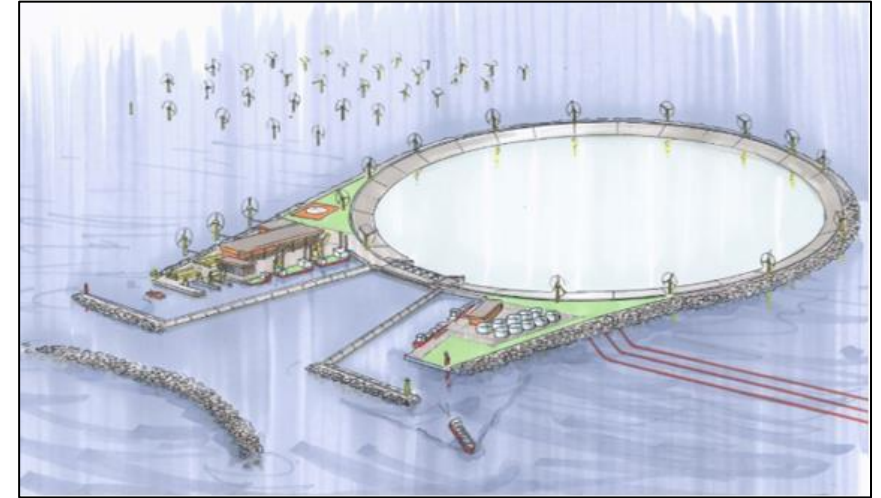


Offshore energieopslag met behulp van waterkracht

Lucas de Vilder, Onderzoeker, TU Delft

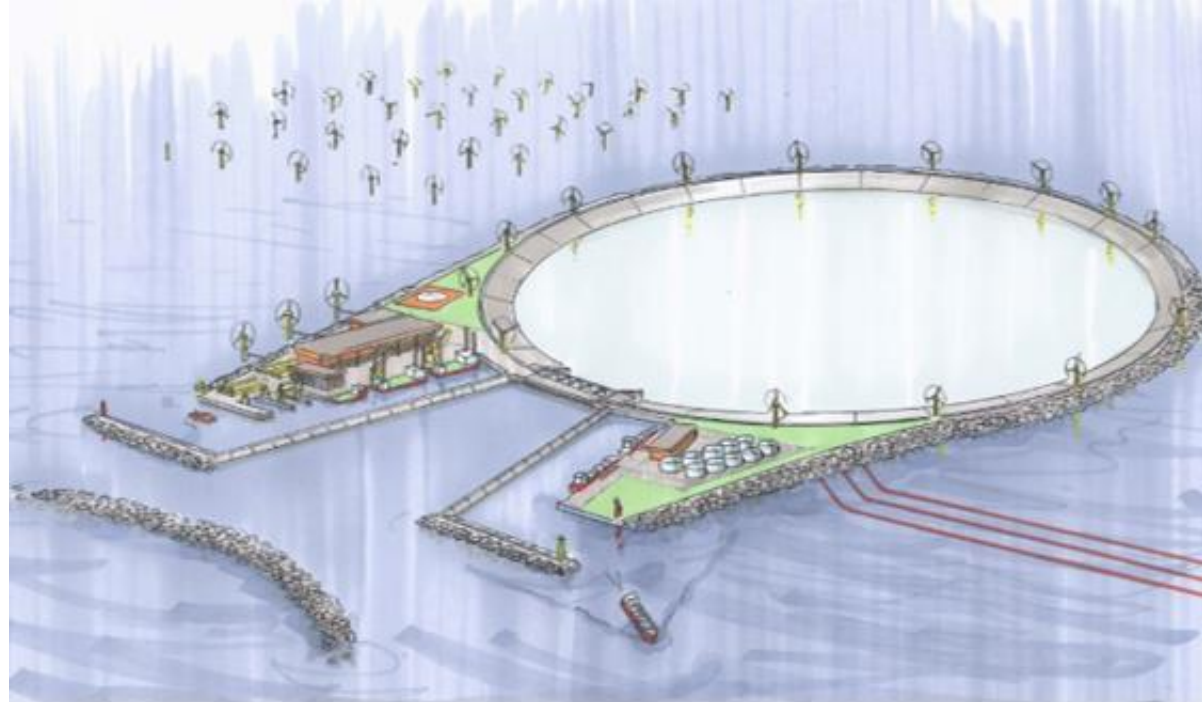
Inhoud

- Introductie valmeer
- Locatie keuze
- Dam ontwerp
- Fasering
- Planning
- Pomp-turbines
- Milieu impact
- Haalbaarheid



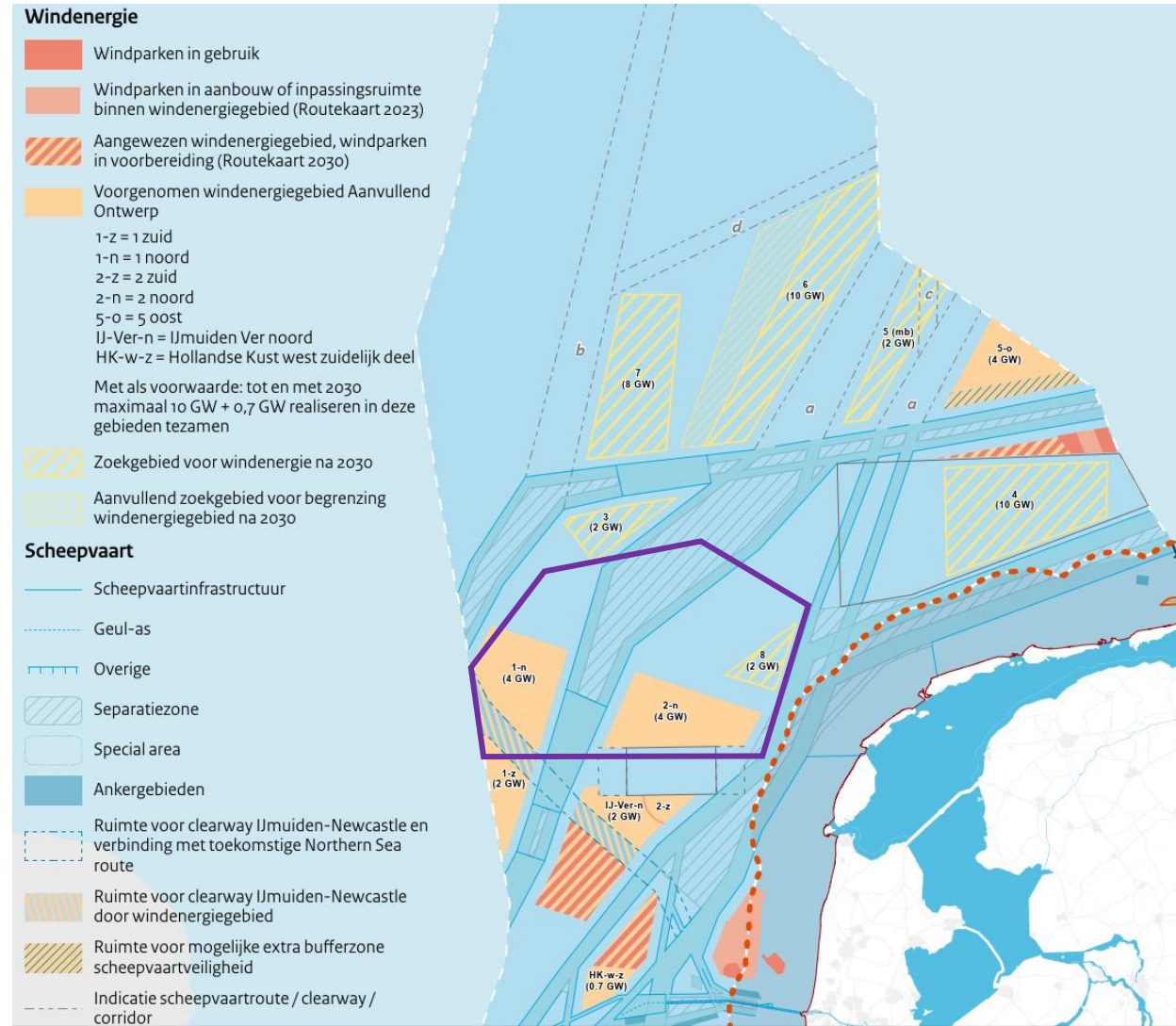
Introductie valmeer

- Offshore wind capaciteit NL: 4,7 GW in 2023 ➔ 70 GW in 2050
- Energie opslag met waterkracht wereldwijd meest toegepaste techniek
- Valmeer op zee: 6 km diameter, 20 GWh opslag, 2 GW vermogen



Locatie keuze

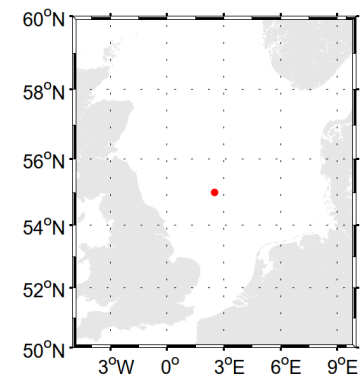
1. Aansluiten op toekomstige windparken
2. Waterdiepte 20 – 30 m
3. Afsluitende kleilaag



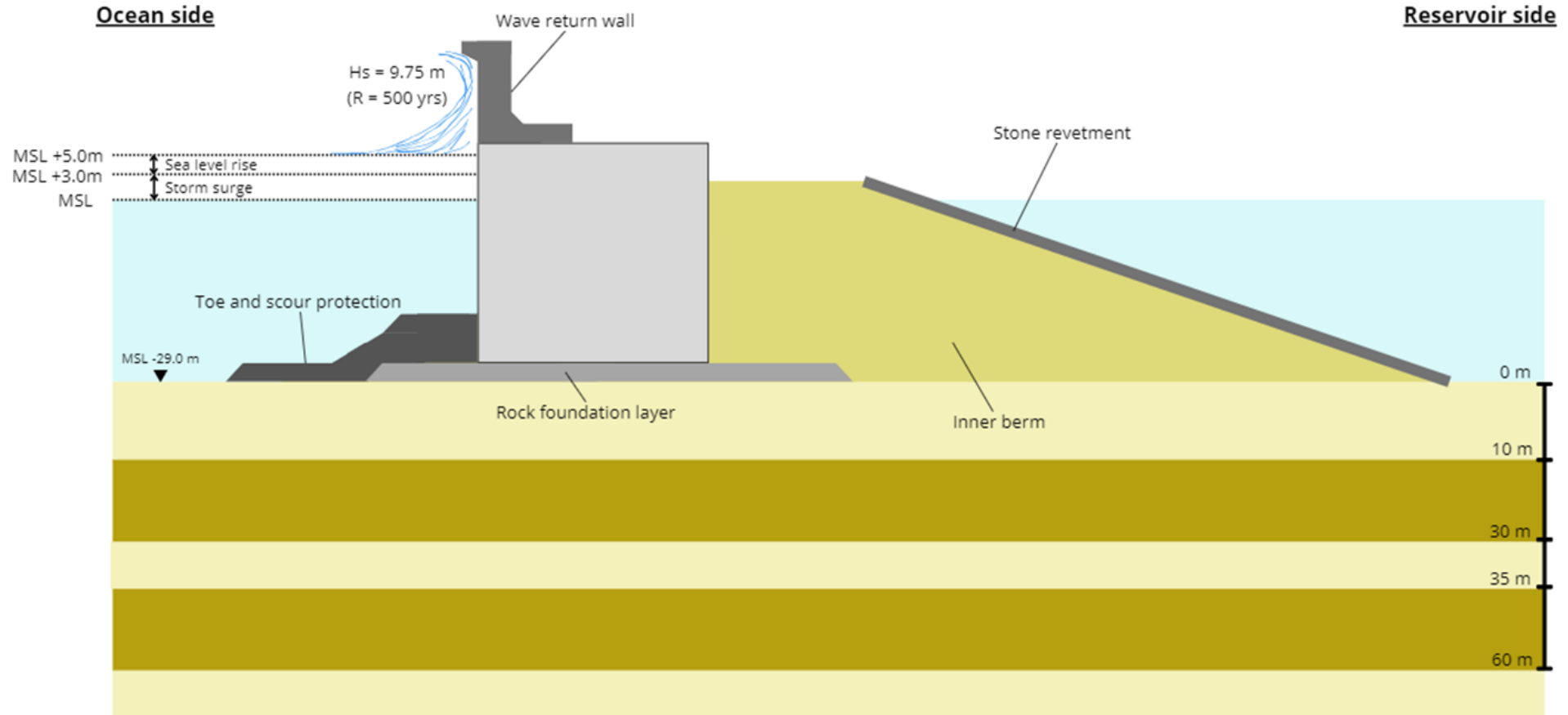
Dam ontwerp



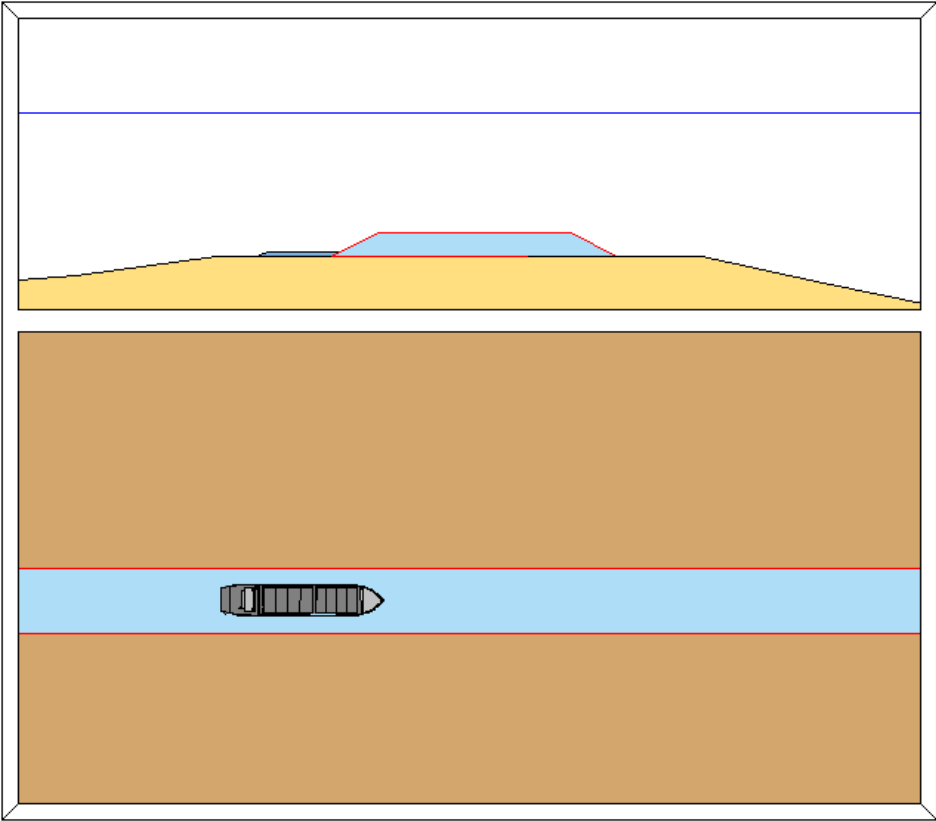
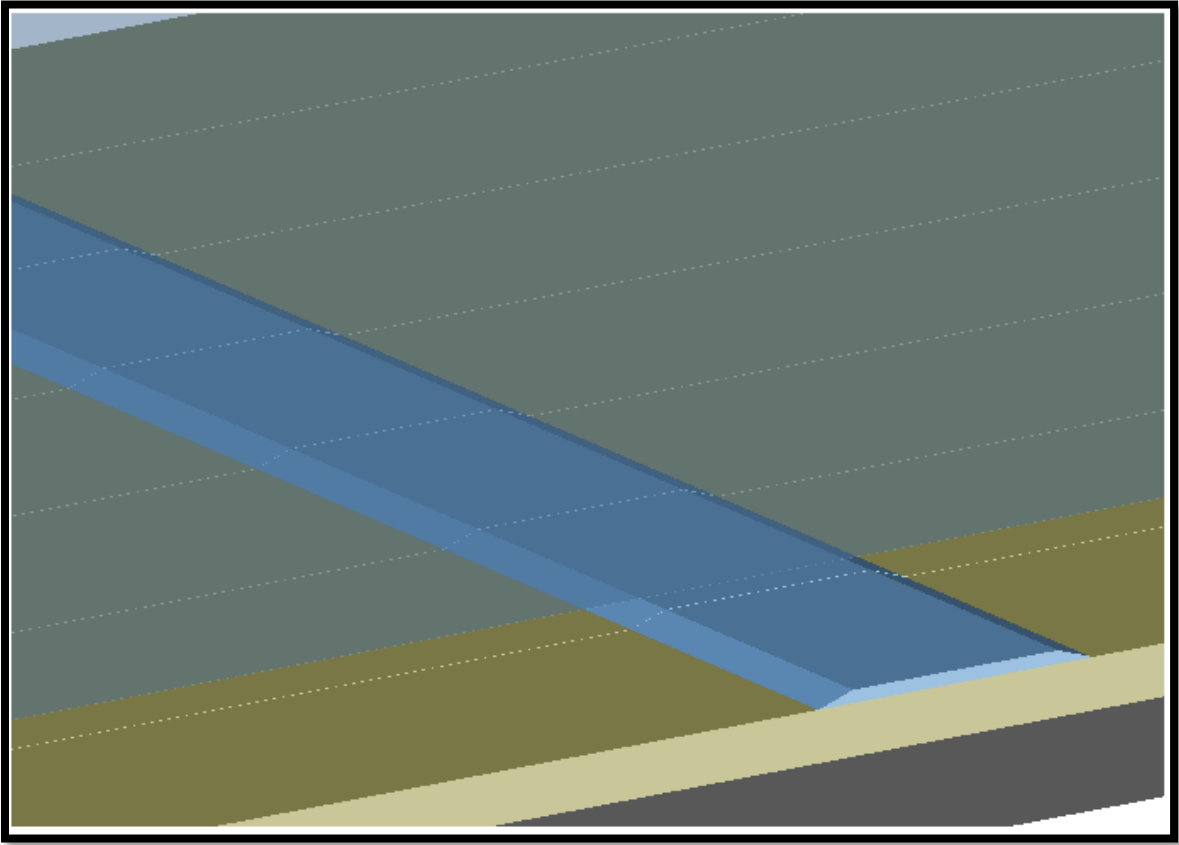
Terugkeertijd [jaar]	Golfhoogte Hs [m]
1	6,1
10	7,6
100	8,8
1000	9,9



