SEDIMENT REALLOCATION STRATEGY TO ‘RESET’ A NATURAL HYDRODYNAMIC SYSTEM: PORT OF ROTTERDAM

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SURICATES closing event 15 December 2022

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Reallocation Pilot Port of Rotterdam

Reallocation of 580.000 m^3 (>200.000 tons) sediments in the Nieuwe Waterweg (NWW) within the Port of Rotterdam as an alternative for reallocation at sea.

Increase the resilience of the river bank and a constructed wetland by increasing the sedimentation outside the navigation channel.

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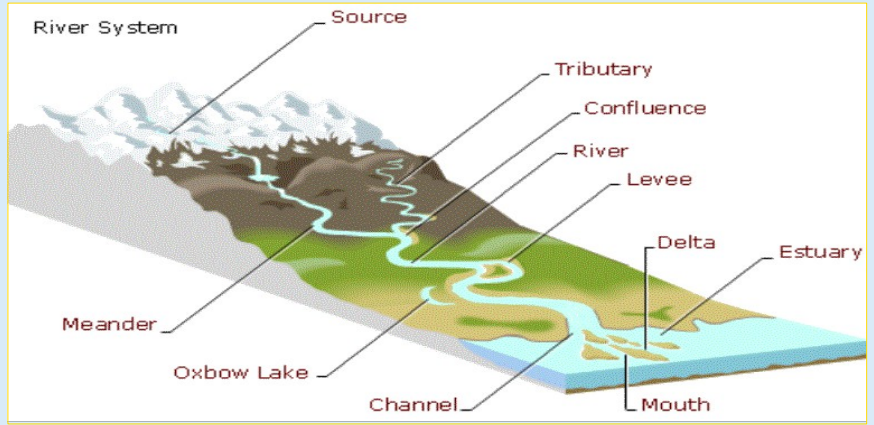
Fluvial delta’s

Sedimentation takes places in almost every port basin

This occurs due to low current velocities in the port.

Influx of marine sediments from tidal pumping & storms ‘’clash’’ with fluvial sediment which are discharge from the river.

Due to the varying conditions over the tide and over the year the resulting sedimentation is hard to predict, although trends can be observed.



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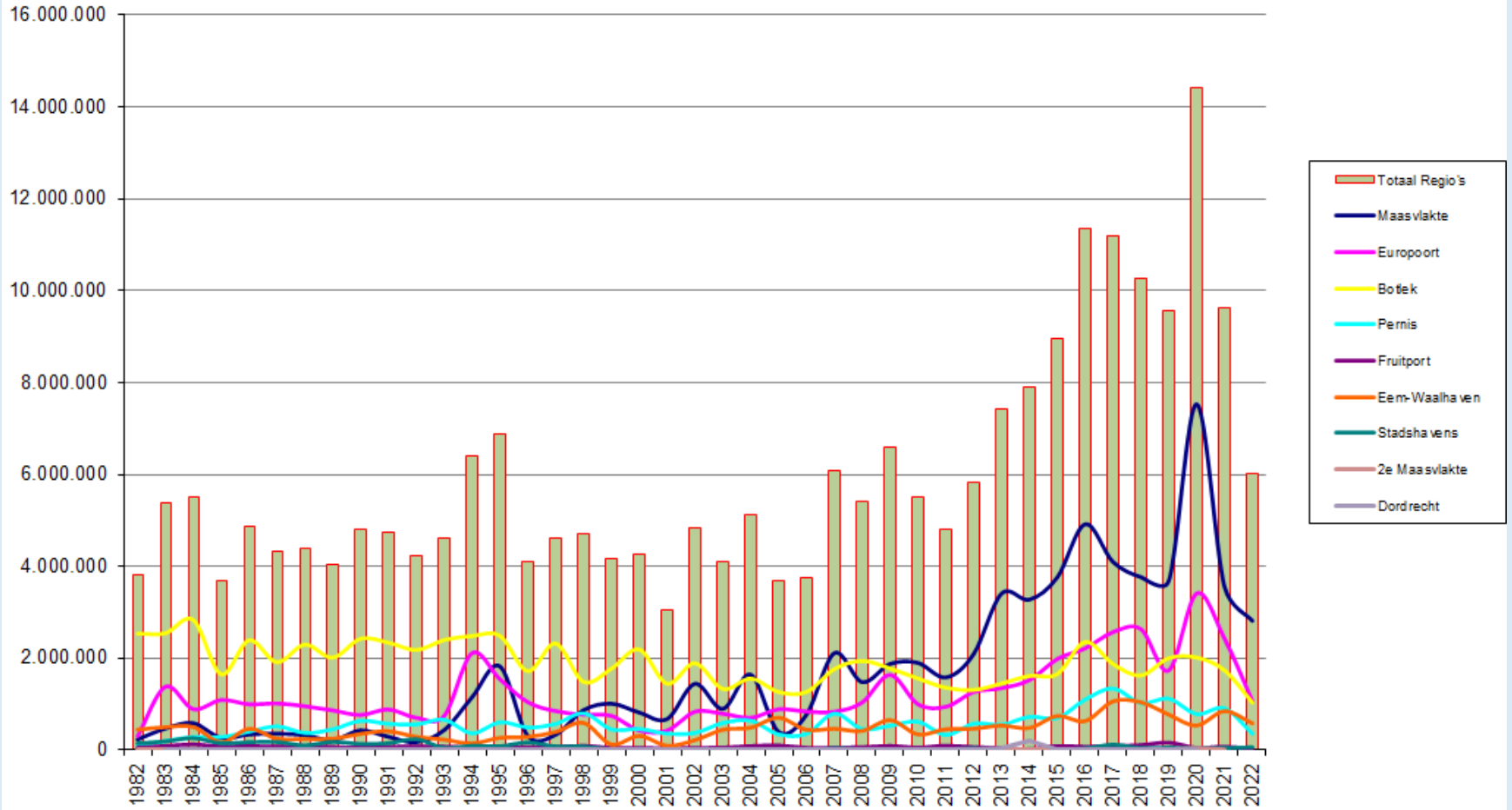
SEDIMENT QUANTITY



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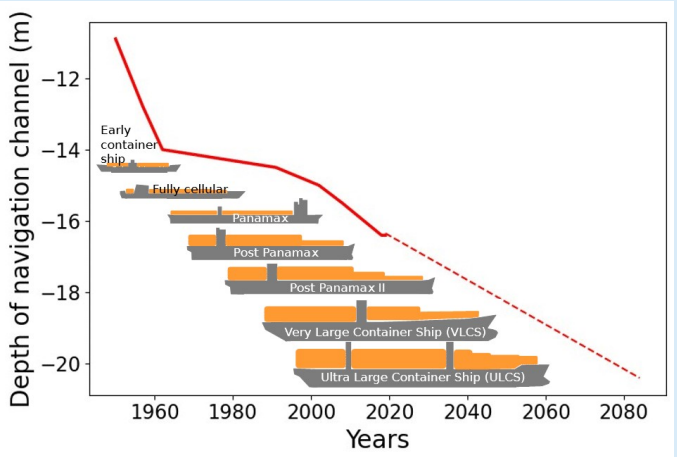
The impact of an increased navigation depth

The increase in navigation depth which has occurred over the years impacts the intrusion of salt water, the flow velocity and the wave height in the port. This can potentially impacting the river shore erosion rate.



