Transport of suspended sediment due to propeller activity

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The problem

- When boats maneuver in shallow water (<20 m), the current created by their propellers may re-suspend sediments
- This is an issue if these sediments are contaminated.
- The re-suspension can contribute to transport of contaminants from a polluted area to a non-polluted area.
- How can the transport of re-suspended sediments be quantified and evaluated?

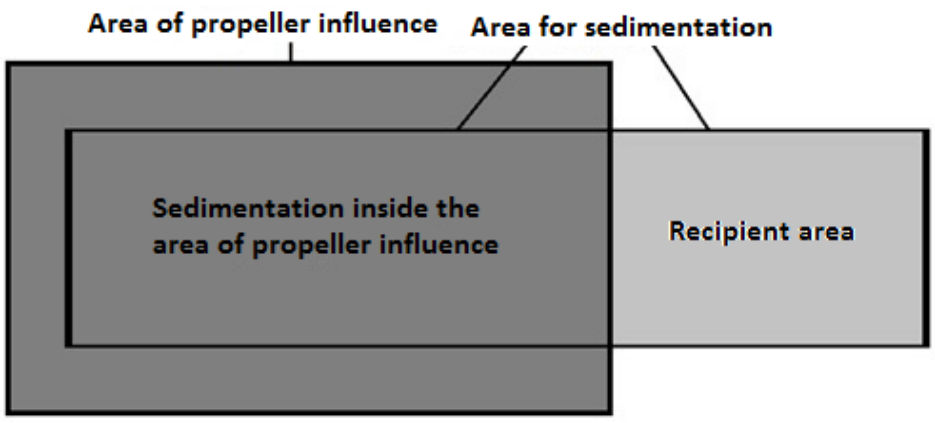
The table solution – Norwegian risk assessment guideline for sediments

Amount of ship induced re-suspension of sediments

- Type of harbor
  - Big harbor (ferries, cruise ships, tugboats,…)
  - Industrial harbor (cargo boat, supply boats,…)
  - Small craft harbor
- Type of sediment
  - Silt and clay
  - Sand
  - Gravel and rock
- Amount re-suspended sediment
  - 1 to 2000 kg per ship maneuver
  - Industrial harbors with silt and clay sediments → 1000 kg per ship maneuver

The measuring solution – Turbidity measurements
The Idea

- In the area of propeller influence, sediments are re-suspended to the water column in a “cloud” or plume
- The plume is influenced by the direction and speed of the current
- Some sediment will deposit in the area of propeller influences and some sediments will be transported out of this area
- The objective is to calculate the amount of sediments transported out of the area of propeller influence