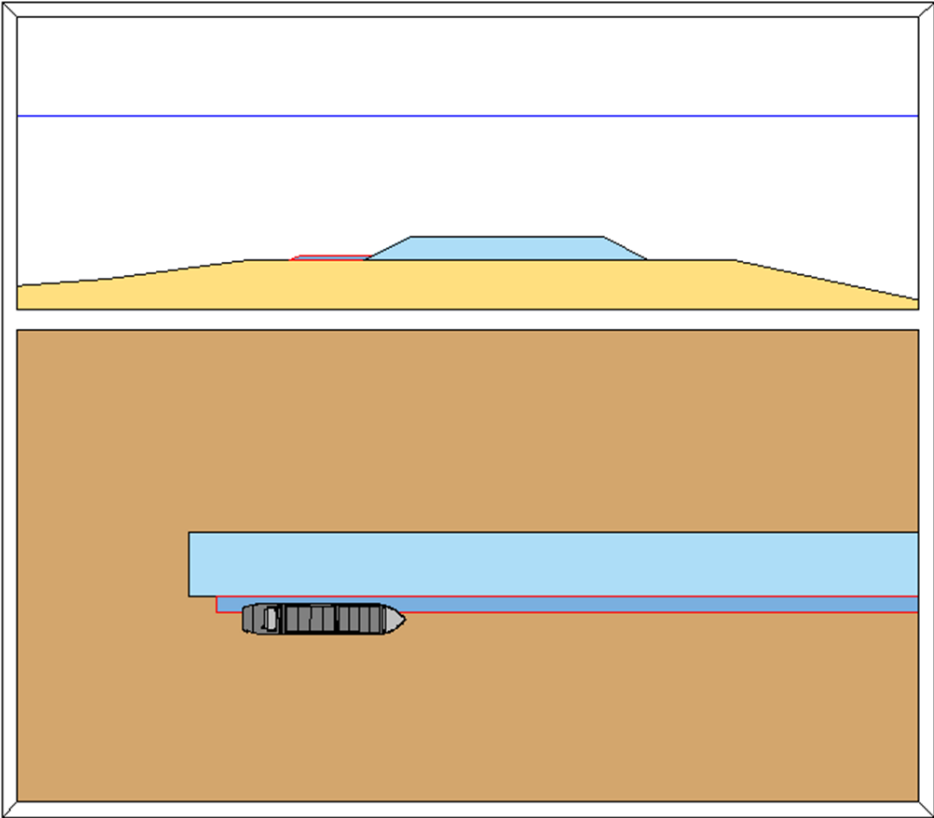
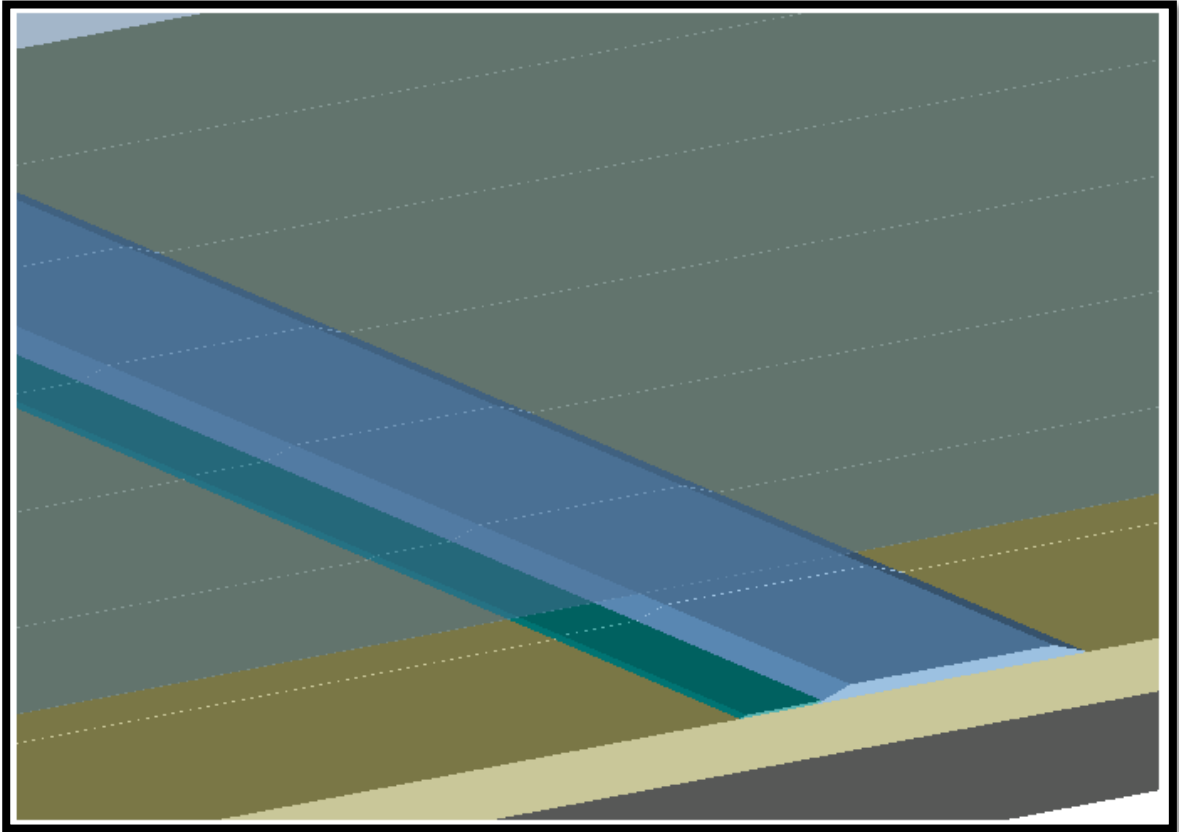
Dam ontwerp



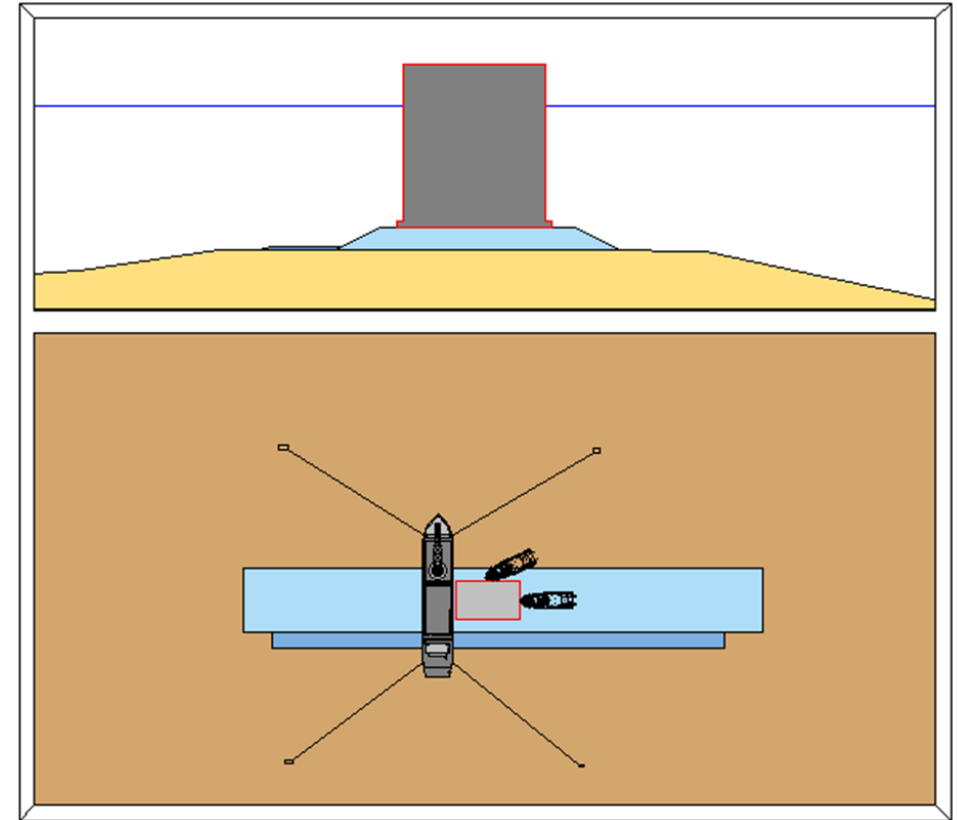
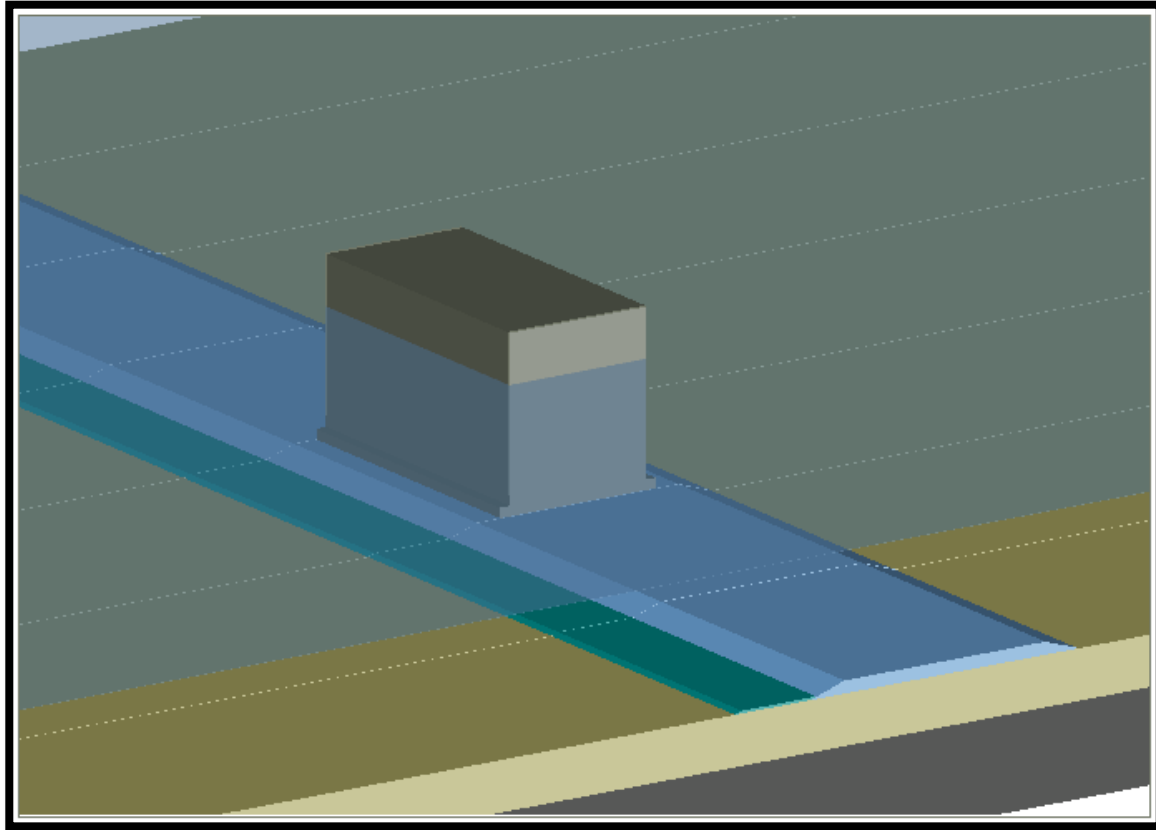
Fasering



