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Enabling Delta Life

How to reduce salinity intrusion in the Rotterdam harbour?

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Outline

- Problem description of siltation in Rotterdam harbour
- Possible remedies
- Introduction to air curtains (bubble plumes)
- Numerical modelling of bubble plumes
- Model results for the Rotterdam harbour
- Conclusions

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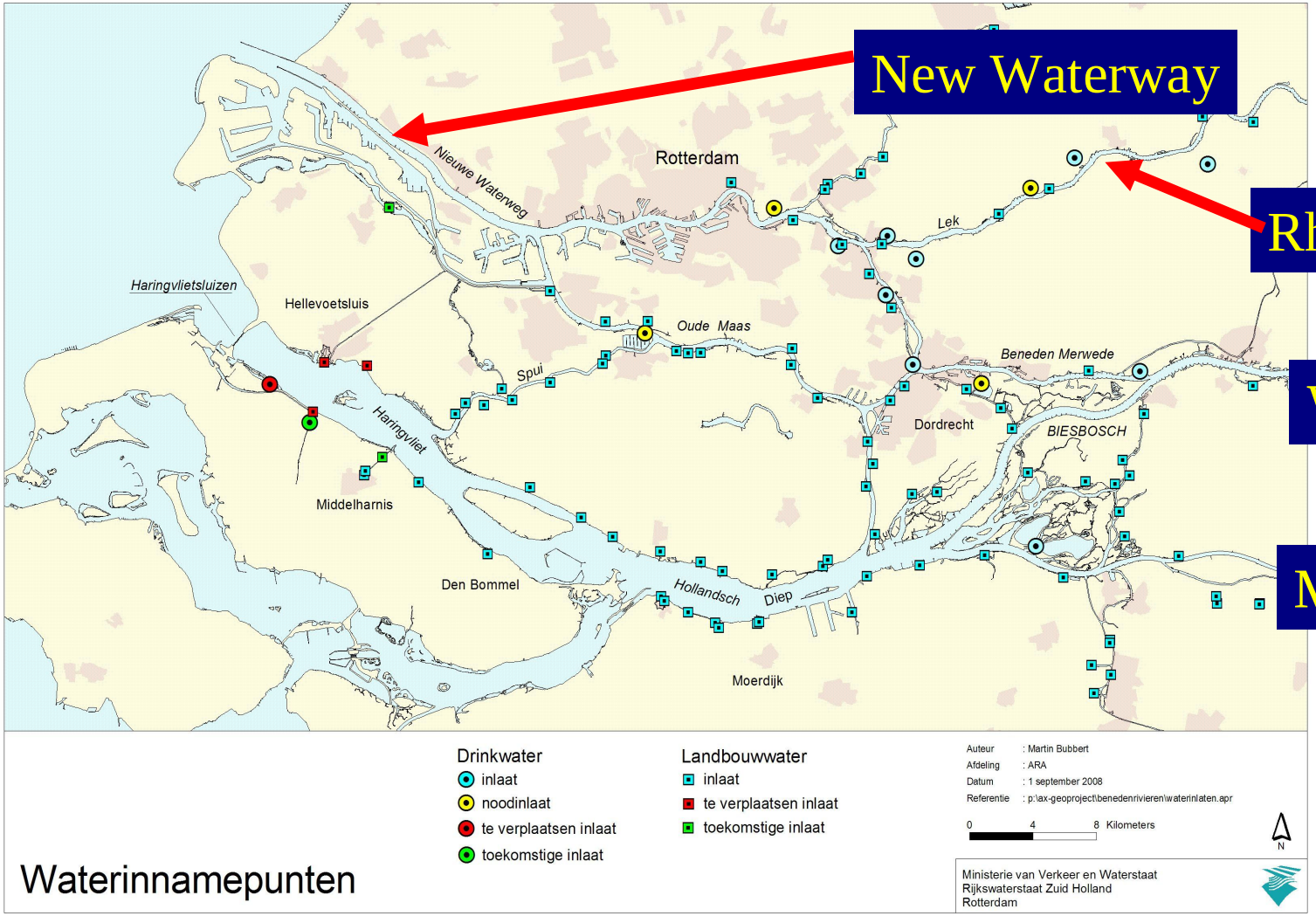
Overview of fresh water intakes

Lobith (German border): 100 mg/l; North Sea 20 g/l
drinking water: < 250 mg/l; agriculture < 700 mg/l



Extreme siltation in November 2005

Afb. 2: Externe verzilting in november 2005.

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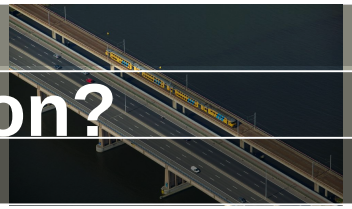
How to reduce salinity intrusion?



Problem will become worse. Sea level rise, lower river discharges, …

Workshop by Dutch Government (February 2010) with 80 ideas.

Global assessment of most promising ideas:

- Moveable barrier
- ….
- Restoration of stair-case bathymetry
- Air curtain(s)

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Stair-case bathymetry for the New Waterway

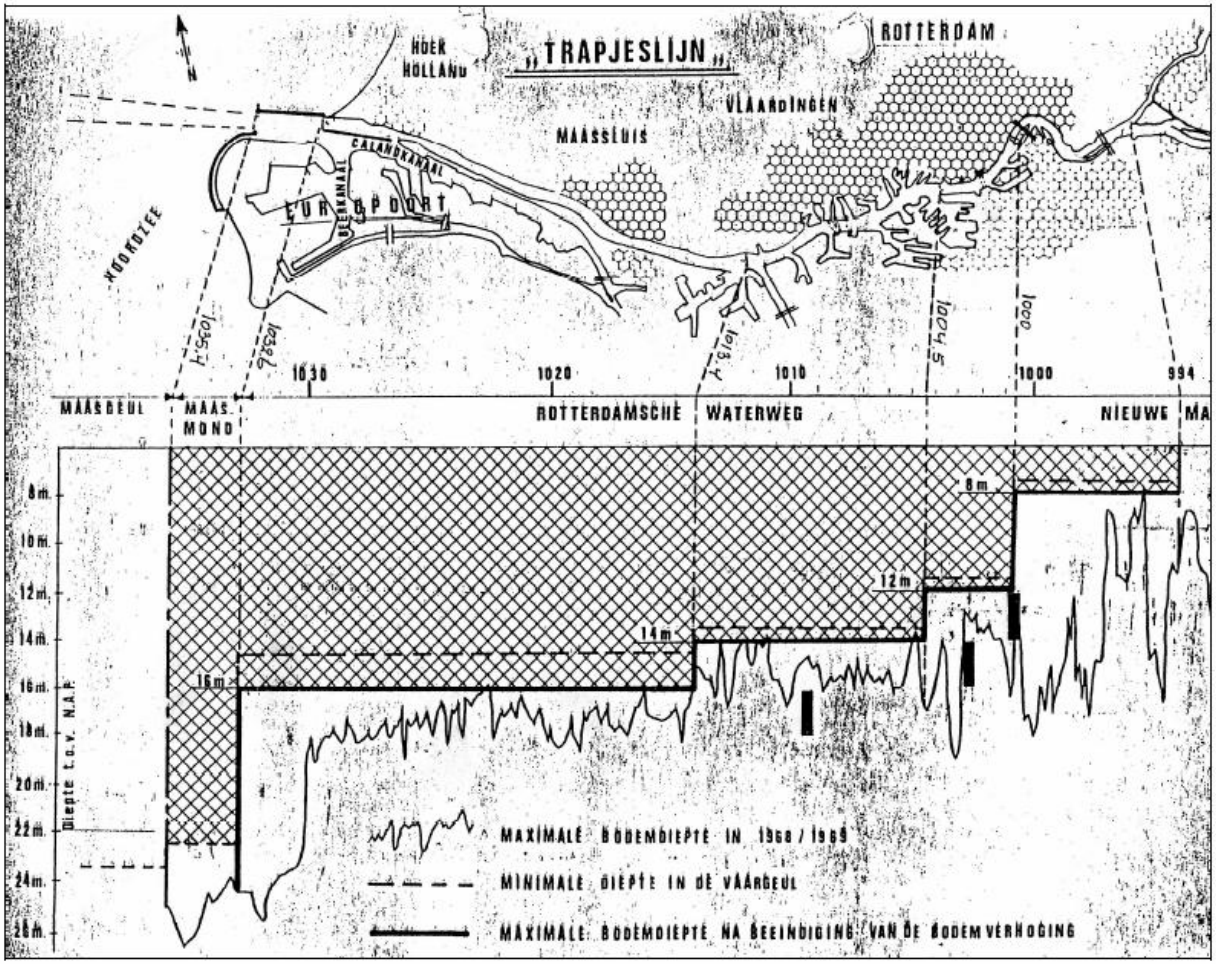

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Illustration of air injection

