the Baltic Sea, including the effect of increased precipitation, increased evaporation, a rising sea level and increased water exchange, cannot be predicted with certainty but is expected, within a few decades, to be much greater than the assessed impacts of the project.

Significance of climate change for the project's impacts

The impacts on hydrography, water quality and plankton of the three project alternatives, immersed tunnel, cable-stayed bridge and bored tunnel, under the new climate conditions, are assessed to correspond to the expected impacts under the present climate conditions.

However, it should be stated that each of these climate changes may lead to considerably greater changes to the conditions in the central parts of the Baltic Sea than any of the link alternatives. For example, model calculations carried out using the MIKE model indicate that the current rise in sea level of 0.003 m per annum will lead, over 8 years, to increased water exchange between the central Baltic Sea in the same order of magnitude as the impact of the establishment of a cable-stayed bridge. This rise in sea level is expected to continue and to accelerate in the decades to come. It is therefore unlikely that it will be possible to determine the impact of the cable-stayed bridge on the Baltic Sea by measuring salinity, for example, as climate change will cause much greater changes in the course of a few decades.

All factors taken into account, the project alternatives' specific impacts on hydrography, water quality and plankton are not assessed as being likely to change in nature or extent as a consequence of the expected climate change and its impacts on the environment in the Baltic Sea (FEHY 2012g).

8.4.2 Coastal morphology, sediment and seabed types

Climate change

The most important parameters for the coastal morphology are prevailing wave factors and water levels. On the basis of existing knowledge, it is not possible to conclude what impact possible climate change and its impact on the wind and wave climate will have on the morphological stability of the coasts of Lolland and Fehmarn. Even relatively small changes in wave directions can change erosion and sedimentation in terms of patterns and speed. This applies in particular to the long stretches of unprotected coastline. Sediment transportation can increase or decrease depending on changes in wave directions (FEHY 2012j, FEHY 2012i).

The expected rise in sea level by up to 1 m will have an impact on the coastal morphology. In general, the coastal landscapes of Lolland and Fehmarn are low-lying, and a rise of the sea level of 1 m will have a detrimental impact on protection
of the land area behind the coast. The land areas behind the coast are currently protected by dikes and other measures on the coast (FEHY 2012j, FEHY 2012i). The current coastal protection will not be sufficient to protect the dikes against erosion.

On the coast, many of the small coast protection structures (coastal protection, groynes, etc.) will be fully or partially flooded. However, the structures can, to a certain extent, maintain their function and limit sediment transportation as they will remain in place in the coastal profile. Climate change will mean that, over time, it will be necessary to take further measures to protect the coasts and the land areas behind them on Lolland and Fehmarn against flooding, whether or not a fixed link is established across Fehmarnbelt.

Significance of climate change for the project's impacts

Climate change is assessed to be able to change the rate of erosion east of the reclaimed land in connection with the establishment of a bored tunnel. The influence of climate change on wave height and/or wave direction may cause erosion to spread faster or more slowly to the east, depending on the influence on sediment transportation (FEHY 2012j).

The impact of the tunnel project is an increase in the erosion pressure on groynes, dikes and beaches at Oldenburgs Huk/Marienleuchte, and this is not expected to be changed significantly as a consequence of climate change (FEHY 2012j).

It is not expected that climate change will change the tunnel project's impacts west of Puttgarden or the north coast of Fehmarn. Moreover, it is not expected that climate impacts as a consequence of a tunnel project will result in increased impacts on seabed morphology in Fehmarnbelt (FEHY 2012i).

Overall, the impacts of the bored tunnel on the coastal morphology and the sediments and seabed morphology are not assessed as being likely to change significantly in nature or extent as a consequence of the expected climate change.

8.4.3 Benthic flora and fauna

Climate change

The resulting impacts of climate change on flora and fauna in Fehmarnbelt have been evaluated via several climate scenarios up to 2080 - 2100. The future climate change will have an impact on various abiotic parameters, but not all have an impact on benthic flora and fauna.

The benthic flora and fauna in Fehmarnbelt are expected to be affected by rising temperature, increased precipitation and higher wind speed as a consequence of climate change. An increased temperature may promote the spread and establishment of species from surrounding marine areas such as the Mediterranean. This may be detrimental to native species from boreal regions (FEMA 2012e, FEMA 2012d).
If the seasonal period for growth increases on account of higher temperatures, opportunistic species in particular will be able to spread faster and in some cases this takes place at the expense of other species. Therefore, it is possible that the conditions in Fehmarnbelt will change, in the longer term, to the advantage of species that thrive in warmer temperatures. The seasonal dynamics of the present species will also change in response to the temperature rise. Together these effects may mean a change in species composition and abundance (FEMA 2012e, FEMA 2012d).

Temperature increases can also increase the occurrence of oxygen deficiency at the seabed with a corresponding impact on benthic flora and fauna.

Increased precipitation will entail higher run-off from onshore with a resulting fall in salinity in the surface water. A large proportion of the marine species in the Baltic Sea have a distribution which is limited by the salinity in the inner, less saline areas. A fall in salinity will therefore entail changes in the species' distribution and community structure.

Increased precipitation will also result in an increase in nutrient runoff and a greater vertical stratification. These effects will stimulate eutrophication in the photic zone and oxygen deficiency in the lower layer.

Increased wind speed may change the zoning by increasing oxygenation and mixing in the water column, whereby the structure of the seabed fauna may change (FEMA 2012e). In addition, an increased wind intensity and a switch towards more westerly winds may increase coastal erosion and sediment processes, thus increasing areas with unstable sediment. The opportunistic filamentous macroalgae may therefore, in the long term, replace the perennial macroalgae communities that are typical of the upper littoral zone, for example bladder wrack. The upper depth limit of soft bed communities with eelgrass may therefore be displaced to deeper water with more stable sediment (FEMA 2012d).

**Significance of climate change for the project's impacts**

It is assessed that the fixed link will not reinforce the impacts of climate change on the benthic flora and fauna. Moreover, it is assessed that recolonisation of the fauna in areas in which the fauna is lost or reduced on account of suspended sediment or sedimentation will most probably occur before the expected climate change leads to significant changes in the marine environment (FEMA 2012c).

### 8.4.4 Fish and fishery

**Climate change**

Fehmarnbelt plays a role in water exchange in the Baltic Sea. Moreover, Fehmarnbelt is an important passage for migrating cod, herring and silver eel, and a spawning area for a number of fish species, including cod and flatfish. Marine fish species are affected by natural hydrological variations and thresholds. The most sensitive life stages are the egg and larval stages. The overall impact that must be taken into consideration is therefore mortality of eggs and larvae and fall
in recruitment. The density of sea water is primarily determined by salinity and temperature, which affects the buoyancy of eggs. A fall in the ambient density may therefore be decisive to an egg's survival as the eggs may sink to the bottom or to the lowest water layer, where the oxygen concentrations may be critical (FeBEC 2012b).

In addition to the density of eggs, salinity gradient, composition and duration of exposure, as well as spawning time, local currents/upwelling may also temporarily postpone or increase descent. Moreover, the water temperature also affects the density of water and thus the buoyancy of eggs, however less than salinity.

In the following, only the extent of the impact on cod, sprat and herring is assessed. This is done because these species are the ones with the highest commercial importance. Moreover, the internal population dynamics between these three species are closely linked and therefore the effect of climate change on one species will inevitably have an influence on the other species. Herring and cod are also extremely sensitive to certain climate changes. For a more detailed description of the many fish species in Fehmarnbelt, please see FeBEC 2012a and FeBEC 2012b.

Cod
Climate change that affects environmental conditions may have a direct impact on cod populations, e.g. their growth and distribution, and an indirect impact via changes in, e.g. food availability and the incidence of predators. Temperature changes have been shown to have an impact on the distribution of a population, spawning time and spawning grounds, as well as preferred habitats and behaviour.

Cod populations that live at the upper limit of their thermal tolerance range will therefore probably undergo a decline in growth and population reproduction in the event of a temperature rise (FeBEC 2012b).

Indirect impacts as a consequence of climate change are expected to consist of changes in the trophic structure (food chain), and have been reported as temperature-dependent changes in food quantity in the larval stage or changed predation.

The area-related distribution and spawning grounds of the adult population occur in fixed areas of the Baltic Sea since spawning is limited to the deep basins. Individual growth may be inhibited due to a fall in ambient oxygen levels. If the food quantity increases due to indirect climate impacts, the quantity and quality of eggs produced may increase (FeBEC 2012b).

In summary, the climatic conditions in the past 10 years and expected climate changes are predominantly considered to be unfavourable for the recruitment, survival and productivity of Baltic cod.

Sprat
Sprat in the Baltic Sea occur at the northern boundary of their geographical distribution and are therefore particularly vulnerable to low temperatures. Sprat are
adapted to marine environments so that brackish waters with lower salinity may be critical. Moreover, passive transportation of the early life stages is significant.

Climate change thus has an impact on the survival of eggs via 1) direct impacts on mortality and 2) changes in egg development time or buoyancy. The direct impacts on egg mortality on account of salinity are currently difficult to assess.

The ambient temperature has a great influence on the duration of the individual egg stages of sprat and rising temperatures thus result in faster egg development. In addition to this indirect influence on mortality, laboratory studies show a marked direct impact of temperature on egg mortality, with mortality reduced at higher temperatures.

The expected impacts of climate change on the conditions for sprat are expected primarily to have positive impacts on the population and the future possible exploitation of sprat in the Baltic Sea (FeBEC 2012b).

**Herring**

The herring populations in the northern hemisphere are affected by climate impacts, including the populations' distribution and migration patterns. Many studies discuss the positive and negative changes in growth in adult herring as a direct (temperature) or indirect (quantity of food) reaction to the climatic changes. Moreover, recruitment success and the frequency of failure to spawn have been identified as being dependent on temperature variability.

The total impact of the expected climate change on Baltic Sea herring populations is difficult to assess. The populations will probably react differently, with some populations increasing and other populations declining. To this is added that the population of herring in the Baltic Sea is closely linked to the population dynamics of cod and sprat (FeBEC 2012b).

**Significance of climate change for the project's impacts**

The Fehmarnbelt Fixed Link will have an impact on fish communities as a consequence of the specific activities during the construction and operation and of the physical structures. The various impact levels are assessed in relation to the sensitivity of species or communities and the impacts are generally small.

The impacts of the bored tunnel under the new climate conditions, are assessed to correspond to the expected impact under the present climate conditions (FeBEC 2012b, FeBEC 2012e).

**8.4.5 Marine mammals**

**Climate change**

Climate change may have an influence on the future population of marine mammals. The future climate change is assessed for marine mammals up to 2100. The assessment focuses on how climate change affects species and their habitats.
Changes that occur approximately 80 years after the baseline studies are taken into consideration in the assessment (FEMM 2012b).

Harbour porpoises
Harbour porpoises are affected by changes in temperature, including ice sheets. An increase in temperature in Fehmarnbelt will probably change the regional and local distribution of fish and thus food availability. However, harbour porpoises are an opportunistic species, as a result of which the impact of changes in food composition in the Fehmarnbelt region may be limited.

Current telemetry data indicates that harbour porpoises range across large distances in the Baltic Sea. On the basis of a comparison of the most recent winters in Fehmarnbelt, a reduced ice sheet in the Baltic Sea in 2100 will not restrict harbour porpoises' movements over large distances or their opportunity to reach important feeding areas. Therefore, it is assessed that climate change in the Fehmarnbelt area is of minor significance for harbour porpoises (FEMM 2012b).

Seals
For both harbour seals and grey seals, analyses of the expected climate changes show that there is still insufficient qualitative data on the changes in the relevant environmental factors up to 2100. Therefore, at present, it is difficult to assess the future trends in status for harbour seals and grey seals in Fehmarnbelt.

Current knowledge leads to the conclusion that changes in water temperature entail changes in food composition and availability for both species. However, both seal species are known to be opportunistic species, as a result of which it is assumed that a change in food composition does not weaken the seals (FEMM 2012b).

Significance of climate change for the project's impacts
The bored tunnel will not change the climate impacts on marine mammals in Fehmarnbelt (FEMM 2012b).

8.4.6 Sea birds

Climate change
Global climate change is expected to change the geographical distribution of species since species follow the climate to which they are adapted. New models thus predict that breeding areas for many European bird species will probably move several hundred kilometres, primarily in a north-east direction (FEBI 2012d).

In Denmark, climate change is expected to produce a change in breeding bird species of up to 20% over the next 50 years. It should be noted that observations of the changes in recent years are generally in accordance with the model predictions (FEBI 2012d).