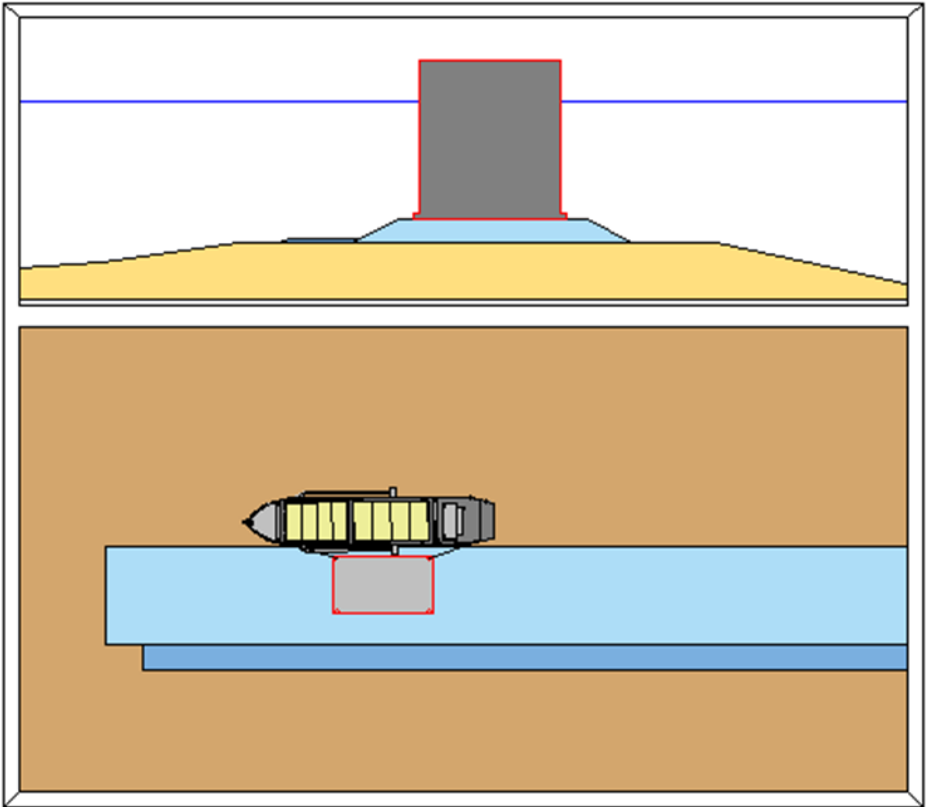
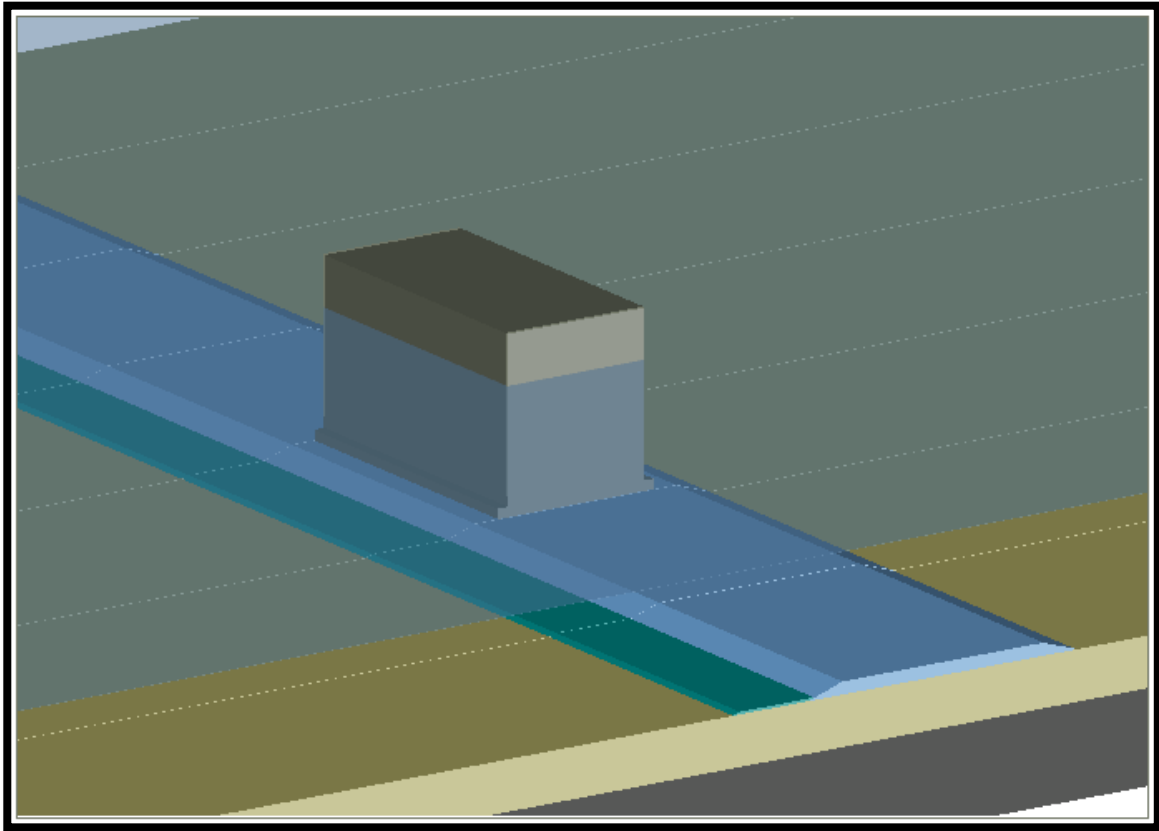
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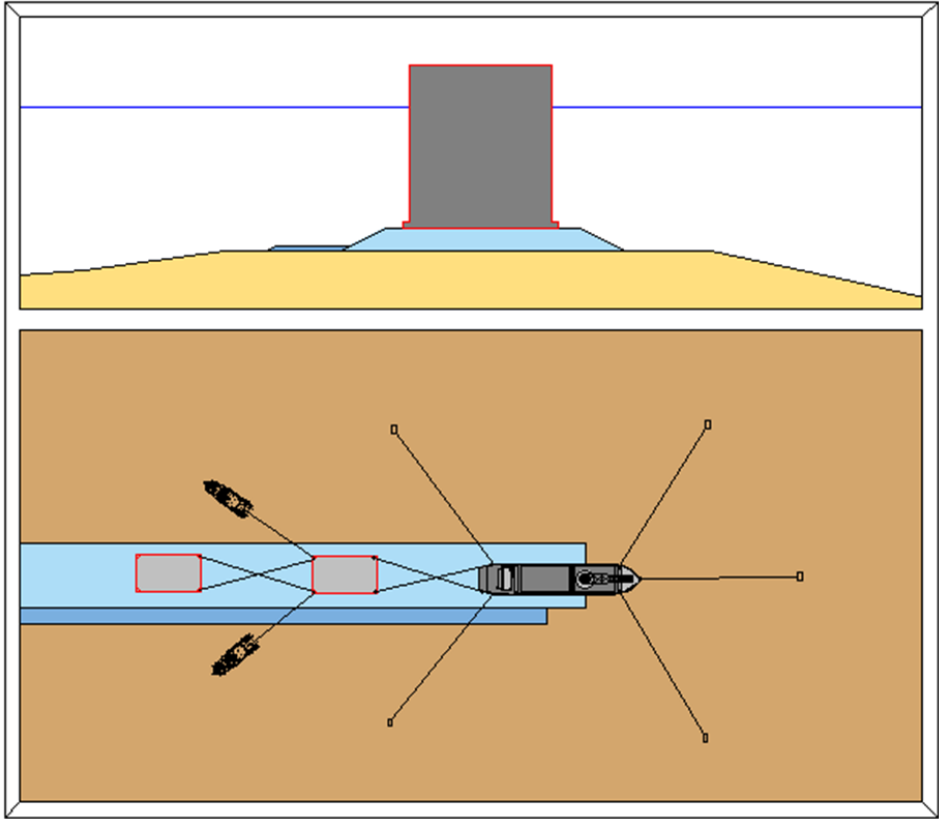
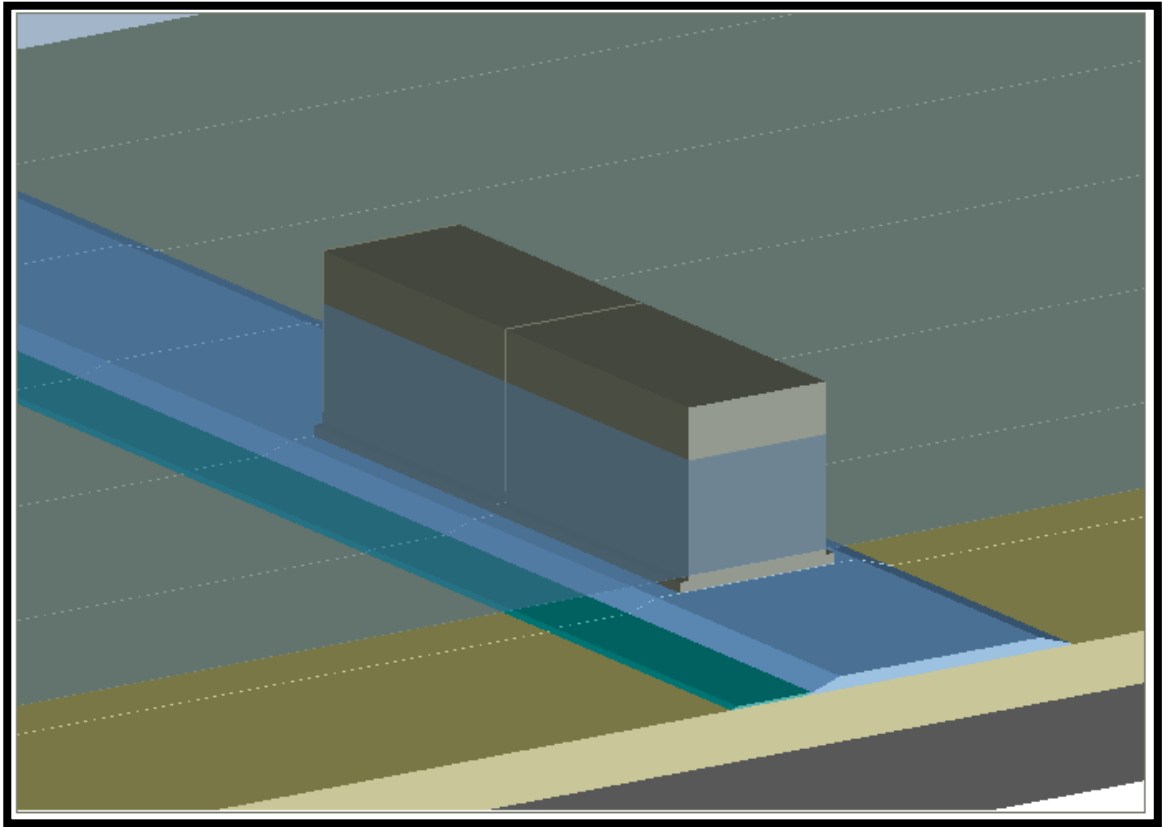
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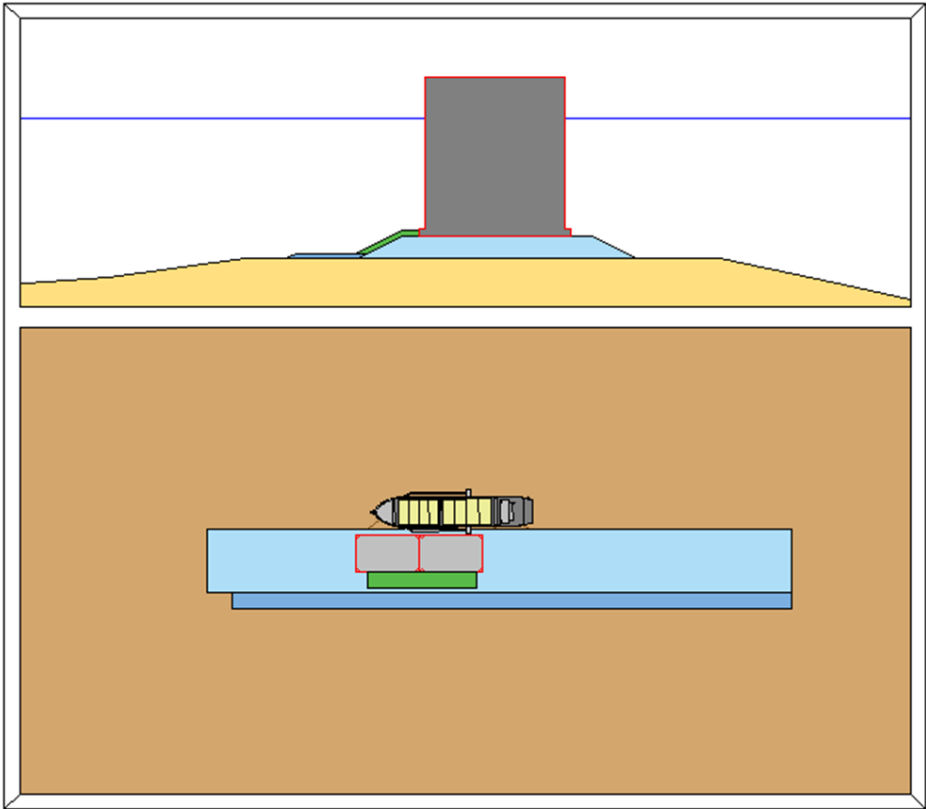
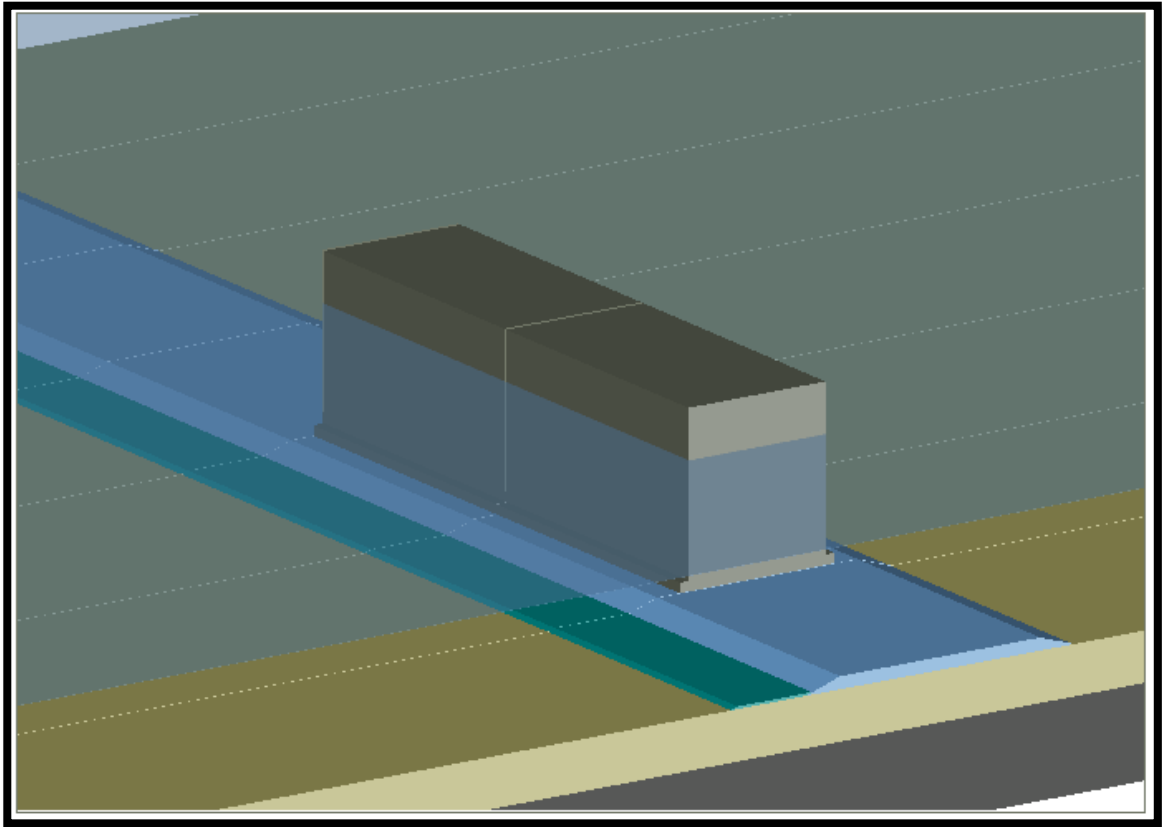