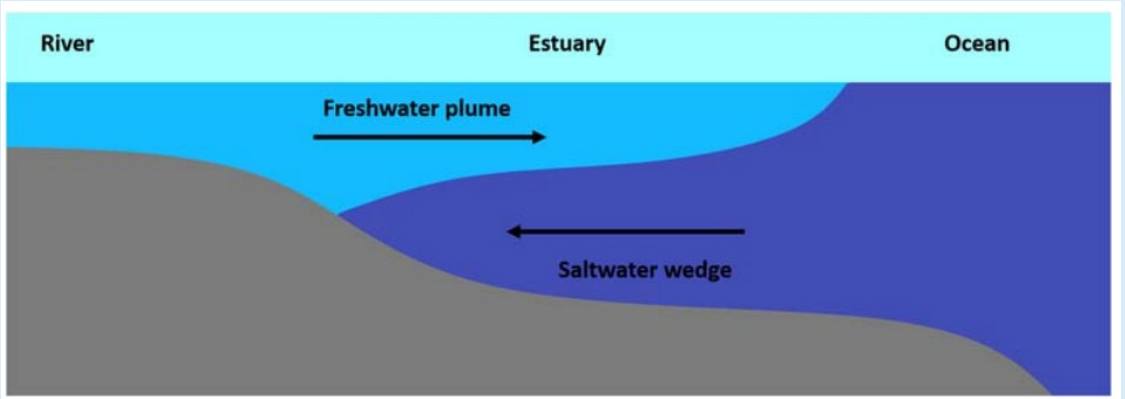


Figure 2.1: Schematization of salt-intrusion within a stratified estuary.

Reallocation pilot Port of Rotterdam

The reallocation pilot with 580.000 m^3 sediment / 220 tons TDS in Port of Rotterdam served multiple purposes:

1) Test of the reallocation could lead to an increased sedimentation in a neighboring constructed wetland, strengthening the wetland against erosion
2) Test if the reallocation would impact the sediment balance, at the site (near field), in the area leading towards the storm surge barrier (2 km, mid field) and in the estuary (40 km of the NWW)
3) Test if the reallocation could reduce the greenhouse gas emission as compared to sialing to sea.

SURICATES - AREA

SURICATES - REALLOCATION

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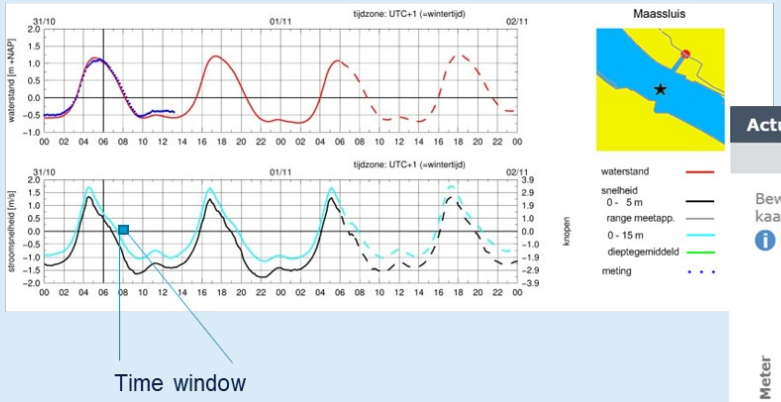
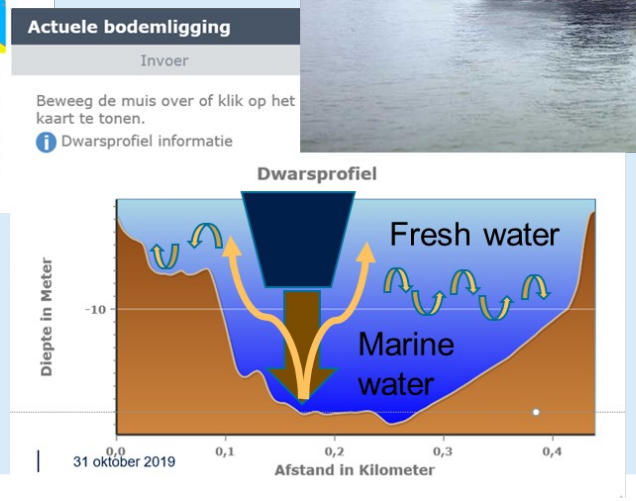
Using the tide to transport the sediment.

Time window: up to 1 hour after turning tide.

Based on operational tidal model Rotterdam





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Facts:

- Period: may – november 2019
- Amound: 220.000 tds (580.000 m3)
- Contributed by: RWS ca 40.000 tds / HbR 180.000 tds
- Savings on travel distance and time as compared to sea: 5.000 km / 250 hour
- Saving on hopper: 600.000 euro

Reduction of green house gas emissions

CO_2: 520.000 kg

NO_x: 3.000 kg

SEDIMENT - ASSESSMENT

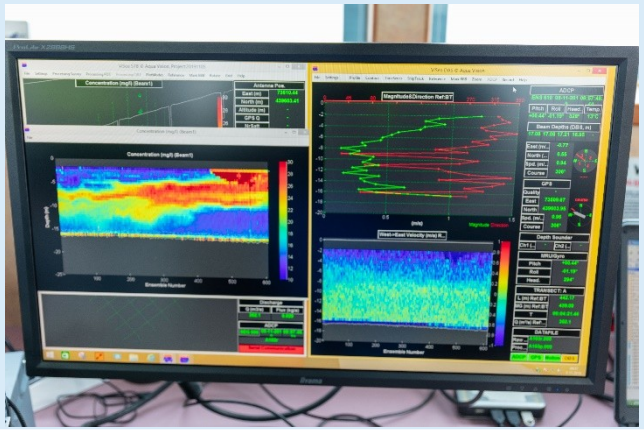
The impact on the systems resilience has been assed by:

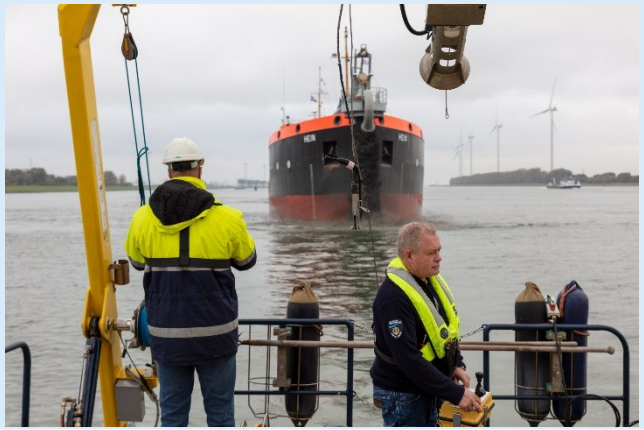
1. The change in **bathymetry** in the main shipping channel, is there extra siltation?
2. The **nourishment** of the constructed wetland, is sediment entrapped?
3. The **sedimentation balance**, is there an observed increase in the amount of fluvial sediments?
4. The **turbidity** in the channel, how is the sediment transported?

SEDIMENT REALLOCATION - MONITORING

Main monitoring tools:

- **Passive optical cable** along and across the channel
- **Actively heated optical cable** for sediment profiles
- Sediment grab sampler and **rare earth lab analyses**
- **ADCP backscatter / multibeam**





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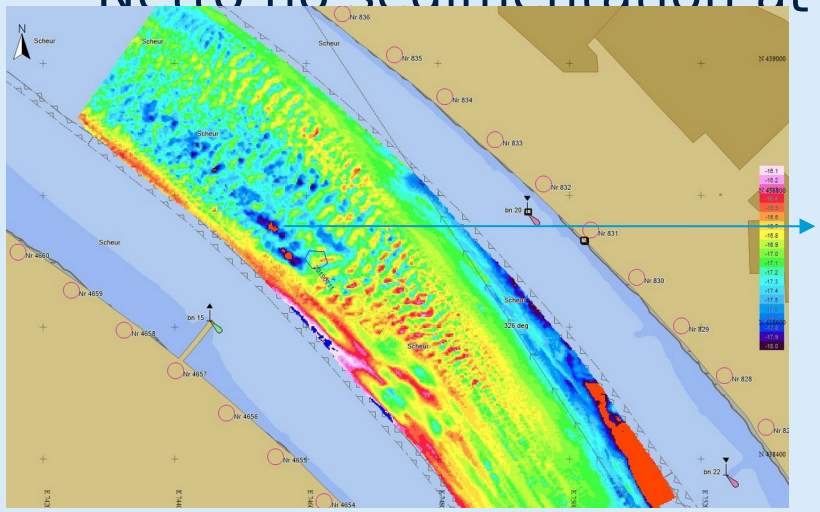
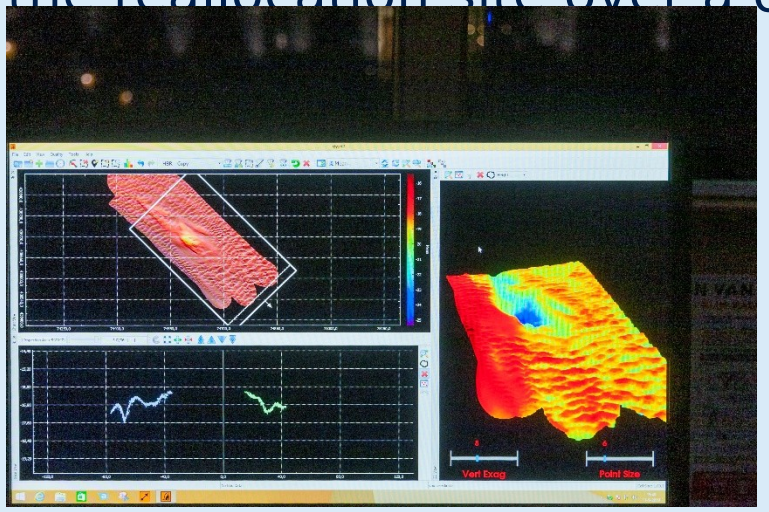
SEDIMENT REALLOCATION - BATHYMETRY

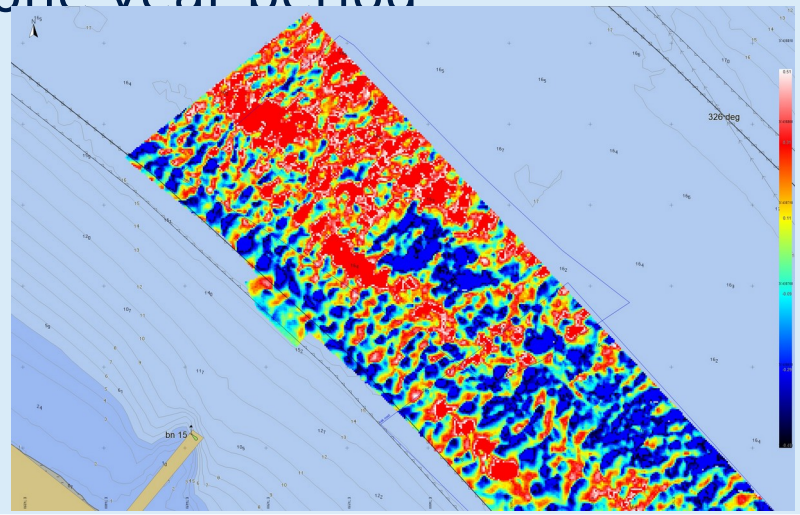
Assessment with multibeam surveys

Surveys at the site during the reallocation and a weekly multi beam surveys of the channel showed:

- A decrease in the amount of sediment at the reallocation site after reallocation
- Netto no sedimentation at the reallocation site over a one year period