For both non-breeding birds and breeding birds, distribution is affected by climate, availability of food and other disturbances. Therefore, it is expected that climate change will cause water birds which are adapted to cold weather to move their
resting places and follow their climate-adapted niches further north. These changes are expected to lead to significant impacts on the ability of the Fehmarnbelt region to support the current population and distribution of water birds (FEBI 2012d). These changes will take place regardless of any future fixed link.

The potential impacts caused by climate change on the distribution of non-breeding sea birds in Fehmarnbelt were studied using species distribution models (SDM). The SDMs were evaluated thoroughly in the light of the most recent scientific literature. The models are statistical models that relate field observations to environmental indicator variables with a view to describing the total distribution of a species on the basis of data on climate and environment (FEBI 2012d).

The overall objective of the model was to:

› Identify significant climatic and environmental variables in relation to the distribution of non-breeding sea birds

› Model the potential impact of changes in the climate and environment on the future distribution of sea birds

› Identify species that are particularly sensitive to climate and environmental changes

The SDM was applied using the MaxEnt algorithm for maximum entropy modelling of the species' geographical distribution. The current potential species-specific distribution is estimated using data on species present and environmental data and topographical/geographical data (FEBI 2012d). The future distribution of species is subsequently estimated using data from future climate scenarios.

The model calculations were carried out for 18 sea birds (black-throated diver/red-throated diver, great crested grebe, red-necked grebe, Slavonian grebe, cormorant, common eider, long-tailed duck, common scoter, velvet scoter, red-breasted merganser, little gull, common gull, black guillemot, guillemot, kittiwake, herring gull, great black-backed gull, razorbill), for which data was available for the entire region (Baltic Sea and North Sea) (FEBI 2012d).

The occurrence of the species varies significantly across the study area. This variation was incorporated in the model calculations by including a sensitivity analysis with data for six different species. In the calculations, the five variables (surface temperature of the sea, sea ice, precipitation, wind speed, air pressure, bathymetry) made available by the IPCC (2007) were considered to be the most relevant for sea birds.

In the two climate scenarios selected for birds (A1B/B1), the best conditions for hibernating sea birds will move in a north-easterly direction. A major change will already be seen in the 2020s, and further changes will occur up to the 2080s. This produces an expectation that the suitability of the environment for water birds will already change in 2025-2030.
The overall pattern shows generally falling suitability in the North Sea and the southern part of the Baltic Sea, plus rising suitability in the northern part of the Baltic Sea and further towards the north-east despite some variation. The biggest shift must be expected to take place within the next four decades (FEBI 2012d).

A similar scenario was estimated for climate scenario B1. For the Fehmarnbelt region, the results show a general fall in the area's suitability for sea birds. In general, the results show a distinct fall in suitability across all species, climate scenarios and time periods. The only exception is the sea bird kittiwake (*Rissa tridactyla*), for which the results show no increase or a small increase in the suitability of the environment for the species. This means that this species may be the only one to increase, according to the model results (FEBI 2012d).

Significance of climate change for the project's impacts
The impacts of the bored tunnel under the new climate conditions are assessed to correspond to the expected impact under the present climate conditions.

### 8.4.7 Migrating bats

**Climate change**
A study of the impact of climate change on migrating bats could not be carried out since current research does not provide information on migrating bat species' reaction to climate change. The impact on migrating bat species is expected to be comparable with the impact on migrating bird species.

In general, it is assessed that the impact of higher temperatures is problematic for bats as higher temperatures can have an impact on hibernation locations, and produce a lower reproduction rate and a higher level of competition between species for food resources and hibernation locations. A more detailed prediction of changes as a result of climate change is not possible, based on current knowledge (FEBI 2012d).

**Significance of climate change for the project's impacts**
The project's impacts on migrating bats have been assessed on the basis of the various possible solutions for a Fehmarnbelt Fixed Link during the construction and operation phases. The project is assessed as not having a significant impact on the migrating bats since they are assessed to migrate widely across Fehmarnbelt and the project area is not seen to be more attractive than other areas for migration across Fehmarnbelt, (FEBI 2012d).

Climate change is assessed as not changing the project's negligible and insignificant impacts on bat migration across Fehmarnbelt.

### 8.4.8 Environmental conditions in the ramp area on Lolland
The following sections describe the potential environmental impacts of expected climate change on Lolland, and the extent to which these impacts change the
assessments made of the impacts of the bored tunnel project on the environment in the operation phase of the project.

The expected climate change in the Baltic Sea region is outlined in section 8.1 and includes changes in temperature, wind and precipitation, plus an expected rise in the sea level. The local climatic conditions will be affected by this and it is assessed that the rise in temperature and increased precipitation will primarily occur in the winter half of the year, that the intensity of precipitation will generally increase and that the average wind speed and frequency of strong wind will increase (COWI 2012a).

8.4.9 Lolland - Landscape and soil

Climate change
A higher water level and a change in wind climate will change the impact on the current coastal landscape. Large parts of the coast, including the dike, are a distinct cultural landscape with the aim of protecting community interests, and it is assumed that the community interests will essentially demand that the coastal landscapes be fundamentally retained in their form and function by means of reinforcement and development of the current measures.

The soil conditions in the area also reflect extensive drainage measures that form the basis of the existing area use, including agricultural management. In the light of the specific climate change that may occur during the operation phase of the project and the rising sea level, it is assumed that maintenance of drainage measures will ensure that the soil conditions are not fundamentally changed (COWI 2012a).

Significance of climate change for the project’s impacts
The bored tunnel project has a number of specific impacts on the landscape and soil which are primarily associated with the loss of the areas used for the project and with the impact of the visible project structures on the landscape. The project impacts are not assessed to change significantly in nature or extent as a result of the climate change that may take place during the operation phase of the project (COWI 2012a).

8.4.10 Lolland – Flora and fauna

Climate change
There is currently only sporadic knowledge about the precise impact climate change will have on flora and fauna and how powerful it will be. It may also be difficult to indicate the precise impact of climate change as the interaction with a number of other natural and cultural factors that affect nature, including cultural geographical factors such as agriculture, infrastructure and urban development, is complex and difficult to predict.
The expected climate change may result in species that currently live south of Denmark spreading northwards and species that live in Denmark at their southern distribution limit disappearing. The species that come from the south will primarily be species with high distribution potential. Therefore, it is conceivable that several generalists will be added while specialists will disappear to a greater extent unless they are able to move to new areas that become suitable for them.

Modelling of plant species under the impact of the expected climate change has shown that south-eastern Denmark in particular (including Lolland-Falster, where the total impact is assessed to be very negative) will be affected severely by climate change. For Denmark in general, it is assessed that 4% of the characteristic species (under the Habitats Directive) are expected to disappear in the longer term, and that 2/3 of the species must be expected to decline to a greater or lesser extent.

The expected climate change is assessed as being likely to increase the diversity of small mammals in Denmark in general and a number of bats may spread northwards. There may also be immigration of several reptile and amphibian species and there may be changes in the fish fauna. Many of the species that will be able to thrive in the Danish climate of the future will, however, find it difficult to immigrate to Lolland. This applies to mammals (apart from bats), reptiles, amphibians and freshwater fish (COWI 2012a).

Groups of animals and plants with good dispersal capacity such as birds, insects and plants with wind-dispersed or bird-dispersed seeds will be able to change their distribution much more quickly under changed climate conditions.

Significance of climate change for the project's impacts
In the following areas, there will be specific and relevant interaction in the study area between project impacts and impacts as a consequence of climate change:

› The fact that the dike is built higher to protect against flooding, resulting in an impact on valuable animals and plants that currently exist on the dike.

› The fact that some of the species that currently only occur on the railway terrain in Rødbyhavn may, in the future, spread to other locations as they become more suitable for the species coming from the south.

› The fact that the natural content of the cultural landscape is changed as agricultural areas are taken out of operation because they are no longer profitable to manage, among other things as a consequence of more intense precipitation events.

› The fact that fauna passages at watercourses and river valleys are dimensioned and berms are protected so the animals can pass in dry conditions despite increased, more intensive precipitation, a higher water level and greater watercourse erosion than today. A change in species diversity is not expected to change the requirements for fauna passages (COWI 2012a).
8.4.11 Lolland - Population/outdoor leisure activities, material assets and cultural heritage

Climate change
The changes in the local climate and a higher water level at the coast are not assessed in themselves as having a negative impact on the conditions for the environmental factors population/outdoor leisure activities, material assets and cultural heritage, as it is assumed that, in the light of the specific climate change in the project's operation phase, the cultural landscape will be protected and developed so that, for example, coastal protection and drainage measures will safeguard the interests associated with the environmental factors in question (COWI 2012a).

Significance of climate change for the project's impacts
The bored tunnel project is assessed only to have limited impacts in the project's operation phase and it is assessed that the project impacts do not significantly change in nature or extent as a result of the climate change (COWI 2012a).

8.4.12 Lolland - Groundwater and surface water

Climate change
Increased precipitation, more frequent violent precipitation events and also periods of drought and a general rise in temperature will be significant for groundwater and surface water in watercourses, ponds and lakes.

The groundwater level will generally vary more and the temperature of the groundwater, which roughly reflects the annual mean temperature of the air, will increase. Aquifers in the coastal area, in particular in the parts of the project area that are former inlets and are already below sea level, are in contact with Fehmarnbelt and will be affected by a sea level rise.

The rate of flow and the watercourse's regime will change. Periods of high run-off will occur and the rate of flow through watercourses will vary considerably.

Ponds and lakes will experience a high variation in the inflow of water and in their water levels, and the maximum and average water temperatures are assessed to increase (COWI 2012a).

Significance of climate change for the project's impacts
The area is currently subject to extensive drainage. It is expected that the drainage will be maintained after the establishment of the fixed link. In the project area, there are predominantly watercourses in the form of drainage channels, controlled by a number of pumping stations, and it is therefore expected that the physical dimensions of the watercourses will receive the necessary protection and that the pumping stations will continue, following climate change, to have sufficient capacity to ensure the desired drainage, particularly in the low-lying coastal areas.
The bored tunnel project will only affect the drainage of water in the watercourses to a limited extent. Some watercourses will be diverted and the pumping station will be renovated in connection with the establishment of the bored tunnel. The project’s impacts on the watercourses are minor and they are therefore, in the operation phase, assessed as having comparable minor impacts on the watercourses, including under the expected changes in climate conditions. This is also assessed as being applicable to the project's impacts on groundwater (COWI 2012a).

A number of ponds and one lake are affected by the bored tunnel project and will be lost. As part of the planned preventative measures, the lost water areas are replaced with new natural areas so that new equivalent water areas are established as far as possible. From this perspective, the project’s impacts are not assessed to change significantly as a result of the climate change that may take place during the operation phase of the projects (COWI 2012a).
9 Sand Mining on Rønne Banke

9.1 Introduction

Sand and gravel is required as aggregate for the concrete in the Bored tunnel alternative solution for the Fehmarnbelt Fixed Link. The volume required is approximately 1 million m$^3$ and it is planned to extract it from Rønne Banke located about 30 km southwest of the Danish island of Bornholm (Figure 9.1). The area is already in use for sand mining purposes.

This chapter summarises the EIA which has been made for the extraction of the sand. For the full details please refer to the background report:


It is noted that the background report concerns the immersed tunnel and cable stayed bridge alternatives for the fixed link. However, the volume of sand required for the bored tunnel is the same as that required for the immersed tunnel and the report is therefore also relevant for the bored tunnel.
9.2 Project description

The three bored tunnels require concrete for the lining on the tunnels and for the internal installations, see Chapter 3 for a full description.

The aggregate for the concrete must fulfil a number of strict requirements regarding the mineral composition, grain size distribution and content of salt. The sand resource on Rønne Banke fulfils these requirements. The water salinity in the area is stable at 7-9 psu and this is low enough for the sand to be used directly without the need to wash out the salt.

9.2.1 Sand extraction plan

The sand extraction from Rønne Banke is recommended to take place by trailing hopper suction dredgers. The volume of the hopper is typically 2-10,000 m³ corresponding to 1,500 to 7,500 m³ 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 expected to continue at a more-or-less constant rate during the boring of the tunnels and the production of the internal installations. According to the construction schedule the sand extraction will take place between October 2015 and December 2019. However, the rate at which the sand is extracted will be decided by the contractor who may prefer to mine all the sand in a shorter period and stockpile it at the production sites. A small amount of sand is also required for the construction of the portals, production facilities and buildings on Lolland and Fehmarn between March 2015 and February 2016.

9.2.2 Extraction area

The designated extraction area at Rønne Banke is approximately 9 km² (Figure 9.2). The investigated area includes a surrounding 500 m impact zone and the total area is approximately 16.5 km² and is together called the impact area. Water depths in the sand extraction area are between 17 and 26 m, and up to 28 m in the 500 m impact zone.