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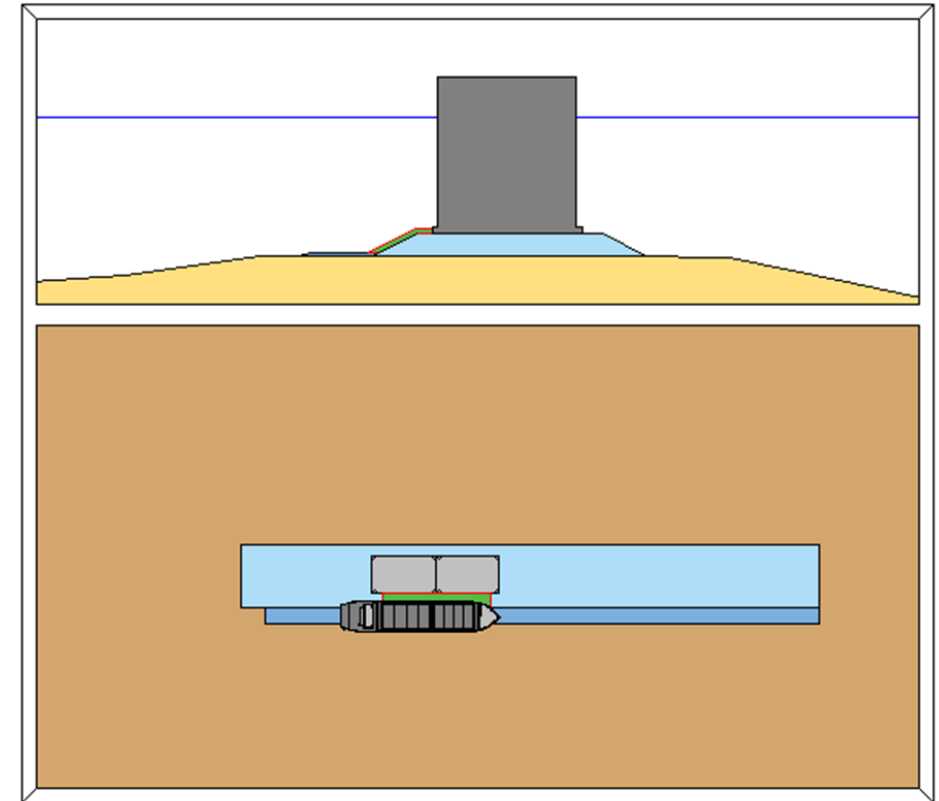
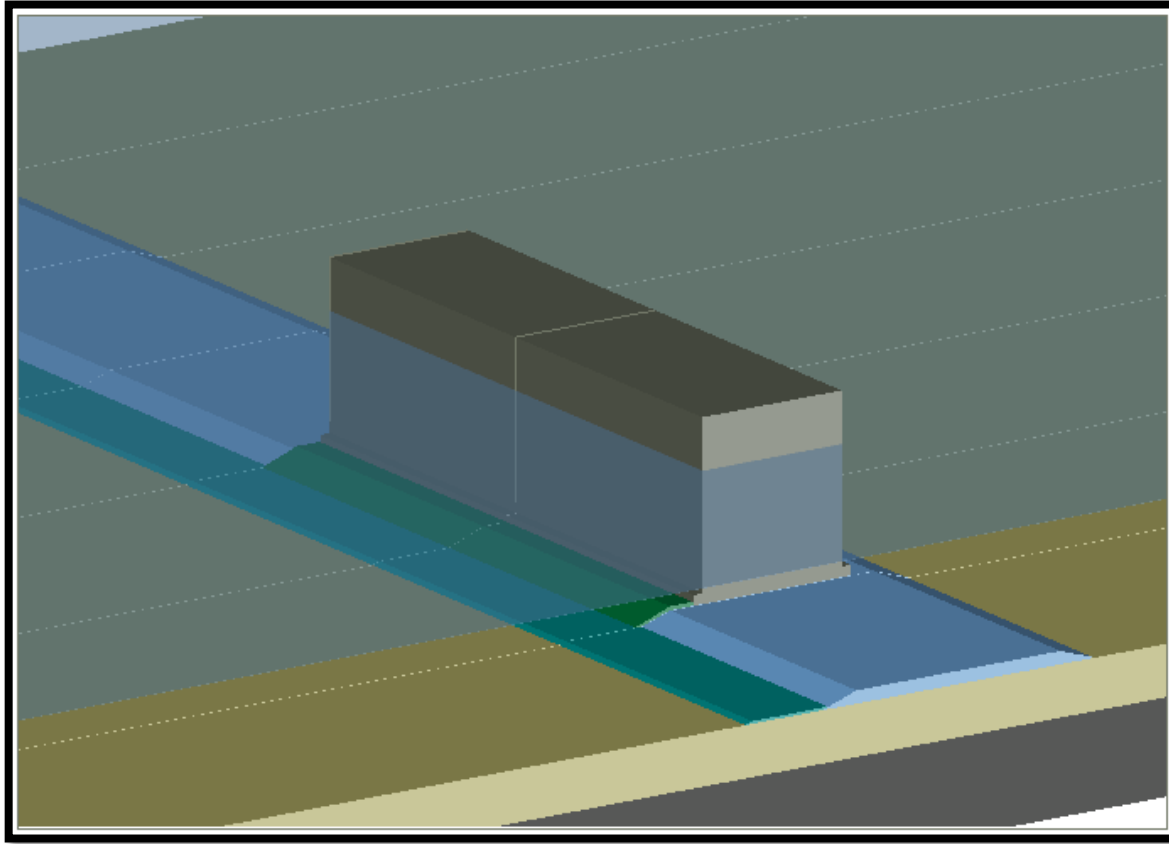
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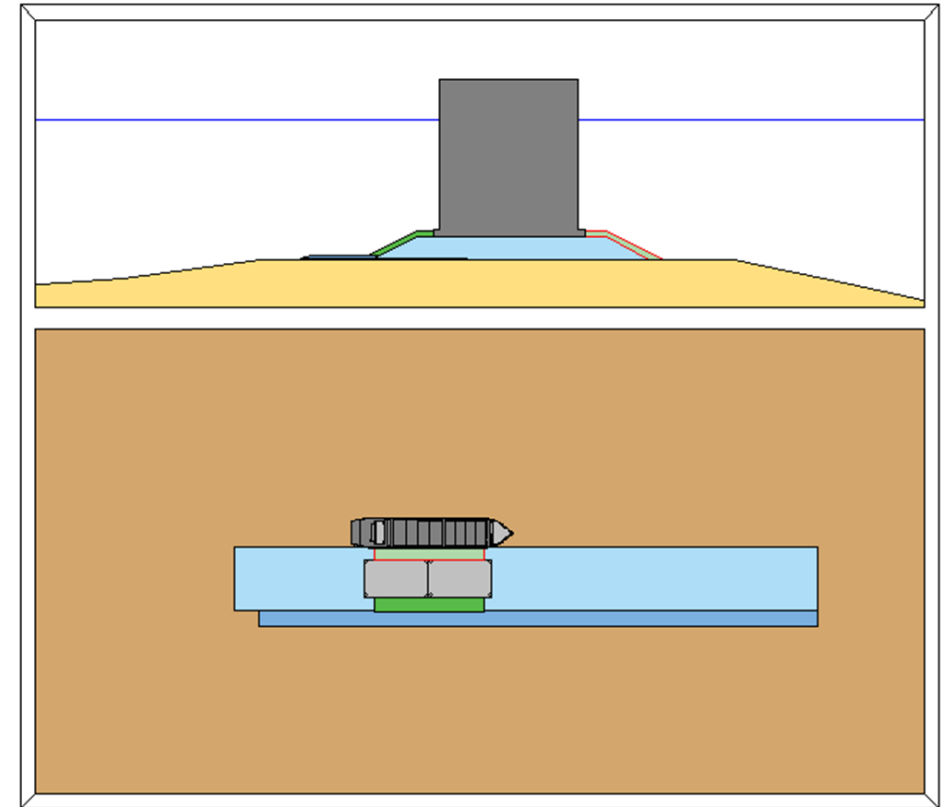
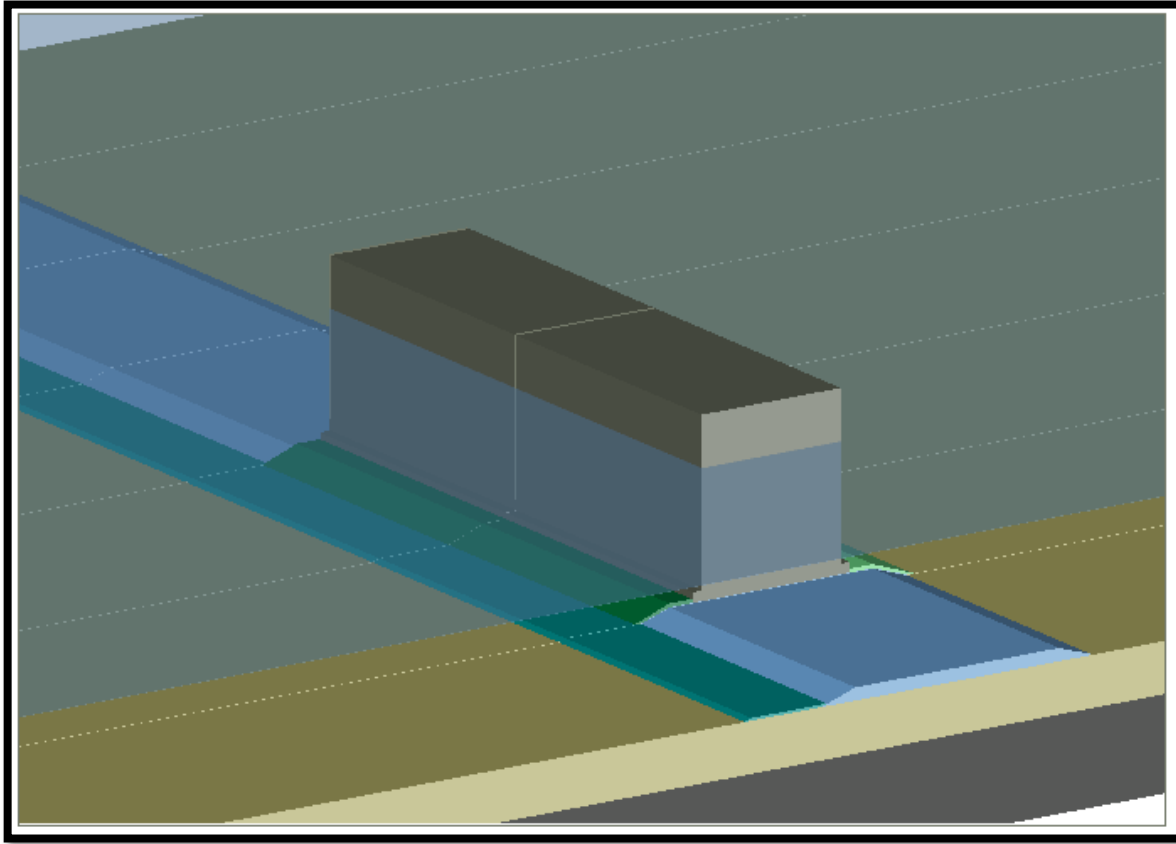
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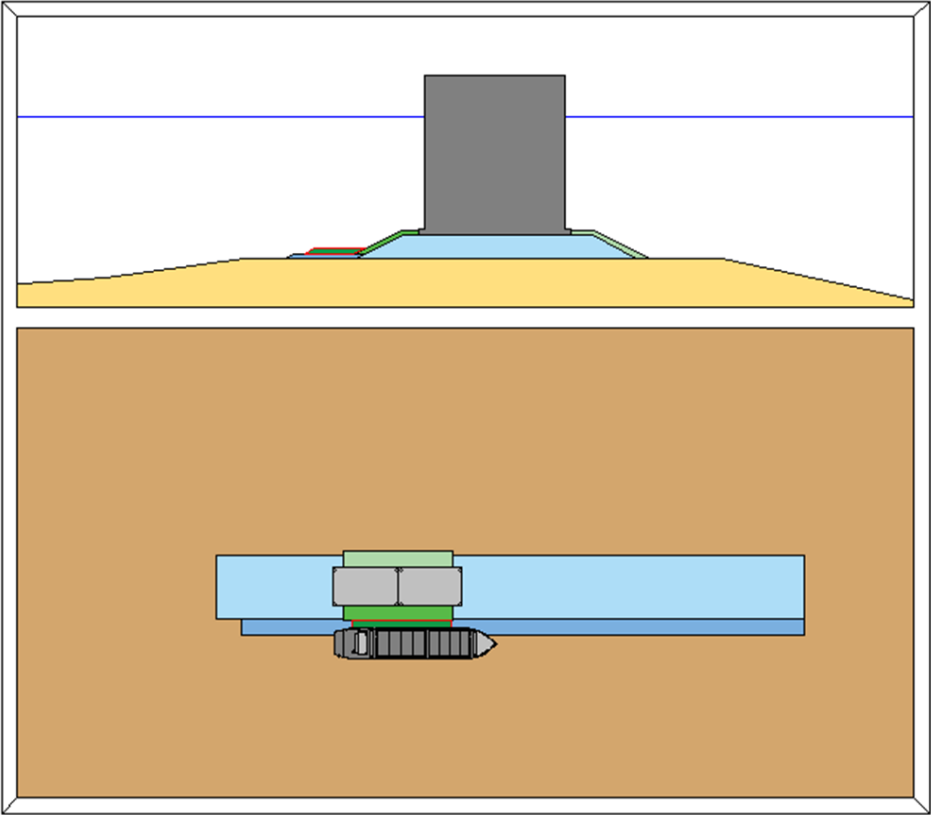
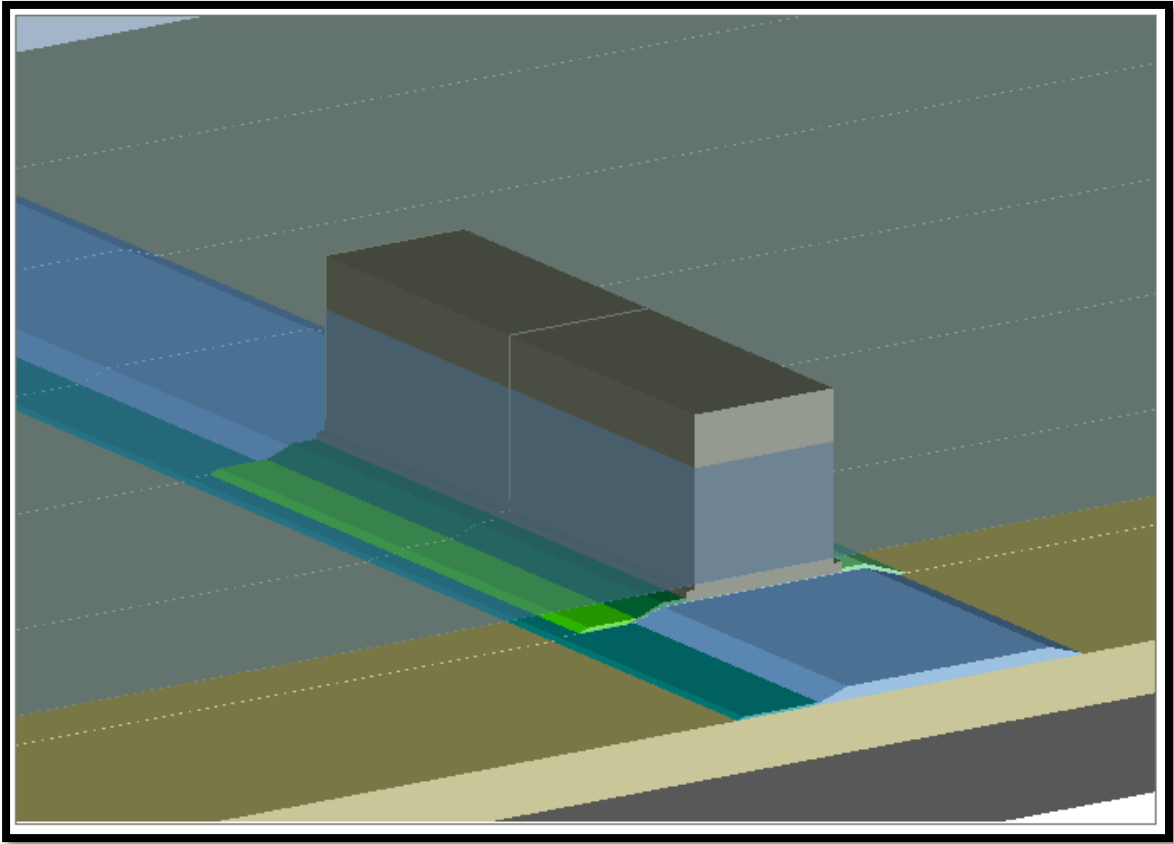