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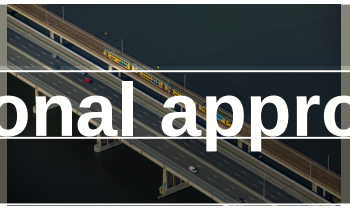
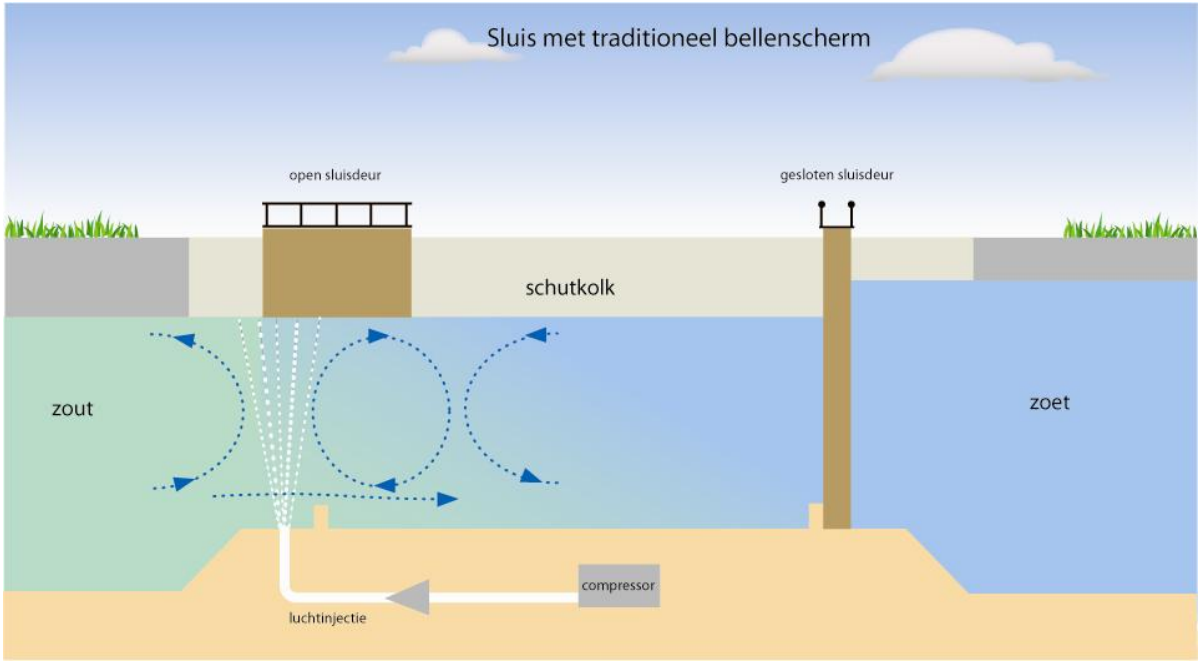
Air injection at sluices (traditional approach)



Volkeraksluices anno 1970

Foto 16. Meetsituatie Proef 2a, Hollands Diep-zijde
(uitwisselen, zoete voorhaven / zoute kolk, luchtbellenscherm)

Foto 17. Luchtbellenscherm Proef 2a



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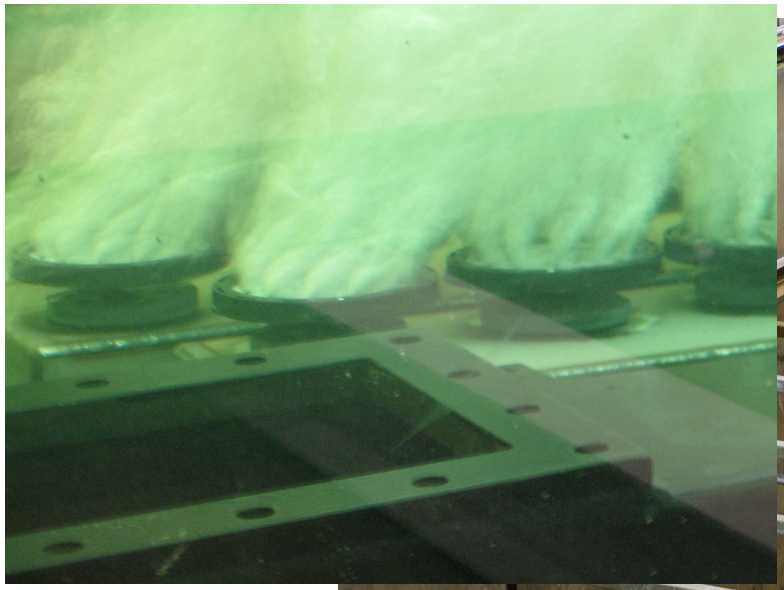
Testing of air curtains at Deltares' laboratory



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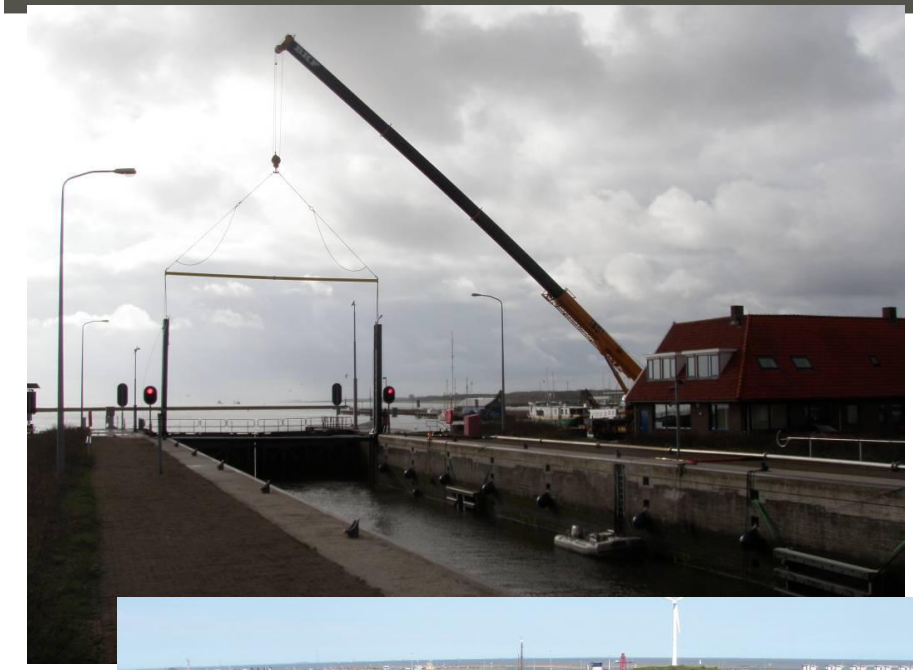
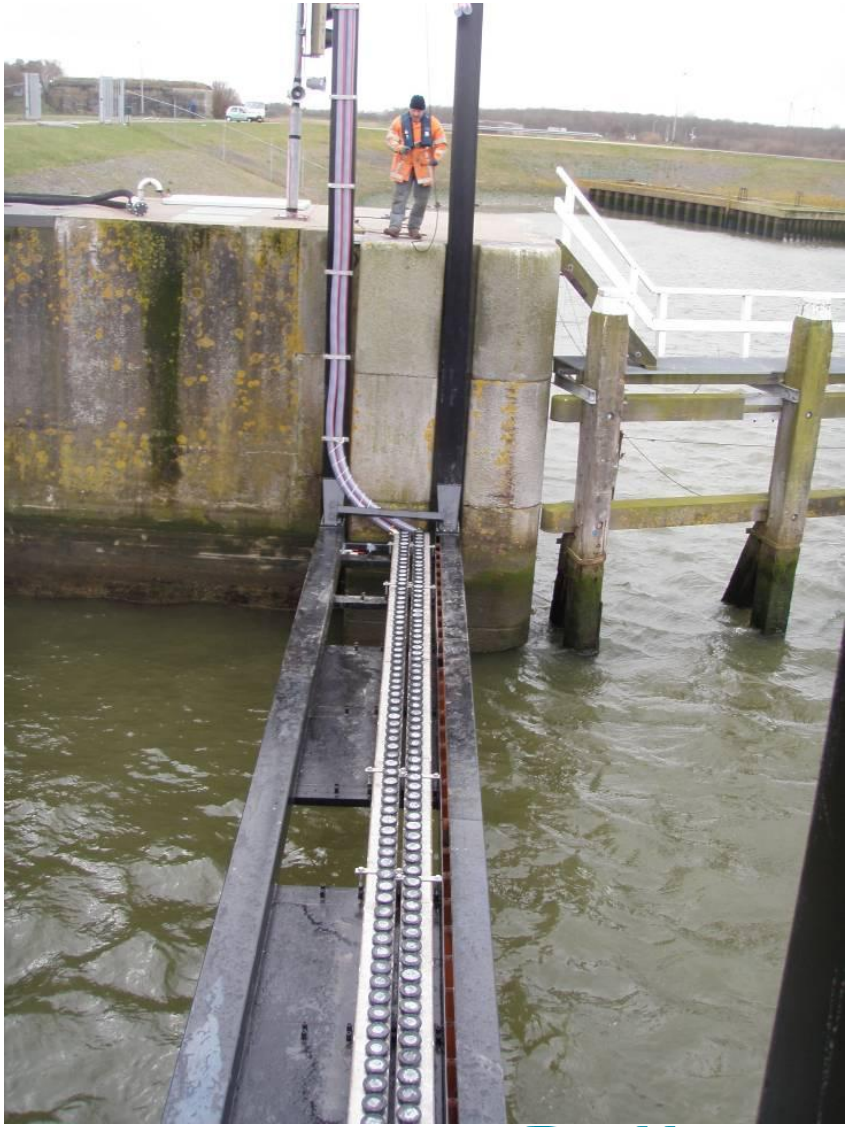
Testing in real-life: Stevinsluis