Figure 9.2 Bathymetry of Rønne Banke showing the extraction and impact area
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 million m$^3$ assuming that a residual sediment layer of about 1 m is left behind after completing the extraction.

To minimize the physical and biological impacts it has been suggested that the volume of approximately 1 million 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.

9.2.3 Alternative sources

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.

Six alternative resource areas are known on the Danish continental shelf in the Baltic region: Kriegers Flak, Vejsnæs Flak, Keldsnor, Rødbyhavn, Gedser and Gedser Rev. None of these areas are protected habitats.

All the German and Danish areas except Adler Ground are in higher salinity areas and the sand would require washing before use in concrete. 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 on land have also been investigated. The southern part of Zeeland and the surrounding islands have estimated approximately 12.5 million m$^3$ resources left in sand and gravel pits. By 2013 less than 10 million m$^3$ will be 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.

The preliminary study of possible resource sites for concrete aggregate indicated that Rønne Banke is the most suitable.

9.3 Existing environment

9.3.1 Baseline studies

New information on the resource and the biological conditions was acquired during July-August 2011 by GEUS and DHI/FEMA. The new data is combined with the previous investigations in the area to prepare the baseline description.
In brief, the baseline studies consisted of the following:

- Bathymetry survey by echo sounding.
- Seismic survey to document the distribution, volume, composition and quality of the sand.
- Core sampling to provide data on distribution, volume, composition and quality of the sand and as ground truth data for the seismic survey.
- Side scan sonar mapping to determine seabed surface characteristics and grain size of surface sand.
- Seabed sediment sampling with Van Veen grabs to provide grain size distribution of surface sand, ground truth data for the side scan sonar mapping, and content of organic material, toxic substances and benthic fauna.
- Video inspection for benthic flora and seabed surface characteristics.
- NOVANA data and other studies for salinity, temperature and water quality.
- Modelling results for defining hydrography, currents, waves and sediment transport.
- Literature and local knowledge for data and information on fish, fishery, birds, marine mammals, material assets, ammunition, recreational interests and archaeology.

### 9.3.2 Seabed sediments

Seabed sediment samples were taken at the 20 stations shown in Figure 9.3.

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, see Figure 9.4. The sand becomes finer in the larger water depths in the south of the extraction area with an average grain size of 0.2 mm.

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 9.4. 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 9.5.
Figure 9.3  Stations for sampling of seabed sediments in August 2011

Figure 9.4  Seabed with medium sand and relatively large sand ripples
9.3.3 Sand transport

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 wave and current conditions were extracted from the regional model simulations conducted for the Fehmarnbelt studies (FEHY 2012e). The predominant waves are from W to NW and from easterly directions, directly reflecting the predominant wind directions. There are two main current directions, towards NW to N and towards SSE to ESE. The flow directions are consistent with the expected flow around the island of Bornholm into and out of the Central Baltic Sea. Sediment brought into suspension by the wave and current generated turbulence will be transported in the direction of the currents.

The resulting sand transport capacity is presented in Table 9.1.

The computations demonstrate 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.
Table 9.1  Transport capacity \([\text{m}^3/\text{m/year}]\) for the sand extraction area at Ronne Banke

<table>
<thead>
<tr>
<th>Wave height (H_s) [m]</th>
<th>Peak wave period, (T_p) [s]</th>
<th>Current speed [m/s]</th>
<th>Yearly duration [%]</th>
<th>Yearly transport capacity ([\text{m}^3/\text{m/year}]) for three water depths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>15 m</td>
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<td>5.0</td>
<td>0.05</td>
<td>57</td>
<td>0</td>
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<td>6.0</td>
<td>0.15</td>
<td>16</td>
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<td>3</td>
<td>7.5</td>
<td>0.25</td>
<td>2.8</td>
<td>1.95</td>
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<tr>
<td>4</td>
<td>8.5</td>
<td>0.35</td>
<td>0.36</td>
<td>1.15</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
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<td>3.1</td>
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9.3.4 Toxic substances

Toxic substances are bound to organic compounds and very fine particles of the sediments. Toxic substances refers to PAH, PCB, TBT and the heavy metals Cd, Cu, Hg, Ni, Pb and Zn.

To survey the occurrence of organic matter in the extraction area 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). The results of the analyses show that the organic content (LOI) is less than 0.73 % DW for all samples. The low content of organic matter resembles what is found in a previous study of 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 were not executed. Deduced from the scarcity of organic material, the content must be expected to be below detection limit.

An estimate of the content of toxic substances was made on the basis of measurements at the NOVANA station Arkona W (DMU web database). 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 Ronne Banke.

A calculation of the expected concentrations at Ronne Banke was made by assuming they would be in the same proportions as the LOI at Ronne Banke and Arkona W. The results show concentrations one or two orders of magnitude under the Lower Action level (L Ac) of the Danish standards for sediment quality. They are even lower that the OSPAR guidelines which are the background levels existing before the pollution of the recent decades.
9.3.5 Water quality

Data from the Danish monitoring programme (NOVANA) were extracted together with data from 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 (total nitrogen TN and total 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.

9.3.6 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 9.3). A total of 14 species and one higher taxon (Oligochaeta) was recorded. The average abundance of the benthic fauna was 755 m⁻² and ranged between 30 and 2,860 m⁻² (see Figure 9.6). The abundance was above 1,000 m⁻² at five stations in the southern and deeper part of the area where the sediment becomes finer and the content of silt/clay and organic matter increases.

The average benthic biomass was 1.443 g AFDW m⁻² (ash-free dry weight) and the range between 0.082 and 9.74 g AFDW m⁻² with the lowest at station RB-7. The biomass was highest and above 1 g AFDW m⁻² at five stations in the deeper southwestern part of the area (Figure 9.6).

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.
9.3.7 Benthic flora

Video observations of benthic flora were conducted in connection with the seabed sampling programme. 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. Therefore vegetation investigations outside the impact area were not conducted.

No macro algae, marine flora or visible concentrations of microalgae (at the seabed surface) were observed in the impact area at the sampling stations.
9.3.8 Fish

Fish studies have not been undertaken on the Danish part of Rønne Banke, neither previously nor in connection with the present project. 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 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 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 with Rønne Banke and is only observed in the area on rare occasions. The remaining eight 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) and twaite shad.

› Demersal (benthic) fish species living in, on or close to the seabed: Cod, sandeel (at night and in wintertime), flatfish-species, eel and lumpsucker (demersal when feeding, pelagic during migration), bull-rout and gobies (transparent goby partly pelagic).

Most of the demersal species prefer a sandy seabed 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.

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 twaide shad are also listed on annex II and V of the Habitats Directive.

9.3.9 Fishery

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

![Map of the Western Baltic Sea showing ICES rectangle 38G4](image)

**Figure 9.7** 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 the 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.

Landings from ICES 38G4 have fluctuated between 1200-2000 tons (14-26 million DKK in value) over the last 6 years (Figure 9.8).

Most of the registered fishing trips in ICES 38G4 are undertaken by vessels using bottom trawls and are dominated by vessels of 8-15 m length. In all, the proportion of fishing trips using trawls represents about 75 % of the total number of fishing
trips 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.) has been relatively limited, without any trend in the period.

![Graph showing landings (kg) and their values (1000 DKK) from ICES 38G4 according to gear types](image)

**Figure 9.8** 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).

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 risks of damage to gear. Fishery with stationary gear, primarily gill nets, is 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 9.9) a significant trawling route passes through the proposed extraction area. No fishery by larger gill netters and seiners takes 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 9.9).

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 by-catch. In the summer (June-July) of 2011 there was also an important fishery which targeted sand eels in the same area. Fishing for sand eels is carried out during the day-time.

9.3.10 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 (Skov et al. 2011). From the modelled densities provided by the review it is clear that the Long-tailed Duck is the only common species and the density of Long-tailed Ducks on the extraction site on Rønne Bank was between 10 and 20 birds/km² (Figure 9.10).
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 water-birds 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 through the Arkona Basin seems mainly to take place over a relatively broad front, and is dominated by Common Eider and Common Scoter.

9.3.11 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 them (Scheidat
et al. 2008, Teilmann et al. 2008). Figure 9.11 shows opportunistic sightings of harbour porpoise without any in the Rønne Banke area. However, individuals might spend time in the area foraging or animals might migrate across the bank eastward into the Baltic Sea.

![Figure 9.11](image)

*Figure 9.11  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.*

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 by mammals as they move between Rødsand and feeding areas in the northern parts of the Baltic Proper (Figure 9.12).
9.3.12 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).

9.3.13 Natura 2000

There are two Danish and two German Natura 2000 sites in the vicinity of Rønne Banke (Table 9.2).
Table 9.2  
Natura 2000 sites in the vicinity of Ronne Banke. DK=Denmark, DE=Germany

<table>
<thead>
<tr>
<th>Natura 2000-site</th>
<th>Distance from project site (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DK00VA261</td>
<td>Adler Grund og Ronne Banke (Habitat site) 3</td>
</tr>
<tr>
<td>DK00VA310</td>
<td>Bakkebrædt og Bakkegrund (Habitat site) 26</td>
</tr>
<tr>
<td>DE1251301</td>
<td>Adlergrund (Habitat site) 5</td>
</tr>
<tr>
<td>DE1552401</td>
<td>Pommersche Bucht (Bird protection site) 5</td>
</tr>
</tbody>
</table>

9.4  Environmental components assessed

Table 5.1 presents the environmental factors, sub-factors and components assessed for the sand mining operations on Ronne Banke.

Table 9.3  Environmental components assessed for Ronne Banke.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sub-factor</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fauna and flora</td>
<td>Marine benthic fauna</td>
<td>In- and epifauna communities</td>
</tr>
<tr>
<td>(including biodiversity)</td>
<td></td>
<td>including blue mussels</td>
</tr>
<tr>
<td></td>
<td>Marine fish</td>
<td>Migration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spawning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Feeding/nursery</td>
</tr>
<tr>
<td></td>
<td>Marine mammals</td>
<td>Harbour Porpoise</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Harbour Seal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grey Seal</td>
</tr>
<tr>
<td></td>
<td>Birds</td>
<td>Non-breeding waterbirds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Breeding waterbirds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bird Migration</td>
</tr>
<tr>
<td>Soil</td>
<td>Marine Soil</td>
<td>Sea bed morphology</td>
</tr>
<tr>
<td>(including marine</td>
<td></td>
<td>Coastal Morphology</td>
</tr>
<tr>
<td>landscape)</td>
<td></td>
<td>Sea Bed Chemistry</td>
</tr>
<tr>
<td>Water</td>
<td>Marine waters</td>
<td>Seawater Quality</td>
</tr>
<tr>
<td>Cultural heritage</td>
<td>Marine archaeology</td>
<td>-</td>
</tr>
<tr>
<td>Material assets</td>
<td>Marine material assets</td>
<td>-</td>
</tr>
<tr>
<td>Natura 2000</td>
<td>-</td>
<td>Designation basis</td>
</tr>
</tbody>
</table>

Impacts on the hydrography, plankton and migrating bats have 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.
9.5  Project pressures

Table 5.2 gives a presentation of all identified possible pressures from the extraction project.

Table 9.4  Possible direct and indirect pressures from the sand extraction project at Rønne Banke.

<table>
<thead>
<tr>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of sediments and benthic habitats due to removal of seabed</td>
</tr>
<tr>
<td>Increase in concentration of suspended matter due to spilled sediments</td>
</tr>
<tr>
<td>Increased deposition due to spilled sediments</td>
</tr>
<tr>
<td>Increased nutrient loading and release of organic material and toxic substances due to spilled sediments</td>
</tr>
<tr>
<td>Increased noise due to extraction activities (dredger)</td>
</tr>
<tr>
<td>Increased air pollution due to spilled sediments (dredger)</td>
</tr>
</tbody>
</table>

9.5.1  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 moves during the dredging operation and the outcome will be a deepening along the dredging path. The dredger will keep dredging until there is a full load in the hopper. This means that excess water and sediment flows 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 the 500 m impact zone) is 9 km². It has been planned that 1 million m³ of sand will be extracted, and hence a similar magnitude of sediment and benthic habitats can be lost.

9.5.2  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 particles because they have 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 (FEMA 2012g). Specific modelling studies for the bored tunnel project have not been carried out. The results presented here are those for the immersed tunnel. Since the volume of sand extracted is the same for the two solution alternatives the immersed tunnel results can be used for the assessment of the bored tunnel project.
The temporal and spatial accumulation and re-suspension of spilled sediments have been modelled for the immersed tunnel project scenario based on a dredging plan provided by Femern A/S. The average depth of the deposited sediment 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 were made for 1 year (2005) to represent the entire dredging period for the immersed tunnel. The actual period for the bored tunnel could be up to 4 years.

