Deltares

Morphodynamics of sand nourishments (sand engines) in eroding sections of the Rhine-Meuse Delta

13th Symposium on River, Coastal and Estuarine Morphodynamics
RCEM 2023

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25 September 2023

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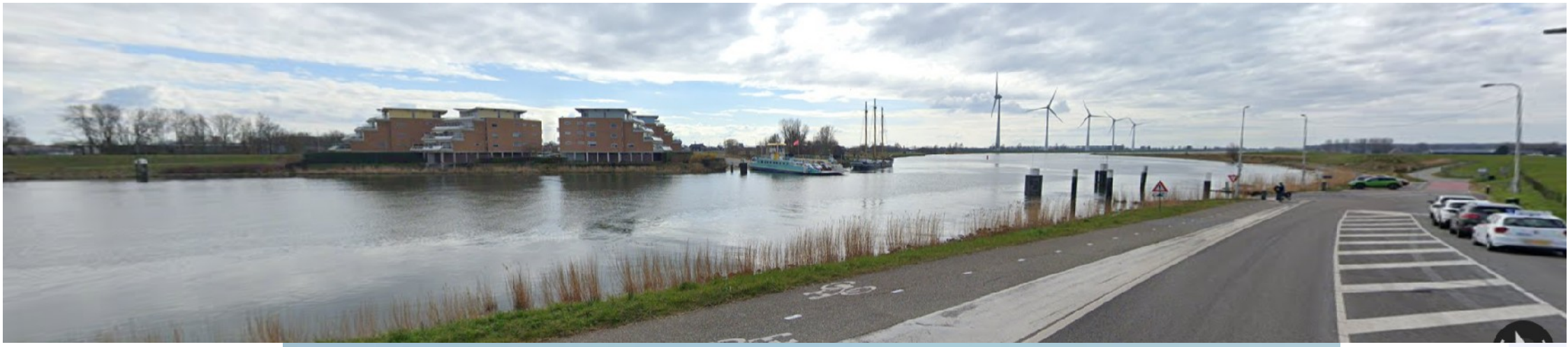
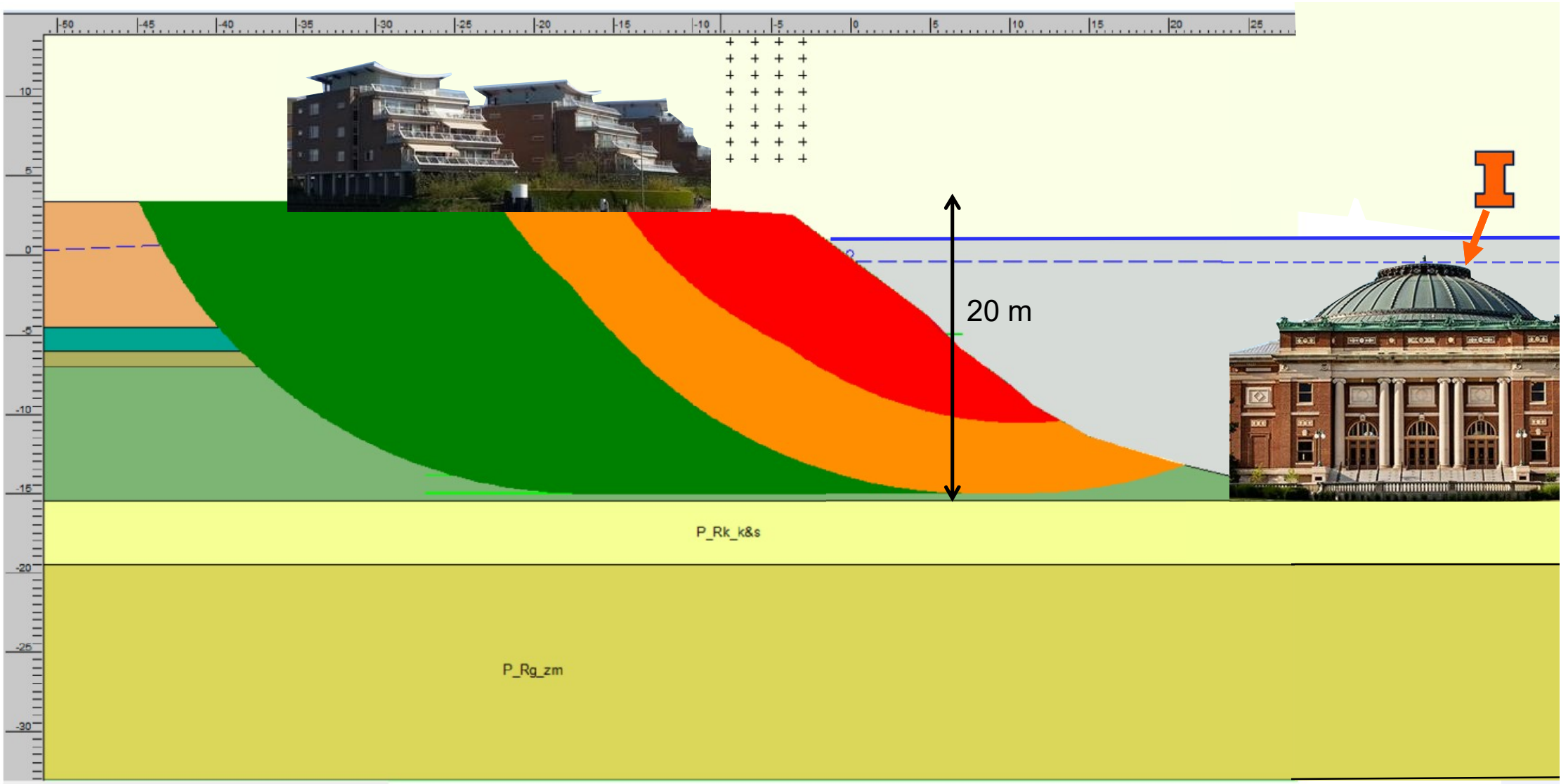
Scour holes are flood-safety issue
Main levee
Main levee
Appartment buildings
Main levee
> 100 scour holes in the Rhine-Meuse Delta



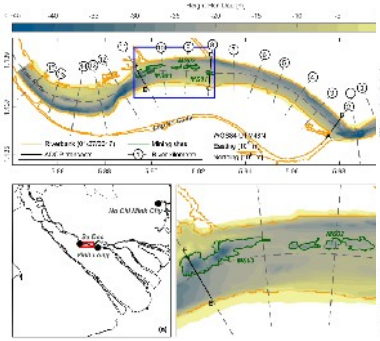
Deltares



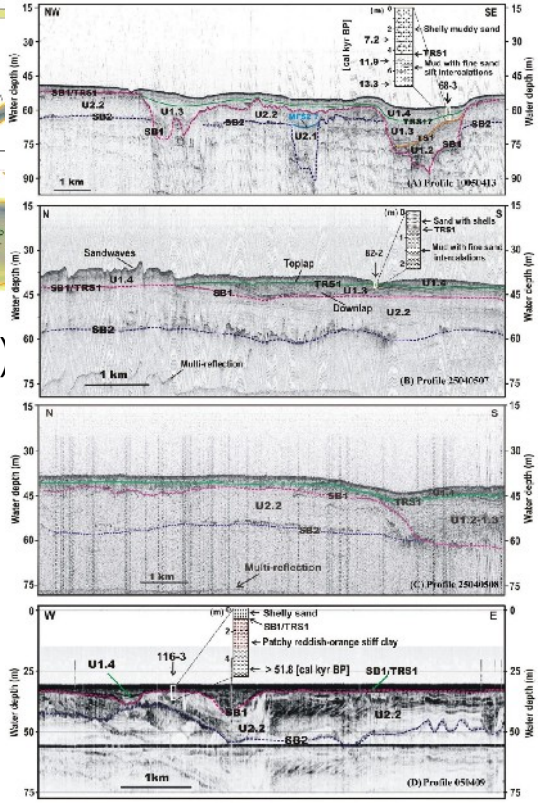
SAFETY AGAINST SLIP FAILURE and FLOW SLIDES

Not of an incidental nature!