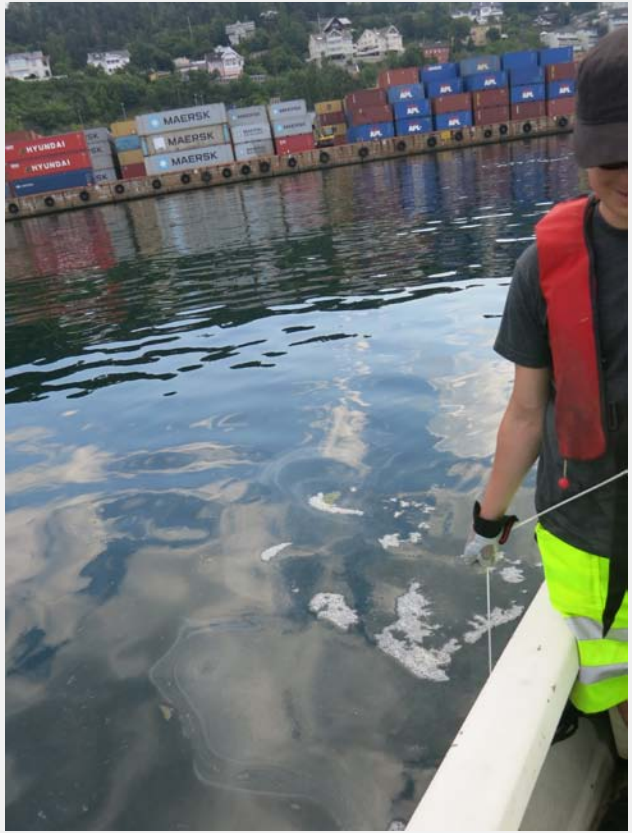


The measuring solution – Turbidity measurements Execution

- Measured turbidity when the sediment was re-suspended
  - The turbidity level
  - The volume of the plume
  - The movement of the plume
- Measured using a CTD with a built-in turbidity meter
- Measured the current direction and velocity in the area

The measuring solution – Turbidity measurements Execution

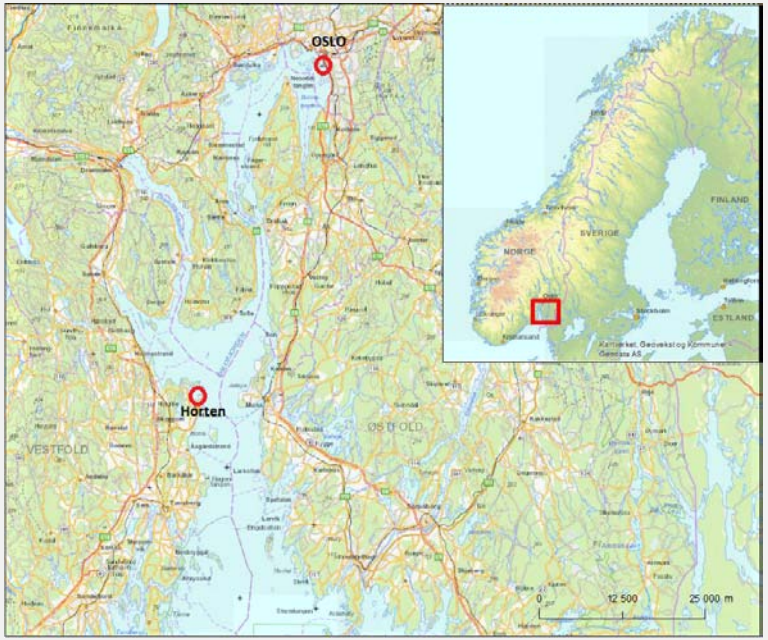
- Measured turbidity in the whole water column at pre-determined locations
  - Stations to define the volume of the plume were measured once, immediately after re-suspension
  - Stations to determine the movement of the plume were measured multiple times



The measuring solution – Turbidity measurements Execution

NGI has used this method at two different harbors in Norway

- Horten Inner harbor
  - Semi-enclosed harbor
  - Fine sediments
  - Shallow, most of the harbor <20 m deep
  - Industrial harbor
- Oslo harbor
  - A limited part of the harbor
  - Some fine sediments have been registered
  - Up to 40-50 m deep
  - Industrial harbor