Air curtain Stevinsluis (1)





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Air curtain Stevinsluis (2)

Will air curtains work for the New Waterway ?

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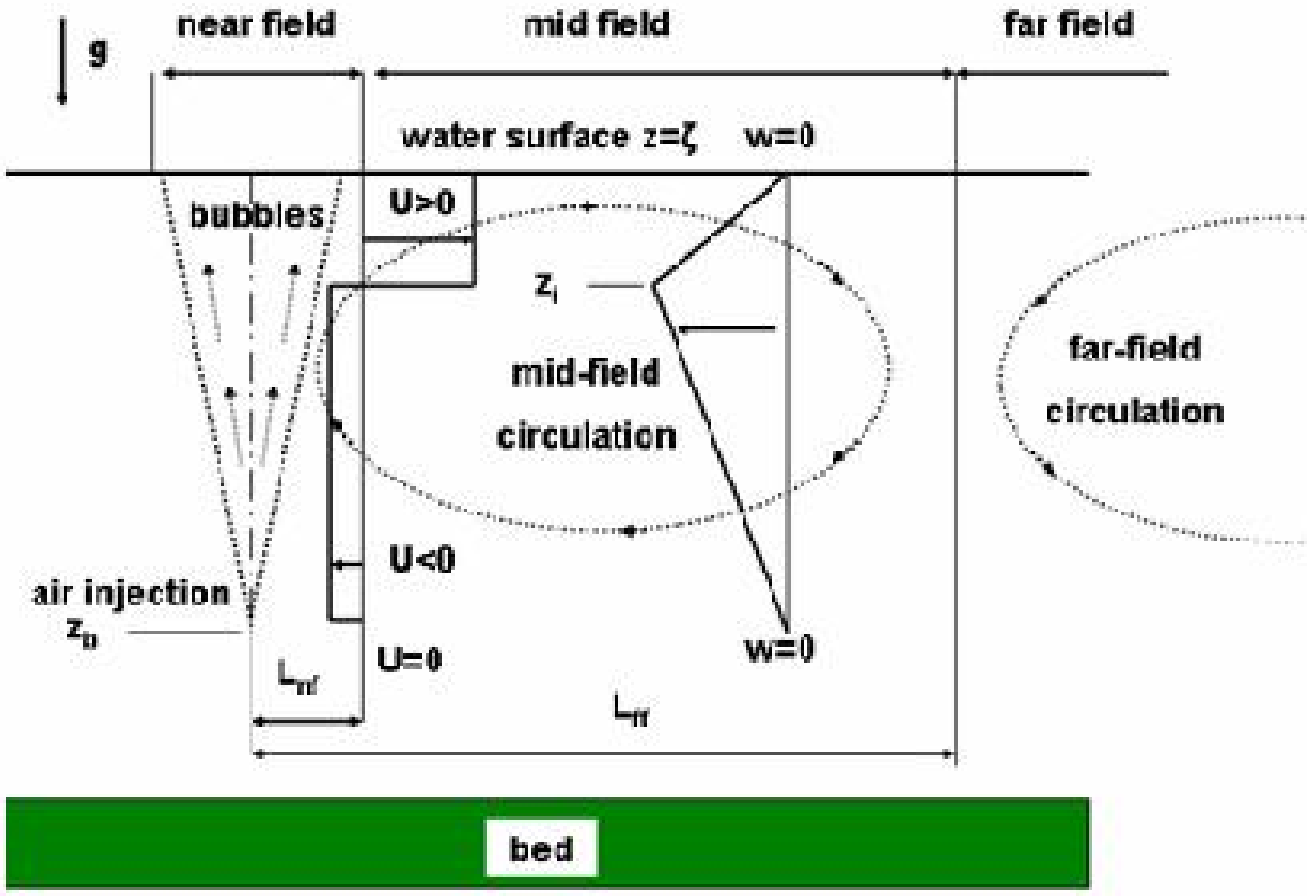
Numerical modelling of air curtains (1)



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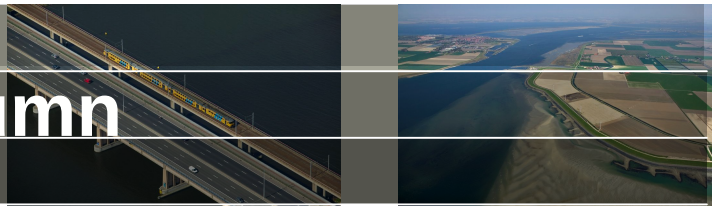
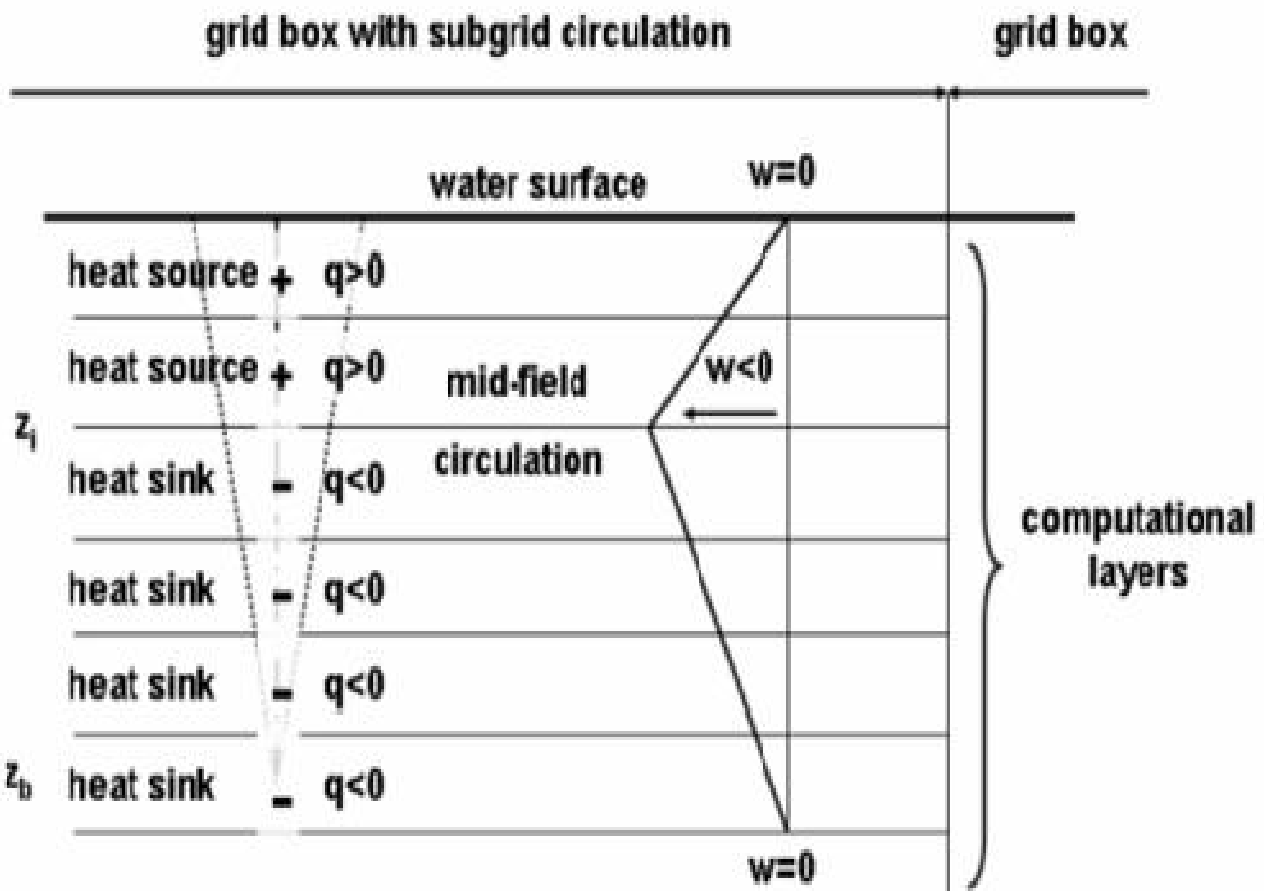
Via discharges in vertical column





