

# Cooling Water System

KGG

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## Cooling Water System

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## Acronyms and Abbreviations

AACE - Association for the Advancement of Cost Engineering  
AP1000 – Pressured Water Reactor developed by Westinghouse Electric Company  
CAPEX – Capital expenditure  
CWS – Cooling Water System  
EPB – Earth Pressure Balance  
ID – Internal Diameter  
KGG – Ministerie van Klimaat en Groene Groei  
LAT – Lowest Astronomical Tide  
LVSE – Low Velocity Side Entry  
MPMZ – Maximum Permissible Mixing Zone  
MWe – Megawatts electrical  
Meth – Megawatts thermal  
NPP – Nuclear Power Plant  
RWS – Rijkswaterstaat  
SPB – Slurry Pressure Balance  
TBM – Tunnel Boring Machine  
TFS – Technical Fact Sheet  
TPR – Third Party Review  
UXO – Unexploded Ordnance  
VD – Variable Density

# 1. Introduction & background information

## 1.1 Introduction

The following document has been prepared by Amentum to assist the Netherlands Ministerie van Klimaat en Groene Groei (KGG) with ongoing technical evaluations for various sites to support the nuclear power programme in the Netherlands. This study specifically relates to the Cooling Water Systems, as part of a wider body of work supporting the technical evaluation. The scope was developed in collaboration with KGG over the initial period.

KGG have identified 7 no. coastal sites that are to be evaluated (2 of which have 2 alternatives). This follows previous Westinghouse and EDF Vendor assessments for the Borssele 2 site that were undertaken in 2024 and reported in the Third Party Review (TPR), with Westinghouse proposing the AP1000 technology and EDF proposing the EPR technology.

KGG wish to evaluate the suitability of the various sites against a 'bounding case' i.e. the requirements to satisfy the site suitability for both Vendor Nuclear Power Plant (NPP) technologies. For the Cooling Water System the key parameters are the volume of water used and the heat load transmitted to that water.

KGG have requested Technical Factsheets for each site to present technical evaluations, these technical evaluations will comprise a series of criteria to assess the suitability of the sites from a Cooling Water Supply point of view, including the design and construction challenges as well as the environmental effects. In addition to scoring of multi-criteria, as part of the evaluations, both the time, referred to as 'Time Impact Classification', and cost, referred to as 'Financial Impact Classification', is required to be assessed against predetermined ranges (as defined by KGG).

It is understood that the Cooling Water Systems findings and recommendations will be incorporated into a wider collated single evaluation study, authored by Antea, that will include evaluations authored by other Consultants.

## 1.2 Orientation

Sites Eemshaven 1A, 1B, 2 and 3 are located close to the port of Eemshaven in the north-east of the country on the Eems estuary. Eemshaven 1A and 1B are to the west of the port, while Eemshaven 2 and 3 are to the east.

One site is located in the Maasvlakte 2 port, close to Rotterdam.

Sloegebied 1 and 2 are located close to the port of Vlissingen. This is also the location of the existing Borssele power station on the north side of the Western Scheldt Estuary in the southwest of the country.

Terneuzen 1A and 1B are located on the southern bank of the Western Scheldt Estuary.

## 1.3 Aims

The overall aims of the report are to:

Evaluate and determine key differentiators between the various sites by scoring against selected criteria related to the design and construction of the cooling water supply system and associated environmental effects; and,

- Estimate the Time and Financial Impact Classifications for each site.
- Highlight risk criteria and any potential mitigation measures.

## 1.4 Objectives

The objectives to achieve the aim are as follows:

- Establish multi-criteria and scoring approach to allow technical evaluation of the sites;

- Subject Matter Experts (SMEs) technically assess the sites against the selected multi-criteria and identify limitations in certainty of information / data;
- Develop appropriate presentation of Technical factsheets (presenting multi-criteria) and populate per site;
- Establish the 'Bounding Case' parameters using available information and establish appropriate assumptions where necessary to perform assessments / calculations;
- Review of existing reporting and data, particularly thermal modelling;
- Generate potentially environmental and compliant options;
- Review potential construction techniques, generate outline construction method statements and confirm feasibility;
- Estimate costs of each scheme and categorise within bands.
- Score options based on cost, constructability, compliance, efficacy and stakeholder acceptability measures;
- Evaluate Risks for each scheme;
- Discuss potential mitigations for low scoring or high risk schemes.

## 1.5 Exclusions and limitations

- The maturity of any CAPEX and programme estimate is commensurate with maturity of the study. No detailed programme or bottom-up estimating is envisaged. Estimating is at Level 5 according to the AACE International Recommended Practice 115R-21

<b>ESTIMATE CLASS</b>	<b>MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES</b> Expressed as % of complete project definition	<b>END USAGE</b> Typical purpose of estimate	<b>METHODOLOGY</b> Typical estimating method	<b>EXPECTED ACCURACY RANGE</b> Typical variation in low and high ranges at an 80% confidence interval
<b>Class 5</b>	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +60% to +200%

- No design activities are performed at this stage. Rough sizing estimations are made, and assumptions stated but no calculations will be submitted as deliverables.
- As this is pre-feasibility stage any schemes proposed are based on Engineering Judgement to support the site selection process. Design Features and Method Statements contained are the minimum to understand the key risks and likely cost and time order of magnitude.
- The scope is limited the solutions outside of the forebay i.e. the water intake and outfall systems are the focus of the study and no attempt is made to influence the actual plant design. Estimates and assumptions on the forebay size and depth may be made to inform the geometry and connection points.
- Technical evaluations are based on the available information presented at the time of the study (see sources of information presented in Section 2).
- Site boundaries have been selected by Antea and provided to us in digital format.
- Bathymetry supplied by Deltares in digital format.
- Water levels and currents supplied by Deltares by email.

- Ground conditions evaluations are predominantly based on geological / geotechnical site evaluations provided by Deltares and national geological databases (see sources of information presented in Section 2).
- The evaluation of sites against multi-criteria is typically qualitative and is based on SME technical experience and judgments.
- For the assessment of logistics, it is assumed existing rail, ports and roads have sufficient capacity to supply the construction activities. Verification of this assumption is known to be covered in other work related to Site Selection. Availability of site area for required working area and the general availability of logistics links to allow support of tunnelling activities are included in the scoring.
- KGG have instructed that intake from the dock systems and outfalls into the dock system are not to be considered.

## 2. Executive Summary

This report considers seven potential sites for a new nuclear power station, two of which have two alternatives. It reviews the potential ways of getting cooling water to the station considering the engineering, construction, stakeholder and environmental challenges.

The Volumetric Flow Rate of water is established as a bounding case for the two technology solutions under consideration and the pros and cons of direct vs tunnel intake and outfall, giving basic sizes that are required and outlining the construction methods likely to be required.

Each site is considered in turn and options for the abstraction and return of cooling water are developed, where appropriate considering both direct and tunnel intake and outfall. For each option an estimate of the design and construction cost is made and this is used as one component of the scoring, along with constructability, environmental impacts of the cooling water, environmental impact on the local habitats, potential thermal recirculation, navigational hazards created, issues with unexploded ordnance and the impact on local stakeholders. In order to assess the constructability of the tunnel options, the local geological conditions were reviewed and the suitability of the site for tunnel construction using a TBM (tunnel boring machine) was evaluated.

The findings for each site are:

Eemshaven 1A and 1B – Only direct intake/tunnel outfall and all tunnel options may be considered due to the environmental impacts of the cooling water. If direct entry is considered then there are likely to be impacts on protected habitats and challenges in permitting. An all tunnel solution would require relatively long and high cost tunnels but largely mitigates environmental permitting concerns and so is preferred.

Eemshaven 2 and 3 – Direct intake and outfall is an attractive, low cost solution in these locations. It has potential risks associated with environmental impacts of the cooling water, impacts on protected habitats but permitting is expected to be easier than other sites. Environmental impacts of the cooling water may be mitigated by construction of a short outfall tunnel, but this would increase costs and risks creating a navigational hazard.

Maasvlakte 2 -Direct intake/tunnel outfall is assessed to be the preferred option which can be constructed at moderate cost. There are risks associated with impacts on protected habitats but permitting is expected to be easier than other sites. There are also risks associated with introduction of a navigational hazard.

Slogebied 1- Direct intake/outfall and tunnel intake/direct outfall were considered in this location and both found to be possible. With both there are issues with environmental impact on the local habitats, risks of navigational hazards being created and an impact on local stakeholders, namely leisure users of the beach.

Slogebied 2 – An all tunnel solution is the best option, but the risk associated with introduction of a navigational hazard is present, and tunnelling under the infrastructure in front of the site represents a risk.

Terneuzen 1A and 1B– An all tunnel solution is preferred on this site, and on balance this site has the best the conditions for tunnelling. However, the tunnels would be long and therefore high cost, and there is a significant risk associated with introduction of navigational hazards in the main channel serving Antwerp and other ports. Direct intake /outfall is a very attractive option on this site, and actually scores highest, but it has an environmental impact on the local habitats and is unlikely to achieve permitting.

Other risks are discussed, as follows; Construction risks associated with direct intake/outfalls that breach the National Dyke or railway lines are discussed and the impact and potential mitigations are discussed. Political risks due to construction close to the Eems-Dollard Line may be an issue on the Eemshaven sites, and the overlay of the proposed options with the various treaty lines is included. Operational risks due to potential increase in ambient temperatures due to climate change, which could necessitate further investment in cooling systems in the event of significant increases in seawater temperatures.

The final conclusion is that abstraction of cooling water is feasible at all sites but that the cost and risk varies. A balanced scorecard is presented which gives a guidance on the ranking of the sites, however it is necessary to consider the implications of risk carefully. For example, the highest score is achieved by a direct intake and outfall system at Terneuzen 1A, but this is considered extremely high risk from a permitting viewpoint. The next scores are direct intake/outfall at Eemshaven 2 and 3. These also have risk associated with the permitting but it is considered to be lower than that at Terneuzen 1A and so they may be considered to be more favourable sites in this regard.

### 3. Sources of information

#### 3.1 Site Information

1. J. van Ruijven (2023), Borssele II: site evaluation Overview
2. A. Cunningham (2023), Borssele II: Site evaluation Wild fires
3. H. de Waal (2024), Assessment of the platform level Technical feasibility study Borssele 2
4. M. C. H. Tiessen, J. Groeneweg et al. (2024), Borssele II: Site evaluation Hydro and meteo hazards
5. C. G. C. van Baak, J. h. van Lopik et al. (2023), Borssele II: Site evaluation Recommended subsurface site investigation
6. J. van Ruijven, R. Morelissen, R. Vlijm, M. Mendoza Viteri (2025), Terneuzen site evaluation Preliminary results
7. Deltares (2025), Location studies new Nuclear Power Plants: Subsurface Urgent actions and attention points
8. P. Kruiver, P. Siegmund (2025), Seismologische en klimatologische gegevens voor drie mogelijke locaties van nieuwe kerncentrales
9. M.P. Hijma, G. Remmerswaal et al. (2025), Maasvlakte 2: Site evaluation Geological and geotechnical characteristics and hazards
10. M. Hijma, G. Remmerswaal et al. (2024), Maasvlakte II potential NPP locations Geological and geotechnical quickscan

#### 3.2 Thermal Modelling Reports

11. M. Georgiou (2024), Maasvlakte site evaluation Cooling water availability
12. R. Vlijm (2024), Borssele II: Site evaluation Cooling water availability
13. J. van Ruijven, R. Morelissen, R. Vlijm (2025), Borssele II: Site evaluation Cooling water availability Assessment of additional layouts (Thermphos)
14. W. Verbruggen, R. Morelissen, R. Vlijm (2025), Eemshaven site evaluation Cooling water availability Preliminary results rapid assessment
15. R. Vlijm, R. Morelissen, M. Mendoza Viteri (2025), Terneuzen site evaluation Cooling water availability

#### 3.3 Geotechnical Reports

##### 16. Sloehaven sites:

- 11209639-013-GEO-0002\_v0.1-Sloehaven Site Evaluation - Geological and geotechnical characteristics and hazards-signed (2), Deltares

##### 17. Eemshaven sites:

- 11209639-011-GEO-0003\_v0.1-Eemshaven site evaluation - signed (1) , Deltares

**18. Maasvalke 2 site:**

- 11209639-004-GEO-0003\_v0.1-Maasvlakte 2 Site evaluation - Geo (1), Deltares

**19. Terneuzen sites:**

- 11209639-013-GEO-0001\_v1.0-Terneuzen Site evaluation - Geological and geotechnical characteristics and hazards – signed, Deltares

### 3.4 Topographical and Bathymetric Information

**20. Digital Terrain Model and Digital Surface Model:**

- Open source data downloaded from <https://www.pdok.nl/>, 07.2025

**21. Google earth**

### 3.5 Metocean Conditions

22. J. Groeneweg, M. de Jong, R. de Graaff, P. Siegmund (2025), Nuclear Power Plant Site Evaluation: additional locations Hydrodynamic and meteorological hazards

23. Email Roelvink – Spolton 08:06 31/7/25 FW:additional water level data with spreadsheet attachment giving WL data for tidal range and extreme events

## 4. Assumptions / Plant Data / Bounding Case

### 4.1 Cooling Water Flow Rates

#### 4.1.1 Bounding Case

Deltares lay out the calculation of expected Thermal Capacity of a NPP in references 11-15, as follows:

The maximum electrical capacity of the NPP is currently estimated at 2x1600 MWe with an estimated efficiency of 35%. The proposed power plant (2x1600 MW electrical capacity) has a total thermal capacity of 4600 MWth. This results in  $(4600-1600)*2 = 6000$  MWth of heat discharge for a once-through cooling system. Since it is unknown at this point at which temperature increase the cooling water will be discharged, 3 different combinations of discharge flow and a temperature increase between the intake and the outfall are considered:

- Discharge option 1: A discharge of 205 m<sup>3</sup>/s and a temperature increase of +7°C.
- Discharge option 2: A discharge of 159.5 m<sup>3</sup>/s and a temperature increase of +9°C.
- Discharge option 3: A discharge of 119.5 m<sup>3</sup>/s and a temperature increase of +12°C.

These volumes and temperature changes are in line with expectations based on other projects

#### 4.1.2 Recirculation

Neither vendor made any statement about engineering limits on recirculation, however it is commonly accepted that inlet temperatures have an impact on the efficiency of the plant. On the basis of experience on other projects, this report adopts a notation of considering >2°C temperature rises due to recirculation as undesirable and >5°C as absolutely not permissible.

#### 4.1.3 Thermal Regulation and Guidance

Advice from Deltares (References 11-15) gives guidance on the criteria that are used to judge the acceptability of the mixing zone extents by the RWS:

The “Maximum Permitted Mixing Zone” (MPMZ) is defined by the 25°C contour. The limitations on the MPMZ are dependent on whether the site is classed as Estuarine or Coastal.

- For Coastal sites the MPMZ may not touch the seabed
- For Estuary sites the MPMZ is 25% of the cross-sectional area of the estuary or channel
- For Estuary sites the overall heating effect may not raise the temperature above 25°C or by more than 2°C

The intent of this guidance is to give a simplified interpretation to the acceptability of thermal discharges from an ecological point of view, and so the 25°C contour and 2°C maximum increase are put forward by the regulator in this context.

### 4.2 Bounding Case

In the absence of clear data and requirements from either vendor, the decision was taken to calculate the preliminary dimensions of the system based on the Deltares assumptions.

- Maximum Flow: A discharge of 205 m<sup>3</sup>/s and a temperature increase of +7°C.
- Normal Flow: A discharge of 159.5 m<sup>3</sup>/s and a temperature increase of +9°C.
- Low Flow: A discharge of 119.5 m<sup>3</sup>/s and a temperature increase of +12°C.

## 5. Basic Design / Construction

### 5.1 Direct Intake

#### 5.1.1 General Information

The Cooling Water Intake and Outfall Solutions are broadly divided into Direct Intake/Outfall or Tunnel systems. Direct intake are normally preferred due to:

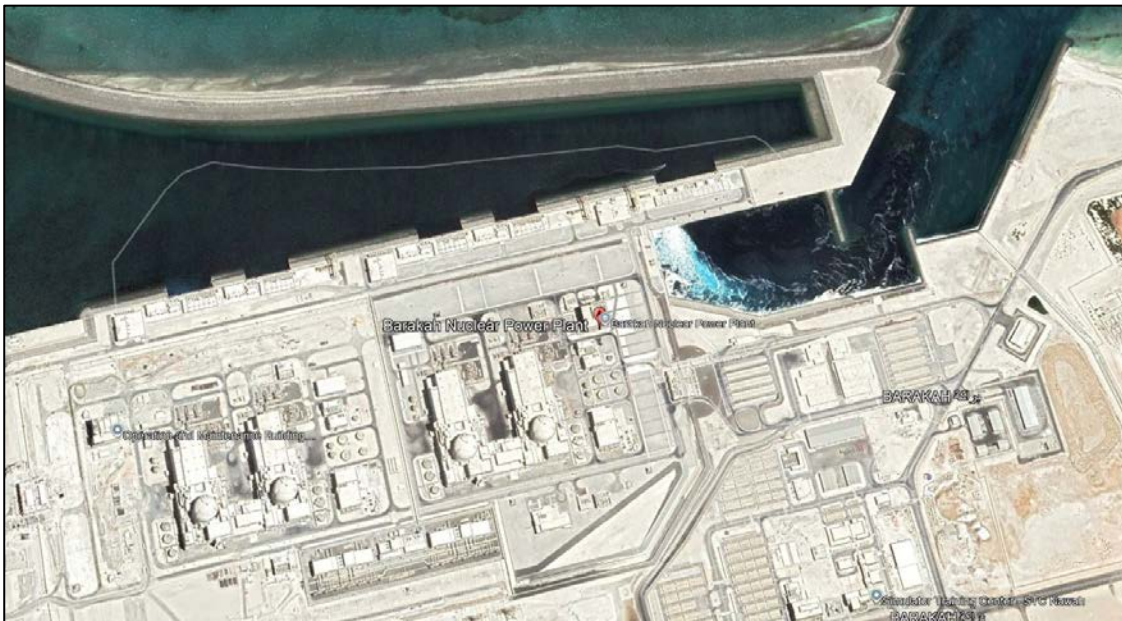
- Lower cost
- Lower pumping costs due to the elimination of frictional drag in tunnel system
- Simplified construction

Direct intake is most suitable and clearly implementable where the power station is sited on a rocky, or at least stable shoreline with deeper water close by. To ensure that excessive recirculation does not occur, either the inlet and outfall are on opposite sides of a geographical feature, like a peninsular, or breakwaters or other devices are needed to keep the inlet and outfall separate. Olkiluoto, shown Figure 5.1 is ideally situated on a rocky peninsular with inlet bottom of picture and outfall top (shared with other smaller stations on same site).



**Figure 5.1 Aerial photo of Olkiluoto**

Figure 5.2 shows the Barakah Power Station, which has deep water close to shore, but is positioned on a relatively featureless shoreline, and large breakwater constructions are required to separate inlet and outfall and have the added benefit of providing wave protection.



**Figure 5.2 Aerial photo of Barakah**

Figure 5.3 shows Taishan NPP which separates the inlet and outfall of the Power Station by use of a significant breakwater on the outfall and by creating a large feeder reservoir inside a culvert which links the reservoir to the sea.



**Figure 5.3 Aerial photo of Taishan**

### 5.1.2 Dredged Channels

Where there is a significant amount of shallow water, or an intertidal zone, and direct intake/outfall is desired, it is necessary to create dredged channels which are likely to have some protection. The protection is required to direct the hotter water into the deeper channels to ensure dispersion and to protect the channel from silting up due to along shore sediment transfer. Figure 5.4 and Figure 5.5 show the Heysham Nuclear Power station in the UK. It can be seen that the inlet is from a deep channel in the entrance to the port but the outlets are via dredged channels protected by rock dumping.

In all of the sites under consideration for this site selection study, there is some intertidal zone and on some of the sites it is rather extensive. Therefore, dredged channels are seen as a necessity for the sites where Direct Intake/outfall is feasible.

Clearly a dredged channel being used as an outfall does not need to be as deep as one being used as an intake. The depth of the outfall is determined by the maximum level of water in the discharge chamber. The depth of water in the intake is determined by the need to maintain an adequate water supply even in extreme low water events, occurring due to a combination of events which may include tidal, surge, seiche and other effects.



Figure 5.4 Aerial photo of Heysham Power Station

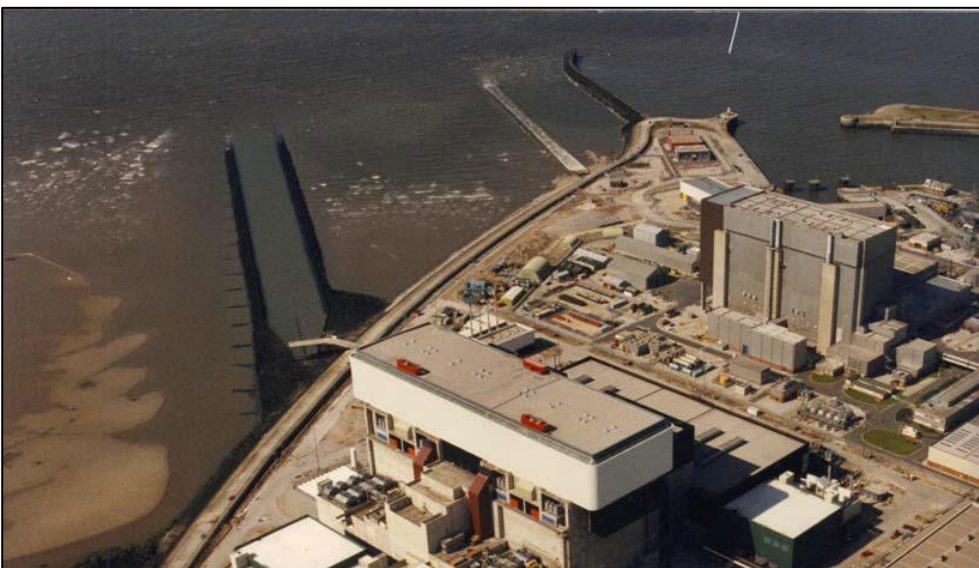


Figure 5.5 Aerial photo of Heysham Power Station (2)

### 5.1.3 Design and Sizing

As noted above, it is likely that for all sites considered within this paper that a dredged channel would be required for the direct intake/outfall and that the intake channels would be deeper than the outfall. Whilst there are a number of ways that this detail could be designed the assumption in this paper is that the dredged channel would come to the seaward side of a sea defence and that a culvert would be constructed through the sea defence directly into either the forebay/pumphouse or into a feeder canal to separate forebay/pumphouses.

Estimates have been made of the size of Intake Culverts and Intake Channel below. These estimates are based on the premise that it is necessary to ensure a supply of water in a 1 in 10,000 yr low water event. This is seen as a conservative position which may be challenged by the technology provider depending on the Employer's Requirements and the Nuclear Safety claims on the Circulating Water System. It should be noted that the sole purpose of this sizing is to allow a basis for visualization, conceptualization of applicable construction methods and to give stakeholders and other relevant outside parties a basis for their opinions and advice. The error band on this sizing is significant.

#### 5.1.3.1 Intake Culverts

This section refers to the sizing of the culverts that pass under the dyke or other sea defence at the entry to the site. They are a relatively short length and so they could be designed for a higher water particle velocity, allowing a smaller penetration through the dyke. We have assumed that the intake culverts need to have sufficient area to have a maximum water particle velocity of 2.5m/s in Normal Conditions. In Extreme Conditions, occurring only a few times per year, the flow could increase to 4.5m/s.

Most Onerous Normal Condition – Mean Low Water Springs at medium flow (159.5 m<sup>3</sup>/s)

Extreme Conditions 1: Lowest Astronomical Tide at high flow (205 m<sup>3</sup>/s)

Extreme Conditions 2: 1:10000yr return water level at low flow (119m<sup>3</sup>/s)

Based on these cases:

The culverts shall be 4m high by a total of 20m wide to achieve the appropriate water flow velocities stated above e.g. 4 culverts 4m total depth and 5 metres wide for a double unit NPP.

The bottom of culverts must be 1.5m below 1 in 10,000 yr return to ensure adequate supply of water in extreme low water events according to the assumptions stated above. As shown in the TFS the 1 in 10,000 yr return varies from site to site, between -4.2m NAP at Eemshaven to -2.8m at Maasvlakte 2 with the result that the level of the bottom of the culverts needs to be between -4.3m NAP and -5.7m NAP.

#### 5.1.3.2 Intake Channels

The intake channels were assumed to be 50m wide, and the bottom of the channels are assumed to be the same level as the bottom of the culverts – 1.5m below the 1 in 10,000 yr return. The channels are wider than the culvert because they are longer than the culvert, engineered to a lower extent and more exposed to the environment. The water velocities should be high enough to maintain a level of self-cleaning but low enough to limit erosion.

To verify this sizing, the water particle velocity in the channel was checked for the mean flow (159.5 m<sup>3</sup>/s) for LAT, MSL and HAT. Water particle velocities were found to be between 0.35 and 1.15 m/s and to be higher than 0.5m/s below roughly half tide, making the channels self-cleaning. An extreme case associated with a low water flow (119.5 m<sup>3</sup>/s) and the 1 in 10,000 yr low water level showed a water velocity of 1.6 m/s, an acceptable speed for this type of location.

By contrast, the outfall would not necessarily need to be of constant depth. The channel could slope downwards at a shallow gradient from the required invert level at the shore provided that the warm outfall water is contained within a channel or between walls or rubble mound breakwater structures until it reaches the desired distance from the shore. Depending on the tidal range and the

topography/bathymetry of each site, this might mean that the breakwaters or training walls to either side of the outfall channel are required to be quite high and/or long as they would need to channel the warm water out to the dispersal point even at high tide. It seems a reasonable assumption that the outfall could be 1m below LAT, varying from -2.0m NAP to -3.7m NAP, and that it may be the same width as the intake, or potentially slightly narrower (e.g. 40m wide).

## 5.1.4 Outline Construction Method Statement

### 5.1.4.1 Intake Structures

Having considered the intake requirements, five basic options have been identified for the construction of the system, these are as follows:

**Option 1** - An open dredged channel approximately 50m wide with a flat base with no protection against erosion or sedimentation designed to provide a minimum maintained depth 1.5m below the 1 in 10 000-year low water level.

**Option 2** - An open dredged channel approximately 50m wide with a flat concrete lined base 1.5m below the 1 in 10 000-year low water level with concrete side walls to offer a degree of protection against sedimentation, as appropriate.

**Option 3** - An open dredged channel approximately 50m wide with a flat base 1.5m below the 1 in 10 000-year low water level with rubble mound (or precast concrete armour unit) structures to either side to protect against sedimentation, as appropriate.

**Option 4** - An enclosed concrete culvert approximately 60m wide, comprising several chambers and constructed in the base of a dredged channel with an invert level 1.5m below the 1 in 10 000-year low water level.

**Option 5** - An enclosed concrete culvert approximately 60m wide, comprising several chambers and constructed in the base of a dredged channel with an invert level designed such that the culvert remains fully submerged at the 1 in 10 000-year low water level.

It should be noted that Options 4 and 5 essentially become cut and cover tunnels. These options are both less exposed to environmental conditions and they disrupt the long shore movement of sediments less than a breakwater. This is a significant environmental advantage but they do still have a large impact during construction due to the dredging and other construction activities.

The merits and drawbacks of each of these options are considered in turn in the Table 5.1.

**Table 5.1 Merits and drawbacks of direct intake construction methods**

Intake Option	Merits	Drawbacks
Option 1	<ul style="list-style-type: none"> <li>• Lowest capital cost relative to other options for each specific site</li> <li>• Dry dock or other concrete casting facility not required</li> <li>• No complex foundations or concrete units required</li> <li>• Potentially good option if foreshore/seabed consists of stiffer or more cohesive material as side slopes can be steeper and ingress of silt is likely to be lower</li> <li>• Lowest width (along with Options 2 and 3) and depth of dredge to achieve intake flow requirements</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Significant maintenance dredging</b> likely to be required in soft sandy or silty materials – <b>make this option inappropriate</b></li> <li>• Increased ingress of sand and silt into forebay area if foreshore is sandy or silty</li> <li>• Channel may need to be deeper than basic requirements to allow for accretion of soft/granular material</li> </ul> <p>Side slopes of dredged channel likely to be very wide/shallow sloping if material is soft or granular leading to higher volume of dredging to form stable channel</p>

	<ul style="list-style-type: none"> <li>Ease of access for maintenance dredging of channel</li> </ul>	
<p><b>Option 2</b></p>	<ul style="list-style-type: none"> <li>Lower capital cost than concrete culvert options for each specific site</li> <li>Side walls to concrete channel provide increased protection from side slope slumping and accretion of soft/granular material in intake channel</li> <li>Lowest width (along with Option 1) and depth of dredge to achieve intake flow requirements</li> <li>Reduced ingress of sand and silt into forebay area in comparison to Option 1, if foreshore is sandy or silty as intake channel protected to a degree by side walls</li> <li>Ease of access for maintenance dredging of channel</li> </ul>	<ul style="list-style-type: none"> <li>Higher level of maintenance dredging likely to be required in soft sandy or silty materials than for Options 3 to 5</li> <li>Logistics of installing precast or insitu concrete base and side walls in c.50m wide underwater channel could be challenging</li> <li>Potential requirement for off-site casting facilities and specialist transportation/heavy lifting vessel</li> <li>Underwater foundations required for concrete channel bed sections</li> <li>Side slopes of dredged channel likely to be very wide/shallow sloping if material is soft or granular</li> <li>Concrete base and side walls unlikely to be necessary if intake is in stiffer or more cohesive soils</li> </ul>
<p><b>Option 3</b></p>	<ul style="list-style-type: none"> <li>Rubble mound walls to either side of concrete channel provide increased protection from side slope slumping and accretion of soft/granular material in intake channel</li> <li>Reduced ingress of sand and silt into forebay area in comparison to Options 1 and 2, if foreshore is sandy or silty as intake channel protected to a degree by side walls</li> <li>Adopts traditional rubble mound construction techniques</li> </ul> <p>Ease of access for maintenance dredging of channel</p>	<ul style="list-style-type: none"> <li>Higher level of maintenance dredging likely to be required in soft sandy or silty materials than for Options 4 and 5</li> <li>Could be costly to construct rubble mounds and concrete if intake channel is long or if seabed material is soft/weak</li> <li>Requirement to import rock armour (or cast concrete armour units) and core material for rubble mound structure</li> <li>Underwater foundations required for rubble mound structures</li> <li>Rubble mound structures to protect intake channel may not be necessary if intake is in stiffer or more cohesive soils</li> </ul>
<p><b>Option 4</b></p>	<ul style="list-style-type: none"> <li>Roofed culvert sections are likely to reduce ingress of soft/granular material into cooling water intake</li> <li>Maintenance dredging will be reduced due to increased protection to covered intake channel</li> <li>Channel will remain fully submerged for the majority of the time with the water level only dropping below the roof of the culvert on extreme low tides</li> <li>Intake culvert will take the form of a cut and cover tunnel adopting tried and tested construction techniques</li> <li>Reduced concern over long term stability of dredged side slopes due to roofed intake culvert</li> </ul>	<ul style="list-style-type: none"> <li>Higher capital cost than open channel options for each specific site</li> <li>Roofed channel will make any maintenance/sediment removal more complex due to restricted access</li> <li>Off-site dry dock facility will be required to cast culvert sections</li> <li>Underwater foundations required for culvert sections</li> </ul> <p>Intake culvert is likely to be wider or deeper than open channel to achieve required inflow rate due to drag caused by additional support walls for roof</p>

<b>Option 5</b>	<ul style="list-style-type: none"> <li>• Lower impact on natural sediment transportation processes</li> </ul>	
	<ul style="list-style-type: none"> <li>• Roofed culvert sections are likely to reduce ingress of soft/granular material into cooling water intake</li> <li>• Maintenance dredging will be reduced due to increased protection to covered intake channel</li> <li>• Channel will remain fully submerged even during extreme low tides</li> <li>• Intake culvert will take the form of a cut and cover tunnel adopting tried and tested construction techniques</li> <li>• Reduced concern over long term stability of dredged side slopes due to roofed intake culvert</li> <li>• Intake culvert is likely to be smaller than other options to achieve required inflow rate due to deeper depth and permanent submersion</li> <li>• No impact on sediment transportation processes</li> </ul>	<ul style="list-style-type: none"> <li>• Higher capital cost than open channel options for each specific site</li> <li>• Deeper initial excavation/dredge than Option 4 as culvert sections will be positioned slightly deeper to remain submerged at extreme low water levels</li> <li>• Roofed channel will make any maintenance/sediment removal more complex due to restricted access</li> <li>• Off-site dry dock facility will be required to cast culvert sections</li> <li>• Underwater foundations required for culvert sections</li> </ul>

In summary, in the areas where the foreshore and seabed at many of the proposed intake channel locations consist of soft silty or granular material along the required length and depth of the dredged channel, then the side slopes are likely to require to be shallow and wide to remain stable. Notwithstanding this, it is likely that there would still be a requirement for regular maintenance dredging to the point where the rate of siltation of the intake channel or the ingress of silt into the forebay proves to be unacceptably high.

It is noted that the intake and outfall structures will require to be designed to remain operational in a 1 in 10,000-year seismic event. At this stage the magnitude of such an event on the coast of the Netherlands is unclear but recognising that the Netherlands is in a zone of low to moderate seismic activity, it is envisaged that peak design accelerations will be relatively low. Notwithstanding this, the design of the intake and outfall structures would need to recognise this, taking into account the risk of liquefaction of the subsoils. Rubble mound structures and joints in concrete channel sections or culverts would be designed for the relevant seismic loading, and the structure remaining would need to be sufficient to preserve water supply commensurate with the shutdown requirements of the NPP.

A further consideration for any intake structure is its proximity to existing dykes. In Eemshaven 1A and B Options 1 and 2, the intake and outfall are currently shown running parallel to the edge of a dyke. Given that the intake would likely be dredged to a reasonable depth – requiring shallow (wide) side slopes – a dredged channel at this location would need to be set back from the base of the dyke to avoid undermining this critical land protection structure. A similar but potentially more controllable situation occurs at Terneuzen and Borssele where canals may be required to transport water along the shore for discharge.

All options have been costed on the basis of Option 3. However there is advantage on a number of sites in adopting Option 5. Preliminary calculations indicate a cost increase varying between 5 and 25%. 5% is applicable to short channels in areas where there is high complexity and cost in penetrating the sea defence. 25% is applicable to sites where the channel is very long and therefore that is the majority of the cost.

#### 5.1.4.2 Direct Outfall Channel

Recognising that the outfall requirements are perhaps less demanding than those of the intake, it is considered that the most practical solution is likely to be a dredged channel with rubble mound arms or walls along the side made of rock armour and possibly reinforced with piles to either side to channel the warm, outfall water to an appropriate distance offshore. It is noted that the rubble mound arms or walls will need to be of sufficient height to channel the outfall water sufficiently far offshore at all states of tide without being overtopped at high tide.

Designing the outfall channel on a gradient similar to that of the surrounding foreshore would have the effect of limiting the width of the side slopes. As with intake Option 3, above, the design of any of rubble mound structures would be dependent on a number of factors including the nature of the seabed material, tidal range, currents and wave characteristics. Naturally, shorter rubble mound arms would be expected to require less material to construct than longer structures built in similar physical conditions and therefore would typically incur lower capital cost.

#### 4.4.4.3 Intake/Outfall from NPP

The Intake/Outfall is required to penetrate through the sea defence in some manner. Obviously this requires mechanism for construction of the breach of the sea defence whilst maintaining the sea defence capability. This is a common issue for coastal civils work and is commonly solved by constructing a temporary flood defence inside or outside of the existing dyke during the works. A potential sequence is shown in Figure 5.6.

Along the coast there is a continuous Dyke which has been constructed to specifically provide sea defence to the land within, much of which would flood very regularly (sometimes on every high tide) without such protection. The RWS is the governing body for this Dyke. On a number of sites under consideration this primary Dyke is also the sea defence for the site and works on the Dyke would be under the governance of the RWS.

In early stakeholder management the RWS has indicated that any work on the Dyke would be subject to significant constraints and that they would require full rights of inspection and access throughout the works. It may be most expedient to make a small diversion of the Dyke inshore which is close to the permanent works and incorporated into the permanent works design. This diversion of the Dyke would include any culvert to allow entry of the water to the plant via the forebay, and could be constructed in dry conditions. Once the works were fully approved the diverted Dyke could be adopted by the RWS and a breach made in the original Dyke.

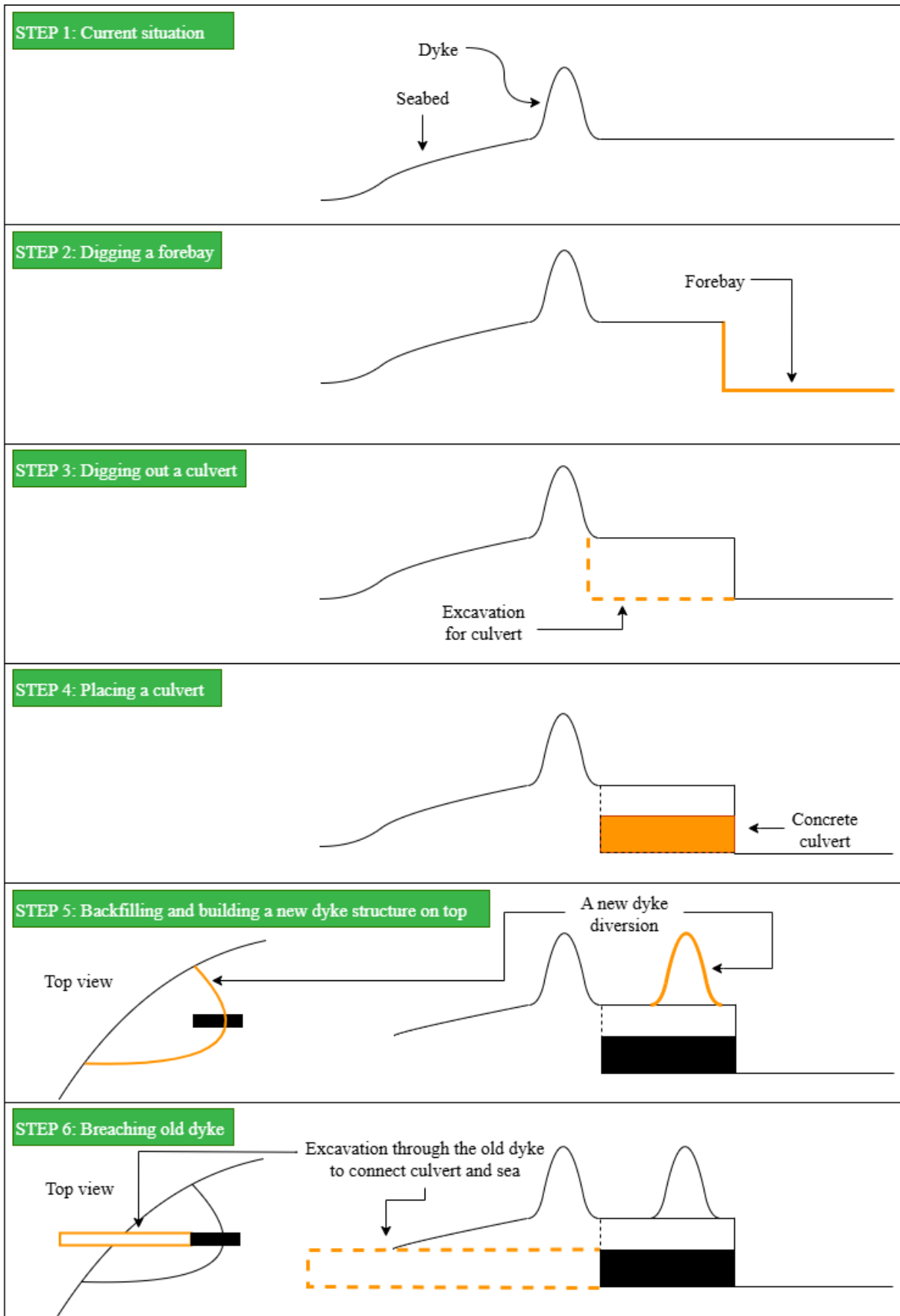


Figure 5.6 Possible Construction Sequence for Culvert

## 5.2 Double Submerged

Double submerged systems refers to a tunnel solution in which both the inshore and offshore end of the system are submerged. The inshore end of the Intake tunnel is typically in the forebay starting from either a horizontal drive or from a shaft in the bottom of the forebay, depending on the seabed geometry. The Outfall is likely to start from a shaft as the discharge chamber is not as deep as the forebay.