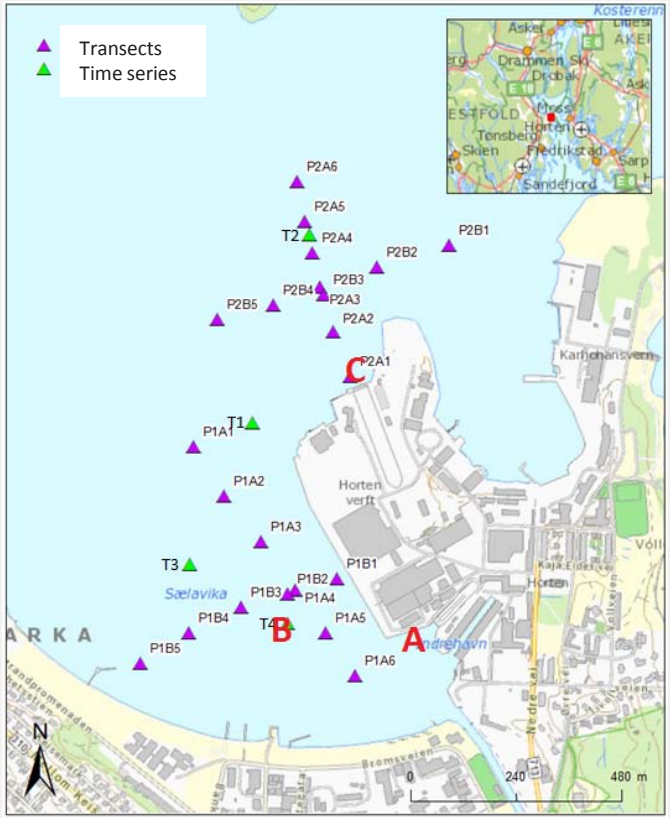
The measuring solution – Turbidity measurements

Horten

- Tugboat simulated re-suspension from a larger ship
- Maneuvered in the locations were boats usually maneuver
- Current direction and velocity was measured at one location

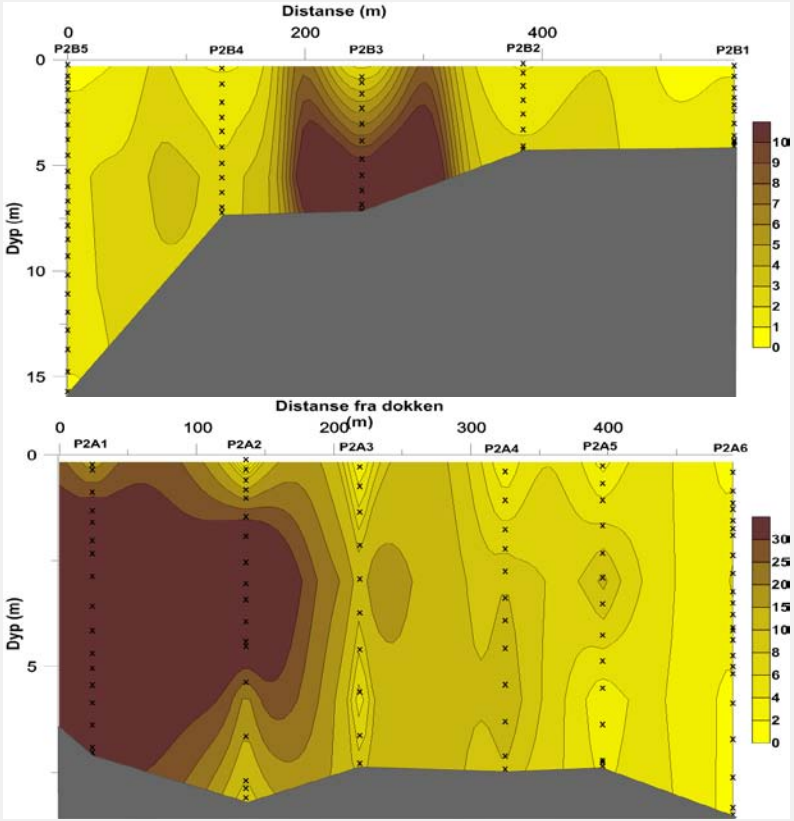
The measuring solution – Turbidity measurements Results Horten

- Turbidity was measured in two areas
  - 4 transects to define the initial plume volume
  - 4 locations with repeated measurements, to determine the movement of the plume
  - 1 location for measuring water current at 9 different depths



