The expert in **WATER ENVIRONMENTS**

Memo

To:	Rambøll and 'By og Havn'
Att.:	Michael Lundgaard, 'By og Havn'
From:	Bo Brahtz Christensen, DHI
Project	11823523 Lynetteholm
Date:	12-04-2021
Topic:	Additional assessments for ESPOO consultation

At the ESPOO consultation on 23 March 2021, the Swedish environmental authorities indicated that they had difficulty getting an overview of the environmental impact of the Swedish waters, as the prepared material is only available in Danish and focuses mainly on Danish conditions. Therefore, it was agreed that a supplementary note should be drawn up summarising the environmental assessments concerning the Swedish waters.

This note contains a number of clarifications and maps that provide better coverage of the Swedish waters. The note has also been prepared in an English version so that the Swedish authorities that are not entirely comfortable with the Danish environmental impact reports can use the English version.

1 Environmental assessment of the hydromorphological quality of the water bodies

Questions have been raised from the Swedish side as to whether the establishment of Lynetteholm can impact the littoral transport, wave conditions and erosion of the Swedish coasts.

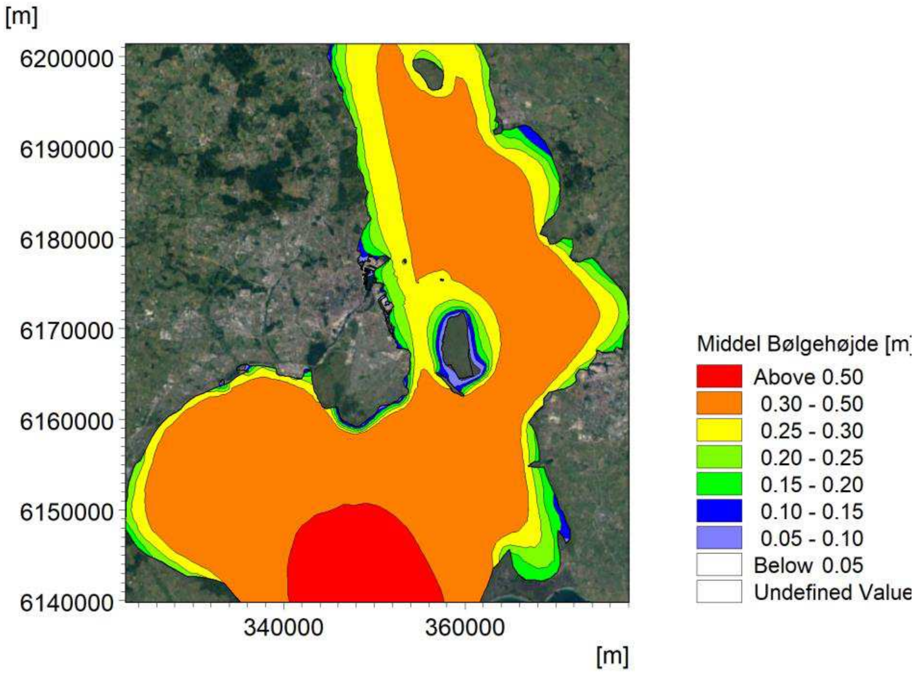
Littoral transport and coastal erosion are primarily determined by the local wave conditions and the current generated by the waves within the surf zone.

Waves in the Sound are wind-generated and thus determined by wind direction and wind speed, as well as the free stretch over which the wind acts. Lynetteholm is located on the western side of the Sound, far away from the Swedish coasts, and will therefore have no significant impact on wind and wave conditions along the Swedish coast.

The following figures show simulated wave heights in the Sound in the model year 2018 as follows:

- Figure 1 shows the annual averaged significant wave height for current and future conditions with Lynetteholm, respectively.
- Figure 2shows the largest significant wave height in 2018 for current and future conditions with Lynetteholm, respectively.
- Figure 3shows the annual average change due to Lynetteholm.

As can be seen from the plots, the differences are negligible. There is a slight shadow effect (i.e., weakening of the waves) in the area south of Lynetteholm of “Prøvestenen” and a minor reinforcement in the area north of Lynetteholm. The impact is seen to be only local. No impact can be observed along the Swedish coast. Figure 4 shows the change of the largest significant wave height occurring during 2018. Here the impact area is a little larger but again entirely local in the area around Lynetteholm. Thus, it can be concluded that Lynetteholm will not affect the wave conditions along the Swedish coasts and, therefore, will not cause any changes in littoral transport. This means that Lynetteholm does not induce erosion along Swedish coasts.



