The use of turbidity measurements in Norwegian remediation projects

Is a “conservative” turbidity limit the most environment-friendly approach?

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- **Turbidity measurements**
  - Transport of particles – turbidity, time, and current
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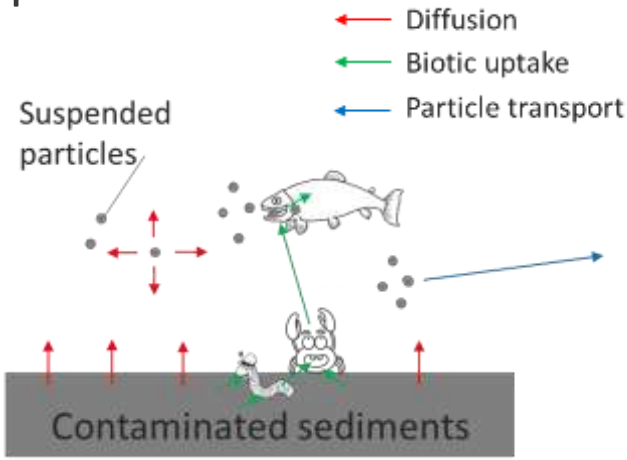
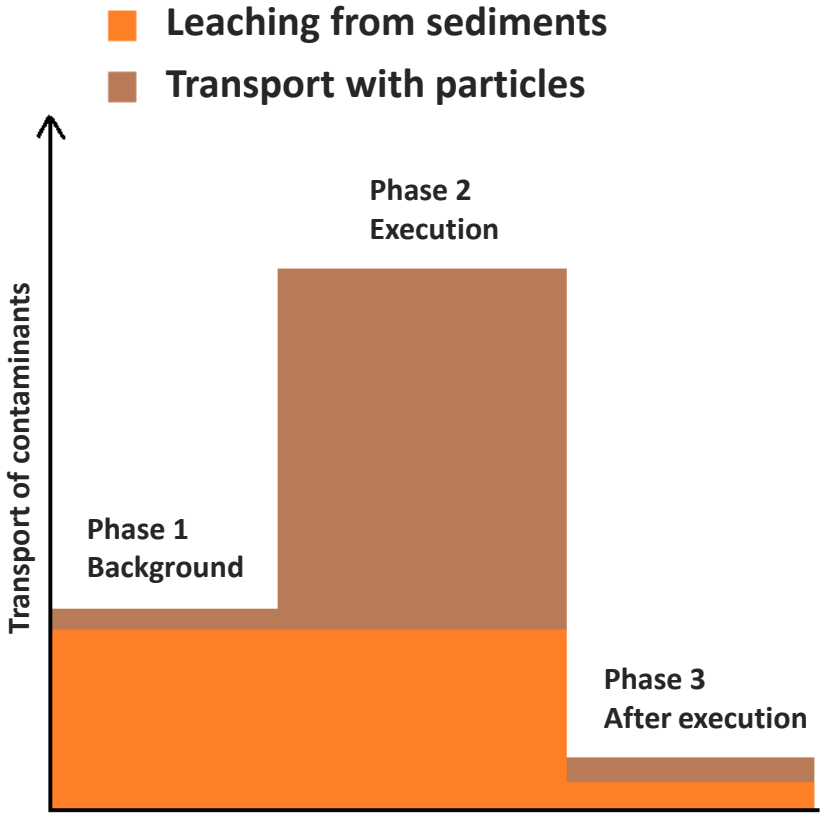
  - Effect of measure vs. increased transport during execution phase
  - Aspects affecting turbidity monitoring and transport of polluted particles
- **Discussion and conclusion**