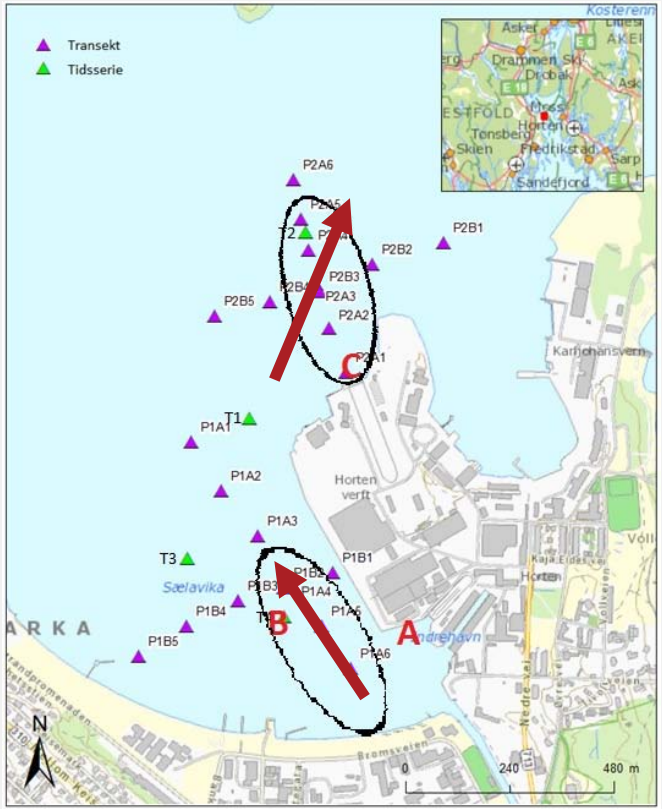
The measuring solution – Turbidity measurements Results Horten

- Transects
  - Re-suspension in location C, when the tugboat simulated departures from the dock
  - There is a very clear turbidity plume, both in vertical and horizontal direction
  - These measurements define the volume of the plume



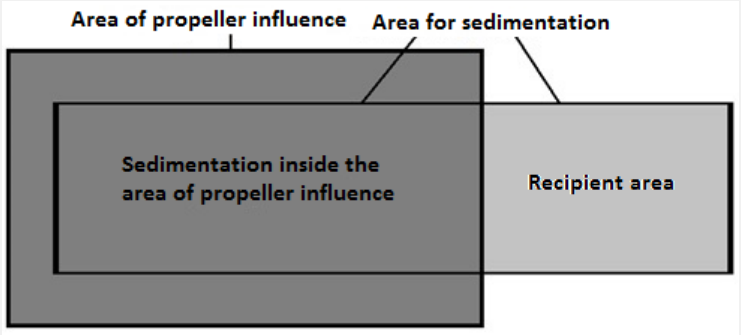
The measuring solution – Turbidity measurements Results Horten

- Turbidity plumes
  - There are registered one turbidity plume in each area
  - The volume, turbidity level and the velocity of the plumes were used to calculate the transport of sediments out of the areas



The measuring solution – Turbidity measurements Calculations Horten

- Original plume
  - 500 meter long, 200 meter wide and 5 meter thick
  - Life time: 1,5 hour
  - Average speed: 6 cm/s
- Plume transported out of the original area:
  - Plume moved 324 meters
  - 100 meter wide and 3 meter thick
  - Volume: 97 200 m^3
  - Average turbidity level: 7 NTU



- Assuming 1 NTU is equal to 1 mg sediment per liter, this give a transport of 680 kg sediment per ship maneuver in this specific area
- There has been made some assumptions during the calculations. These can be sources of inaccuracy.