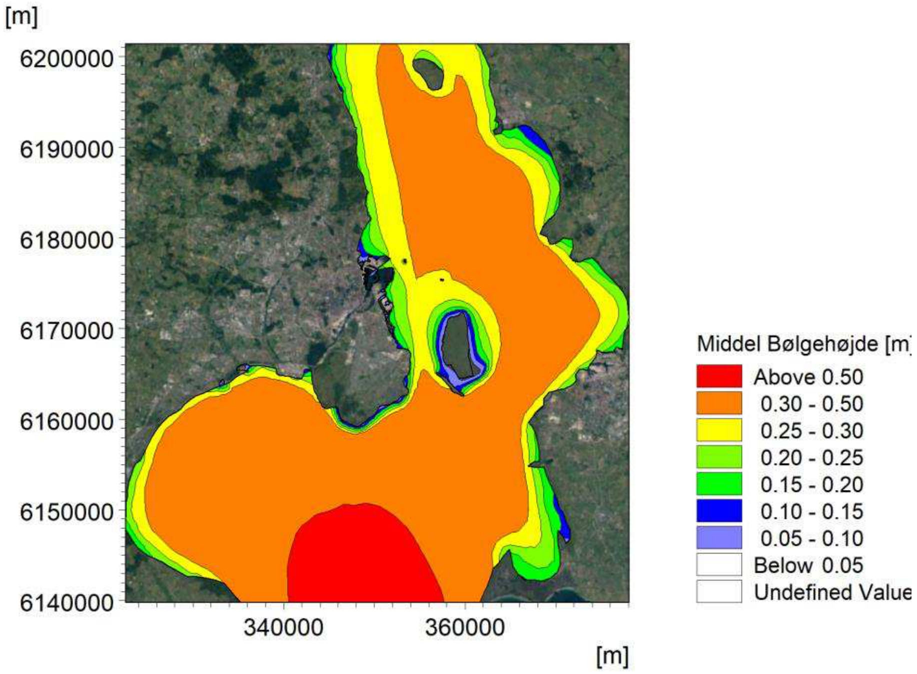
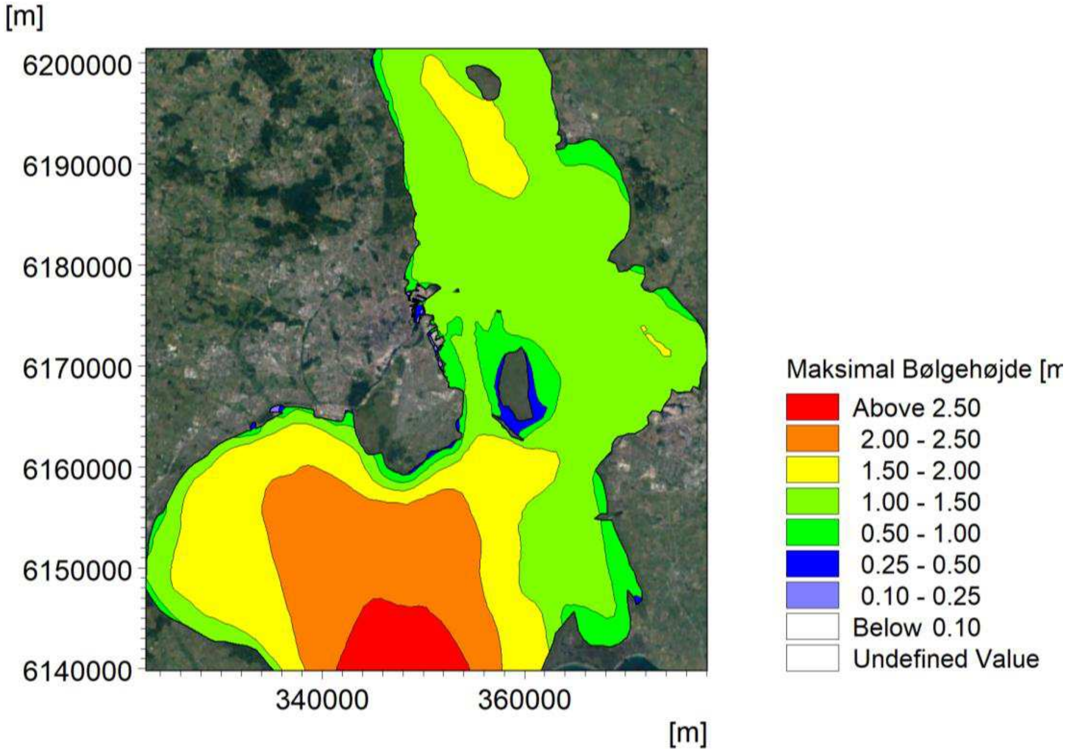


Figure 1 Annual average wave height. Top: present conditions. Bottom: future conditions with Lynetteholm.