Mekong Delta Vietnam

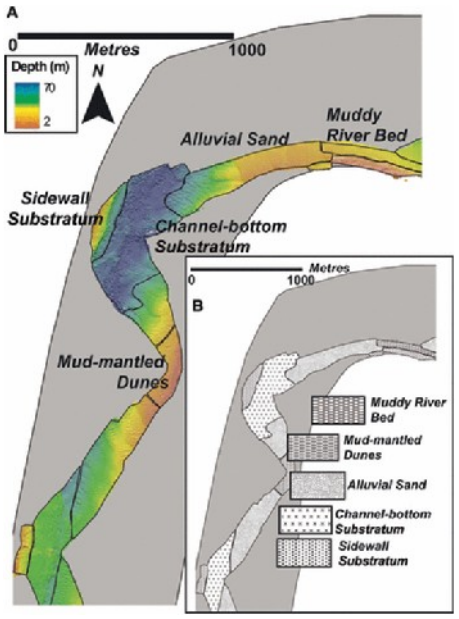


Jordan et al. (2020)
(sand mining)



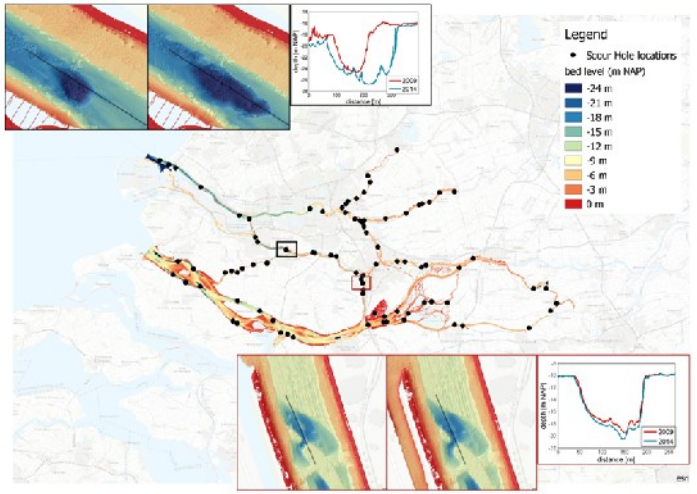
Nguyen et al (2021)

Mississippi Delta USA



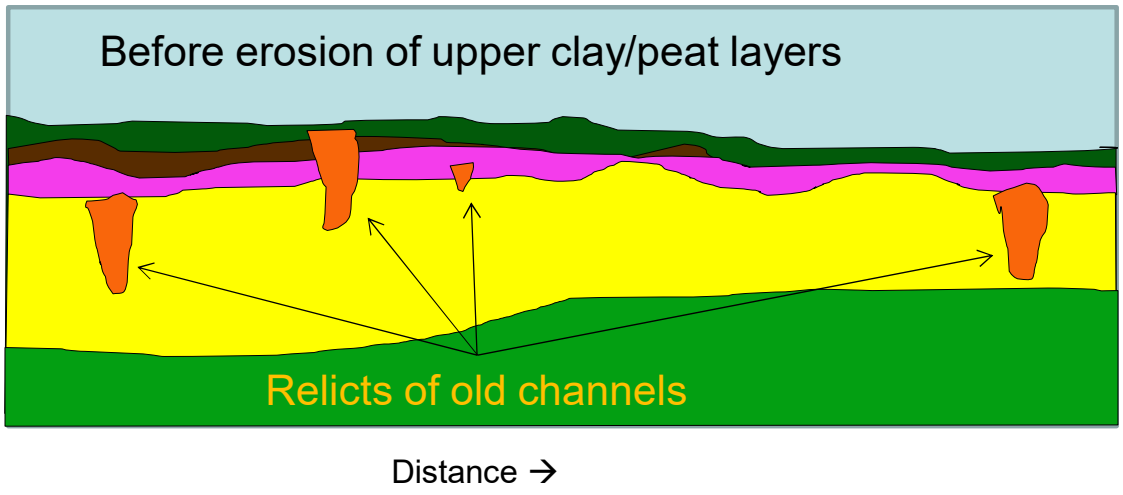
Nittrouer et al. (2011)

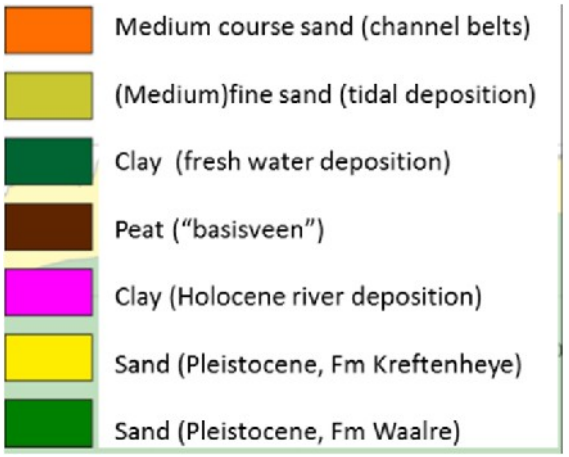
Rhine-Meuse Delta Netherlands

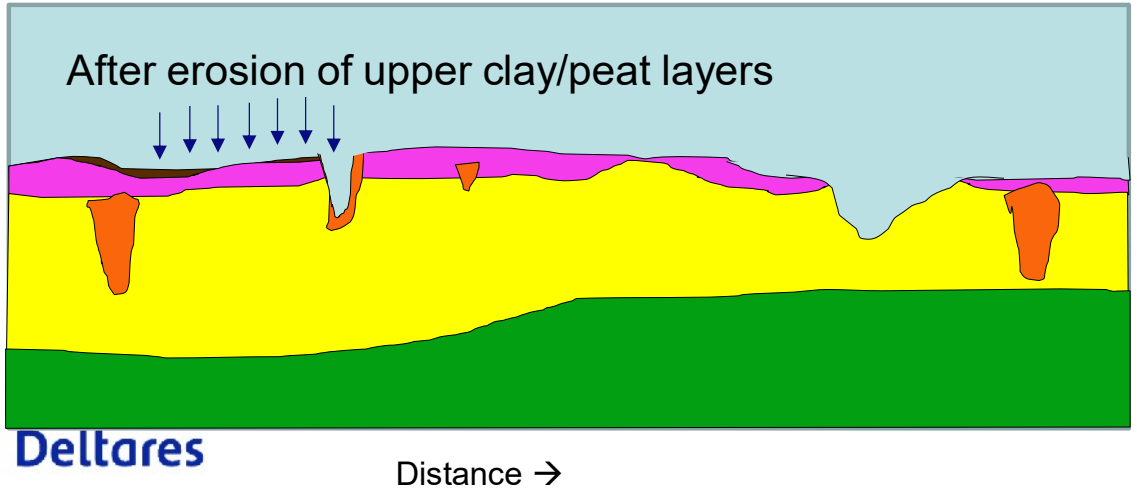


Huismans et al. (2021)