› 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 million m$^3$, i.e. 2.6 times the required quantity (1.0 million 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 diameter less than 63 µm (clay-silt) is spilled in the overflow. These finer sediment fractions will be dispersed. Coarser particles are predicted to settle within the dredging site (close to the dredger, and within 20 minutes after dredging).

› 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.

› The year 2005 has been used as hydrographical model year. Year 2005 is generally considered representative and used in assessment in relation to the Fehmarnbelt Fixed Link.

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 for the immersed tunnel. For the bored tunnel, it could be termed a "worst worst case" since the dredging rate could be one quarter of that for the immersed tunnel.

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. In addition, the maximum deposition is shown for a full year period (2005) and for the summer period.
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. Figure 9.13 shows the exceedance of 2 mg/l at the surface and bottom for a summer period.

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.

The 2 mg/l exceedance plot showes that the bottom plume is transported in south-south-eastern direction following the bathymetry depth curves south-east of Rønne Banke. 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 results show a smaller extension of the bottom plume to the south of 5 km and 3 km from the source, respectively. Exceedance values are in the order of 1% of the time.

Deposition

The model results on the deposition show that sediment fraction smaller than 63 µm deposits far from the source and with a thickness less than 1.5 mm (Figure 9.14).

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 patchiness of the maximum temporary deposition (Figure 9.14) shows the effect of re-suspension due to storm waves removing the sediment from the bed and moving it to a new location where it re-settles to the bed when the storm has passed.
Figure 9.13  Exceedance of 2 mg/l for 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. Labels with DE and DK mark the Natura 2000 areas.
9.5.3 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 (see section 9.3.4 above).

9.5.4 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 will not 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.

9.5.5 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 million m$^3$. Total emissions cover dredging at Rønne Banke, transport between Rønne Banke and the construction site at the Fehmarnbelt Fixed Link, off-loading and return in ballast. The distance to the construction site is approximately 220 km.

Dredgers of 6,000 or 10,000 m$^3$ are most likely to be used with the calculated emissions being: CO$_2$ 8,500 to 7,400 tonnes respectively, NO$_x$ 220 to 200 tonnes, SO$_2$ 130 to 110 tonnes and particles about 5 tonnes.

9.6 Assessment methodology

This impact assessment is part of the environmental impact assessment for the Fehmarnbelt Fixed Link. The criteria for assessing the impacts of the sand extraction will be, to the extent it is possible, similar to the criteria used in the 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 assessments are made by 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.

The impact assessment is made for a worst case scenario:

- The spill scenario assumes that all dredging occurs in 1 year instead of up to 4 years and that 2.6 million m$^3$ is extracted instead of 1 million m$^3$ (see explanation above).

- The actual removal of the seabed is less than the assessed. The assessment assumes that 9 km$^2$ of seabed are removed, but since the dredging will occur down to 0.5 to 1 m, only 1-2 km$^2$ will be actually be removed to provide the 1 million m$^3$. Since the actual area and location are not known the assessment is made for the entire extraction area.
9.7 Assessment of impacts

9.7.1 Coastal morphology
The closest coast is located about 30 km NE off the extraction area, on the shore of Bornholm. Rügen, Germany is 59 km away and the southern coast of Sweden is 67 km away (Figure 9.1).

There are two items to be considered in the assessment of the possible impacts of the sand extraction on the coastal conditions:

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

 › Will a possible impact on the waves have an impact on the adjacent coasts of Møn, Rügen and southern Sweden?

The sand extraction in the extraction area will on the average lower the seabed by maximum 1 m (but will most likely be 0.5 m), i.e. from a depth of about 17 to 26 m to about 18 to 27 m. This approximately 5 % increase in the water depth over the extraction area of 9 km² will have insignificant impact on the wave conditions in the deepened area and absolutely no impact on the wave conditions at a distance of 30 km away from the sand extraction area.

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

9.7.2 Seabed morphology
The immediate impact of the sand extraction will be the creation of trenches along the path of the drag head of the trailer suction hopper dredger. The trenches will be approximately 2 m wide and 0.5 to 1 m deep and the total trench length will be 500 – 1000 km spread out over the 9 km² extraction area.

The sand at the new seabed will have the same structure and composition as the present sand due to the uniformity of the sand throughout the depth.

The recovery of the disturbed seabed morphology is dependent on the sediment transport capacity in the disturbed 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 m³/m/year at 15 m depth to 0.1 m³/m/year at 30 m depth. The transport situations only occur under very rough wave conditions typically for a duration of 1 to 2 weeks per year.

The natural transport of sand will therefore fill in the dredged trench in about 4 months at 15 m depth and up to 10 years at 30 m depth. The actual water depth is mostly between 17 and 20 m, so the mean recovery time is expected to be 3 - 5 years.
The impact on the seabed is unavoidable but considered insignificant due to the small magnitude the low importance and the short recovery time.

9.7.3 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 9.3.4). There is therefore no impact on the marine environment due to release of toxic substances from dredging activities.

9.7.4 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 the nutrient and oxygen regimes 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.

Potentially, nutrient and oxygen concentration may also be affected by changes in the concentration of organic material due to release from dredged sediments. The degradation of the organic material can potentially lead to a minor decrease oxygen concentration and a release of nutrients.

The content of organic material in the sediments (LOI) of the investigation area is very low (between 0.08 and 0.73 % DW, see section 9.3.2). Such low levels cannot give rise to perceptible effects on the concentration of oxygen, nutrients, or chlorophyll-a concentrations. There will hence not be any impact on the marine environment due to changes in water quality.

9.7.5 Benthic fauna
Impact on benthic fauna from sand extraction can be due to

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

Loss of benthic habitat
The loss of benthic fauna habitat will correspond to the area exploited for sand extraction; i.e. the maximum extracted area is 9 km². 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 the entire area will not be dredged and the impact hence will be much smaller (2 km²).
Re-colonisation of the seabed after the end of the dredging activities will take place by migration of adult species and settling of larvae from nearby unaffected areas. Most of the species which are abundant at Rønne Banke, especially polychaetes and oligochaetes (which account 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 2 to 5 years.

**Increased suspended sediment concentration**

Several groups of benthic invertebrates can be affected by high suspended sediment concentrations. Suspension-feeders such as mussels, clams and other bivalves, barnacles, or tunicates are most sensitive to high concentrations because the solids can dilute their primary food (i.e. phytoplankton) and overload the filter-feeding apparatus. The threshold for no impact is defined as 25 mg/l (FEMA 2012e).

The modelling of the sediment spill showed that suspended sediment concentrations at the seabed exceeded 15 mg/l for 1-3% of the time at distances up to 3 km from the dredging site. Hence the concentrations will only rarely exceed 25 mg/l and then only very close to the dredger. Consequently it can be concluded that the benthic fauna will not be impacted as a result of the increased suspended sediment concentrations.

**Increased 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). 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 2012e). 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 9.14). Consequently, there will be no impact on the benthic fauna due to deposition of the sand fraction less than 63 µm.

Deposition of sand (> 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.

### 9.7.6 Benthic vegetation

Potentially an increase in suspended sediment concentration 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 concentrations seen in this project
(section 9.5.2) will have any impact on the benthic vegetation. Furthermore, there is almost no vegetation in the area and an impact is negligible.

9.7.7 Fish
The most serious physical impacts potentially having implications for 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

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.

The conclusion on the loss of benthic fauna is that re-establishment will take 1 - 5 years depending on the species. 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 on fish are difficult to predict as many fish are flexible in their choice of prey and eat and adapt to what is available. An impact on fish populations is highly unlikely due to the small area affected (2 km²) and the abundance of food in the surroundings.

Suspended sediment
The potential impacts of increased suspended sediment concentrations on fish, fish larvae and fish eggs are described in section 5.9 above. Fish may avoid the sediment plume behind the dredger and higher concentrations can affect fish eggs and larvae.

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. The suspended sediment plumes are mostly localized close to the extraction 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 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

One of the prime risks of increased deposition or re-deposition is the smothering of fish eggs on spawning grounds. Sand eels lay their eggs in the sand, and sand grains of a certain size adhere to them. When sand eel eggs are fully covered with fine material, the development of the embryo will be negatively affected, resulting in a less successful hatching. 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 9.14). The impact on the fish is therefore low and the temporary (months).

Thus, after the seabed is naturally re-established after a few months, it is not expected that there will be an impact on the fish community due to deposition and re-deposition of spilled sediment.

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

Avoidance reactions will typically occur when fish are 100-200 m from vessels and up to 400 m for particularly noisy vessels (Mitson 1995).

In general it is expected that noise from a trailer suction hopper dredger may cause some avoidance response by hearing sensitive fish in the near vicinity, 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 Ronne Banke area, are included in the HELCOM list of threatened and declining species of lamprey and fish (HELCOM 2007), and salmon and twaite 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 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. 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 spilled sediment will have a temporary impact for approximately 1-5 years on the prey for demersal fish species. Only a small, maximum area of 9 km² 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.

Overall, the impact of the dredging on the fish populations in the Southern Baltic Sea area is regarded as insignificant.

9.7.8 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 fish:

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

The last impact is not relevant in the present case since the sand is homogeneous and without boulders which could be left on the seabed after a dredger passes.

Changes in the distribution of fish

Changes in the distribution of fish due to loss of benthic fauna and fish habitats can affect fishery in the extraction area. However, the fish, if affected, will move to other nearby areas on Rønne Banke and the overall impact on fishery on Rønne Banke is assessed to be insignificant. The local impact on the fish will be temporary (1-5 years) after which the fish community will be fully re-established. It is also concluded above that noise and suspended sediment impacts on fish distribution are insignificant.
Restriction of fishing activity
Fishing will be restricted in the vicinity of the dredger when it is operating in the extraction area. The effect of such a restriction on trawl fishing (there is no gill net fishing in the area) will be very limited since the dredger will only be on site for about 1 hour every 8 hours. The impact on fishery is assessed as insignificant.

9.7.9 Birds
The project pressures which can affect birds either directly or by interaction with other environmental factors are:

› Noise, causing displacement of birds.
› Habitat change caused by reduction of food supply by loss of benthic fauna or by sediment spill.
› Risk of collision with migrating birds.

Noise
The impact of noise on birds varies with the sensitivity of the bird species commonly found on Rønne Banke. Of the species occurring in medium or higher densities at the extraction site, four (Red-throated Diver, Black-throated Diver, Long-tailed Duck, Black Guillemot) have been identified as being sensitive to disturbance (see Table 9.5). Based on the available information about planned dredger activities it is assumed, that these species will be displaced within the given distance.

Table 9.5 Reported response of waterbirds to shipping (Bellebaum et al. 2006, Schwemmer et al. 2011)

<table>
<thead>
<tr>
<th>Species</th>
<th>Response to shipping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red-throated Diver (<em>Gavia stellata</em>)</td>
<td>1-2 km</td>
</tr>
<tr>
<td>Black-throated Diver (<em>Gavia arctica</em>)</td>
<td>1-2 km</td>
</tr>
<tr>
<td>Long-tailed Duck (<em>Clangula hyemalis</em>)</td>
<td>100-500 m</td>
</tr>
<tr>
<td>Black Guillemot (<em>Cepphus grylle</em>)</td>
<td>100-500 m</td>
</tr>
</tbody>
</table>

As the numbers of waterbirds using the area shows strong seasonal variability, the potential displacement of divers, Long-tailed Duck and Black Guillemot will depend on the timing of extraction activities with the largest impacts expected during winter and spring (November-April). Given the small impacted area (9 km²) 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 displacement impacts on waterbirds will be very small.
Habitat change caused by reduction of food supply

The key food resources for waterbirds are mussels and fish. The benthic fauna is dominated by mussels, which comprise approximately 78% of the total benthic biomass.

The actual loss of seabed and thereby mussels is 2 km², in which area there will be less than 100 Long-tailed ducks and single individuals of divers and Black Guillemots. The birds will move to other nearby area to feed. The available food supply is such that there will be no impact on the bird population.

Suspended sediment and deposition will not have any measureable effect on the food supply.

Bird migration – collision risk

There is a risk of collision of generally flying and especially migrating birds with vessels at sea. The birds are attracted particularly by the strong artificial light which is common on ships and especially construction vessels.

Studies and incident reports reveal that passerines collide with vessels in larger numbers than other birds. Larger, migration species are expected to be more sensitive to collision with ships.