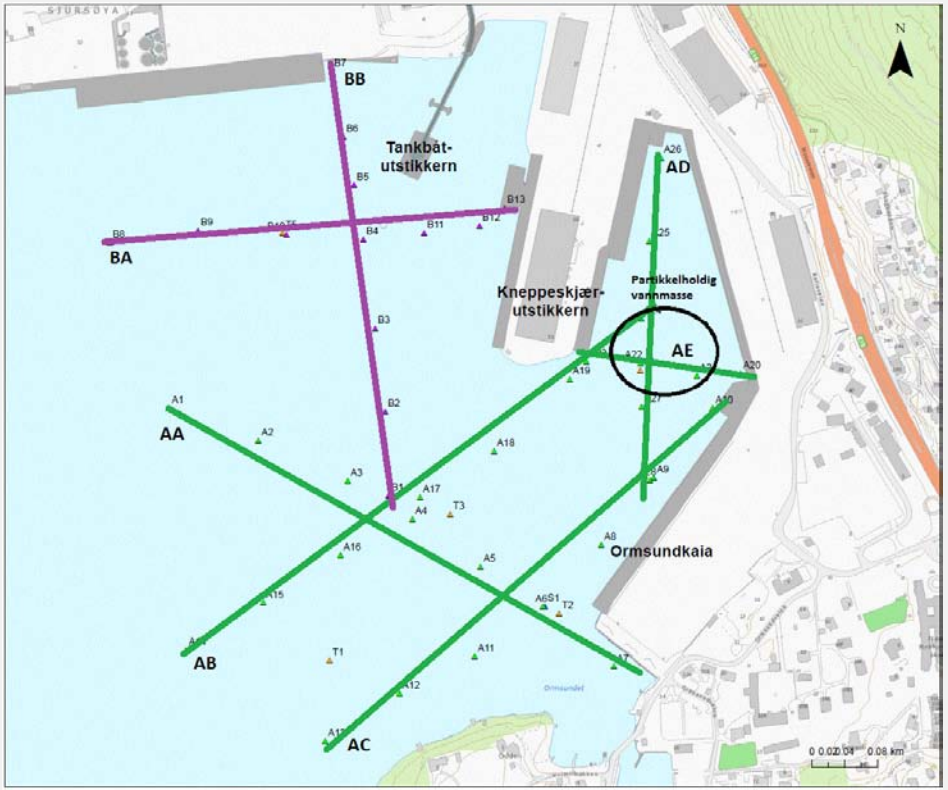
The measuring solution – Turbidity measurements

Oslo

- Heavy trafficked harbor
- NGI measured after the cargo boats had arrived or departed at Sjursøya south quays
- Current direction and velocity was measured at three different locations

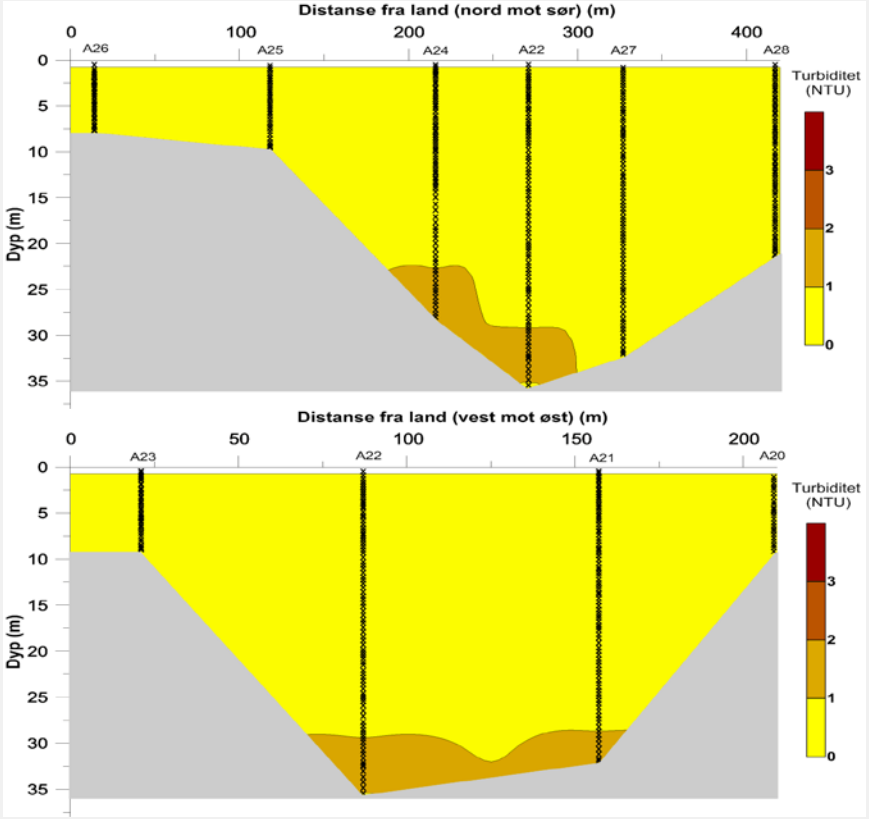
The measuring solution – Turbidity measurements Results Oslo