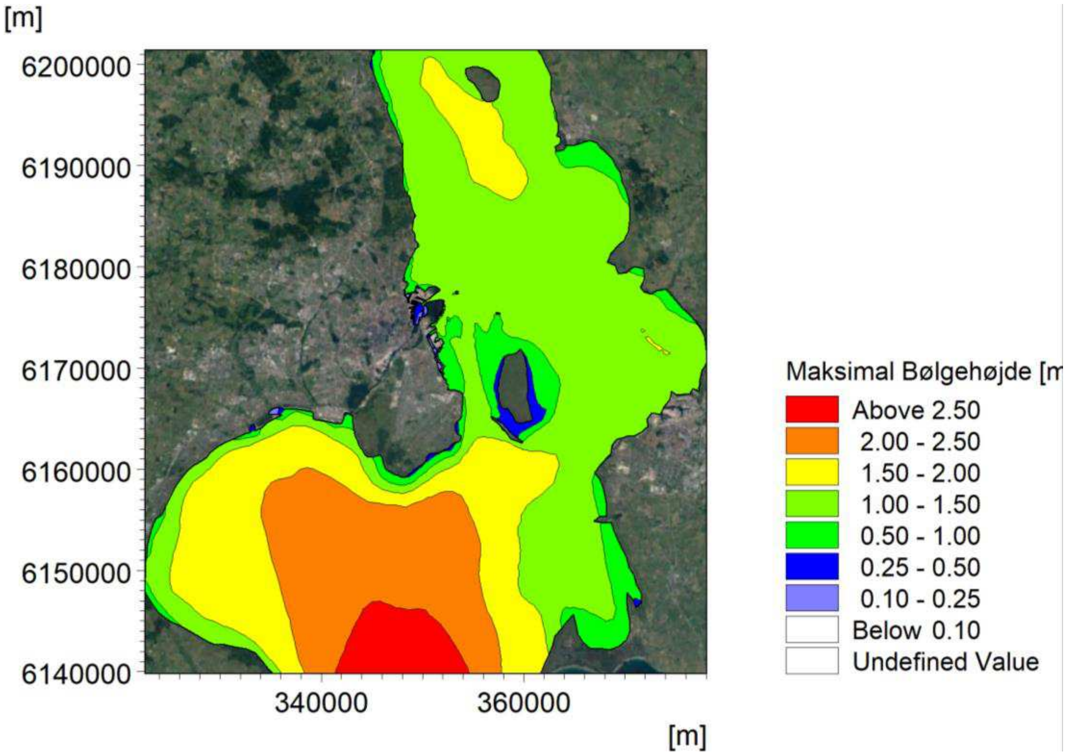


Figure 2 Maximum significant wave height. Top: present conditions. Bottom: future conditions with Lynetteholm.

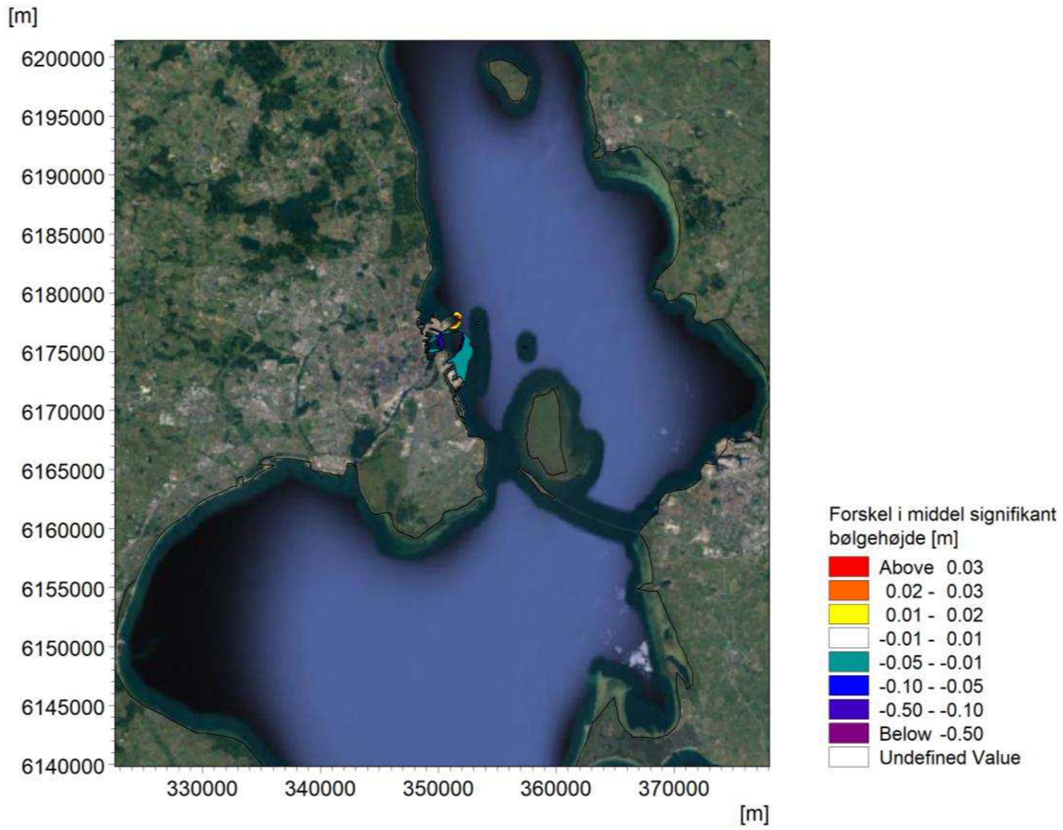


Figure 3 Change in annual average of significant wave heights.