At the seaward end of the tunnels, the tunnel will be some distance below the seabed, and the connection between the tunnel and seabed is normally via a vertical shaft capped by an offshore “Head”. Water flows through the Head, down the shaft and into the tunnel for the intake (and the reverse for the outfall). However, the actual water intake and outfall is normally through a head structure, most likely constructed of reinforced concrete.

The design of the heads is dictated by the required water flow characteristics. For Intake structures a key driver of the design is fish welfare, and water velocities into the Head of more than 0.3 m/s are generally considered unacceptable. All sites considered have tidal flows >0.3m/s and therefore will require Low Velocity Side Entry (LVSE) Heads, which are long rectangular Heads with the water intake on the sides. By aligning the rectangles with the water velocity into the Head is limited even in high tidal current environments.

The outfall geometry is governed by the thermal effects created by the warm outflowing water and may be a “diffuser” or “directed flow” design. The selection will depend on the thermal modelling in detailed design stage.

The LVSE Heads are significantly larger than other Head types, including both types of outfall Heads, and they are therefore a larger obstruction to shipping.

### 5.2.1 TBM

The most common method of constructing tunnels is using a Tunnel Boring Machine (TBM) and this has been considered as the “first choice” in this study.

There are generally three types of TBM available on the market suitable to undertake boring of the Cooling Water System tunnels in water bearing soils. Each of these machines has been briefly discussed in the following sections with a summary providing a comparison of each technology.

### 5.2.2 Earth Pressure Balance TBM

This technology is most suited to soft and cohesive soils containing no water or water under limited pressure of up to 3-4 bars. Machines are readily available for tunnel diameters from 2.0m ID to 16m ID.

An Earth Pressure Balance (EPB) TBM turns the excavated soil into a soil paste that serves as a support medium for the excavation face during the advance of the TBM. It is based on the principle of maintaining the suitable pressure (equal to the support pressure required to maintain a stable excavation face as the tunnel advances) inside the cutterhead chamber in order to avoid water under pressure and ground flowing into the tunnel.

The screw conveyor carries the muck from the excavation (plenum) chamber to the conveyor belt and is used to match the spoil removal volume with TBM advance to maintain the face support pressure.

The excavated material from an EPB machine is transported from the tunnel either using continuous conveyor systems or specialist rail mounted or tyred transport methods. Once out of the tunnel the excavated material may need some conditioning before being disposed of either on site or offsite and for beneficial use where possible.

A summary of the properties of an EPB machine is included shown in Table 5.2 and a representation is shown in Figure 5.7.

Table 5.2 Properties of EPB

<b>Ground Conditions Best Suited For:</b>	<ul style="list-style-type: none"> <li>• Best for <b>soft cohesive soils</b> with <b>limited water pressure</b> (i.e. 2 bar).</li> <li>• Can be used at <b>higher pressures</b> if soil <b>permeability is low</b>.</li> <li>• Simplest set-up and muck processing</li> </ul>
<b>Tunnel Diameter Range:</b>	<ul style="list-style-type: none"> <li>• Suitable for diameters from <b>2.0 to 16 m ID</b>.</li> </ul>
<b>Excavation &amp; Support Mechanism:</b>	<ul style="list-style-type: none"> <li>• Converts excavated soil into a <b>soil paste</b> that serves as a support medium for the advance of the TBM.</li> <li>• Maintains <b>pressure in cutterhead chamber</b> to prevent water ingress.</li> </ul>
<b>Spoil Removal:</b>	<ul style="list-style-type: none"> <li>• <b>Screw conveyor</b> removes spoil at a rate matched to TBM advance.</li> <li>• Ensures <b>consistent support pressure</b> during excavation.</li> </ul>
<b>Adaptability:</b>	<ul style="list-style-type: none"> <li>• Use of <b>foams and polymers</b> at the face broadens applicable ground conditions.</li> </ul>

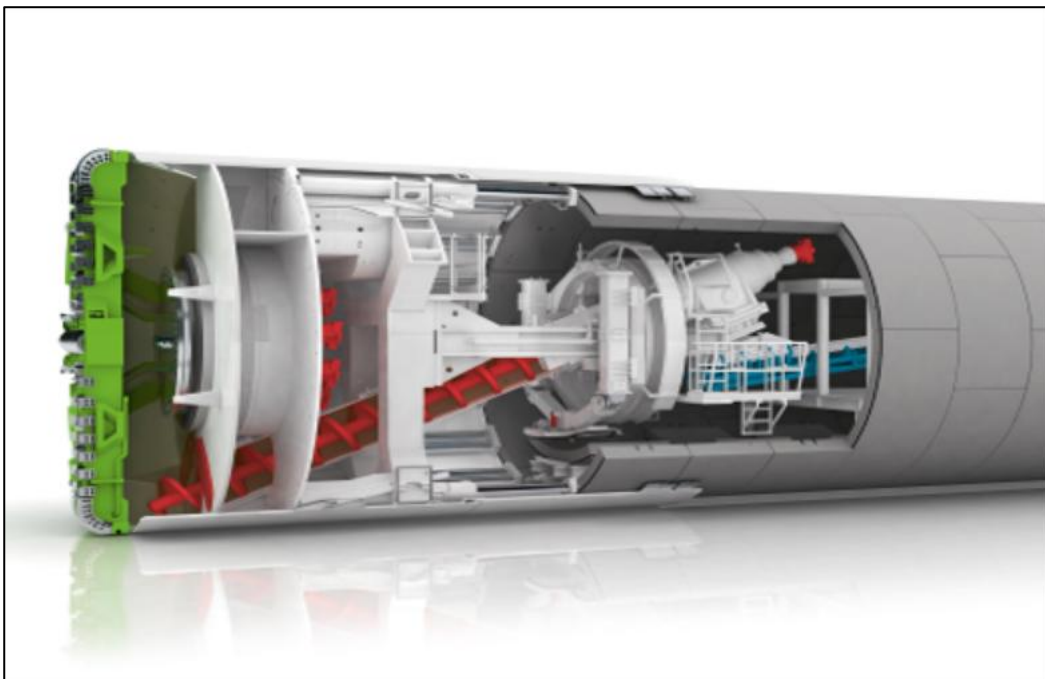


Figure 5.7 EPB TBM

### 5.2.3 Slurry Pressure Balance TBM

This technology is most suited to use in sands and gravels (non-cohesive soils) and in highly permeable unstable soils. Slurry TBM's are available in diameters from 4.5m ID to 19m ID and capable of managing water pressure of 4-5 bar or higher.

The pressure exerted by the ground and groundwater is directly governed by the depth at which digging is performed. It is therefore necessary to balance the pressure exerted by the ground and groundwater. In a Slurry Pressure Balance (SPB) TBM the front plenum chamber is filled with excavated material and bentonite slurry. The slurry is introduced to the excavation chamber by pipework and the muck out is also carried out by pipework. The support pressure in a SPB TBM can be controlled by the rate of

pumping in and out of the chamber and in mix shield the use of a pressurised air bubble behind the front bulkhead. The use of an air bubble allows control of the face pressure to 0.1 bar increments giving a high degree of control to the support pressure.

To deal with boulders, the slurry TBM can be equipped with a jaw crusher which is positioned in front of the intake screen. Special equipment (drum crushers) can also be installed on the TBM to deal with cobbles and boulders when expected along the alignment.

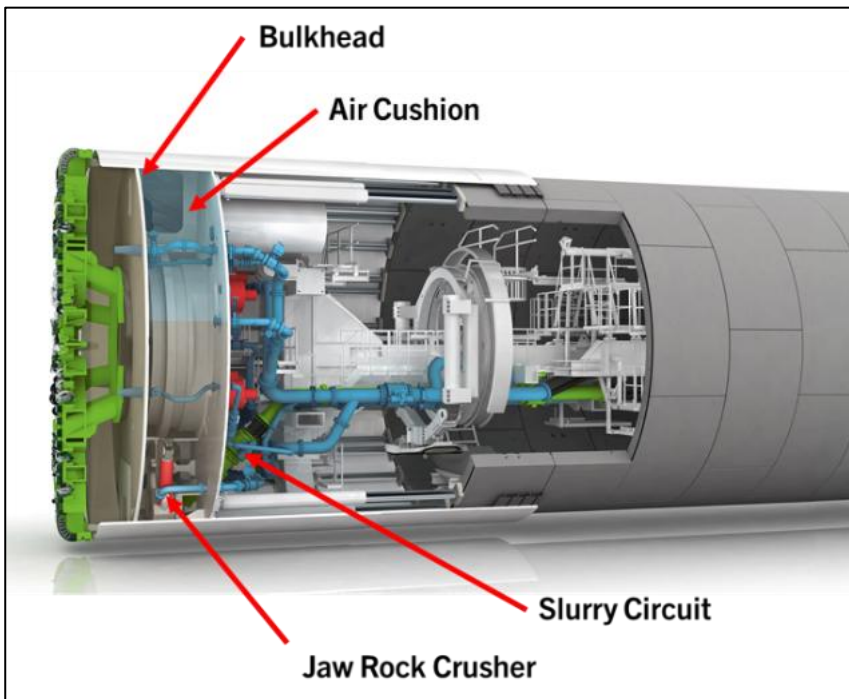
The excavated mix (bentonite + excavated material) is then subjected to separation to make the bentonite slurry ready for reuse. It has to be noted that complexity and rate of the separation operation is to a large extent governed by the content of fine particle within the ground. If the content of fines is over 20% the separation is no longer economically feasible, and the excavated slurry mix becomes a waste.

This technology requires a slurry treatment plant which has to be accommodated on the construction site to treat the excavated slurry mix, separating the spoil and cleaning, and reconditioning the slurry which is then recirculated to the tunnel face. The slurry treatment plant would be approximately 2500 m<sup>2</sup> for 7-10m tunnels but varies with expected TBM advance rates and complexity of the soils.

The properties of a Slurry machine are summarised in Table 5.3 and there is a representation shown in Figure 5.8.

**Table 5.3 Slurry TBM properties**

<b>Ground Conditions Best Suited For:</b>	<ul style="list-style-type: none"> <li>• Tunnels in <b>non-cohesive soils</b> like gravels and sands.</li> <li>• <b>Highly permeable, unstable soils with high water pressure</b></li> </ul>
<b>Tunnel Diameter Range:</b>	<ul style="list-style-type: none"> <li>• Suitable for diameters from <b>4.5 to 19 m ID</b>.</li> </ul>
<b>Excavation Process:</b>	<ul style="list-style-type: none"> <li>• <b>Bentonite slurry</b> is injected into the excavation chamber and provide support pressure.</li> <li>• Slurry mixes with soil to enable <b>pumping out</b> via a piping system.</li> </ul>
<b>Material Separation:</b>	<ul style="list-style-type: none"> <li>• Excavated mix (bentonite + soil) undergoes <b>separation</b> to clean and <b>reuse bentonite</b>.</li> <li>• <b>Critical Limitation:</b> If <b>fine particles exceed 20%</b>, separation is not feasible — the excavated mix becomes <b>waste</b>.</li> <li>• <b>Slurry processing plant required</b>, larger footprint than EPB system only.</li> </ul>



**Figure 5.8 Representation of a Slurry TBM**

#### 5.2.4 Variable Density TBM

This is a relatively new technology combining features of both SPB and EPB technologies and is most suited to highly varying geological and hydrogeological conditions. It can manage tunnel diameters from 2.4m ID to 19m ID. Key features are shown in Table 5.4 and Figure 5.9.

The Variable Density (VD) TBM combines the advantages of both methods – EPB and SPB - in one machine. Without major mechanical modifications, the machine can switch between different tunnelling modes directly in the tunnel. This means that geological and hydrogeological changes along the alignment can be managed with greater flexibility enhancing the range of operation of the TBM.

The excavated material is removed from the pressurized excavation chamber through a screw conveyor both in the earth pressure and in the slurry mode. Depending on the mode used, the support pressure is controlled via the screw conveyor speed and advance rate or when using slurry, it is automatically controlled by an air bubble at pressure behind the front bulkhead. The front bulkhead opening is replaced by communicating pipes. An additional slurryfier box at the end of the screw conveyor makes it possible to operate the TBM with a hydraulic slurry circuit in slurry mode. In the latter case, either a normal bentonite suspension or a high-density suspension can be used to support the face as it can be later treated in the slurryfier box to suitable density parameters which will allow pumping. A jaw crusher is provided to deal with boulders, which are transported via the screw conveyor and is located in the slurryfier box. This solution allows for jaw crusher maintenance under atmospheric pressure and does not require intervention to the excavation chamber under compressed air conditions.

This technology uses pipework to pump the slurry and excavated material out of the tunnel to a slurry treatment plant to treat the excavated spoil in a similar way to a Slurry TBM.

**Table 5.4 Variable Density TBM summary**

<b>Machine Type:</b>	<ul style="list-style-type: none"> <li>• Combines <b>EPB (Earth Pressure Balance) and slurry-supported modes</b> — the <b>most complex form of convertible TBM</b>.</li> <li>• New technology maximise ground condition range.</li> </ul>
<b>Excavation Material Removal:</b>	<ul style="list-style-type: none"> <li>• EPB Mode Cohesive Material is extracted from the <b>pressurised excavation chamber</b> via a screw conveyor into slurry circuit or conveyor.</li> <li>• Slurry mode Cohesionless/cohesive Material uses pipework much transport</li> </ul>
<b>Slurry Mode Conversion:</b>	<ul style="list-style-type: none"> <li>• A <b>slurryfier box</b> at the end of the screw conveyor enables <b>operation in hydraulic slurry mode</b>.</li> </ul>
<b>Muck treatment:</b>	<ul style="list-style-type: none"> <li>• Slurry processing plant required, large footprint than EPB system only.</li> </ul>

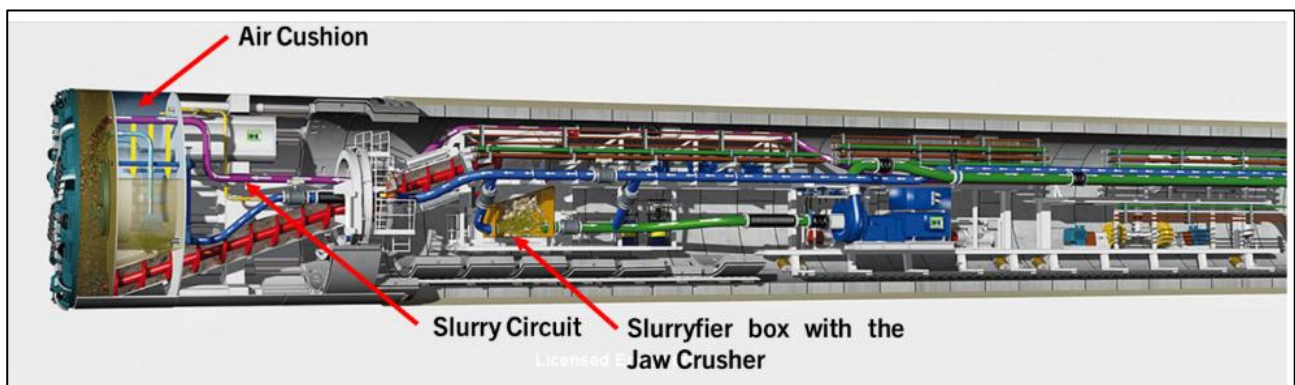


Figure 5.9 Representation of a Variable Density TBM

### 5.2.5 Comparison Earth Pressure Balance, Slurry Pressure Balance and Variable Density TBM

The choice of the TBM is critical for the successful completion of the tunnelling operations. TBM choice and specifications has to be based on complete and comprehensive geotechnical investigations which are performed to establish ground and hydraulic parameters required for the machine design. Incorrectly specified machines, based on incomplete or limited GI data can result in significant construction delays, contractor claims, significant rise in costs and in extreme situations inability to complete the tunnel without major remedial measures. Additionally, it is critical to select specialist tunnelling contractors who have the experience to select, specify and operate the TBM technology to manage the project risks.

For the purpose of this study, a preliminary review of the available information has been made, particularly the particle size distribution, and selection has been based on this information only to allow the relevant comparisons of cost and constructability to be made. Significant further study is required in later stages.

It should be noted that both bentonite used widely with Slurry machines and the conditioners and foams used with EPB machines are used subject to permit which comes with conditions and the maximum volumes permitted for use normally stipulated. Care must be taken to prevent these chemicals getting into the water, particularly in sensitive areas such as the Waddensee.

## 5.2.6 Submerged Tube / Trench and Cover

As discussed in the section on Direct Intake/Outfall there is a possibility to construct tunnels by dredging, inserting a culvert using a Shearleg or Heavy Lift Vessel as illustrated in Figure 5.10 and Figure 5.11 below. In reality this is a hybrid method owing as much to marine construction as traditional tunnelling methods.

It has the advantage that it will normally be cheaper than a traditional tunnel, particularly for shorter tunnels where the bespoke manufacturing of a TBM and the relatively high setup costs are only offset by a relatively short tunnel. However, there are disadvantages compared to a TBM:

- The trench has a significant environmental impact and may be particularly difficult to get Permits for through inter-tidal zones in protected areas. All sites are in either UNESCO World Heritage Areas or Natura 2000 areas.
- Cohesive soils are required to allow reasonably steep trench side-slopes. In a related point, in longer tunnels, where sandbanks have to be crossed, maintaining the depth of the tunnel may result in excessive trench depths and widths.
- Where there is railway or critical sea defence, enabling works and diversions may be required, (as in the case of direct intake).

The scoring has been based on the construction of TBM tunnels for double submerged systems. Where trench and cover tunnels could be adopted there may be an opportunity to reduce costs but this has been seen as an opportunity and has not been incorporated into the scoring.

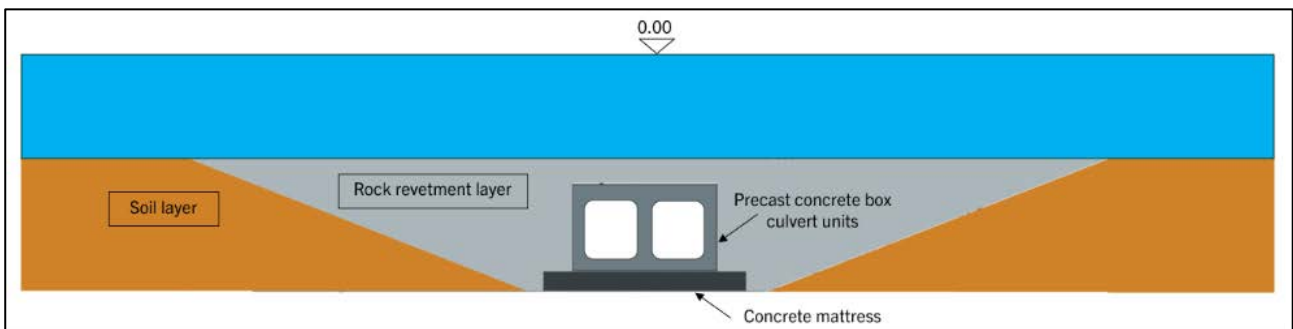
## 5.2.7 Factors in determining the applicability of trenching

In locations that require a tunnel solution for reasons of thermal compliance, construction of a trench and cover culvert construction may be adopted as a cost saving opportunity. The risk factors entailed in this choice are similar to the factors in determining whether a Direct Intake/Outfall would be applicable.

- Marine conservation protected zones – trench and cover is inherently more environmentally damaging than a TBM tunnel which has relatively low impact. Permitting may be difficult or impossible for a trenched solution in the UNESCO World Heritage Site, or in Natura 2000 sites.
- National Sea Defence – A trench and cover tunnel would entail construction of a culvert through the national dyke.
- Harbour and transport infrastructure – In some locations the trench would be required to cross a railway or other logistics infrastructure
- Marine infrastructure – Marine cables are the most common and important form of infrastructure. Crossings may be engineered but they are costly and not risk free
- Unexploded Ordnance (UXO) – In the case where a significant trench is envisaged the issue of UXO becomes more severe due to the widened volume required to be clear



**Figure 5.10 Construction of a tunnel by trench and cover**



**Figure 5.11 Cross-section through a trench and cover tunnel**

### 5.2.8 Sizing Calculations

A larger Intake tunnel diameter is desirable because, by lowering the water particle velocity it minimises frictional losses and hence lowers pumping costs, minimises forebay depth and minimises undesirable transient dynamics in the CWS circuit. However, in practice water particle velocities need to be high enough to ensure that the tunnels are self-cleaning for sediments. In contrast the outfall tunnel is able to have larger flow velocities, which are limited by negative impacts on concrete lining.

Two 7.0m Intake tunnels in each location have been considered, based on the volume flow rates described in Section 3.4. This results in water velocity at 119.5m<sup>3</sup>/s (lowest flow) of 1.55m/s and water velocity at 205 m<sup>3</sup>/s (highest flow) of 2.66m/s.

A single 8.6 m Outfall tunnel is considered which results in water velocity at 119.5m<sup>3</sup>/s (lowest flow) of 2.06m/s and water velocity at 205 m<sup>3</sup>/s (highest flow) of 3.53m/s.

Whilst further refinement is clearly required in design stages, these sizes align well with sizes observed in existing, in-construction and in-design power plants and are deemed to give a good basis for comparison.

## 6. Scoring methodology

The different options have been scored based on the information in the references listed in Section 2 utilising subject matter expert interpretation and judgement. Further details of the methodology are given below. The objective is to determine the favoured CWS option for each site and further to give a basis for comparing the sites with each other.

### 6.1 Tunnel Evaluation and Scoring

The first pass on scoring considered the tunnelling aspects of each option. As a starting point, different aspects of TBM tunnel construction were considered, generating a balanced scorecard, considered further below. Once the TBM tunnel was assessed further consideration was made regarding whether there might be cost optimization possible by adopting a trench and cover technique. This part of the process highlighted risk factors weighed against the optimization.

### 6.2 Scoring of Tunnels for TBM Construction

The tunnels were scored on the following criteria:

- **Constructability** was judged on three sub-factors
  - Ground conditions – suitability of the actual material being tunneled through, with homogeneous stiff clay with low permeability being the best and mixed soft strata with high fines content and high permeability being the worst
  - Interventions – how difficult will be to carry out TBM head interventions, with low water pressure (<3 bar) and low permeability being worst and high-water pressure (>5bar) and high permeability being worst
  - Offshore connections - ease of connecting the tunnel to the shaft offshore, with low ground improvement conditions being best and local conditions that require special enhanced methods of ground improvement being the worst
- **Logistics** had two sub criteria
  - Work Site Availability – Big sites with lots of space are best, with cramped sites with little access worst
  - Supply Chain Logistics – Sites with the capability to receive large loads, typically through port infrastructure are preferred and sites where receiving AILS and other large loads is difficult are worse.
- **Tunnelling Hazards** – Greenfield sites with the expectation of being clear of any foundation structures, pipelines, cables or outfalls are best while brownfield sites that may have been developed over several generations and where existing infrastructure may not be fully mapped are worst
- **Environmental Impact** was judged on the factors below:
  - Type of excavated material – Homogenous clay requires no treatment during mining, whereas mixed material with high silt content needs additional treatment
  - Reusability - >90% material available for use would be the best expectation and no material available for re-use the worst-case scenario

The full tunnel scoring criteria are shown in Appendix A

### 6.3 Scoring of overall schemes

The overall schemes were a combination of tunnels and direct intake/outfall. The overall scoring therefore took input from the tunnel scoring and combined it with the considerations in designing and constructing the entire scheme. In doing this process it was acknowledged that Direct Intake and Outfall

tend to be inherently cheaper and more easily constructed on a like for like basis than a solution that includes tunnels.

The scoring considered the following factors:

- **Cost** – A class 5 estimate was made of all of the proposed schemes. This was based on a measure of the key dimensions of the proposed schemes with unit rates applied which have been derived from other similar jobs. For example the key parameters for the tunnels are diameter and length, while the direct intake require length of the dredged channel and dimensions of the channel. Corrections were made as a factor or a lump sum as appropriate where constructability issues are anticipated (e.g. railways, national dyke etc). For the scoring matrix the bands were set as 0-0.5B euro, 0.5-1.0B euro, 1.0-1.50B euro, 1.5-2.00B euro, >2.00B euro. This is different to the categories requested for Risk, and this difference is in order to make the cost work in the scoring matrix.
- **Constructability** – The constructability of both the tunnels and direct intake/outfall aspects of the schemes are considered. The tunnel scoring for constructability is described above. The constructability of the direct intake schemes are related to the extent of the schemes and the marine environment in which they are being constructed.
- **Cooling water environmental** – There are RWS guidelines which are summarized in section 3.3, and this score is based on the level of compliance with these guidelines, with 1 indicating a major non-compliance, 5 indicating complete and unambiguous compliance that has been demonstrated by modelling and the scores between the two indicate minor and potentially defensible non-compliance, or a risk of non-compliance because the option has not been modelled.
- **Cooling Water Temperature** - This refers to the level of recirculation expected. Although the technology vendors have declined to give guidance on this aspect of the thermal performance of the cooling water system, it is noted that this will directly raise the intake and outfall temperatures and will at some level have an impact on the operation of the plant. We have considered that <2C is normal and therefore low scoring and >5C highly negative and high scoring.
- **Other Environmental** – This score is based on the impact of the construction on the environment. In general the impact of TBM constructed tunnels are lower on the environment and the impact of a direct intake may be higher. The impact of direct intake is most important in the coastal and intertidal areas in protected areas (UNESCO world heritage area and Natura 2000) where there tend to be more sensitive flora and fauna. It is possible to construct direct intakes as covered culverts rather than dredged channels and this may mitigate concerns on morphology and sediment transfer.
- **Ship Impact** – Where tunnels are considered as part of the solution it is necessary to consider the location of the subsea “heads”, with a low score indicating that the heads are located in, or close to, a shipping lane and a high score indicating that they are well outside of any shipping lanes and in an area deemed to be low shipping density
- **UXO Risk** – based on preliminary searches of public domain sources the level of potential UXO has been evaluated as high, medium or low risk
- **Local amenities** – This refers to the impact on local leisure and business stakeholders. The most common are fishermen, beach users and watersports enthusiasts. This is measured on a scale from “No impact, temporary or permanent” to “Major permanent impact

The tabulation of the Overall Criteria is shown in Appendix B.

## 6.4 Weighting of Overall Schemes

The objective of scoring the different criteria is to place a quantitative measure on a qualitative opinion and to thereby give the reader further information to supplement the narrative which in turn allows them

to make a more informed opinion on the relative merits of the sites. The reader is discouraged from simply deciding the preference based on the overall scores presented but encouraged to use the scores to highlight issues and to consider how they balance in their own mind.

However, it is acknowledged that the different factors are difficult to balance against each other and in order to aid the reader in this process, a weighting scheme has been devised (shown in Table 6.1) in order to help making this judgement. This scheme seeks to allocate different levels of importance to the different scoring criteria.

In the base weighting cost and constructability are weighted highest with environmental and stakeholder concerns next and the operational water temperature, UXOs and the risk of ship impacts lowest.

An alternative weighting mechanism was also formulated, giving a heightened prominence to environmental scores and significantly less to construction, and this is used as sensitivity. Where large deviations in the preferred option between the different scoring schemes is observed the reasons should be investigated and implications considered.

Further, where an option scores 1 or 2 on any particular scoring criteria, it should be considered whether this could constitute a “red flag” and further work to investigate should be considered.

**Table 6.1 Weightings used in the ranking of the sites**

Scoring Criteria	Base Weighting %	Alternative Weighting (sensitivity) %
Cost	25	20
Constructability (Overall)	20	8
Cooling Water Environmental	15	20
Cooling Water Temperature	5	8
Other Environmental	15	20
Ship Impact	5	8
UXO risk	5	8
Impact local stakeholders	10	8

## 7. Eemshaven

### 7.1 Summary of Cooling Water Modelling

The Eemshaven sites lie on the boundary between a coastal and estuarine regime, such that Eemshaven 1A and 1B are designated as Coastal and Eemshaven 2 and 3 are designated as Estuarine.

Eight configurations (shown in Figure 7.1) were modelled by Deltares in Reference 14 ,covering 4 proposed sites.

- Configurations 4,6, and 7 are applicable to sites 1A and 1B
- Configurations 1,3 and 8 are applicable to site 2 but also inform on site 3
- Configurations 2 and 6 are applicable to site 3 but also in inform on site 2

The results are summarised in Table 7.1 and have been marked up in a Red/Amber/Green designation as follows:

- All configurations considered Estuarine (1,2,3,5,8) pass RWS guidance for Maximum Permissible Mixing Zone (MPMZ), partly due to the width of the Eems at this point. Configuration 2 has high recirculation. => Green
- Configuration 4 is mixing zone is not acceptable as the MPMZ is in contact with the seabed for a significant area. => Red
- Configurations 6 and 7 mixing zones are potentially acceptable, as the MPMZ touches the seabed only locally – further checks required. => Amber
- Configurations 5 and 8 are acceptable with regards to the MPMZ, but the recirculation is moderately high which is not desirable. =>Amber
- Intakes and Outfalls to and from the dock system are not to be considered. => Red

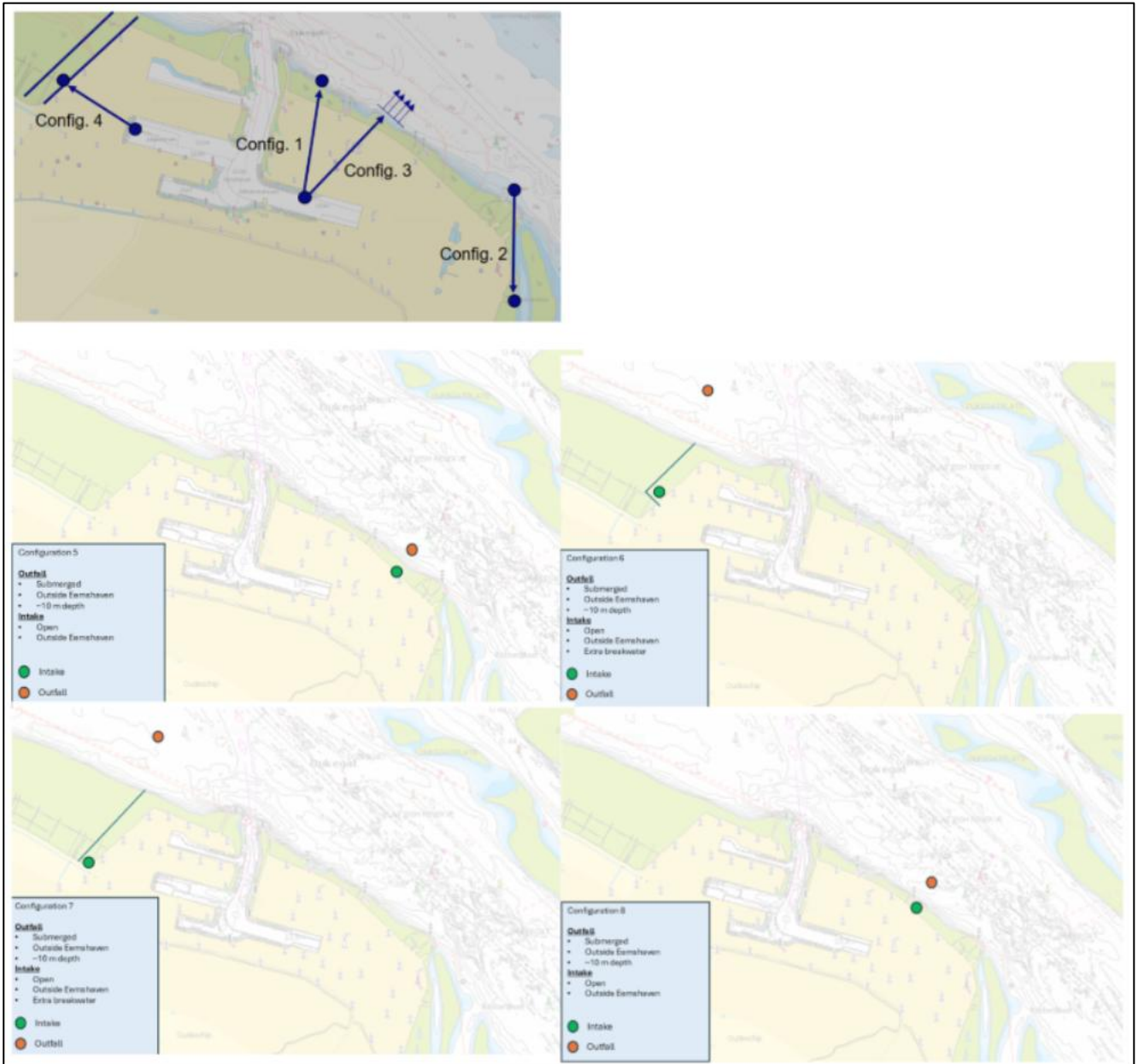


Figure 7.1 Configurations modelled for Eemshaven

Table 7.1 Summary of results of thermal modelling

		Intake	Outfall	Mixing zone %	Mixing zone seabed *	Temp. [°C]	Recirculation Max/mean
Configuration 1	Estuarine	Direct dock	Direct sea	11	N/A	1.6	1.6/1.3
Configuration 2	Estuarine	Direct sea	Direct sea	12	N/A	1.8	5.4/2.4
Configuration 3	Estuarine	Direct dock	Tunnel sea	11	N/A	1.5	1.6/1.4
Configuration 4	Coastal	Direct dock	Direct dredge	N/A	Y	1	1.7/1.5
Configuration 5	Estuarine	Direct sea	Tunnel sea	9	N/A	1.7	4.1/1.7
Configuration 6	Coastal	Direct dredge	Tunnel sea	N/A	Local	1.1	1.4/1.1
Configuration 7	Coastal	Direct dredge	Tunnel sea	N/A	Local	1.1	1.4/1.1
Configuration 8	Estuarine	Direct sea	Tunnel sea	9	N/A	1.7	4.1/1.6

\* In coastal waters

## 7.2 Eemshaven 1A

### 7.2.1 Options Considered

At Eemshaven 1A it is not practical to have a direct outfall and intake as the geometry is unlikely it is not practical to have two channels across the extensive intertidal zone. Therefore, the options are confined to either a direct outfall with tunnel intake, direct intake with tunnel outfall or an all tunnel solution. In this case two different geometries of all-tunnel solution are possible, making 4 options in total.

#### 7.2.1.1 Option 1

This option entails an outfall tunnel and direct intake as shown in Figure 7.2, with dimensions shown in Table 7.2.

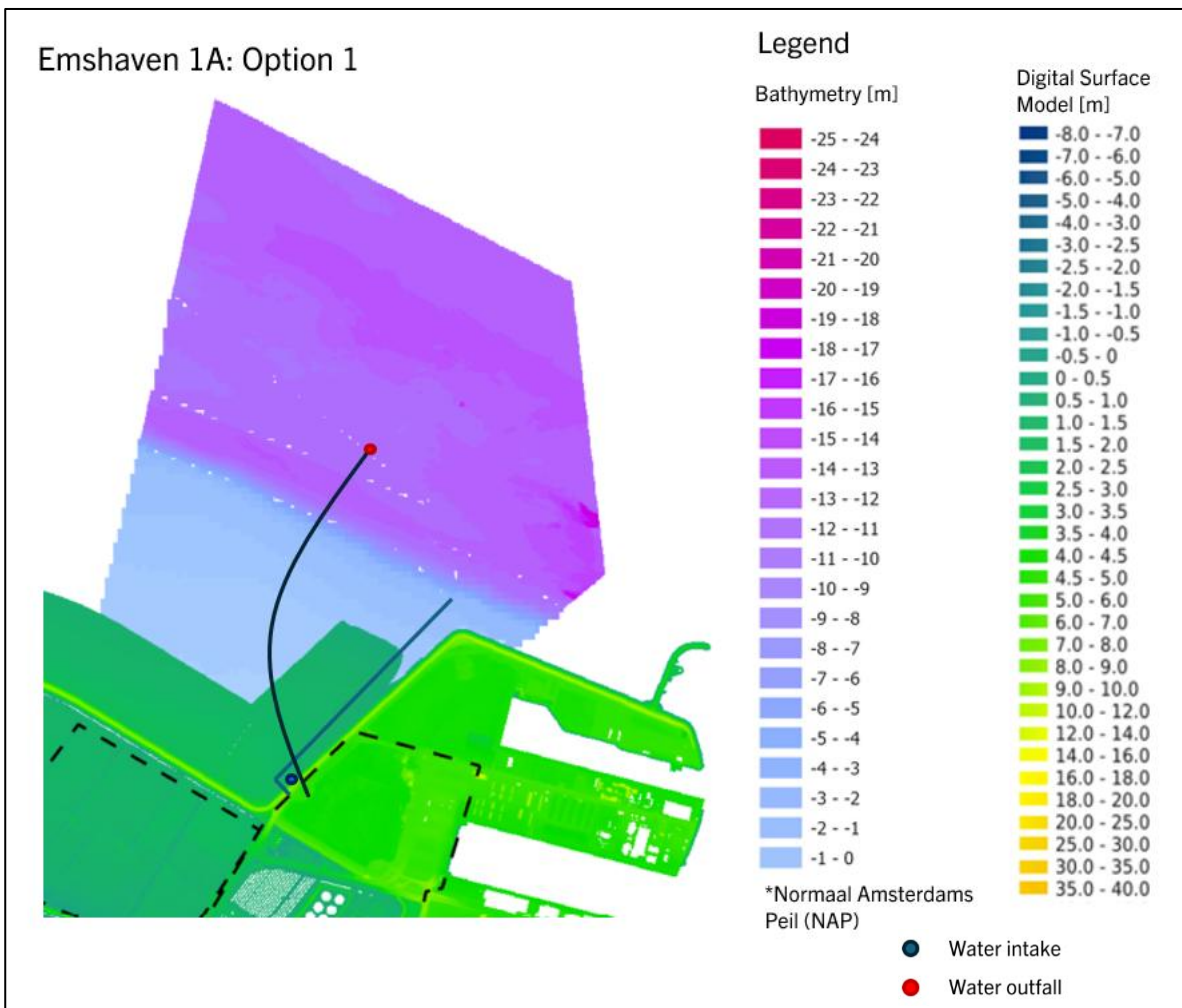


Figure 7.2 Eemshaven 1A - Option 1

Table 7.2 Dimensions - Eemshaven 1A Option 1

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Tunnel (out)	~ 3 300	~ - 11.8	1 528 714	1 528 714
Dredged channel	~ 2 600	-	-	

\*Normaal Amsterdams Peil (NAP)

7.2.1.2 Option 2

This option entails two intake tunnels and direct outfall as shown in Figure 7.3, with dimensions shown in Table 7.3.