Introduction – transport of contaminants and particles

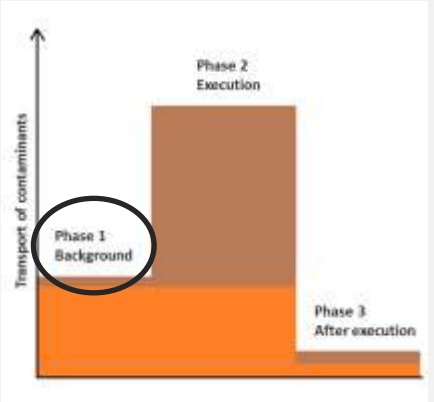
- Increased amount of suspended particles when working with sediments
- Turbidity – estimate amount of particles

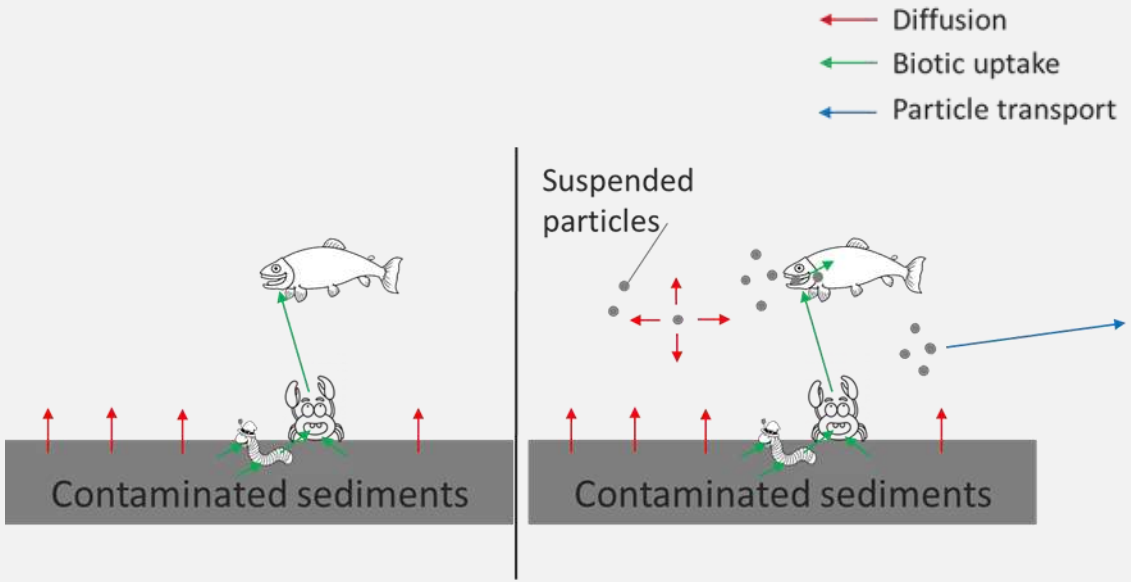




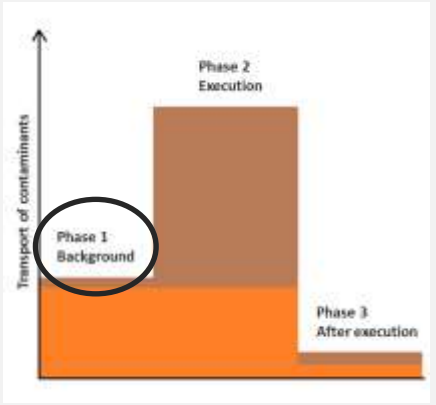
Introduction – transport of contaminants and particles

- Transport of contaminants from the sea floor
  - Diffusion from sediments to water and biota
  - (Transport with particles)