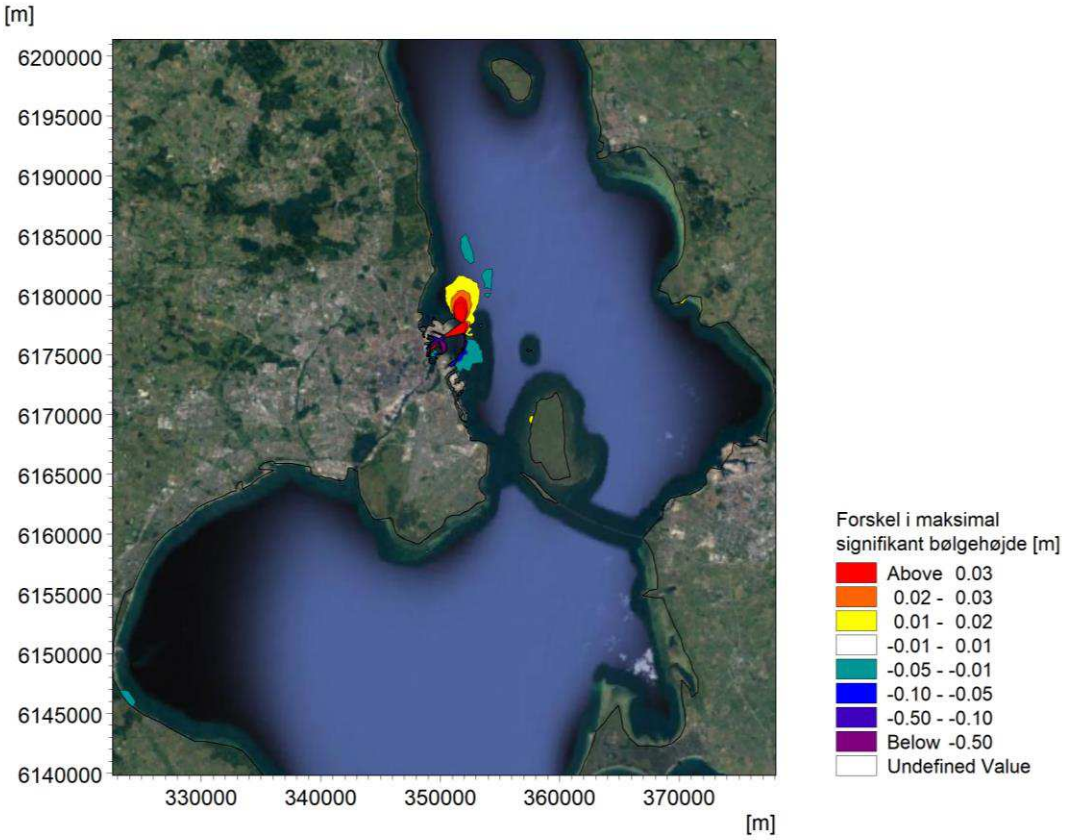


Figure 4 Change of the maximum significant wave height.

2 Sediment dispersion in connection with disposal of dredged sediments in Køge Bay

Sediment dispersion calculations have been carried out in connection with the disposal of dredged sediments in Køge Bay. The calculations are carried out with a coupled near-field description, where the sediment disposal's movement towards the bottom is described by a near-field model, which is transferred to the far-field model when density-driven effects no longer determine the movement of the disposed sediment. The disposed material is estimated to have a relatively high moisture content, which entails a large loss in connection with the disposal itself, since the dry matter density is not large enough to send the disposed material directly down to the bottom, which is why it instead settles as a sediment cloud just above the bottom, from which it gradually deposit. It should be noted here that it is assumed that the dry matter represents only 23% of the disposal volume in the model calculations. Therefore, the relative loss from the disposal area will be reduced if the volume of dry matter proves to be a larger part of the disposal material, reinforcing the density-driven effect of the fall towards the bottom. Furthermore, the dry matter will tend to be compressed in the lower part of the split barge hopper during the transport to the disposal area, making it easier to deposit directly on the bottom. This is process is not taken into account in the model calculations, which conservatively are based on the fact that the disposal material is evenly mixed up in the hopper of the split barge during disposal.

In the report describing the disposal of dredged material, ref. /1/, in Chapter 4, current roses are shown, which describe the current conditions on the two disposal areas at the seabed, in the middle of the water column, and at the surface. Furthermore, it is shown how salinity can vary over time in the two areas at the bottom, in the middle of the water column, and at sea level. The Baltic Sea is a brackish water area, where water supply from rivers implies a net transport of water to the north (from the Baltic Sea to the Kattegat). The net transport takes place primarily in the upper part of the water column due to the interaction between the heavier salty water from the Kattegat and the lighter brackish water from the Baltic Sea. In the disposal areas, the net drift on the seabed is directed towards southwest. Strong currents at the seabed in the two disposal areas are always directed to the southwest. Therefore, the disposals primary advection and dispersion will be directed to the southwest, as the sediment cloud is overlaid just above the seabed and advected with the current. Therefore, the sediment clouds will most often move as shown in the figure below (Figure 5), which shows the trail of 6 disposal events with a time lag of one hour between each.

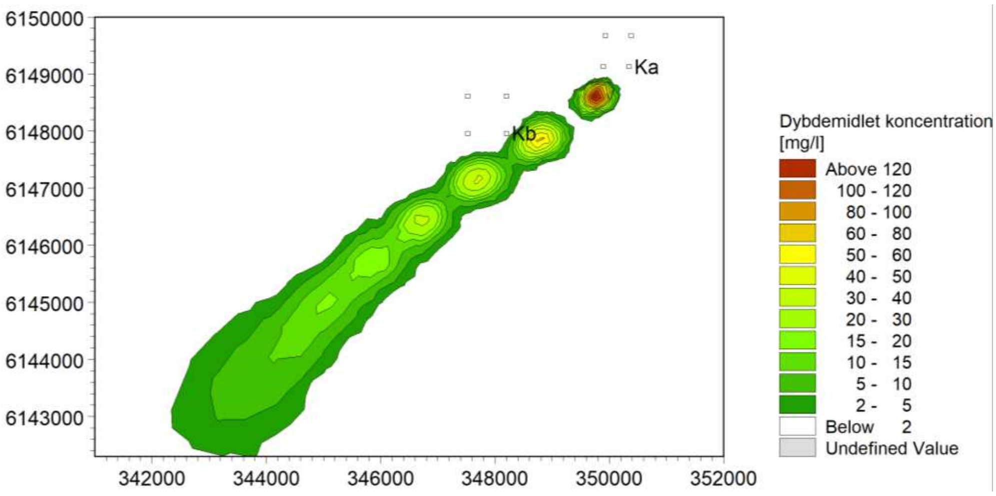


Figure 5 Example of the sediment dispersion associated with disposal of dredged sediments.

The deposition maps in ref. /1/ and the map in Figure 6show, as the above sediment plume, that the material is primarily deposited on deeper water in the southwest direction. As the advection and dispersion of the disposal material is associated with the bottom current, the deposits take place mainly in the deeper water area southwest of the disposal sites. If resuspended, the sediment will primarily move in the deeper channels in the direction further into the Baltic Sea. Outside the area shown, the deposits are so thin that secondary and tertiary resuspension is of no importance to the concentrations in the water column. If sediment is resuspended in these areas, it will be dominated by the already present bottom sediment and not the contribution from the disposal material.