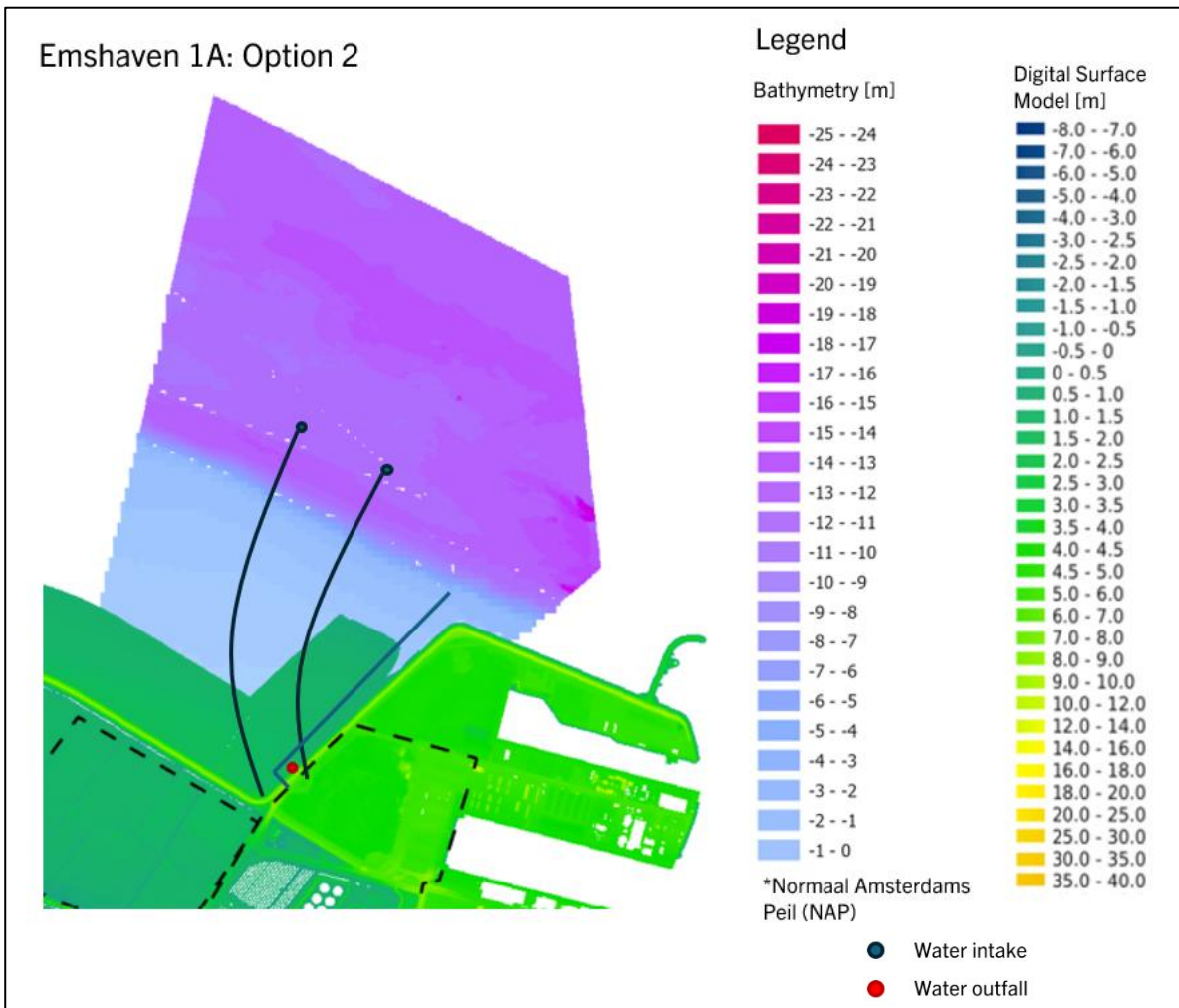


Figure 7.3 Eemshaven 1A - Option 2

Table 7.3 Dimensions - Eemshaven 1A Option 2

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel	~ 2 600	~ - 11.8	-	2 091 044
Tunnel (in, west)	~ 3 500	~ - 11.3	1 125 947	
Tunnel (in, east)	~ 3 000	~ - 11.7	965 097	

\*Normaal Amsterdams Peil (NAP)

### 7.2.1.3 Option 3

This option entails two intake tunnels and an outfall tunnel as shown in Figure 7.4, with dimensions shown in Table 7.4.

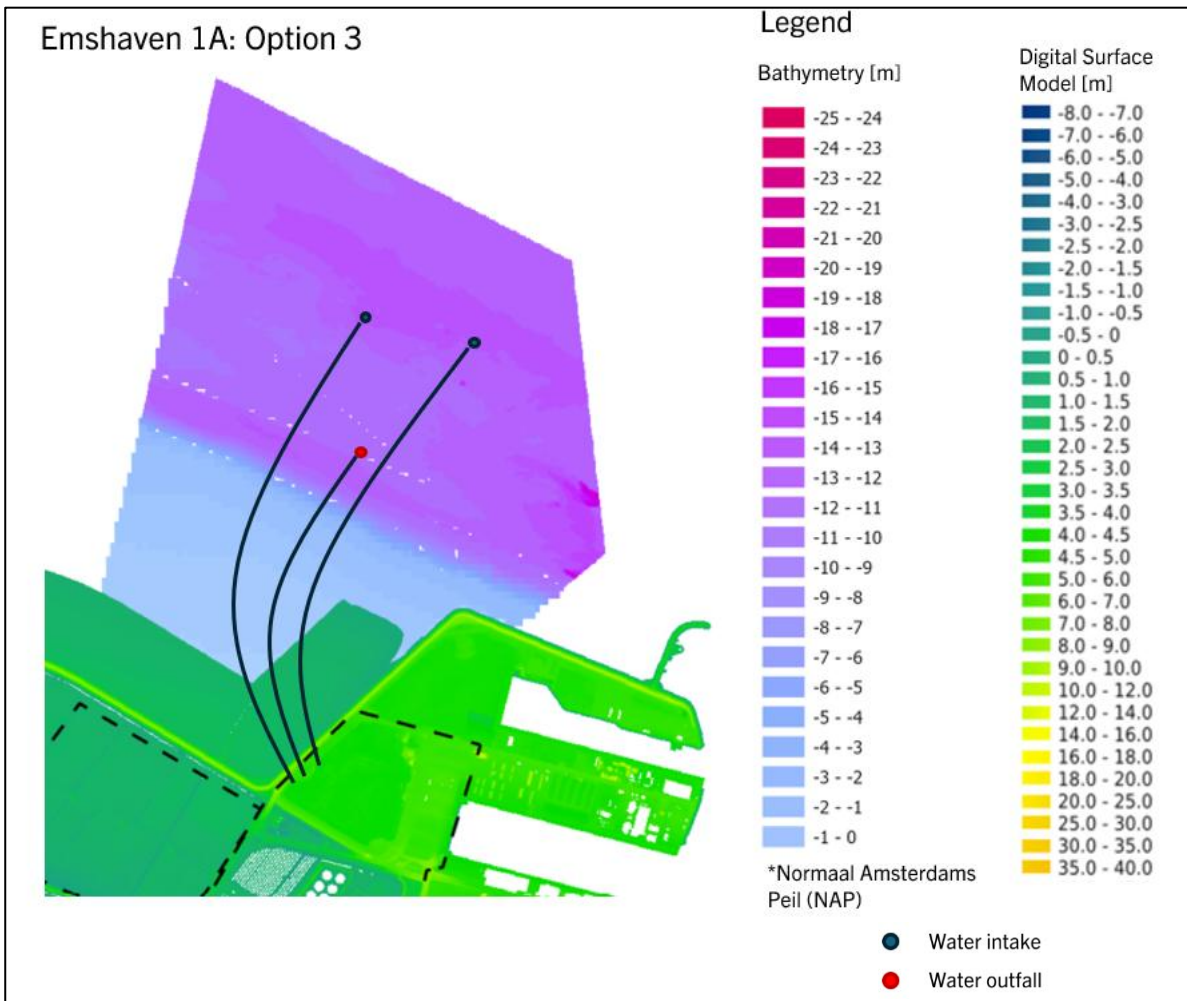


Figure 7.4 Eemshaven 1A - Option 3

Table 7.4 Dimensions - Eemshaven 1A Option 3

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Tunnel (out)	~ 3 300	~ - 11.8	1 528 714	4 359 666
Tunnel (in, west)	~ 4 500	~ - 13.2	1 447 646	
Tunnel (in, east)	~ 4 300	~ - 13.2	1 383 306	

\*Normaal Amsterdams Peil (NAP)

### 7.2.1.4 Option 4

This option entails two intake tunnels and an outfall tunnel as shown in Figure 7.5, with dimensions shown in Table 7.5. This is an alternative fully tunnelled solution to limit the length of the tunnels.

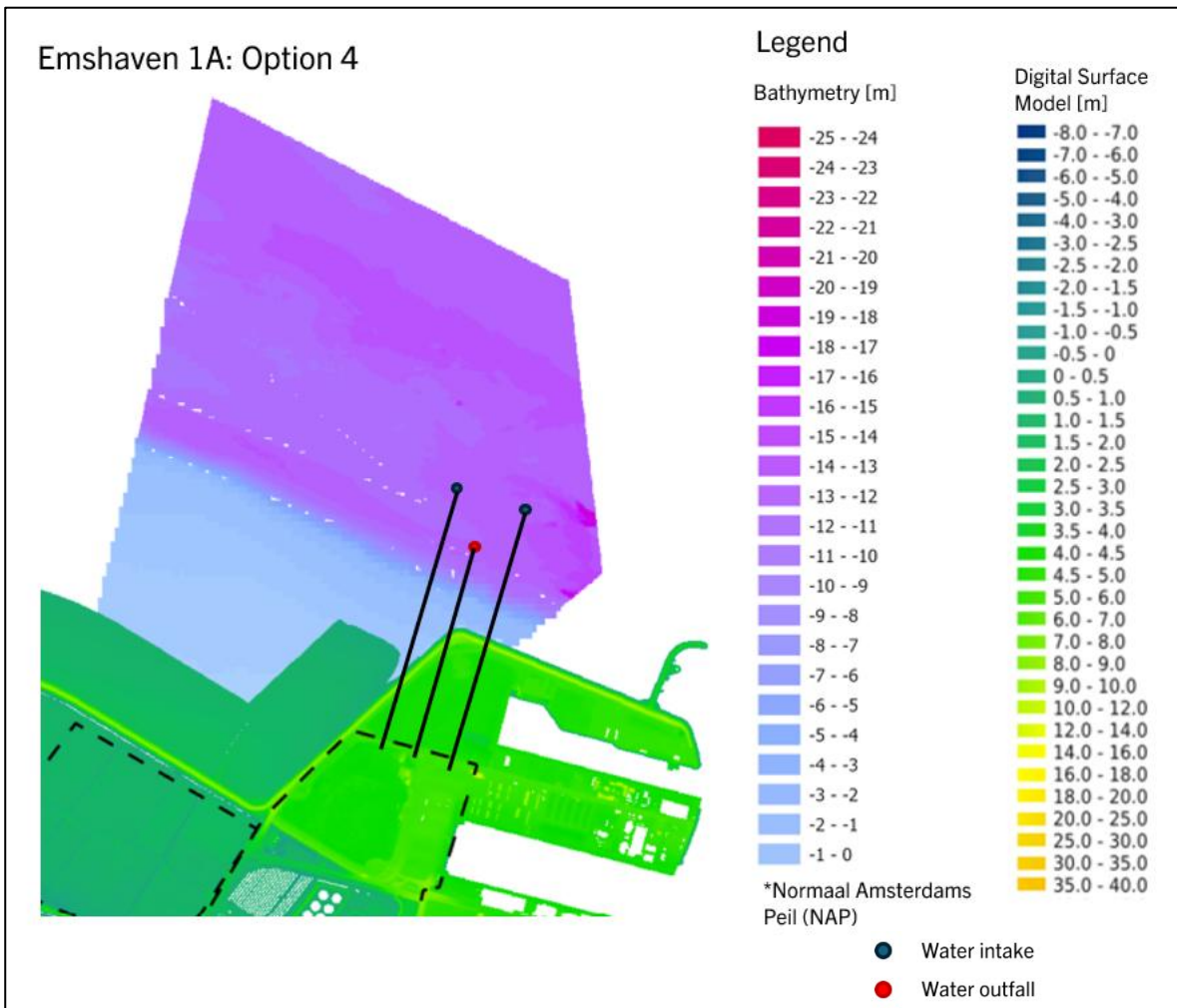


Figure 7.5 Eemshaven 1A - Option 4

Table 7.5 Dimensions - Eemshaven 1A Option 4

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Tunnel (out)	~ 2 100	~ - 12.0	972 818	2 581 313
Tunnel (in, west)	~ 2 500	~ - 12.3	804 248	
Tunnel (in, east)	~ 2 500	~ - 12.3	804 248	

\*Normaal Amsterdams Peil (NAP)

## 7.2.2 Scoring narrative

### 7.2.2.1 Tunnel Scoring

Review of the particle size distribution shows that a slurry or variable density TBM is identified as being the most suitable for the ground conditions.

For all options the moderately high water pressure, permeable strata and challenges in achieving sufficient ground improvement to facilitate construction of the tunnel shaft connection dictate a low Constructability score, while the large site and proximity of the port lead to a higher logistics score.

Option 4 is highlighted as potentially being subject to underground hazards as it goes beneath a significant area of the port. The concern would be that there may be unmapped service, foundations associated with current or previous development. Further investigation may allow this score to be increased. Options 1-3 do have some offshore obstructions (power cables), which are seen as lower impact and result on a score of 3.

In all options the spoil is seen as potentially recoverable with low treatment and large quantities may be re-usable in landscaping or disposed of locally.

The tunnel scoring is for this site is shown in Table 7.6.

**Table 7.6 Scoring of Tunnels Options 1-4 Eemshaven 1A**

Site designation	Eemshaven - 1A			
Preferred Technology	Slurry or variable density TBM			
Options Considered	Option 1	Option 2	Option 3	Option 4
Scoring Criteria				
Constructability	2	2	2	2
Logistics	4	4	4	4
Tunnelling Hazards	3	3	3	1
Environmental	4	4	4	4

### 7.2.2.2 Overall Scoring

**Cost** – The Class 5 estimates show that the most likely cost of Option 1 is 1-1.5 B euros while all other options are 1.5-2B euros.

**Constructability** - All tunnels have low constructability and option 4 tunnels have additional potential for underground hazards. In addition, the extremely long channel that requires either large breakwaters or culverts to be constructed in relatively exposed environmental conditions clearly has some construction challenges. In options 1 and 2 it is also necessary to build a significant culvert under the railway line that runs to the port.

**Cooling Water Environmental** – Option 1 has been modelled by Deltares and shown to be largely compliant with the guidance, whereas option 2 has been shown to be non-compliant. Options 3 and 4 have an outfall location similar to Option 1 and have a relatively large horizontal and vertical separation from the outfall and so are judged by the author as likely to be compliant but have not been modelled hence score 3 not 4.

**Cooling Water temperature** – ambient temperatures are acceptable and low levels of recirculation are anticipated.

**Other Environmental** – The two options (1 and 2) that entail a long channel through the intertidal zone are seen as very high risk. This work is very extensive and has to be completed in a Natura 2000 and UNESCO World Heritage area and permitting would be challenging. There is a possibility to make the

direct intake outfalls into a covered culvert which improves the sediment transfer and morphology but potential impacts remain on flora and fauna.

**Ship Impact** – The Heads are located outside of the shipping channels in all cases, but there are known to be leisure boats and fishing vessels in the vicinity.

**UXO risk** – Literature searches indicate moderate UXO risk in this area

**Impact on local stakeholders** – no local leisure activities are known of and fishing activity is present but not highly concentrated in this area.

The overall scoring for this site is shown in Table 7.7.

**Table 7.7 Overall Scoring of Options 1-4 Eemshaven 1A**

Site designation	Eemshaven - 1A			
Preferred Technology	Slurry or variable density TBM			
Options Considered	Option 1	Option 2	Option 3	Option 4
Scoring Criteria				
Cost	3	2	2	2
Constructability (Overall)	2	2	2	1
Cooling Water Environmental	4	1	3	3
Cooling Water Temperature	5	5	5	5
Other Environmental	1	1	5	5
Ship Impact	3	3	3	3
UXO risk	3	3	3	3
Impact local stakeholders	5	5	5	5
Total score - baseline weighting	295	225	315	295
Total score - alternative weighting	304	224	344	336

### 7.2.3 Preferred Option Eemshaven 1A

The preferred option from a cost point of view is Option 1, however the score of 1 in the “other environmental” category indicates very high risk in this category. Considering both weighting methods Option 3 scores better and provides a lower risk but higher cost alternative.

## 7.3 Eemshaven 1B

### 7.3.1 Options considered

The options possible are the same as Eemshaven 1A except that the geometry does not allow a second tunnel option.

#### 7.3.1.1 Option 1

This option entails an outfall tunnel and direct intake as shown in Figure 7.6, with dimensions shown in Table 7.8.

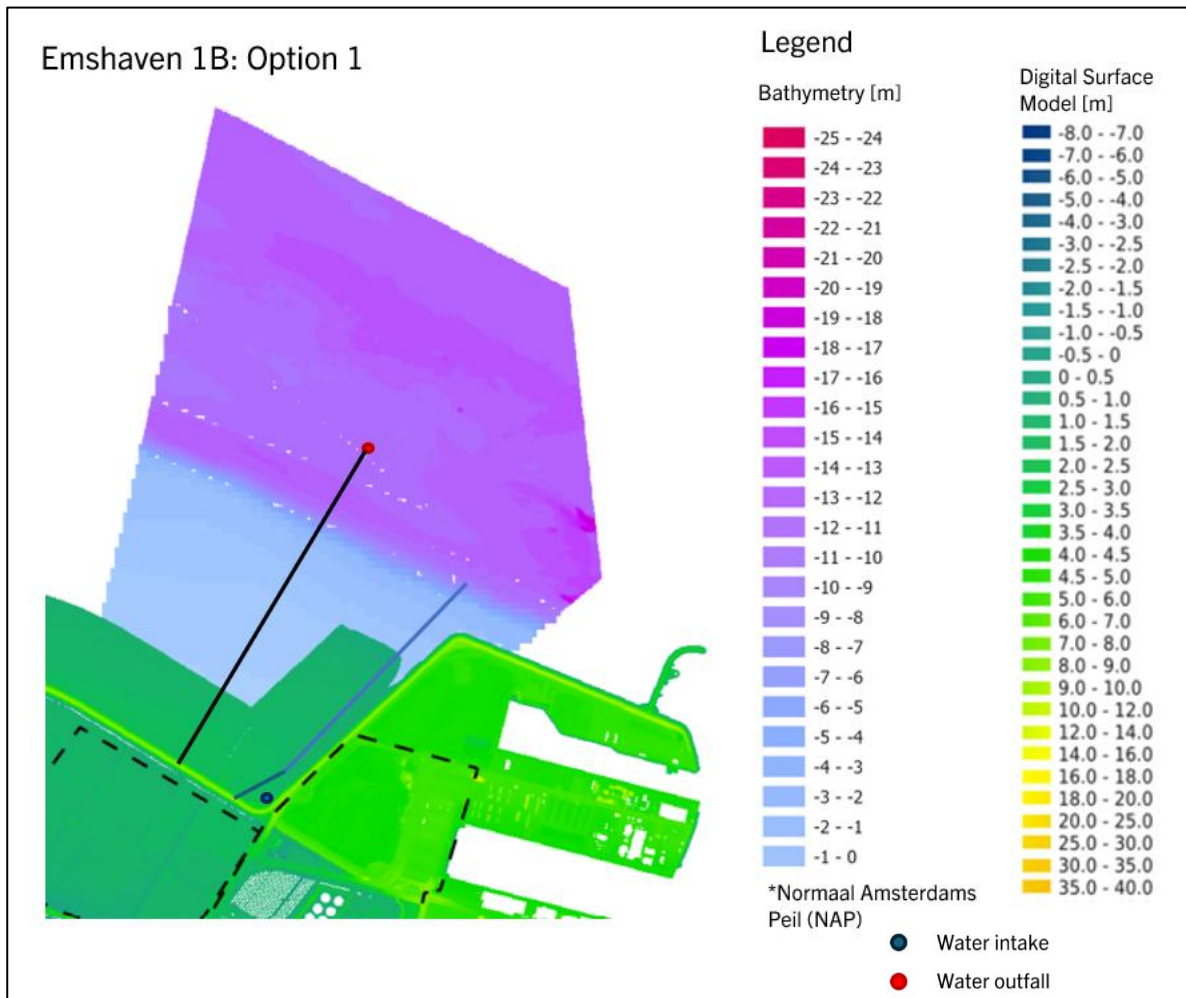


Figure 7.6 Eemshaven 1B - Option 1

Table 7.8 Dimensions - Eemshaven 1B Option 1

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Tunnel (in)	~ 3 400	~ -11.6	1 093 777	1 093 777
Dredged channel	~ 2 900	-	-	

\*Normaal Amsterdams Peil (NAP)

### 7.3.1.2 Option 2

This option entails two intake tunnels and direct outfall as shown in Figure 7.7, with dimensions shown in Table 7.9.

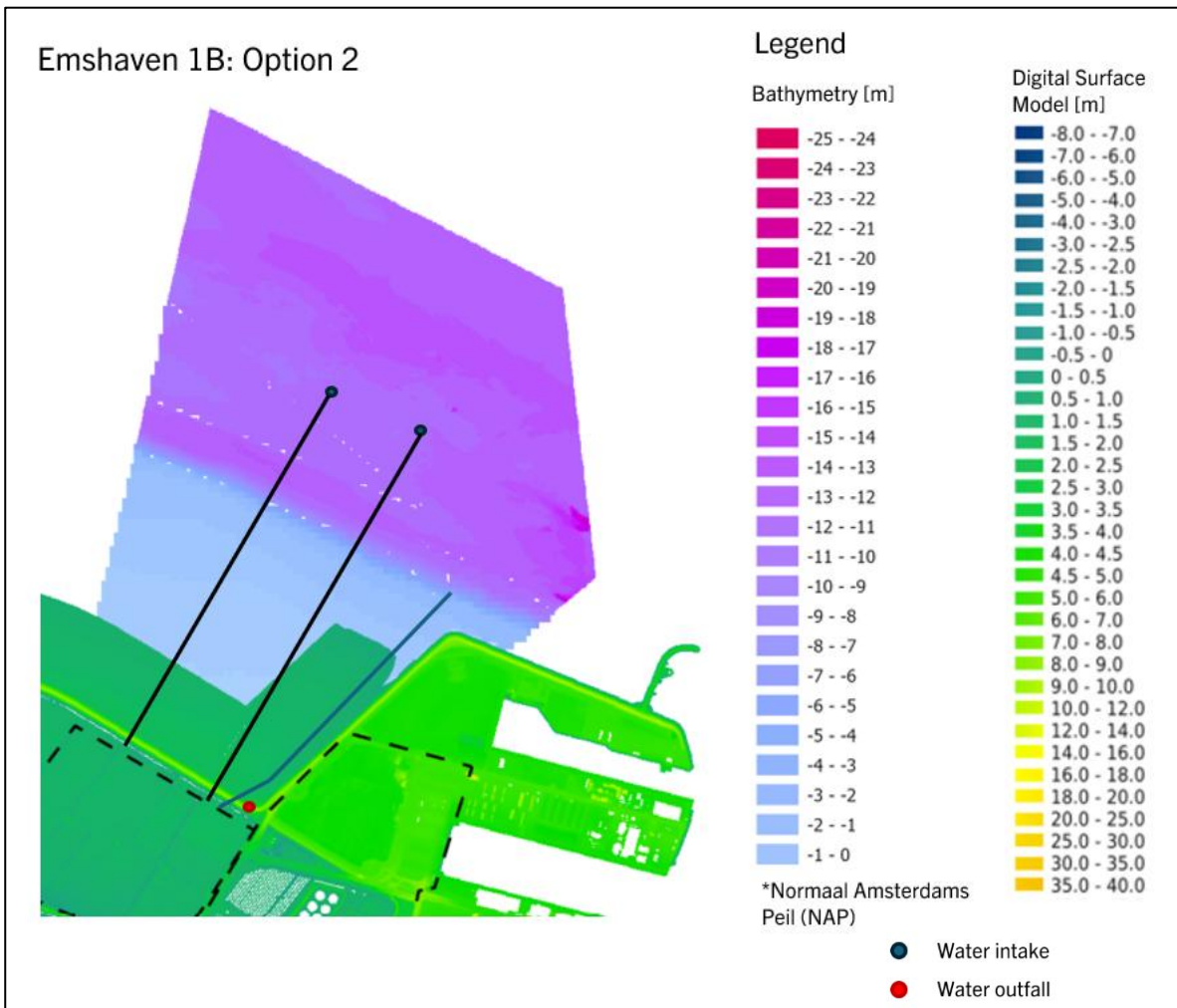


Figure 7.7 Eemshaven 1B - Option 2

Table 7.9 Dimensions - Eemshaven 1B Option 2

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel	~ 2 900	~ -11.6	-	2 895 292
Tunnel (in, west)	~ 4 300	~ - 13.3	1 383 306	
Tunnel (in, east)	~ 4 700	~ - 13.3	1 511 986	

\*Normaal Amsterdams Peil (NAP)

### 7.3.1.3 Option 3

This option entails two intake tunnels and one outfall tunnel as shown in Figure 7.8, with dimensions shown in Table 7.10.

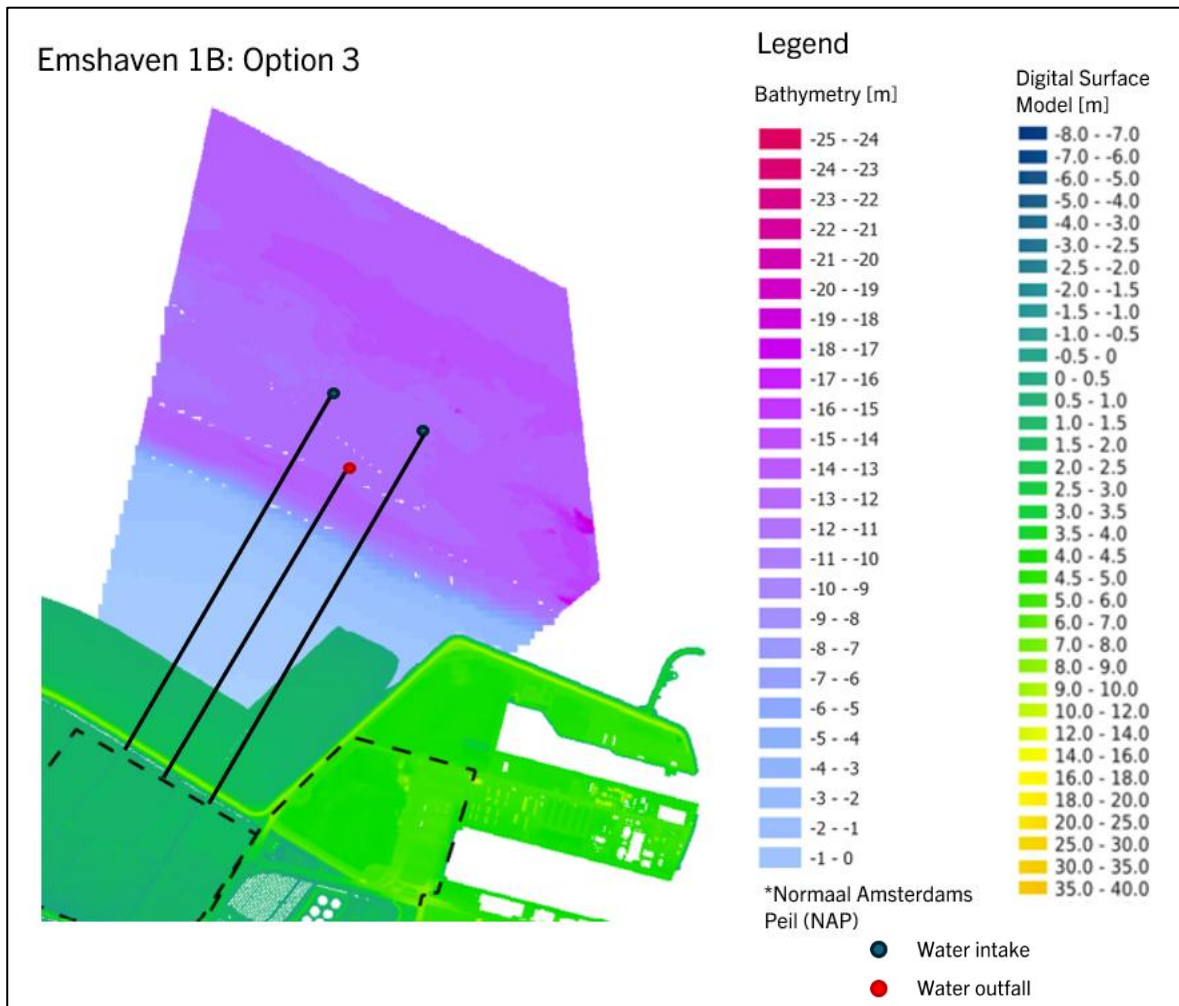


Figure 7.8 Eemshaven 1B - Option 3

Table 7.10 Dimensions - Eemshaven 1B Option 3

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Tunnel (out)	~ 3 400	~ -11.6	1 575 039	4 470 331
Tunnel (in, west)	~ 4 300	~ - 13.3	1 383 306	
Tunnel (in, east)	~ 4 700	~ - 13.3	1 511 986	

\*Normaal Amsterdams Peil (NAP)

## 7.3.2 Scoring Narrative

### 7.3.2.1 Tunnel Scoring

Review of the particle size distribution shows that a slurry or variable density TBM is identified as being the most suitable for the ground conditions.

For all options the moderately high water pressure, permeable strata and challenges in achieving sufficient ground improvement to facilitate construction of the tunnel shaft connection dictate a low Constructability score, while the large site and proximity of the port lead to a higher logistics score.

All options have some offshore obstructions (power cables), which result on a score of 3.

In all options the spoil is seen as potentially recoverable with low treatment and large quantities may be re-usable in landscaping or disposed of locally.

The tunnel scoring for this site is shown in Table 7.11.

**Table 7.11 Scoring of Tunnels Options 1-3 Eemshaven 1B**

Site designation	Eemshaven - 1B		
Preferred Technology	Slurry or variable density TBM		
Options Considered	Option 1	Option 2	Option 3
Scoring Criteria			
Constructability	2	2	2
Logistics	4	4	4
Tunnelling Hazards	3	3	3
Environmental	4	4	4

### 7.3.2.2 Overall Scoring

**Cost** - Class 5 estimates show that the most likely cost of Option 1 is 1-1.5 B euros while other options are 1.5-2B euros.

**Constructability** - All tunnels have low constructability. In addition, the extremely long channel that requires either large breakwaters or culverts to be constructed in relatively exposed environmental conditions clearly has some construction challenges.

**Cooling Water Environmental** – Option 1 has been modelled by Deltares and shown to be largely compliant with the guidance, whereas option 2 has been shown to be non-compliant. Options 3 is likely, by inspection to be compliant but has not been modelled hence scores 3 not 4.

**Cooling Water temperature** – ambient temperatures are acceptable and low levels of recirculation are anticipated.

**Other Environmental** – The two options (1 and 2) that entail a long channel through the intertidal zone are seen as very high risk. This work is very extensive and has to be completed in a UNESCO World Heritage area and permitting would be challenging. There is a possibility to make the direct intake outfalls into a covered culvert which improves the sediment transfer and morphology but potential impacts remain on flora and fauna.

**Ship Impact** – The Heads are located outside of the shipping channels in all cases but there are known to be fishing vessels and leisure boats in the vicinity.

**UXO risk** – Literature searches indicate moderate UXO risk in this area

**Impact on local stakeholders** – no local leisure activities are known of and fishing activity is not concentrated in this area.

The overall scoring for this site is shown in Table 7.12.

**Table 7.12 Overall Scoring of Options 1-3 Eemshaven 1B**

Site designation	Eemshaven - 1B		
Preferred Technology	Slurry or variable density TBM		
Options Considered	Option 1	Option 2	Option 3
Scoring Criteria			
Cost	3	2	2
Constructability (Overall)	2	2	2
Cooling Water Environmental	4	2	3
Cooling Water Temperature	5	5	5
Other Environmental	1	1	5
Ship Impact	3	3	3
UXO risk	3	3	3
Impact local stakeholders	5	5	5
Total score - baseline weighting	295	240	315
Total score - alternative weighting	304	244	344

### 7.3.3 Preferred Option

The preferred option from a cost point of view is Option 1, however the score of 1 in the “other environmental” category indicates very high risk in this category. Considering both weighting methods Option 3 scores better and provides a lower risk but higher cost alternative.

## 7.4 Eemshaven 2

### 7.4.1 Options Considered

At Eemshaven 2 only two options are considered, direct intake and outfall and direct intake with a tunnel outfall. No fully tunnelled option was considered as at the time of the scoring , no advantage could be seen in a fully tunnelled solution.

#### 7.4.1.1 Option 1

This option entails direct intake and outfall as shown in Figure 7.9, with dimensions shown in Table 7.13.

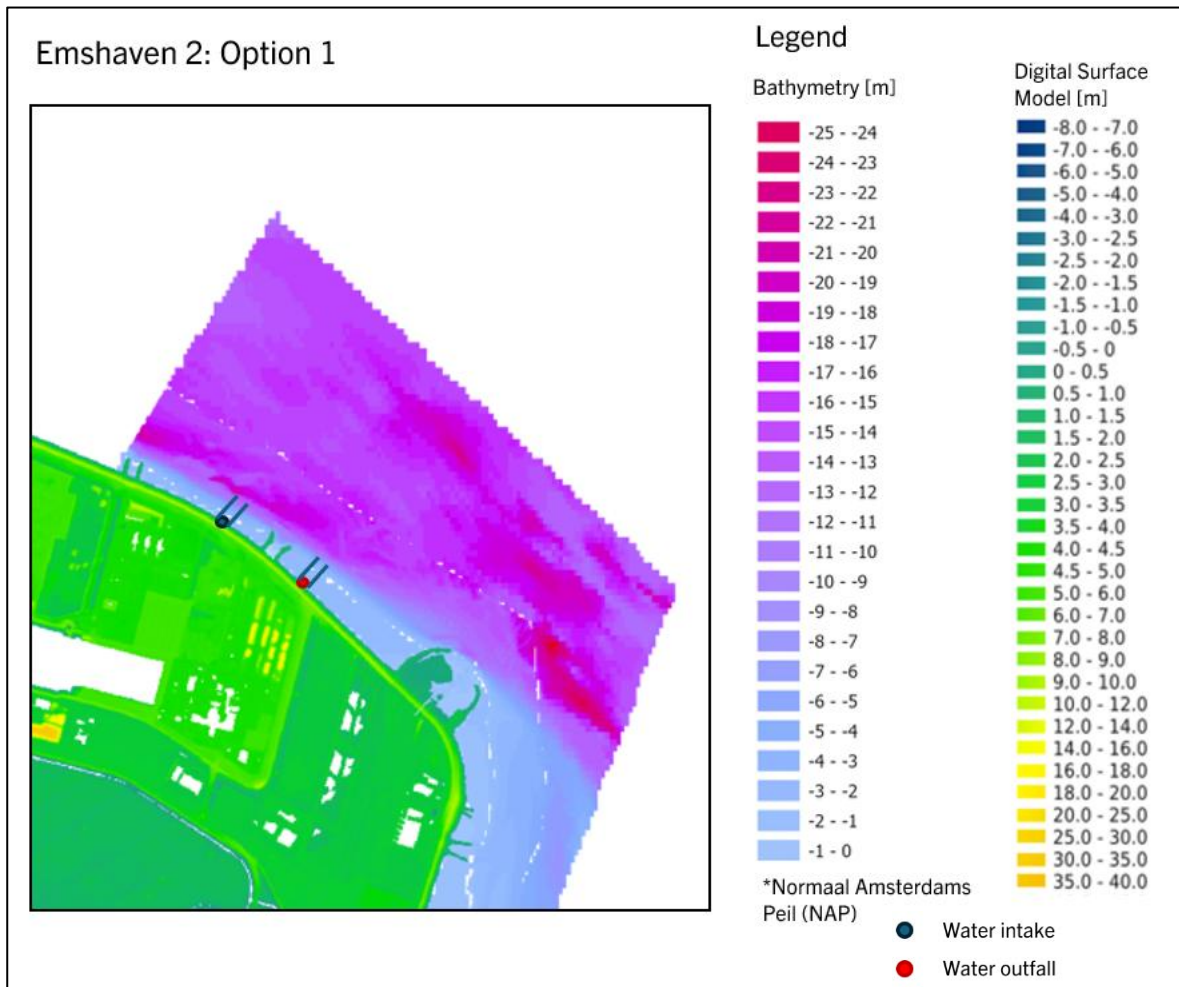


Figure 7.9 Eemshaven 2 - Option 1

Table 7.13 Dimensions - Eemshaven 2 Option 1

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (in)	~ 250	-	-	0
Dredged channel (out)	~ 350	-	-	

\*Normaal Amsterdams Peil (NAP)

7.4.1.2 Option 2

This option entails outfall tunnel and direct intake as shown in Figure 7.10, with dimensions shown in Table 7.14.