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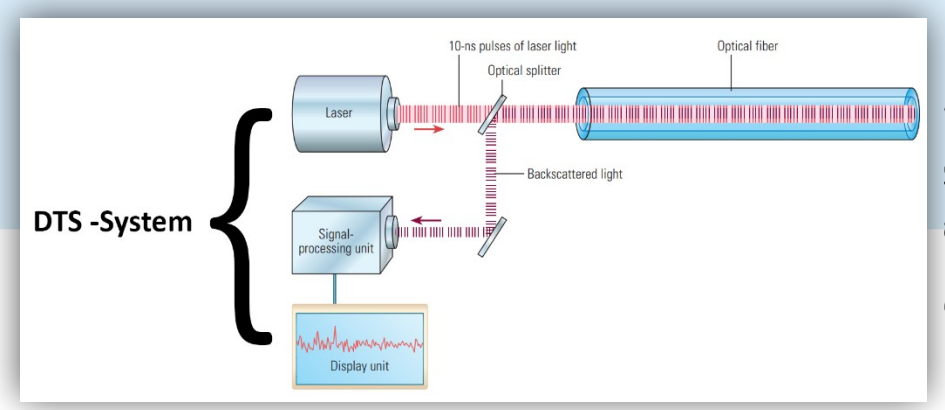
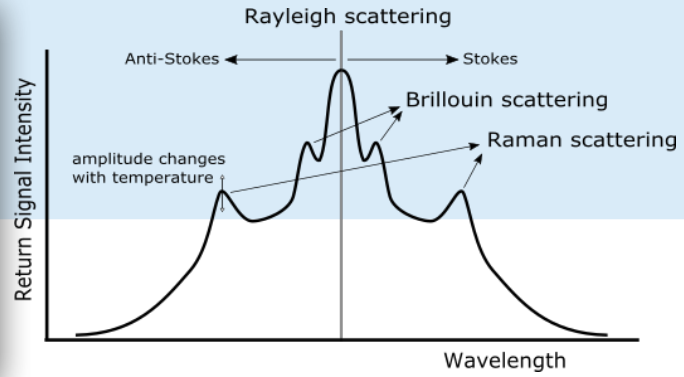
SEDIMENT REALLOCATION - BATHYMETRY

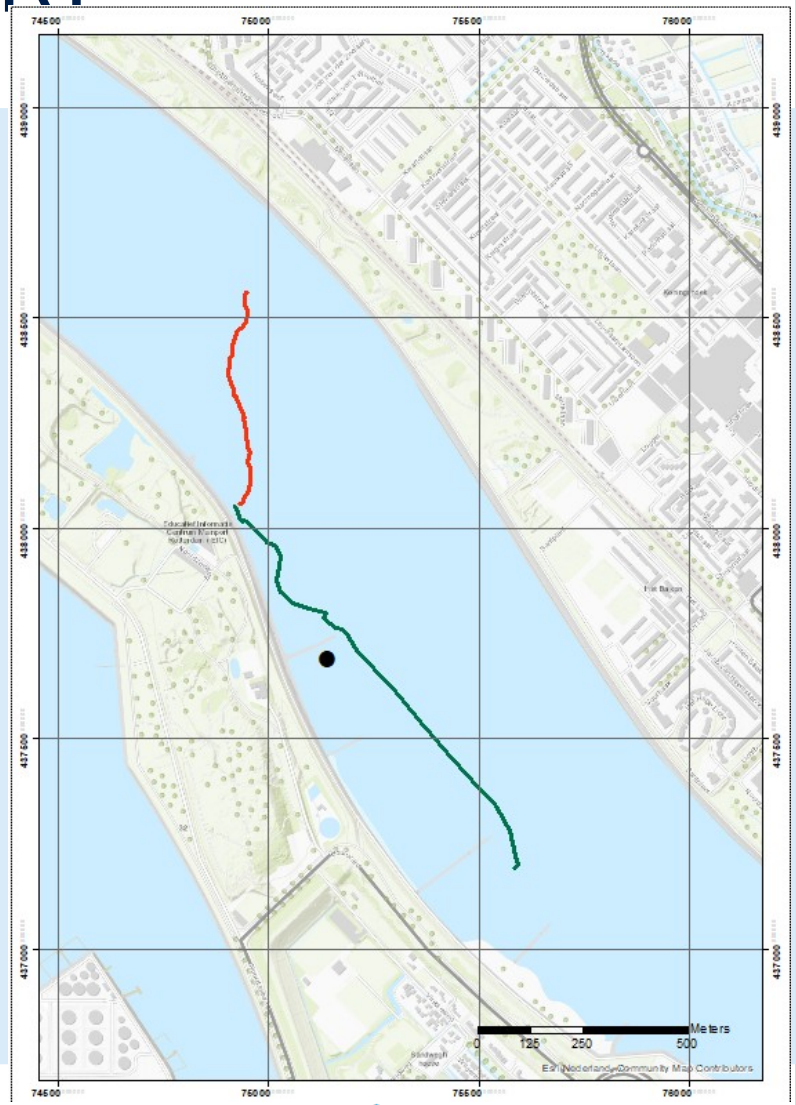
Sedimentation assessment with passive optical cable

If the cable gets covered by siltation, the temperature fluctuation is ‘out of phase’ with the water temperature due to the time needed to transfer heat.

This phase shift can be used to monitor sediment coverage.







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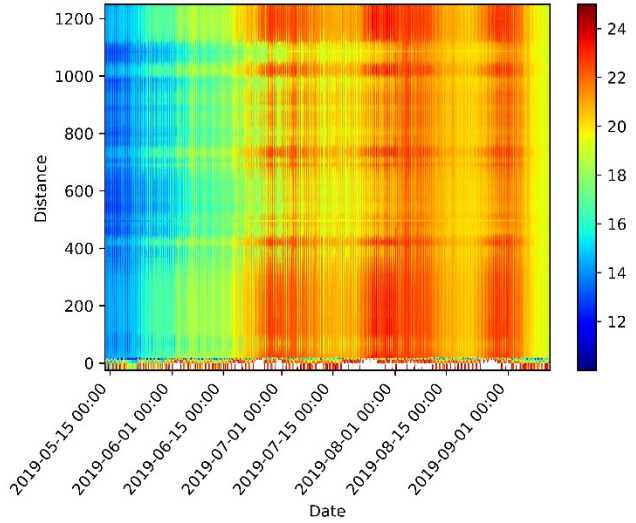
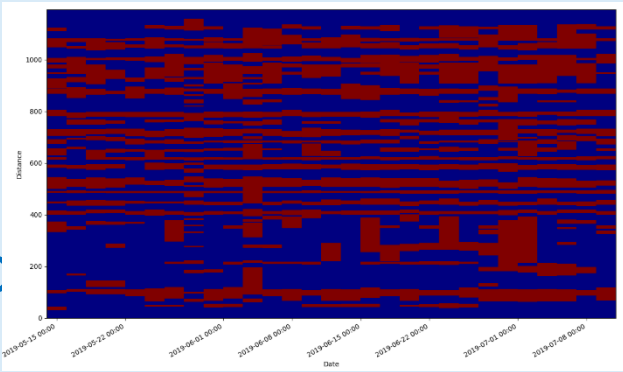
SEDIMENT REALLOCATION - BATHEMYTRY

Sedimentation assessment with passive optical cable

The technique is promising, but not yet fully developed.