The water depths in the Natura 2000 sites are shallow compared to the water depths of the disposal areas. Therefore, it will primarily be in connection with the disposal release that there may be a risk that parts of the sediment cloud may reach the Natura 2000 areas. Here, maps showing duration of sediment concentrations exceeding 5 mg/l and a time series from the model calculations extracted in the western part of the Natura 2000 area at Falsterbo (see Figure 8 and Figure 8 show that it will occur only sporadically. The criterion for a visible sediment plume is typically 2-5 mg/l.

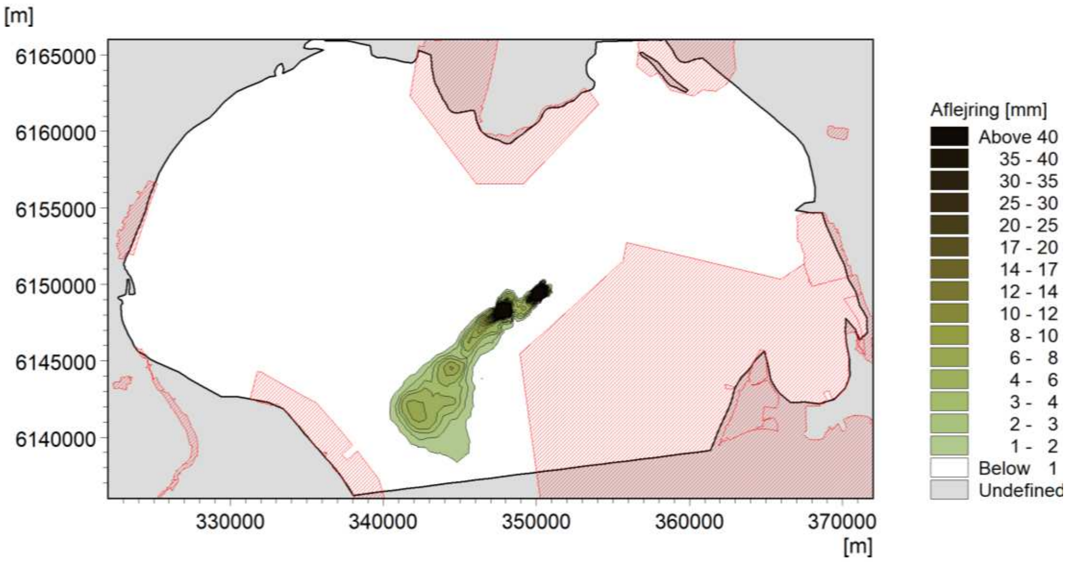


Figure 6 Deposition maps due to disposal of dredged sediments, ref. /1/.

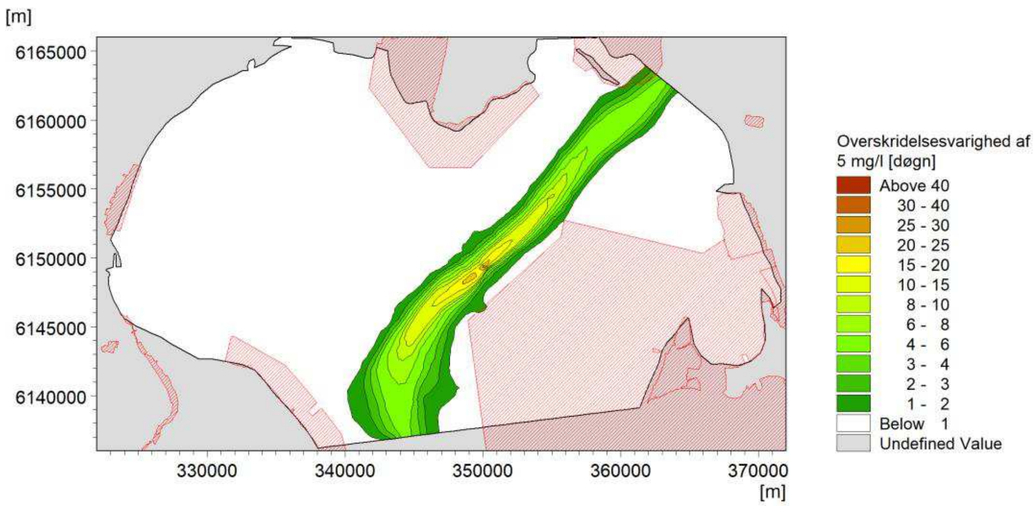


Figure 7 Duration of sediment concentrations exceeding 5 mg/l during the winter months (October-March) using disposal site Ka.

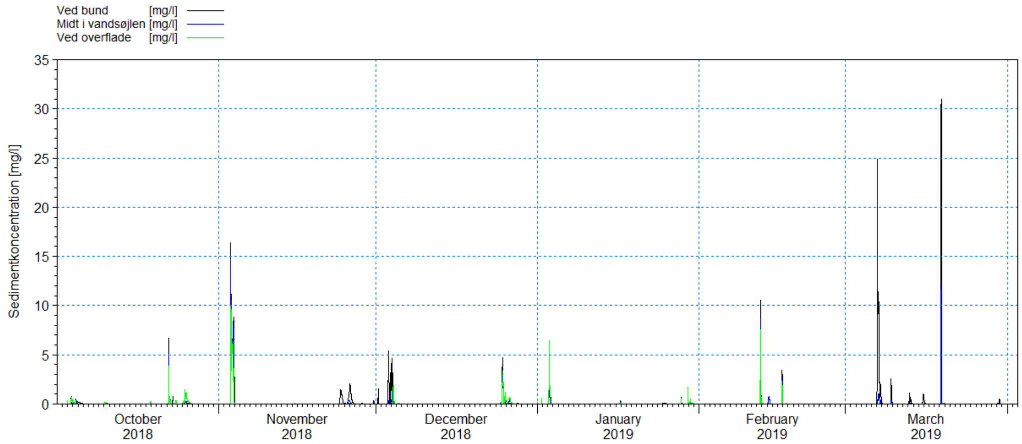


Figure 8 Time series of sediment concentrations at the bottom, in the middle of the water column, and at the surface at point E 350,000 m and N 6,146,000 (UTM-33) located in the outermost part of the Natura 2000 area at Falsterbo.