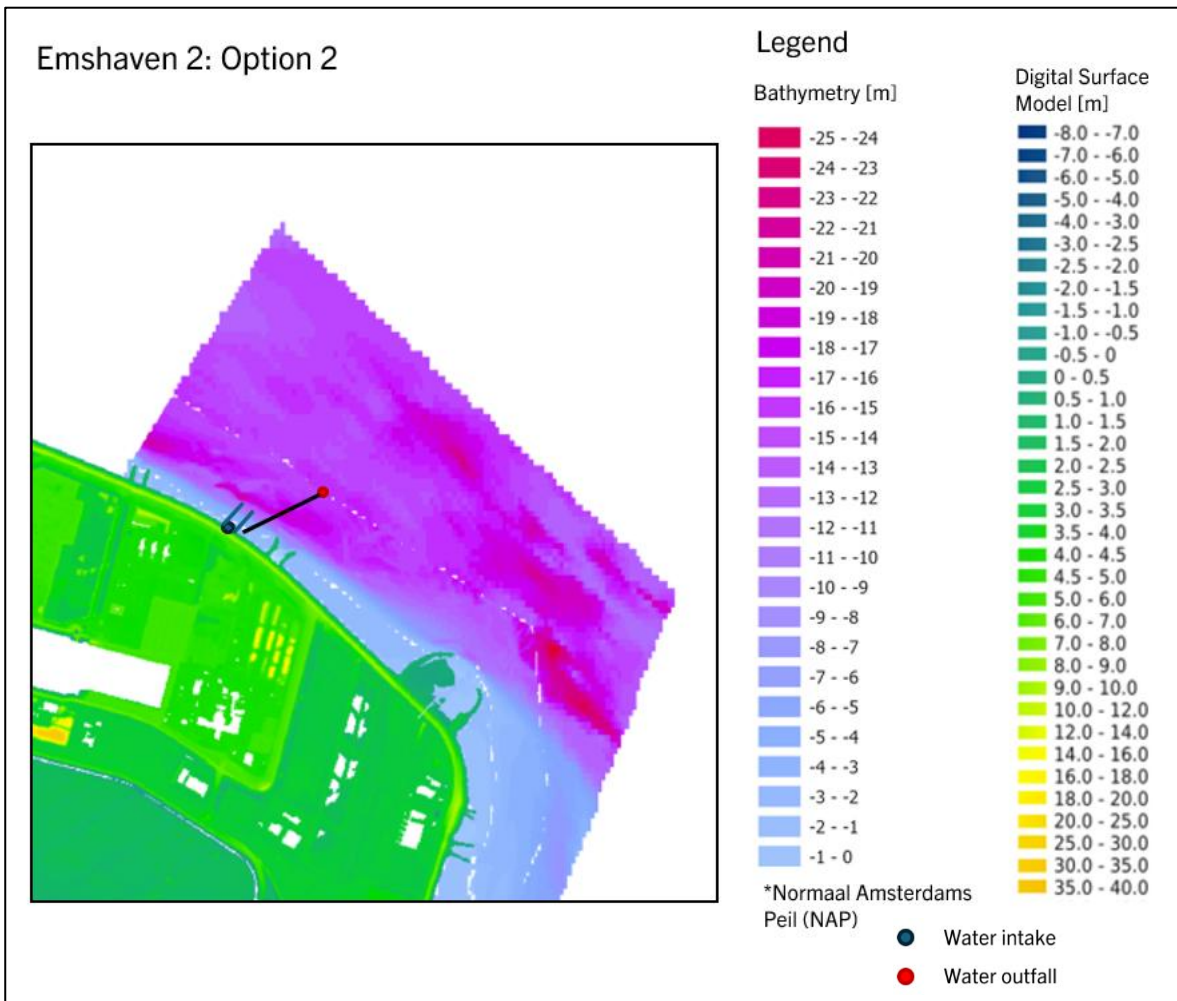


Figure 7.10 Eemshaven 2 - Option 2

Table 7.14 Dimensions - Eemshaven 2 Option 2

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (in)	~ 250	-	-	463 247
Tunnel (out)	~ 1 000	~ -15.6	463 247	

\*Normaal Amsterdams Peil (NAP)

## 7.4.2 Scoring Narrative

### 7.4.2.1 Tunnel Scoring

Only option 2 includes a tunnel.

The review of the particle size distribution shows that a slurry or variable density TBM is identified as being the most suitable for the ground conditions.

The moderately high water pressure, permeable strata and challenges in achieving sufficient ground improvement to facilitate construction of the tunnel shaft connection dictate a low Constructability score, while the large site and proximity of the port lead to a higher logistics score.

There are some offshore obstructions (power cables), which result on a score of 3.

In all options the spoil is seen as potentially recoverable with low treatment and large quantities may be re-usable in landscaping or disposed of locally.

The tunnel scoring is for this site is shown in Table 7.15.

**Table 7.15 Scoring of Tunnels Option 2 Eemshaven 2**

Site designation	Eemshaven - 2
Preferred Technology	Slurry or variable density TBM
Options Considered	Option 2
Scoring Criteria	
Constructability	2
Logistics	4
Tunnelling Hazards	3
Environmental	4

### 7.4.2.2 Overall Scoring

**Cost** - Class 5 estimates show that the most likely cost of Option 1 is >0.5 B euros while Option 2 is 0.5-1.0B euros. Although there are intake and outfall structures from previous power stations present it is unlikely that reuse would provide any cost benefit. Those structures may, however, prove to be an advantage in the permitting process.

**Constructability** – Option 1 has direct intake and outfall and no tunnelling, with relatively short channels and a slightly more protected environment than the sites to the west of the port, and so has relatively good constructability, while the Option 2 score is reduced by the introduction of the requirement for a short tunnel for the outfall.

**Cooling Water Environmental** – Option 2 has been modelled by Deltares and shown to be compliant with the guidance, whereas option 1 has not been modelled. However Deltares have modelled a direct outfall and a short tunnel to a diffuser in their configurations 1 and 3, with only small differences in the overall results. Therefore, by inspection there seems to be a good chance that Option 1 may be compliant.

**Cooling Water temperature** – ambient temperatures are acceptable however recirculation is shown as 2.1C average, hence amber rating.

**Other Environmental** – Although both require dredged channels in a Natura 2000 and UNESCO World Heritage Area, the channels are relatively short and are in an area where there are already direct intakes and outfalls for other industrial purposes.

**Ship Impact** – Option 1, there are no tunnel heads, option 2 the Heads are located outside of the shipping channels in all cases. However they are close to high density commercial shipping and there is leisure boat and fishing activity in this area.

**UXO risk** – Preliminary searches conducted by the author indicate moderate UXO risk in this area.

**Impact on local stakeholders** – no local leisure activities are known of and fishing activity is not concentrated in this area.

The overall scoring for this site is shown in Table 7.16.

**Table 7.16 Overall Scoring of Options 1-2 Eemshaven 2**

Site designation	Eemshaven - 2	
Preferred Technology	Slurry or variable density TBM	
Options Considered	Option 1	Option 2
Scoring Criteria		
Cost	5	4
Constructability (Overall)	4	3
Cooling Water Environmental	3	5
Cooling Water Temperature	2	3
Other Environmental	2	2
Ship Impact	5	2
UXO risk	3	3
Impact local stakeholders	5	5
Total score - baseline weighting	380	355
Total score - alternative weighting	352	348

### 7.4.3 Preferred Option

The preferred option from a cost and construction point of view is Option 1, however the score of 2 in the “other environmental” and “cooling water temperature” categories indicate high risk for this option. It is important to ensure that these risk areas are mitigated and it is noted that Option 2 is potentially better regarding cooling water environmental and cooling water temperature at cost of an increased ship impact risk.

## 7.5 Eemshaven 3

### 7.5.1 Options Considered

The options considered at Eemshaven 3 are the same as Eemshaven 2, for the same reasons.

#### 7.5.1.1 Option 1

This option entails direct intake and direct outfall as shown in Figure 7.11, with dimensions shown in Table 7.17.

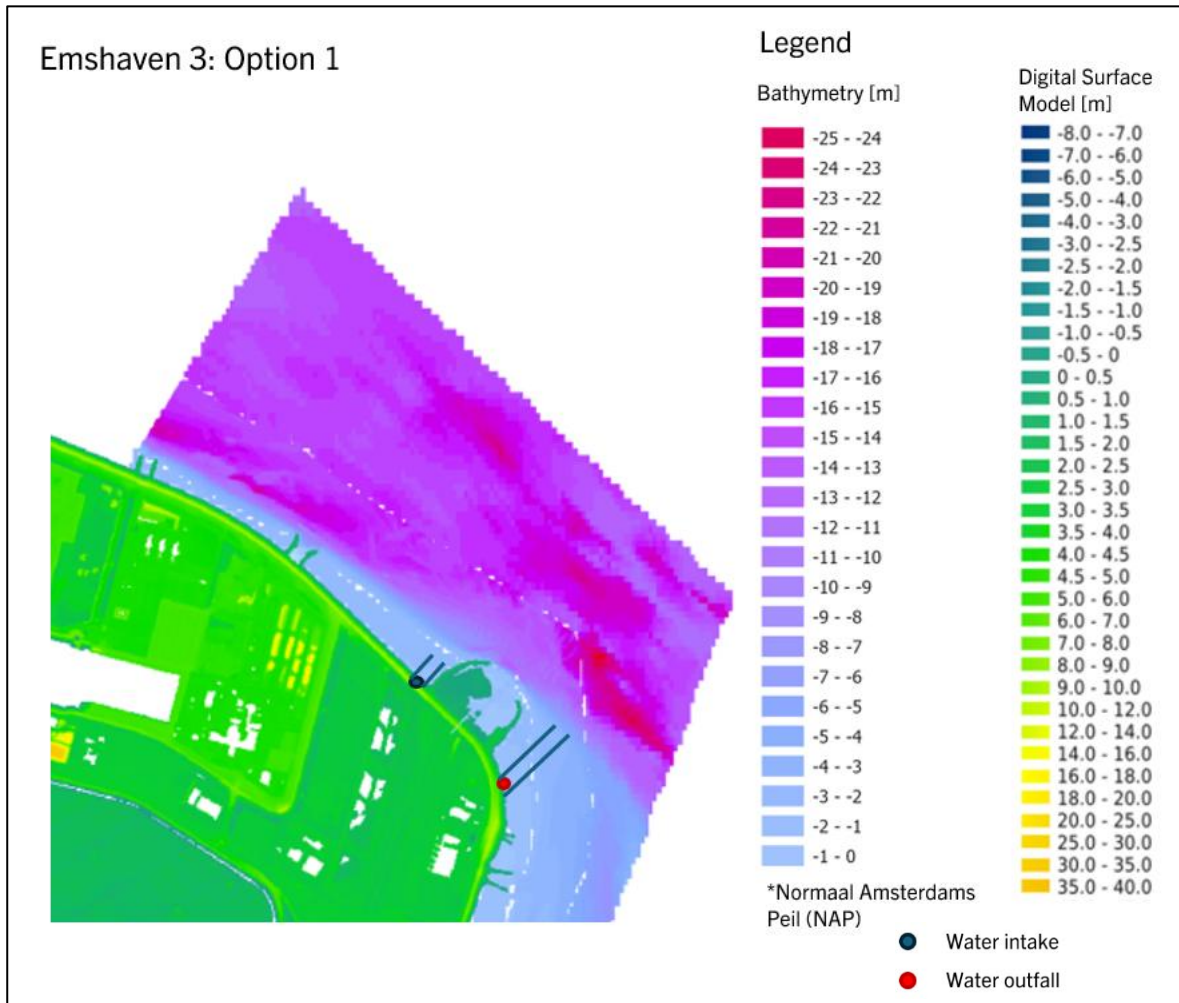


Figure 7.11 Eemshaven 3 - Option 1

Table 7.17 Dimensions - Eemshaven 3 Option 1

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (out, west)	~ 450	-	-	0
Dredged channel (in)	~ 550	-	-	
Dredged channel (out, east)	~ 850	-	-	

\*Normaal Amsterdams Peil (NAP)

### 7.5.1.2 Option 2

This option entails direct intake and outfall tunnel as shown in Figure 7.12, with dimensions shown in Table 7.18.

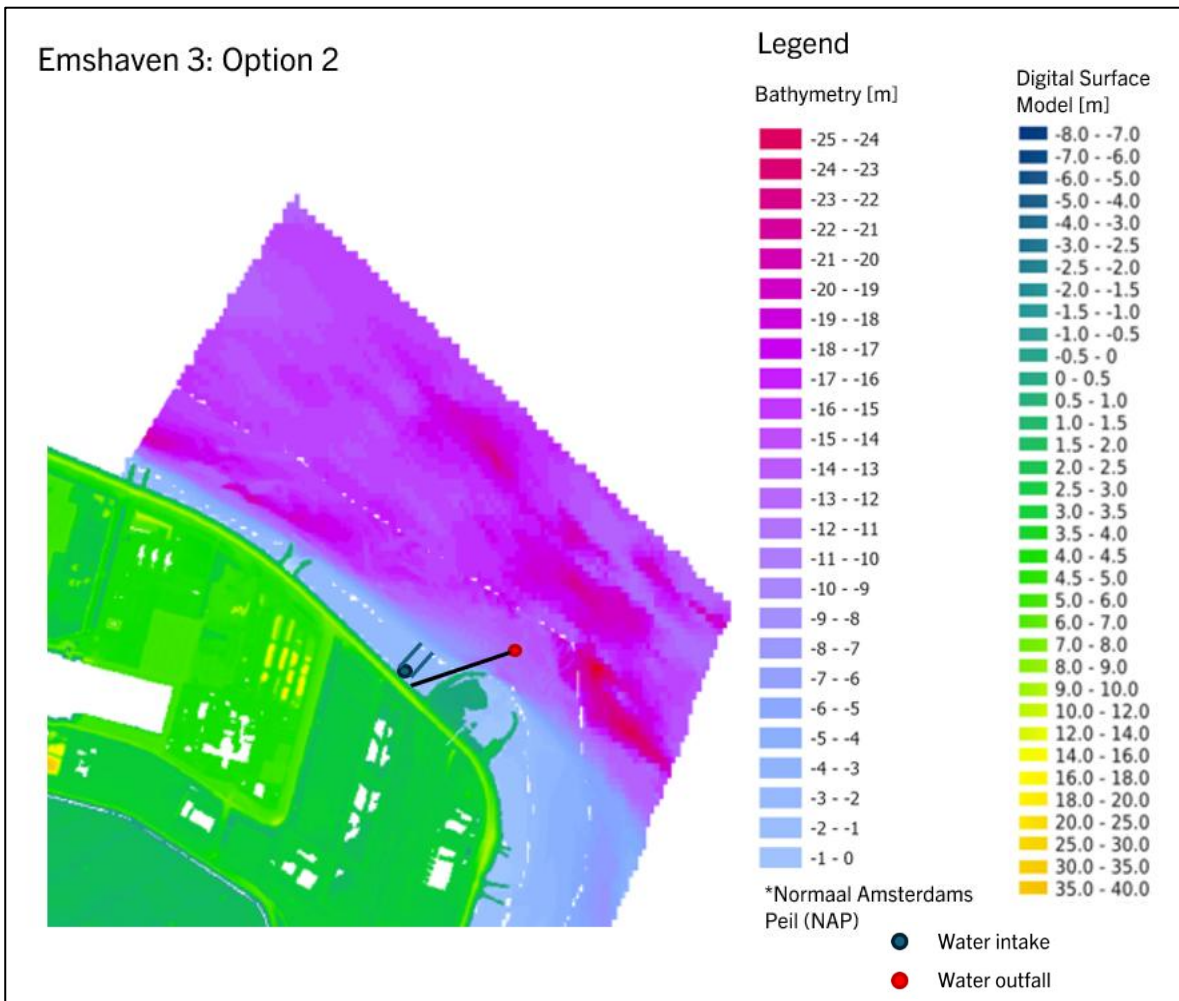


Figure 7.12 Eemshaven 3 - Option 2

Table 7.18 Dimensions - Eemshaven 3 Option 2

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (in)	~ 550	-	-	555 896
Tunnel (out)	~ 1 200	~ -12.9	555 896	

\*Normaal Amsterdams Peil (NAP)

## 7.5.2 Scoring Narrative

### 7.5.2.1 Tunnel Scoring

From a tunnelling viewpoint, Eemshaven 3 is identical to Eemshaven 2 and this section is a direct repeat of the earlier description.

Only option 2 includes a tunnel.

Review of the particle size distribution shows that a slurry or variable density TBM is identified as being the most suitable for the ground conditions.

The moderately high water pressure, permeable strata and challenges in achieving sufficient ground improvement to facilitate construction of the tunnel shaft connection dictate a low Constructability score, while the large site and proximity of the port lead to a higher logistics score.

There are some offshore obstructions (power cables), which result in a score of 3.

In all options the spoil is seen as potentially recoverable with low treatment and large quantities may be re-usable in landscaping or disposed of locally.

The tunnel scoring is for this site is shown in Table 7.19.

**Table 7.19 Scoring of Tunnels Option 2 Eemshaven 3**

Site designation	Eemshaven - 3
Preferred Technology	Slurry or variable density TBM
Options Considered	Option 2
Scoring Criteria	
Constructability	2
Logistics	4
Tunnelling Hazards	3
Environmental	4

### 7.5.2.2 Overall Scoring

In overall scoring Eemshaven 3 is similar to Eemshave2. The construction costs are higher but in the same band and there is less certainty around thermal compliance.

**Cost** - Class 5 estimates show that the most likely cost of Option 1 is >0.5 B euros while Option 2 is 0.5-1.0B euros. Although there are intake and outfall structures from previous power stations present it is unlikely that reuse would provide any cost benefit. Those structures may, however, prove to be an advantage in the permitting process.

**Constructability** – Option 1 has direct intake and outfall and no tunnelling, with relatively short channels and a slightly more protected environment than the sites to the west of the port, and so has relatively good constructability, while Option 2 score is reduced by the introduction of the requirement for a short tunnel for the outfall.

**Cooling Water Environmental** – Option 2 has been modelled by Deltares and shown to be compliant with the guidance, whereas option 1 has not been modelled. On the positive side Deltares have modelled a direct outfall and a short tunnel to a diffuser in their configurations 1 and 3, with only small differences in the overall results which is positive. However the actual outfall is further east for this site and therefore close to the modelling in configuration 2 which was shown to be unacceptable. Modelling of the proposed layout is required to close the issue.

**Cooling Water temperature** – ambient temperatures are acceptable however recirculation is shown as 2.1C average, hence amber rating.

**Other Environmental** – Although both require dredged channels in a UNESCO World Heritage Area, the channels are relatively short and are in an area where there are already direct intakes and outfalls for other industrial purposes.

**Ship Impact** – Option 1, there are no tunnel heads, option 2 the Heads are located outside of the shipping channels in all cases. However, they are close to high density commercial shipping and there is leisure boat and fishing activity in this area.

**UXO risk** – Literature searches indicate moderate UXO risk in this area.

**Impact on local stakeholders** – no local leisure activities are known of and fishing activity is not concentrated in this area.

The overall scoring for this site is shown in Table 7.20.

**Table 7.20 Overall Scoring of Options 1-2 Eemshaven 3**

Site designation	Eemshaven - 3	
Preferred Technology	Slurry or variable density TBM	
Options Considered	Option 1	Option 2
Scoring Criteria		
Cost	5	4
Constructability (Overall)	4	3
Cooling Water Environmental	2	4
Cooling Water Temperature	2	3
Other Environmental	2	2
Ship Impact	5	2
UXO risk	3	3
Impact local stakeholders	5	5
Total score - baseline weighting	365	340
Total score - alternative weighting	332	328

### 7.5.3 Preferred Option

The preferred option from a cost and construction point of view is Option 1, however the score of 2 in the “other environmental” and “cooling water temperature” categories indicate high risk for this option. It is important to ensure that these risk areas are mitigated and it is noted that Option 2 is potentially better regarding cooling water environmental and cooling water temperature at cost of an increased ship impact risk.

## 8. Maasvlakte 2

### 8.1 Summary of Cooling Water Modelling

Maasvlakte 2 is classed as a Coastal location, except where outfalls are located to the north in the entrance to the Maas. For Coastal locations the key point is that the MPMZ must not touch the seabed.

The results of the thermal modelling by Deltares in Reference 11 are summarised in Table 8.1, and RAG a status is allocated for clarity, as explained below:

A number of the configurations modelled in Reference 11 consider the intake or outfall in the dock system which has been ruled out by KGG and they are not considered further in this report. => Red

Configurations 1 and 1b (Esturine) create a MPMZ 23% of the estuary area, close to the 25% limit => Amber.

Configurations 3 and 5 (Coastal) model direct intake and outfall and finds that the MPMZ is in contact with the seabed over a significant area, and is therefore deemed unlikely to gain regulatory approval.=>Red

Configuration 5 also has moderately high recirculation. The maximum of 4.2 is  $2 < 5$  =>Amber

Configuration 6 models a direct intake and a tunnel outfall with a diffuser and demonstrates that this configuration shows good compliance.



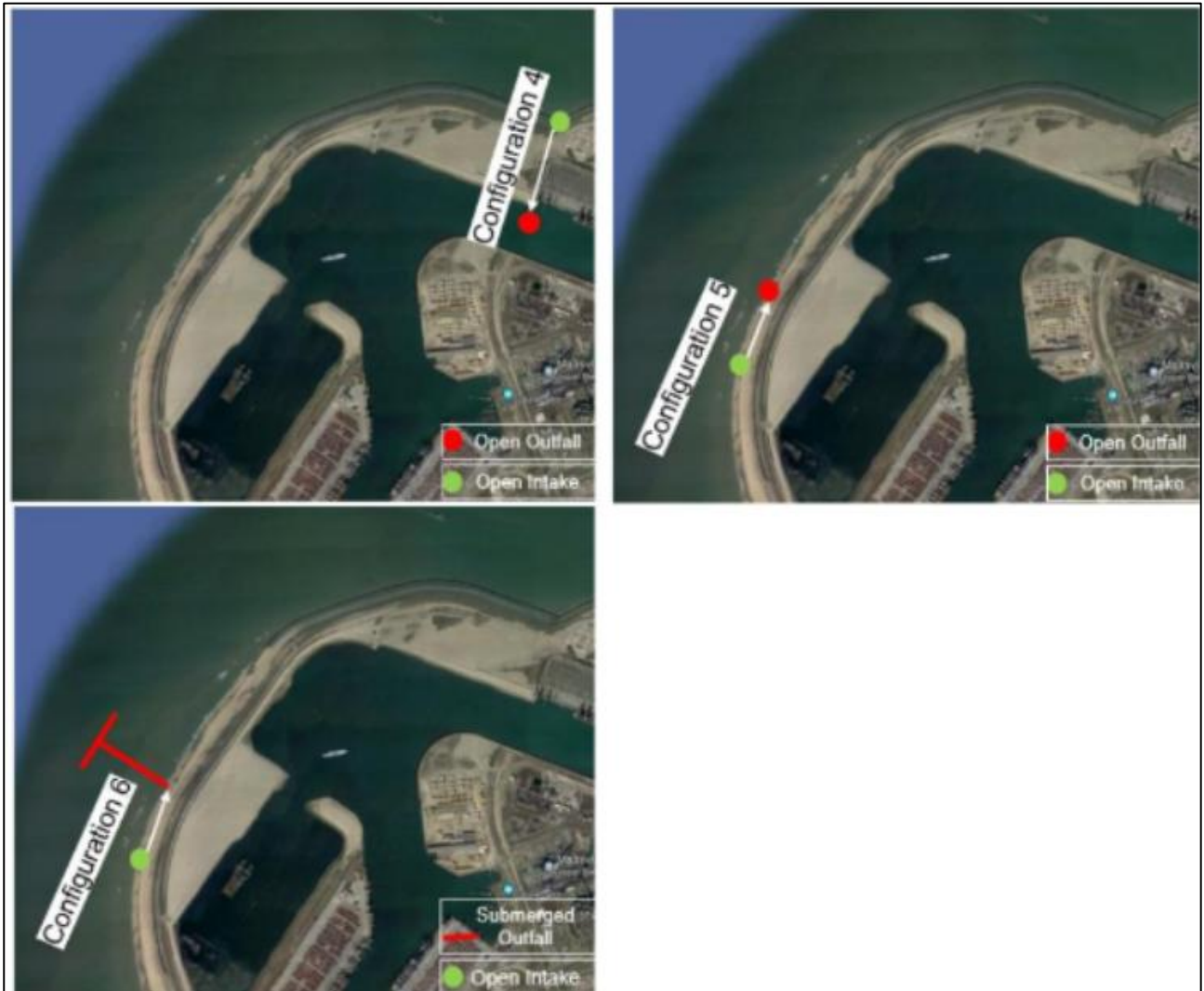


Figure 8.1 Configurations modelled by Deltares – Maasvlakte 2

Table 8.1 Summary of results of thermal modelling at Maasvlakte 2

		Intake	Outfall	Mixing zone %	Mixing zone seabed *	Temp. [°C]	Recirculation max/mean
Configuration 1	Estuarine	Direct dock	Direct sea	23	N/A	1	0.2 / 0.1
Configuration 1b	Estuarine	Direct dock	Direct sea	23	N/A	1	0.2 / 0.1
Configuration 2	Estuarine	Direct dock	Tunnel sea	0	N/A	1	0.2 / 0.1
Configuration 3	Coastal	Direct dock	Direct dredge	N/A	Y	N/A	0.2 / 0.1
Configuration 4	Estuarine	Direct sea	Direct dock	100	N/A	3+	0.6 / 0.1
Configuration 5	Coastal	Direct sea	Direct sea	N/A	Y	N/A	4.3 / 1.2
Configuration 6	Coastal	Direct sea	Tunnel sea	N/A	N	N/A	0.5 / 0.2

\* In coastal waters

## 8.2 Options Considered

For Maasvlakte options with direct intake and outfall are considered, although the thermal modelling shows an issue with this option, as well as direct intake/ tunnel outfall which addresses that issue and an all tunnel option.

### 8.2.1.1 Option 1

This option entails direct intake and direct outfall as shown in Figure 8.2, with dimensions shown in Table 8.2.

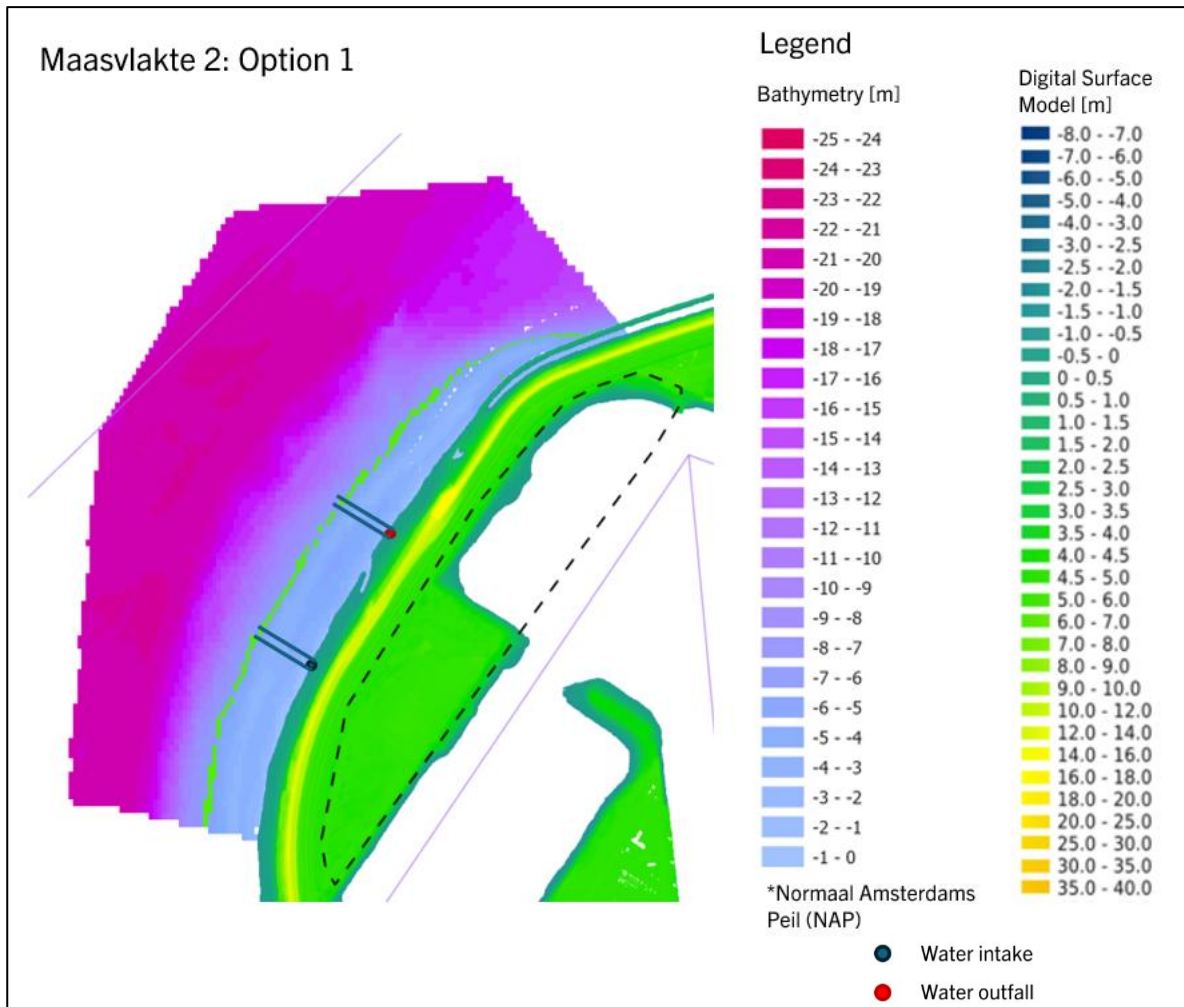


Figure 8.2 Maasvlakte 2 - Option 1

Table 8.2 Dimensions - Maasvlakte 2 Option 1

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (in)	~ 800	-	-	0
Dredged channel (out)	~ 800	-	-	

\*Normaal Amsterdams Peil (NAP)

### 8.2.1.2 Option 2

This option entails direct intake and outfall tunnel as shown in Figure 8.3, with dimensions shown in Table 8.3.

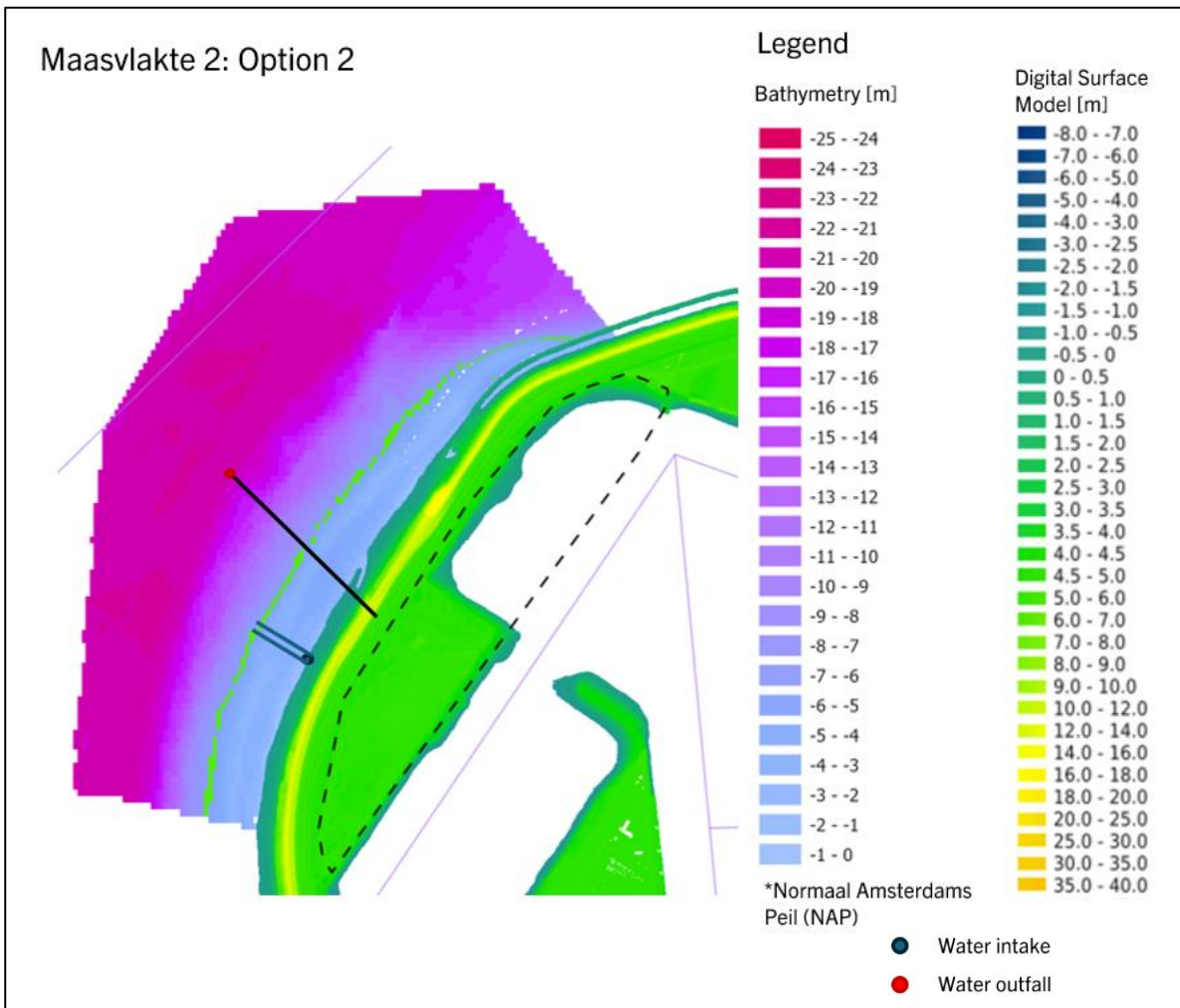


Figure 8.3 Maasvlakte 2 - Option 2

Table 8.3 Dimensions - Maasvlakte 2 Option 2

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (in)	~ 800	-	-	833 844
Tunnel (out)	~ 1 800	~ -20.4	833 844	

\*Normaal Amsterdams Peil (NAP)

### 8.2.1.3 Option 3

This option entails two intake tunnels and one outfall tunnel as shown in Figure 8.4, with dimensions shown in Table 8.4.

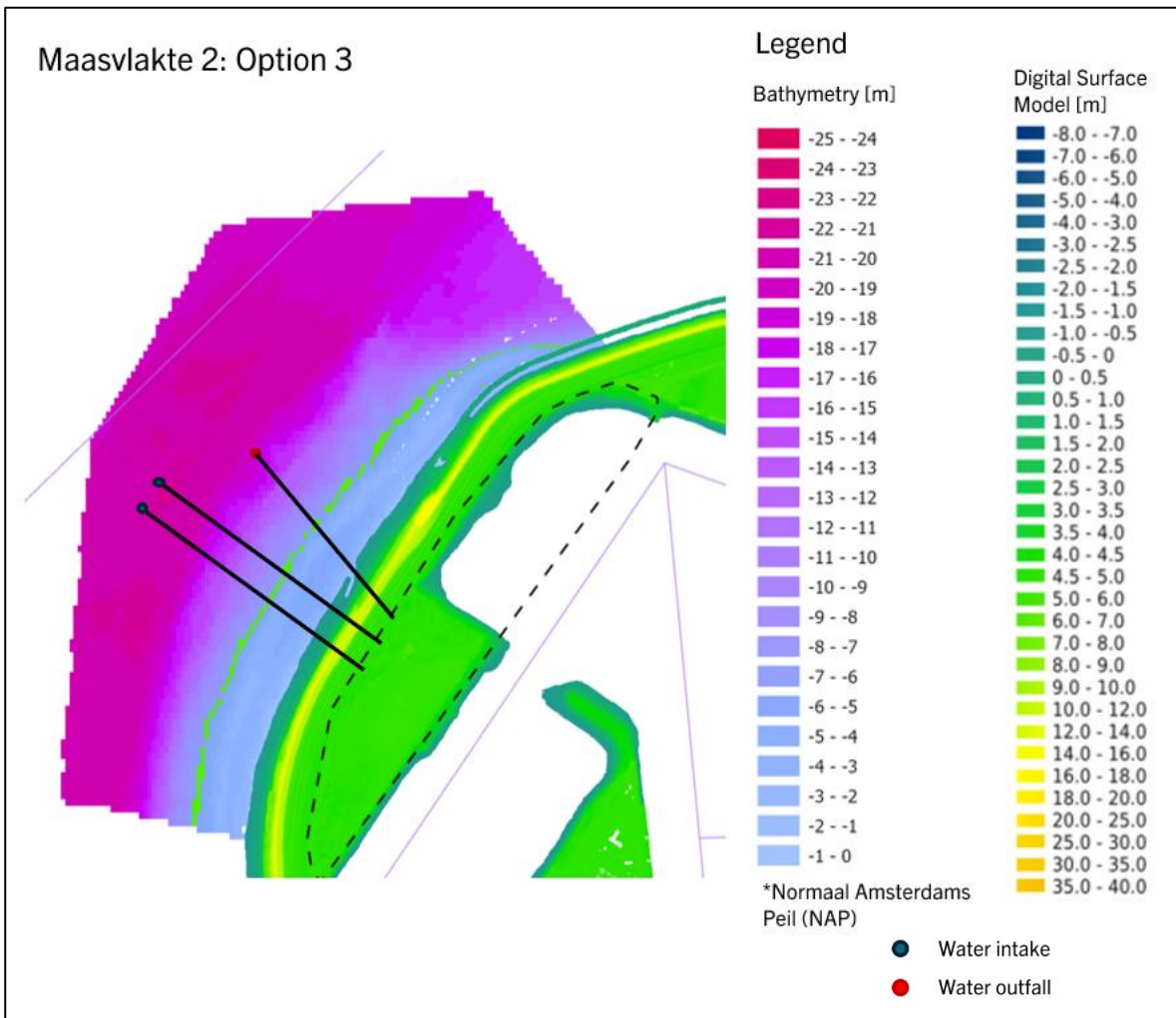


Figure 8.4 Maasvlakte 2 - Option 3

Table 8.4 Dimensions - Maasvlakte 2 Option 3

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Tunnel (out)	~ 1 700	~ - 18.1	787 519	2 202 995
Tunnel (in, north)	~ 2 200	~ -20.0	707 738	
Tunnel (in, south)	~ 2 200	~ -20.0	707 738	

\*Normaal Amsterdams Peil (NAP)

## 8.2.2 Scoring Narrative

### 8.2.2.1 Tunnel Scoring

Review of the particle size distribution shows that a slurry or variable density TBM is identified as being the most suitable for the ground conditions.

The moderately high water pressure, permeable strata and challenges in achieving sufficient ground improvement to facilitate construction of the tunnel shaft connection dictate a low Constructability score, while the large site and proximity of the port lead to a higher logistics score.

All options have some offshore obstructions (power cables), which result on a score of 3.

In all options the spoil is seen as medium recovery/reuse and some conditioning and additives required during mining.

The tunnel scoring for this site is shown in Table 8.5.

**Table 8.5 Scoring of Tunnels Option 1-2 Maasvlakte 2**

Site designation	Maasvlakte 2	
Preferred Technology	Slurry or variable density TBM	
Options Considered	Option 2	Option 3
Scoring Criteria		
Constructability	2	2
Logistics	4	4
Tunnelling Hazards	3	3
Environmental	3	3

### 8.2.2.2 Overall Scoring

**Cost** - Class 5 estimates show that the most likely cost of Options 1 and 2 is 0.5-1.0B euros while Option 3 is 1.5-2.0B euros.

**Constructability** – Option 1 has direct intake and outfall and no tunnelling, with relatively short channels. However there is an exposed environment and a trench and cover methodology that may need to be adopted. Overall constructability is judged to be moderate. Options 2 and 3 score is reduced by the introduction of the requirement for tunnels, which are judged to be a score of 2 in the section above.

**Cooling Water Environmental** – Option 1 has been modelled (configuration 5) and is shown to breach guidelines, whereas Option 2 has been modelled and is compliant. Option 3 has not been modelled but it appears, by inspection, that it is likely to be compliant.

**Cooling Water temperature** – ambient temperatures are acceptable however recirculation is shown as high in Option 1.

**Other Environmental** – Although options 1 and 2 require dredged channels in a Natura 2000, the channels are relatively short. It may be that a covered culvert needs to be adopted and this would eliminate effects on sediment transportation as well as working better on the exposed shoreline with high wave environment. Option 3 is a lower environmental impact with no dredging in the shallow water required.

**Ship Impact** – Option 1, there are no tunnel heads, Options 2 and 3 the Heads are located outside of the shipping channels in all cases. However, they are close to high density commercial shipping and there is leisure boat and fishing activity in this area.

**UXO risk** – Literature searches indicate moderate UXO risk in this area.

**Impact on local stakeholders** – no local leisure activities are known of and fishing activity is not concentrated in this area.

The overall scoring for this site is shown in Table 8.6.

**Table 8.6 Overall Scoring of Options 1-3 Maasvlakte 2**

Site designation	Maasvlakte – 2		
Preferred Technology	Slurry or variable density TBM		
Options Considered	Option 1	Option 2	Option 3
Scoring Criteria			
Cost	4	4	2
Constructability (Overall)	3	2	2
Cooling Water Environmental	1	5	4
Cooling Water Temperature	1	5	5
Other Environmental	2	2	5
Ship Impact	5	2	2
UXO risk	3	3	3
Impact local stakeholders	5	5	5
<b>Total score - baseline weighting</b>	300	345	325
<b>Total score - alternative weighting</b>	276	356	356

### 8.2.3 Preferred Option

While Option 1 is lower cost, it is clearly non-compliant with thermal guidelines. The weighted score show that Option 2 is preferred. Option 3 provides a low risk fall-back position, should permitting not be possible, however it does have a higher estimated cost.