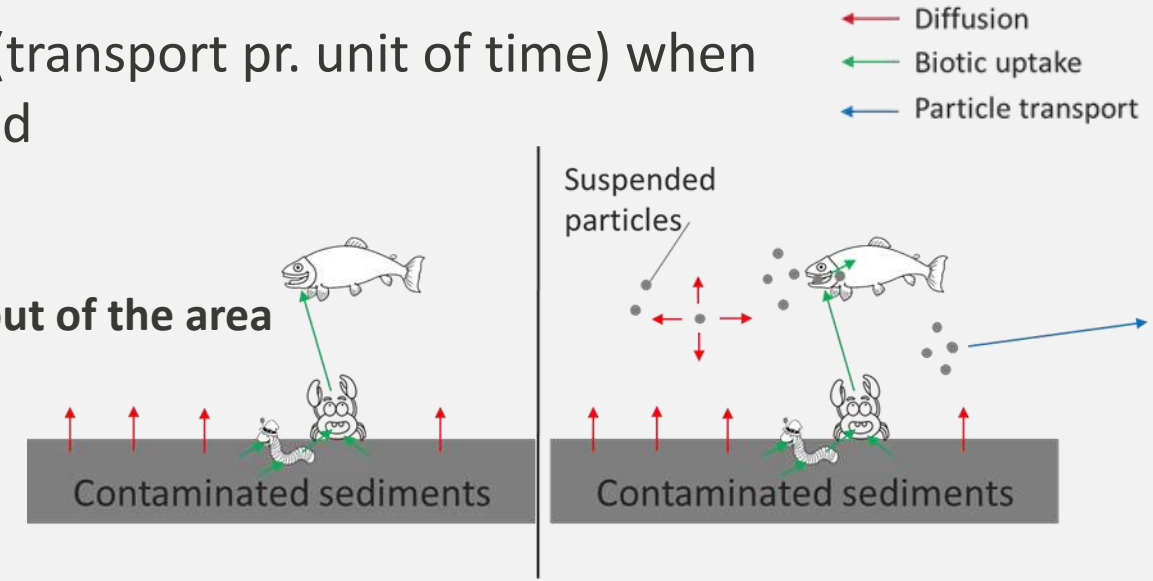




Introduction – transport of contaminants and particles

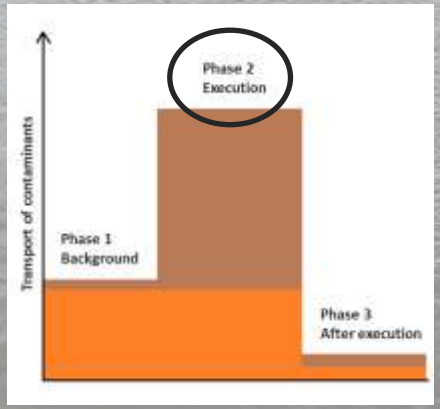


- Transport of contaminants from the sea floor
  - Diffusion from sediments to water and biota
  - (Transport with particles)
- Higher transport-rate (transport pr. unit of time) when particles are suspended
  - Larger surface area
  - Increased biotic uptake
  - **Transport with particles out of the area**