The bottom fauna also experiences shadow effect at night, and since the length of the day is shorter in the winter season (when disposal is carried out), more than half of the sporadic events will occur at times when there is no light supply anyway. As there is no significant deposition in the Natura 2000 areas, and since any shadow effect occurs only sporadically, briefly, and outside of the growing season, the disposal is not considered to have a tangible impact on Natura 2000 areas.

3 Flow/blockage in the Sound

Lynetteholm is a land reclamation, which has as a consequence that the flow cross section of the flow in the Sound is narrowed locally. The narrowing causes a local increase in flow resistance and thus has a slight dampening effect on the dynamics, which manifests itself in the calculated blockage. To change the frequency and amount of saltwater inlet to the Baltic Sea, the project must have a real threshold effect, and the Lynetteholm project has not. Hollænderdybet east of Middelgrunden is both deeper and wider than the Kongedybet and will therefore continue to direct salt towards the Baltic Sea. The controlling flow margin for the exchange of salt and water between the Baltic Sea and the Kattegat will consequently be made up of the Drogden Threshold. Therefore, the general assessment is that Lynetteholm will not change the frequency and amount of saltwater intrusions to the Baltic Sea.

Lynetteholm differs from the Øresund Bridge project in that the impact is more local. The Øresund Bridge stretches across the Sound in the Drogden Threshold area, where the actual regulation of the water change occurs. Therefore, the Øresund Link could contribute further to the threshold effect, thereby making it more difficult to exchange water and salt between the Baltic Sea and the Kattegat via the Sound. This is not the case with Lynetteholm.

Lynetteholm's impact on the current conditions in the Sound is described in ref. /2/ and the following figures:

- Figure 9 shows the annual mean of the average depth current calculated without direction (gross current) for current conditions and future conditions with Lynetteholm, respectively.

- Figure 10 shows the most significant occurring maximum current (depth average) during 2018 for current conditions and future conditions. The plot does not represent a snapshot because the maximum current rate will not occur simultaneously everywhere. The plots show that the area around the Øresund Link forms the regulating cross-section of the Sound since it is in this area that the highest current speeds occur due to the Drogden Threshold and the narrower cross-section.

- Figure 11shows the change in the annual average current. It can be seen that there is a reinforcement taking place in the area east of Lynetteholm, which extends into Hollænderdybet, and a local weakening in the area just north and south of the land reclamation.
- Figure 12 shows the change in maximum current. The picture is the same as for the current annual change, but the impact area is slightly larger. However, it should be borne in mind that the maximum current relates to a short-term picture, while the mean current indicates the more permanent impact.