Given the broad front migration of waterbirds at the site collision risks with the dredging vessel are expected to be low with no or minor consequences for the populations passing the site. This applies when the dredger is sailing between Fehmarnbelt and Rønne Banke as well as while dredging at the extraction site.

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

9.7.10 Marine mammals

Marine mammals can be affected by noise, increased suspended sediment and reduced prey availability as a result of the dredging activities. However, as shown above, there are few mammals in the extraction area. Furthermore, the noise levels will not affect the animals except at very close range. They are also accustomed to seeking prey in turbid waters and the fish they need as food are still available, just displaced a little. The impact on marine mammals is so low that it is not significant.

9.7.11 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 pass around Rønne Banke and not through. However, a smaller amount of traffic does 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.

9.7.12 Marine archaeology

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

9.8 Natura 2000

Natura 2000 is a network of protected areas in the EU with the purpose of saving habitats, flora and fauna, especially birds which are rare, threatened or characteristic for Europe.

There are two Danish and two German Natura 2000 areas near the extraction site on Rønne Banke, see Figure 9.13. Regulations require that a screening of possible impacts on the areas due to nearby construction projects is carried out with the purpose of determining if an appropriate assessment is required.

The impact assessment described above show that impacts on the Natura 2000 areas from the sand mining on Rønne Banke are very unlikely and therefore will not affect their conservation objectives. It is therefore not necessary to prepare an appropriate assessment.

9.9 Climate

The sand mining will occur over a maximum 4 year period and full recovery of the local environment is expected within 5 years. In this short period it is not expected that there will be any climate changes which would change the conclusions of the assessments reported here.
The total emission of greenhouse gases is calculated to be between 7,400 and 11,600 tonnes depending on the size of the trailer hopper suction dredger. For comparison the total emission from Denmark in 2008 was approximately 50 million tonnes (excluding shipping).

9.10 Transboundary impacts

The assessments described above in this chapter show that there will be no impacts on the territorial waters of countries other than the host countries, Denmark and Germany.

Figure 9.13 shows that the sediment spill from the sand mining operations will spread into a small area of German territorial waters, otherwise all impacts are in Danish waters.

9.11 Cumulative impacts

The Danish Ministry of Climate, Energy and Building (DMCEB) has recently published an update of the Danish strategy which identifies localities for future wind farms until 2025 (Danish Ministry of Climate, Energy and Building 2011). These plans include two wind farms on 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. 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 farms. This means that the planned wind farms will not affect the sand extraction for Fehmarnbelt Fixed Link at Rønne Banke and vice versa.

In summary, cumulative impacts are not likely between the sand extraction project and the wind farm projects due to the large distance between them. The impacts on the benthic fauna communities and the consequent 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 (impacts assessments have not yet been made of this). The impact is limited to the areas close to the wind farms. The distance between the wind parks and the extraction area is so large and the impact so limited that it cannot be expected that there will be any impacts on the overall Cerastoderma community at Rønne Banke and in the Baltic Sea. The benthic fauna will hence still sustain its ecological function in area.

9.12 Mitigation and compensation

The physical and biological impacts of the sand mining are insignificant and mitigation and compensation measures are not necessary.

There will be a temporary impact on fishery since fishery will not be possible near the dredger when it is working in the extraction area. Mitigation of impacts on fishery can be carried out by a close and continuous contact with active fishermen.
in the area, and, if necessary, 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.

9.13 Monitoring programme
The proposed monitoring programme consists of measurements of the sediment spill during dredging operations and surveying the seabed after completion of the work.

9.13.1 Surveillance of the environmental conditions during extraction
Investigations of sediment discharge through the overflow from the dredger by spot tests are proposed. 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.

9.13.2 Documentation of the environmental conditions immediately after the end of 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 re-establishment of the seabed.

9.14 Summary
The sand mining on Rønne Banke will cause a temporary loss of benthic fauna habitats and a disturbance of the seabed morphology. The sediment transport caused by the prevailing waves and currents will re-establish the seabed morphology within 3 – 5 years.

The benthic fauna will start re-colonising the dredged area immediately after the works stop, in fact immediately the dredger has completed work in each sub-area. Benthic fauna with a short reproduction time will be re-colonise the area in 1 – 2 years and full re-establishment of benthic fauna communities will occur within 5 years. The small size of the area affected and the rapid recovery gives the assessment that the impact on benthic fauna is not significant.

The temporary loss of benthic fauna is also a temporary loss of food supply for some fish species and they will be displaced to nearby areas. The displacement of the fish and the restrictions on fishery around the dredger will have a potential impact on trawl fishery in the extraction area. The potential impact and conflict can be avoided by planning and communication with fishermen.

Other direct and indirect impacts inside and outside the extraction area such as seabed morphology, coastal morphology, water quality, benthic flora, birds and
marine mammals together with potential impacts on shipping, recreation, archaeology and material assets are assessed to be insignificant. There are either no impacts or they are minor and temporary.

There are no impacts on Natura 2000 area or on protected species.

The overall conclusion is that there will be impacts on the marine environment within the extraction area due to the sand mining. 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.
10 Cumulative Impacts

This chapter assesses the accumulated impacts of the bored tunnel alternative of the Fehmarnbelt Fixed Link project and other planned projects in the area. Both the construction and operation phases of all the projects considered are included in the assessment.

The impacts of the bored tunnel are described in Chapters 5, 6 and 7 of this report while the impacts of the other planned projects are based on EIAs where available and on experience with similar projects. The assessment of the cumulative impacts is based on expert judgement.

10.1 Criteria for inclusion of projects with potential cumulative impacts

Cumulative impacts arise when a number of planned projects within the same area would have an impact on the same environmental factors at the same time. For a planned project to be relevant for inclusion, the project is required to meet one or more of the following conditions:

› The project and the project's impacts will be within the same geographical area as the fixed link.
› The project will have some of the same impacts as the fixed link.
› The project will have an impact on some of the same, or related, environmental factors as the fixed link.
› The project will have permanent impacts in its operation or construction phase.

10.2 Projects with potential cumulative impacts in the marine area

Table 10.1 and Figure 10.1 show the marine projects that are assessed as relevant to include in the assessment of the cumulative impacts on various environmental factors. All of these projects are offshore windfarms.
Table 10.1  Projects on water of relevance for assessment of cumulative impacts

<table>
<thead>
<tr>
<th>Project</th>
<th>Location</th>
<th>Phase</th>
<th>Impact on main project or raw materials recovery</th>
<th>Potential interaction</th>
<th>Construction period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arkona-Becken Südost</td>
<td>Northeast of Rügen (D)</td>
<td>Construction</td>
<td>Main project</td>
<td>Sediment spill, bird displacement, collision risk, barrier effect</td>
<td>Unknown (?)</td>
</tr>
<tr>
<td>EnBW Baltic 2</td>
<td>Southeast of Kriegers Flak (D)</td>
<td>Construction</td>
<td>Raw materials recovery</td>
<td>Sediment spill, bird displacement, collision risk, barrier effect</td>
<td>From 2014 - ?</td>
</tr>
<tr>
<td>Wikinger</td>
<td>Northeast of Rügen (D)</td>
<td>Construction</td>
<td>Main project</td>
<td>Sediment spill, bird displacement, collision risk, barrier effect</td>
<td>Commencement in 2012 and completion in 2013</td>
</tr>
<tr>
<td>Rødsand II</td>
<td>Off the south coast of Lolland (DK)</td>
<td>Operation</td>
<td>Main project</td>
<td>Coastal erosion, collision risk, barrier effect</td>
<td>In operation</td>
</tr>
<tr>
<td>Kriegers Flak II</td>
<td>Kriegers Flak (DK)</td>
<td>Construction</td>
<td>Raw materials recovery</td>
<td>Sediment spill, bird displacement, collision risk, barrier effect</td>
<td>30 months (estimated in Ramboll study)</td>
</tr>
<tr>
<td>GEOPReE</td>
<td>Bay of Lübeck (D)</td>
<td>Construction</td>
<td>Main project</td>
<td>Sediment spill, bird displacement, collision risk, barrier effect</td>
<td>Due for completion in 2012</td>
</tr>
</tbody>
</table>

Rødsand II is included specifically as this project went into operation while Femern A/S was conducting its environmental investigations, as a result of which a cumulative impact cannot, in principle, be excluded.

Nysted offshore windfarm (Figure 10.1) was in operation when the baseline investigations of existing factors were conducted. Any adverse impacts of the windfarm are therefore included in the baseline data and it has therefore not been assessed as a future source of cumulative impacts.
10.3 Assessment and significance of cumulative impacts in the marine area

The descriptions concern cumulative impacts arising from interaction between the projects and installations listed in Table 10.1 and the construction and operation of a bored tunnel including the raw materials recovery (sand mining) at Ronne Banke.

10.3.1 Bored tunnel

As shown in Table 10.1, the potential cumulative impacts arise from sediment spill, bird displacement, collision risk, barrier effect and coastal erosion. The impacts of the construction and operation of a bored tunnel are outlined below.

Sediment spill

Sediment spill from the establishment of a bored tunnel is described in Chapter 5 together with the impact on the ecosystem resulting from the spill. The sediment spill stems primarily from the dredging of the work harbours and their access.
channels. Sediment spill will mostly occur within the first six months after project commencement.

The sediment plumes with concentrations of suspended materials exceeding 2 mg/l will be confined to areas in the vicinity of the actual work site. In addition, computer modelling predicts negligible or no sedimentation within most of the Fehmarnbelt area. The spilled sand fractions will be deposited within a distance of 200 to 600 m from the dredging site and will be absorbed by the naturally occurring sand transport at the seabed.

The suspended sediments at larger distances from the dredging sites will be transported at concentrations of less than 2 mg/l at the surface and less than 10 mg/l at the seabed. At the surface, the sediment plume will not be visible, and, at the seabed, the concentration will not exceed naturally occurring maximum concentrations.

**Habitat loss**

Permanent habitat loss occurs locally as a result of the land reclamation at at the Lolland and Fehmarn coasts and is confined to the project's footprint.

Habitat loss also occurs in access channels to work harbours. Modelling predicts that the seabed and habitats will be affected for up to 12 years but the areas affected are small compared to the total habitat area in Fehmarnbelt. Chapter 5 concludes that this habitat loss is not of crucial significance for biogeographical populations, and that there will be no significant impact on migrating fish, birds and marine mammals.

**Coastal erosion**

Chapter 5 reports that coastal erosion may increase as a result of the project. This impact will be confined to the coast east of Rødbyhavn as far as Rødsand Lagoon. The plan is to compensate for this coastal erosion by beach nourishment.

**Collision risk and barrier effect**

These effects are not relevant for the construction and operation of a bored tunnel.

### 10.3.2 Arkona-Becken Südost, EnBW Baltic 2, Wikinger and Kriegers Flak II

As stated, the above projects are all offshore windfarms, which, as shown in Figure 10.1, are located more than 100 km from the project zone for the bored tunnel. Potential cumulative impacts are due to sediment spill and displacement of birds.

**Sediment spill**

For a cumulative impact to occur, the construction phase which involves dredging at the windfarms would have to coincide with the six months of dredging for the bored tunnel. Furthermore, the distance between the dredging for the bored tunnel and the location of the offshore windfarms is more than 100 km. This means that sediment from the spill resulting from construction of the bored tunnel will
exclusively be fine-grained. The suspended sediment will occur at such low concentrations that it will not be visible and will not have an impact on flora or fauna to any significant degree.

The Arkona-Becken and Wikinger windfarms are more than 20 km west of the Rønne Banke sand mining site. The most significant adverse impact of sand mining at Rønne Bank is sediment spill. Dredging will be carried out within a designated extraction zone where the materials are sand and gravel. The resulting sediment spill will settle rapidly. The sediment spill modelling results described in Chapter 9 show that the sediment plumes and deposition will not impact the areas of the Arkona-Becken and Wikinger windfarms.

Displacement of birds
As stated earlier, any hypothetical displacement of a number of water birds caused by the bored tunnel would be confined to the first six months of the construction phase. The distance between the dredging for the bored tunnel and the location of the offshore windfarms is more than 100 km. Taking into account the limited period of time in which a bored tunnel might result in habitat displacement for individual birds, and the general adaptability of the birds, the construction of a bored tunnel is assessed as not giving rise to cumulative impacts of any significance.

In summary, the conclusion is that no significant cumulative impacts will arise as a result of the establishment of a bored tunnel and the offshore windfarms Arkona-Becken Südost, EnBW Baltic 2, Wikinger and Kriegers Flak II.