## 9. Sloegebied

### 9.1 Summary of Cooling Water Modelling

The two Sloegebied sites are both classed as estuarial sites. Eight main configurations and three variations were modelled by Deltares references 12 and 13, and they are shown in Figure 9.1 and Figure 9.2.

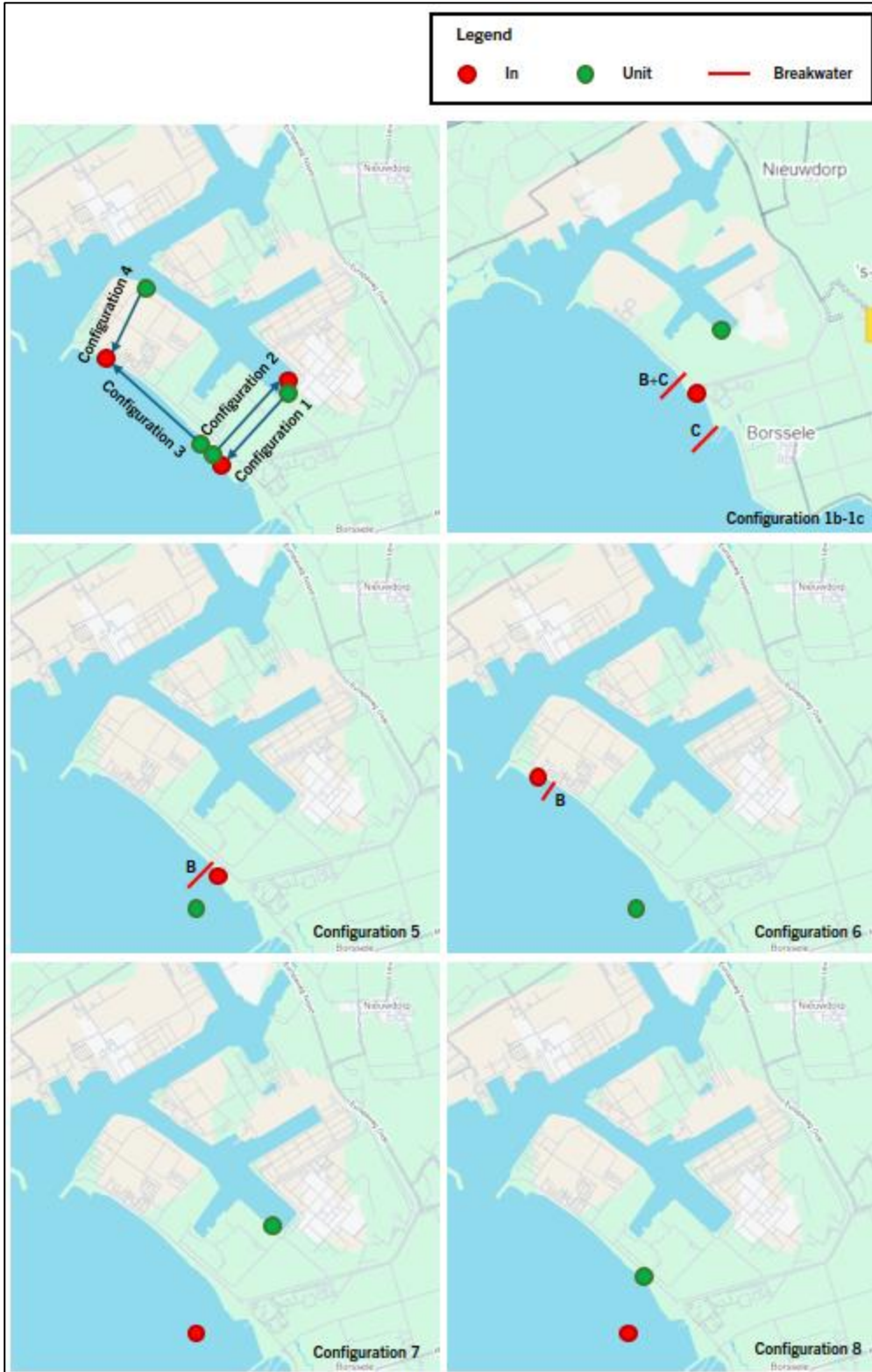
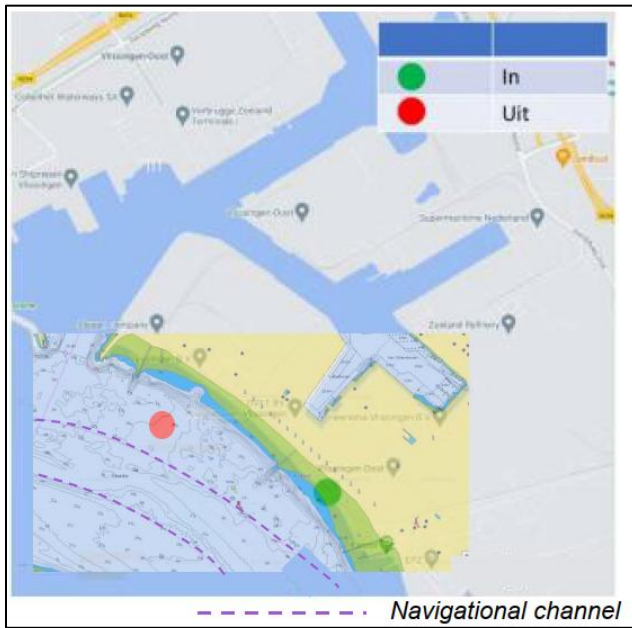


Figure 9.1 Eight configurations modelled - Sloegebied



**Figure 9.2 Final alternative configuration modelled – Sloegebied**

The results of the modelling are summarised in Table 9.1 and given a RAG status as explained below:

Configurations that use the port as the intake or outfall are discarded=> Red

Configuration 3 is directly relevant to Option 1, and this modelling shows that direct intake and outfall can work but are prone to high recirculation even with a large separation.

In all cases, except Configuration 2, where the outfall is into the dock, the MPMZ is safely within guidelines, as well as the mean temperature rise => green.

Recirculation is a concern for configurations 3, 8 and alternative, and they are categorised as Amber.

Configuration 8 informs the selection of the final Option, because it shows that there is no improvement by using an outfall tunnel and direct intake over having direct intake and outfall, and indeed, the recirculation is significantly worse.

Configuration 5 and 6 model an intake tunnel and direct outfall and are directly applicable to Option 2. They demonstrate a configuration that satisfies the thermal guidelines.

**Table 9.1 Summary of Thermal Modelling Results - Sloegebied**

		Intake	Outfall	Mixing zone %	Temp. [°C]	Recirculation mean/max
Configuration 1	Estuarine	Direct-dock	Direct-Scheldt	8	1	0.9/1.0
Configuration 2	Estuarine	Direct-Scheldt	Direct-dock	>50%	>8	0.8/1.0
Configuration 3	Estuarine	Direct-Scheldt	Direct-Scheldt	8	1	1.1/3.4
Configuration 4	Estuarine	Direct-dock	Direct-Scheldt	8	1	0.9/1.2
Configuration 5	Estuarine	Tunnel-Scheldt	Direct-Scheldt	8	1	0.7/1.0
Configuration 6	Estuarine	Tunnel-Scheldt	Direct-Scheldt	7	1.2	0.7/1.2
Configuration 7	Estuarine	Direct-dock	Tunnel-Scheldt	5	1	0.8/1.0
Configuration 8	Estuarine	Direct-Scheldt	Tunnel-Scheldt	5	1	1.0/2.6
Configuration 1b	Estuarine	Direct-dock	Direct-Scheldt	8	1	0.9/1.0
Configuration 1c	Estuarine	Direct-dock	Direct-Scheldt	8	1	0.9/1.0
Alternative	Estuarine	Direct-Scheldt	Tunnel-Scheldt	5	1	0.8/2.6

## 9.2 Sloegebied 1

### 9.2.1 Options Considered

Only two options are considered in this location, direct intake and outfall which is similar to configuration 3 and tunnel intake and direct outfall, similar to configuration 5/6 which is preferred to a tunnel outfall and direct intake based on the comparison with configuration 8 due to the lower recirculation.

#### 9.2.1.1 Option 1

This option entails direct intake and direct outfall as shown in Figure 9.3, with dimensions shown in Table 9.2.

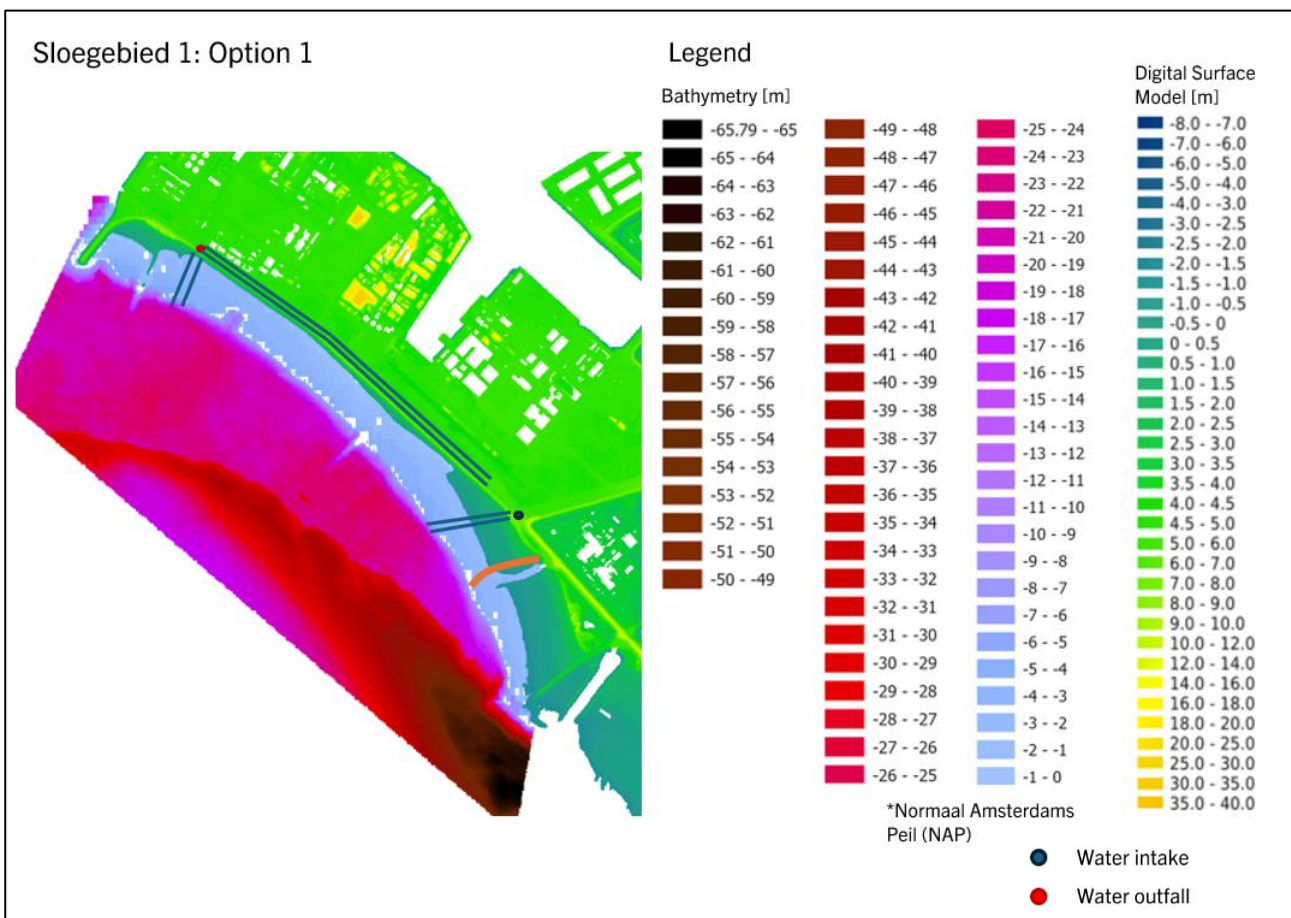


Figure 9.3 Sloegebied 1 - Option 1

Table 9.2 Dimensions - Sloegebied 1 Option 1

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (in)	~ 750	-	-	-
Dredged channel (out)	~ 600	-	-	
Canal (connecting)	~ 3 700	-	-	

\*Normaal Amsterdams Peil (NAP)

9.2.1.2 Option 2

This option entails two intake tunnels and direct outfall as shown in Figure 9.4 Sloegebied 1 - Option 2, with dimensions shown in Table 9.3.

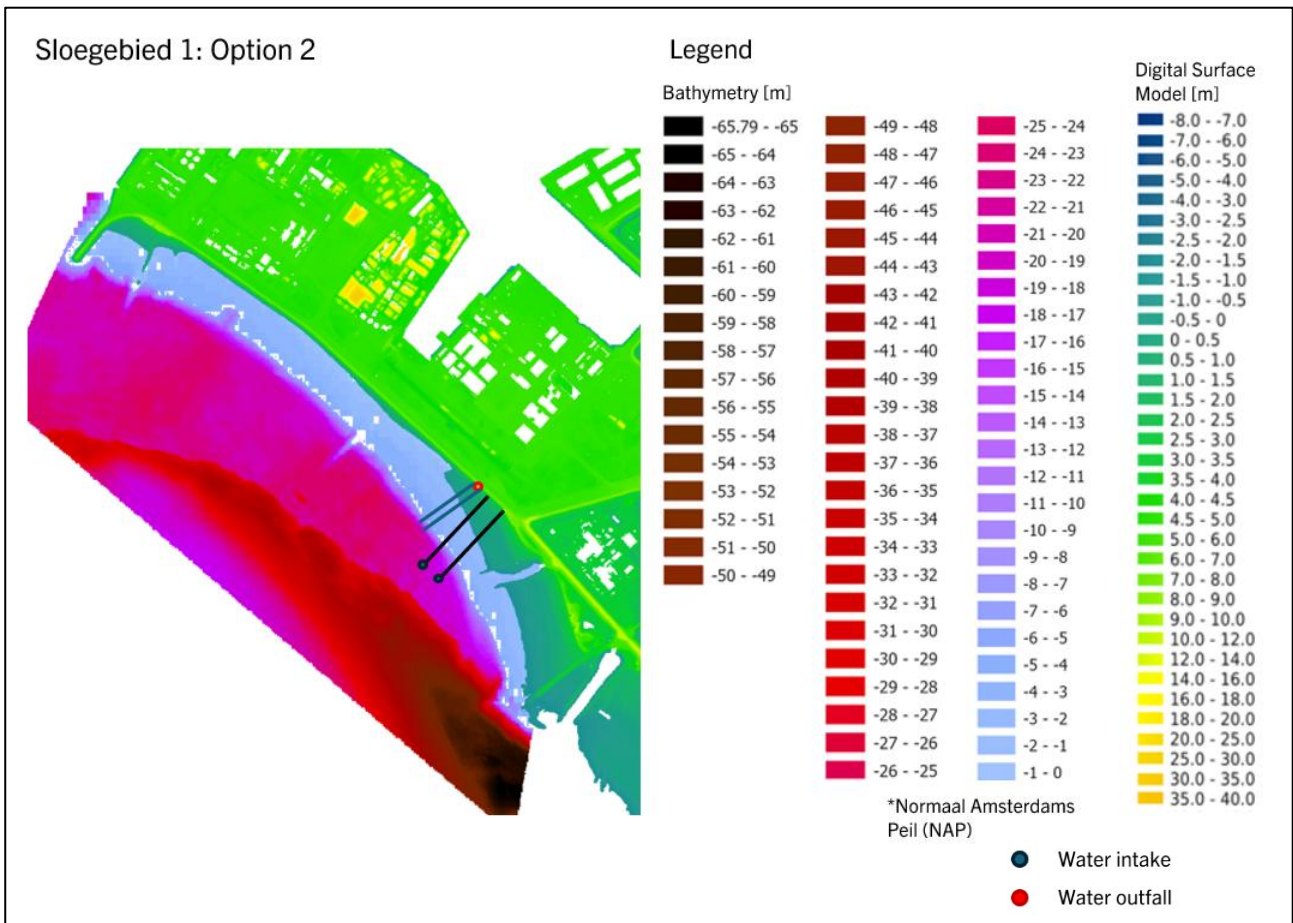


Figure 9.4 Sloegebied 1 - Option 2

Table 9.3 Dimensions - Sloegebied 1 Option 2

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (out)	~ 650	-	-	579 058
Tunnel (in, north)	~ 900	~ -20.0	289 529	
Tunnel (in, south)	~ 900	~ -18.5	289 529	

\*Normaal Amsterdams Peil (NAP)

## 9.2.2 Scoring Narrative

### 9.2.2.1 Tunnel Scoring

Only option 2 includes tunnels.

Review of the particle size distribution shows that a slurry or variable density TBM is identified as being the most suitable for the ground conditions.

The moderately high water pressure, permeable strata and challenges in achieving sufficient ground improvement to facilitate construction of the tunnel shaft connection dictate a low Constructability score.

The logistics score is reduced because the site is a lower area and worse access, although the proximity of the port is seen as positive.

Tunnelling hazards are not considered likely as there are no cables identified and there is no dock area to tunnel under.

The spoil is likely to require more treatment during mining and the re-use is likely to be lowest at this location.

The tunnel scoring is for this site is shown in Table 9.4.

**Table 9.4 Scoring of Tunnels Option 2 Sloegebied 1**

Site designation	Sloegebied 1
Preferred Technology	Slurry or variable density TBM
Options Considered	Option 2
Scoring Criteria	
Constructability	2
Logistics	3
Tunnelling Hazards	4
Environmental	2

### 9.2.2.2 Overall Scoring

**Cost** - Class 5 estimates show that the most likely cost of Options 1 is 0.5-1.0B euros while Option 2 is 1.0-1.5B euros.

**Constructability** – Option 1 has direct intake and outfall and no tunnelling, with relatively short channels. Overall constructability is judged to be moderate. Options 2 is reduced by the introduction of the requirement for tunnels, which are judged to be a score of 2 in the section above.

**Cooling Water Environmental** – Option 1 has been modelled in configuration 3 and Option 2 has been modelled in configuration 5 and compliance with guidelines in demonstrated in both cases.

**Cooling Water temperature** – ambient temperatures are acceptable however recirculation is shown as high in Option 1.

**Other Environmental** – Both options 1 and 2 require dredged channels in a Natura 2000 area, however the channels are relatively short and are in an area where other industrial outfalls are present. It may be that a trench and cover could be adopted and this would eliminate effects on sediment transportation if necessary. Option 2 is lower impact with no intake and the outfall right next to the outfall for EPZ.

**Ship Impact** – Option 1, there are no tunnel heads, Options 2 the Heads are located outside of the shipping channels in all cases. However, they are close to high density commercial shipping and there is leisure boat and fishing activity in this area.

**UXO risk** – Literature searches indicate that UXO risk is likely to be higher on the Scheldt than in the other locations.

**Impact on local stakeholders** – The channels cross a leisure beach and kitesurfing area. In option 1 there are two channels crossing the beach, while in Option 2 there is one channel which is close to the end of the beach and to an existing outfall.

The overall scoring for this site is shown in Table 9.5.

**Table 9.5 Overall Scoring of Options 1-2 Sloegebied 1**

Site designation	Borssele (Sloegedbied) - 1	
Preferred Technology	Slurry or variable density TBM	
Options Considered	Option 1	Option 2
Scoring Criteria		
Cost	4	3
Constructability (Overall)	3	2
Cooling Water Environmental	5	5
Cooling Water Temperature	3	5
Other Environmental	2	3
Ship Impact	5	2
UXO risk	2	2
Impact local stakeholders	1	3
Operability		
Total score - baseline weighting	325	310
Total score - alternative weighting	332	332

### 9.2.3 Preferred Option

The weighted scores show the two options are close together in scoring. Option 1 is preferred with the Base Weighting methodology and they are equal with the Alternative Weighting. The low scoring sections should be considered as a risk and the risks of permitting either option should be evaluated carefully along with the potential challenges, both legal and reputational, indicated by the low stakeholder score for Option 1. In summary, there is a lower cost, higher risk option and a higher cost lower risk option.

### 9.3 Sloegebied 2

#### 9.3.1 Options Considered

##### 9.3.1.1 Option 1

This option entails outfall tunnel and direct intake via a canal as shown in Figure 9.5, with dimensions shown in Table 9.6.

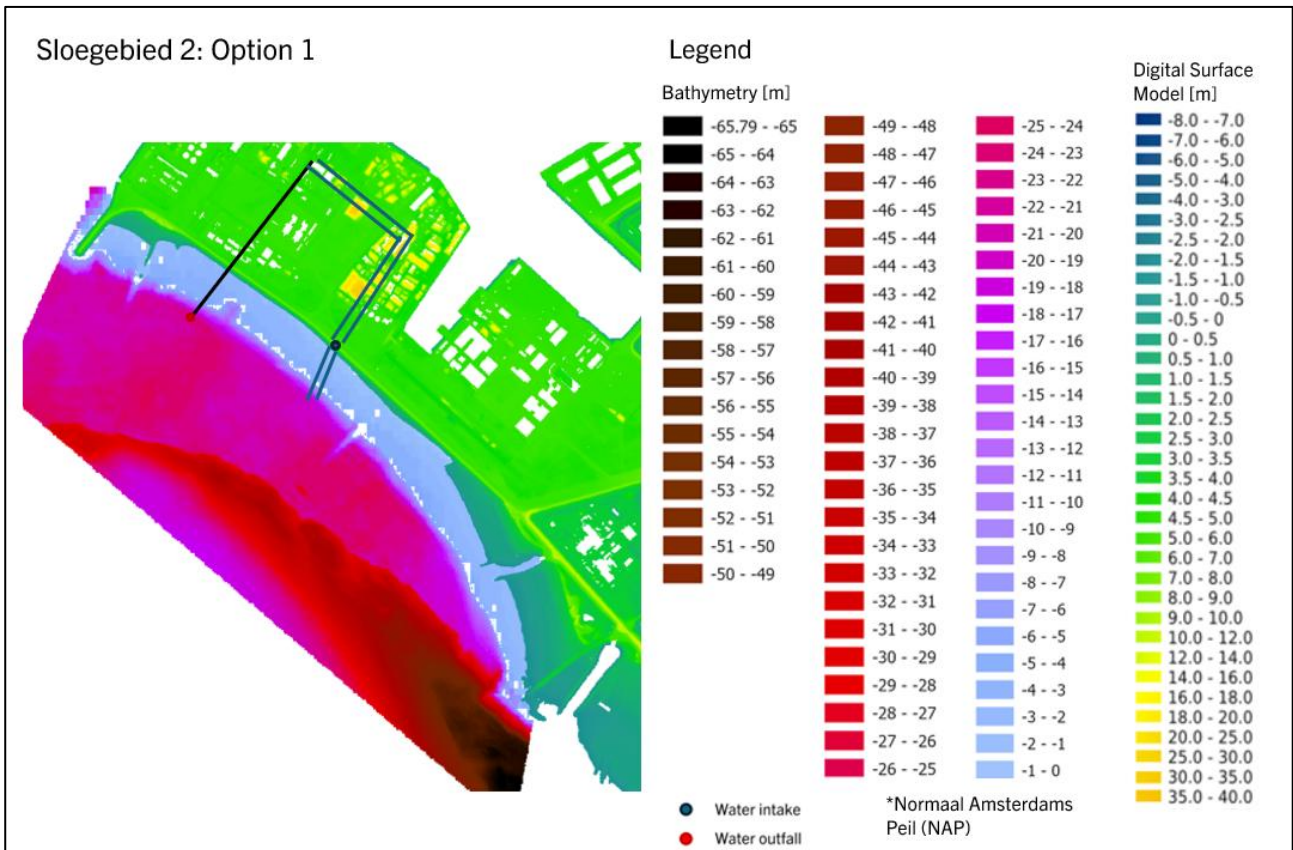


Figure 9.5 Sloegebied 2 - Option 1

Table 9.6 Dimensions - Sloegebied 2 Option 1

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Connecting channel	~ 2 300	-	-	833 844
Tunnel (out)	~ 1 800	~ -22.6	833 844	
Dredged channel (in)	~ 400	-	-	

\*Normaal Amsterdams Peil (NAP)

### 9.3.1.2 Option 2

This option entails two intake tunnels and direct outfall via an onshore canal or culvert as shown in Figure 9.6, with dimensions shown in Table 9.7.

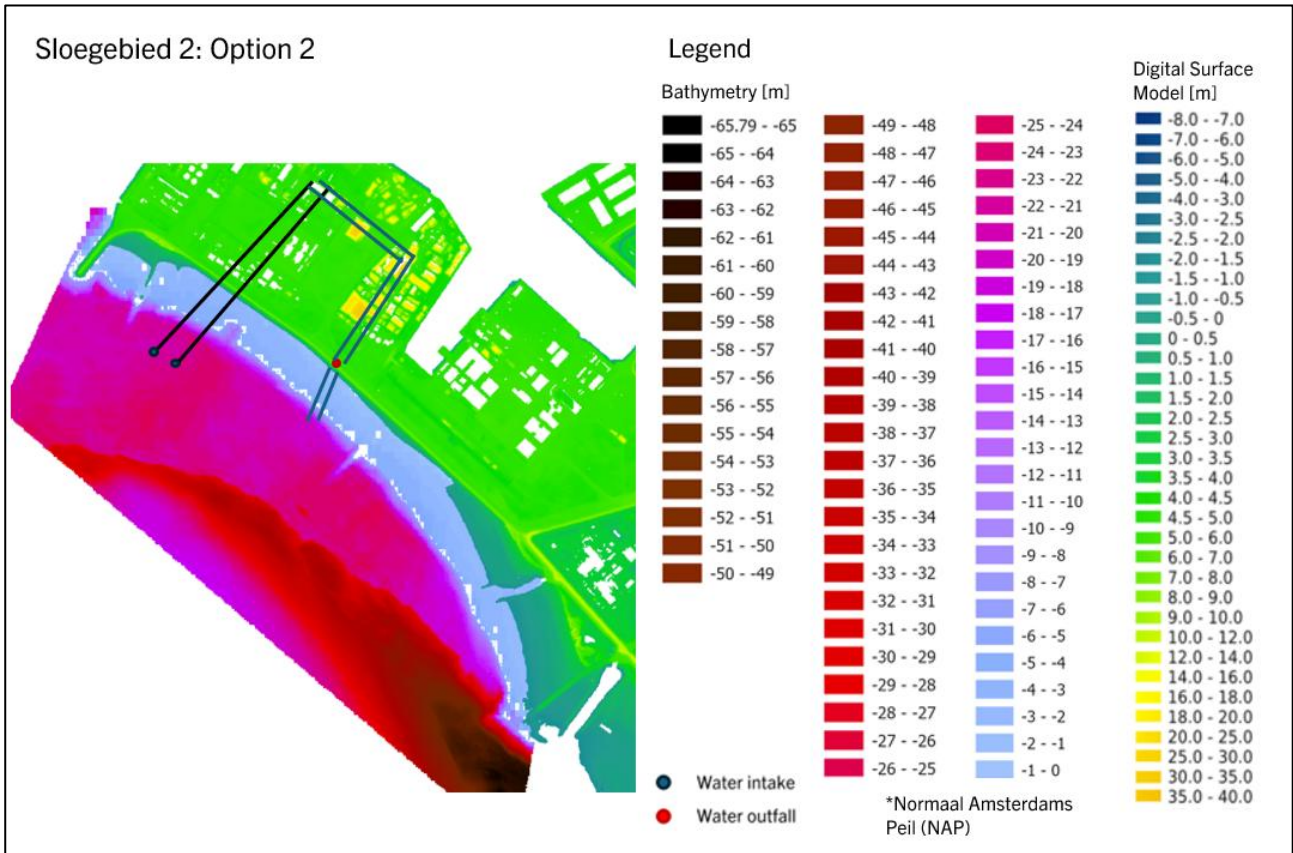


Figure 9.6 Sloegebied 2 - Option 2

Table 9.7 Dimensions - Sloegebied 2 Option 2

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Connecting channel	~ 2 300	-	-	1 351 136
Tunnel (in, west)	~ 2 100	~ -21.5	675 568	
Tunnel (in, east)	~ 2 100	~ -21.8	675 568	
Dredged channel (out)	~ 400	-	-	

\*Normaal Amsterdams Peil (NAP)

### 9.3.1.3 Option 3

This option entails two intake tunnels and one outfall tunnel as shown in Figure 9.7, with dimensions shown in Table 9.

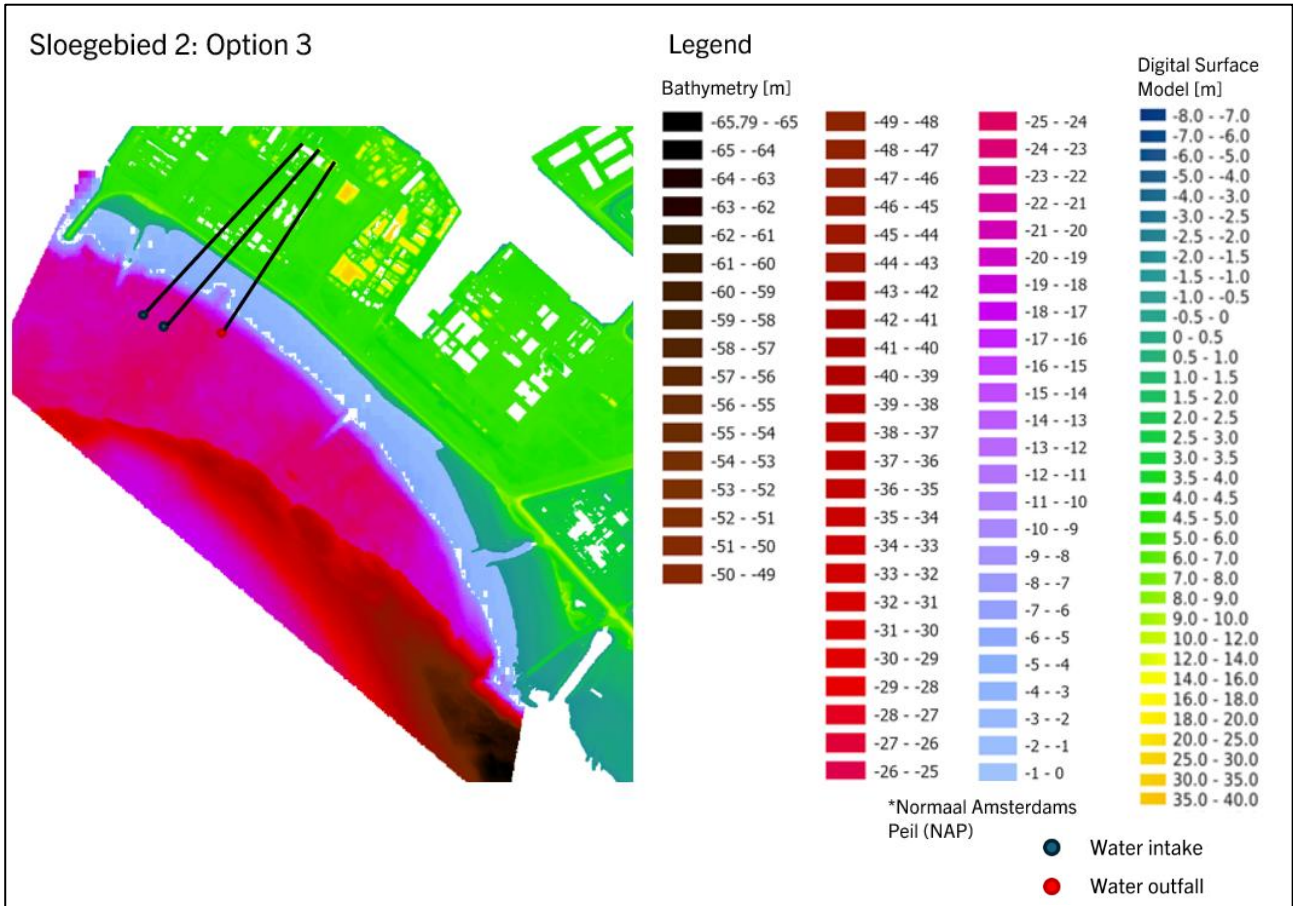


Figure 9.7 Sloegebied 2 - Option 3

Table 9.8 Dimensions - Sloegebied 2 Option 3

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Tunnel (in, north)	~ 2 100	~ -22.0	675 568	2 138 656
Tunnel (in, south)	~ 2 100	~ -22.0	675 568	
Tunnel (out)	~ 1 700	~ -21.0	787 519	

\*Normaal Amsterdams Peil (NAP)

## 9.3.2 Scoring Narrative

### 9.3.2.1 Tunnel Scoring

Review of the particle size distribution shows that a slurry or variable density TBM is identified as being the most suitable for the ground conditions.

The moderately high water pressure, permeable strata and challenges in achieving sufficient ground improvement to facilitate construction of the tunnel shaft connection dictate a low Constructability score.

The logistics score is reduced because the site is a lower area and worse access, although the proximity of the port is seen as positive.

Tunnelling hazards are considered likely. There are cables and gas pipelines present. More importantly, the area of land adjacent to the Scheldt that is to be tunnelled under is a power station with deep foundations likely.

The spoil is likely to require more treatment during mining and the re-use is likely to be lowest at this location.

The tunnel scoring for this site is shown in Table 9.

**Table 9.9 Tunnel Scoring – Sloegebied 2**

Site designation	Sloegebied- 2		
Preferred Technology	Slurry or variable density TBM		
Options Considered	Option 1	Option 2	Option 3
Scoring Criteria			
Constructability	2	2	2
Logistics	3	3	3
Tunnelling Hazards	2	2	2
Environmental	2	2	2

### 9.3.2.2 Overall Scoring

**Cost** - Class 5 estimates show that the most likely cost of Options 1 is 1.0-1.5B euros, Option 2 is 0.5—1.0B euros and Option 3 is 1.5-2.0B euros.

**Constructability** – All three options include tunnelling which is judged to have a constructability score of 2. The constructability of the extensive canal system is not seen as particularly problematic although the depth of the canal is significant in option 2 where it carries the inlet.

**Cooling Water Environmental** – Although all three options are informed by configurations 5,6 and 8 in the Deltares modelling reports, and appear likely to satisfy the RWS guidelines, they are not directly modelled and therefore score 4 not 5.

**Cooling Water temperature** – ambient temperatures are acceptable however recirculation having the potential to be above 2°C in option 2 and possibly, but far from certainly in option 3.

**Other Environmental** – Both Options 1 and 2 require dredged channels in a Natura 2000 area, however the channels are relatively short and are in an area where other industrial outfalls are present. It may be that a trench and cover could be adopted and this would eliminate effects on sediment transportation if necessary.

**Ship Impact** – There are tunnel heads in all three cases, and none of them are in a shipping lane. However, they are close to high density commercial shipping and there is leisure boat and fishing activity in this area.

**UXO risk** – Literature searches indicate that UXO risk is likely to be higher on the Scheldt than in the other locations.

**Impact on local stakeholders** – In Options 1 and 2 channels cross a leisure beach and kitesurfing area. They cross close to the middle causing maximum inconvenience.

The overall scoring for this site is shown in Table 9.

**Table 9.10 Overall Scoring of Options 1-3 Sloegebied 2**

Site designation	Sloegedebied - 2		
Preferred Technology	Slurry or variable density TBM		
Options Considered	Option 1	Option 2	Option 3
Scoring Criteria			
Cost	4	3	2
Constructability (Overall)	2	2	2
Cooling Water Environmental	4	4	4
Cooling Water Temperature	4	4	4
Other Environmental	2	2	5
Ship Impact	2	2	2
UXO risk	2	2	2
Impact local stakeholders	2	2	5
<b>Total score - baseline weighting</b>	<b>290</b>	<b>265</b>	<b>315</b>
<b>Total score - alternative weighting</b>	<b>296</b>	<b>276</b>	<b>340</b>

### 9.3.3 Preferred Option

The weighted scoring indicates that Option 3, the full tunnel solution would be the most favourable. The other options are high risk in a number of areas including stakeholder and environmental/permitting. The introduction of navigational hazards near a major port needs to be addressed whichever of the options is adopted.

## 10. Terneuzen

### 10.1 Summary of Cooling Water Modelling

Terneuzen is classed as an estuarine site.

Five configurations have been modelled at Terneuzen as described in Reference 15 and shown in Figure 10.1. The results are summarised in Table 10.1 and given an explanatory RAG status as follows:

- Mixing Zone - <20% is Green, >20%<25% is Amber, >25% is Red.
- Mean temperature rise - <2C is Green, 2C is Amber, >2C is Red.
- Recirculation – Max <2C is green, Max>2C<5C is Amber, >5C is Red

Configuration 2 informs us about the thermal effects from a direct outfall at the eastern end of the site and suggests that this creates a mixing zone that complies with the guidelines however they are interpreted. This validates the outfall location in Options 1 and 2.

Configurations 1,3 and 5 inform us of the effect of a tunnel outfall significantly into the Scheldt and suggests that the mixing zone is fully compliant with the guidelines if the entire width of the Scheldt is considered as the reference. However, it is very marginal (MPMZ = 25%) of whether it is compliant if only the southern channel is considered.

Configuration 5 informs us that it is possible to take water from the inshore southern channel, as is proposed in Option1.

Configuration 4 informs us that if a tunnel outfall is adopted then it is advantageous for it to be located clearly within the main southern channel of the Scheldt rather than close to the edge where the direct outfall would be.

Table 10.2 is produced in order to show the effect of the proposed Terneuzen development on other intakes in the area. It shows that Configurations 2 and 4 have a significant impact (circa 2°C) on Dow Benelux. This indicates that Option 1 (preferred option for both Terneuzen 1A and 1B) would also impact Dow Benelux and some engagement and legal advice would be merited before adoption of this option.