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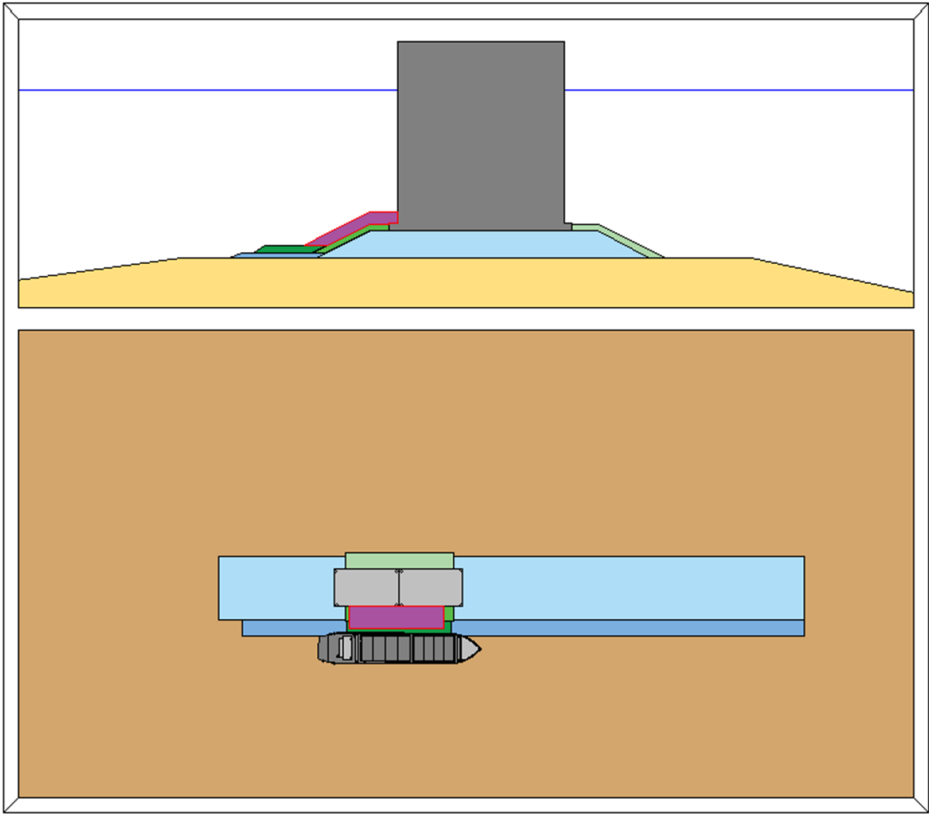
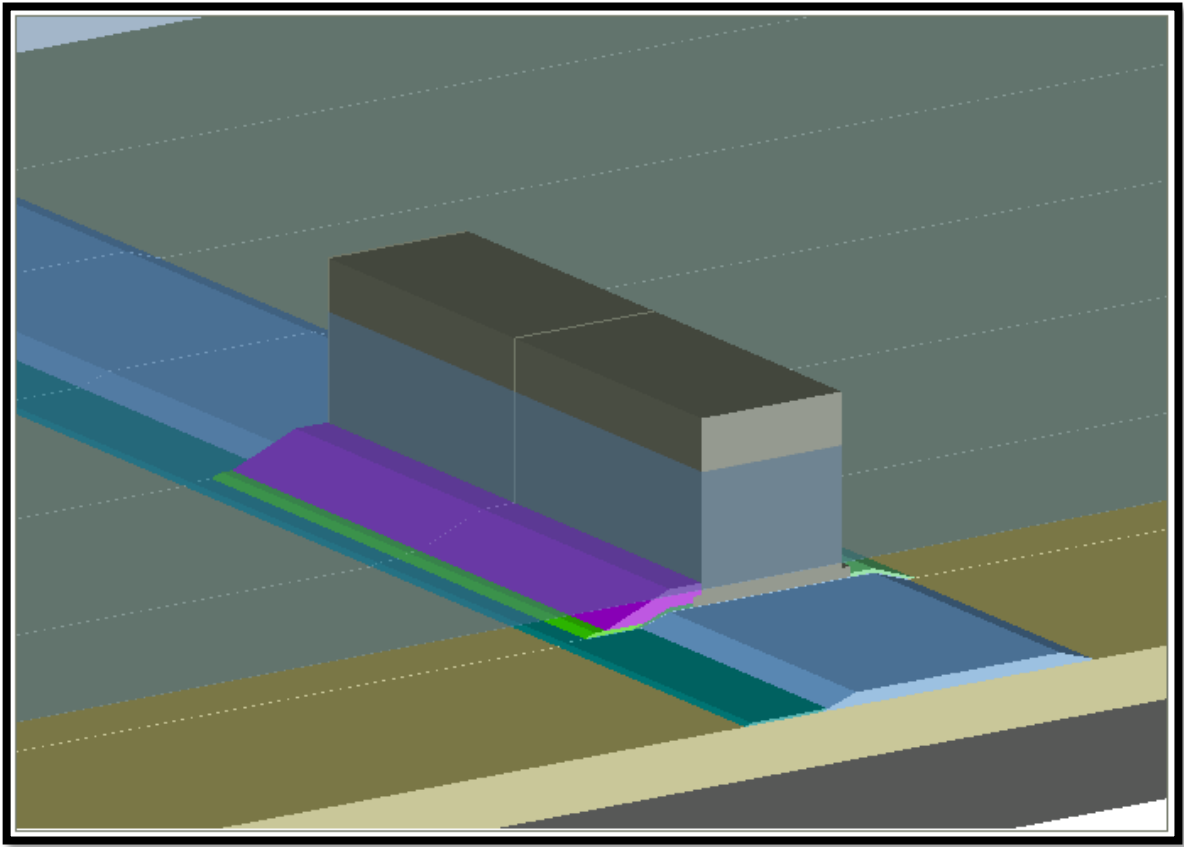
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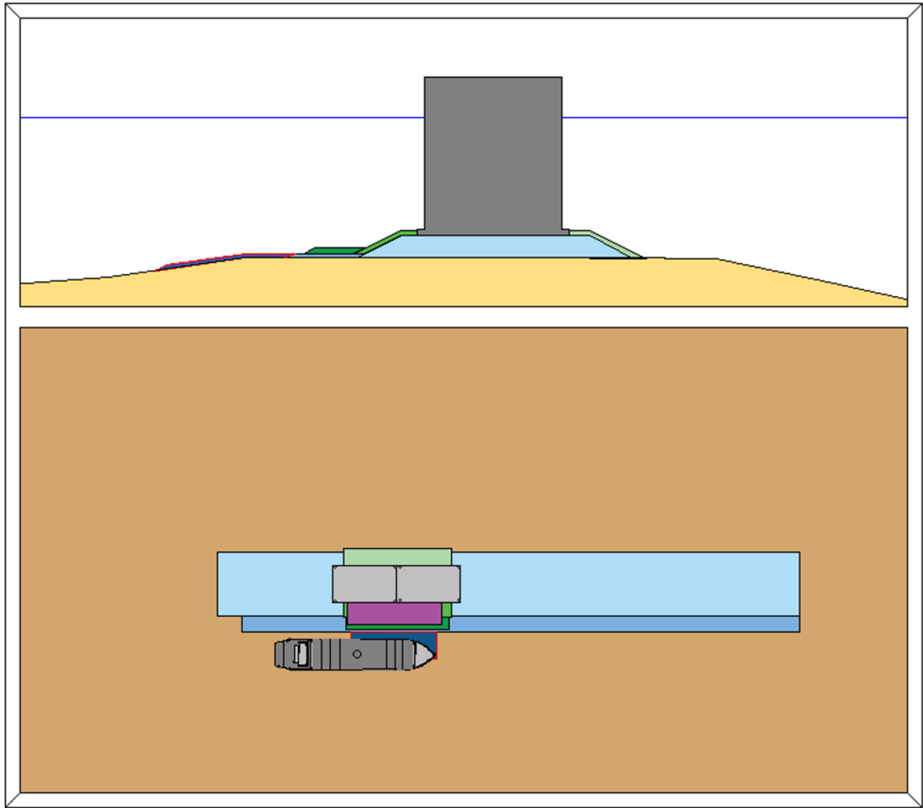
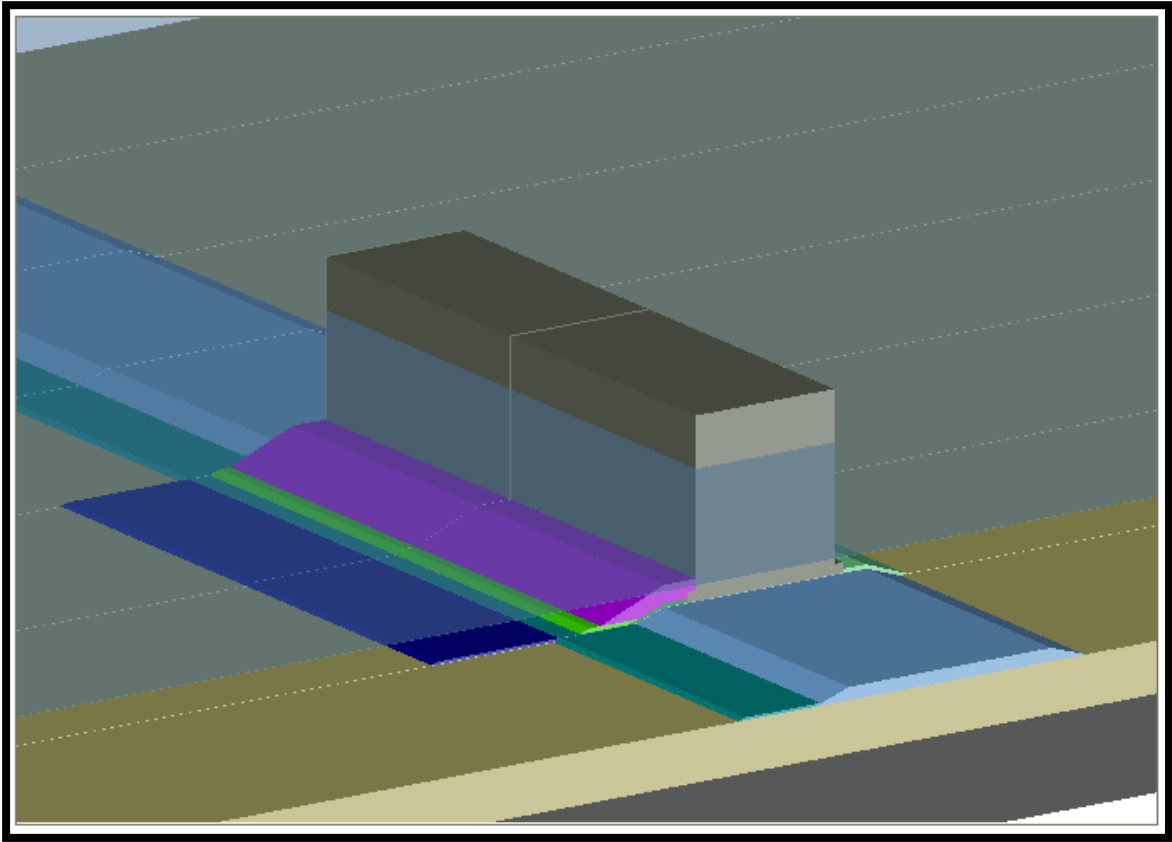
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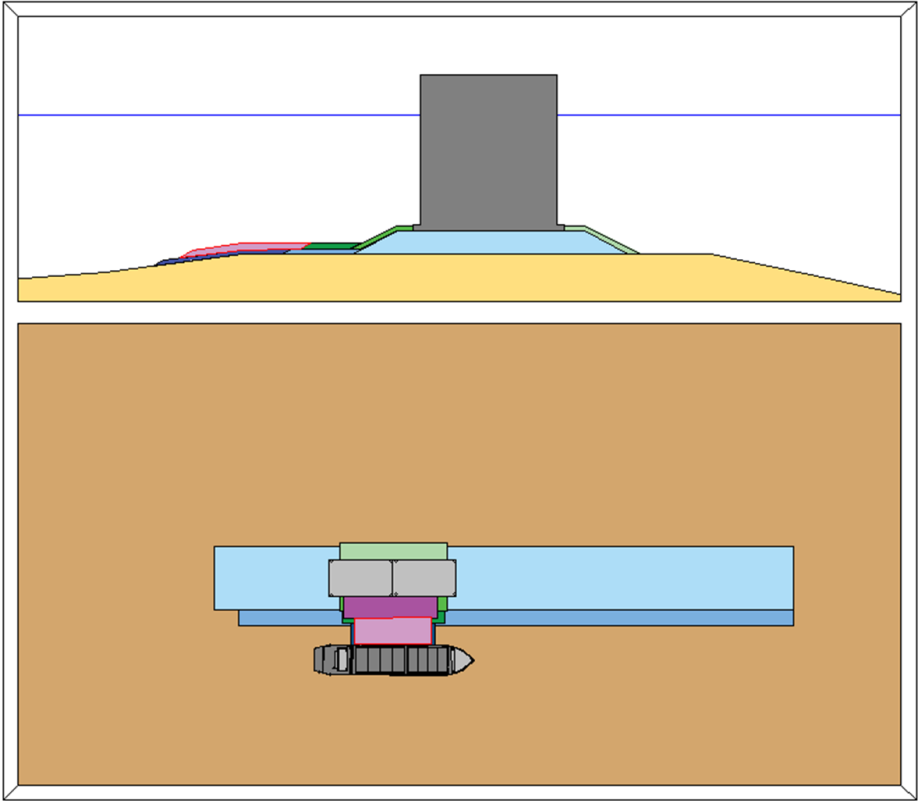
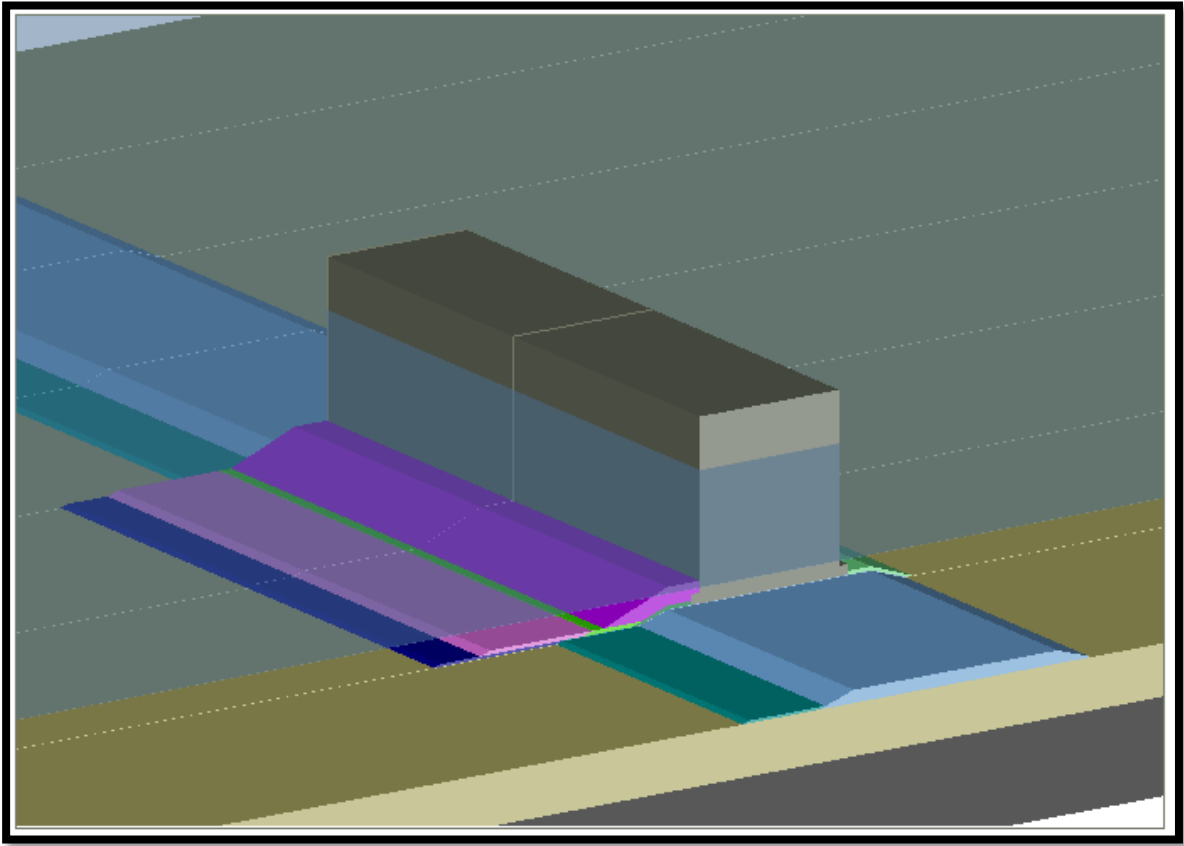