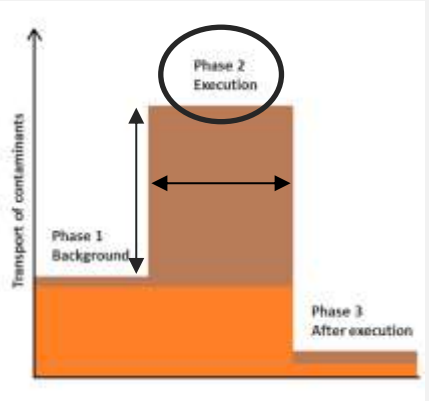
Turbidity monitoring

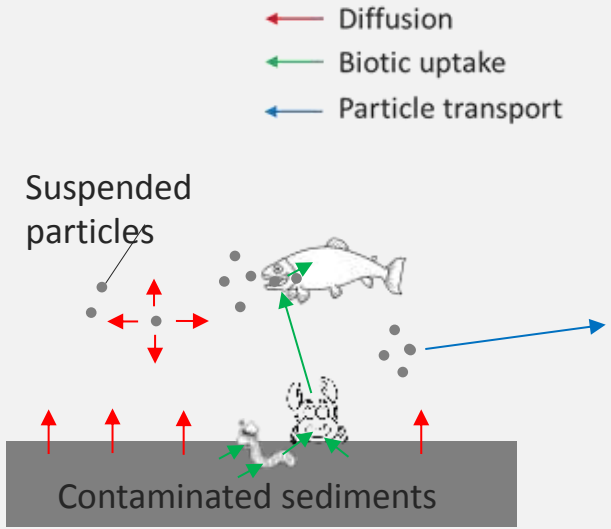
- Estimate amount of suspended particles
- Can be used to quantify the amount of suspended particles in a project area
- Limits of turbidity have been set in different projects in Norway. These limits are defined with a time interval and a turbidity level (e.g. 10 NTU over background in 20 min)
- The limit can be related to the possible harmful effect of an elevated particle concentration, **or one wants to limit the transport of pollutants**.



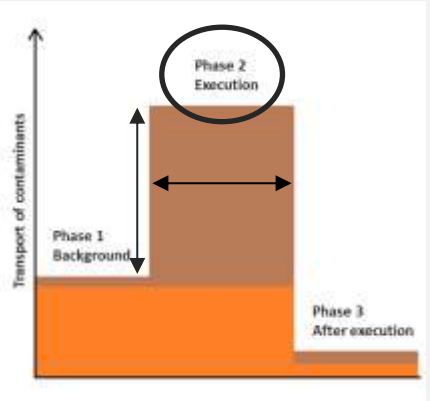
Transport of contaminated particles from measures in water bodies

- Factors affecting total particle transport:
  - Turbidity ↕
  - Current ↕
  - Time (phase 2) ↔
- Low turbidity may contribute to a low transport rate, but may be time consuming due to the need for many stops and careful work

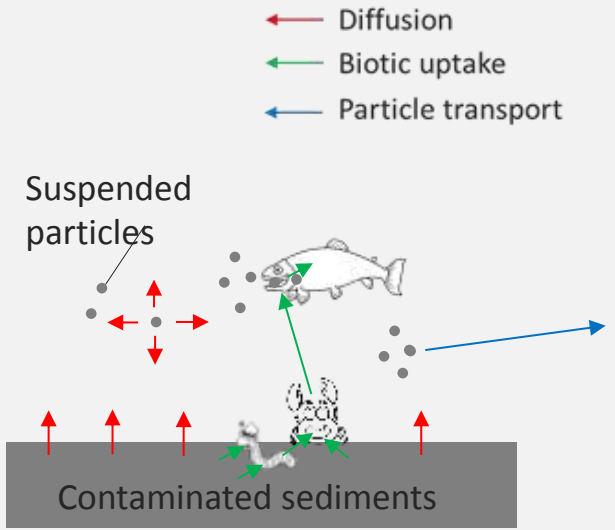




Transport of contaminated particles from measures in water bodies



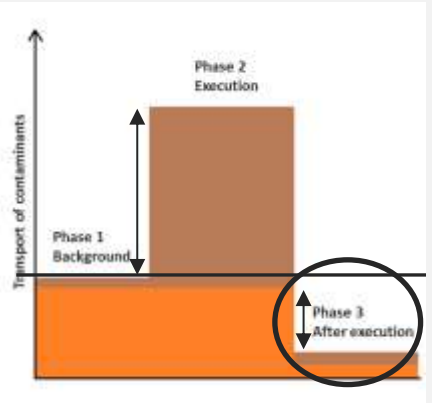
- A low water flow out of the area contributes to a low rate of transport (contaminant transport per unit of time)
- A high water flow out of the area will facilitate a high particle transport out of the area
  - → Measured turbidity would be low, even with high resuspension of sediments
  - → Low turbidity, but a high rate of transport