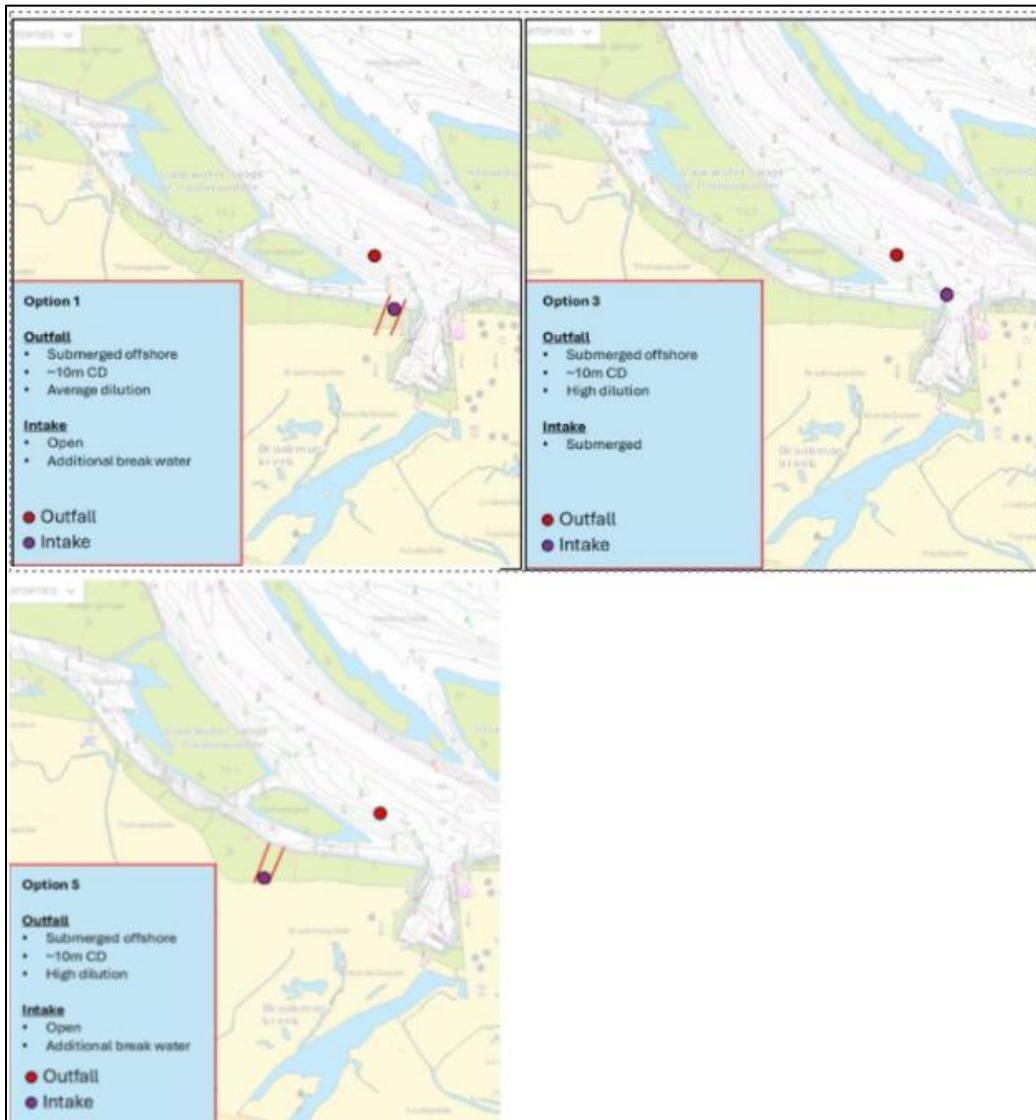


Figure 10.1 Configurations modelled – Terneuzen

Table 10.1 Summary of results of thermal modelling - Terneuzen

		Intake	Outfall	Mixing zone % Full area	Temp. [°C] Full area	Mixing zone % South Channel	Temp. [°C] South Channel	Recirculation Mean/max
Configuration 1	Eustarine	Direct sea	Tunnel sea	10	1.0	25	1.8	1.2/1.4
Configuration 2	Eustarine	Tunnel sea	Direct sea	8	1.0	18	1.8	0.9/1.8
Configuration 3	Eustarine	Tunnel sea	Tunnel sea	10	1.0	25	1.9	1.2/1.6
Configuration 4	Eustarine	Tunnel sea	Tunnel sea	18	1.2	43	2.0	1.0/2.1
Configuration 5	Eustarine	Direct sea	Tunnel sea	10	1.0	25	1.9	1.1/1.5

Table 10.2 Temperature Effect of Terneuzen NPP on other intakes

Intakes	DowBenelux [°C]		EPZ [°C]		SloeCentale [°C]		Zalco BV [°C]	
	mean	max	mean	max	mean	max	mean	max
Configuration 1	1.1	1.5	0.6	1.1	0.5	0.9	0.5	0.9
Configuration 2	1.8	2.3	0.5	0.9	0.4	0.8	0.5	0.8
Configuration 3	1.1	1.5	0.6	1.1	0.5	0.9	0.5	0.9
Configuration 4	2.4	3.4	0.5	1.0	0.5	0.8	0.5	0.9
Configuration 5	1.1	1.5	0.6	1.1	0.5	0.8	0.5	0.9

## 10.2 Terneuzen 1A

### 10.2.1 Options Considered

Direct intake and outfall are considered, taking water from the southern inshore channel and discharging to the east where the southern channel meets the main channel. Tunnel intake from the main channel and direct outfall is considered. Finally an all tunnel option is considered with both the intake and outfall in the main channel are considered.

The direct intake at the eastern end of the southern channel is not considered as the intake from the southern channel is shown to be acceptable thermally and is assessed to be preferred from a construction viewpoint.

The tunnel outfall to the east where the southern channel meets the main channel is not considered as it appears to be worse thermally than an outfall in the main channel.

#### 10.2.1.1 Option 1

This option entails intake tunnel and direct outfall as shown in Figure 10.2, with dimensions shown in Table 10.3.

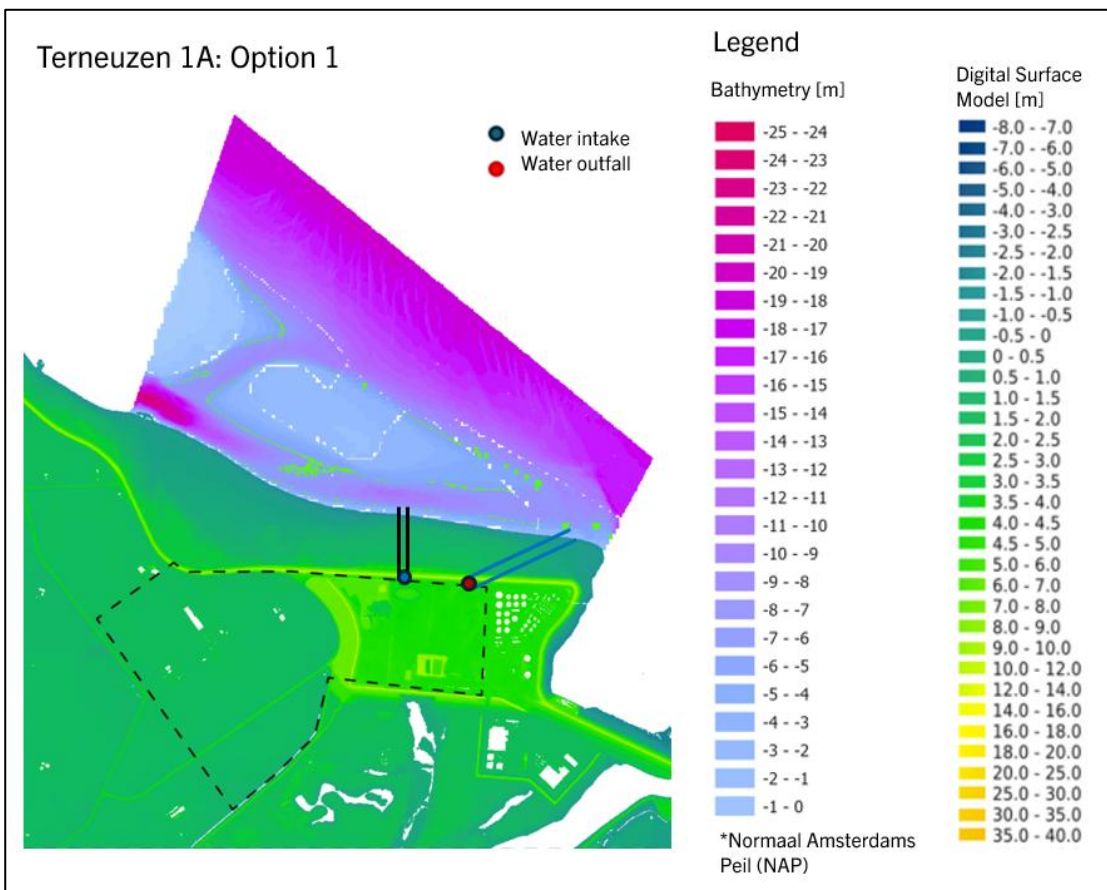


Figure 10.2 Terneuzen 1A - Option 1

Table 10.3 Dimensions - Terneuzen 1A Option 1

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (out)	~ 1 300	-	-	-
Dredged channel (in)	~ 750	-	-	-

\*Normaal Amsterdams Peil (NAP)

10.2.1.2 Option 2

This option entails two intake tunnels and direct outfall as shown in Figure 10.3, with dimensions shown in Table 10.4.

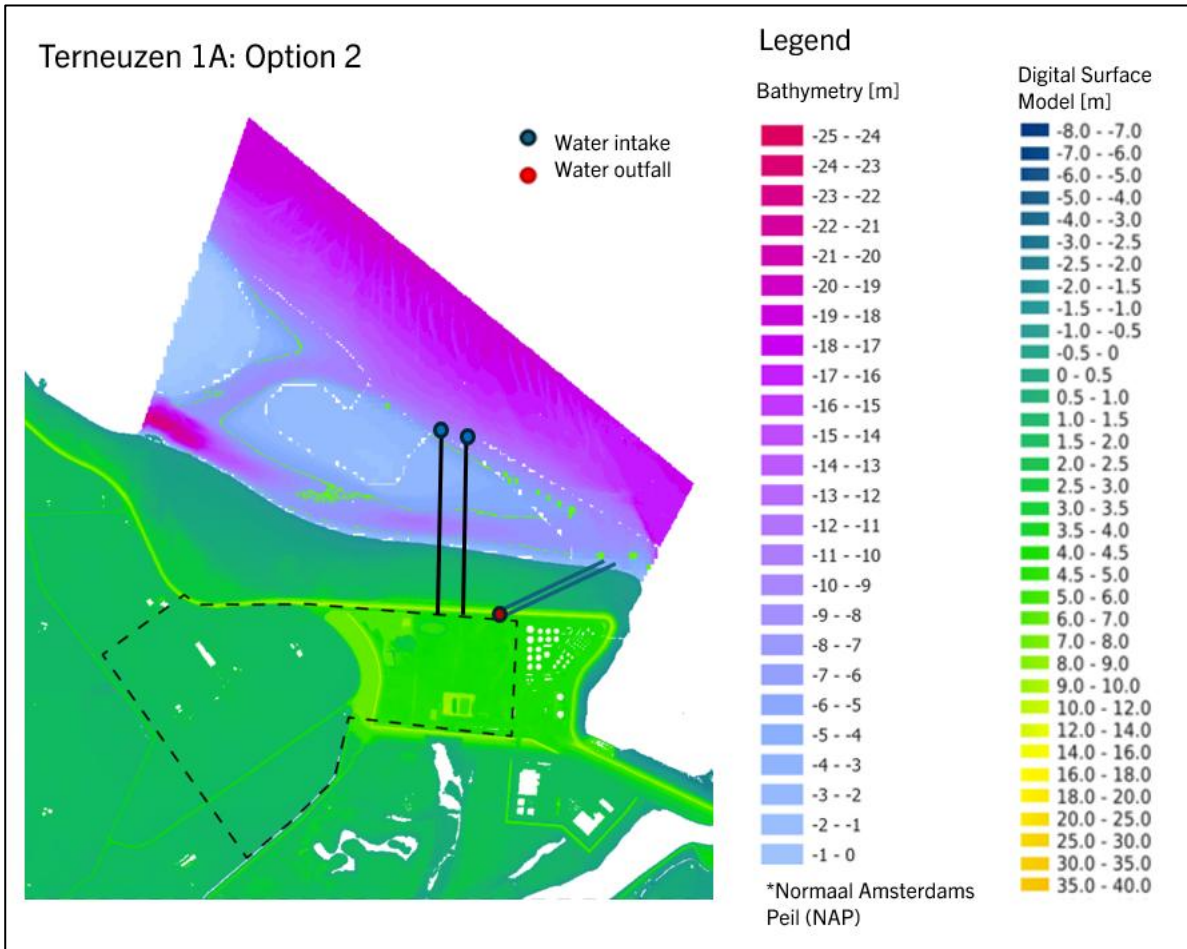


Figure 10.3 Terneuzen 1A - Option 2

Table 10.4 Dimensions - Terneuzen 1A Option 2

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (out)	~ 1 300	-	-	1,254,626
Tunnel (in, west)	~ 2 000	~ -12.6	643 398	
Tunnel (in, east)	~ 1 900	~ - 11	611 228	

\*Normaal Amsterdams Peil (NAP)

### 10.2.1.3 Option 3

This option entails two intake tunnels and outfall tunnel as shown in Figure 10.4, with dimensions shown in Table 10.5.

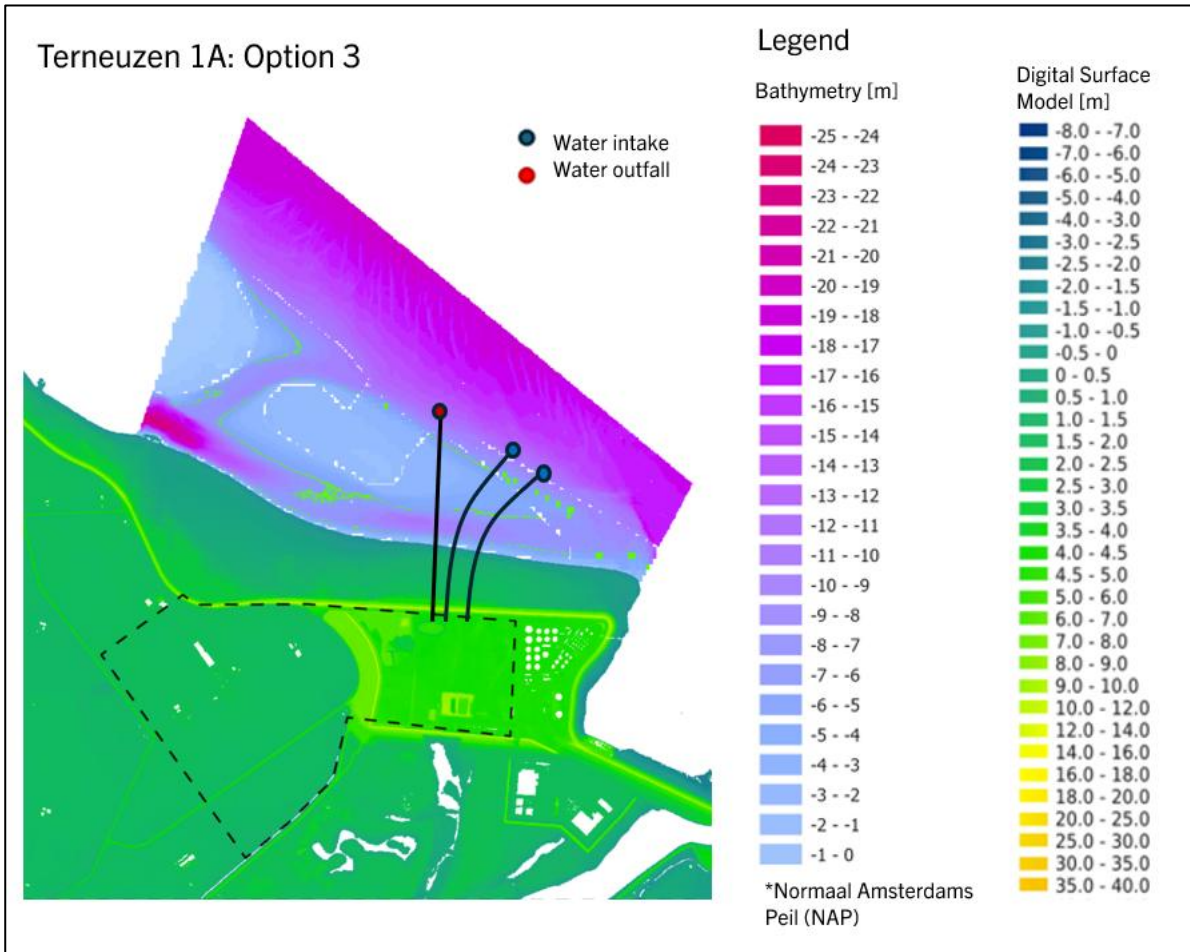


Figure 10.4 Terneuzen 1A - Option 3

Table 10.5 Dimensions - Terneuzen 1A Option 3

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Tunnel (out)	~ 2 600	~ -14.2	1 204 441	2 555 578
Tunnel (in, west)	~ 2 200	~ -13.2	707 738	
Tunnel (in, east)	~ 2 000	~ -13.2	643 398	

\*Normaal Amsterdams Peil (NAP)

## 10.2.2 Scoring Narrative

### 10.2.2.1 Tunnel Scoring

Review of the particle size distribution shows that an EPB TBM is identified as being the most suitable for the ground conditions.

The moderately high water pressure and challenges in achieving sufficient ground improvement to facilitate construction of the tunnel shaft connection are negative for constructability, however the ground conditions at this site are mainly stiff homogeneous clay with some discrete cohesionless zones. These ground conditions are better than any other location.

The logistics score is based on sufficient site area being available and the proximity of the port is seen as positive.

The spoil is relatively homogenous and the amount of treatment required is expected to be limited with good opportunities for re-use.

The tunnel scoring is for this site is shown in Table 10.6.

**Table 10.6 Tunnel Scoring Terneuzen 1A**

Site designation	Sloegebied- 2	
Preferred Technology	Slurry or variable density TBM	
Options Considered	Option 2	Option 3
Scoring Criteria		
Constructability	3	3
Logistics	4	4
Tunnelling Hazards	3	3
Environmental	4	4

### 10.2.2.2 Overall Scoring

**Cost** - Class 5 estimates show that the most likely cost of Options 1 is 0-0.5B euros, Option 2 is 1.0—1.5B euros and Option 3 is 1.5-2.0B euros.

**Constructability** – Options 2 and 3 include tunnelling, which has been scored as 3 above. Option 1 is a direct intake with the marine works in an environment with lower waves than most other sites.

**Cooling Water Environmental** – Option 1 intake maps onto configuration 5 which was modelled by Deltares while the outfall corresponds to configuration 2. Both show full compliance with the guidelines. Option 2 maps onto configuration 2 completely and compliance to guidelines is demonstrated. Option 3 is close to configuration 3, but with the outfall moved to the northwest, which shows compliance so long as the reference area is the full width of the Scheldt.

**Cooling Water temperature** – ambient temperatures are acceptable however recirculation is shown as high in Option 3.

**Other Environmental** – Both Options 1 and 2 require dredged channels in a Natura 2000 area. It may be that a covered culvert could be adopted and this would eliminate effects on sediment transportation if necessary, but there is a very high risk that permitting may not be possible and that full tunnel solution would be required.

**Ship Impact** – There are tunnel heads in Options 2 and 3. They are in an area with a high density of commercial shipping with fishing and leisure vessels also present and limited navigational options due to the sandbank to the south.

**UXO risk** – Literature searches indicate that UXO risk is likely to be higher on the Scheldt than in the other locations.

Impact on local stakeholders – No leisure users have been identified at Terneuzen.

The overall scoring for this site is shown in Table 10.7.

**Table 10.7 Overall Scoring of Options 1-3 Terneuzen 1A**

Site designation	Terneuzen - 1A		
Preferred TBM Technology	EPB TBM		
Options Considered	Option 1	Option 2	Option 3
Scoring Criteria			
Cost	5	3	2
Constructability (Overall)	4	3	3
Cooling Water Environmental	5	5	4
Cooling Water Temperature	5	5	4
Other Environmental	1	1	5
Ship Impact	5	1	1
UXO risk	2	2	2
Impact local stakeholders	5	5	5
<b>Total score - baseline weighting</b>	<b>405</b>	<b>315</b>	<b>330</b>
<b>Total score - alternative weighting</b>	<b>388</b>	<b>308</b>	<b>340</b>

### 10.2.3 Preferred Option

Option 1 shows as the lowest score in this location. However, the score of 1 for other environmental should be taken as a risk flag indicating that permitting for this scheme may not be possible. Option 3 represents a lower risk, higher cost alternative although it has potential risks flagged for ship impact.

### 10.3 Terneuzen 1B

#### 10.3.1 Options Considered

The same set of options are considered for Terneuzen 1B as Terneuzen 1A with the addition of direct intake tunnel outfall. This is considered in this location as the tunnel is naturally further west in the main channel than if this configuration was adopted in Terneuzen 1A.

##### 10.3.1.1 Option 1

This option entails direct intake and direct outfall as shown in Figure 10.5, with dimensions shown in Table 10.8.

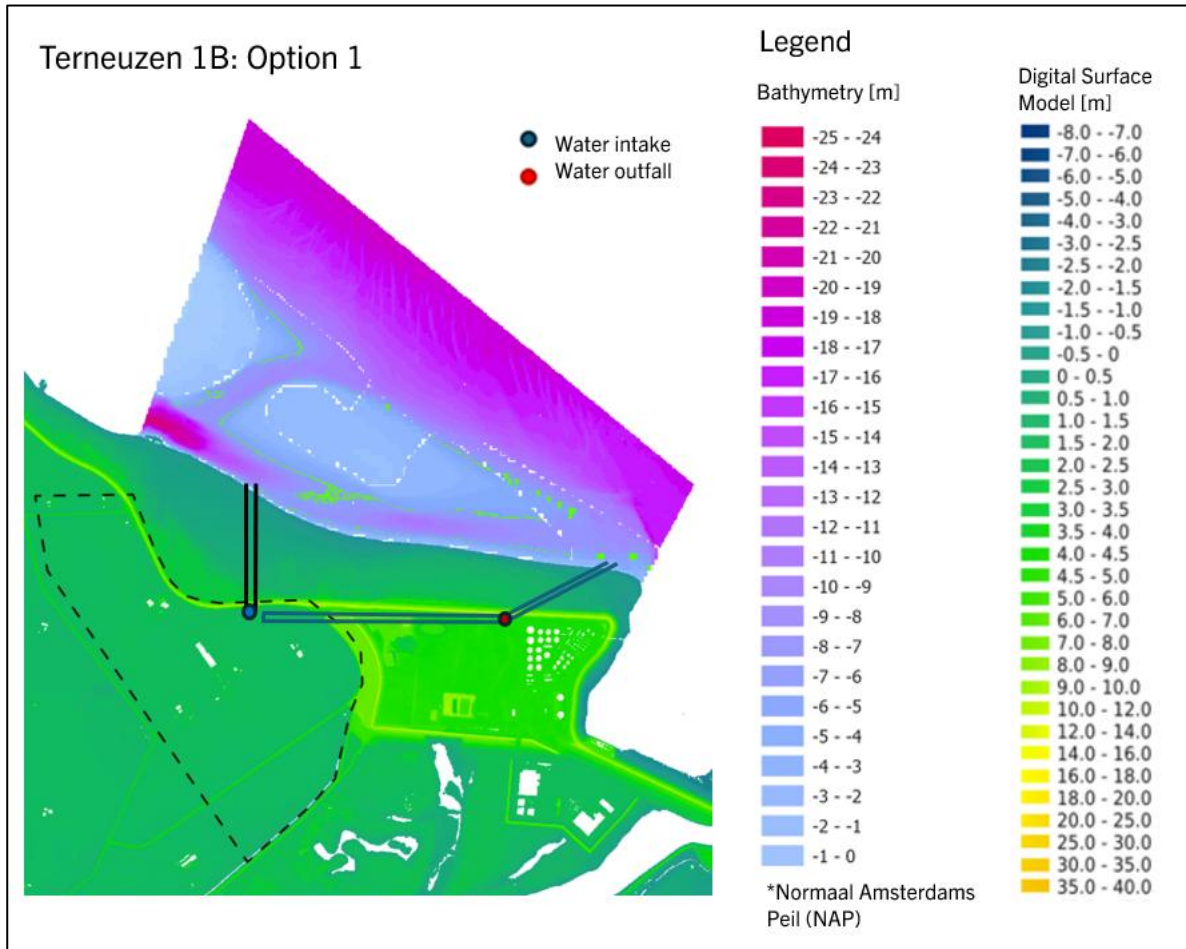


Figure 10.5 Terneuzen 1B - Option 1

Table 10.8 Dimensions - Terneuzen 1B Option 1

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (out)	~ 1 300	-	-	-
Dredged channel (in)	~ 1 300	-	-	
Canal (connecting)	~ 2 800	-	-	

\*Normaal Amsterdams Peil (NAP)

### 10.3.1.2 Option 2

This option entails direct intake and outfall tunnel as shown in Figure 10.6, with dimensions shown in Table 10.9.

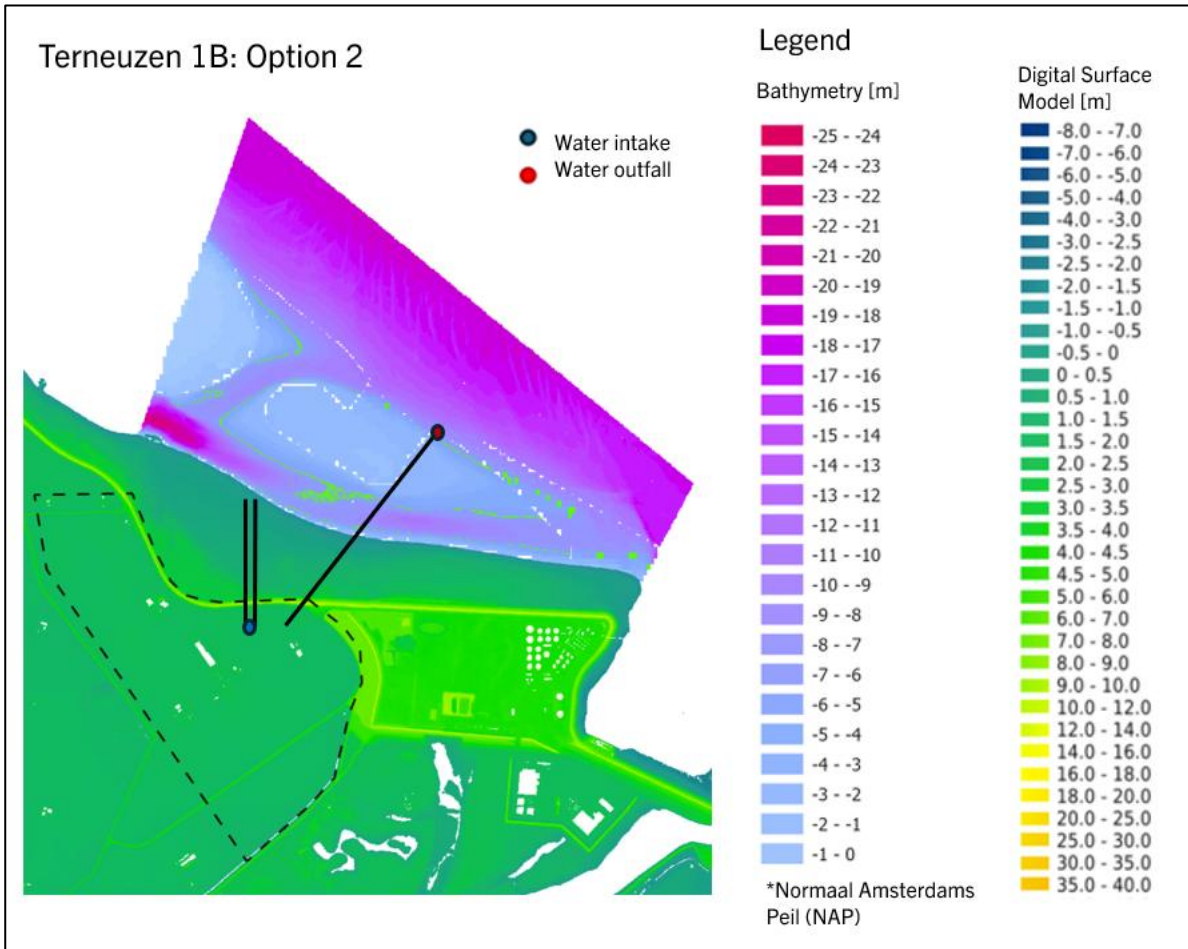


Figure 10.6 Terneuzen 1B - Option 2

Table 10.9 Dimensions - Terneuzen 1B Option 2

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Dredged channel (in)	~ 1 300	-	-	900 757
Tunnel (out)	~2 800	~ -12.6	900 757	

\*Normaal Amsterdams Peil (NAP)

### 10.3.1.3 Option 3

This option entails two intake tunnels and direct outfall as shown in Figure 10.7, with dimensions shown in Table 10.10.

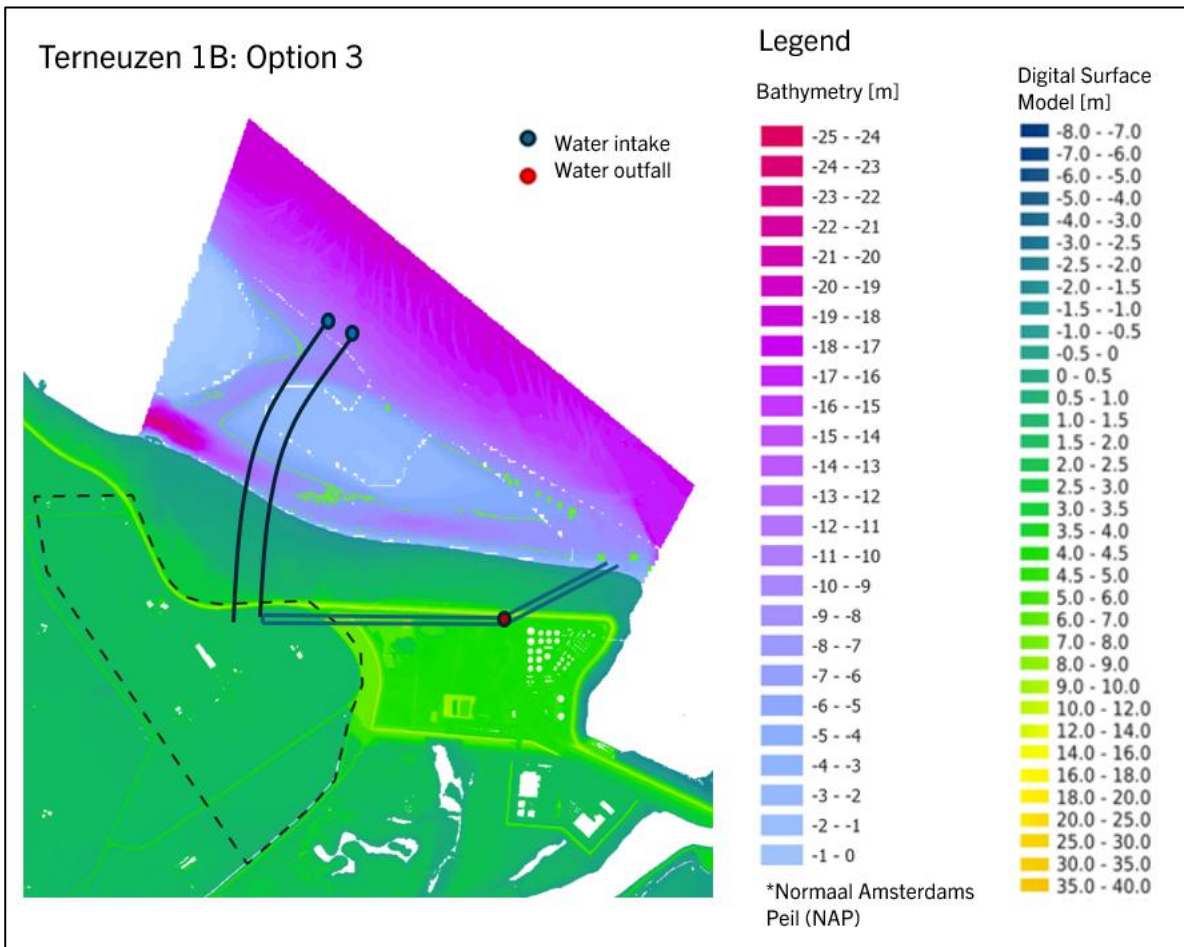


Figure 10.7 Terneuzen 1B - Option 3

Table 10.10 Dimensions - Terneuzen 1B Option 3

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Tunnel (in, west)	~ 3 400	~ -10.9	1 093 777	2 187 554
Tunnel (in, east)	~ 3 400	~ -12.4	1 093 777	
Dredged channel (in)	~ 1 300	-	-	
Canal (conntecting)	~ 2 800	-	-	

\*Normaal Amsterdams Peil (NAP)

### 10.3.1.4 Option 4

This option entails two intake tunnels and one outfall tunnel as shown in Figure 10.8, with dimensions shown in Table 10.11.

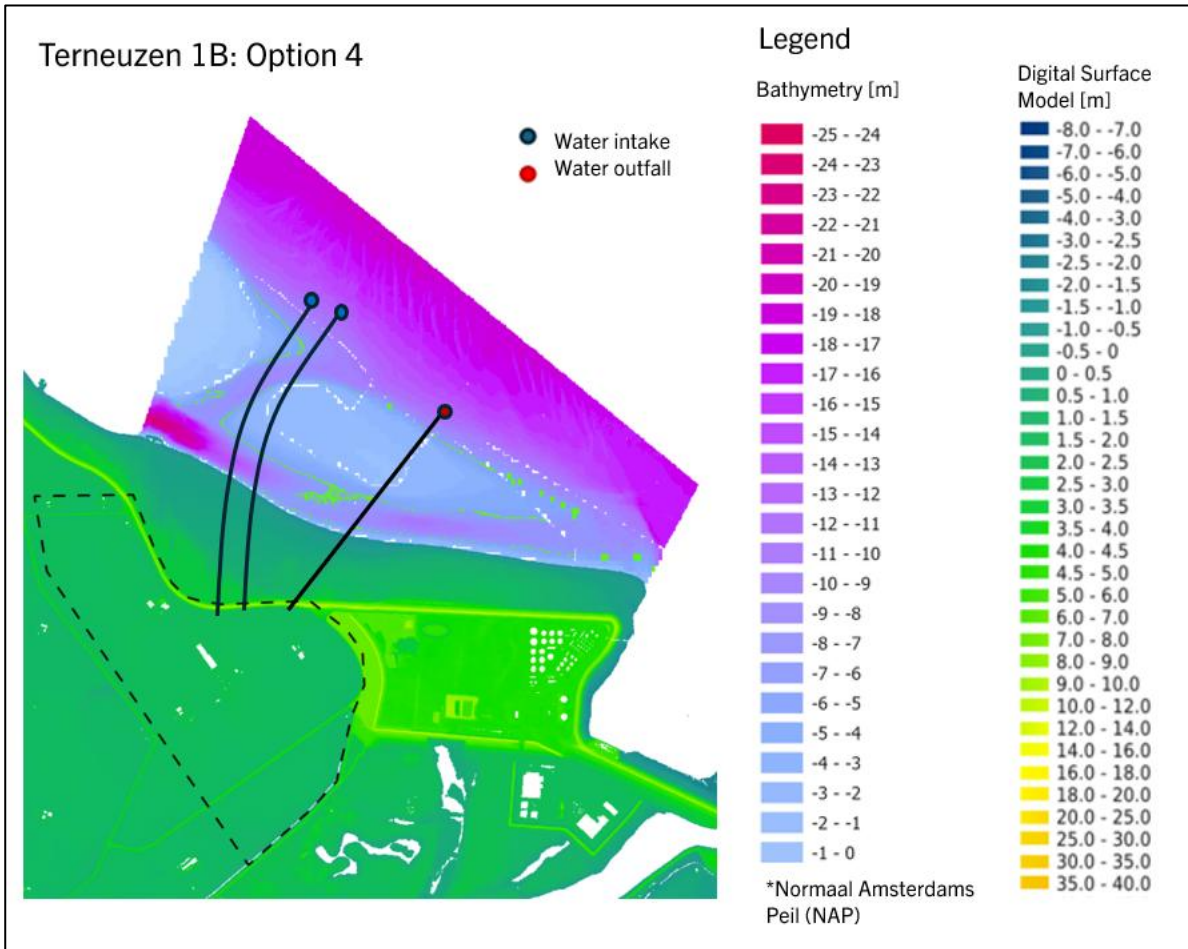


Figure 10.8 Terneuzen 1B - Option 4

Table 10.11 Dimensions - Terneuzen 1B Option 4

Object	Length [m]	Depth of the sea at the end of the tunnel [m]*	Spoil volume [m <sup>3</sup> ]	Total spoil per option [m <sup>3</sup> ]
Tunnel (in, west)	~3 400	~ -10.9	1 093 777	3 484 645
Tunnel (in, east)	~3 400	~ -12.4	1 093 777	
Tunnel (out)	~2 800	~ -12.6	1 297 091	

\*Normaal Amsterdams Peil (NAP)

## 10.3.2 Scoring Narrative

### 10.3.2.1 Tunnel Scoring

Review of the particle size distribution an EPB TBM is identified as being the most suitable for the ground conditions.

The moderately high water pressure and challenges in achieving sufficient ground improvement to facilitate construction of the tunnel shaft connection are negative for constructability, however the ground conditions at this site are mainly stiff homogeneous clay with some discrete cohesionless zones.

The logistics score is based on sufficient site area being available and the proximity of the port is seen as positive.

The spoil is expected to be slightly more mixed and the amount of treatment required is expected to be slightly higher than Terneuzen 1A with correspondingly slightly less opportunities for re-use.

The tunnel scoring is for this site is shown in Table 10.12.

**Table 10.12 Tunnel scoring – Terneuzen 1B**

Site designation	Slogebied- 2		
Preferred Technology	EPB TBM		
Options Considered	Option 2	Option 3	Option 4
Scoring Criteria			
Constructability	3	3	3
Logistics	4	4	4
Tunnelling Hazards	3	3	3
Environmental	3	3	3

### 10.3.2.2 Overall Scoring

**Cost** - Class 5 estimates show that the most likely cost of Options 1 and 2 is 0.5-1.0B euros, Option 3 is 1.0—1.5B euros and Option 4 is 1.5-2.0B euros.

**Constructability** – Options 2, 3 and 4 include tunnelling, which has been scored as 3 above. Option 1 is a direct intake with the marine works in a lower impact environment. However it does have significant onshore works with associated construction and land ownership issues.

**Cooling Water Environmental** – Option 1 intake maps onto configuration 5 which was modelled by Deltares while the outfall corresponds to configuration 2. Both show full compliance with the guidelines. Option 2 maps onto configuration 5 completely and compliance to guidelines is demonstrated. Option 3 maps onto configuration 2, which shows full compliance with guidelines. Option 4 is close to configuration 3 which shows compliance so long as the reference area is the full width of the Scheldt.

**Cooling Water temperature** – ambient temperatures are acceptable however recirculation is shown as high in Option 4.

**Other Environmental** – Options 1, 2 and 3 require dredged channels in a Natura 2000 area. It may be that a covered culvert could be adopted and this would minimise effects on sediment transportation, but there is a very high risk that permitting may not be possible and that full tunnel solution would be required.

**Ship Impact** – There are tunnel heads in Options 2, 3 and 4. They are in an area with a high density of commercial shipping with fishing and leisure vessels also present and limited navigational options due to the sandbank to the south.

**UXO risk** – Literature searches indicate that UXO risk is likely to be higher on the Scheldt than in the other locations.

**Impact on local stakeholders** – No leisure users have been identified at Terneuzen.

The overall scoring for this site is shown in Table 10.13.

Table 10.13 Overall Scoring of Options 1-4 Terneuzen 1B

Site designation	Terneuzen - 1B			
Preferred Technology	EPB TBM			
Options Considered	Option 1	Option 2	Option 3	Option 4
Scoring Criteria				
Cost	4	4	3	2
Constructability (Overall)	3	3	3	3
Cooling Water Environmental	5	5	5	4
Cooling Water Temperature	5	5	5	4
Other Environmental	1	1	1	5
Ship Impact	5	1	1	1
UXO risk	2	2	2	2
Impact local stakeholders	5	5	5	5

Total score - baseline weighting	360	340	315	330
Total score - alternative weighting	360	328	308	340

### 10.3.3 Preferred Option

Option 1 shows as a the lowest scoring option. However, the score of 1 for other environmental should be taken as a risk flag indicating that permitting for this scheme may not be possible. Option 4 represents a lower risk but higher cost alternative. However, Option 4 is high risk regarding ship impact.