Heatmap translated to areas with sediment coverage

Question 1: Suitability for spatial impact assessment c
sedimentation: *For now, questionable.*

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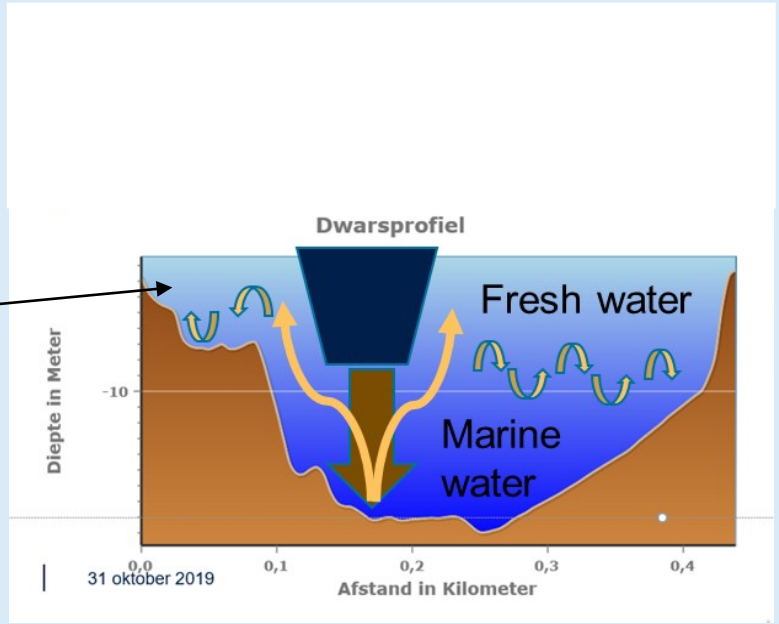
SEDIMENT REALLOCATION - NOURISHMENT

Assessment of Wetland nourishment with active optical cable

The hopper reallocated 580.000 m³ at the doorstep of the constructed wetland.

Did this help to increase the sedimentation rate within the wetland?



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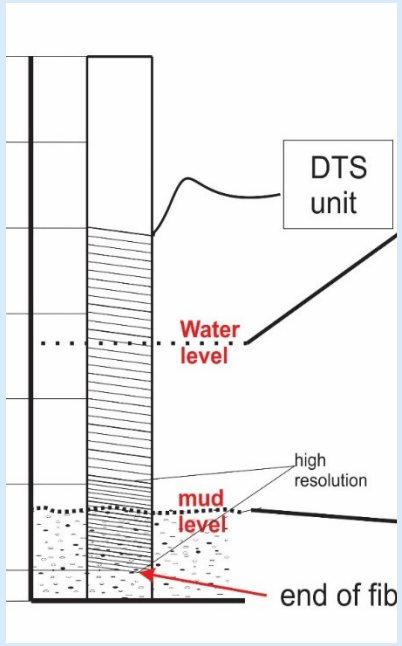
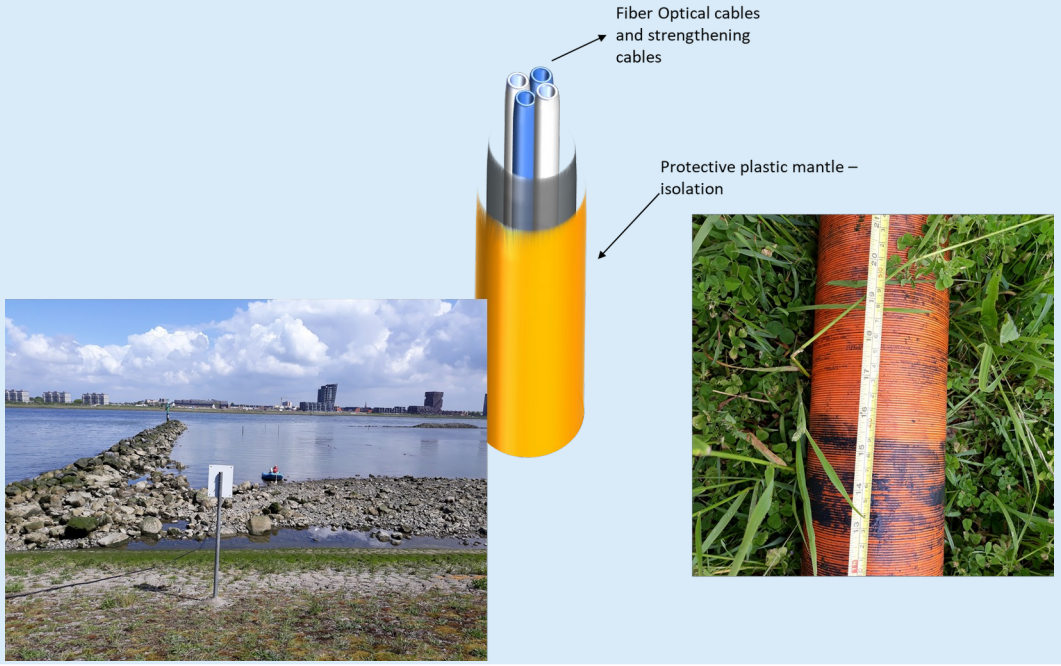
SEDIMENT REALLOCATION - NOURISHMENT

Assessment of Wetland nourishment with active optical cable

This was assessed with actively heated optical cables.





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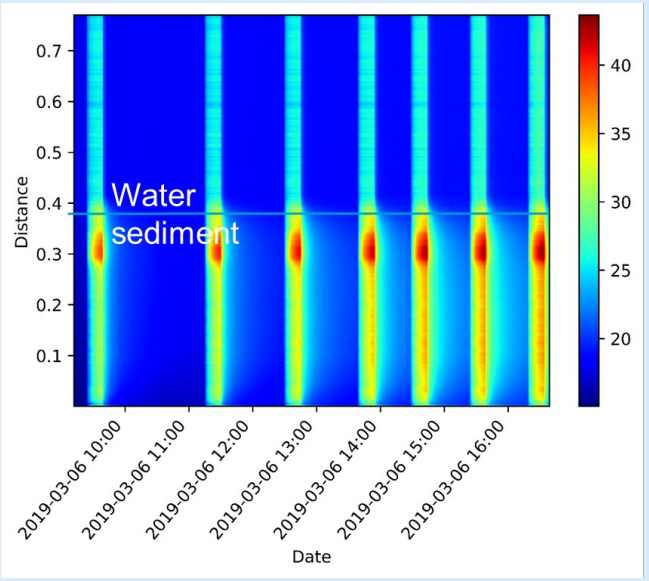
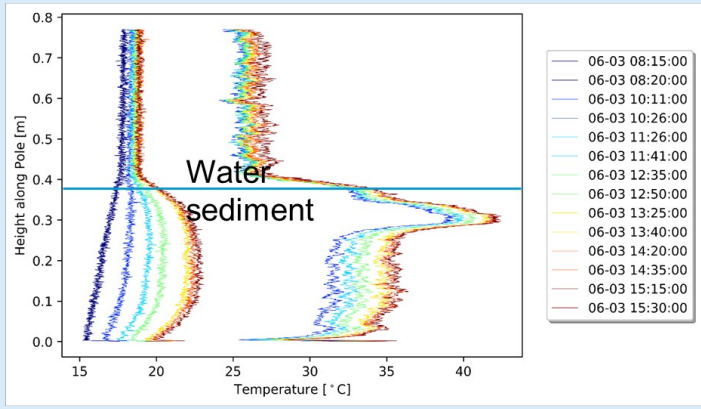
SEDIMENT REALLOCATION - NOURISHMENT

Assessment of Wetland nourishment with active optical cable

The technique works, although the determination of sediment density needs more work.