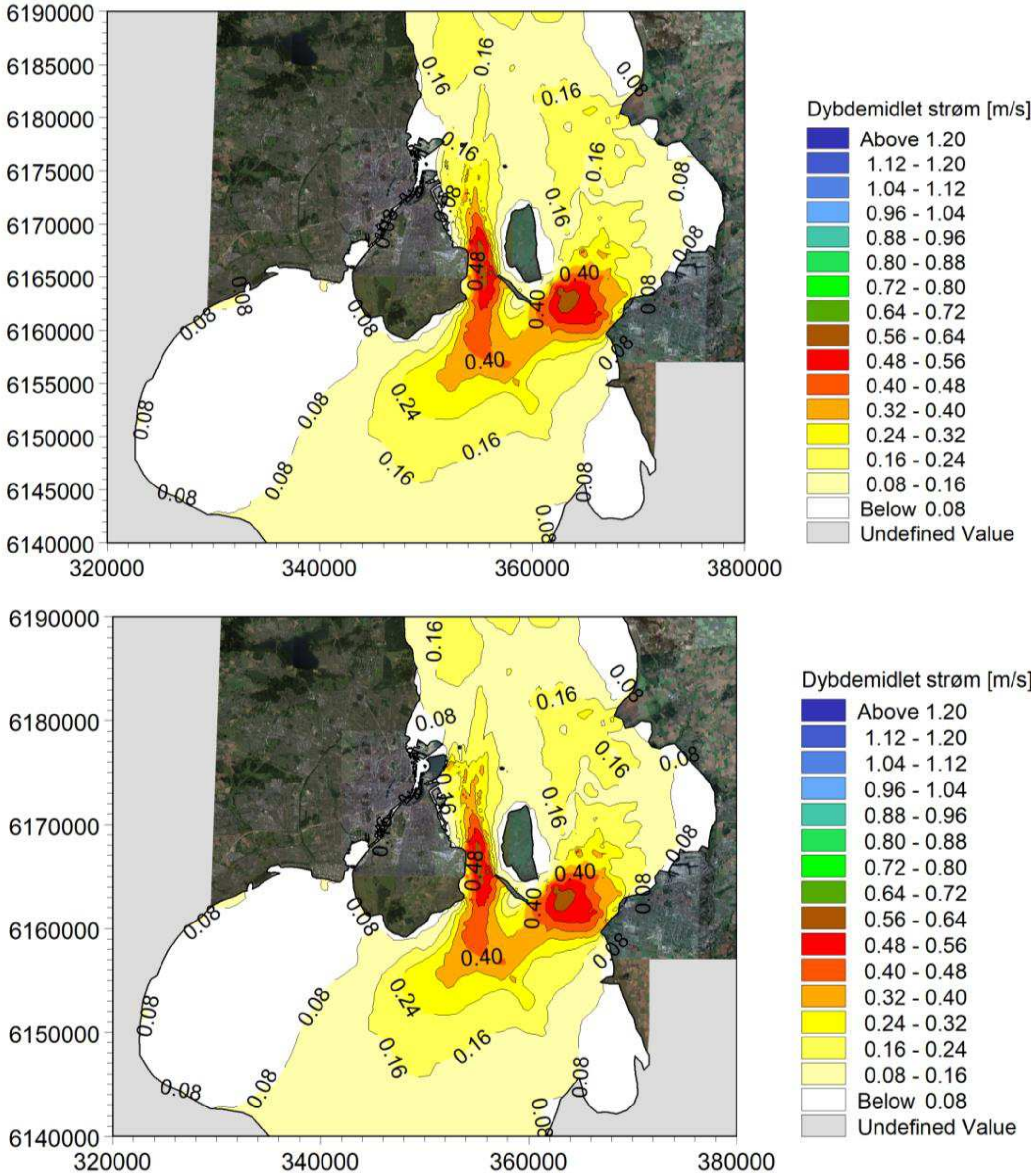


Figure 9 Annual mean of the depth-integrated current calculated without direction (gross current). Top: present conditions. Bottom: future conditions with Lynetteholm.

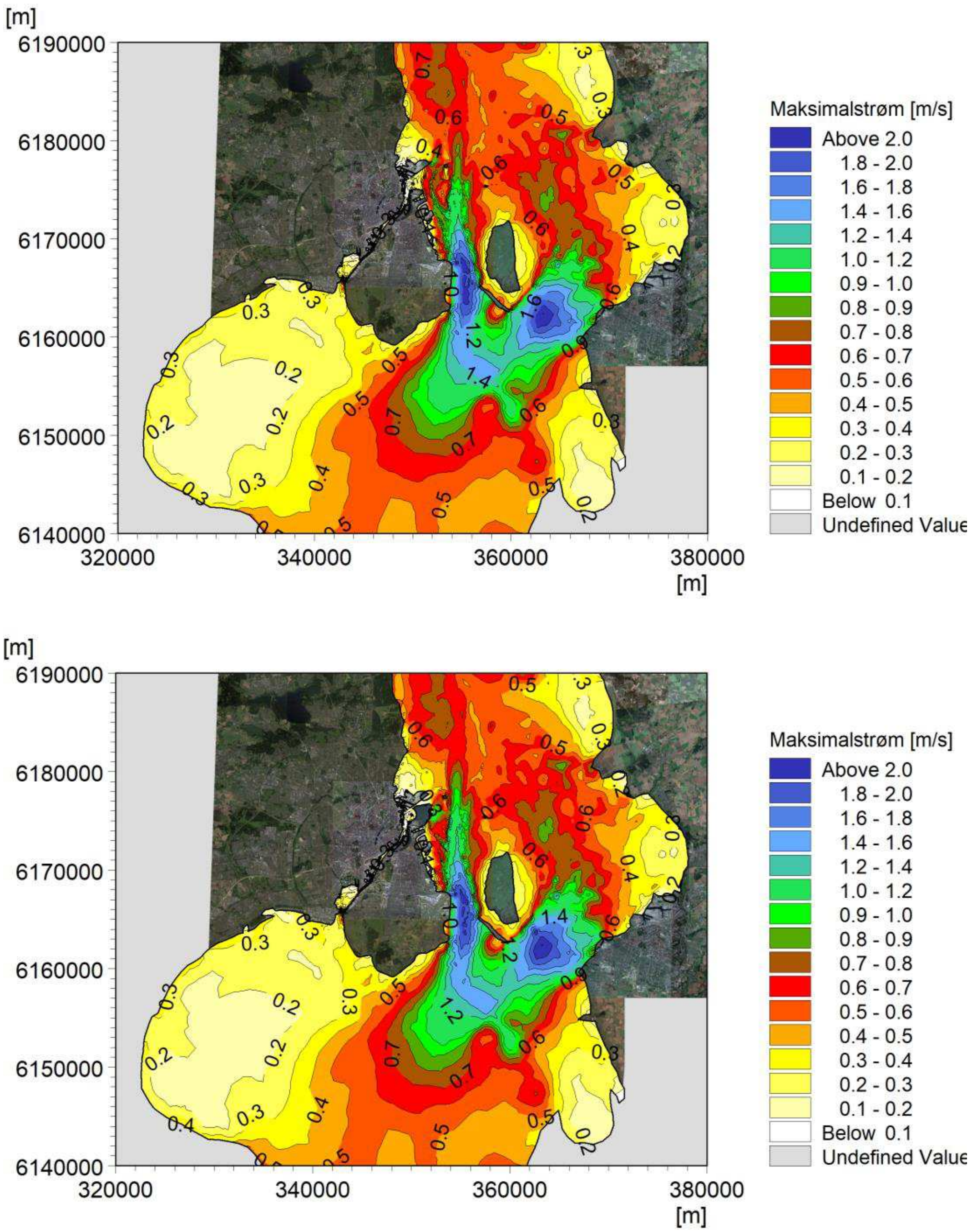


Figure 10 Maximum depth-integrated current in 2018. Top: present conditions. Bottom: future conditions with Lynetteholm.