Cause: large scale incision in heterogeneous subsurface geology

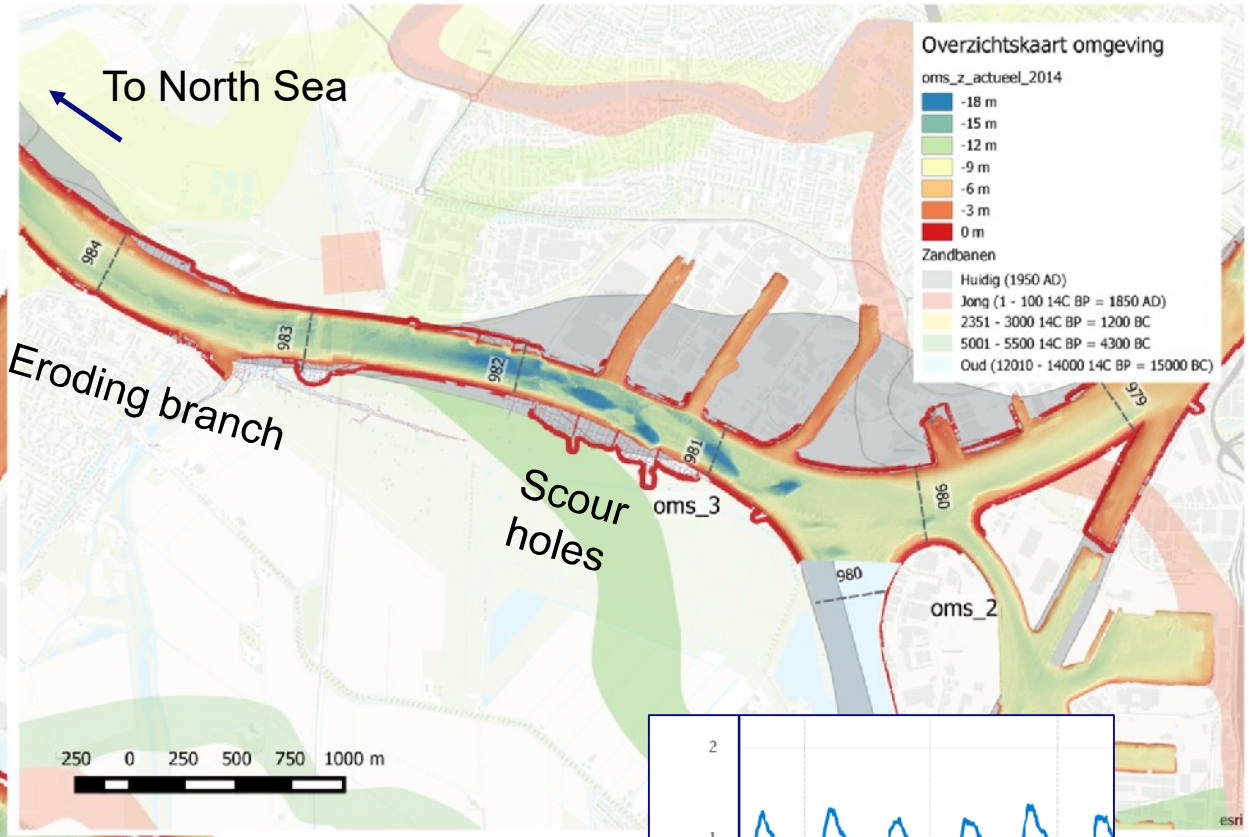






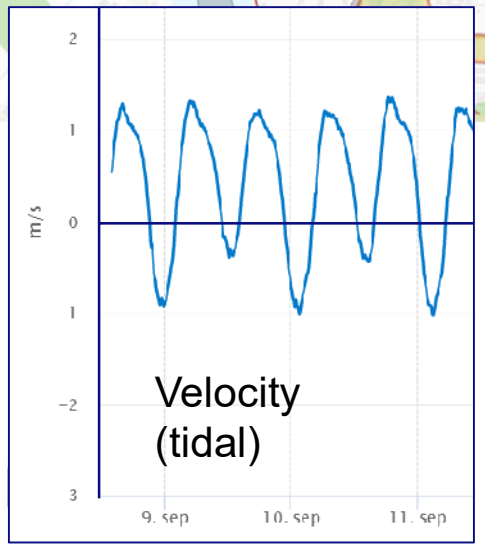
See Huismans et al. (2021)

Pilot site



Depth ~10 m

Depth ~20 m

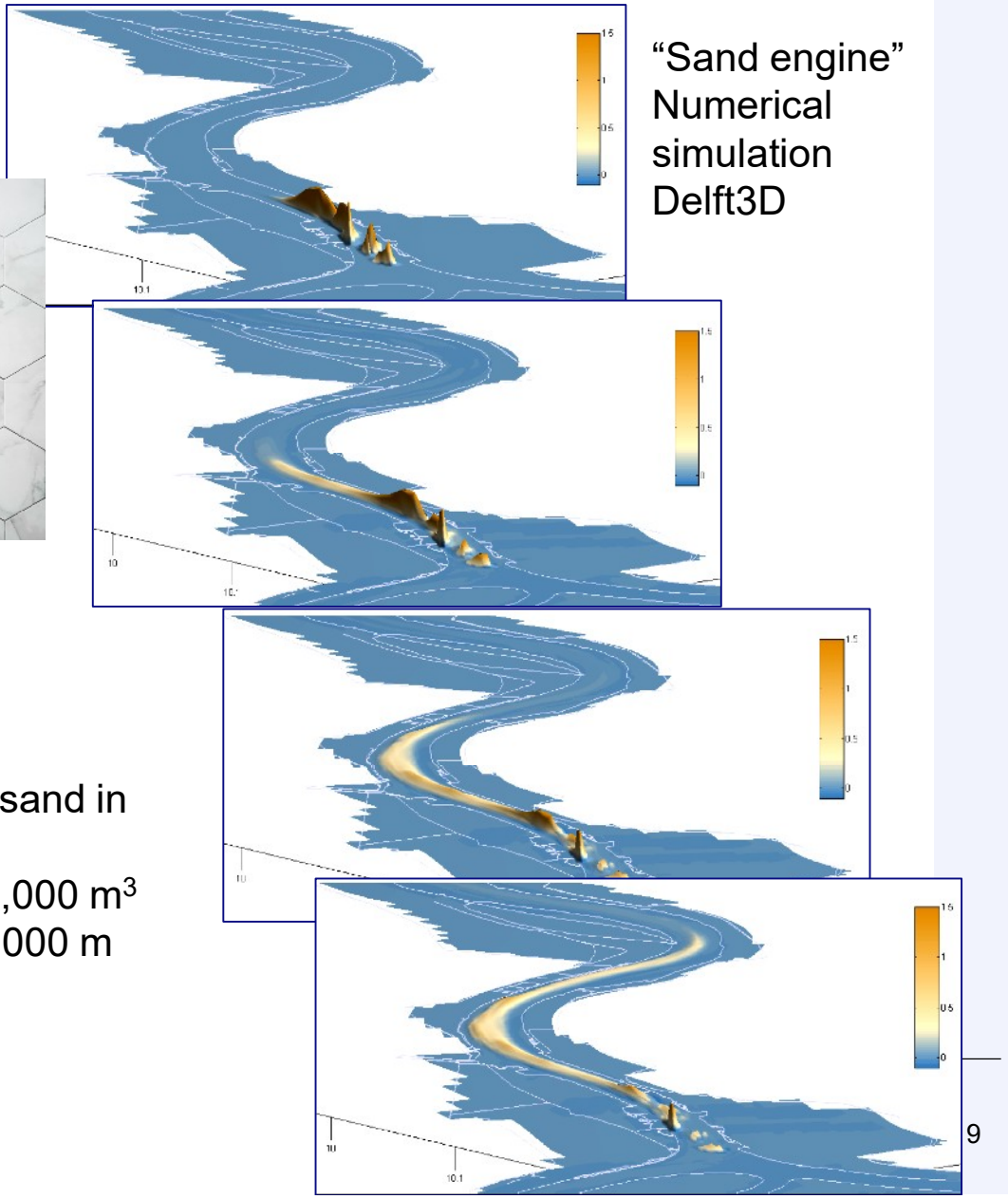


“kill two birds with one stone”