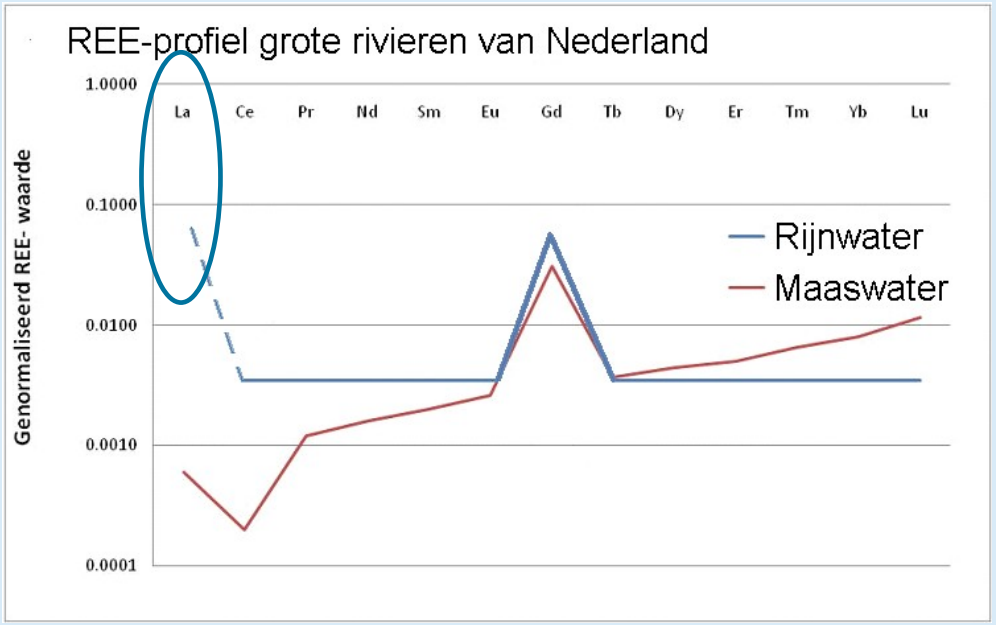
Question 2: Suitability for local impact assessment of sedimentation: *Yes, but need for additional calibration of sediment density.*

SEDIMENT REALLOCATION - BALANCE

Assessment of sediment balance with rare earth elements

Rhine sediment has an enrichment in Lanthanum.

Therefore the reallocated sediment (Rhine source) can be distinguished from marine sediment.



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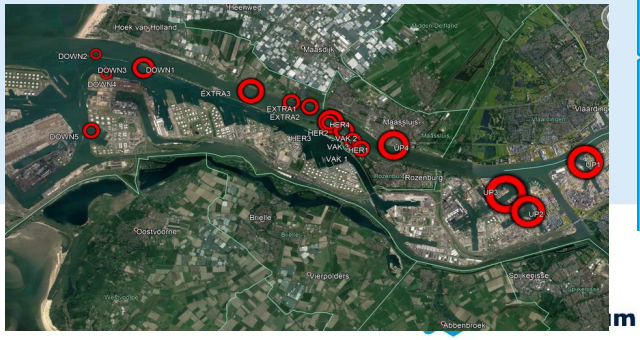
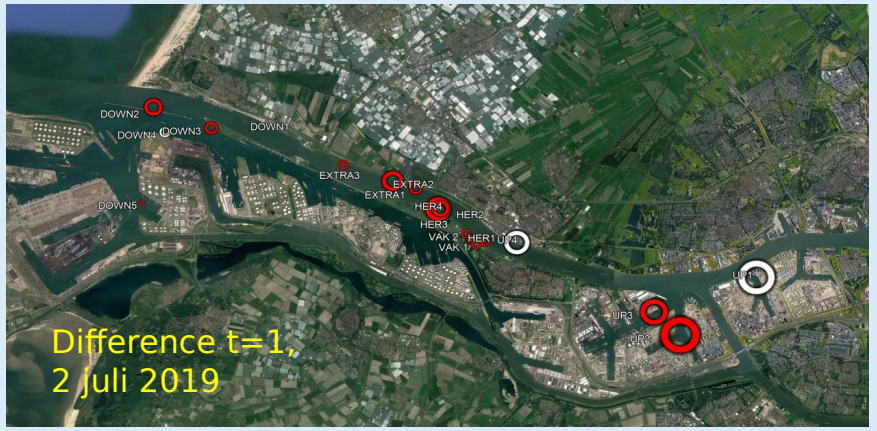
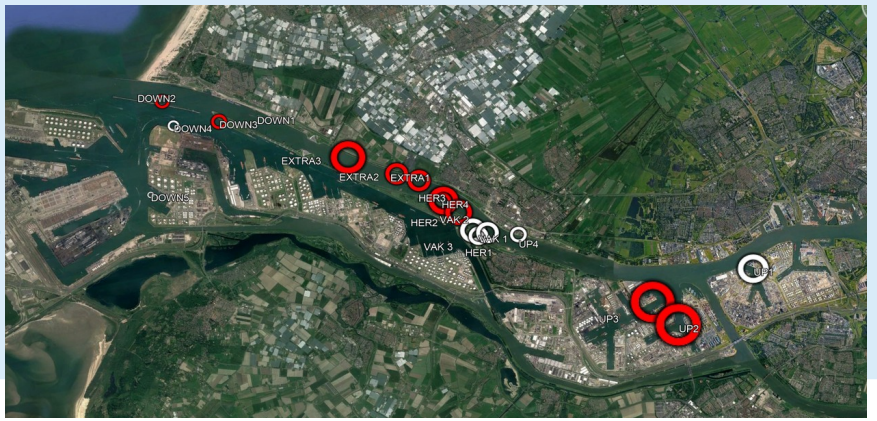
SEDIMENT REALLOCATION - BALANCE