# 11. Risks and Mitigations

The following risks are present in one or more sites. In terms of their effect they are evaluated as part of the scoring on a risk-neutral basis, however by their nature they all have an uncertain element to them which are highlighted here.

KGG requested an impact evaluation which estimated the probability of risk realisation, the time impact and the cost impact categorised according to the bands shown in Figure 11.1. The emojis shown in the table have been used in the main body of the report to give a quick , understandable summary. Due to the nature of the work this is based on expert judgement but is not amenable to quantification.

Gevolgen kosten (costs)				Gevolgen uitloop tijd (time)				Risico-inschatting (risks)			
Class	Consequence for costs	Range		Class	consequence for time	Range		Class	chance of occurrence	Range	
		Euro				months				%	
1 / 🟡	Low	0	100 mln	1 / 🟡	Low	0	6	1 / 🟡	Low	0	2,5
2 / 🟡🟡	Medium	100 mln	500 mln	2 / 🟡🟡	Medium	6	12	2 / 🟡🟡	Medium	2,5	10
3 / 🟡🟡🟡	High	500 mln	1 mld	3 / 🟡🟡🟡	High	12	24	3 / 🟡🟡🟡	High	10	25
4 / 🟡🟡🟡🟡	Very high	1 mld	2 mld	4 / 🟡🟡🟡🟡	Very high	24	36	4 / 🟡🟡🟡🟡	Very high	25	50
5 / 🟡🟡🟡🟡🟡	Exeptional	> 2 mld		5 / 🟡🟡🟡🟡🟡	Exeptional	> 36		5 / 🟡🟡🟡🟡🟡	Almost certain	> 50	

Figure 11.1 Overall Scoring Terneuzen 1B

## 11.1 Permitting Risks

### 11.1.1 Risk

The Risk described is the risk of environmental permitting in the marine environment, and while significant work has been carried out on the thermal effects of the CWS, this risk focusses particularly on the difficulty in achieving a permit to construct the CWS in a marine environment considering:

- The wide range of characteristics of the local marine environment used for cooling water abstraction and discharge;
- The physical and environmental characteristics of the local estuarine, shoreline and near on-shore environment; and
- The specific factors of engineering design, construction method and plant operations which are pertinent to quantification and assessment of environmental risk.

‘Permitting risk’ as defined above will feature in all site feasibility studies applies to all sites to varying degrees. The potential for major coastal construction projects to affect the marine/estuarine environment should always be assessed and it is to be expected that a significant amount of effort and resources will be expended on defining the relevant conditions and any follow-on constraints on the design, construction and operating processes in order to ensure its impact on the environment does not present unacceptable risk, therefore resulting in a failure to achieve the required permit.

In this case this risk is more acute because the Eemshaven sites are in a UNESCO World Heritage Site, specifically denoted as such due to its exceptional ecological value, dynamic natural processes, and critical role in global biodiversity. It is also, along with all of the other sites completely within a Natura 2000 areas. Natura 2000 is a network of protected areas covering Europe's most valuable and threatened species and habitats. It is the largest coordinated network of protected areas in the world,

extending across all 27 EU Member States, both on land and at sea. The sites within Natura 2000 are designated under the Birds and the Habitats Directives (SPAs or SACs).

Direct intake/outfall, by virtue of the requirement to have an open water channel into the site, is likely to have a significant impact on the environment, and will require a robust programme of investigation, assessment and analysis which may result in argumentation and significant constraints on the construction methodology in order to gain the permits. Factors to consider include, but are not limited to:

- A large area of the intertidal zone and shallow water has to be dredged disturbing the flora and fauna in that zone and potentially changing the hydrology and near-surface hydrogeology of the area;
- Shoreline sediment transfer is disrupted, and the long term effects such as disturbance of habitats, pollutant release, shoreline instability and effects on movement of species of must be considered.
- A barrier is created to some species moving along the shore
- The spoil generated is large and needs to be disposed of if no re-use can be achieved. Normally this is offshore disposal and that impacts the disposal zone.
- Air and water borne noise are extensive, particularly if piling is required to reinforce parts of the structure.

Tunnelling using a TBM is normally seen as lower environmental impact, with the main areas of focus being the installation of the offshore shaft and head. The area directly impacted is relatively small and the spoil generated is relatively low, compared to direct intake. Underwater and airborne noise are a key issue as piling is often required during construction.

### 11.1.2 Impact

While all statements of quantified risks, costs and time impacts come with a large degree of uncertainty, the following points should be considered:

- The requirement to carrying out permitting is absolutely certain, and therefore not a risk, however the possibility that the permitting process runs into significant opposition to the point where either extensive constraints are placed on the construction, or where an alternative option is adopted.
- All of the sites are protected although the exact details require further investigation. A visual review of the sites allows the inference that Eemshaven 1A and 1B and Terneuzen 1A and 1B may carry the most risk because they have the largest extent of intertidal zone (expected to be rich in biodiversity) and they are currently undeveloped. Eemshaven 2 and 3 and Sloedebieg 1 and 2 have a smaller intertidal zone and significant industry including existing outfalls. However it must be stressed that this opinion cannot be substantiated without further work as described in Section 11.1.3.

Therefore the probability of this risk impacting is seen as >50% on all sites where a direct intake and /or outfall is considered. 🎲 🎲 🎲 🎲 🎲

The time impact is equally uncertain, but there are examples of significant delays where this type of risk is not addressed early. 🕒 🕒 🕒

The financial impact of the decision is relatively low, as the majority of the work is likely to be desk studies with some site investigation 💰

The financial impact of moving to a fully tunnelled design varies from site to site but sits in the band 0.5-1.0B euros 💰 💰 💰 .

### 11.1.3 Mitigation

1. Engagement of a consultant to make a Preliminary Environmental Impact Assessment and a formal risk evaluation.
2. Where key issues are identified the design may be modified to address specific issues. These mitigations vary from site to site. For example, where sediment transfer mechanisms are a particular concern, extending the culvert and, in effect constructing a short trench and cover tunnel across the shallow water and intertidal zone as described in Section 5.1.4.1. For other issues there may be other specific responses available.
3. Adoption of TBM tunnelling is not strictly mitigation, but risk would be made significantly smaller by adopting a full tunnel solution.

## 11.2 National Dyke

### 11.2.1 Risk

This risk applies to Eemshaven 1B, Eemshaven 3, Terneuzen 1A and Terneuzen 1B.

There is an extensive system of dykes in the Netherlands that are crucial to control of the water levels across the country. Along the coast there is a continuous “*National Dyke*” which has been constructed to specifically provide sea defence to the land within, much of which would flood very regularly (sometimes on every high tide) without such protection. The RWS is the governing body for this “*National Dyke*”.


The sites listed above are inside the “*National Dyke*” and on these sites it typically also forms the sea defence for the site. Where a Direct Intake and/or Outfall is proposed on these sites it must, by definition, breach the “*National Dyke*” either entirely or via a culvert to the forebay.


As explained in Section 4, it is assumed in this paper that a culvert penetrating the dyke is constructed, and that it is constructed using the existing dyke as the barrier to the sea whilst constructing the culvert within a local diversion of the dyke inshore. This would allow inspections by the RWS during construction and the “signoff” of the diversion prior to breakthrough of the original dyke.


On possible methodology for this construction is described in Section 4.4.4.3. There are others and significant options studies would be expected before finalisation. However, the key risk lies around the RWS acceptance of the methodology and their timely approvals of the design and construction.


### 11.2.2 Impact

The situation on the four sites where this risk is applicable is very similar:

The probability of this risk impacting is very difficult to quantify, but it is judged to be quite high 

The time impact is equally uncertain, but it is known that diversion of the primary dyke has normally taken more than 12 months 

The financial impact of the decision may, in the worst case lead to extensive civils works. Physical work on site tends to be more costly than consultancy 

A full tunnel solution would go under the dyke and would be expected to be subject to some governance, but diversion of the dyke would not be an expected outcome. Therefore, this risk would be significantly lower for a fully tunnelled solution. The financial impact of moving to a fully tunnelled design varies from site to site but sits in the band 0.5-1.0B euros 

### 11.2.3 Mitigations

1. Early engagement with the RWS to ensure that the principle of the least onerous construction methodology is accepted, and where they are not comfortable to understand their concerns.
2. Establish timelines for acceptance of design, inspections and other interfaces.
3. Adoption of a full TBM tunnel solution is likely to significantly reduce the impact of this risk.

## 11.3 Railway

### 11.3.1 Risk

This risk applies at Eemshaven 1A, Maasvlakte 2, Sloegebied 2.

Where the National Dyke does not form the sea defence for the site, a secondary dyke is present. In these three locations a railway runs along the sea defence. By definition a direct intake/outlet has to breach this sea defence. This means that it is necessary to either divert or close the railway, at least temporarily.

### 11.3.2 Impact

The situation on the three sites where this risk is applicable is physically similar but the actual impact will be based on the volume of use of the railway. At Eemshaven there is a station beyond the site implying higher use, at Maasvlakte2 and Sloegebied it appears to be freight and it is not clear how heavily used the line is:

The probability of this risk impacting is very difficult to quantify, but it is judged to be quite high in Eemshaven (>50%) but lower in Sloegebied and Maasvlakte (25-50%) 🎲 🎲 🎲 / 🎲

The time impact is equally uncertain, but it is known that closure of the may take more than 12 months to negotiate 🕒 🕒 🕒

The financial impact of the decision may , in the worst case lead to extensive civils works. Physical work on site tends to be more costly than consultancy 💰 💰

A full tunnel solution would go under the railway and would be expected to be subject to some governance, but closing the railway would not be an expected outcome. Therefore, this risk would be significantly lower for a fully tunnelled solution. The financial impact of moving to a fully tunnelled design varies from site to site but sits in the band 0.5-1.0B euros 💰 💰 💰 .

### 11.3.3 Mitigation

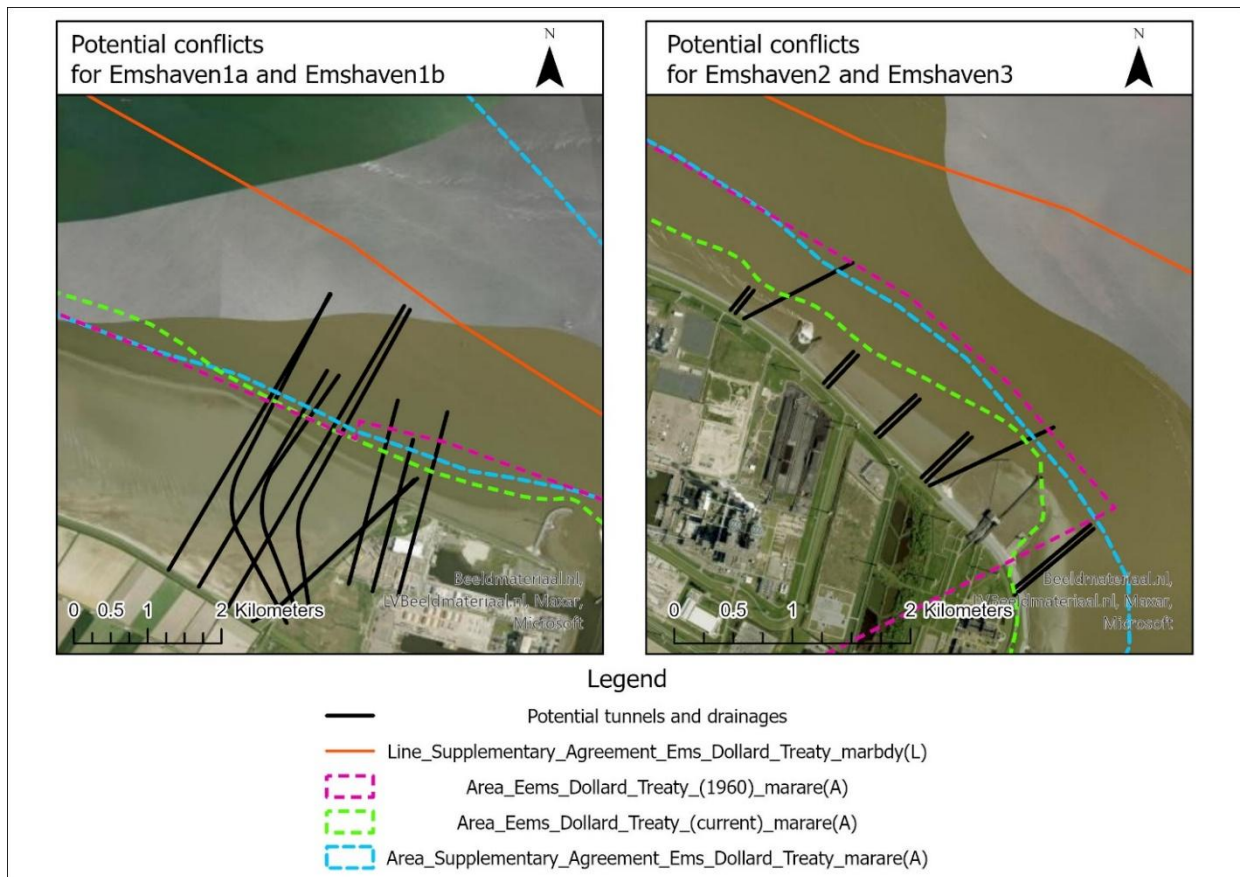
1. Early engagement with the railway company to understand the volume and type of the service on this branch
2. It may be possible, given innovative construction techniques and good planning to minimise any closure
3. Adoption of a full TBM tunnel solution is likely to significantly reduce the impact of this risk.

## 11.4 International Border

### 11.4.1 Risk

This applies to all Eemshaven sites.

The border with Germany remains in dispute following the end of World War 2. It is understood that there is a current treaty line, which none of the tunnels breach, but there are also a number of lines representing disputed areas, and some of the tunnels do go into these areas.



**Figure 11.2 Potential conflicts between Cooling System and disputed zone**

### 11.4.2 Impact

This risk is unique to Eemshaven and all of the sites at Eemshaven are effected by it to some extent. The writer has expressed a common-sense opinion below, but the Client is in a position to be better informed than the consultant, and it is suggested that the opinion below is treated only as a starting point:

The probability of this risk impacting is very difficult to quantify, but it is judged to be a relatively low risk that it cannot be solved with pro-active engagement 🎲 🎲

The time impact is equally uncertain, but if there is an issue, it is suspected that it may be difficult to get full engagement at the appropriate level from a foreign government and it may take more than 12 months to negotiate 🕒 🕒 🕒

The financial impact of the decision is likely to be limited to negotiation time and some desk studies 💰

### 11.4.3 Mitigation

Engage early in the process with the German government, mobilising the highest ranked politicians available.

## 11.5 Stakeholder pressure

### 11.5.1 Risk

At the Sloegebied 1 site both options impact the use of the leisure beach, with the most significant impact created by Option 1. There is a risk that there may be publicity campaigns, leading to reputational damage, and potentially legal challenge generated by this development.

### 11.5.2 Impact

This risk is only relevant to Sloegebied 1.

The probability of this risk impacting is difficult to quantify but is judged to be significant 🇺🇸 🇺🇸 🇺🇸

The time impact is equally uncertain, but legal challenges from this type of group have caused delays of more than 12 months 🕒 🕒 🕒

The financial impact is likely to be more time and convenience based than financial 💰

A full tunnel solution would not impact the leisure users. Therefore this risk would be significantly lower for a fully tunnelled solution. The financial impact of moving to a fully tunnelled design varies from site to site but sits in the band 0.5-1.0B euros 💰 💰 💰 .

### 11.5.3 Mitigation

1. Public consultations and surveys may be used to further evaluate this risk and PR campaigns may be used to sway public opinion.

## 11.6 Location of Offshore Heads

### 11.6.1 Risk

At any location where a tunnel solution is considered there is an introduction of a navigational hazard. There may be an objection to this from the marine authority, unless they perceived a significant shipping hazard they would normally be expected to engage constructively in fine-tuning the location and agreeing the navigation aids to be provided. A further complication, particularly in Sloegebied and Terneuzen is that there is an obligation to Belgium to maintain the navigational safety of the channel up to Antwerp and associated Belgian ports.

In order to give further information on the navigational risk posed, commercial vessel densities for the area around the proposed sites for 2023 are included in Figure 11.3. It should be noted that these densities are for commercial shipping comprised of tankers, LNG carriers, LPG carriers, Cargo vessels and Container Ships. Passenger vessels, leisure craft, fishing vessels and tugs are not included and are known to follow paths well out of the main shipping lanes shown in Figure 11.3. Fishing vessels in particular tend to cover the vast majority of the navigable areas and engagement with representatives of the industry would be essential.

The risks can be seen to vary at the different sites are reflected in the scoring at individual sites but are summarised below for convenience as follows:

- Eemshaven 1A and 1B are well out of the significant shipping lanes.
- Eemshaven 2 and 3, Maasvlakte 2 and Sloegebied 1 and 2 are on the edge of significant shipping lanes and are close to areas dense commercial shipping. However in these cases there are deep water areas where it may be possible to place heads with a manageable navigational hazard profile as they are just outside the densely used lanes, particularly with appropriate nav aids and notices to mariners.

- Terneuzen 1A and 1B heads would initially appear to need to be in the main channel up the Scheldt which is heavily used by commercial traffic. Navigation is limited by the presence of shallow water and the channel is required for access to Antwerp and other major ports.

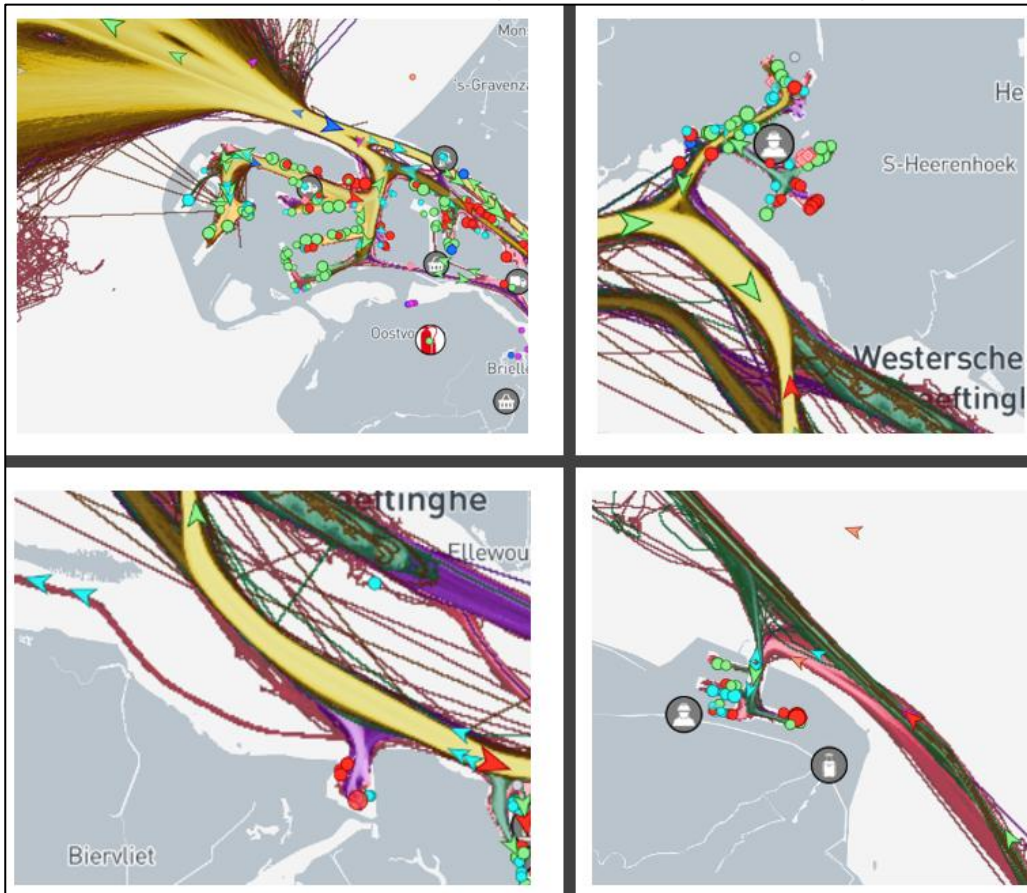


Figure 11.3 Commercial Shipping Density around the proposed sites

## 11.6.2 Impact

### 11.6.2.1 Eemshaven 1A and 1B

The probability of difficult negotiations being required is relatively low 🎲

If they are required, they are likely to be relatively quick 🕒

They do not typically have high cost implications,. Some physical navigation aids are often required and they need to be added to the navigation charts. 💰

### 11.6.2.2 Eemshaven 2 and 3, Maasvlakte 2 and Sloegebied 1and 2

The probability of difficult negotiations being required is significant with a major shipping channel adjacent and major port authorities involved (Rotterdam, Vlissingen, Antwerp) and potentially transnational negotiations 🎲 🎲 🎲 🎲

If they are required, they may well take more than a year 🕒 🕒 🕒

They do not typically have high cost implications. Some physical navigation aids are often required and they need to be added to the navigation charts. It is not thought on balance that this will block the project or require major reconfiguration. Clearly the costs are significantly higher 💰

### 11.6.2.3 Terneuzen 1A and 1B

Difficult negotiations are almost certain with a major shipping channel impacted and major port authorities involved (Antwerp) and transnational negotiations 🇧🇪 🇩🇪 🇬🇧 🇫🇷 🇪🇺

If they are required, they may well take more than a year and may have knock-on effects into constraints on construction. 🕒 🕒 🕒

Although they do not typically have high cost implications and requirements are limited to addition of the obstruction to charts and installation of some physical navigation aids, it is thought on balance that at this location there may need to be significant studies into tunnel locations and other mitigations including different heads locations or novel engineering solutions. Clearly the costs could be significantly higher 💰 💰

### 11.6.3 Mitigation

1. Review shipping density charts and study detailed siting options possibly with other arrangements. For Terneuzen, which is the highest risk, consider siting intakes in southern channel.
2. Perform thermal modelling to verify impact of any alternatives on MPMZ.
3. Engage with marine authorities for the relevant areas.

## 11.7 Increase in Ambient Water Temperatures

### 11.7.1 Risk

This risk is applicable to all sites.

A potential future risk associated with the use of once-through cooling is compliance with environmental regulations, specifically the requirement that water bodies temperature must not exceed 25 °C. The current system design satisfies this criterion.

However, 98% exceedance ambient temperatures are between 21.8 °C and 22.8 °C and climate change projections indicate an uncertain level of change in the ambient seawater temperature, potentially exceeding the 2.2-3.2°C over the next 100 years that would lift the 98% exceedance ambient temperature above the not to exceed limit, which implies an increased potential for mandatory curtailments during summer periods. This curtailment may be a full shutdown or a reduction in power generation to one unit only or to partial power on one or both units.

It is recommended that prior to taking further mitigation action as described below, significant analysis is spent on getting the best forecasts for increase in ambient water temperatures at the plant and on modelling the implied curtailment for different scenarios.

### 11.7.2 Mitigation

To ensure long-term regulatory compliance and operational resilience, the integration of contingency cooling systems may be considered during the design phase of the power station.

Supplementary cooling systems can be broadly categorised into wet and dry configurations. These additional methods each have distinct advantages and disadvantages, but all could be used to help maintain the 25°C requirement.

#### **Cooling Ponds**

Indirect cooling can be achieved through utilisation of a cooling pond which is a type of closed cycle cooling that offers lower water evaporation than using cooling towers. Cooling spray can be utilised to maintain the cooling pond at lower temperatures.

#### **Cooling Towers**

Similarly closed loop cooling can be achieved through utilisation of cooling towers with a condenser circuit. There are two primary categories of towers natural draft, which uses the chimney effect to cool, or mechanical draft which uses large fans. Both tower types cool the system by transferring the water's heat to the air, this happens both directly and through evaporation.

- Utilise the chimney effect to induce airflow, requiring no mechanical fans. These towers offer reduced electrical consumption but demand significant land area and structural height (up to 200 m depending on plant capacity).
- Employ large fans to force air through the system, typically achieving lower outlet water temperatures than natural draft towers. While more compact (often below 50 m in height), they impose a parasitic electrical load on the plant.

### ***Dry cooling***

This uses a series of finned tubes within a condenser system with a high flow forced draft to cool the water. This method of cooling allows a nuclear plant to consume less water than a traditional indirect water system, making it suitable for regions with limited water availability or stringent environmental constraints.

### ***Hybrid/Dual Cooling Systems***

In order to utilise the technologies described above they would need to be implemented alongside the originally installed once-through cooling system.

Dual systems using both once-through and indirect methods are commonplace where supplementary cooling is required, such as with TVA's Browns Ferry and Sequoyah stations in the USA. At Browns Ferry, for example, the Tennessee Valley Authority (TVA) operates a combination of once-through cooling from Wheeler Lake and multiple mechanical-draft cooling towers. During the summer months, six seasonal towers (approximately 18–24 m high) typically run at full capacity to manage thermal discharge limits. In response to increased power demands and environmental constraints, TVA invested \$160 million to commission a larger (50 m) mechanical-draft cooling tower in 2012 and has since been progressively replacing older towers with improved designs. This upgrade supports extended power uprates while enhancing thermal efficiency and environmental compliance.

Additionally, more recently, designs for hybrid wet/dry cooling systems are being explored as this allows sites to tackle the additional environmental challenge of water use. These supplementary systems commonly function in the hotter summer months and may not be required in cooler environmental conditions. Consequently, dual/hybrid systems can be designed to run in parallel and independent of each other or to run in series.

1. Parallel: Both systems operate concurrently and independently, allowing load distribution and redundancy. While offering operational flexibility, this configuration may introduce complexity in control and maintenance.
- Series: The primary (once-through) system handles baseline cooling, with the secondary (indirect) system activated as needed. This approach simplifies integration but may limit redundancy and operational flexibility.

### **Timing and Phasing**

As risk of the rise in ambient water temperature above the not to exceed level of 25°C is uncertain and some decades in the future, it is likely that it would not be necessary to build the contingency cooling system with the initial plant. However, depending on the layout (parallel or series) selected systems may need to be designed with this future integration in mind. Similarly, a parcel of land will need to set aside for the future cooling method. This means that though the system does not necessarily require immediate construction, it will need to be at least functionally designed, especially systems that will integrate with the main station to ease design and construction when required.

## 12. Conclusions and Recommendations

### 12.1 Conclusions

#### 12.1.1 Preferred Site

1. A Preferred Option has been identified for every site and in no case was the technical solution found to be not feasible.
2. A summary of the scoring of all the options each site is shown below in Table 12.1. The Preferred Option is highlighted green for ease of identification. In most cases the Preferred option involves a Direct Intake and/or Outfall driven primarily by the opportunity to lower costs and minimise constructability issues.
3. A ranking of the Preferred Options shows Terneuzen 1A to be the highest scored site, followed by Eemshaven 2 and 3. This is the column labelled “Rank (all options)” in Table 12.1.
4. The key and over-riding risk that was identified is the environmental/permitting risk associated with the construction of a direct intake/outfall, driven by the sensitivity of the locations indicated by the fact that all sites are located within either a UNESCO World Heritage Site or a Natura 2000 area. In the event that this risk impacted at its fullest extent, permitting may be a significant challenge and the tunnel-only option may need to be adopted to achieve a permit.
5. In order to aid the comparison of the fallback position, the all-tunnel options have been highlighted amber and ranked where they exist.
6. All tunnel solutions were not considered at Eemshaven 2 and 3 and Sloegebied 1 because the permitting was deemed initially achievable and all-tunnel solutions appeared to have very limited advantages.

**Table 12.1 Summary of scoring at all sites**

Intake		Direct	Direct	Tunnel	Tunnel	Tunnel	Rank	Rank
Outfall		Direct	Tunnel	Direct	Tunnel	Tunnel	(All options)	(Tunnel only)
Eemshaven - 1A	Option		1	2	3	4		
	Score		295	225	315	295	6=	4=
Eemshaven - 1B	Option		1	2	3			
	Score		295	240	315		6=	4=
Eemshaven - 2	Option	1	2					
	Score	380	355				2	
Eemshaven - 3	Option	1	2					
	Score	365	340				3	
Maasvlakte - 2	Option	1	2		3			
	Score	300	345		325		5	3
Sloegebied - 1	Option	1		2				
	Score	325		310				
Sloegebied - 2	Option		1	2	3			
	Score		290	265	315		6=	4
Terneuzen - 1A	Option	1		2	3			
	Score	405		315	330		1	1=
Terneuzen - 1B	Option	1	2	3	4			
	Score	360	340	315	330		4	1=

Note: In order to input into the final site selection decision it is important that the scores and rankings be considered as guidance and that the detail of the risks and issues be considered fully by the decision makers, including their interactions with other work package results.

For example Terneuzen 1A Option 1 scores very highly, but there appears to be a very high environmental permitting risk and so it is important to mitigate this risk prior to final selection.

## 12.2 Recommendations

### 12.2.1 Engagement with regulatory bodies

1. The over-riding risk highlighted is environmental permitting where direct intake/outfalls are considered. The opinion of the regulatory bodies on the issues with this permitting should be sought. Further work will be required to consider environmental impact caused by the development including sediment transportation and morphology, impact on flora and fauna of both construction and operational phases and other subjects to fully bound and mitigate the risk. However, engagement with the regulatory bodies at this time would give them an opportunity to highlight what they see as the key issues, direct initial studies allow the risk to be better understood and quantified.
2. Separately from 1, but in a closely related point, the environmental regulator will have an opinion on disposal of spoil at sea.
3. As highlighted in Section 10, a number of the sites are inside the “National Dyke” and on these sites it typically also forms the sea defence for the site. Where a Direct Intake and/or Outfall is proposed on these sites it must, by definition, breach the “National Dyke”, it is assumed by introducing a culvert. A basic sequence of steps will be required to maintain the integrity of the sea defence during construction.

The “National Dyke” is under the governance of the RWS, as explain in Reference 23, and their guidance should be sought on the method of introducing the culvert

4. Local navigation - Where a tunnel solution is proposed, there will need to be an offshore head structure through which the water enters or leaves the tunnel. At every site the tidal currents dictate that the intake heads will be of allow Low Velocity Side Entry type, which are significant in size. The local navigation authority’s view on the location and marking of such Heads should be sought.

### 12.2.2 Engagement with stakeholders

1. Port owners - Logistics are key to any construction activity, but they are particularly important to tunnelling activities. Large volumes of materials are required such as segments, as well as AILs. It is recommended that the spare capacity at each of the nearby ports is evaluated to ensure that it can accommodate both volume of traffic and the larger loads.
2. Railway Owner – If a site with a railway on the sea defence is considered it is recommended that the volume of traffic on the railway line is understood, and the level of financial impact of closing the line is further evaluated.

### 12.2.3 Further investigation work

1. Engage a marine environmental specialist to identify the total body of law comprising all relevant national, supra-national (by virtue of EU membership) and international convention which has pertinence in relation to the protection of the local natural environment in question. They should also identify and review existing information of relevance and use this information to further inform the permitting risk at each site.

2. If tunnelling options are to be taken forward, procurement of historical marine traffic density (available from AIS records) is recommended to allow further study of navigational hazards posed by heads. Alternative positions for the Heads should be evaluated based on these records.
3. At a number of locations the selected option or fallback option has not been modelled by Deltares. It is recommended that the exact selected configuration be modelled prior to making a down-selection of that site.

## Appendix A. Tunnel Scoring Criteria

Scoring Criteria	Constructability			Logistics	
	Score	Ground conditions suitability	Water pressure	Offshore connections	Work site availability
5	Homogeneous stiff high clay content low permeability strata [EPB TBM suitable, shallow trench to competent strata <5m]	0 to 3 bar theoretical - low permeability (<10 <sup>-6</sup> m/s)	Low risk in good impermeable strata, depth <20m to base excavation level. Minimal treatment or water management	Large greenfield site with no restrictions, could accommodate precast facility, offshore works clear of shipping risks, depth <20m	Facility for receiving large components MOLF, existing road/rail links, spoil disposal within site, power and water supply available within site.
4	Mainly stiff homogeneous clay some discrete cohesionless zones. [EPB TBM suitable with treatment or shallow trench to competent strata <5m local extra excavation]	0 to 3 bar theoretical - some high permeability zones (>10 <sup>-5</sup> m/s)	Low risk in good impermeable strata, depth between 20m and 30m to base excavation level. Some allowance for local treatment.	Large brown field site with no restrictions, could accommodate precast facility, offshore works occasional/infrequent shipping risks, depth <20m	Facility for receiving large components MOLF, existing road/rail links and spoil disposal site available nearby, power and water supply locally available.
3	Uniform cohesionless strata limited water bearing lenses strata [Slurry or variable density TBM required, trench to competent strata >5m, local excavation stability issues]	3 to 5 bar theoretical but aquiclude from sea and medium permeability (< 10 <sup>-5</sup> m/s)	Solution requires local treatment or ground water management risk mitigation but using standard methods.	Adequate site available for tunnelling operations, access can be developed to nearby infrastructure, no room for precast facility. Marine regular small shipping risks. Depth to seabed between 20 and 30m	Facility for receiving large components could be developed, transport to spoil disposal site available locally, power and water supply can be made to local infrastructure <5km
2	Mixed strata extensive water bearing lenses strata, [Slurry or variable density TBM required, trench to competent strata >5m, extensive trench stability issues]	3 to 5 bar theoretical with connection risk to sea and high permeability (>10 <sup>-5</sup> m/s)	Solution requires local treatment or ground water management risk mitigation using enhanced methods.	Adequate site available for tunnelling operations, access can be developed to infrastructure but not local, no room for precast facility. Marine manageable shipping risks, enhanced controls. Depth to seabed between 20 and 30m for Marine	Facility for receiving large components could be developed, transport to spoil disposal site available, power and water supply 5 to 10km connections
1	Mixed, soft strata high permeability connection to sea. Spoil with high fines requires extra treatment with standard set-up. [Slurry or variable density TBM required, stability issues trenching lateral extent increased 100%]	Permeability >10 <sup>-5</sup> m/s, >5 bar interventions and diving works high risk, enhanced treatment mitigation risk, marine avoid diving operations with remote methods ROVS etc	Solutions requires extensive ground treatment using enhanced methods	Site area small and need for satellite facilities, with poor links to road and rail infrastructure. High marine traffic zones some restrictions on work windows. Depth to seabed >30m	Remote site needing development of necessary infrastructure for receiving TBM's and providing power and water, spoil disposal and supply of components

Scoring Criteria	Tunnelling Hazards	Environmental impact		
		Type of excavated material	Reusability of the excavated material	Ease of disposal
Score	Impact on existing structures & presence of critical structures	Type of excavated material	Reusability of the excavated material	Ease of disposal
5	Tunnel route clear of infrastructure. Trenches clear of any structure, pipelines, cables or outfalls.	Homogeneous materials - clay no treatment required	>90% of material available for re-use, minimal treatment	Disposal >90% beneficial use on site. Marine 100% disposal local to works no treatment
4	Route clear of sensitive infrastructure. Some low sensitive infrastructure present. Trenches clear of significant structures, pipelines, cables or outfalls. Minor diversions possible. Route clear of sea defences. Risk easily managed limited standard mitigations required	Homogeneous materials - clay or sand standard treatment required	50 to 90% material available for reuse with minor treatment	Disposal up to 50% beneficial use on site. Other material local beneficial use or local disposal. Marine <100% disposal local to works but needs treatment.
3	Route includes single sensitivity structure, damage risk manageable. Trenches may impact structures, pipelines, cables or outfalls. Diversions are possible may need long lead times. Does pass under railway and wind farms, sea defences but manageable effect.	Mixed material but can be separated no treatment	<50% material available for reuse no treatment	No disposal on site. Material beneficial use disposal local. Marine disposal to approved area within 5km of the site and needs some treatment
2	Route includes several sensitivity structures, damage risk manageable. Trenches may impact structures, pipelines, cables or outfalls. Diversions require significant enabling works.	Mixed material but can be separated some standard treatment	<50% material available for reuse minimal treatment	No disposal on site. Material beneficial use disposal not local. Marine disposal to approved area within >5km of the works and needs treatment
1	Route includes several critical sensitive structures or risk of buried structure. Trenches need relocation of several critical structures/infrastructure. Enabling works approvals outside project influence and major project risk.	Mixed material , high silt content, needs additional treatment plant.	No material suitable for reuse but disposal with treatment	No disposal on site no beneficial use, some material contaminated needs transport >5km to disposal site. Marine disposal has some contamination needs treatment and disposal to restricted areas

## Appendix B. Overall Scoring Criteria

+	1	2	3	4	5
Cost	>2B euros	1.5-2B euros	1-1.5B euros	0.5-1B euros	0-0.5B euros
Constructability	Tunnel with low constructability and channel exposed conditions	Tunnel with normal constructability and channel exposed conditions	Tunnel with normal constructability/long channel normal conditions	Tunnel with easy constructability, channel, normal constructability	channel in sheltered conditions, no tunnel
Cooling Water Environmental	Does not satisfy RWS guidelines for mixing zones	Clearly Does not satisfy RWS guidelines for mixing zones but is a defensible position	Not analysed but looks likely to marginally satisfy RWS guidelines	Marginally satisfies RWS guidelines for Mixing Zone, or not analysed but looks very	Clearly satisfies RWS guidelines for Mixing Zone
Cooling Water Temperature	This configuration ensures cooling water supply with max recirculation >5C	Not directly modelled, >2C, and possibly >5C	This configuration ensures cooling water supply with max recirculation >2C but <5C	Not directly modelled, potentially >2C	This configuration ensures cooling water supply with max recirculation <2C
Other Environmental	Causes impact to intertidal zones within a Natura 2000 in areas likely to be protected	Causes impact to coastal and intertidal zones within Natura 2000 in areas possibly protected	Causes impact to coastal and intertidal zones in Natura 2000 in areas less likely to be protected	Requires work coastal and intertidal zones with no permanent impact	Does not cause any impact to coastal and intertidal zones
Ship Impact	Offshore Heads in high density commercial shipping lane	Offshore Heads on the edge of high density commercial shipping lane	Offshore heads outside high density commercial shipping lane but inside leisure and fishing area	Offshore heads outside high density commercial shipping lane and outside high density leisure and fishing area	No offshore Heads
UXO risk	High Risk area based on desktop research of historical activity in the area	High - Medium Risk area based on desktop research of historical activity in the area	Medium Risk area based on desktop research of historical activity in the area	Medium-Low Risk area based on desktop research of historical activity in the area	Low Risk area based on desktop research of historical activity in the area
Impact local stakeholders	Permanent major negative impact on any leisure water/beach users	Permanent minor negative impact on any leisure water/beach users	Temporary major impact on any leisure water/beach users	Temporary minor impact on any leisure water/beach users	No negative impact on any leisure water/beach users

## Appendix C. Technical Fact Sheets for Cooling Water System

### Table of Contents

- Summary
- Eemshaven 1A
- Eemshaven 1B
- Eemshaven 2
- Eemshaven 3
- Maasvlakte 2
- Slogebied 1
- Slogebied 2
- Terneuzen 1A
- Terneuzen 1B