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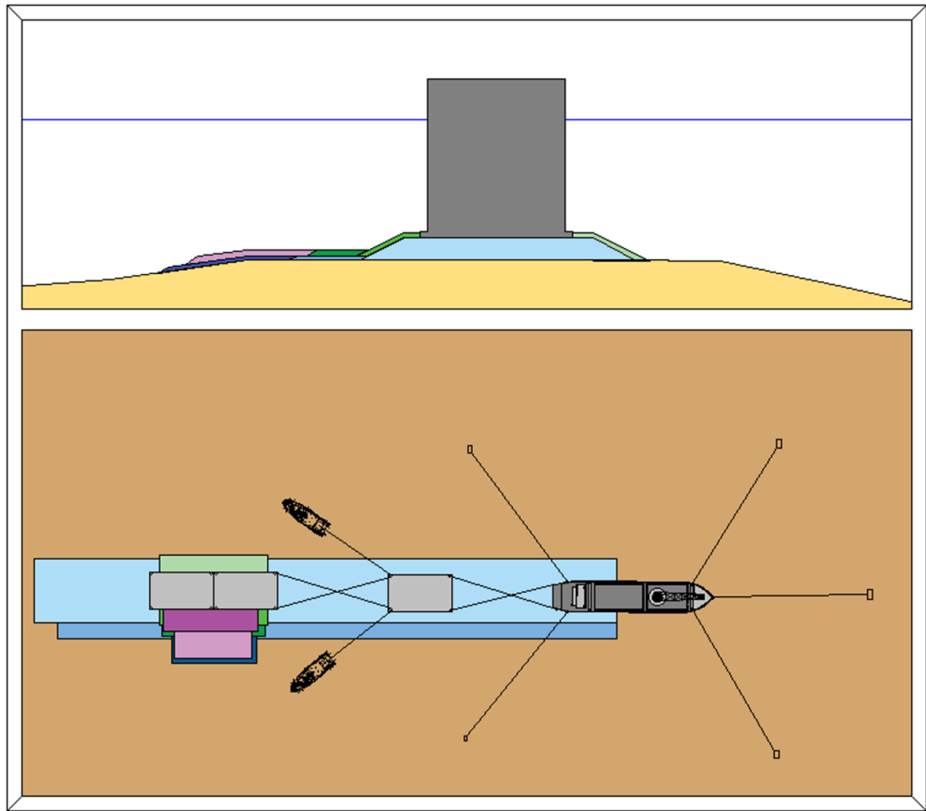
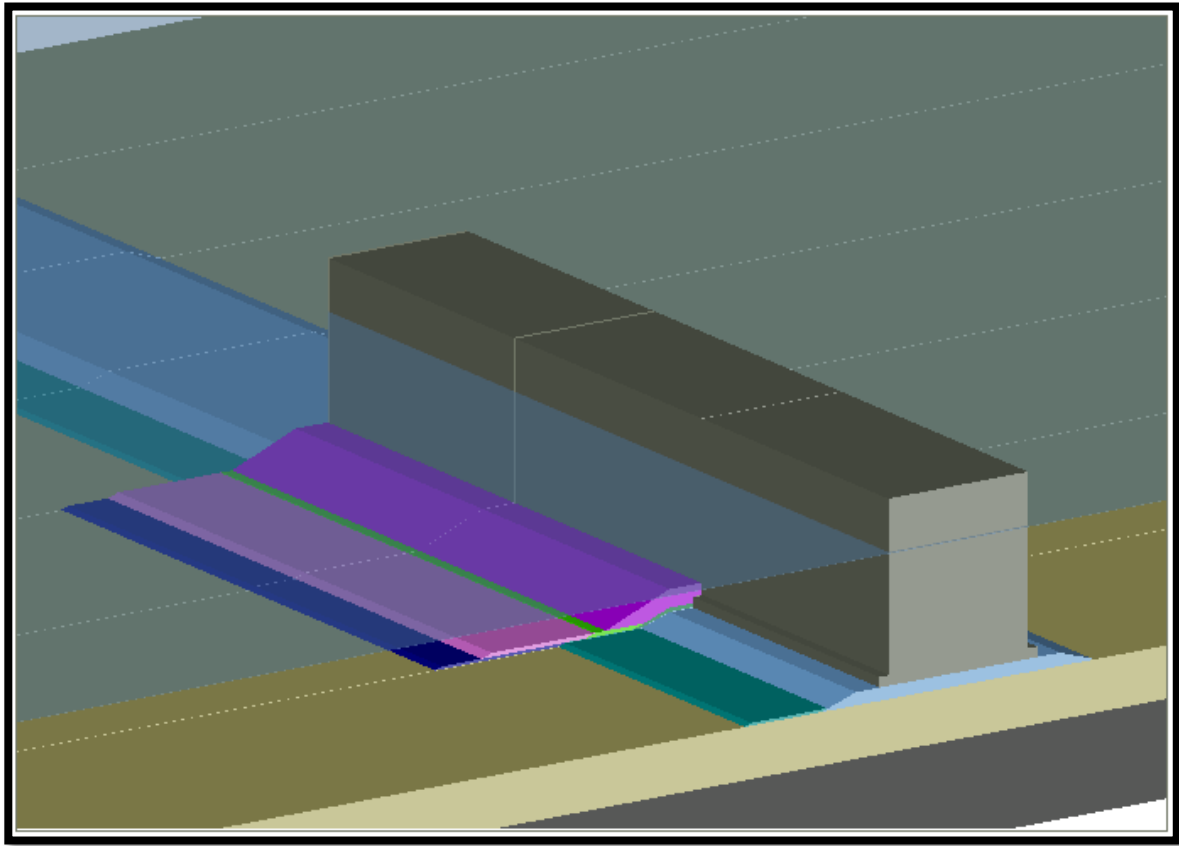
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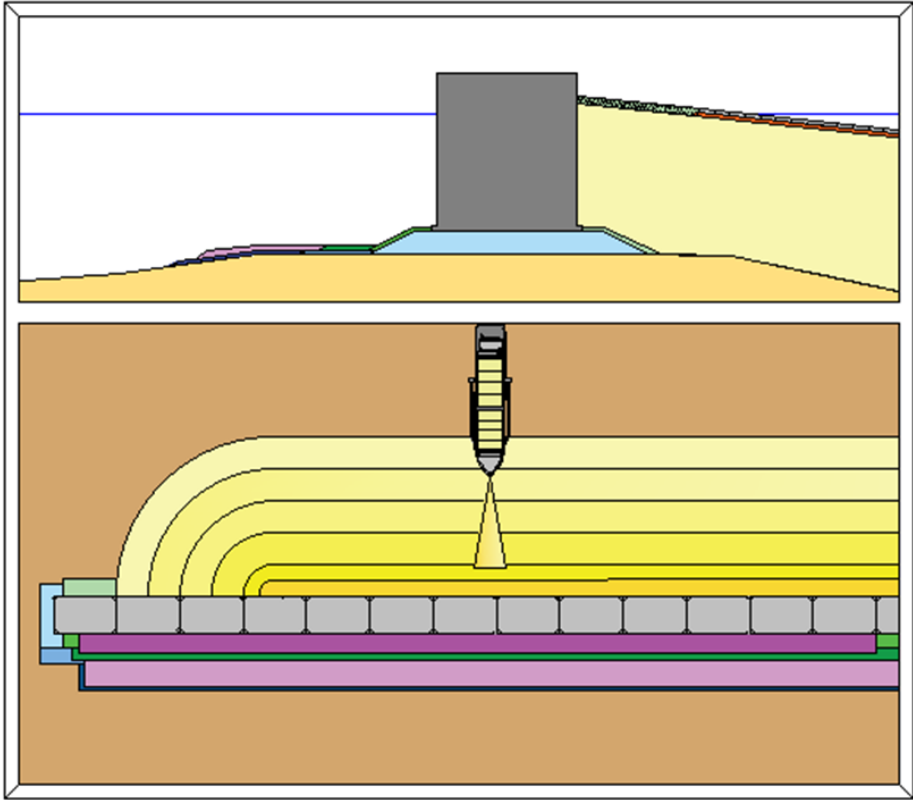
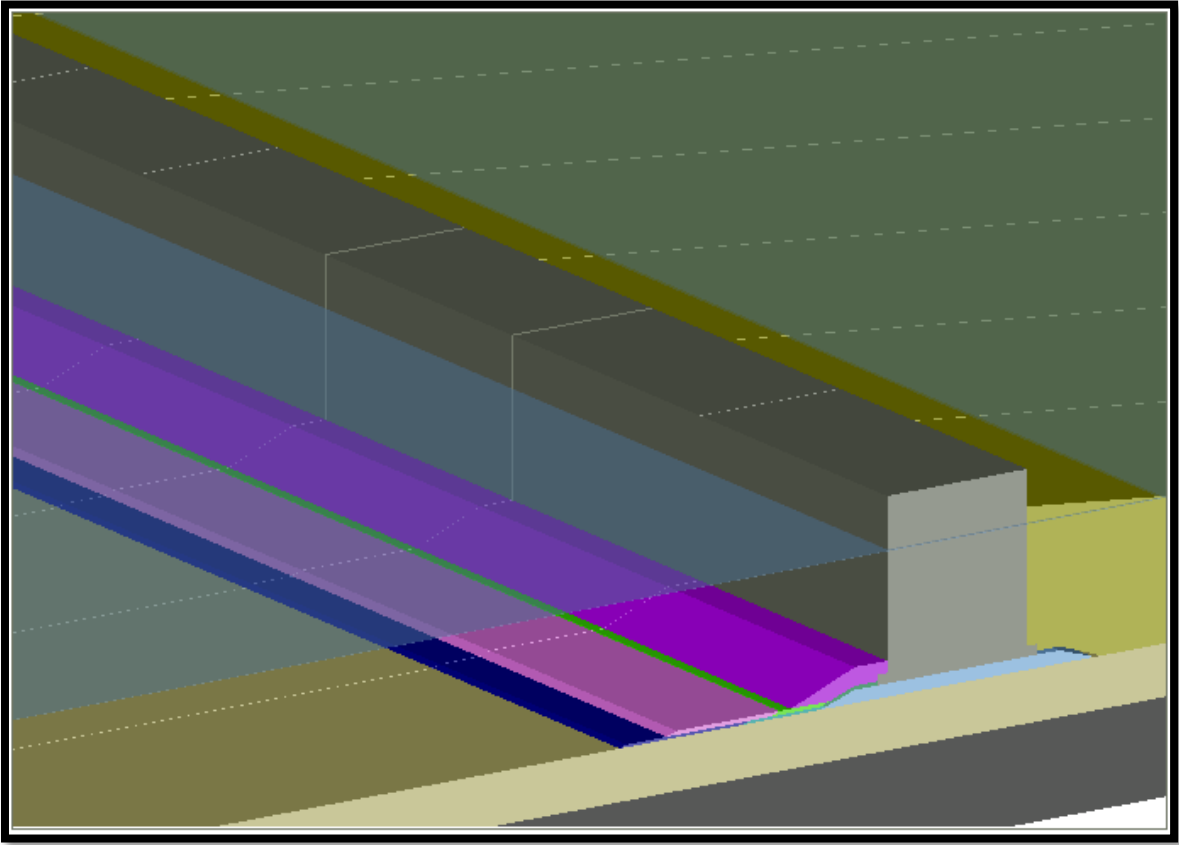
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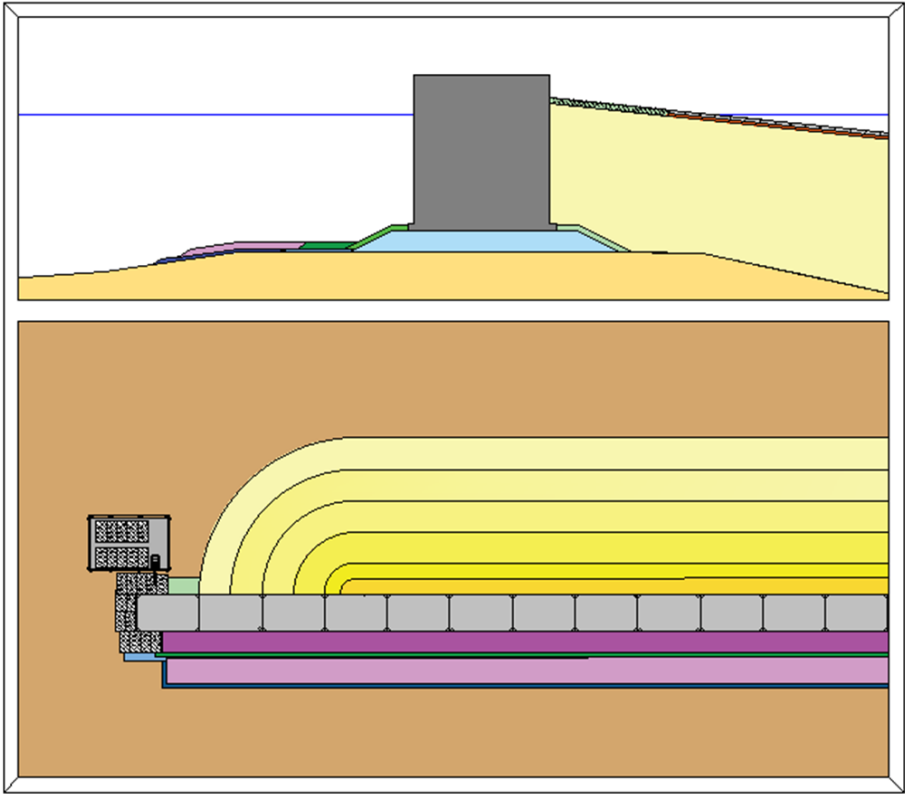
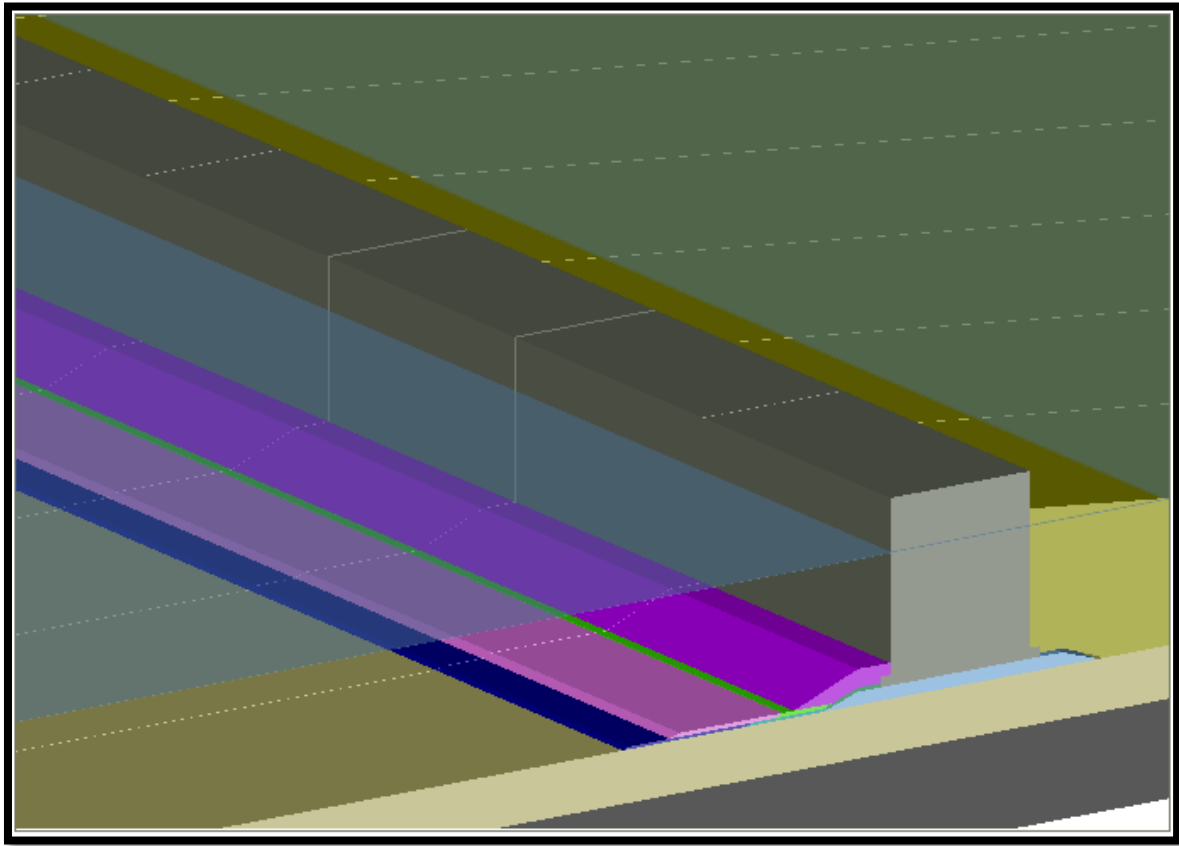