Stabilize scour hole

&

Stop bed degradation



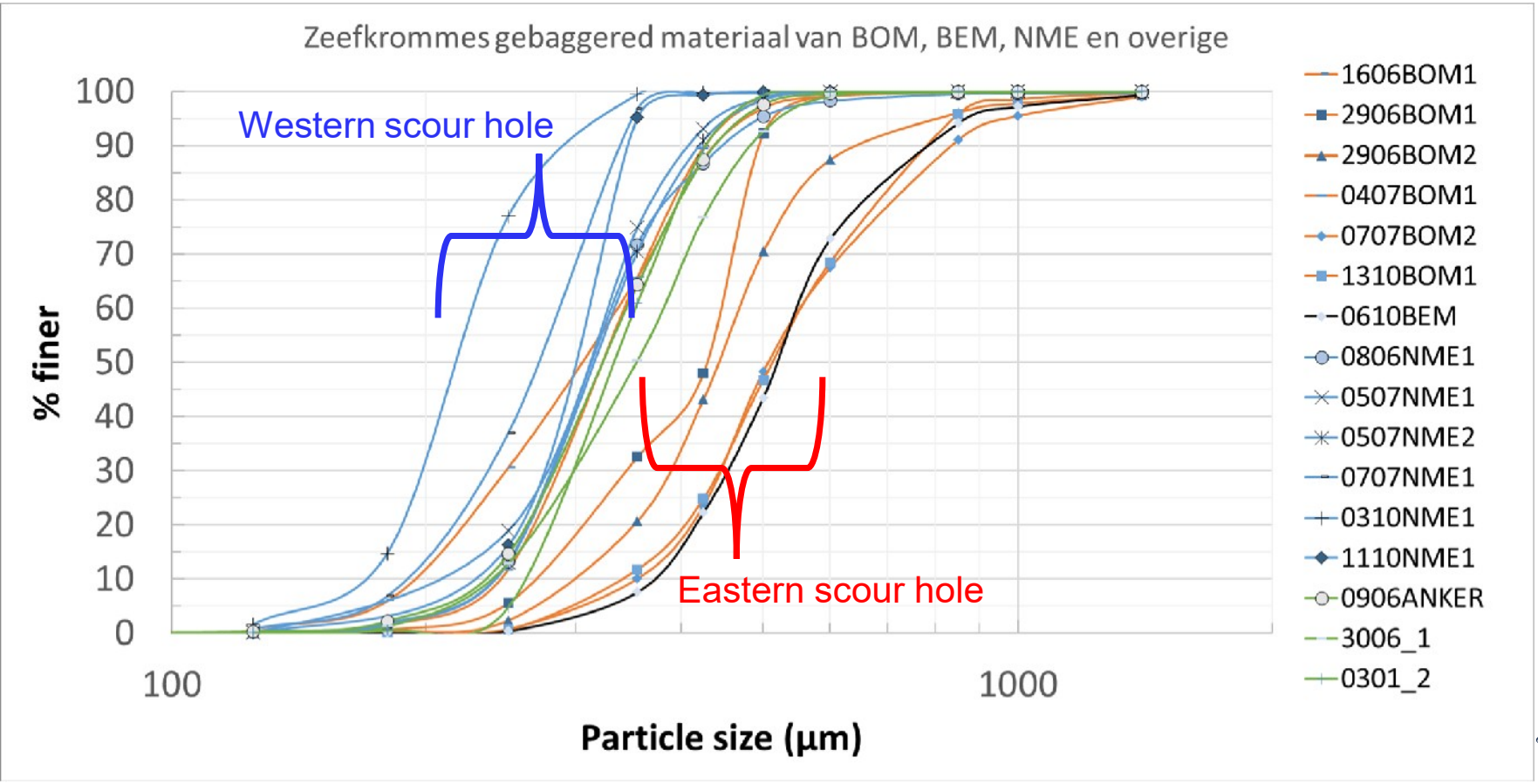
“Sand engine” Numerical simulation Delft3D

Nourishments of sand in scour hole:

- June 2022: 50,000 m^3
- April 2023: 11,000 m

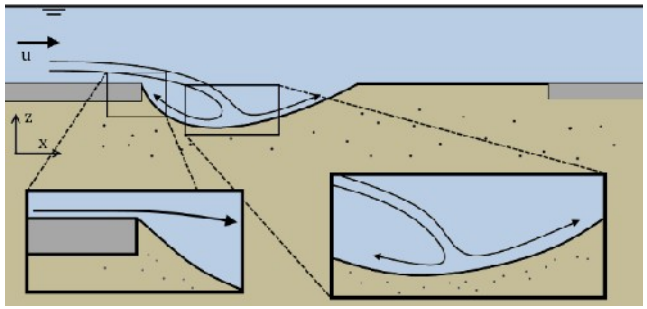
Grain-size distribution

- Samples taken from the hopper

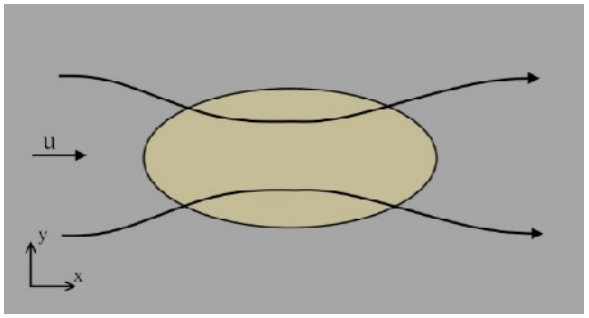


Principle hydraulic and morphological processes

Plunging and separation



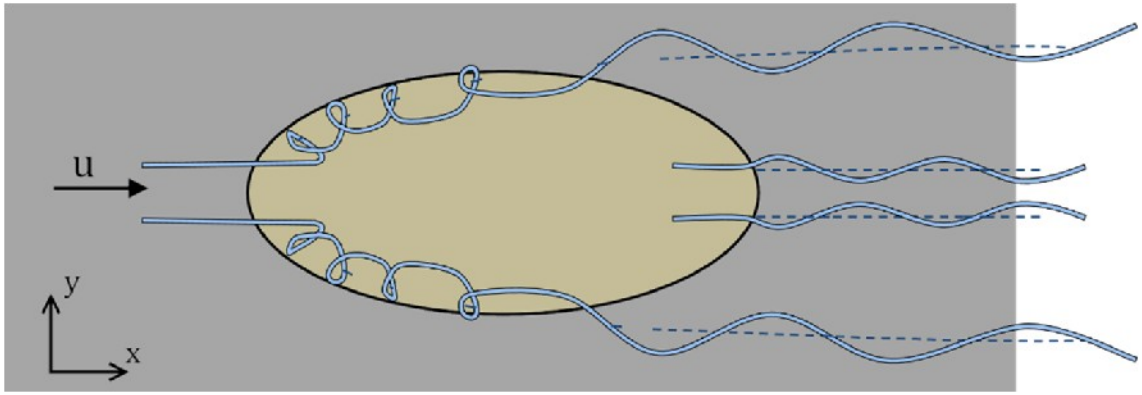
Contraction

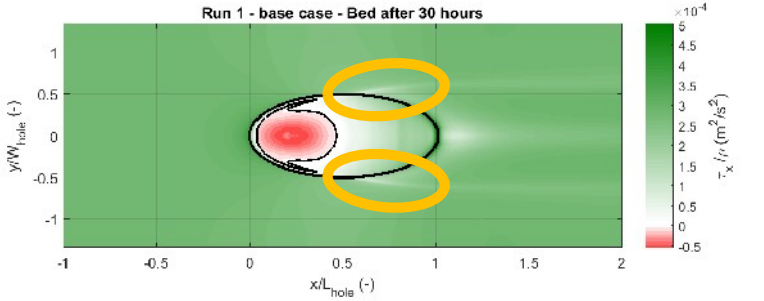


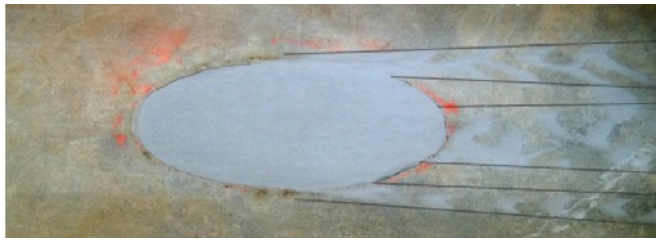
Lab.scale (TU-Delft):

- Flume experiments J.G. Stenfert (2017)
- OpenFOAM numerical simulations S. Bom (2017)