### Summary

Site		Intake	Outfall	Score	Cost	RISKS						
						Habitat Permitting	Ship Impact	Eems Dollard	Dyke	Railway	Stakeholder	CW Permitting
Eemshaven - 1A	1 <sup>st</sup> Choice	Tunnel	Tunnel	315	👛👛👛👛							
	2 <sup>nd</sup> Choice	Direct	Tunnel	295	👛👛👛👛							
Eemshaven - 1B	1 <sup>st</sup> Choice	Tunnel	Tunnel	315	👛👛👛👛							
	2 <sup>nd</sup> Choice	Direct	Tunnel	295	👛👛👛👛							
Eemshaven – 2	1 <sup>st</sup> Choice	Direct	Direct	380	👛👛							
	2 <sup>nd</sup> Choice	Direct	Tunnel	355	👛👛👛							
Eemshaven – 3	1 <sup>st</sup> Choice	Direct	Direct	365	👛👛							
	2 <sup>nd</sup> Choice	Direct	Tunnel	340	👛👛👛							
Maasvlakte 2	1 <sup>st</sup> Choice	Direct	Tunnel	345	👛👛👛							
	2 <sup>nd</sup> Choice	Tunnel	Tunnel	325	👛👛👛👛							
Slogebied - 1	1 <sup>st</sup> Choice	Direct	Direct	325	👛👛👛							
	2 <sup>nd</sup> Choice	Tunnel	Direct	310	👛👛👛👛							
Slogebied – 2	1 <sup>st</sup> Choice	Tunnel	Tunnel	305	👛👛👛👛							
	2 <sup>nd</sup> Choice	Tunnel	Direct	290	👛👛👛👛							
Terneuzen – 1A	1 <sup>st</sup> Choice	Direct	Direct	405	👛👛							
	2 <sup>nd</sup> Choice	Tunnel	Tunnel	330	👛👛👛👛							
Terneuzen – 1B	1 <sup>st</sup> Choice	Direct	Direct	360	👛👛👛							
	2 <sup>nd</sup> Choice	Direct	Tunnel	340	👛👛👛							
	3 <sup>rd</sup> Choice	Tunnel	Tunnel	330	👛👛👛👛							

# Eemshaven 1A

## General Site Information

Location	Topography	Bathymetry

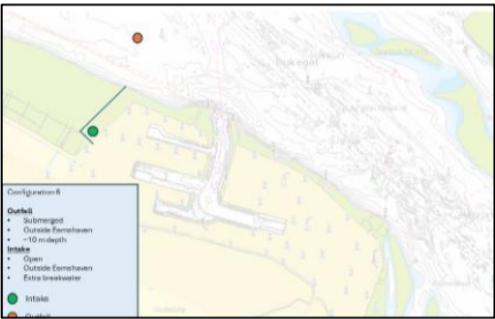
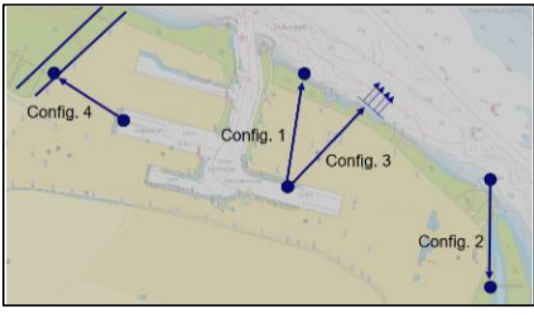
## Metocean Data

Water Levels – NAP (m)	Wave Heights Hs (m)	Current Data (m/s)																																														
<table border="1"> <tr><td>High WL -10,000 yr</td><td>5.7</td></tr> <tr><td>High WL -100 yr</td><td>4.4</td></tr> <tr><td>HAT</td><td>2.0</td></tr> <tr><td>LAT</td><td>-2.1</td></tr> <tr><td>Low WL -100 yr</td><td>-3.3</td></tr> <tr><td>Low WL -10,000 yr</td><td>-4.2</td></tr> <tr><td>Climate Change</td><td>1.24</td></tr> </table>	High WL -10,000 yr	5.7	High WL -100 yr	4.4	HAT	2.0	LAT	-2.1	Low WL -100 yr	-3.3	Low WL -10,000 yr	-4.2	Climate Change	1.24	<table border="1"> <tr><td>10,000 yr</td><td>2.4</td></tr> <tr><td>10 yr</td><td>1.3</td></tr> </table> <table border="1"> <tr><td colspan="2">Ambient Temperature (C)</td></tr> <tr><td>98 percentile</td><td>21.5</td></tr> </table>	10,000 yr	2.4	10 yr	1.3	Ambient Temperature (C)		98 percentile	21.5	<table border="1"> <tr><td colspan="3">End of dredged channel</td></tr> <tr><td></td><td>Spring</td><td>Neap</td></tr> <tr><td>Velocity</td><td>1.5</td><td>0.7</td></tr> <tr><td>Direction</td><td>290</td><td>110</td></tr> </table> <table border="1"> <tr><td colspan="3">End of Tunnel</td></tr> <tr><td></td><td>Spring</td><td>Neap</td></tr> <tr><td>Velocity</td><td>1.6</td><td>1.1</td></tr> <tr><td>Direction</td><td>290</td><td>110</td></tr> </table>	End of dredged channel				Spring	Neap	Velocity	1.5	0.7	Direction	290	110	End of Tunnel				Spring	Neap	Velocity	1.6	1.1	Direction	290	110
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## Options

Option 1	Option 2	Option 3


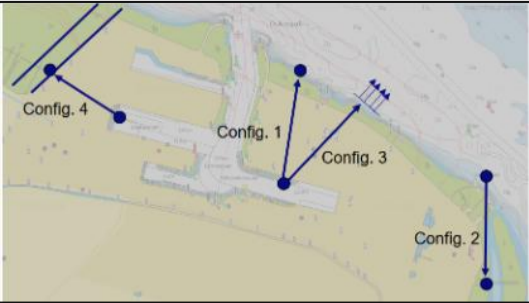
### Option 4

Outfall Dimensions				
Option 1	Option 2	Option 3	Option 4	
Tunnel – TBM Length 3300 m Seabed depth at Heads -11.8 m NAP	Direct – dredged channel Length – 2600m Depth - -3.1m NAP	Tunnel – TBM Diameter 8.6m Length 3300 m Seabed depth at Heads -11.8 m NAP	Tunnel – TBM Diameter 8.6m Length 2100 m Seabed depth at Heads -12.0 m NAP	
Intake Dimensions				
Option 1	Option 2	Option 3	Option 4	
Direct – dredged channel Length – 2600m Depth - -5.7m NAP	Tunnel – TBM Length 3300 m Seabed depth at Heads -11.5 m NAP	Tunnel – TBM Diameter 7.0m Length 4500 m Seabed depth at Heads -13.2 m NAP	Tunnel – TBM Diameter 7.0m Length 2500 m Seabed depth at Heads -12.3 m NAP	
Thermal plume				
Option 1	Option 2	Option 3 and 4		
 <p>Based on configuration 6, above. Mixing zone in contact with seabed only locally. Likely to be environmentally acceptable.</p>	 <p>Based on configuration 4 above. Mixing zone in contact with seabed for several hundred metres. Technically breaches environmental guidelines but may be acceptable in wider context.</p>	<p>Not modelled but by inspection likely to be acceptable with regards to thermal environmental and recirculation constraints.</p>		
Tunnel Construction Criteria				
Preferred Technology	Slurry or variable density TBM			
	Option 1	Option 2	Option 3	Option 4
Constructability	2	2	2	2
Logistics	4	4	4	4
Tunnelling Hazards	3	3	3	1
Environmental	4	4	4	4
Overall Scoring				
	Option 1	Option 2	Option 3	Option 4
Cost*	3	2	2	2
Constructability (Overall)	2	2	2	1
Cooling Water Environmental	4	1	3	3
Cooling Water Temperature	5	5	5	5
Other Environmental	1	1	5	5
Ship Impact	3	3	3	3
UXO risk	3	3	3	3
Impact local stakeholders	5	5	5	5
<b>Overall (weighting 1)</b>	295	225	315	295
<b>Overall (weighting 2)</b>	304	224	344	336
Risks				
	Option 1	Option 2	Option 3	Option 4
Permitting of construction of direct intake or outfall in an environmentally protected zone	🚫🚫🚫🚫🚫 🚫🚫🚫 💰	🚫🚫🚫🚫🚫 🚫🚫🚫 💰	N/A	N/A
Construction of the direct entry/intake under the railway	🚫🚫🚫🚫🚫 🚫🚫🚫 💰	🚫🚫🚫🚫🚫 🚫🚫🚫 💰	N/A	N/A
Negotiation of construction in Eems-Dollard treaty zone	🚫🚫🚫 🚫🚫🚫 💰	🚫🚫🚫 🚫🚫🚫 💰	🚫🚫 🚫🚫 💰	🚫🚫 🚫🚫 💰
Obstructions to tunnelling due to industrial infrastructure	N/A	N/A	N/A	🚫🚫🚫🚫🚫 🚫🚫🚫 💰
Navigational Hazard – Offshore Heads	🚫 🚫 💰	🚫 🚫 💰	🚫 🚫 💰	🚫 🚫 💰
Financial				
	Option 1	Option 2	Option 3	Option 4
Cost of scheme*	💰💰💰💰	💰💰💰💰	💰💰💰💰	💰💰💰💰

\*In scoring the bands considered were €0-0.5B, €0.5-1.0B, €1.0-1.5B, €1.5-2.0B, >€2.0B. In Risk and cost of scheme the 🏠 refer to the bands instructed by KGG, per Appendix A

## Eemshaven 1B

General Site Information																																														
Location	Topography	Bathymetry																																												
Metrocean Data																																														
<b>Water Levels – NAP (m)</b> <table border="1"> <tr><td>High WL -10,000 yr</td><td>5.7</td></tr> <tr><td>High WL -100 yr</td><td>4.4</td></tr> <tr><td>HAT</td><td>2.0</td></tr> <tr><td>LAT</td><td>-2.1</td></tr> <tr><td>Low WL -100 yr</td><td>-3.3</td></tr> <tr><td>Low WL -10,000 yr</td><td>-4.2</td></tr> <tr><td>Climate Change</td><td>1.24</td></tr> </table>	High WL -10,000 yr	5.7	High WL -100 yr	4.4	HAT	2.0	LAT	-2.1	Low WL -100 yr	-3.3	Low WL -10,000 yr	-4.2	Climate Change	1.24	<b>Wave Heights Hs (m)</b> <table border="1"> <tr><td>10,000 yr</td><td>2.4</td></tr> <tr><td>10 yr</td><td>1.3</td></tr> </table> <b>Ambient Temperature (C)</b> <table border="1"> <tr><td>98 percentile</td><td>21.5</td></tr> </table>	10,000 yr	2.4	10 yr	1.3	98 percentile	21.5	<b>Current Data (m/s)</b> <table border="1"> <thead> <tr><th colspan="3">End of dredged channel</th></tr> <tr><th></th><th>Spring</th><th>Neap</th></tr> </thead> <tbody> <tr><td>Velocity</td><td>1.5</td><td>0.7</td></tr> <tr><td>Direction</td><td>290</td><td>110</td></tr> </tbody> </table> <table border="1"> <thead> <tr><th colspan="3">End of Tunnel</th></tr> <tr><th></th><th>Spring</th><th>Neap</th></tr> </thead> <tbody> <tr><td>Velocity</td><td>1.6</td><td>1.1</td></tr> <tr><td>Direction</td><td>290</td><td>110</td></tr> </tbody> </table>	End of dredged channel				Spring	Neap	Velocity	1.5	0.7	Direction	290	110	End of Tunnel				Spring	Neap	Velocity	1.6	1.1	Direction	290	110
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Option 1	Option 2	Option 3																																												
Outfall Dimensions																																														
Option 1	Option 2	Option 3																																												
Tunnel – TBM Length 3400 m Seabed depth at Heads -11.6 m NAP	Direct – dredged channel Length – 2900m Depth - -3.1m NAP	Tunnel – TBM Diameter 8.6m Length 3400 m Seabed depth at Heads -11.6 m NAP																																												
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Option 1	Option 2	Option 3																																												
Direct – dredged channel Length – 2900m Depth - -5.7m NAP	Tunnel – TBM Length 4500 m Seabed depth at Heads -13.3 m NAP	Tunnel – TBM Diameter 7.0m Length 4300 m Seabed depth at Heads -13.3 m NAP																																												

Thermal plume		
Option 1	Option 2	Option 3 and 4
 <p>Based on configuration 7, above. Mixing zone in contact with seabed only locally. Likely to be environmentally acceptable.</p>	 <p>Based on configuration 4 above. Mixing zone in contact with seabed for several hundred metres. Technically breaches environmental guidelines but may be acceptable in wider context.</p>	<p>Not modelled but by inspection likely to be acceptable with regards to thermal environmental and recirculation constraints.</p>

**Tunnel Construction Criteria**

Preferred Technology	Slurry or variable density TBM		
	Option 1	Option 2	Option 3
Constructability	2	2	2
Logistics	4	4	4
Tunnelling Hazards	3	3	3
Environmental	4	4	4

**Overall Scoring**

	Option 1	Option 2	Option 3
Cost*	3	2	2
Constructability (Overall)	2	2	2
Cooling Water Environmental	4	2	3
Cooling Water Temperature	5	5	5
Other Environmental	1	1	5
Ship Impact	3	3	3
UXO risk	3	3	3
Impact local stakeholders	5	5	5
<b>Overall (weighting 1)</b>	295	240	315
<b>Overall (weighting 2)</b>	304	244	344

**Risks**

	Option 1	Option 2	Option 3
Permitting of construction of direct intake or outfall in an environmentally protected zone	🚫🚫🚫🚫🚫 💰	🚫🚫🚫🚫 💰	N/A
Construction of the direct entry/intake under the National Dyke	🚫🚫🚫🚫🚫 💰💰	🚫🚫🚫🚫 💰💰	N/A
Negotiation of construction in Eems-Dollard treaty zone	🚫🚫🚫 💰	🚫🚫🚫 💰	🚫🚫🚫 💰
Navigational Hazard – Offshore Heads	🚫 💰	🚫 💰	🚫 💰

**Financial**

	Option 1	Option 2	Option 3
Cost of scheme*	💰💰💰💰	💰💰💰💰	💰💰💰💰

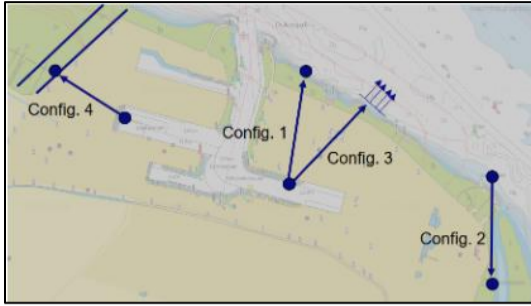
\*In scoring the bands considered were €0-0.5B, €0.5-1.0B, €1.0-1.5B, €1.5-2.0B, >€2.0B. In Risk and cost of scheme the 💰 refer to the bands instructed by KGG, per Appendix A

## Eemshaven 2

General Site Information																																														
Location	Topography	Bathymetry																																												
Metrocean Data																																														
<b>Water Levels – NAP (m)</b> <table border="1"> <tr><td>High WL -10,000 yr</td><td>5.9</td></tr> <tr><td>High WL -100 yr</td><td>4.5</td></tr> <tr><td>HAT</td><td>2.0</td></tr> <tr><td>LAT</td><td>-2.1</td></tr> <tr><td>Low WL -100 yr</td><td>-3.3</td></tr> <tr><td>Low WL -10,000 yr</td><td>-4.2</td></tr> <tr><td>Climate Change</td><td>1.24</td></tr> </table>	High WL -10,000 yr	5.9	High WL -100 yr	4.5	HAT	2.0	LAT	-2.1	Low WL -100 yr	-3.3	Low WL -10,000 yr	-4.2	Climate Change	1.24	<b>Wave Heights Hs (m)</b> <table border="1"> <tr><td>10,000 yr</td><td>3.7</td></tr> <tr><td>10 yr</td><td>1.9</td></tr> </table> <b>Ambient Temperature (C)</b> <table border="1"> <tr><td>98 percentile</td><td>21.5</td></tr> </table>	10,000 yr	3.7	10 yr	1.9	98 percentile	21.5	<b>Current Data (m/s)</b> <table border="1"> <tr><th colspan="3">End of dredged channel</th></tr> <tr><td></td><td>Spring</td><td>Neap</td></tr> <tr><td>Velocity</td><td>1.6</td><td>0.7</td></tr> <tr><td>Direction</td><td>300</td><td>120</td></tr> </table> <table border="1"> <tr><th colspan="3">End of Tunnel</th></tr> <tr><td></td><td>Spring</td><td>Neap</td></tr> <tr><td>Velocity</td><td>1.9</td><td>1</td></tr> <tr><td>Direction</td><td>300</td><td>120</td></tr> </table>	End of dredged channel				Spring	Neap	Velocity	1.6	0.7	Direction	300	120	End of Tunnel				Spring	Neap	Velocity	1.9	1	Direction	300	120
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Outfall Dimensions																																														
Option 1	Option 2																																													
Direct – dredged channel Length – 350m Depth - -3.1m NAP	Tunnel – TBM or trench and cover Diameter 8.6m Length 1000m Seabed depth at Heads -15.6 m NAP																																													
Intake Dimensions																																														
Option 1	Option 2																																													
Direct – dredged channel Length – 250m Depth - -5.7m NAP	Direct – dredged channel Length – 250m Depth – 5.7m NAP																																													

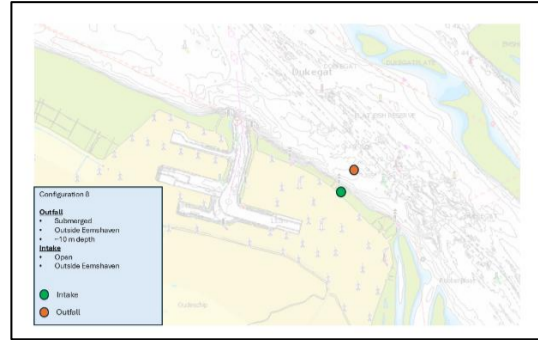
## Thermal plume

### Option 1



Configuration 1 models a direct outfall on site 2, but not a direct intake. The mixing zone is well within guidance and can be expected to remain so with an intake close by. Recirculation is expected to be high.

### Option 2



Configuration 8 models is this option. It shows that the mixing zone is well within guidance but that the recirculation is >2°C average. Tunnel is offset and slightly lengthened to try to reduce these effects.

## Tunnel Construction Criteria

Preferred Technology	Slurry or variable density TBM	
	Option 1	Option 2
Constructability	N/A	2
Logistics	N/A	4
Tunnelling Hazards	N/A	3
Environmental	N/A	4

## Overall Scoring

	Option 1	Option 2
Cost*	5	4
Constructability (Overall)	4	3
Cooling Water Environmental	3	5
Cooling Water Temperature	2	3
Other Environmental	2	2
Ship Impact	5	2
UXO risk	3	3
Impact local stakeholders	5	5
<b>Overall (weighting 1)</b>	380	355
<b>Overall (weighting 2)</b>	352	348

## Risks

	Option 1	Option 2
Permitting of construction of direct intake or outfall in an environmentally protected zone		
Negotiation of construction in Eems-Dollard treaty zone	N/A	
Navigational Hazard – Offshore Heads	N/A	

## Financial

	Option 1	Option 2
Cost of scheme*		

\*In scoring the bands considered were €0-0.5B, €0.5-1.0B, €1.0-1.5B, €1.5-2.0B, >€2.0B. In Risk and cost of scheme the 💰 refer to the bands instructed by KGG, per Appendix A

### Eemshaven 3

General Site Information																																														
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Metocean Data																																														
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Option 1	Option 2																																													
Outfall Dimensions																																														
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Direct – dredged channel Length – 850m Depth – -3.1m NAP	Tunnel – TBM or trench and cover Diameter 8.6m Length 1200m Seabed depth at Heads -12.9 m NAP																																													
Intake Dimensions																																														
Option 1	Option 2																																													
Direct – dredged channel Length – 550m Depth – -5.7 m NAP	Direct – dredged channel Length – 550m Depth – -5.7 m NAP																																													

Thermal plume		
Option 1	Option 2	
<p>Configuration 1 models a direct outfall on site 2, but not a direct intake. The mixing zone is well within guidance and can be expected to remain so with an intake close by. Recirculation is expected to be high.</p>	<p>Configuration 5 models is this option. It shows that the mixing zone is well within guidance but that the recirculation is &gt;2°C average. Tunnel is offset and slightly lengthened.</p>	
Tunnel Construction Criteria		
Preferred Technology	Slurry or variable density TBM	
	Option 1	Option 2
Constructability	N/A	2
Logistics	N/A	4
Tunnelling Hazards	N/A	3
Environmental	N/A	4
Overall Scoring		
	Option 1	Option 2
Cost*	5	4
Constructability (Overall)	4	3
Cooling Water Environmental	2	4
Cooling Water Temperature	2	3
Other Environmental	2	2
Ship Impact	5	2
UXO risk	3	3
Impact local stakeholders	5	5
<b>Overall (weighting 1)</b>	<b>365</b>	340
<b>Overall (weighting 2)</b>	<b>332</b>	328
Risks		
	Option 1	Option 2
Permitting of construction of direct intake or outfall in an environmentally protected zone		
Construction of the direct entry/intake under the national dyke		
Negotiation of construction in Eems-Dollard treaty zone	N/A	
Navigational Hazard – Offshore Heads	N/A	
Financial		
	Option 1	Option 2
Cost of scheme*		

\*In scoring the bands considered were €0-0.5B, €0.5-1.0B, €1.0-1.5B, €1.5-2.0B, >€2.0B. In Risk and cost of scheme the 💰 refer to the bands instructed by KGG, per Appendix A

## Maasvlakte 2

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Metocean Data																																														
<b>Water Levels – NAP (m)</b> <table border="1"> <tr><td>High WL -10,000 yr</td><td>5.2</td></tr> <tr><td>High WL -100 yr</td><td>3.7</td></tr> <tr><td>HAT</td><td>1.9</td></tr> <tr><td>LAT</td><td>-1.0</td></tr> <tr><td>Low WL -100 yr</td><td>-2.2</td></tr> <tr><td>Low WL -10,000 yr</td><td>-2.9</td></tr> <tr><td>Climate Change</td><td>1.24</td></tr> </table>	High WL -10,000 yr	5.2	High WL -100 yr	3.7	HAT	1.9	LAT	-1.0	Low WL -100 yr	-2.2	Low WL -10,000 yr	-2.9	Climate Change	1.24	<b>Wave Heights Hs (m)</b> <table border="1"> <tr><td>10,000 yr</td><td>10.0</td></tr> <tr><td>10 yr</td><td>5.5</td></tr> </table> <b>Ambient Temperature (C)</b> <table border="1"> <tr><td>98 percentile</td><td>22.96</td></tr> </table> <p>Value used in thermal analysis at edge of site, values at actual intake likely to be 20.9 to 22°C</p>	10,000 yr	10.0	10 yr	5.5	98 percentile	22.96	<b>Current Data (m/s)</b> <table border="1"> <tr><th colspan="3">End of dredged channel</th></tr> <tr><td></td><td>Spring</td><td>Neap</td></tr> <tr><td>Velocity</td><td>1.1</td><td>0.4</td></tr> <tr><td>Direction</td><td>200</td><td>20</td></tr> </table> <table border="1"> <tr><th colspan="3">End of Tunnel</th></tr> <tr><td></td><td>Spring</td><td>Neap</td></tr> <tr><td>Velocity</td><td>1.6</td><td>0.6</td></tr> <tr><td>Direction</td><td>200</td><td>20</td></tr> </table>	End of dredged channel				Spring	Neap	Velocity	1.1	0.4	Direction	200	20	End of Tunnel				Spring	Neap	Velocity	1.6	0.6	Direction	200	20
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Direct – dredged channel or covered culvert Length – 800m Depth - -2.0m NAP	Tunnel – TBM or trench and cover Diameter 8.6m Length 1700 m Seabed depth at Heads -18.1 m NAP	Tunnel – TBM or trench and cover Diameter 8.6m Length 1700 m Seabed depth at Heads -18.1 m NAP																																												
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Thermal plume			
Option 1	Option 2	Option 3	
<p>Configuration 5 is very similar to option 1. The mixing zone stays in contact with the seabed which contravenes the guidelines. There is also significant recirculation, although not red flag level.</p>	<p>There is no significant contact between the mixing zone and the seabed and very low recirculation</p>	<p>Not modelled, but likely to be compliant by inspection. Significant horizontal separation between inlet and outfall, and outfall is 2 m higher than intake.</p>	
Tunnel Construction Criteria			
Preferred Technology	Slurry or variable density TBM		
	Option 1	Option 2	Option 3
Constructability	N/A	2	2
Logistics	N/A	4	4
Tunnelling Hazards	N/A	3	3
Environmental	N/A	3	3
Overall Scoring			
	Option 1	Option 2	Option 3
Cost*	4	4	2
Constructability (Overall)	3	2	2
Cooling Water Environmental	1	5	4
Cooling Water Temperature	1	5	5
Other Environmental	2	2	5
Ship Impact	5	2	2
UXO risk	3	3	3
Impact local stakeholders	5	5	5
<b>Overall (weighting 1)</b>	300	<b>345</b>	325
<b>Overall (weighting 2)</b>	276	<b>356</b>	<b>356</b>
Risks			
	Option 1	Option 2	Option 3
Permitting of construction of direct intake or outfall in an environmentally protected zone			N/A
Construction of the direct entry/intake under the railway			N/A
Navigational Hazard – Offshore Heads	N/A		
Financial			
	Option 1	Option 2	Option 3
Cost of scheme*			

\*In scoring the bands considered were €0-0.5B, €0.5-1.0B, €1.0-1.5B, €1.5-2.0B, >€2.0B. In Risk and cost of scheme the 💰 refer to the bands instructed by KGG, per Appendix A

# Sloegebied 1

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Direct – dredged channel Length – 750m Depth - -3.6m NAP Connecting canal length – 3700m	Direct – dredged channel Length – 550m Depth - -3.6m NAP																																													
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Direct – dredged channel Length – 600m Depth - -5.4 m NAP	Tunnel – TBM or trench and cover Diameter 7.0 m Length 900m Seabed depth at Heads -20.0 m NAP																																													

Thermal plume		
Option 1	Option 2	
<p>Configuration 3 is similar to Option 1 and shows that this is thermally compliant to guidelines but with an amber flag for recirculation</p>	<p>Configuration 5 is equivalent to Option 2 which is thermally compliant. There remains some recirculation but it is reduced</p>	
Tunnel Construction Criteria		
Preferred Technology	Slurry or variable density TBM	
	Option 1	Option 2
Constructability	N/A	2
Logistics	N/A	3
Tunnelling Hazards	N/A	4
Environmental	N/A	2
Overall Scoring		
	Option 1	Option 2
Cost*	4	3
Constructability (Overall)	3	2
Cooling Water Environmental	5	5
Cooling Water Temperature	3	5
Other Environmental	2	3
Ship Impact	5	2
UXO risk	2	2
Impact local stakeholders	1	3
<b>Overall (weighting 1)</b>	<b>325</b>	<b>310</b>
<b>Overall (weighting 2)</b>	<b>332</b>	<b>332</b>
Risks		
	Option 1	Option 2
Permitting of construction of direct intake or outfall in an environmentally protected zone		
Construction of the direct entry/intake under the national dyke		
Construction of the direct entry/intake under the railway		
Stakeholder pressure – local beach users and watersports enthusiasts		
Navigational Hazard – Offshore Heads	N/A	
Financial		
	Option 1	Option 2
Cost of scheme*		

\*In scoring the bands considered were €0-0.5B, €0.5-1.0B, €1.0-1.5B, €1.5-2.0B, >€2.0B. In Risk and cost of scheme the refer to the bands instructed by KGG, per Appendix A

## Sloegebied 2

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Thermal plume			
Option 1	Option 2	Option 3	
<p>This option is not modelled but configurations 5 and 6 both model tunnel intake and direct outfall. Both are compliant with guidelines and they show little difference with separation distance, indicating that this option should also comply.</p>	<p>This option is not modelled but configuration 8 and the alternative configuration both model tunnel outfall and direct intake. Both are compliant with guidelines and they show little difference with separation distance, indicating that this option should also comply. Both show amber flag for recirculation.</p>	<p>This option is not modelled but it is informed by configurations 5,6, 8 and the alternative configuration. These indicate that the all tunnel option is likely to be compliant but that there may be recirculation at an elevated level.</p>	
Tunnel Construction Criteria			
Preferred Technology	Slurry or variable density TBM		
	Option 1	Option 2	Option 3
Constructability	2	2	2
Logistics	3	3	3
Tunnelling Hazards	3	3	3
Environmental	2	2	2
Overall Scoring			
	Option 1	Option 2	Option 3
Cost*	4	3	2
Constructability (Overall)	2	2	2
Cooling Water Environmental	4	4	4
Cooling Water Temperature	4	4	4
Other Environmental	2	2	5
Ship Impact	2	2	2
UXO risk	2	2	2
Impact local stakeholders	2	2	5
<b>Overall (weighting 1)</b>	290	265	<b>305</b>
<b>Overall (weighting 2)</b>	296	276	<b>340</b>
Risks			
	Option 1	Option 2	Option 3
Permitting of construction of direct intake or outfall in an environmentally protected zone			N/A
Construction of the direct entry/intake under the railway			N/A
Stakeholder pressure – local beach users and watersports enthusiasts			N/A
Navigational Hazard – Offshore Heads			
Financial			
	Option 1	Option 2	Option 3
Cost of scheme*			

\*In scoring the bands considered were €0-0.5B, €0.5-1.0B, €1.0-1.5B, €1.5-2.0B, >€2.0B. In Risk and cost of scheme the refer to the bands instructed by KGG, per Appendix A

# Terneuzen 1A

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Intake Dimensions																																														
Option 1	Option 2	Option 3																																												
Direct – dredged channel or covered culvert Length – 750m Depth - -5.6 m NAP	Tunnel – TBM Diameter 7.0m Length 1800 m Seabed depth at Heads -12.0 m NAP	Tunnel – TBM Diameter 7.0m Length 2600 m Seabed depth at Heads -13.2 m NAP																																												

Thermal plume			
Option 1	Option 2	Option 3	
<p>Option 1 is the Intake from configuration 5 (left above) and the Outfall from configuration 2 (inverse of configuration 1, right above). In both cases the mixing zone is fully compliant. The actual option requires modelling to ensure that there is not excessive recirculation.</p>	<p>Option 2 is very similar to configuration 2 (inverse of configuration 1, above). This is compliant with guidelines.</p>	<p>Configurations 1 and 2 model the outfall and intake respectively as tunnels with Heads in a location similar to our Option 3. In both cases the mixing zone complies with guidelines.</p>	
Tunnel Construction Criteria			
Preferred Technology	Earth Pressure Balance TBM		
	Option 1	Option 2	Option 3
Constructability	N/A	3	3
Logistics	N/A	4	4
Tunnelling Hazards	N/A	3	3
Environmental	N/A	4	4
Overall Scoring			
	Option 1	Option 2	Option 3
Cost*	5	3	2
Constructability (Overall)	4	3	3
Cooling Water Environmental	5	5	4
Cooling Water Temperature	5	5	4
Other Environmental	1	1	5
Ship Impact	5	1	1
UXO risk	2	2	2
Impact local stakeholders	5	5	5
<b>Overall (weighting 1)</b>	<b>405</b>	315	330
<b>Overall (weighting 2)</b>	<b>388</b>	308	340
Risks			
	Option 1	Option 2	Option 3
Permitting of construction of direct intake or outfall in an environmentally protected zone			N/A
Navigational Hazard – Offshore Heads	N/A		
Construction of the direct entry/intake under the National Dyke			N/A
Financial			
	Option 1	Option 2	Option 3
Cost of scheme*			

\*In scoring the bands considered were €0-0.5B, €0.5-1.0B, €1.0-1.5B, €1.5-2.0B, >€2.0B. In Risk and cost of scheme the refer to the bands instructed by KGG, per Appendix A

# Terneuzen 1B

## General Site Information

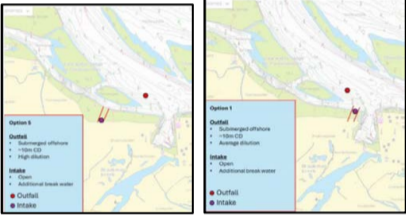




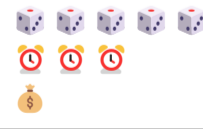

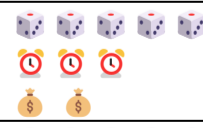
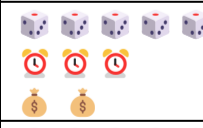
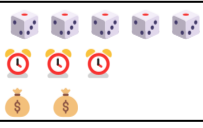

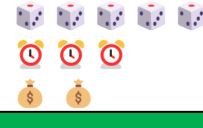
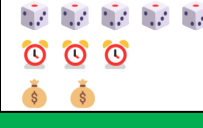
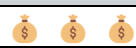
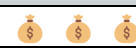
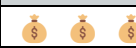
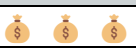
Location	Topography	Bathymetry

## Metocean Data

Water Levels – NAP (m)	Wave Heights Hs (m)	Current Data (m/s)																																														
<table border="1"> <tr><td>High WL -10,000 yr</td><td>6.0</td></tr> <tr><td>High WL -100 yr</td><td>4.7</td></tr> <tr><td>HAT</td><td>3.4</td></tr> <tr><td>LAT</td><td>-2.7</td></tr> <tr><td>Low WL -100 yr</td><td>-3.4</td></tr> <tr><td>Low WL -10,000 yr</td><td>-4.1</td></tr> <tr><td>Climate Change</td><td>1.24</td></tr> </table>	High WL -10,000 yr	6.0	High WL -100 yr	4.7	HAT	3.4	LAT	-2.7	Low WL -100 yr	-3.4	Low WL -10,000 yr	-4.1	Climate Change	1.24	<table border="1"> <tr><td>10,000 yr</td><td>2.6</td></tr> <tr><td>10 yr</td><td>1.4</td></tr> </table> <table border="1"> <tr><td colspan="2">Ambient Temperature (C)</td></tr> <tr><td>98 percentile</td><td>21.8</td></tr> </table>	10,000 yr	2.6	10 yr	1.4	Ambient Temperature (C)		98 percentile	21.8	<table border="1"> <tr><td colspan="3">End of dredged channel</td></tr> <tr><td></td><td>Spring</td><td>Neap</td></tr> <tr><td>Velocity</td><td>0.8</td><td>0.5</td></tr> <tr><td>Direction</td><td>280</td><td>100</td></tr> </table> <table border="1"> <tr><td colspan="3">End of Tunnel</td></tr> <tr><td></td><td>Spring</td><td>Neap</td></tr> <tr><td>Velocity</td><td>1.9</td><td>0.6</td></tr> <tr><td>Direction</td><td>300</td><td>120</td></tr> </table>	End of dredged channel				Spring	Neap	Velocity	0.8	0.5	Direction	280	100	End of Tunnel				Spring	Neap	Velocity	1.9	0.6	Direction	300	120
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## Options

Option 1	Option 2	Option 3
Option 4		

Outfall Dimensions				
Option 1	Option 2	Option 3	Option 4	
Direct – dredged channel or covered culvert Length – 1300m Depth - -3.7m NAP Canal 3600m	Tunnel – TBM Diameter 8.6m Length 2800 m Seabed depth at Heads -12.6 m NAP	Direct – dredged channel or covered culvert Length – 1300m Depth - -3.7m NAP Canal 3600m	Tunnel – TBM Diameter 8.6m Length 2800 m Seabed depth at Heads -12.6 m NAP	
Intake Dimensions				
Option 1	Option 2	Option 3	Option 4	
Direct – dredged channel or covered culvert Length – 1300m Depth - -5.6 m NAP	Direct – dredged channel or covered culvert Length – 1300m Depth - -5.6 m NAP	Tunnel – TBM Diameter 7.0m Length 3400 m Seabed depth at Heads -10.9 m NAP	Tunnel – TBM Diameter 7.0m Length 3400 m Seabed depth at Heads -10.9 m NAP	
Thermal plume				
Option 1	Option 2	Option 3	Option 4	
 <p>Option 1 is the Intake from configuration 5 (left above) and the Outfall from configuration 2 (inverse of configuration 1, right above). In both cases the mixing zone is fully compliant. The actual option requires modelling to ensure that there is not excessive recirculation.</p>	 <p>Option 2 is very similar to configuration 5, above. This is compliant with mixing zone guidelines and low recirculation.</p>	 <p>Option 3 is very similar to configuration 2(inverse of configuration 1, above). This is compliant with guidelines.</p>	 <p>Configurations 1 and 2 model the outfall and intake respectively as tunnels with Heads in a location similar to our Option 4. In both cases the mixing zone complies with guidelines.</p>	
Tunnel Construction Criteria				
Preferred Technology	Earth Pressure Balance TBM			
	Option 1	Option 2	Option 3	Option 4
Constructability	3	3	3	3
Logistics	4	4	4	4
Tunnelling Hazards	3	3	3	3
Environmental	3	3	3	3
Overall Scoring				
	Option 1	Option 2	Option 3	Option 4
Cost*	4	4	3	2
Constructability (Overall)	3	3	3	3
Cooling Water Environmental	5	5	5	4
Cooling Water Temperature	5	5	5	4
Other Environmental	1	1	1	5
Ship Impact	5	1	1	1
UXO risk	2	2	2	2
Impact local stakeholders	5	5	5	5
<b>Overall (weighting 1)</b>	<b>360</b>	340	315	330
<b>Overall (weighting 2)</b>	<b>360</b>	328	308	340
Risks				
	Option 1	Option 2	Option 3	Option 4
Permitting of construction of direct intake or outfall in an environmentally protected zone				N/A
Navigational Hazard – Offshore Heads	N/A			
Construction of the direct entry/intake under the National Dyke				N/A
Financial				
	Option 1	Option 2	Option 3	Option 4
Cost of scheme*				

\*In scoring the bands considered were €0-0.5B, €0.5-1.0B, €1.0-1.5B, €1.5-2.0B, >€2.0B. In Risk and cost of scheme the refer to the bands instructed by KGG, per Appendix A

## Appendix D. KGG Impact Classification

**Table 1: Financial Impact Classification**

**Class Consequence Money Range**

0	None	€ 0
1	Low	€ 0 – € 100,000,000
2	Medium	€ 100,000,000 – € 500,000,000
3	High	€ 500,000,000 – € 1,000,000,000
4	Very High	€ 1,000,000,000 – € 2,000,000,000
5	Exceptional	€ 2,000,000,000 and above

**Table 2: Time Impact Classification**

**Class Consequence Time Range (months)**

0	None	0
1	Low	0 – 6
2	Medium	6 – 12
3	High	12 – 24
4	Very High	24 – 36
5	Exceptional	36 and above

Gevolgen kosten (costs)				Gevolgen uitloop tijd (time)				Risico-inschatting (risks)			
Class	Consequence for costs	Range		Class	consequence for time	Range		Class	chance of occurrence	Range	
		Euro				months				%	
1 / 🟡	Low	0	100 mln	1 / 🟡	Low	0	6	1 / 🟡	Low	0	2,5
2 / 🟡🟡	Medium	100 mln	500 mln	2 / 🟡🟡	Medium	6	12	2 / 🟡🟡	Medium	2,5	10
3 / 🟡🟡🟡	High	500 mln	1 mld	3 / 🟡🟡🟡	High	12	24	3 / 🟡🟡🟡	High	10	25
4 / 🟡🟡🟡🟡	Very high	1 mld	2 mld	4 / 🟡🟡🟡🟡	Very high	24	36	4 / 🟡🟡🟡🟡	Very high	25	50
5 / 🟡🟡🟡🟡🟡	Exeptional	> 2 mld		5 / 🟡🟡🟡🟡🟡	Exeptional	> 36		5 / 🟡🟡🟡🟡🟡	Almost certain	> 50	