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Pearson, Stuart; van Prooijen, Bram; Poleykett, Jack; Wright, Matthew; Black, Kevin; Wang, Zhengbing

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Monitoring sediment transport patterns on an energetic ebb-tidal delta using dual-signature tracers

Stuart G. Pearson[1,2], Bram van Prooijen[1], Jack Poleykett[3], Matthew Wright[3], Kevin Black[3], Zheng Bing Wang[2,1]

[1]Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, Netherlands. [2]Department of Applied Morphodynamics, Unit of Marine and Coastal Systems, Deltares, Delft, Netherlands. [3]Partrac Ltd., Newcastle-Upon-Tyne, United Kingdom

1. Motivation

Dutch Wadden Islands

Flood safety and vital ecosystems in the northern Netherlands depend on the fate of the Wadden Islands. Their morphodynamic response to sea level rise and sand nourishments is closely tied to the evolution of the ebb-tidal deltas between them.

Sediment Pathways

To understand the fate of these ebb-tidal deltas, we must quantify the behaviour and transport patterns of sediment as it moves across them.

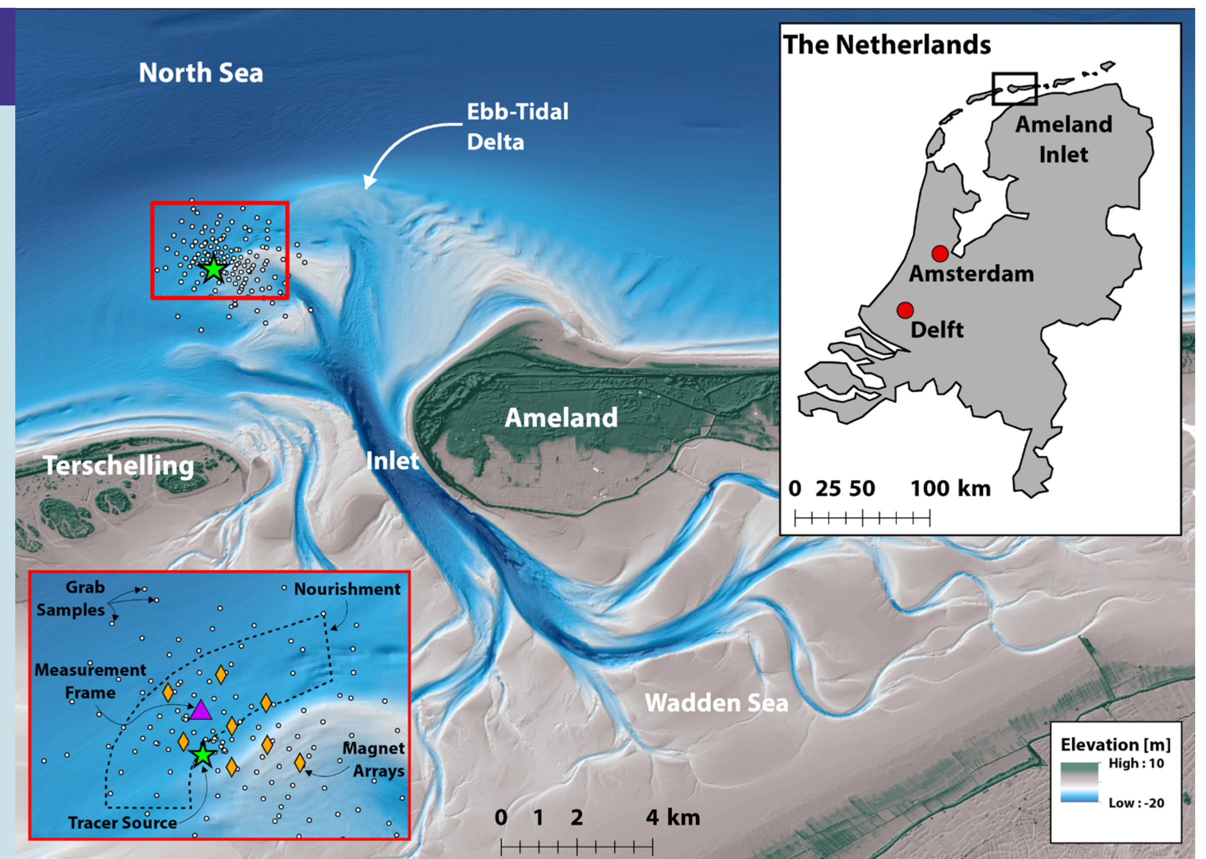

Figure 1. Location of project site at Ameland Inlet, the Netherlands.