- Turbidity measured in three areas
  - 7 transects
  - 5 locations with repeated measurements
  - 3 locations for measuring water current direction and velocity



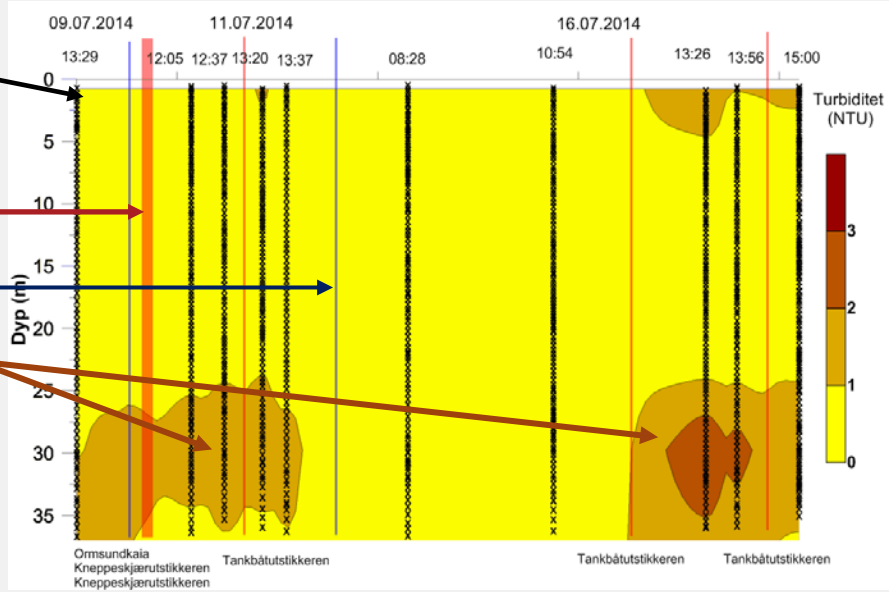
The measuring solution – Turbidity measurements Results Oslo

- Transects
  - Transects to define the initial volume of the plume
  - No clear plume
  - Some elevated level of turbidity in a limited area, at ~ 30 meters depth



The measuring solution – Turbidity measurements Results Oslo

- Repeated measurements
  - Background measurements were made
  - Red line is boat activity
  - Blue line is jump in time
  - Some turbidity registered, but lower level and at a deeper location than expected



The table solution versus the measuring solution

- The risk assessment assumes a transport of 1000 kg sediment out of the area per ship maneuver.
- Calculations for Horten based on in-situ measurements:
  - Area B: 460 kg sediment transported per ship maneuver
  - Area C: 680 kg sediment transported per ship maneuver
- In the three areas in Oslo harbor there are no registered transport of re-suspended sediments related to the boat traffic in the areas we investigated.

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Conclusions

- Risk assessment guidelines are conservative
- Local in-situ measurements provide a more accurate quantification and evaluation of the amount of transported re-suspended sediments
- For Horten it means the accuracy of the areas influences by ship induced re-suspension are better defined, which is used in capping design for the area
- For Oslo it provide documentation that there is very little re-suspension of contaminated sediments in the areas, and this has been reported to the environmental authorities

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