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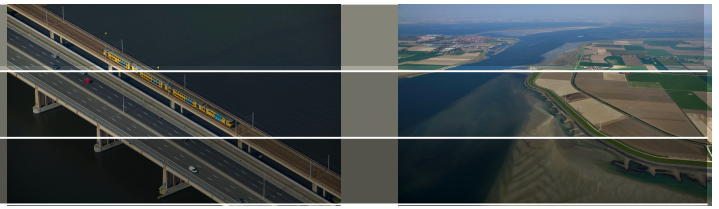
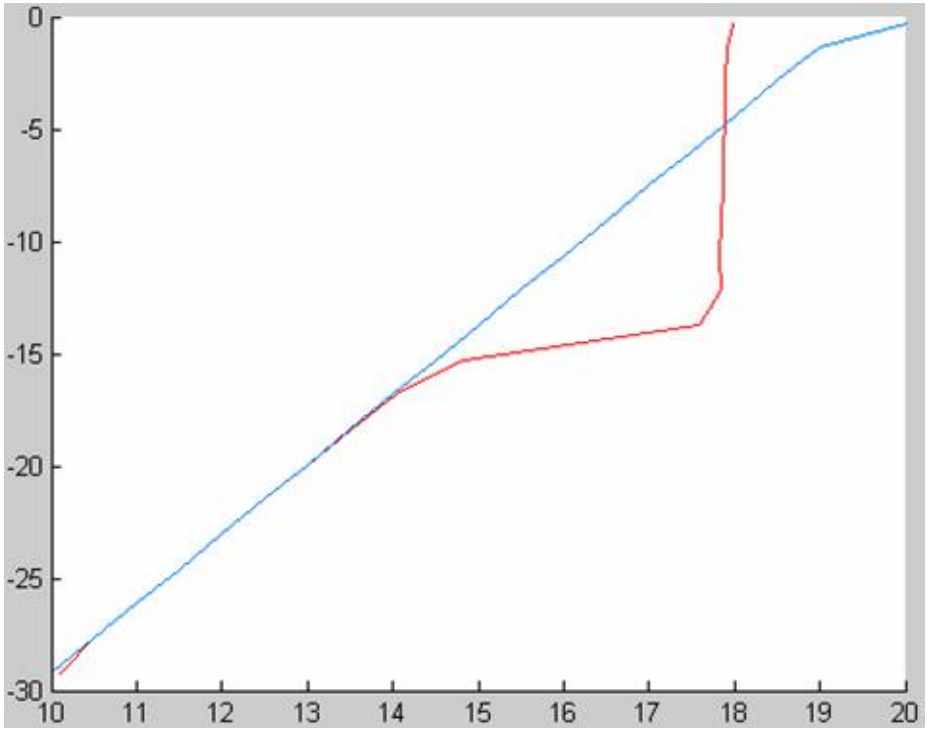
Simplified validation case





Initially: linear temperature profile (blue line)

Mixing above the air injection point (red line)

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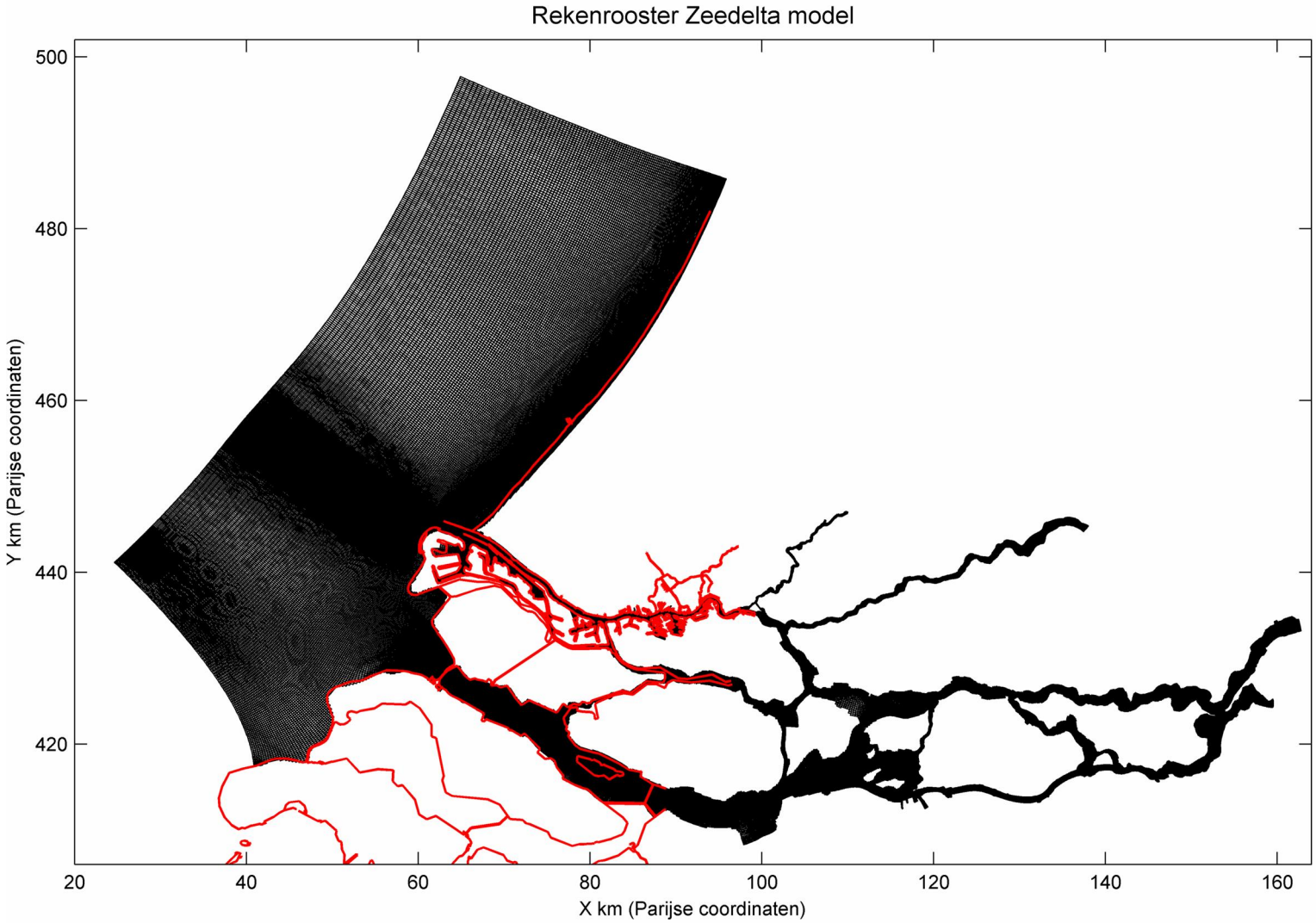
3D model for Rotterdam harbour (1)