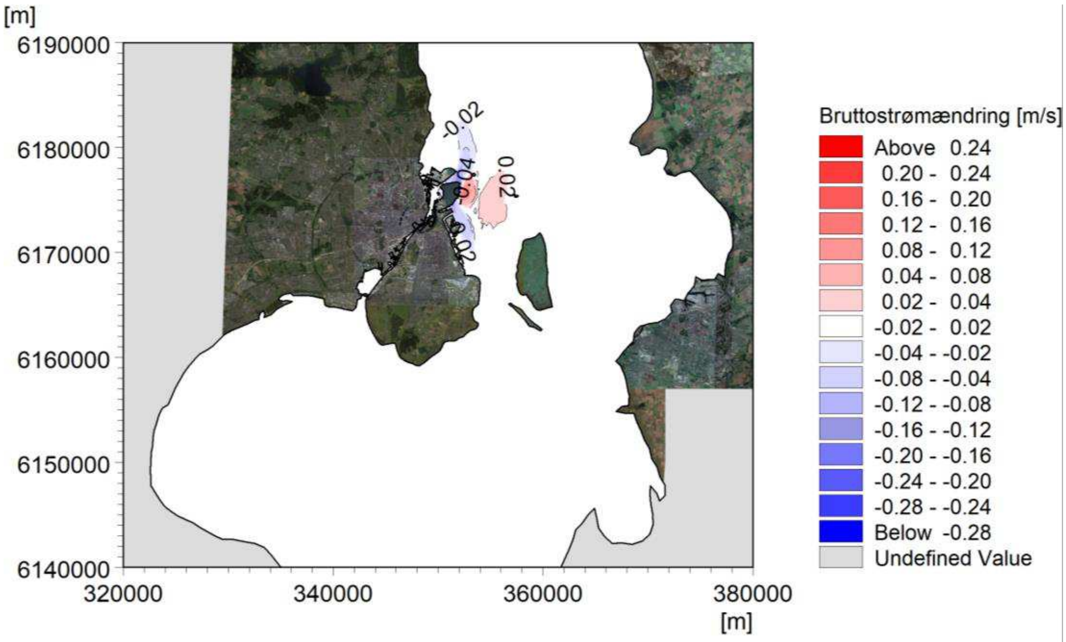


Figure 11 Change in the annual mean current (mean depth-integrated gross current change).

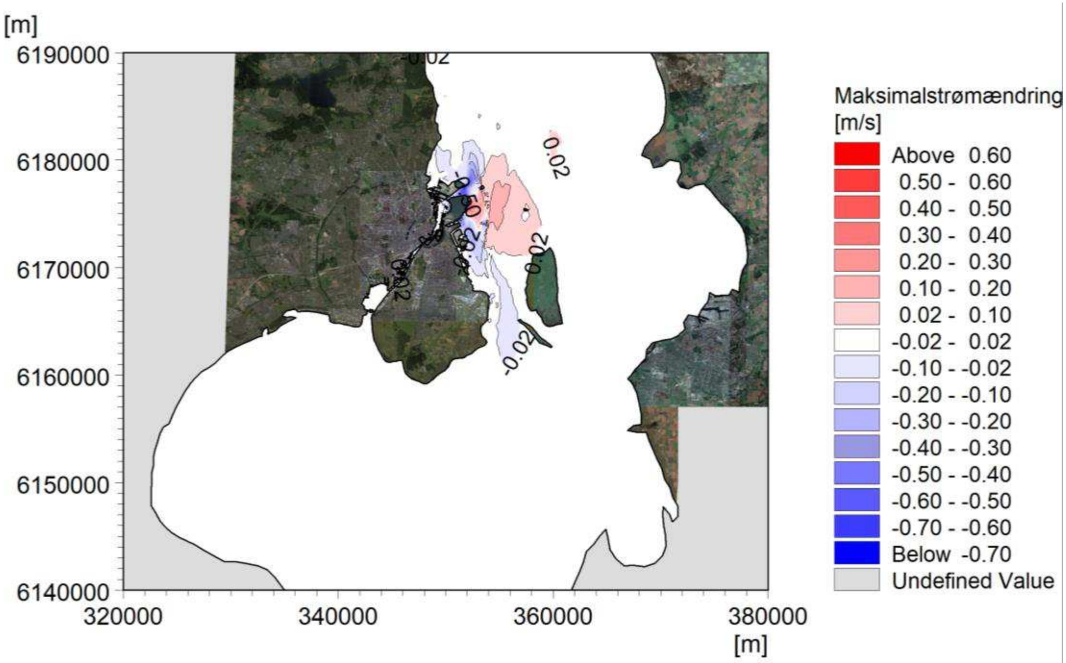


Figure 12 Modification of the mean depth-integrated maximum current.

Lynetteholm's impact on current conditions in the Sound is local seen in the Øresund scale. Furthermore, the impact is not one-sided, as there are both areas with current amplification and current relaxation. The impact is estimated to have a non-significant effect on the exchange of water, salt and oxygen between the Kattegat and the Baltic Sea. Generally, the assessment is therefore, that Lynetteholm will not change the frequency and amount of saltwater intrusions to the Baltic Sea.

4 References

/1/ DHI: ATR-11-klapning Køge bugt - spredningsberegninger. 16. december 2020.

/2/ Anlæg af Lynetteholm. VVM – Teknisk Baggrundsrapport nr. 1. Hydrauliske undersøgelser. Endelig rapport version 1.6, 2. november 2020.