10.3.3 Rødsand II
Rødsand II was erected and commissioned while the baseline studies in Fehmarnbelt were in progress. The EIA for Rødsand II showed that it will cause coastal erosion on Hyllekrog (DHI 2007). The Lolland reclamation of the bored tunnel project will also cause erosion of Hyllekrog if not mitigated (see Chapter 5). There is thus a potential cumulative impact on the coastal morphology of Hyllekrog. Rødsand II was included into the hydrodynamic models employed in assessing the impacts on hydrography and coastal morphology.

In assessment of the impacts on birds, Rødsand II is included in the individual-based-model (IBM) for Common eider and is taken into account in the assessment of the impacts on the other bird species. No significant cumulative impacts on any of these birds are predicted.

Coastal erosion
For a cumulative impact to occur coastal erosion must be exacerbated as a result of the establishment of the coast-to-coast project. However, as part of the coast-to-coast project, the plan is to compensate for coastal erosion by means of beach nourishment, while the windfarm's contribution in relation to the coast-to-coast project is assessed as negligible. Thus, construction of a bored tunnel is not assessed as giving rise to cumulative impacts of any significance.
In summary, the conclusion is that no significant cumulative impacts will arise in relation to the Rødsand II windfarm.

10.3.4 GEOFReE
Potential cumulative impacts are sediment spill and displacement of birds. The distance from the project zone for a bored tunnel to the GEOFReE offshore windfarm is more than 30 km.

Sediment spill
For a cumulative impact due to sediment spill to occur the dredging during the construction phase of the GEOFReE windfarm would have to coincide with the six months of dredging for the bored tunnel. As indicated in Table 10.1, this is not likely to happen.

Displacement of birds
Any hypothetical displacement of a number of water birds due to the bored tunnel will be limited to a six month period in the construction phase, as described above. Taking into account the distance to the GEOFReE windfarm and the limited period of time in which a bored tunnel might result in habitat displacement, and the general adaptability of the birds, the construction of a bored tunnel is assessed as not giving rise to cumulative impacts of any significance.

In summary, the conclusion is that no significant cumulative impacts will arise in relation to the GEOFReE windfarm.
10.4 Projects with potential cumulative impacts on Lolland and Fehmarn

On land, the projects assessed as relevant to include in the assessment of cumulative impacts are shown in Table 10.2.

Table 10.2 Projects on land of relevance for assessment of cumulative impacts

<table>
<thead>
<tr>
<th>Project</th>
<th>Location</th>
<th>Phase</th>
<th>Potential cumulative impact</th>
<th>Construction period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extension and electrification of railway</td>
<td>Ringsted to Holeby (DK)</td>
<td>Construction</td>
<td>Area loss, noise and dust</td>
<td>Approx. 5 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operation</td>
<td>Landscape, barrier effect</td>
<td></td>
</tr>
<tr>
<td>Upgrade of the E47 motorway (Sydmotorvejen)</td>
<td>Sakskøbing to Rødbyhavn (DK)</td>
<td>Construction</td>
<td>Area loss, noise and dust</td>
<td>Ca. Approx. 2 years (plus 1-2 years prior detailed planning)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operation</td>
<td>Landscape, barrier effect</td>
<td></td>
</tr>
<tr>
<td>Extension of railway</td>
<td>Puttgarden to Lübeck (D)</td>
<td>Construction</td>
<td>Area loss, noise and dust, landscape</td>
<td>Ca. Approx. 4 years from 2016 – 2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operation</td>
<td>Landscape, barrier effect</td>
<td></td>
</tr>
<tr>
<td>Upgrade to motorway</td>
<td>Heiligenhafen to Puttgarden (D)</td>
<td>Construction</td>
<td>Area loss, noise and dust, landscape</td>
<td>Unknown (?)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operation</td>
<td>Landscape, barrier effect</td>
<td></td>
</tr>
</tbody>
</table>
Figure 10.2  Extension and electrification of railway from Ringsted to Holeby (Banedanmark 2011)
Figure 10.3  Extension and electrification of railway from Puttgarden to Lübeck. (Deutsche Bahn NETZE, 2011).
Figure 10.4 Upgrading of the E47 motorway (Sydmotorvejen) from Sakskebing to Rødbyhavn (Vejdirektoratet 2012).
10.5 Assessment and significance of cumulative impacts on Lolland and Fehmarn

The increase in traffic and its derived adverse environmental impacts form the basis for the environmental assessment of the fixed link in the operation phase and do not count as cumulative impacts. In the event that one or more of the railway and motorway projects is delayed, the cumulative impact will be less than predicted in this EIA.

Area loss (construction phase)
Both the land works and the fixed link's approach and ramp areas will result in loss of farmland and nature areas. Any nature areas that are lost will be compensated by the creation of new ones, both for the fixed link and for the transport infrastructure. The cumulative impact is thus not assessed as significant.
The loss of farmland to the above-mentioned transport infrastructure (Table 10.2) is so limited, however, that the cumulative impact of the approach and ramp areas is not assessed as significant.

Noise (construction phase)
The environmental impacts of construction equipment are very limited in scale and geographical range. The cumulative impacts of noise and dust will, in fact, be confined to the small area where the approach and ramp areas serving the fixed link abut the existing road and rail connections, and occur only in the event that construction activities in the projects are carried out concurrently within that area. Even in the event of concurrent construction activities, the cumulative impacts are assessed as not significant. The reason for this is that noise effects cannot be compounded. Noise is assessed solely in terms of maximum impact. For dust, an environmental management plan will be established to prevent dust from occurring at unacceptable levels, including any cumulative impact.

Landscape (operation phase/construction phase)
The approach and ramp areas serving the fixed link will have a significant impact on coastal stretches of the Lolland landscape. The land works will also affect the landscape, but their impacts will be minor and not have an impact on coastal landscapes. Given that the significant impact of the fixed link will thus arise in the coastal zone, while the impact of the land works will occur some kilometres inshore, the cumulative impact overall is not regarded as significant.

The fixed link's approach and ramp areas on Fehmarn will have an impact on the landscape. The adverse impact is classified in Chapter 7 as very high at the coast and at the avenue off the K49 road. In addition, the tunnel will give rise to pronounced, but temporary, effects at Marienleuchte, since a section of the green area east of the harbour (operation) will be appropriated, and an area immediately north of Marienleuchte will be affected visually by the erection of silos, buildings, cranes, etc. (construction).

The impact on the landscape of the fixed link's approach and ramp areas is consequently assessed as dominant compared to the cumulative impact of the land works, as the latter will on the whole derive from existing facilities. The cumulative impact of the transport infrastructure on Fehmarn thus does not alter the significance of impacts on the landscape deriving from the fixed link's approach and ramp areas.

Barrier effect (operation phase)
The barrier effect of the fixed link may be exacerbated by the interaction with the road and rail approaches. The design of the approach and ramp areas incorporates fauna passages on Lolland and Fehmarn so that the barrier effect of the land works serving the fixed link does not exacerbate the barrier effect already caused by the existing transport infrastructure. The cumulative impact of the transport infrastructure is thus not assessed as significant.
10.6 Conclusion

The EIA establishes the extent to which any impacts of a bored tunnel are caused on land and in the marine area vis-à-vis a number of projects listed in Table 10.1 and Table 10.2. No significant cumulative impacts are assessed as occurring on land.

Similarly, for the marine area, the assessment is that no significant cumulative impacts will occur as a result of interaction between construction and operation of a bored tunnel and the projects listed in Table 10.1 and Table 10.2.
11 Natura 2000

11.1 Introduction

11.1.1 EU Habitat and Bird Directives

Natura 2000 is the term for a network of protected areas in the European Union. The network includes protected areas designated under both the Habitats Directive and the Birds Directive. The aim of the network is to ensure favourable conservation status for the designation basis of the areas. The designation basis is composed of a number of defined habitats and listed species.

The EU Habitats Directive (92/43/EEC) forms the legal basis for designation of Sites of Community Interest (SCI) as part of the Natura 2000 network. Annex I of the Directive provides a list of habitat types which are to be considered for protection. Annex II lists the flora and fauna species requiring protection in Europe. Each country is responsible for selecting SCIs which contain the habitat types and species to be protected with the purpose of ensuring the continued existence in sufficient areas and numbers in the country. Annex IV is a list of species which are to be protected both inside and outside SCIs.

Similarly, Special Protected Areas (SPA) are designated under the EU Birds Directive (79/409/EEC) which are also integrated into the Natura 2000 network. Annex I lists the protected bird species. Again, it is each country’s responsibility to define SPAs to ensure the protection of the species in Annex I. The SPAs are nearly always identical with some of the SCIs.

11.1.2 Natura 2000 areas in the Fehmarnbelt region

The Natura 2000 areas which potentially could be impacted by the bored tunnel project in the Fehmarnbelt region in Denmark and Germany are listed below and shown in Figure 11.1 and Figure 11.2.

- SCI DK 00VA200 “Stenrev sydøst for Langeland” (Stone reef southeast of Langeland)
11.1.3 Screening and Appropriate Impact Assessment

The assessment of impacts on the Natura 2000 areas is conducted in two phases. The first phase concerns a screening of the potential impact on each designated site to assess whether a “significant impact” on the conservation status of the habitats and/or species that are the reasons for designation of the site can be excluded. If such an impact cannot be excluded an appropriate Natura 2000 assessment of that site should be carried out.

The term “significant” is used where the result of the screening shows that a significant impact cannot be excluded.

Detailed reports on the screening process were prepared for the Danish and German Natura 2000 areas and form the basis for this short summary chapter. The screening covered the three alternative solutions for the fixed link, i.e. the preferred solution of the immersed tunnel, the cable stayed bridge (the preferred alternative) and the bored tunnel.


FeBEC 2012g. FFH – Verträglichkeitsvorprüfung DE. Feste Fehmarnbeltquerung. Mai 2012.
Similarly, detailed appropriate assessment reports were prepared, but only for the immersed tunnel since it has already been chosen as the preferred solution for other reasons. However, the appropriate assessment of the immersed tunnel is also useful for evaluating the bored tunnel due to the similarities between the two solutions:


Figure 11.1 Danish and German SCIs in the Fehmarnbelt region
11.2 Screening

The screening process used the results of the impact assessments described in Chapters 5, 6 and 7 of this report, and the results will not be repeated here.

11.2.1 Danish Natura 2000 areas

The screening of the Danish Natura 2000 areas showed that a significant negative impact on the Hyllekrog-Rødsand part of SCI DK 006X238 (Smålandsfarvandet north of Lolland, Guldborg Sound, Boto North and Hyllekrog-Rødsand) and on SPA DK 006X083 (Coastal Zone Hyllekrog-Rødsand) could not be excluded. The latter SPA area forms part of the former SCI area and they will be treated as one area.

The screening showed that the sediment spill during the dredging works in the first year of the construction phase could give rise to increased suspended sediment concentrations and deposition which affect benthic flora and fauna in the coastal...
zone and in Rødsand Lagoon. The impacts could thereby affect the conservation objectives:

›  Habitat 1160 Inlets and bays - marine biology
›  Habitat 1170 Reefs – marine biology
›  Bird species protected in the SPA

The bird species in the conservation objectives which could be affected are the Mute Swan, Whooper Swan, Common Goldeneye, Tufted Duck and Common Pochard.

An appropriate Natura 2000 assessment would therefore have been required for these two areas if the bored tunnel was chosen as the preferred solution.

The screening showed that significant negative impacts on the other six Danish SCIs and SPAs could be excluded. The sediment spill modelling showed that none of the other areas would be affected by excess sediment and, simply because of the large distance between the link and the other areas, all other project pressures would not have any impacts. Please refer to FeBEC 2012f for the details of the screening process and results.

11.2.2 German Natura 2000 areas

The screening of the German Natura 2000 areas showed that a significant negative impact could not be excluded for the area SPA DE 1332-301 Fehmarnbelt. There is only one potential impact, viz. the effect of noise from the driving of sheet piles at the work harbour on harbour porpoise. Harbour porpoise is one of the conservation objectives for the Fehmarnbelt Natura 2000 area. An appropriate assessment would have been required if the bored tunnel had been chosen as the preferred solution.

The screening showed that significant negative impacts on the other seven German Natura 2000 areas could be excluded. Please refer to FeBEC 2012g for details.

11.3 Appropriate assessment

The legal requirement concerning appropriate assessment is that it is required only for the selected project solution, in the present case, the immersed tunnel. Therefore appropriate assessments have not been made for the cable stayed bridge or the bored tunnel alternatives.

However, the appropriate assessments use the results of the detailed impact assessments made for all the environmental factors, e.g. those reported in Chapters 5, 6 and 7 of this report. Therefore it is possible to reach the overall conclusions of an appropriate assessment for the bored tunnel without going through the normal procedures.