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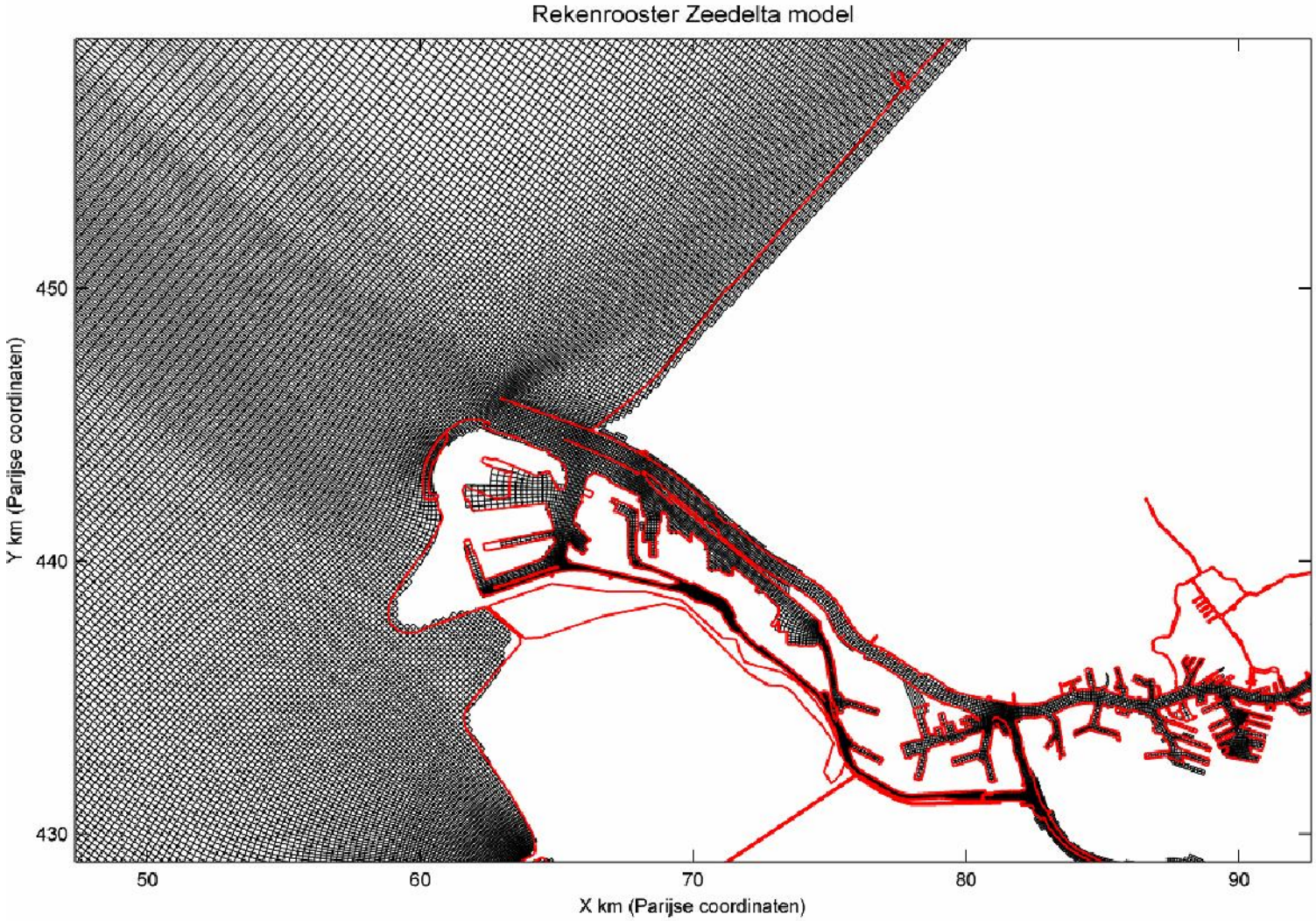
3D model for Rotterdam harbour (2)



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Detailed model grid for New Waterway