Circulation





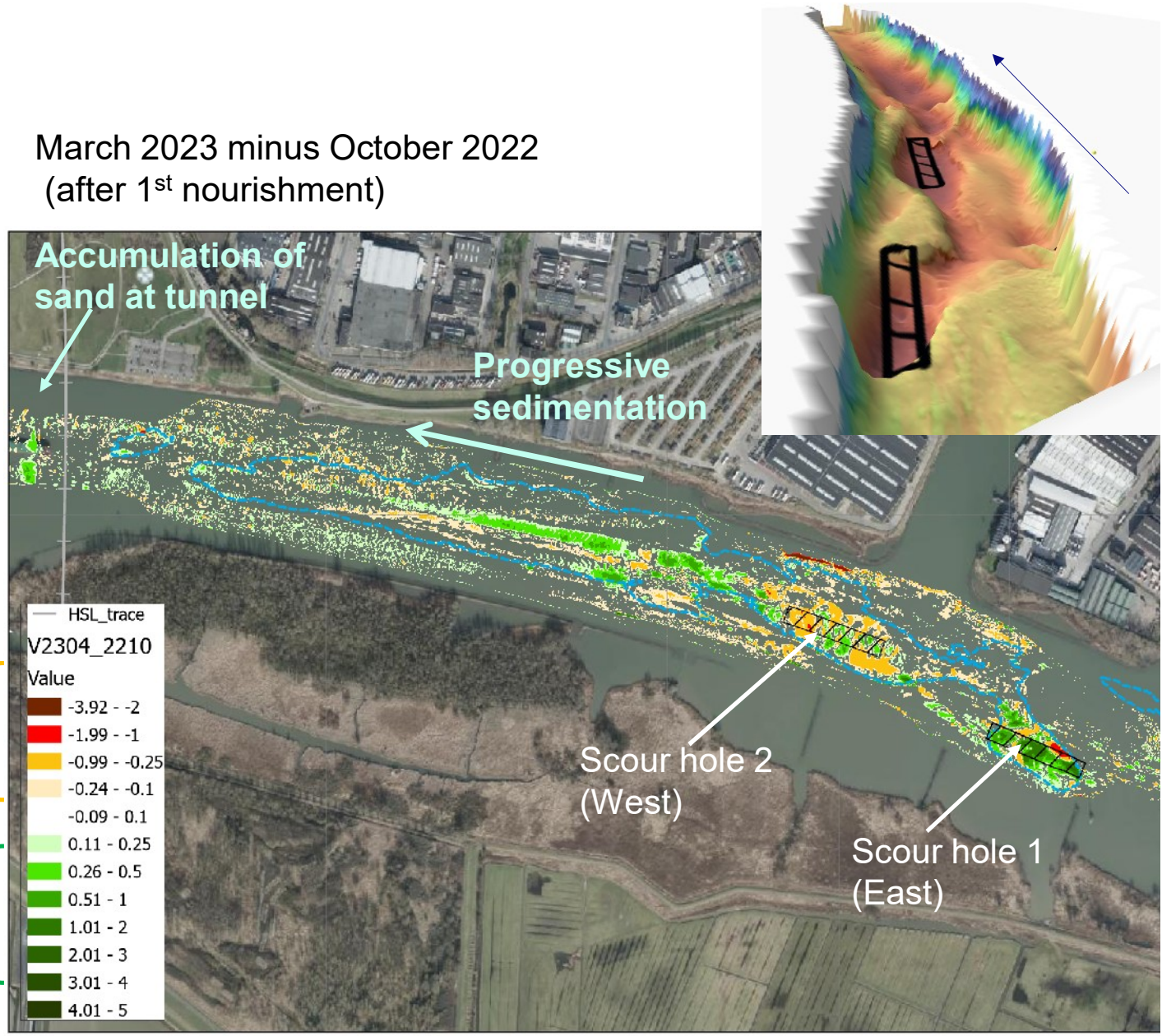


Deltares

Observations

- Eastern scour hole:
  - Max. fill 5 m
  - Low erosion rate (deep, coarser, groyne impact)
  - Some failure on edge
- Western scour hole
  - Higher erosion rate (shallow, more exposed)
- Downstream
  - Sediment deposition in river axis

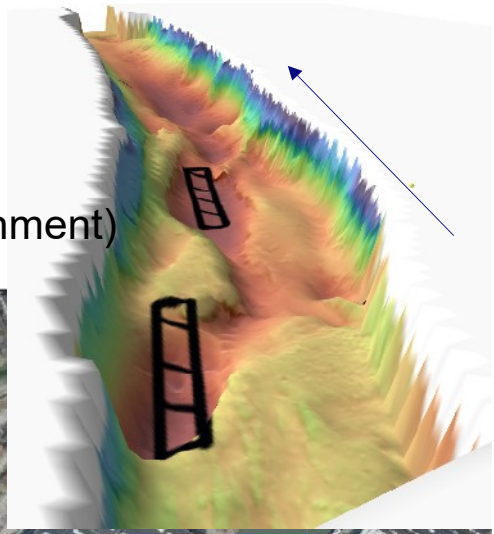
March 2023 minus October 2022
(after 1st nourishment)



Deltares

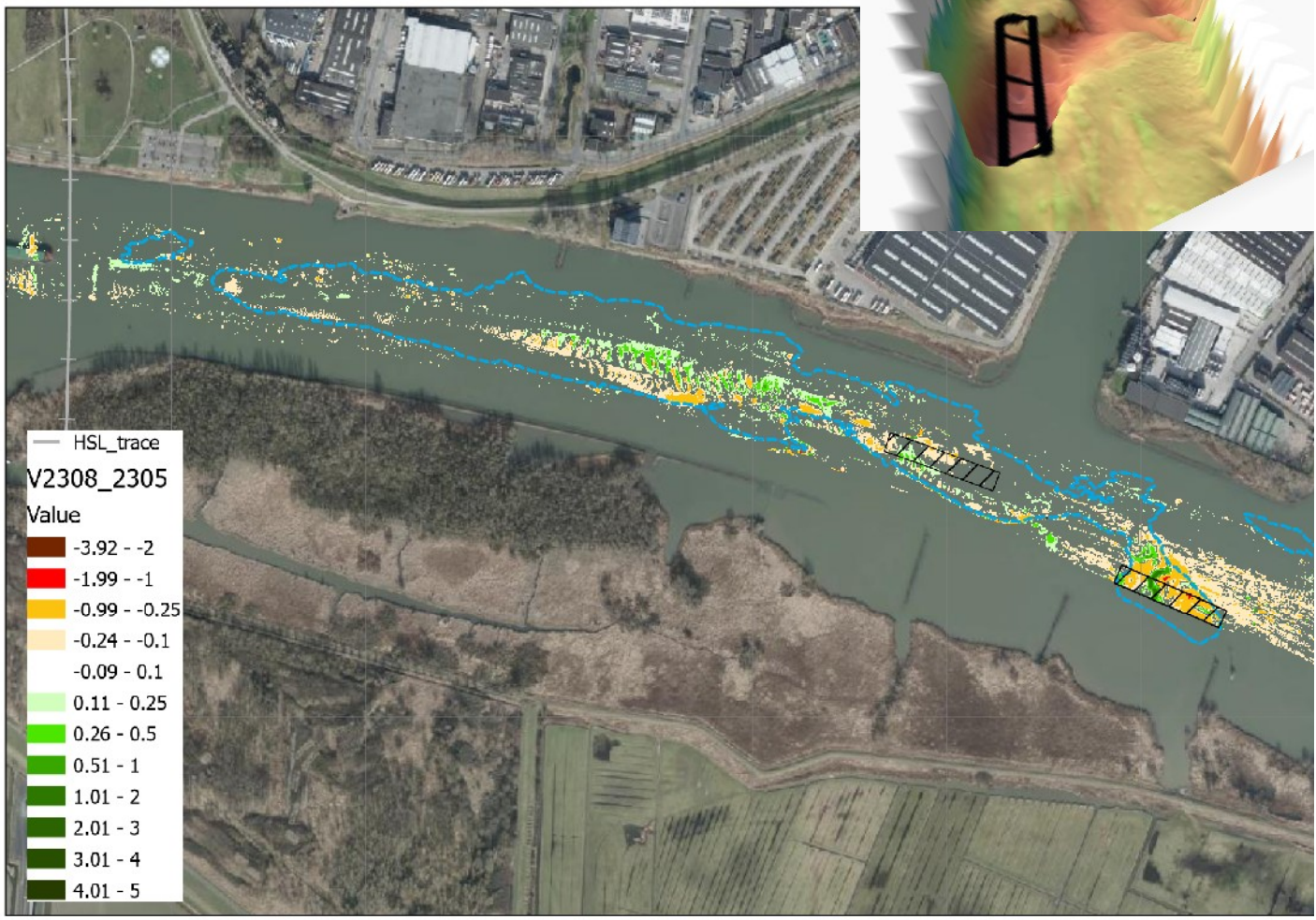
Observations

August 2023 minus April 2023 (after 2nd nourishment)