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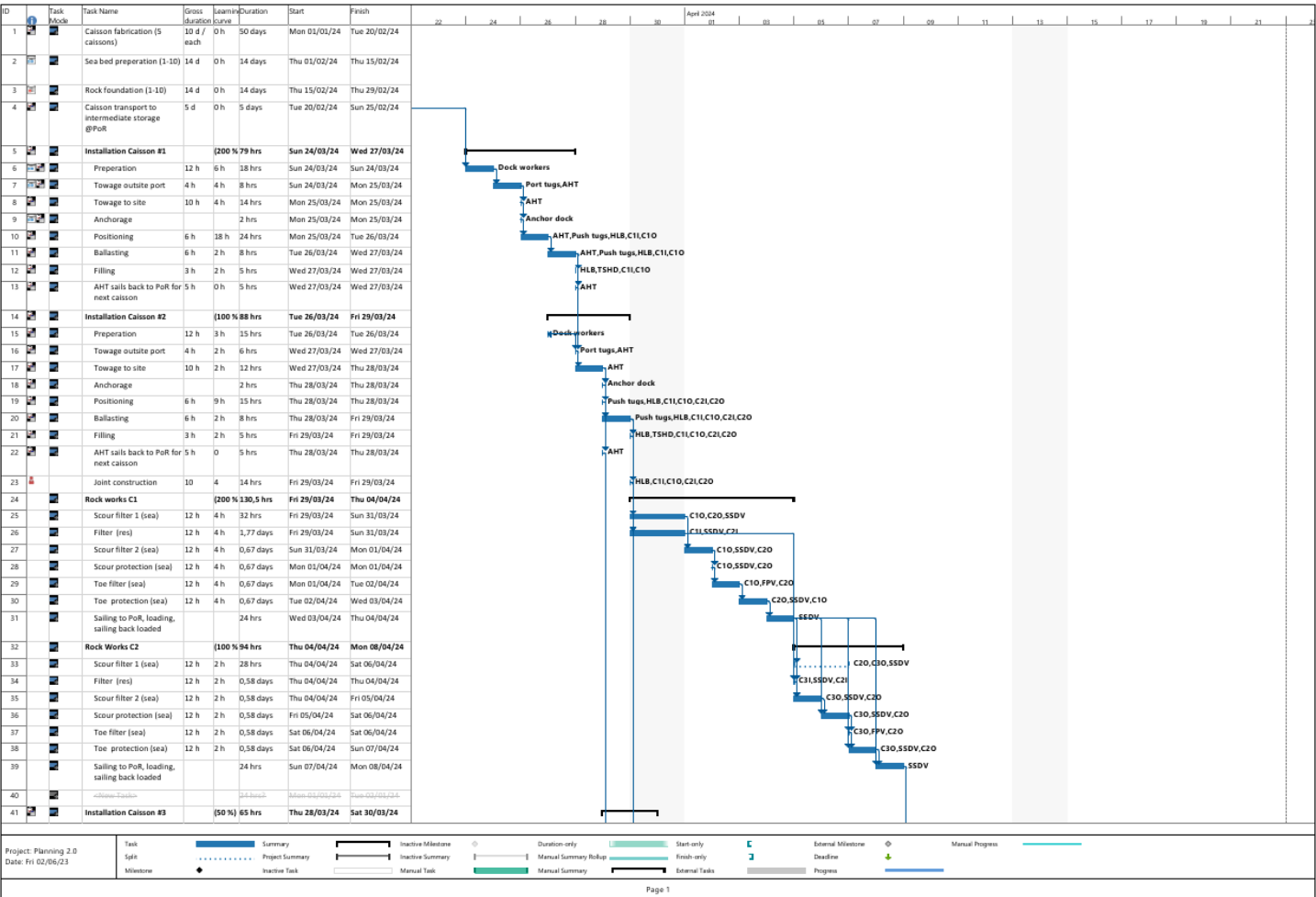
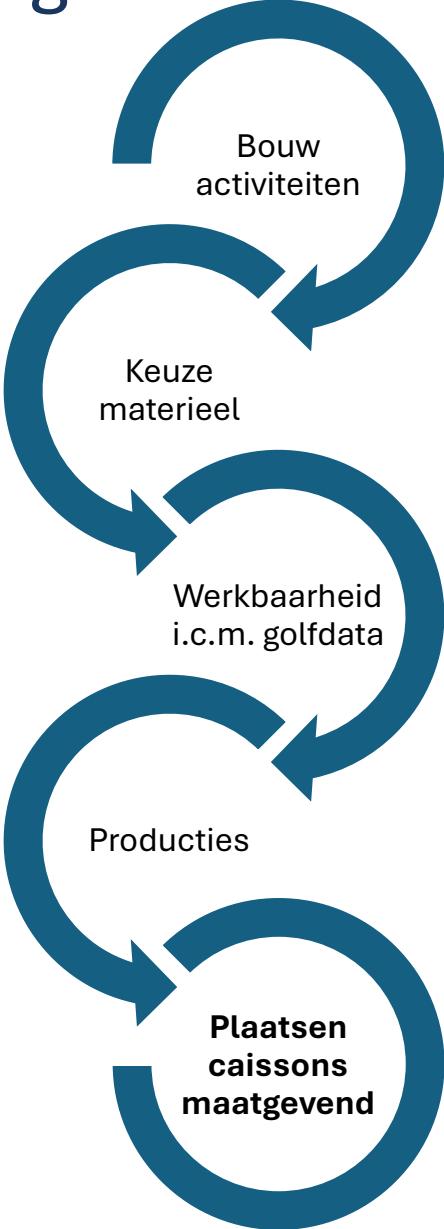
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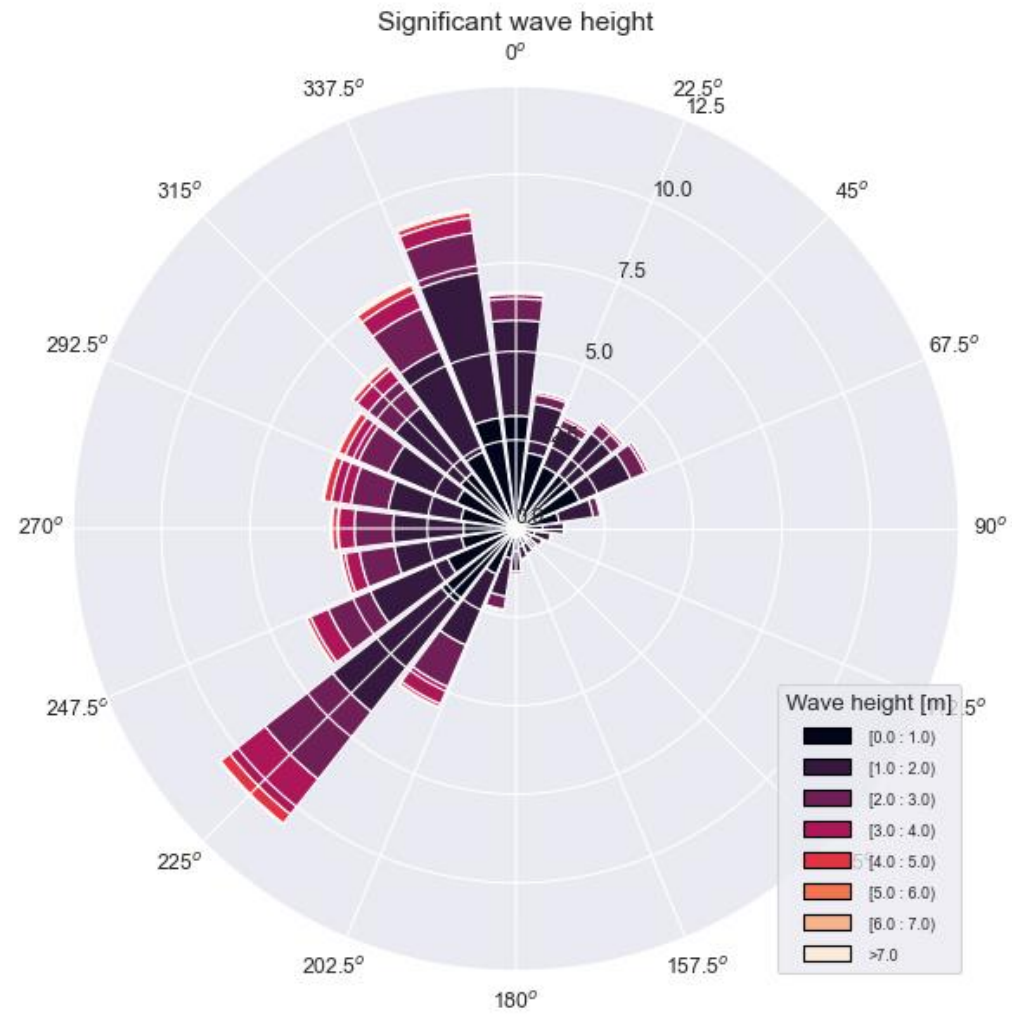
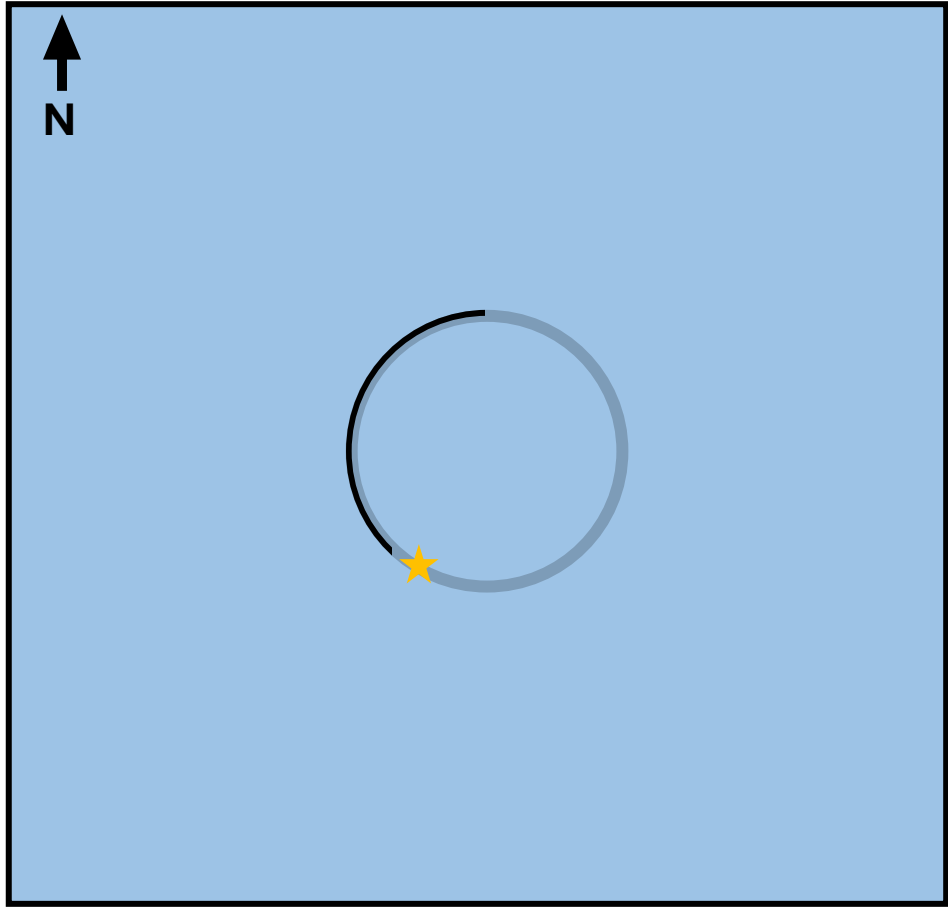
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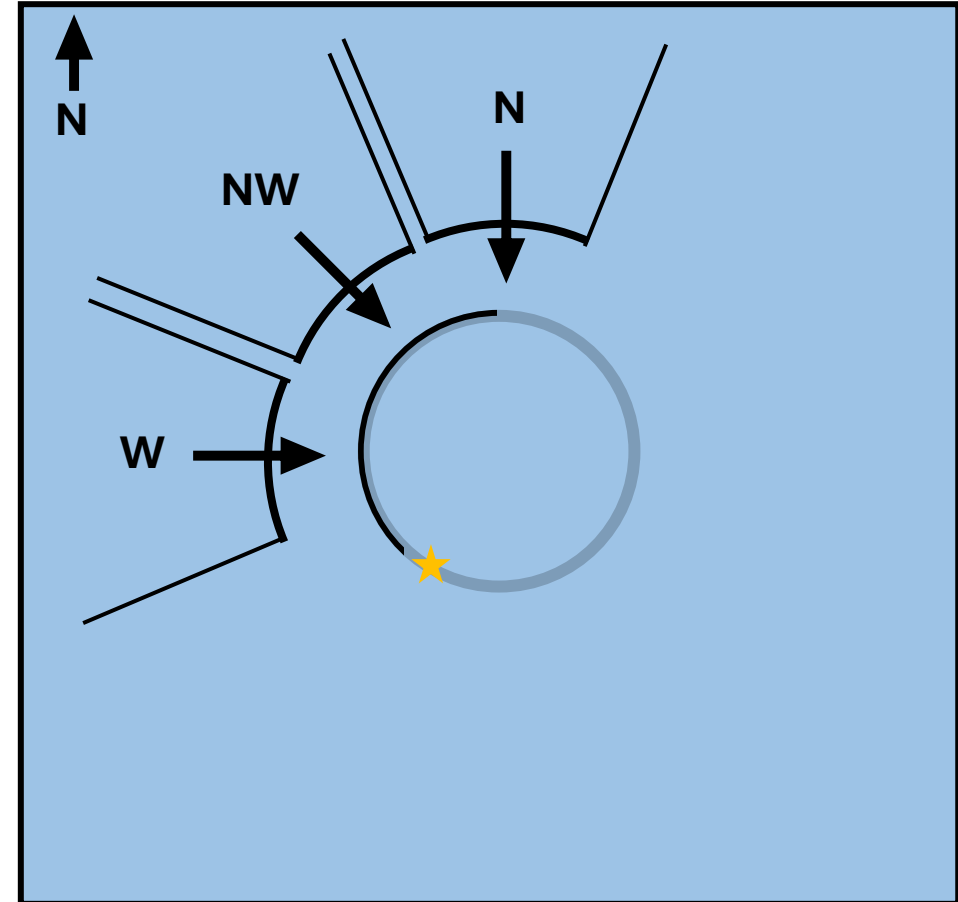
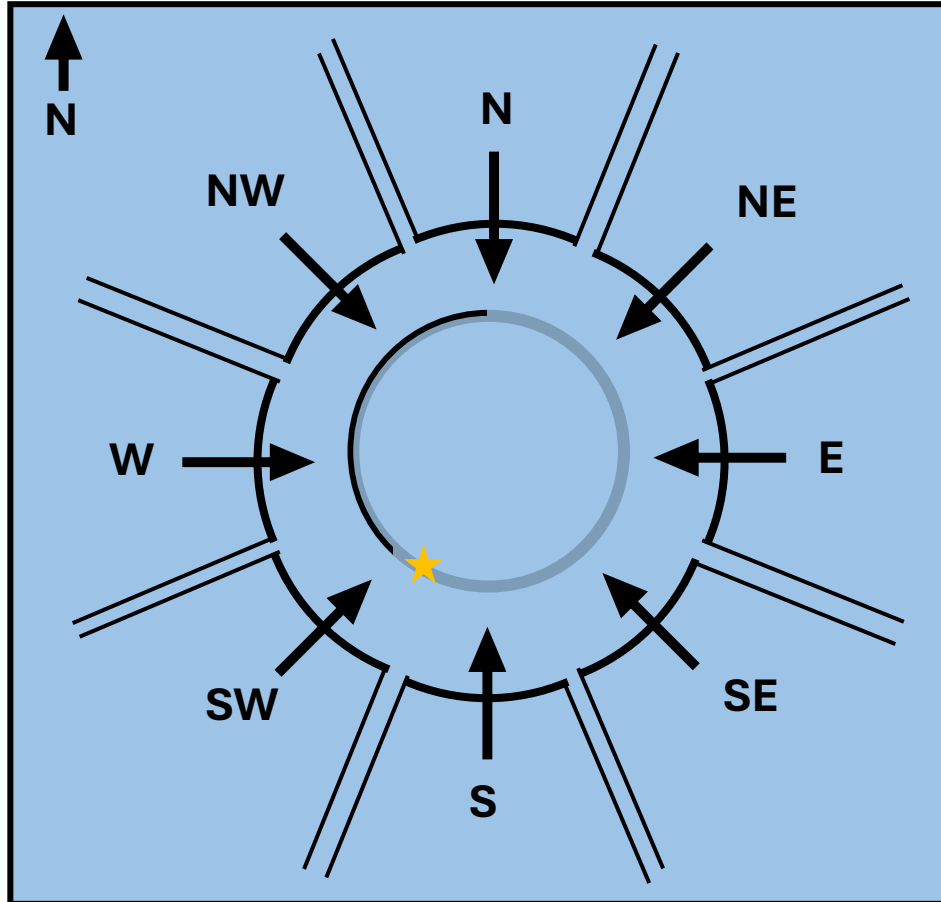
Planning