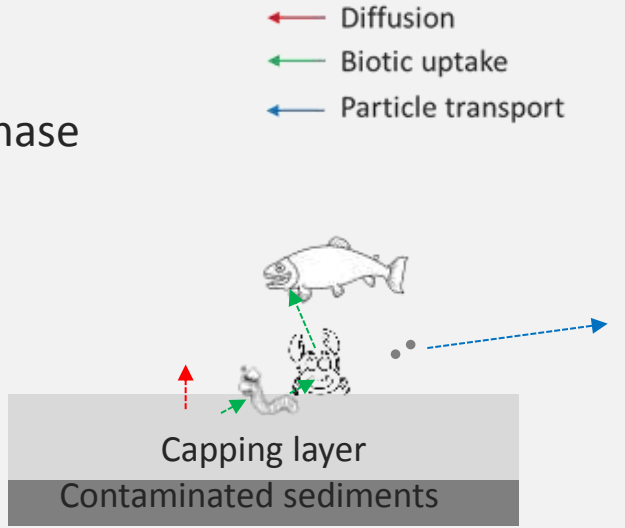


Effect of measure vs. increased transport

- Measures in a highly polluted area are expected to largely reduce the transport of contaminants

- After execution of a measure which gives a large effect, an extensive amount of contaminants will be avoided in a short period of time → If a measure in a project had infinitely large effect, the positive effect on contaminant transport would occur immediately after the execution phase → The transport rate would be of limited importance compared to the importance of the time of completion

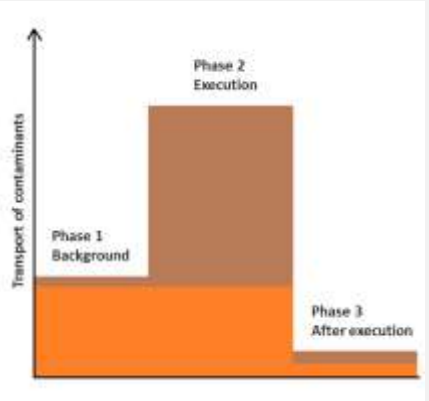


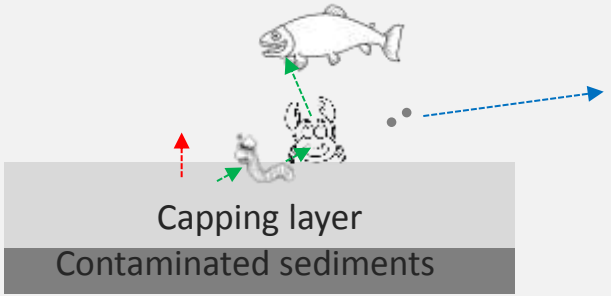


Transport of contaminants and particles

- Transport rate of contaminants with particles are a result of turbidity, current conditions, and sediment contaminant concentrations
- Total amount of contaminant transport during phase 2 is a result of the transport rate and time

Should factors other than the turbidity be included in turbidity limits?





Examples from Norwegian remediation projects

Stamsund harbor

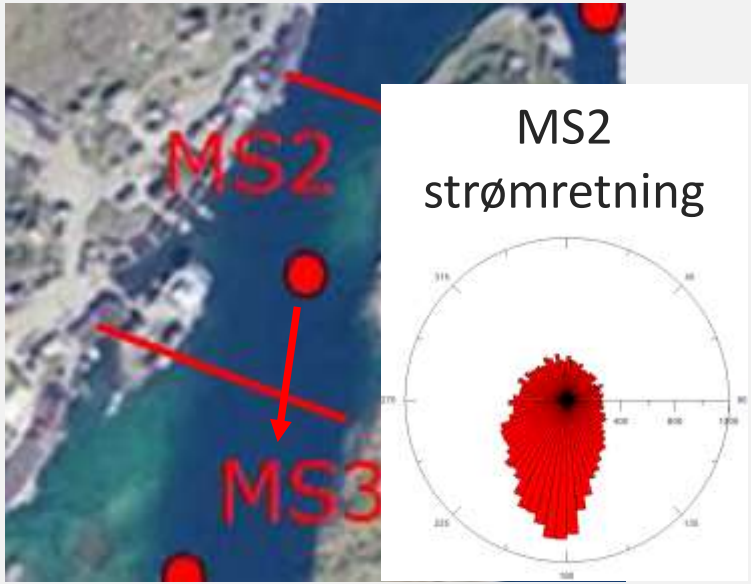
- Dredging
- Sea deposit with capping
- Turbidity measurements