2nd nourishment was placed only in the Eastern scour hole

- Not much sediment seems to leave the scour holes
- Sand engine slowing down?

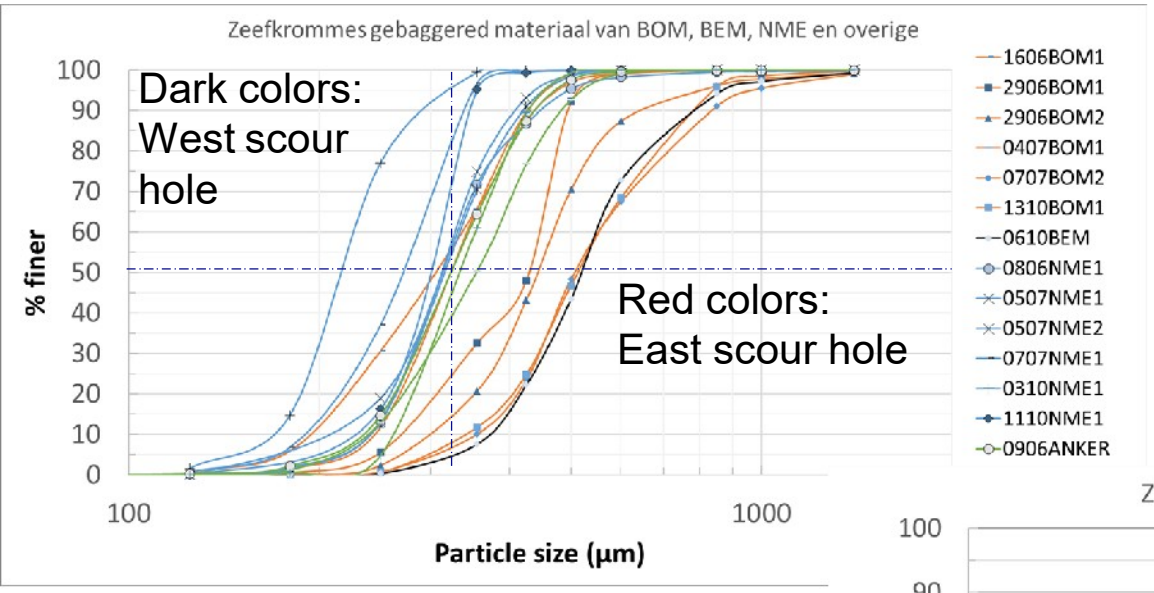


Deltares

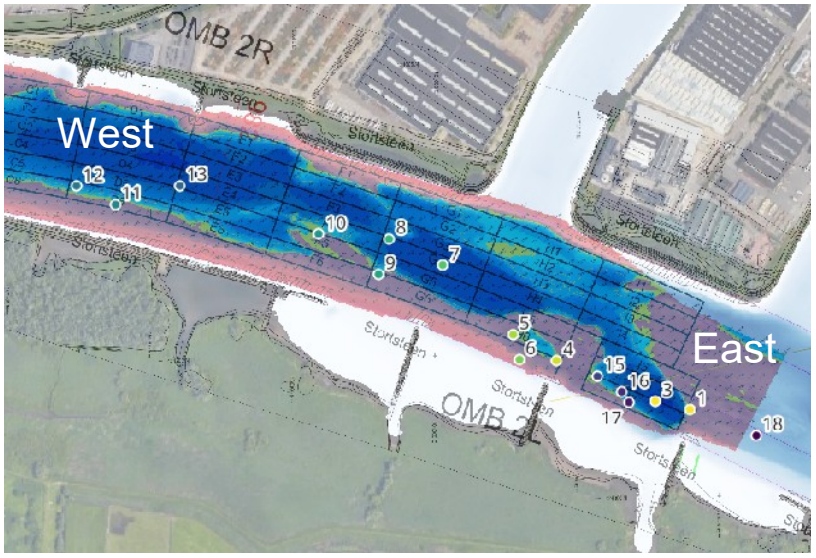
Post nourishment bed-sediment sampling (7 April 2023): unintended catch

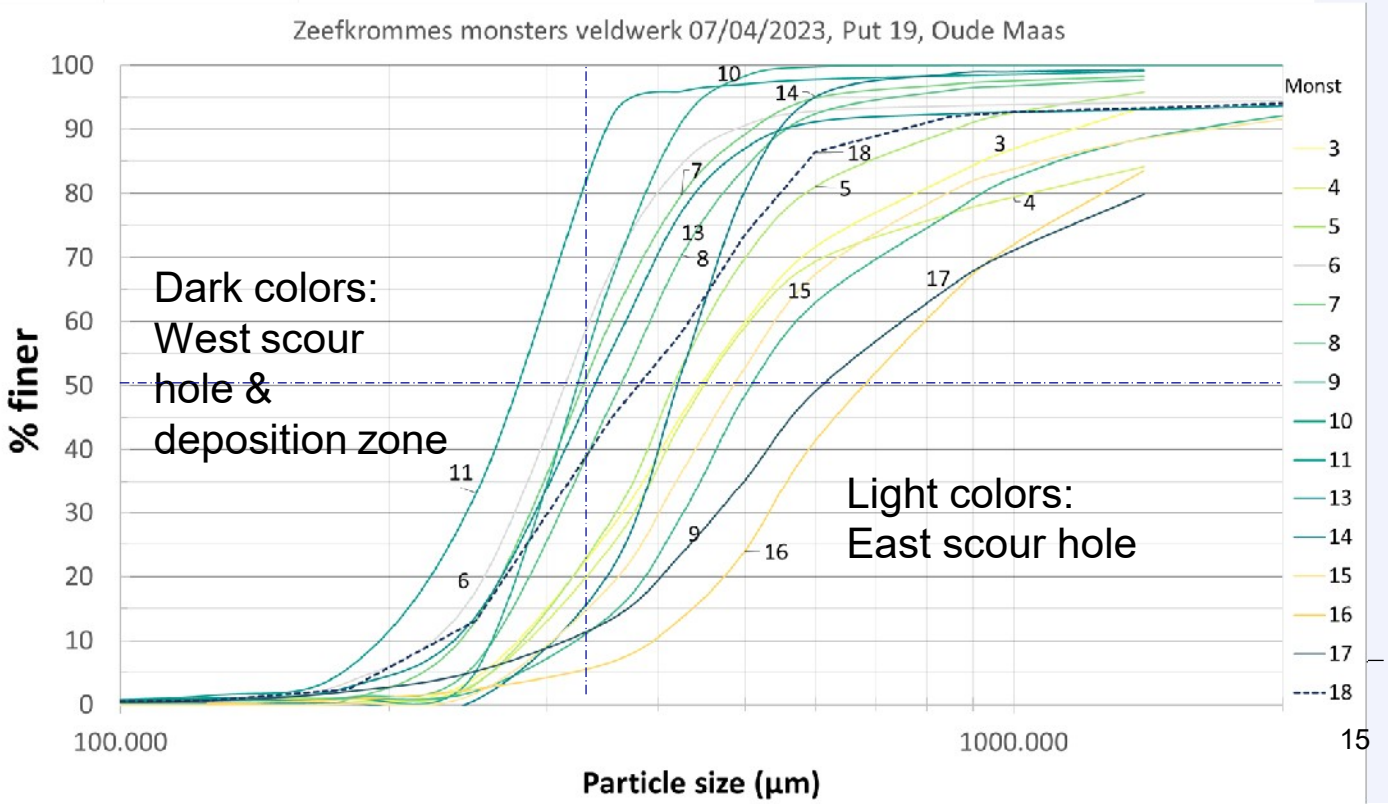
Corbicula fluminea (invasive Asian clams) & some sand