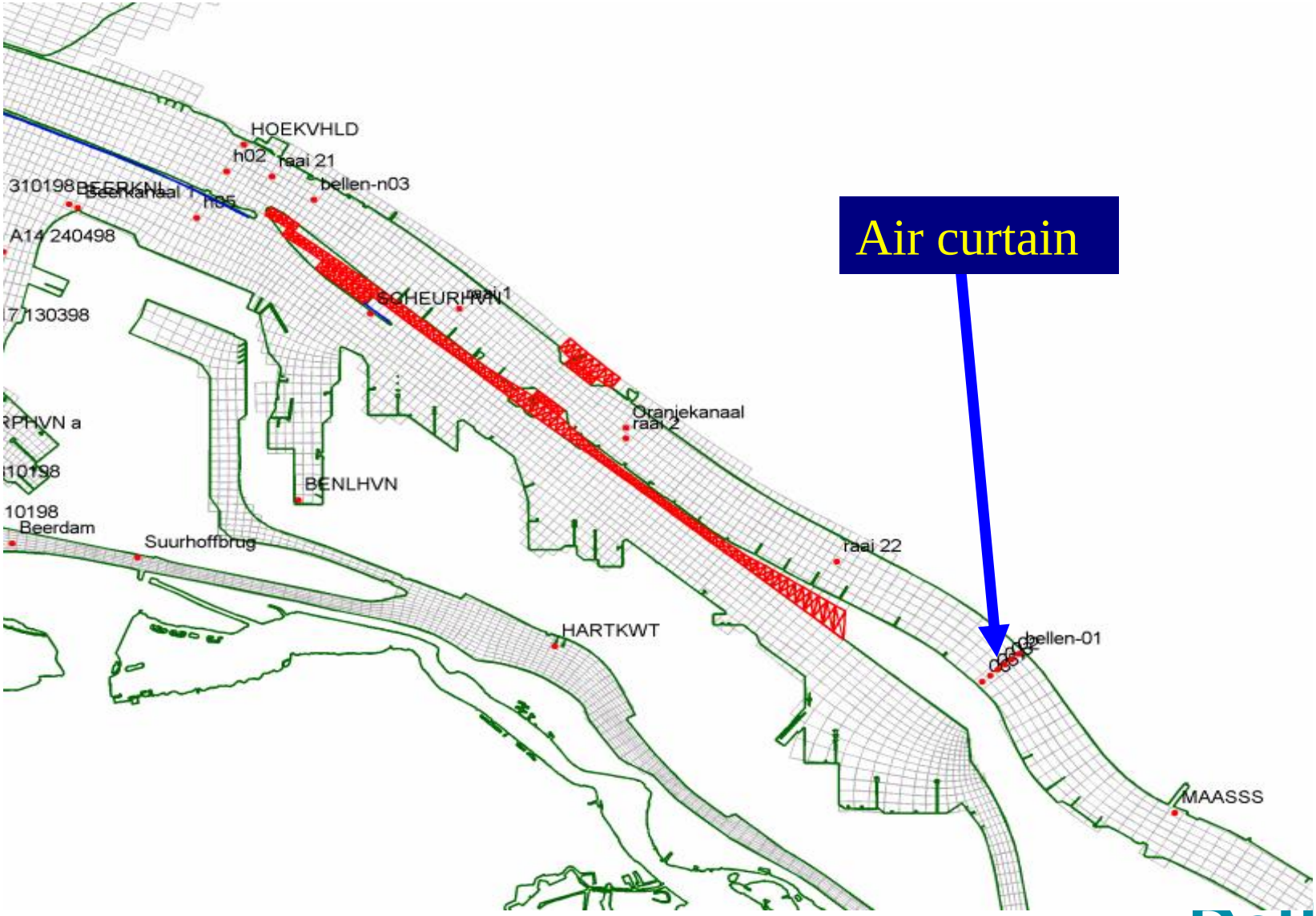

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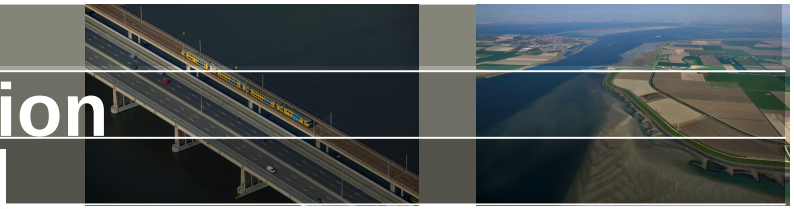
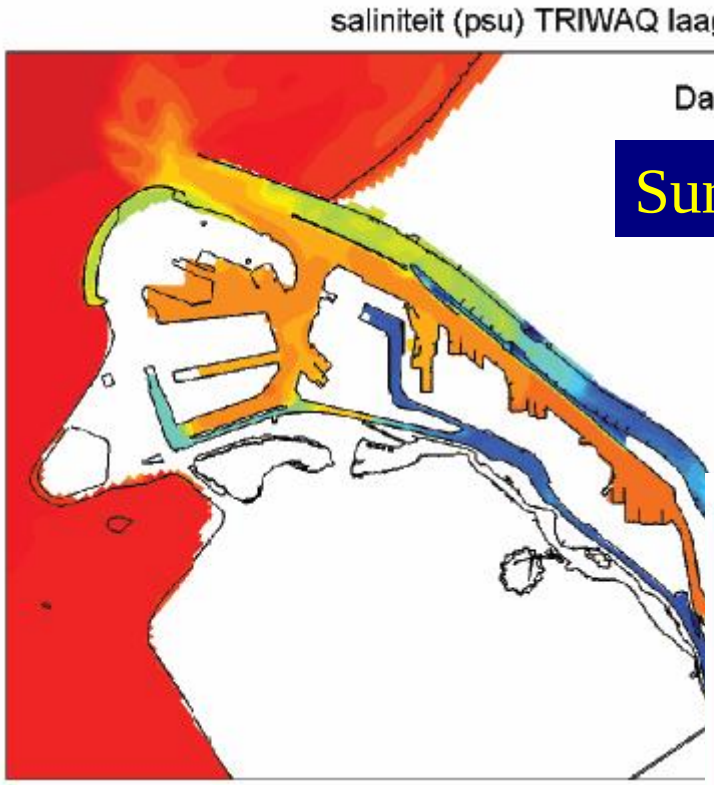
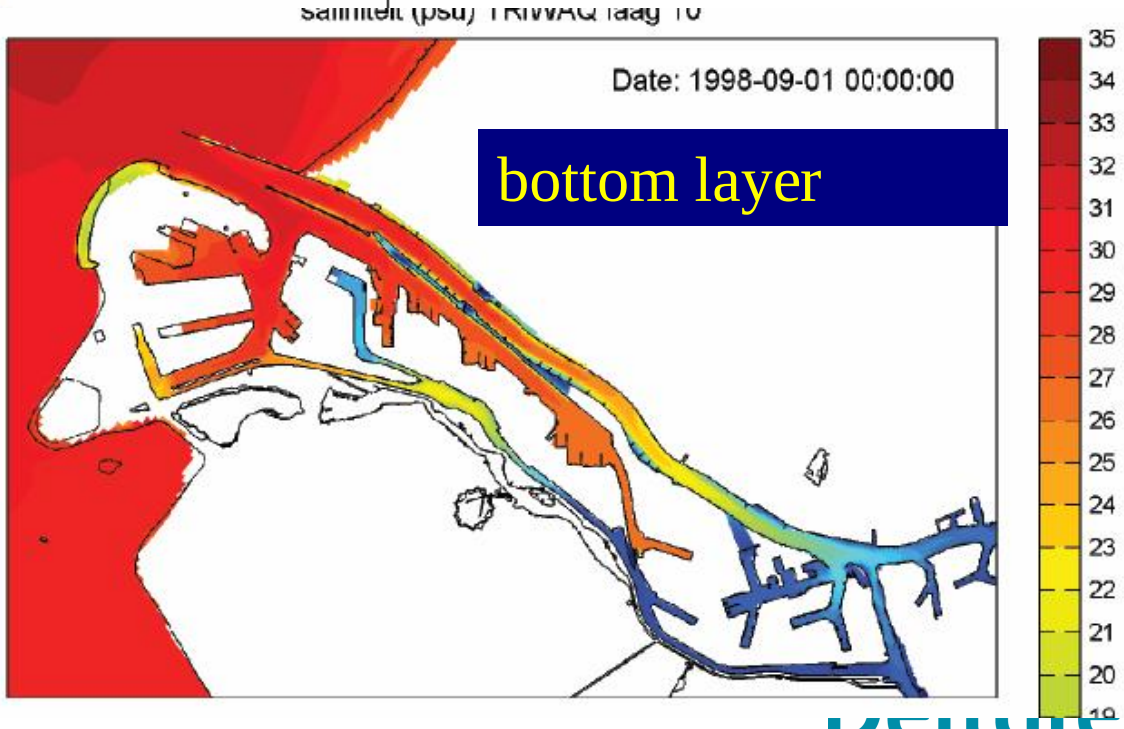
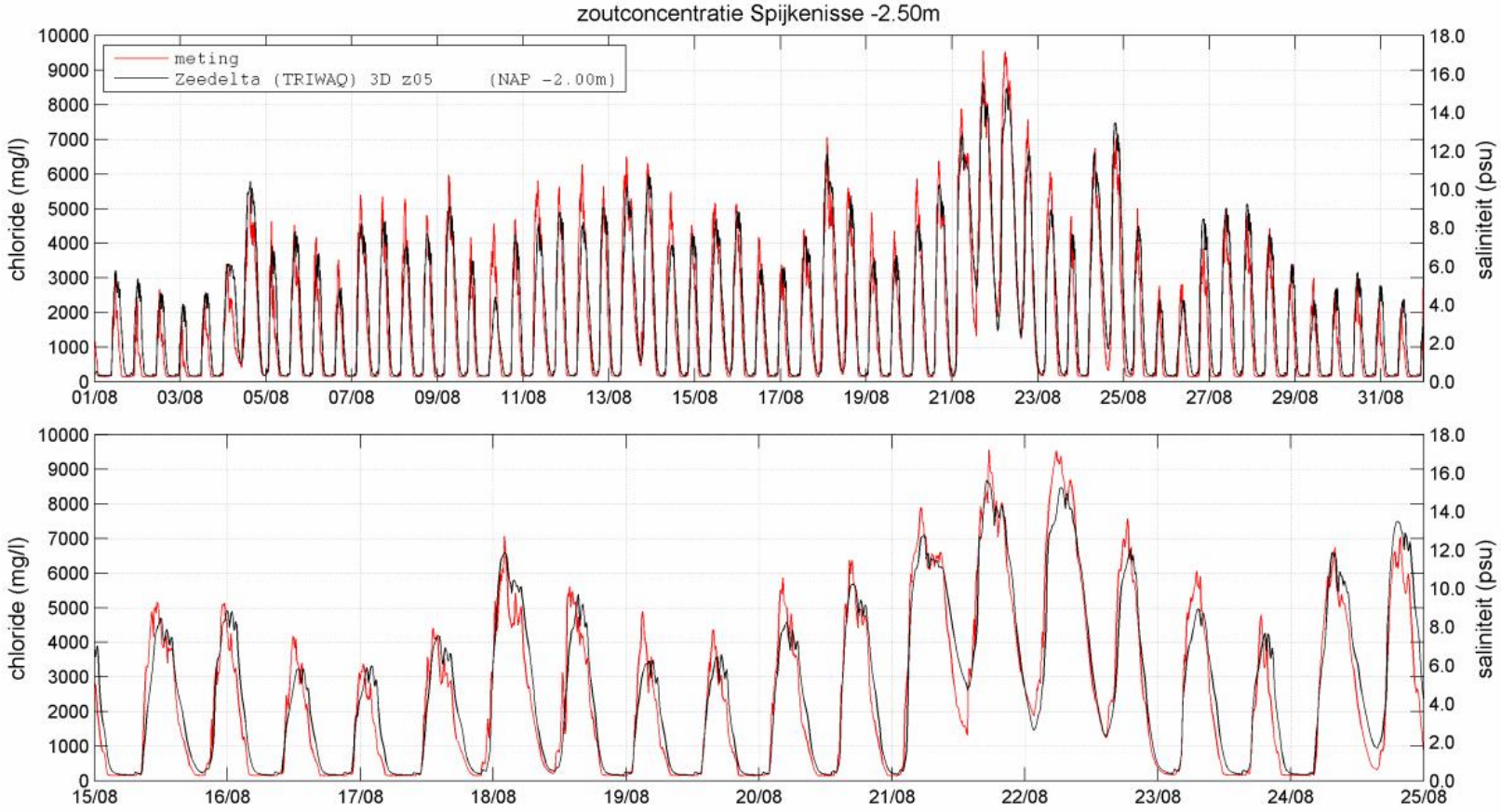
Illustration of salinity intrusion