Trondheim harbor

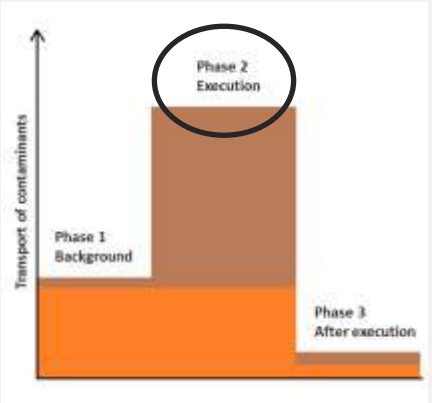
- Dredging
- Capping under two different turbidity limits
- Turbidity measurements

Particle transport

Stamsund harbor



- Flow measurements shows a net water flow inn southern direction (1,1 cm/s)
- Net water transport of 27 mill m^3/month
- Calculated the average monthly particle transport using turbidity and water flow

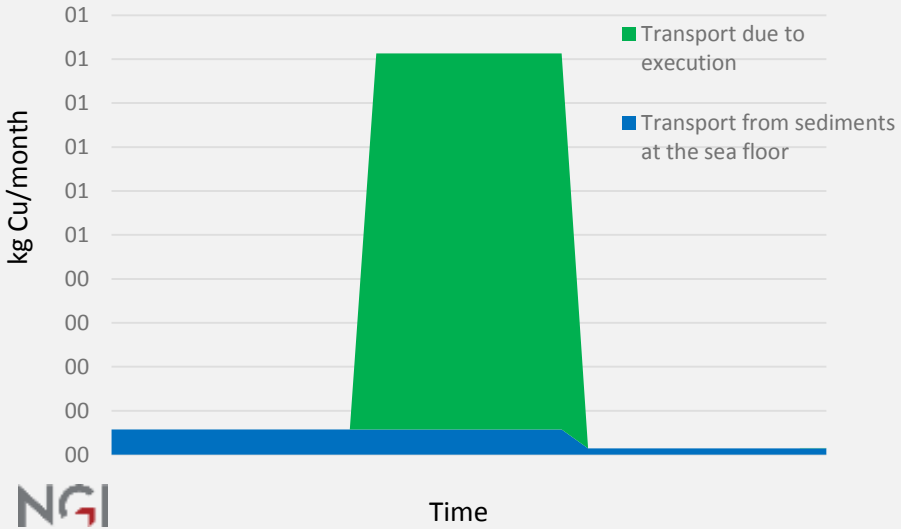


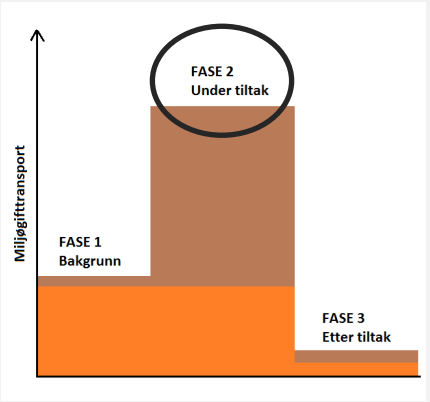
- Extra transport of copper (Cu) during execution phase (phase 2):

Sediment conc. x turb. x water transport
= Extra transport of copper (Cu) during phase 2

Particle transport

Stamsund harbor





Effects the duration of phase 2?