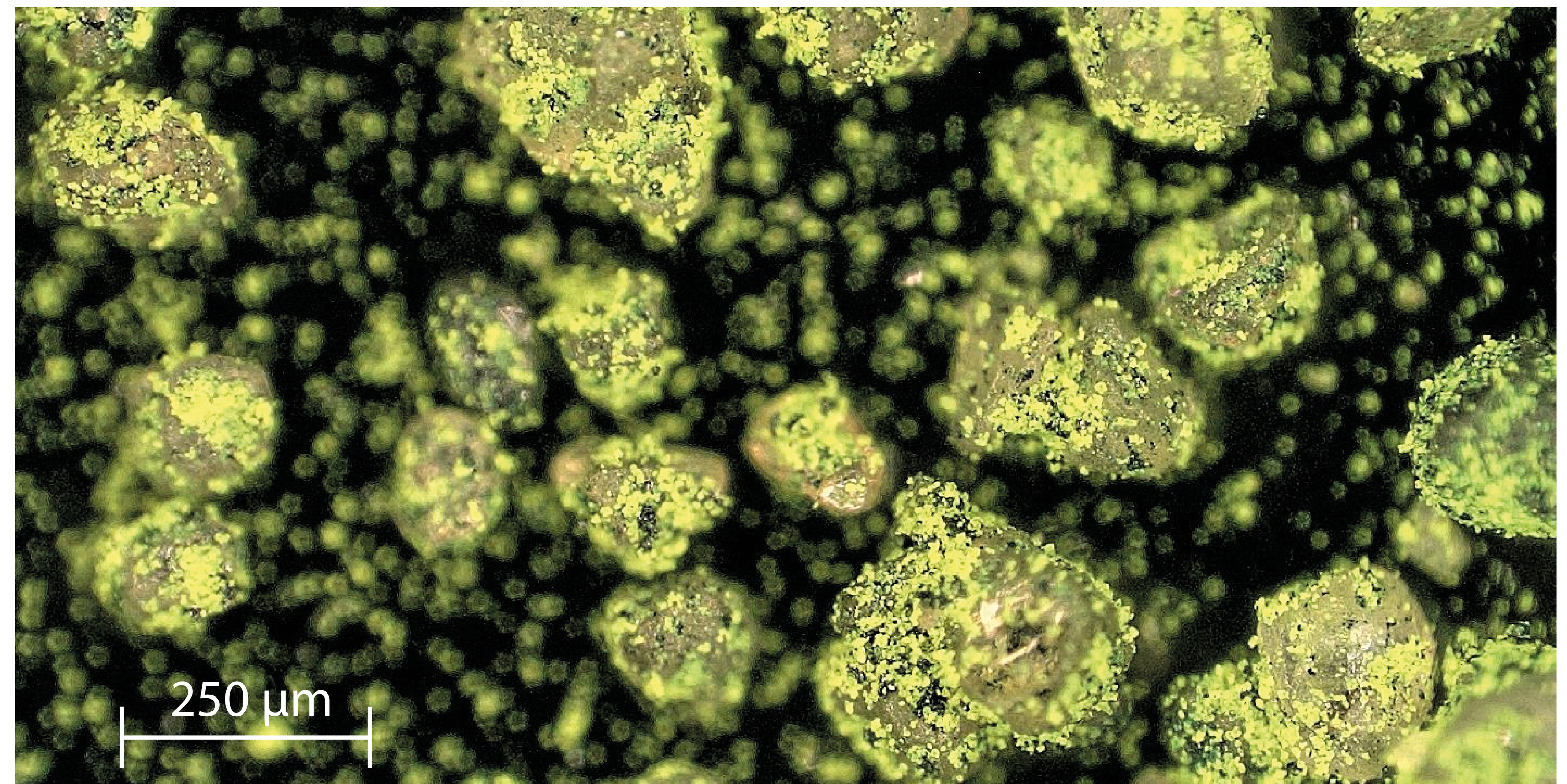

Figure 3. Tracer sediment particles with fluorescent and ferrimagnetic coating (x100 magnification).