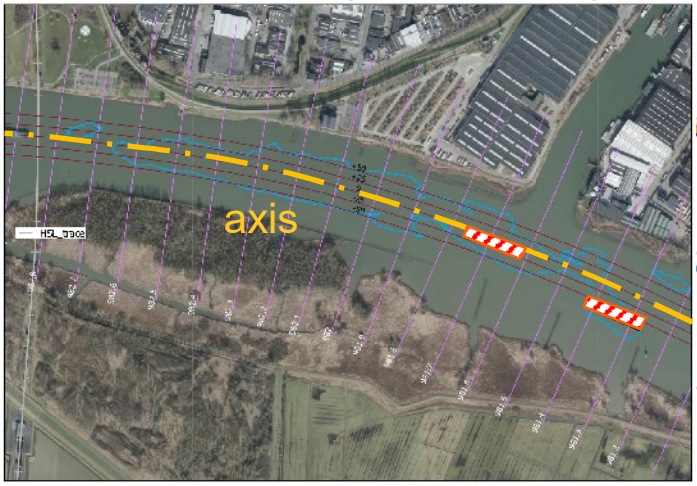
Nabil Majdi (2014):
C. Fluminea causes effective bioturbation (biodiffusor)

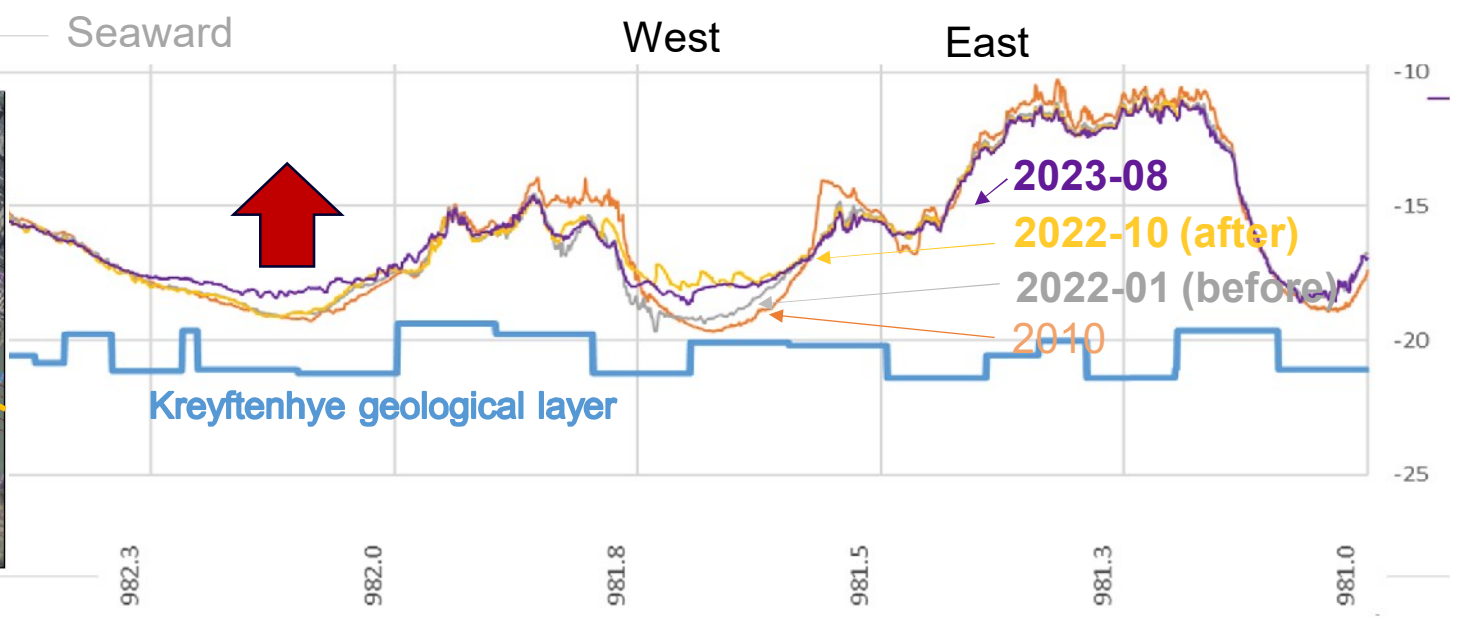


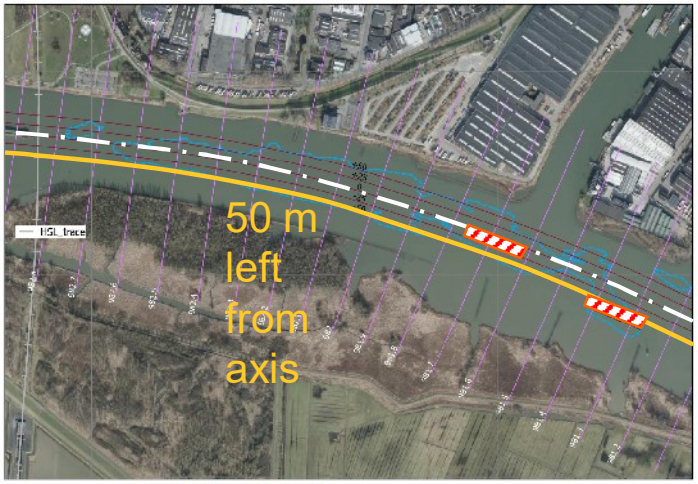
- Coarsening of sediment in the scour holes

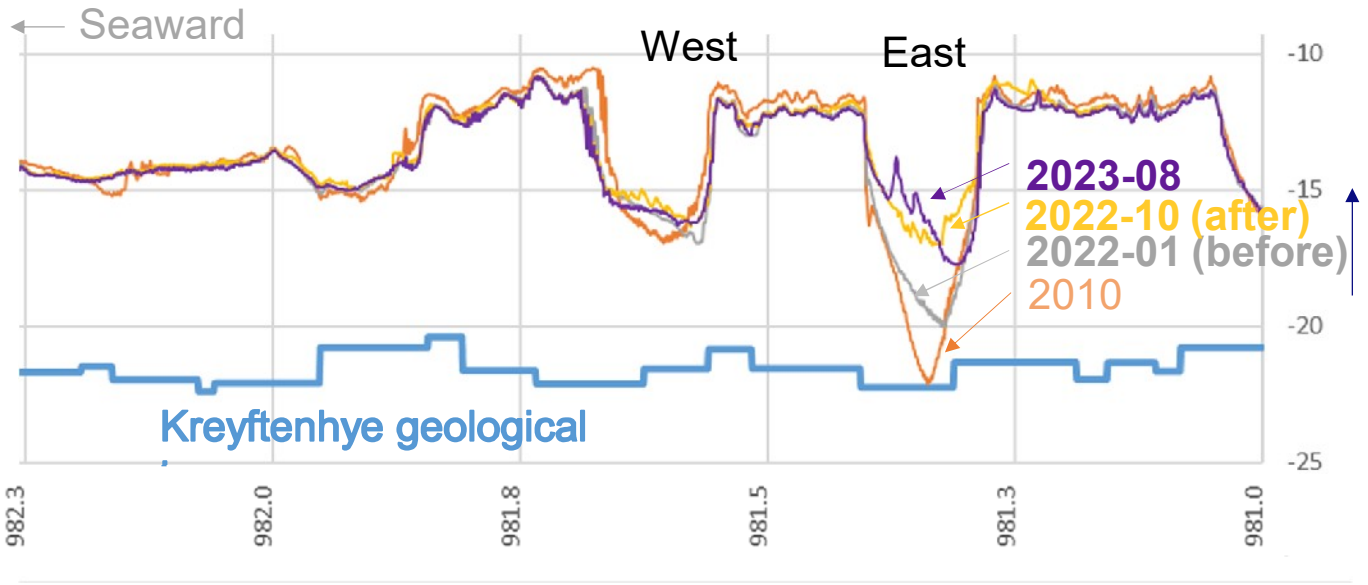





axis


Seaward
West
East
2023-08
2022-10 (after)
2022-01 (before)
2010
Kreyftenhye geological layer
-10
-15
-20
-25
982.3
982.0
981.8
981.5
981.3
981.0