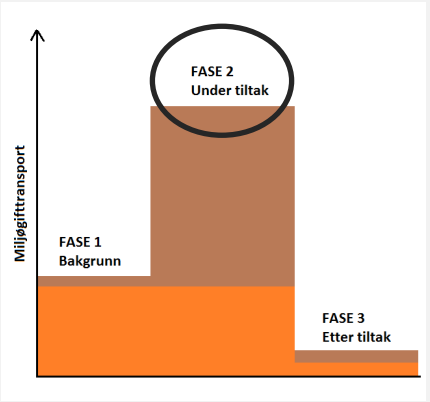
Turbidity limit

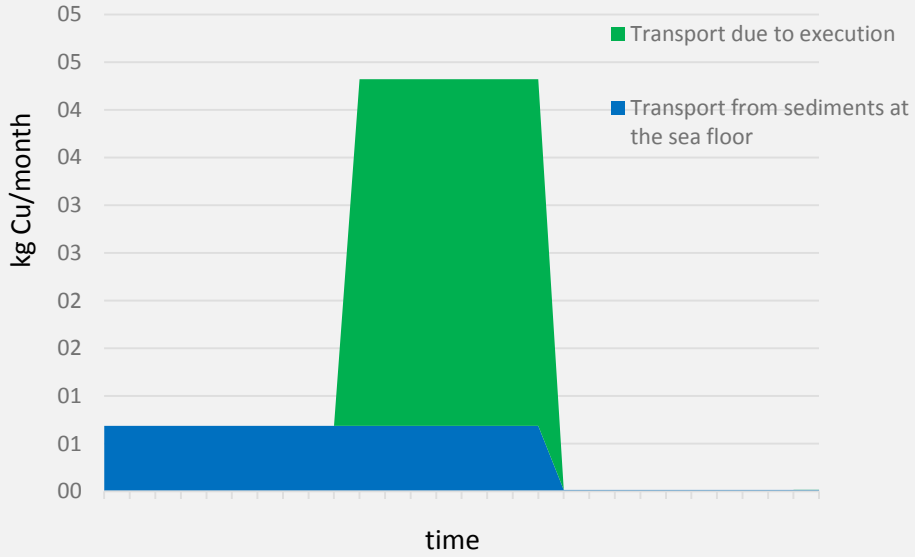
Current conditions

Sediment conc. x turb. x water transport
= Extra transport of copper (Cu) during phase 2

Turbidity limits and duration of phase 2

Trondheim harbor





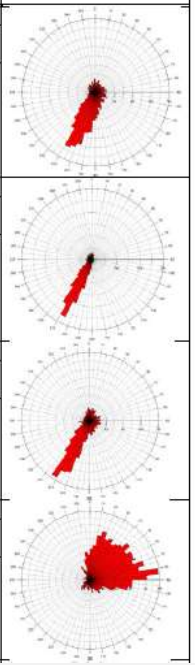
- After 1. capping layer was finished, the turbidity limit was increased (From 10 NTU over background for 20 min, to 20 NTU over background for 4 h)
- Worked 20 % more efficient with the high turbidity limit

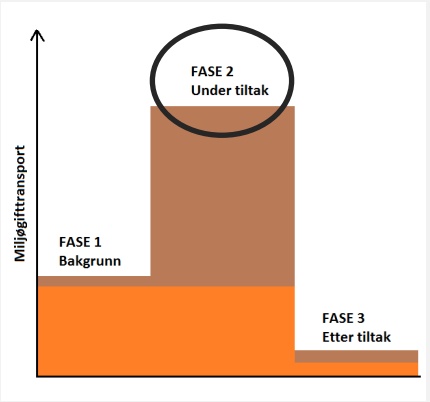
Turbidity limit affects the efficiency, and hence the duration of phase 2