Furthermore, the results of the appropriate assessment for the immersed tunnel can be used for the bored tunnel where the impacts are similar.
11.3.1 Hyllekrog-Rødsand Natura 2000 area

Benthic flora
Section 5.7 in this report reaches the conclusion that the bored tunnel project will have a significant effect on the Furcellaria community along the Lolland coast due to the reclamation which cover the benthic vegetation. However, the reclamation does not extend into the Hyllekrog-Rødsand Natura 2000 area and therefore does not impact the benthic flora in that area.

Benthic fauna
Section 5.8 finds that the impacts on benthic fauna are due to the reclamation and deposition of sediment but they are assessed as insignificant. The effects on Hyllekrog-Rødsand are only due to deposition and are insignificant since the impacts are minor and only a very small area is affected, less than 1% of the communities considered.

Birds
Section 5.11 assesses the impacts on birds for the four relevant pressures habitat loss from footprint, habitat change from sediment spill, reduced water transparency and disturbance from construction activities. It concludes that the bored tunnel project will not have any significant impacts on any bird species. The footprint does not encroach onto the Hyllekrog-Rødsand area and the other pressures result in the temporary displacement of less than 1% of the bird populations, which is the limit for a significant impact.

11.3.2 Fehmarnbelt Natura 2000 area

Harbour porpoise
Section 5.10 reaches the conclusion that the impact of noise from construction activities on harbour porpoises is insignificant. Noise will not result in the death of harbour porpoises. The number which could be affected by noise is less than 1% of the Fehmarnbelt populations, which is the limit for a significant impact.

11.3.3 Immersed tunnel appropriate assessments
The appropriate assessments for the immersed tunnel (FeBEC 2012h-k) conclude that there are no significant impacts on Danish or German Natura 2000 areas. Since the impacts of the bored tunnel on the marine area are the same or less than those for the immersed tunnel it supports the overall conclusion that the bored tunnel also does not have significant impacts on Natura 2000 areas.

11.4 Conclusion
The overall conclusion is that the bored tunnel project is assessed to have no impacts which would have significant effects on the conservation status or the integrity of the Natura 200 areas.
12 Mitigation and Compensation

This chapter summarises the mitigation and compensation measures which have been proposed in the impact assessment chapters on the marine area, Lolland, Fehmarn and Rønne Banke.

The measures are divided into three types: measures built into the project design, mitigation measures during construction and operation of the fixed link and compensation measures.

Measures built into the project design
The project design phase and the environmental investigations were carried out in parallel with a close interaction between the teams. The environmental studies identified a number of impacts which could be reduced or even avoided by adjustment of the design. Where feasible, the proposed adjustments were incorporated into the design.

An example is the construction of beaches along the edges of the land reclamations to offset the loss of bathing beaches.

Mitigation during construction and operation
Mitigation measures are introduced during the construction and operation phases to reduce those impacts which cannot be avoided by design adjustments.

Many such measures during construction will be requirements which the contractors will be obliged to include in their Construction Environmental Management Plan, e.g. maintenance of machinery to reduce noise and exhaust gas emissions. Such measures are not included in the summary table below.

Others are aimed at reducing physical and biological impacts and impacts on the local population. An example is the requirement for beach nourishment during both construction and operation to avoid the erosion of the beaches and coastline east of the Lolland reclamation.

Compensation
Some impacts cannot be completely avoided by design adjustments and mitigation measures. These are called residual impacts and, if significant, shall be
compensated if possible. The compensation can be “in kind” or, in the case of Germany, monetary through the so-called eco-account.

An example of “in kind” compensation is the establishment of new ponds to compensate for those lost under the permanent land works and the construction sites on both Lolland and Fehmarn.

In Germany the practice is for the project owners to pay monetary compensation through the eco-account for impacts which are of minor or higher severity and which cannot be mitigated completely.

The mitigation and compensation measures for the bored tunnel project are summarised in Table 12.1 in these three categories.

Construction Environmental Management Plan

A Construction Environmental Management Plan (CEMP) will be developed for the project and implemented by the contractors. The plan will require contractors to inspect construction sites, monitor and control environmental conditions and take action to clean up after accidents and implement measures to prevent repeats. A series of procedure documents will be developed including those for:

› Solid and liquid waste management
› Waste water management
› Air emissions control
› Dust control
› Noise control
› Archaeological late finds protocol
› Oil and fuel storage and refuelling
› Dangerous goods and hazardous substances
› Reinstatement plan
› Traffic management
› Small spill management
› Oil spill response
› Emergency response plans

All such plans serve to reduce environmental impacts during construction. However the specification of the CEMP is outside the scope of an EIA and the measures are therefore not listed in Table 12.1.
Table 12.1 Summary of mitigation and compensation measures

<table>
<thead>
<tr>
<th>Component</th>
<th>Measures built into the project design</th>
<th>Mitigation measures during construction and operation</th>
<th>Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Marine</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrography</td>
<td>Establishment of new beaches along the edges of the Lolland and Fehmarn reclamations compensates for the lost, high importance water areas in front of existing beaches.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Water quality</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Seabed morphology</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coastal morphology</td>
<td>Establishment of new beaches along the edges of the Lolland and Fehmarn reclamations compensates for the lost beaches. Reconstruction of outlets for pumping stations draining the land behind the Lolland reclamation and for the sewage treatment plant.</td>
<td>Beach nourishment of 19,000 m³/year of sand at Hyldtofte Østersøbad to offset erosion caused by the Lolland reclamation. Coastline of Fehmarn southeast of Puttgarden to be monitored for erosion and mitigated if necessary.</td>
<td>-</td>
</tr>
<tr>
<td>Plankton and jellyfish</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Benthic flora</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Benthic fauna</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fish ecology</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Marine mammals</td>
<td>-</td>
<td>Conduct warnings for harbour porpoises in the form of controlled underwater noise prior to the start of driving of sheet piles at the work harbours. Alternatively use vibration instead of hammer driving.</td>
<td>-</td>
</tr>
<tr>
<td>Birds</td>
<td>Land reclamations will provide suitable habitats for roosting and breeding by some bird species.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Migrating bats</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Commercial fishery</td>
<td>-</td>
<td>-</td>
<td>The Danish pound het fishermen will be compensated for the loss of fishing area due to the reclamation.</td>
</tr>
<tr>
<td>Material assets</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Component</td>
<td>Measures built into the project design</td>
<td>Mitigation measures during construction and operation</td>
<td>Compensation</td>
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</tr>
<tr>
<td>Recreation</td>
<td>In the Lolland reclamation, a new beach at the western end, a bay with beach and a lagoon with beach connecting the bay with Rødbyhavn which will compensate for the loss of bathing beaches.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>The bay and lagoon in the Lolland reclamation will provide opportunities for water sports.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A new beach along the southeast side of the Fehmarn reclamation will compensate for the lost bathing beach.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The seadikes around the reclamations will provide new opportunities for recreational fishing.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cultural heritage and archaeology</td>
<td>-</td>
<td>Construction vessels will be prohibited entrance to defined areas around the ship wrecks and the old anchor.</td>
<td>-</td>
</tr>
<tr>
<td>Shipping</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lolland</td>
<td>Landscape and soils</td>
<td>Top soil at the construction site will be removed and stored at the start of construction. The land surface and soil at the construction site will be restored at the end of construction. Compacted soil will be loosened and top soil replaced.</td>
<td>-</td>
</tr>
<tr>
<td>Component</td>
<td>Measures built into the project design</td>
<td>Mitigation measures during construction and operation</td>
<td>Compensation</td>
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</tr>
<tr>
<td>Flora and fauna</td>
<td>Three fauna passages along the banks of Næsbæk will be established to secure the passage of the watercourse and animals under roads and rail. Establish one fauna passage under the railway and one under the motorway Establish a fauna passage over the tunnel at the tunnel mouth. New nature areas will be established on the land reclamation. Lighting technology which reduces impacts on animals and insects will be chosen.</td>
<td>1 km of amphibian fence along motorway. Restoration of 0.5 ha marshland, 1.75 ha freshwater meadow and 6.6 ha salt meadow at the construction site. Selective clearing of sea buckthorn on the railway terrain. Trees and buildings which can be used by bats will be re-investigated before removal. Monitor existing and new nature areas at regular intervals to check their function.</td>
<td>New nature areas will be established to compensate for lost areas (14 ponds, 0.5 ha marshland, 1.75 ha freshwater meadow, 18.6 ha of salt meadow).</td>
</tr>
<tr>
<td>Cultural heritage and archaeology</td>
<td>-</td>
<td>Detailed archaeological studies will be carried out prior to start of construction. The coastal storm surge dike will be restored at end construction.</td>
<td>-</td>
</tr>
<tr>
<td>Recreation</td>
<td>In the Lolland reclamation, a new beach at the western end, a bay with beach and a lagoon with beach connecting the bay with Redbyhavn which will compensate for the loss of bathing beaches. Subdued lighting technology will be used at the tunnel portals. The land reclamation around Redbyhavn will be designed so it will still be possible to see the sea from the marina. Recreational facilities such as cycle and walking paths and picnic areas will be established on the land reclamation.</td>
<td>National cycle route 38 will be re-routed and marked with signs during construction and re-established at end construction.</td>
<td>A new lake will be established to replace Strandholm Lake.</td>
</tr>
<tr>
<td>Component</td>
<td>Measures built into the project design</td>
<td>Mitigation measures during construction and operation</td>
<td>Compensation</td>
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</tr>
<tr>
<td>Water</td>
<td>Retention basis with oil separators will be established to collect and treat runoff from sealed surfaces. The section of 17RØ channelled in pipes will be compensated by improving the physical state of the existing section elsewhere in the watercourse. A subsection of Næsbæk will be adjusted, a tributary to Næsbæk that is currently channelled in pipes will be opened and subsections of watercourse 16RØ will have less steep slopes. Drainage of water from pumping stations and sluices to the sea through the land reclamation area will be ensured.</td>
<td>Groundwater lowering will be limited as much as possible. Retention basis with oil separators will be established to collect and treat runoff from construction sites.</td>
<td>One or two new lakes will be established instead of Strandholm Lake in accordance with public authority directions.</td>
</tr>
<tr>
<td>Noise and vibrations</td>
<td>If required, design noise barriers along the new motorway and railway to comply with noise standards. If required design use of noise reducing asphalt for new motorway to comply with noise standards.</td>
<td>Noise barriers will be provided by the 8-10 m high embankments around the production facilities at the main construction site. Noise and vibrations from piling will be reduced by vibrating or pre-boring where possible.</td>
<td>-</td>
</tr>
<tr>
<td>Air quality and climate</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Material assets</td>
<td>The new solutions in relation to the sewage treatment plant and the pumping stations will be established before the existing facilities are removed.</td>
<td>-</td>
<td>Owners of all areas expropriated and material assets affected (e.g. Syltholm wind farm) will be compensated.</td>
</tr>
<tr>
<td>Population and health</td>
<td>Establishment of new paths and roads across/around permanent structures. Unnecessary light pollution during operation will be avoided.</td>
<td>Establishment of paths and roads during the construction phases. Unnecessary light pollution during construction will be avoided.</td>
<td>-</td>
</tr>
<tr>
<td>Derived socio-economic effects</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Component</td>
<td>Measures built into the project design</td>
<td>Mitigation measures during construction and operation</td>
<td>Compensation</td>
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</tr>
<tr>
<td>Fehmarn</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population and health</td>
<td>Trees and bushes will be planted along various sections of the new motorway and railway to screen the view of the traffic. Grass will be planted on embankments and in the road and rail corridors. Permanent new roads and footpaths will be established for the operation phase to ensure the continued movement of people in the area as well as for recreation. Establish a new beach along the reclamation edge. Recreational facilities such as cycle and walking paths and picnic areas will be established on the land reclamation. Reclaimed land designed to maintain visual contact with the sea.</td>
<td>Areas temporarily affected during construction will be restored to original condition at the end of construction and returned to their original land-use where relevant. Temporary footpaths and roads will be established during the construction phase to ensure the continued movement of people in the area.</td>
<td>Owners of all temporarily or permanently lost areas will be compensated by renting or buying their properties.</td>
</tr>
<tr>
<td>Soil</td>
<td>The black top soil will be removed from the affected areas and stored for later use on the construction and work areas to be re-established at the end of construction. The underlying soil layers in the areas to be re-established at the end of construction will be loosened to remove the compaction before the top black soil is replaced.</td>
<td>Re-establishment of the soil conditions in areas affected by human activities in other parts of Fehmarn and Schleswig-Holstein (the so-called Ökokontofläche or eco-account)</td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Measures built into the project design</td>
<td>Mitigation measures during construction and operation</td>
<td>Compensation</td>
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</tr>
<tr>
<td>Water</td>
<td>Culverts will be constructed under the new motorway and railway and other new roads to ensure the continued function of the Drohngraben and Nielandsgraben as drainage ditches in both the construction and operation phases. Sections of the ditches will also be rehabilitated to improve their function.</td>
<td>-</td>
<td>New ponds will be established to compensate for the lost ponds. The number and location of the ponds are to be agreed with the authorities.</td>
</tr>
<tr>
<td>Fauna</td>
<td>Amphibian fences will be established at required locations to mitigate impacts during construction and operation. Fauna passages will be established. The culverts which lead the drainage ditches under the motorway and railway will be wide enough and have paths at the side to function as fauna passages. Another new fauna passage will be established across a small stream. Lighting used along the motorway and railway will be of a type which reduces the attraction of insects.</td>
<td>Clearing of vegetation will occur outside the bird breeding season. Restoration of construction areas and the road and railway corridors with trees and bushes at the end of construction will mitigate impacts on bats, birds and reptiles. It will provide commuting lines for bats. Lighting used at the construction sites will be of a type which reduces the attraction of insects.</td>
<td>New ponds will be established to compensate for the losses which impact birds (breeding), amphibians and dragonflies. Hibernation habitats will be established for the Northern Crested Newt (compensation for lost areas). Monetary compensation will be made through the eco-account for the residual impacts which are not negligible according to the German practice.</td>
</tr>
<tr>
<td>Flora</td>
<td>Plant trees and shrubs along the marshalling yard and along the overpass over K49. Develop natural coastal vegetation on the reclamation area.</td>
<td>-</td>
<td>Establish new ponds with suitable vegetation to compensate for those lost. Create new biotope types outside the project area on Fehmarn and other areas in Schleswig-Holstein to compensate for those lost via the eco-account.</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>The mitigation and compensation measures proposed for other factors such as fauna, flora, water, soil and landscape are also relevant measures for biodiversity.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Component</th>
<th>Measures built into the project design</th>
<th>Mitigation measures during construction and operation</th>
<th>Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landscape</td>
<td>Compensatory landscape will be developed on the land reclamation including design to ensure visual connection with the sea. Coastal erosion is reduced in the design phase to avoid the possible loss of coastal landscape. The footprint of the construction sites, work harbour and permanent structures are minimised in the design to reduce impacts on landscape.</td>
<td>The landscape in the construction sites will be restored at the end of construction.</td>
<td>Compensatory, typical landscapes will be developed in other areas on Fehmarn. The number, area and type are to be agreed with authorities. Monetary compensation for the permanent loss and impairment of landscapes through the eco-account.</td>
</tr>
<tr>
<td>Cultural heritage and material assets</td>
<td>-</td>
<td>-</td>
<td>Losses of material assets such as the wind turbines will be compensated by Femern A/S.</td>
</tr>
</tbody>
</table>