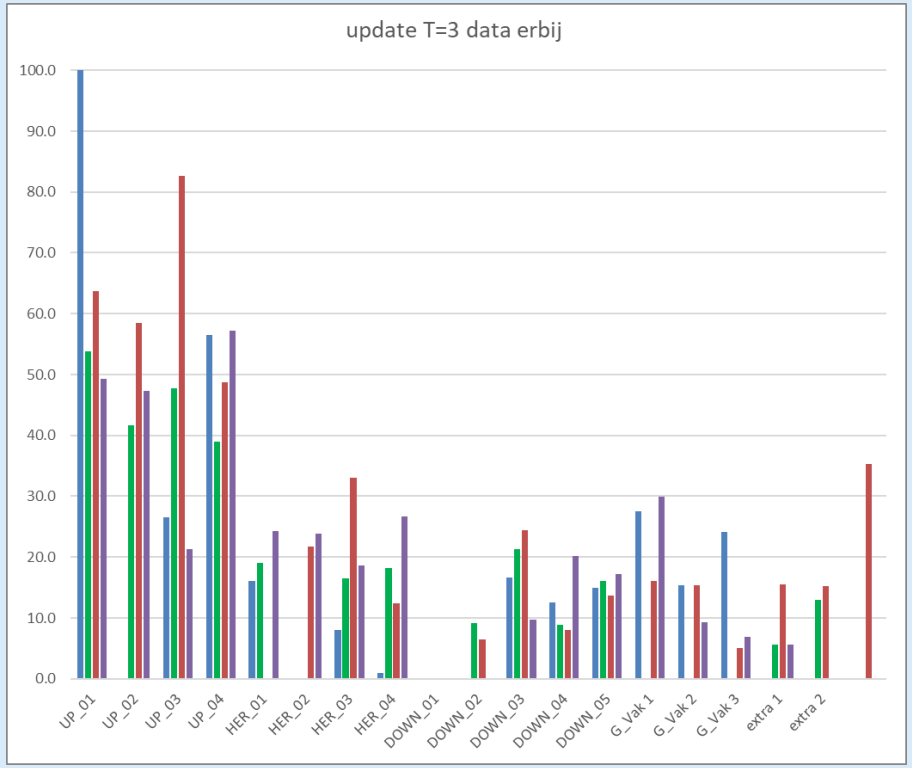
Assessment of sediment balance with rare earth elements







Trends in fluvial sediment contribution



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SEDIMENT REALLOCATION - BALANCE

Assessment of sediment balance with rare earth elements

System sediment balance, main results:

- On average the increase in the Rhine sediment fraction in the studied area due to the reallocation is +0.2%.

In conclusion, there is no significant system impact based on the reallocation of 580.000 m^3 within the harbor.

Question 3: Suitability for impact assessment of the system sedimentation balance: *Rare earth elements are suitable for finger printing sources*

SEDIMENT REALLOCATION – TURBIDITY

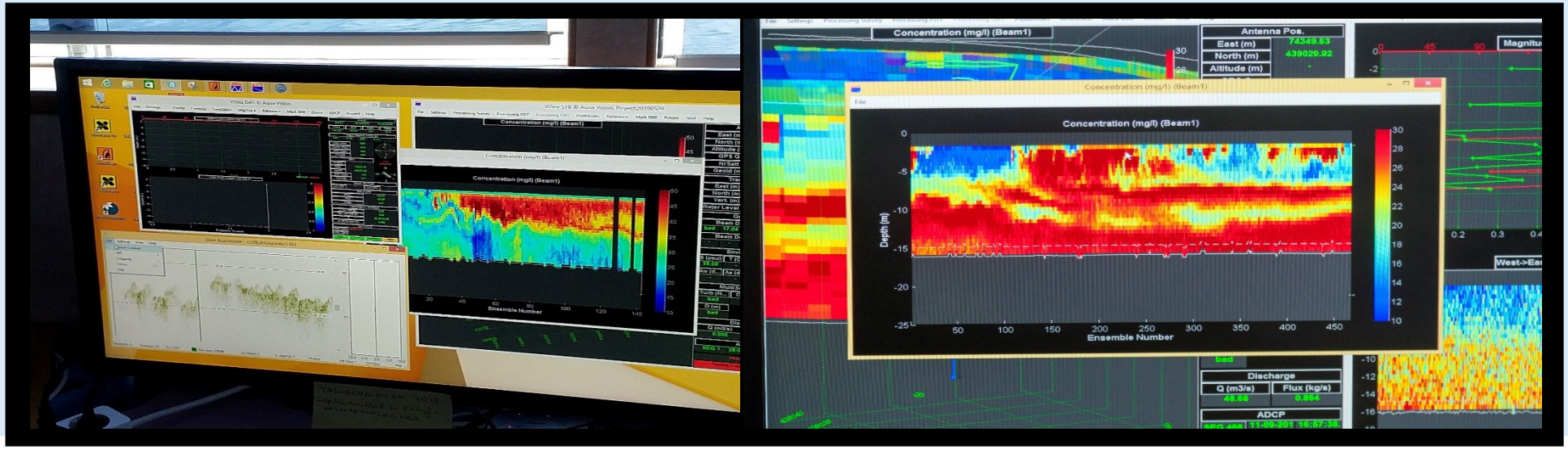
Turbidity during reallocation – on site

The reallocation had a direct impact on the turbidity at the reallocation site.

Depending on the reallocation method, the turbidity increased the most in the top fresh water layer (rainbowing) or in the bottom salt water layer (opening of barge doors).