Water flow

Trondheim harbor

Brattorbassenget Brattorløpet	Beskrivelse	Inn i bassenget	Ut av bassenget	Rosegraf
1 m	% tid	33 %	67 %	
	Gjennomsnitts-hastighet	11,3cm/s	13,4 cm/s	
	Mengde vann i døgnet	290 000 m³	700 000 m³	
2,8 m	% tid	22 %	78 %	
	Gjennomsnitts-hastighet	18,8 cm/s	18,8 cm/s	
	Mengde vann i døgnet	330 000 m³	1 100 000 m³	
4,6 m	% tid	36 %	64 %	
	Gjennomsnitts-hastighet	6,8 cm/s	12,9 cm/s	
	Mengde vann i døgnet	190 000 m³	640 000 m³	
6,4 m	% tid	83 %	17 %	
	Gjennomsnitts-hastighet	5,5 cm/s	4,1 cm/s	
	Mengde vann i døgnet	340 000 m³	67 000 m³	





- Water flow (intensity and direction) varies depending on depth and time of day

↓

Water transport varies - both between areas, and over time in the same area

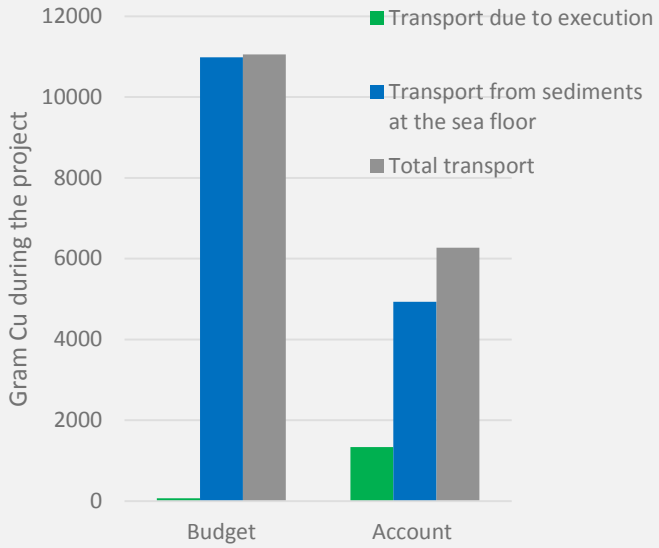
↓

Large variations in particle transport at a given turbidity level

Effect of time

Trondheim harbor

- The environmental account shows a higher transport due to execution, but a lower total contaminant transport, because the measure was finished earlier



Spredningsvei	Cu
Spredning før tiltak beregnet fra forurenset sjøbunn (g/år)	8235
Miljøbudsjett (NGI, 2013)	
Spredning fra mudring (g)	49
Spredning fra tildekking (g)	23
Spredning under tiltak fra sedimenter (g)	10980
Budsjettert total spredning under tiltak (g)	11052
Budsjettert spredning etter tiltak fra forurenset sjøbunn gjennom tildekkingslaget via diffusjon (g/år)	79
Miljøregnskap	
Spredning fra mudring (g)	1333
Spredning ved tildekking (1. tildekkingslag)	0
Bakgrunnsspredning fra utildekket sjøbunn i anleggsperioden (g)	4804
Spredning fra ferdig tildekket sjøbunn i anleggsperioden (g)	130
Total spredning fra fysiske tiltak (g)	1333
Total spredning fra tiltak og sjøbunn under tiltak (g)	6266
Beregnet spredning fra ny sjøbunn etter tiltak (stedsspesifikk Kd fra før tiltak)	173

Summary and discussion

- Total transport of particles from an area is highly affected by the water current
- Water current conditions in an area varies over time (tide, rainfall, etc.)
- Total contaminant transport with particles is a result of turbidity, concentrations in suspended particles, current conditions, and time
- The turbidity limits affected work efficiency in Trondheim harbor

Summary and discussion

- Considering both environmental and cost –consequences, it does not seem like it is suitable to use one turbidity limit which applies for all Norwegian measures in water bodies
- Local conditions, including current conditions and sediment quality should be included in turbidity monitoring, and turbidity limits in future remediation projects

Thank you for your attention!

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