Planning - Sheltering



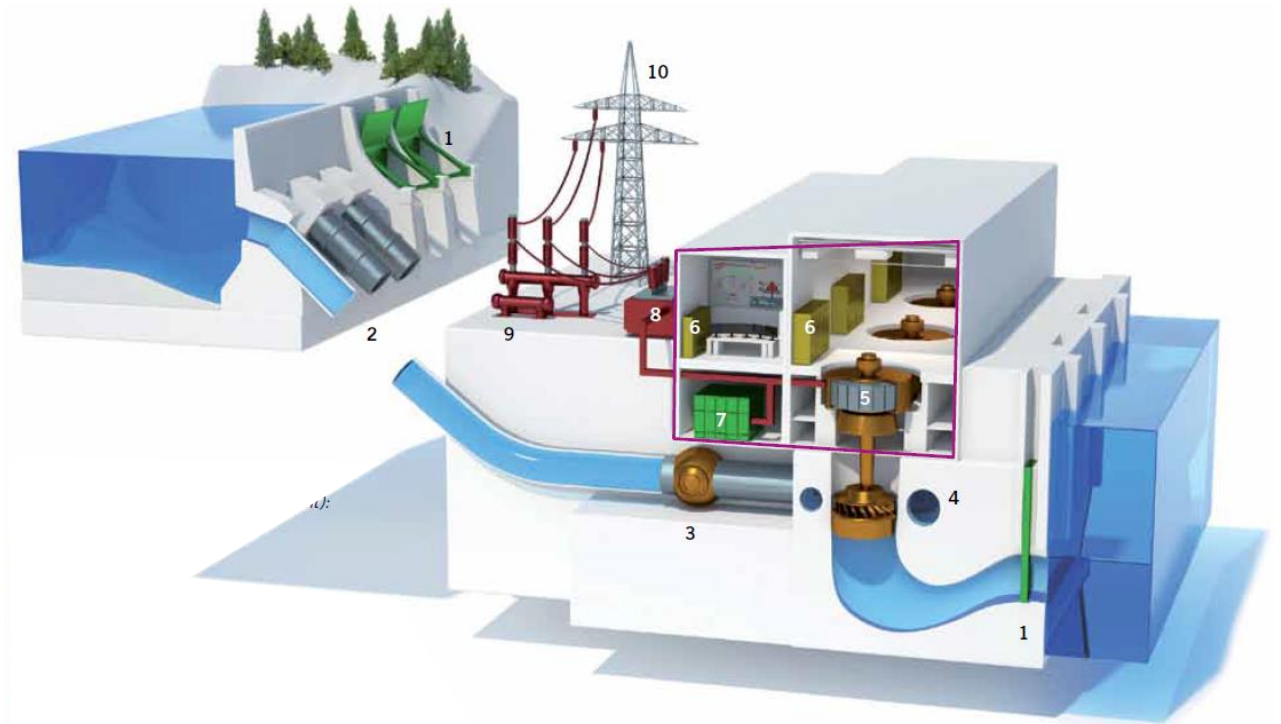
Planning - Sheltering



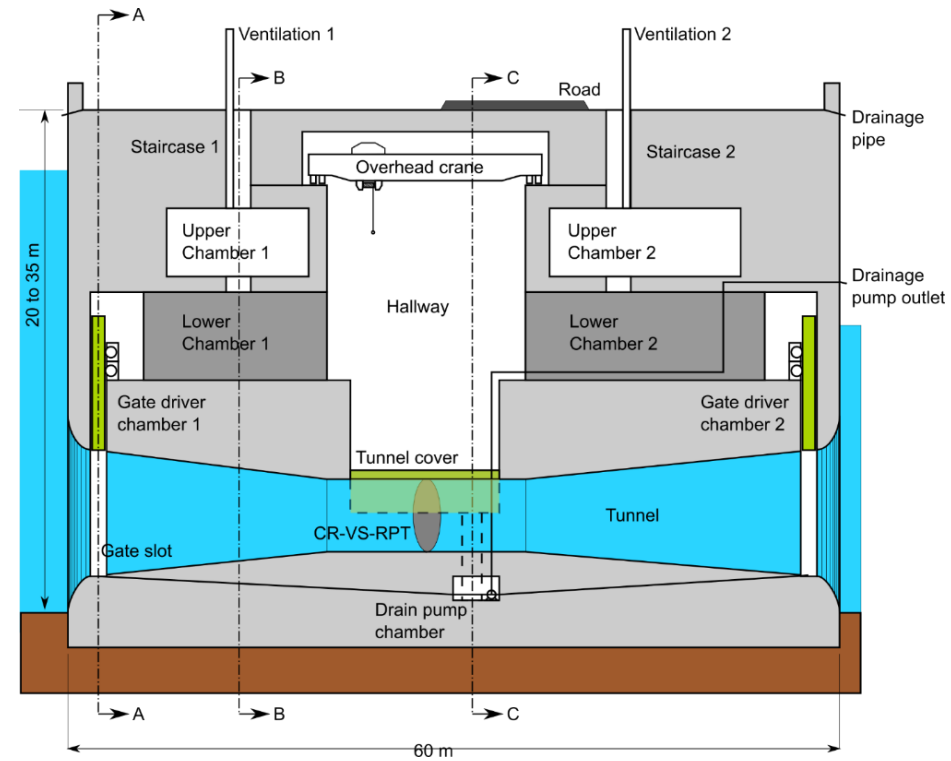
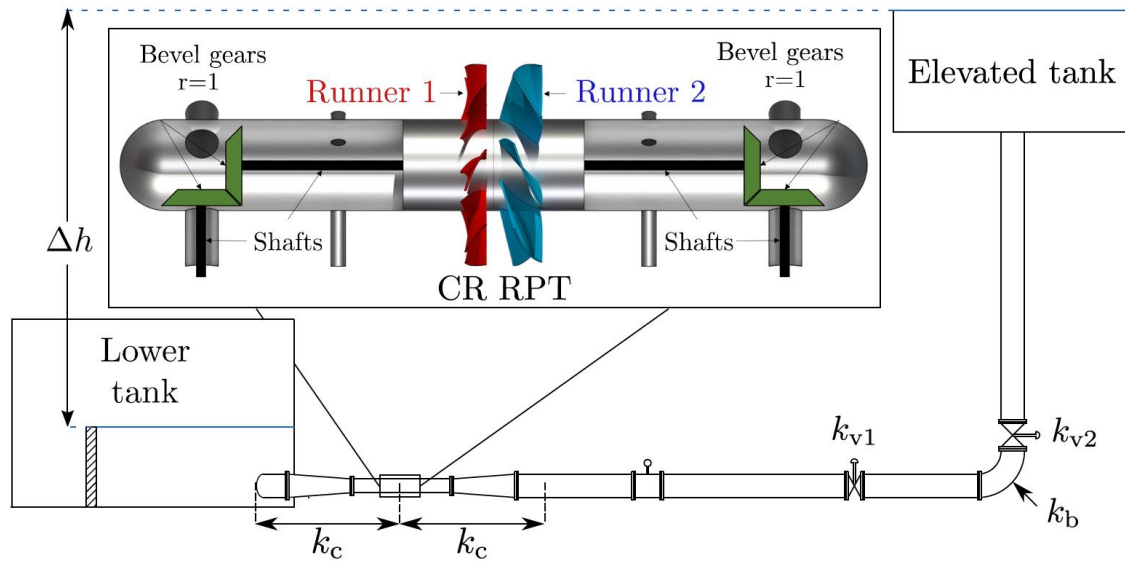
- ➔ Sheltering effect reduceert bouwtijd ringdijk met >13 maanden (van 55 naar 42 maanden)
- ➔ Verdere reductie mogelijk i.v.m. conservatieve aanname (schatting ca. 18 md à 30%!)

Pomp-turbines

- + Francis pomp-turbines meest gebruikt
- + Efficiëntie van 80% (ca. 2 x 90%)
- Groot verval en beperkt bereik
- Diepe constructie i.v.m. uitlaat



Pomp-turbines

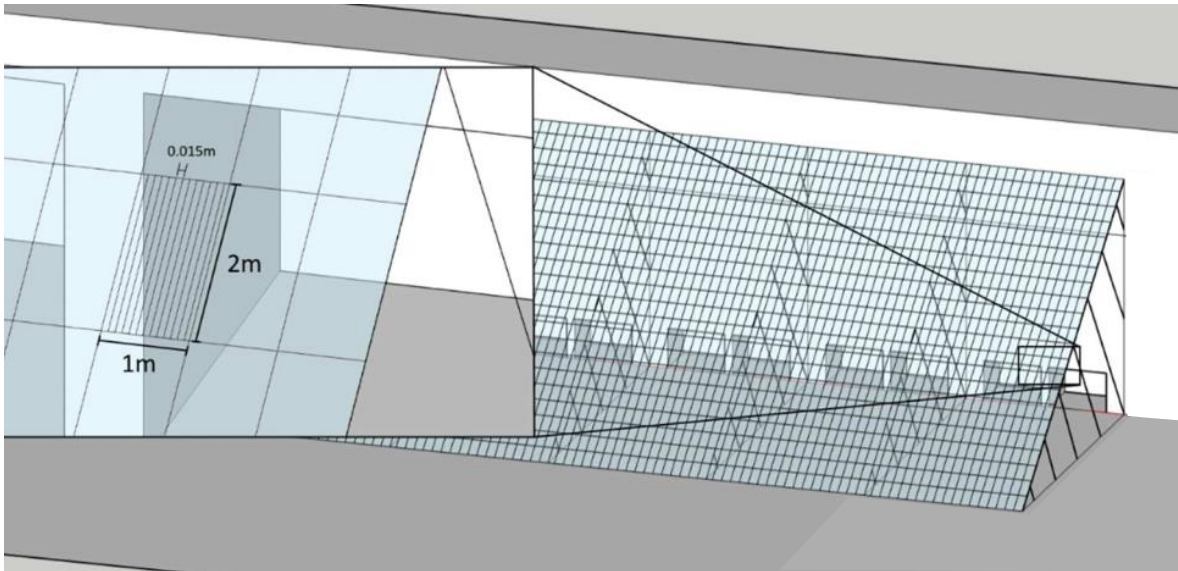


Totale efficiëntie	72%
(Doel) verval	2 – 25 m
Wisseltijd pomp-turbinemodus	110 s
Wisseltijd vermogen +/- 10%	<1 s
Horizontale in-/uitlaat	

Milieu impact

Effect visrekken op aal en regenboogforel
getest op fysieke impact en cortisol-waarden

➔ Alle 800 vissen ongedeerd
en ontspannen!



Haalbaarheid

Opslag capaciteit 20 GWh
 Vermogen 2 GW
 Levensduur 100 jaar
 Rentevoet 5%
 Totale efficiëntie 70%

Onderdeel	Kosten [mld. €]
Dam	3,1
Pomp-turbines	2,9
Pomp-turbine behuizing	3,2
Totaal	9,2

$$LCOS \left[\frac{\text{€}}{MWh} \right] = \frac{\sum_n^N \frac{\text{Investment cost}}{(1+r)^n} + \sum_n^N \frac{\text{Risk cost}}{(1+r)^n} + \sum_n^N \frac{\text{O\&M cost}}{(1+r)^n} + \sum_n^N \frac{\text{Charging cost}}{(1+r)^n} + \sum_n^N \frac{\text{End-of-life cost}}{(1+r)^n}}{\sum_n^N \frac{\text{Elec}_{Discharged}}{(1+r)^n}}$$

LCOS ≈ 310 €/MWh

Discussievoer

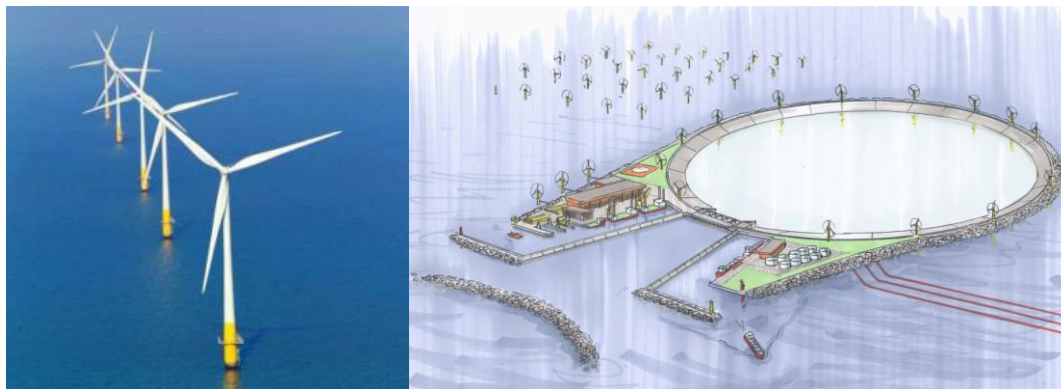
Offshore wind + opslag

Investeringskosten

- 10 GW offshore wind incl. kabels en aansluiting (raming VindØ [COWI, 2021]) € 27,2 mld
- Valmeer (2 GW - 20 GWh) € 9,2 mld
- Totaal € 36,4 mld
€ 3,6 mld/GW

Totaal kosten over levensduur (LCOE)

- Offshore wind NL (o.b.v. 2022) 60 €/MWh
- 20% opslag met valmeer 62 €/MWh
- Totaal energiekosten **122 €/MWh**



Kernenergie

Investeringskosten

Recente projecten	Capaciteit [GW]	Kosten raming	Kosten [mld. €]	Kosten [mld €/GW]
Olkiluoto 3 (Finland)	1,6	3,0	11,0	6,9
Hinkley Point C (VK)	3,3	16,0	35,0 – 40,3	11,5
Flamanville 3 (Frankrijk)	1,7	3,3	13,2	8,0
Mochovce 3 & 4 (Slowakije)	0,9	2,8	6,2	6,6

- Gemiddelde investeringskosten € 8,3 mld/GW
 - Gem. kostenoverschrijding 120% (o.b.v. 150 projecten [Flyvbjerg, 2023])
- Exclusief opslag nucleair afval € 0,8-2,6 mld/GW [WNA, 2024; CoRWM, 2022]
 - Excl. gem. kostenoverschrijding 239% [Flyvbjerg, 2023]

Totaal kosten exclusief opslag (LCOE) [Lazards, 2024; BNEF, 2023]

208 €/MWh