50 m
left
from
axis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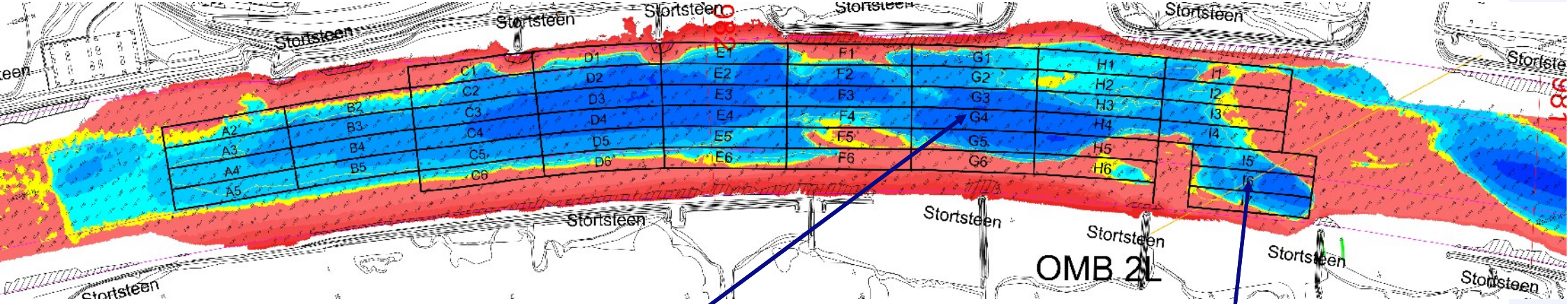
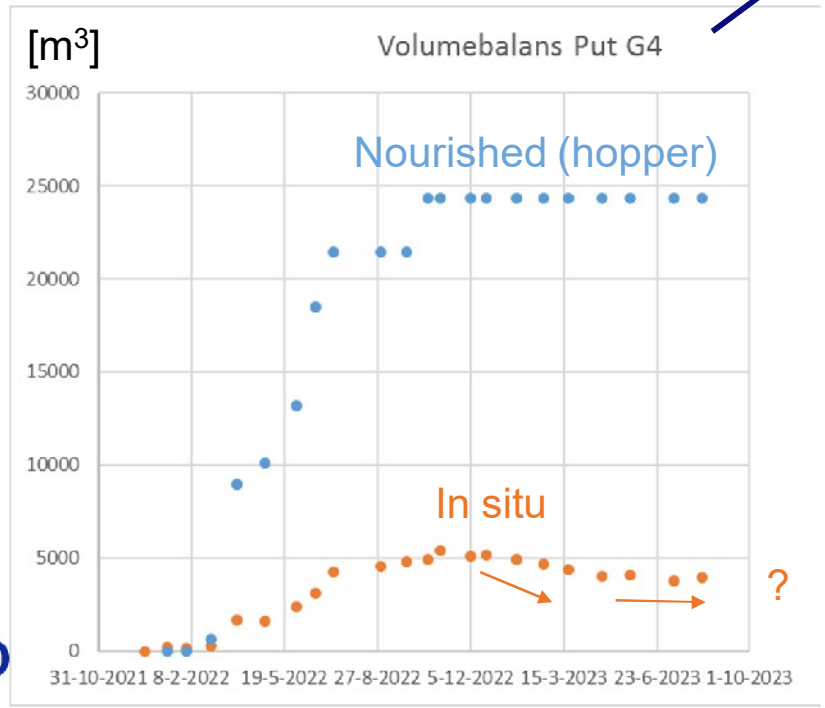
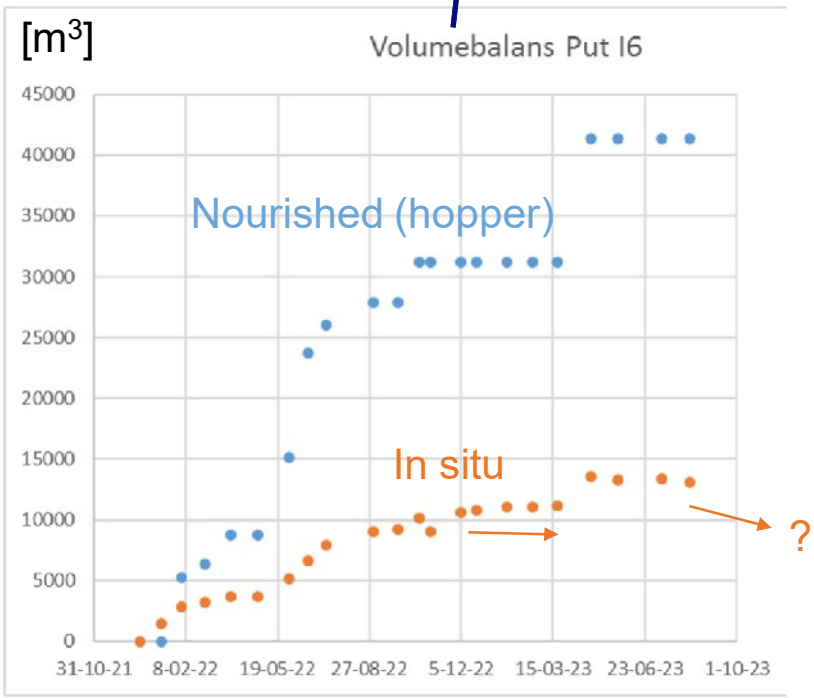

Stortsteen
OMB 2L
A2
A3
A4
A5
B2
B3
B4
B5
C1
C2
C3
C4
C5
C6
D1
D2
D3
D4
D5
D6
E1
E2
E3
E4
E5
E6
F1
F2
F3
F4
F5
F6
G1
G2
G3
G4
G5
G6
H1
H2
H3
H4
H5
H6
I1
I2
I3
I4
I5
I6


[m3]
Volumebalans Put G4
Nourished (hopper)
In situ
?
30000
25000
20000
15000
10000
5000
0
31-10-2021 8-2-2022 19-5-2022 27-8-2022 5-12-2022 15-3-2023 23-6-2023 1-10-2023


[m3]
Volumebalans Put I6
Nourished (hopper)
In situ
?
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
31-10-21 8-02-22 19-05-22 27-08-22 5-12-22 15-03-23 23-06-23 1-10-23

Future prospects

Research questions:

- Related to stability of the scour hole during and after filling
- Related to functioning of the ‘sand engine’

Monitoring:

- Repeated MultiBeam-EchoSounding coming years
- Grain-size sampling

Modelling:

- 3D modelling of the turbulent flow inside the scour holes
- Scour processes (include geotechnics?)
- Far-field modelling of progressing sand wave (3D RMM model)

Potential additional nourishments on this site are possible in the near future (maintenance contract)

Acknowledgement

proeftuin sediment rijnmond

DEME
Dredging, Environmental & Marine Engineering

Rijkswaterstaat

waterschap Hollandse Delta

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www.proeftuinsediment.nl

Thank you for listening!