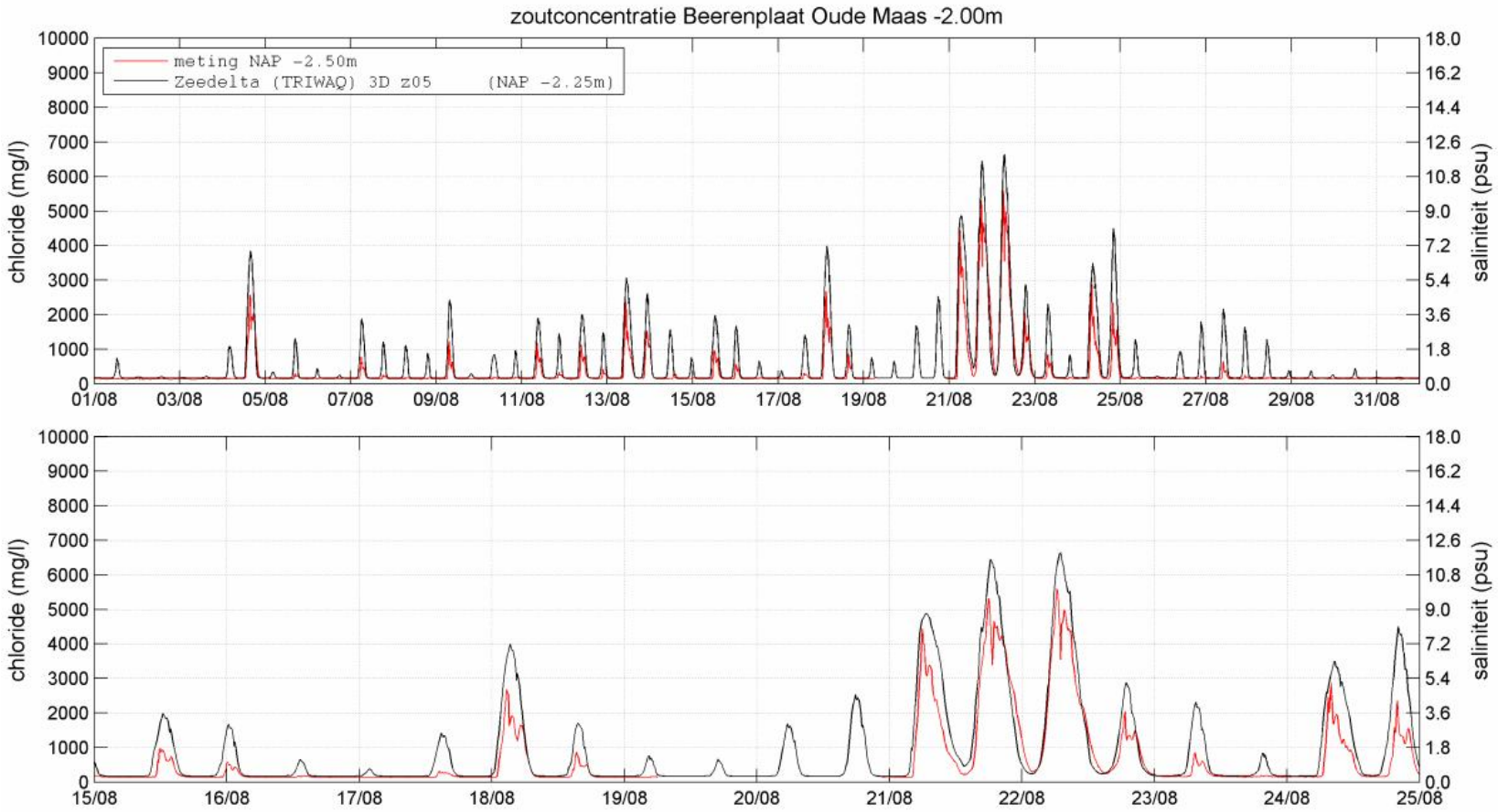




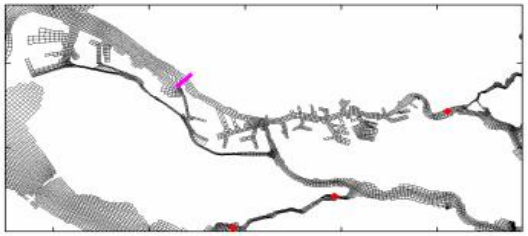
Model performance for salinity intrusion (1)



Model performance for salinity intrusion (2)



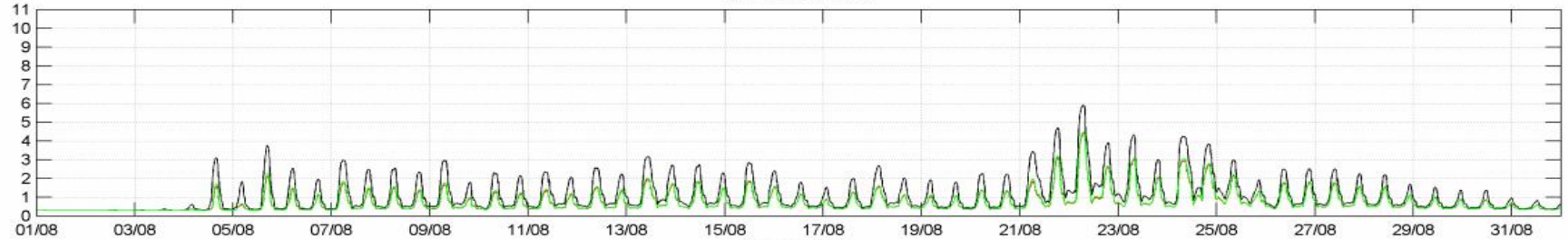
Impact of air curtain of salinity intrusion



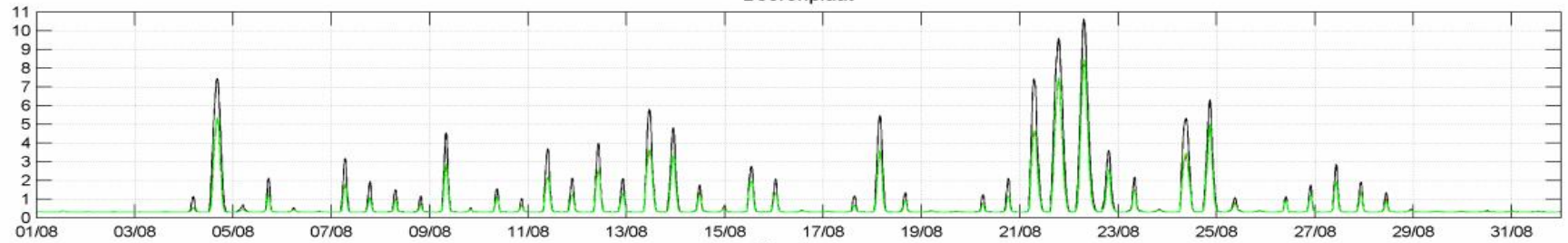
Fijn Grid : Q_{br} = 800 m^3/s

a07 : zonder bellenscherm
a20 : bellenscherm Maassluis 15000 m^3/s
a21 : bellenscherm Maassluis 3750 m^3/s