Reallocation by rainbowing

Reallocation by opening barge doors



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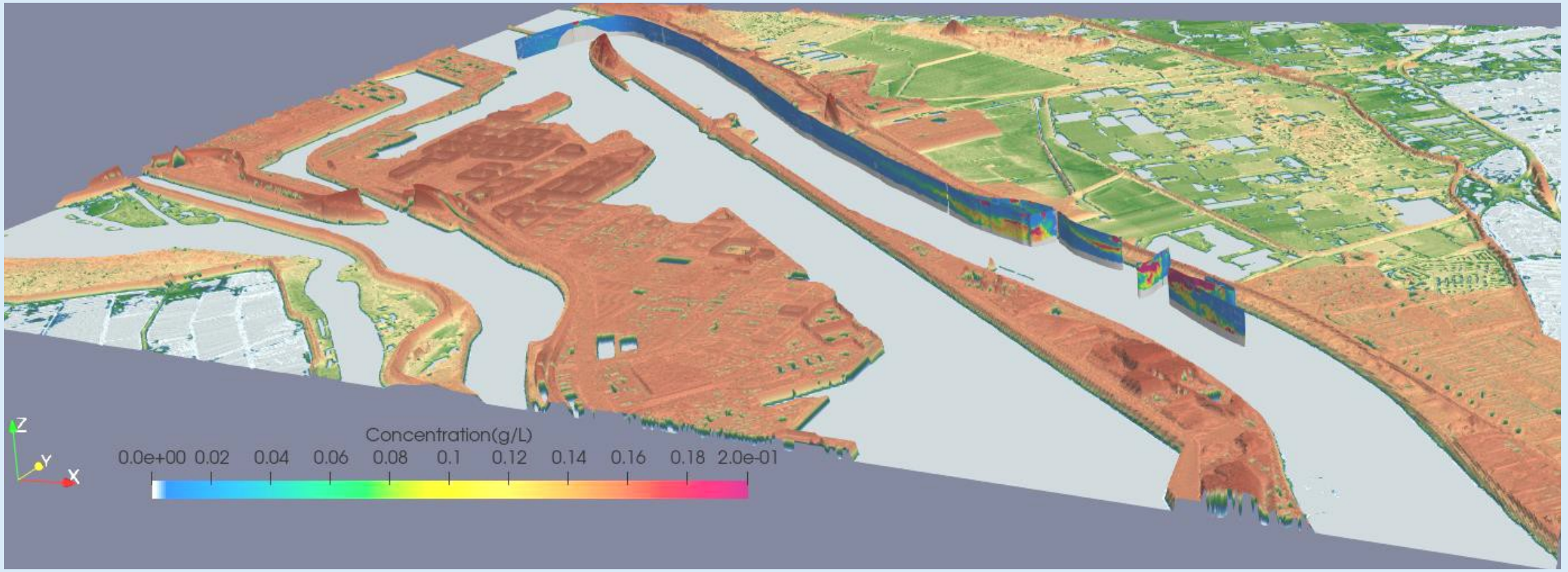
SEDIMENT REALLOCATION– TURBIDITY

Turbidity during reallocation - downstream

ADCP constructed turbidity profiles – following the reallocation flume downstream



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SEDIMENT REALLOCATION– TURBIDITY

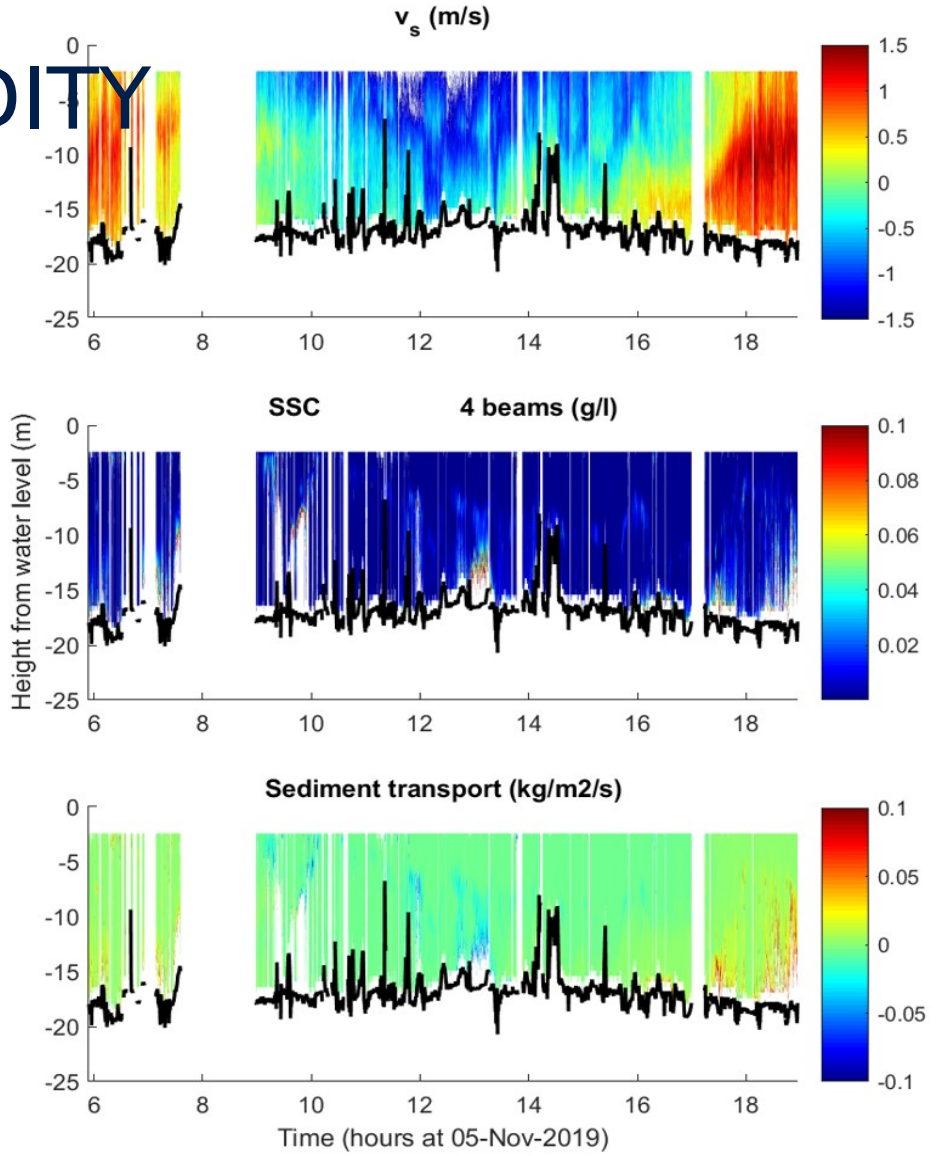
Turbidity during reallocation - downstream

Sediment transport mass balance, 13 hours campaign.

- The flow velocity along the channel (top),
- The suspended sediment concentration (SSC) (middle), and
- The sediment transport per unit width (bottom).

The absolute sediment transport in the profile is highest when the ebb flow velocities are highest.

Question 4: Turbidity. *Sediment transport mostly takes places at the bottom (salt water layer) during outgoing tide. This is in accordance with the reference (T_0) si*



DISCUSSION

We were able to quantify the answers for the four questions on the impact on the systems resilience, but there are still knowledge gaps.

- The **near field** data is based on bathymetry and the optical cable results, given that the reallocation volume is <10% of the total sediment balance in the up and downstream area the observed (lack of) impacts can also be the results of other change in the system behavior.
- The **mid field** evaluation (the dredging flume towards the storm surge barrier) is based on multiple detection techniques (ADCP, OBS and Niskin bottles). But especially the river bottom transport (the 1 m above the river bed) is uncertain.
- The **far field** (40 km of the river) sediment balance with rare earth elements has a margin of error due to the sample size and frequency of sampling.

Overall the results are promising enough to continue the pilot and upscale to a larger reallocation volume.

A SPECIAL THANKS TO THE FIELD TEAMS!