**Rønne Banke**

<table>
<thead>
<tr>
<th>Component</th>
<th>Measures built into the project design</th>
<th>Mitigation measures during construction and operation</th>
<th>Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical and biological issues</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fishery</td>
<td>-</td>
<td>Maintain close and continuous contact with active fishermen in the area and, if necessary, with a person with knowledge of fishery on board the dredging vessel to make direct contact with fishing vessels to reduce the level of possible conflicts.</td>
<td>-</td>
</tr>
</tbody>
</table>
13 Environmental Inspection and Monitoring Programme

13.1 Introduction
This chapter outlines the general framework and principles for an inspection and monitoring programme for the construction and operation of the fixed link. It sets out how such a programme might be organised, executed and documented, and what focus areas might be of relevance.

13.2 Statutory obligations
Neither the Danish nor German statutory orders require that an EIA should include a description of an inspection and monitoring programme. However, the Danish Act on environmental assessment does require such a programme for selected projects. It is therefore normal practice is to prepare a programme if the project includes impacts which cannot be inspected or monitored on the basis of requirements and thresholds already prescribed by public authorities. German law does not require monitoring a priori since it is assumed that the implementation of mitigation and compensation measures will effectively reduce all impacts to near zero. On the other hand it is known from other projects that the German authorities may require some monitoring to be carried out.

13.3 Purpose
The purposes of the inspection and monitoring programme are:

› To verify that the project is compliant with prevailing standards, requirements and thresholds for construction and operation.
› To monitor that any adverse impacts are as assumed in the environmental impact assessments.
› To monitor that mitigation and compensation measures function as assumed.
› To be able to implement corrective action, if necessary.
13.4 Principles of the inspection and monitoring programme:

› The programme will be based on the environmental impacts of construction and operation activities, the cause of which can be recognised as deriving from the project, and for which it is possible to measure an effect.

› Monitoring is not required where:
  › There are no impacts.
  › Impacts are negligible.

› Monitoring is required where:
  › Impacts occur, but they are insignificant.
  › Impacts are significant.
  › There is a legal requirement.

› Implementation of the programme shall conform with Femern A/S's environmental policy, including an environmental management system.

› The programme will be based on the concept of self-control where the requirements for the contractor's proof of compliance with terms and requirements, etc. will be specified contractually.

› The findings of the programme will be reported to the authorities at regular intervals.

› Stakeholders, especially affected parties and the general public, will have access to monitoring data and results.

› The programme will be implemented prior to commencement of construction and is expected to be concluded during the operation phase.

13.5 Organisation

The environmental management system will describe Femern A/S's organisation, and the roles and distribution of responsibilities between Femern A/S, the contractor and the authorities. The environmental management programme will also set out guidelines and procedures for carrying out the programme, indicating what is to be inspected and monitored, by whom, when and how. In addition, the format and frequency of reporting will be specified.

13.6 Component packages

The inspection and monitoring programme will be based on the following main component packages:

1  Requirements for inspections at the construction site in compliance with statutory environmental requirements.
2 Requirements for control of sediment spill during dredging operations in the interests of verifying spill rates and compliance with contractually specified requirements.

3 Monitoring of implementation of mitigation and compensation measures.

4 Monitoring of selected biological/chemical components.

13.6.1 Requirements for inspections at the construction site
This would primarily relate to standards, requirements and thresholds for, e.g. air emissions, noise, oil and chemicals handling, waste management, effluent discharge and raw materials consumption. Inspection and monitoring of these parameters will not in principle differ from the customary practice at any construction site and will to a great extent be based on the contractor's self-control and reporting to the client and the authorities. There will be construction sites both onshore and offshore.

Femern A/S will monitor the contractor's activities in accordance with the environmental management system's guidelines and procedures, and persons appointed by Femern A/S to supervise the contractor will be granted the requisite authority and right, where necessary, to implement corrective action, including suspension of work in progress.

It is expected that the authorities will require Femern A/S to submit documentation as proof that the activities have been carried out in compliance with applicable legislation. It is also expected that the authorities themselves will perform their own inspections of the project.

13.6.2 Requirements for control of sediment spill
Sediment spill control is a key parameter in relation to the potential marine impacts on, e.g. benthic flora and fauna, and is therefore also important as regards the implementation of any mitigation measures (e.g. reduction in dredging intensity) which may be required to reduce impacts in the marine environment. This is the only possibility for feedback monitoring in the present project, i.e. when the monitoring can result in an immediate requirement for the dredging contractor to reduce spill in order to prevent impacts. All other monitoring activities will only be able to reveal impacts after they have occurred.

Sediment spill will occur during the actual dredging of the work harbours and their access channels, and when unloading barges and draining the sedimentation basins in the planned land reclamation zones. The potential impacts of sediment spill on marine flora and fauna, including birds, are described in earlier chapters. The spill volumes per unit of time vary according to the type of dredging equipment, the type of seabed spoil and the water depth at the site.
The contractor who is awarded the contract for marine construction works will be contractually responsible for monitoring of sediment spill from all relevant sources at sea.

Femern A/S will inspect the contractor's control measures by means of its own monitoring and/or by having representatives onboard the contractor's vessels and at the onshore work sites.

The contractor will be required to report to Femern A/S in compliance with guidelines and procedures laid down in the contracts and in accordance with the environmental management system.

13.6.3 Monitoring of implementation of mitigation compensation measures

Monitoring of implementation of mitigation and compensation measures will be performed to track their progress in order to ensure that the predicted ecological functionality is achieved. This targeted monitoring process may also cover specially protected species.

The individual mitigation and compensation measures are described in Chapter 12 and will mainly concern factors on shore such as the creation of a replacement lake, ponds and the Danish Nature Conservation Act's §3-areas.

The monitoring will seek to ensure that the objectives of water plans prepared in accordance with the Water Framework Directive continue to be met, and that the area's ecological functionality is sustained.

In the marine area, monitoring will also be performed of, e.g. coastal erosion and the regeneration of seabed forms.

Femern A/S will undertake the monitoring, which will be performed in accordance with the Environmental Management System's guidelines and procedures. Reports will be submitted to the authorities, but data and results will also be made available to the public.

Monitoring will continue until the anticipated ecological functionality has been achieved.

13.6.4 Monitoring of selected biological/chemical components

The purpose of monitoring selected biological components is two-fold: the intention is, first, to verify basic model assumptions, and second, to document the actual environmental status by means of selected parameters which are representative of the ecosystems. These would consist specifically of statutory parameters, such as the Natura 2000 areas' designation basis, the Water Framework Directive's and Marine Strategy Framework Directive's requirements for good
qualitative status of bodies of water and the preservation of good environmental status in marine ecosystems.

Environmental assessments in the marine area are based on 3D models, including a sediment spill model and an ecological model (see the sections on benthic flora and fauna in Chapter 5). In order to verify these models and their assumptions and to facilitate their use in predicting the effects of the ongoing dredging activities, measurements may be performed for selected parameters. These parameters may be the actual sediment spill, the physical conditions that contribute to sediment transport such as currents, wind, waves and direct effects of suspended sediment in the form of light reduction and the subsequent effect on the growth of vegetation.

In Fehmarnbelt the impact of spilled sediment on important benthic flora and fauna (e.g. eelgrass in Rødsand Lagoon) does not occur until up to several months after the sediment is actually spilled. This is due to the fact that the sediment settles during calm periods and is re-suspended during storms and moved on towards the important benthic flora and fauna areas in a series of steps. It is therefore not possible to design the marine biology monitoring as a feedback monitoring programme. The monitoring programmes for biological components will thus solely be for the purpose of following the changes and to relate them to impacts from sediment spill or to impacts of natural phenomena, e.g. meteorological conditions.

For the EU Directives on Habitat, Birds, Marine Strategy and Water Framework, the environmental authorities have, for the majority, set goals and created monitoring and intervention programmes. It would be natural for the monitoring of the selected biological/chemical components in the present project to be based on these goals and plans, their indicators, and for them, as far as possible, to support the official monitoring programmes. An example of a selected component would be the monitoring of swans for which eelgrass is a food source. Eelgrass is part of the designation basis for the Hyldekrog-Rødsand habitat area, and whooper and mute swans are two of the designation species for the Hyllekrog-Rødsand bird conservation area.

Also in this area Femern A/S will undertake the monitoring itself and it will be performed in accordance with the Environmental Management System's guidelines and procedures. Reports will be submitted to the authorities, but data and results will also be made available to the public.
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Table 8.6 Main material used for maintenance and replacement during operation of the bored tunnel.

Table 8.7 Distances driven between Denmark/Scandinavia and Germany, 2025, million km/year.

Table 8.8 Reduction of CO₂ emissions for traffic in 2025 due to the existence of a Fehmarnbelt Fixed Link.

Table 8.9 Reduction of CO₂ emissions for traffic in 2025 due to the simultaneous existence of a Fehmarnbelt Fixed Link and the Rødby-Puttgarden ferry service.

Table 8.10 Total greenhouse gas emissions compared with the zero-alternative (tonne).

Table 9.1 Transport capacity [m³/m/year] for the sand extraction area at Rønne Banke.

Table 9.2 Natura 2000 sites in the vicinity of Rønne Banke. DK=Denmark, DE=Germany.

Table 9.3 Environmental components assessed for Rønne Banke.

Table 9.4 Possible direct and indirect pressures from the sand extraction project at Rønne Banke.

Table 9.5 Reported response of waterbirds to shipping (Bellebaum et al. 2006, Schwemmer et al. 2011).

Table 10.1 Projects on water of relevance for assessment of cumulative impacts.

Table 10.2 Projects on land of relevance for assessment of cumulative impacts.

Table 12.1 Summary of mitigation and compensation measures.
16 References


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