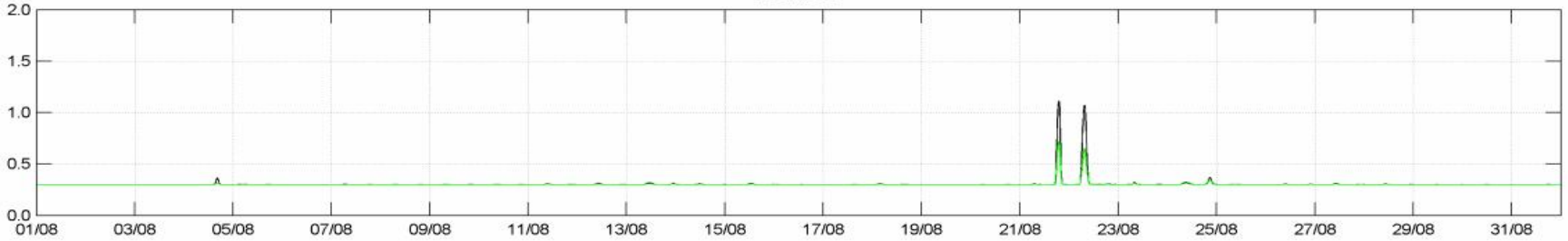
Van Brienenoord



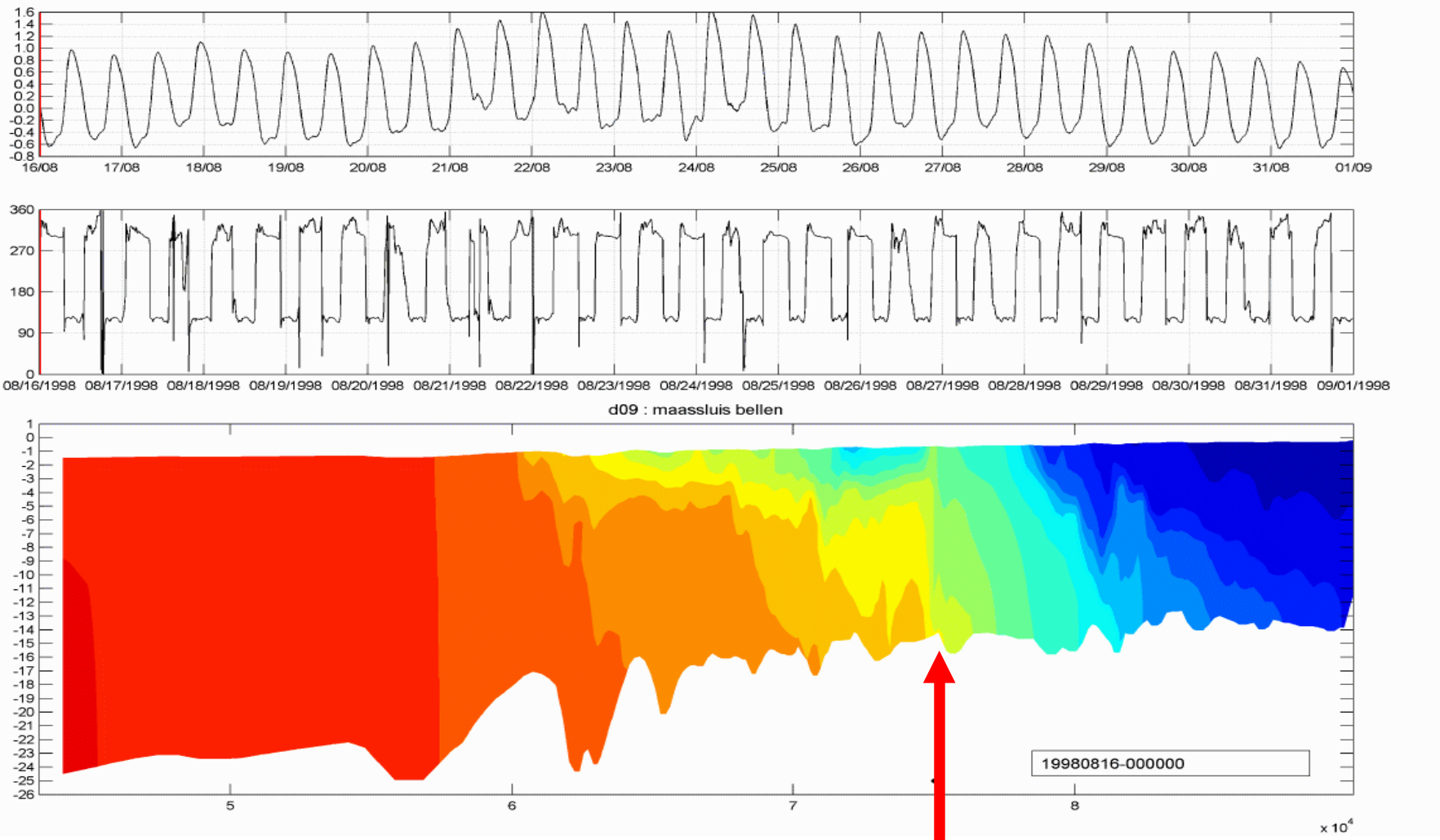
Beerenplaat



Bernisse



Animation of 2DV salinity contours



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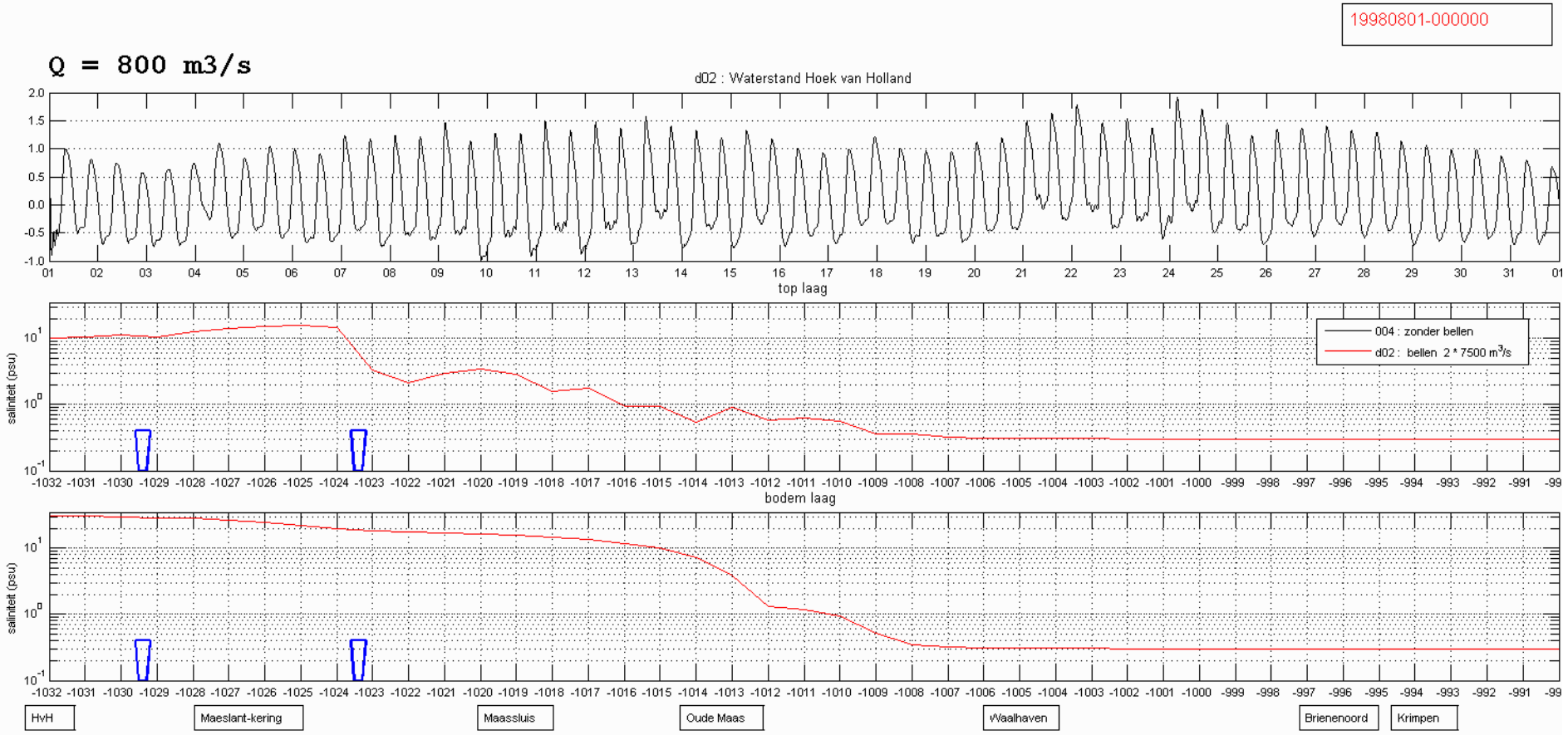
Cross sectional salinity at surface and bottom



Conclusions

- Air curtains are a promising option to reduce salinity intrusion in rivers

- Detailed analysis of physics; detailed numerical study via several computer codes; validation with measurements

- Successfully applied for the New Waterway
- Intrusion for Rhine discharge of 1200 m3/s ≈ Intrusion for Rhine discharge of 800 m3/s with air curtain of 3750 m3/s

- Further research required, in particular ratio air-flux to entrainment-flux

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