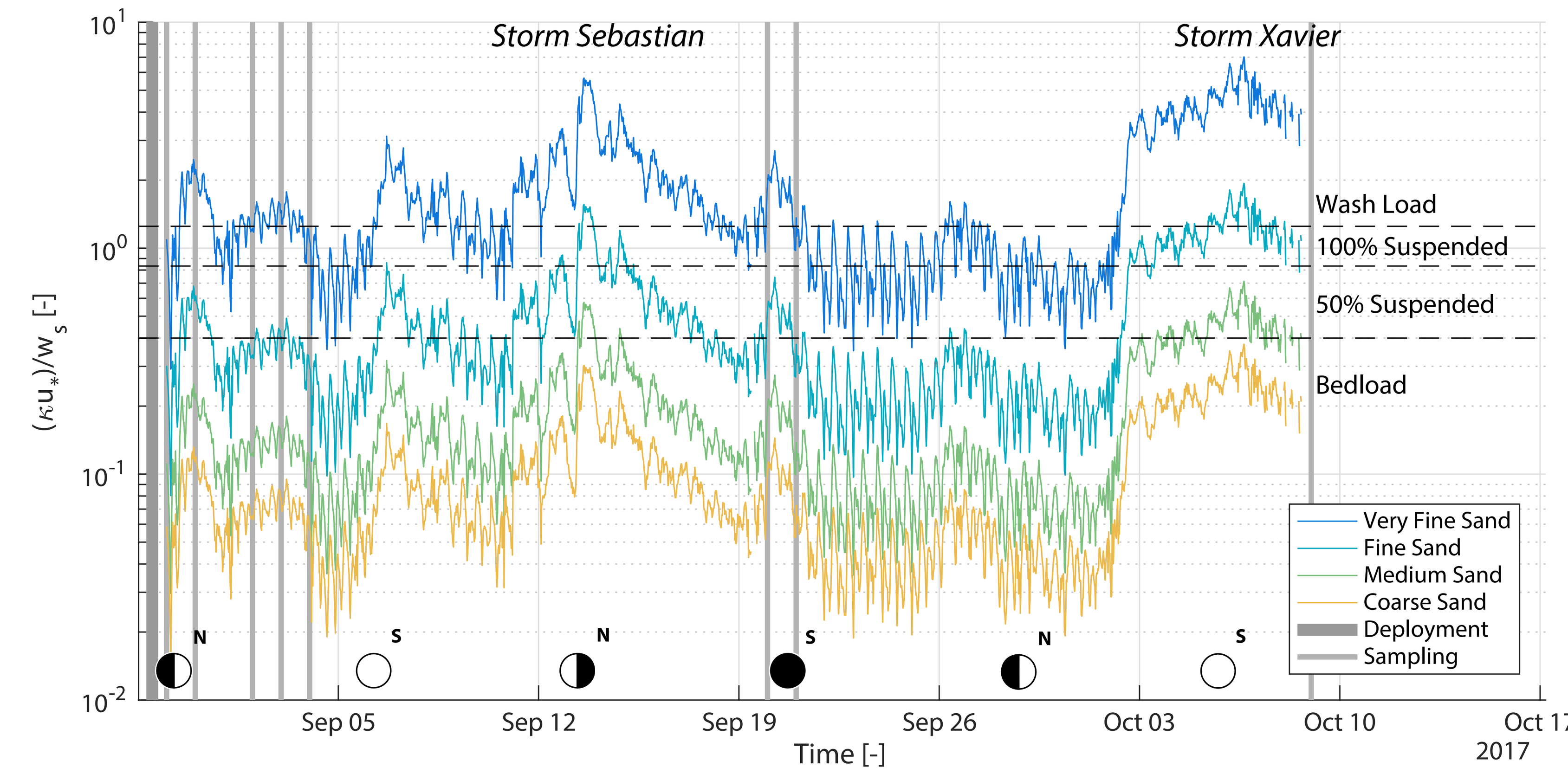

Figure 5. Inverse Rouse number ($\kappa u_*/w_s$) and transport mode for each sediment class. Calculated using the method of Soulsby (1997) from wave and near-bed velocity measurements taken near the tracer source.

2. Methodology

Tracer Preparation

Dual signature (fluorescent and ferrimagnetic) sediment tracer was developed by Partrac Ltd. for use in this study. The tracer's physical characteristics (**d_{50} = 285 µm, ρ_s = 2628 kg/m^3**) closely matched those of the native sediment to ensure that it was eroded, transported and deposited in a similar manner.

Deployment & Monitoring

In September 2017, 2000 kg of tracer was deployed at slack tide on the seabed at Ameland ebb-tidal delta in the Netherlands. Simultaneous measurements of hydrodynamics and suspended sediment were made near the tracer source. Over the next 41 days, the tracer's dispersal was monitored via the collection of seabed grab samples. In addition, high-field magnets mounted on mooring lines 1, 2, and 5 m above the seabed around the source were used to sample suspended tracer particles.

Laboratory Analysis

Tracer particles were magnetically separated from the background sediment and counted under UV lights. Samples containing visible tracer particles were then further analyzed using a Keyence VHX-5000 digital microscope. Particle size analysis of the separated tracer was performed using the microscope's built-in image processing software.

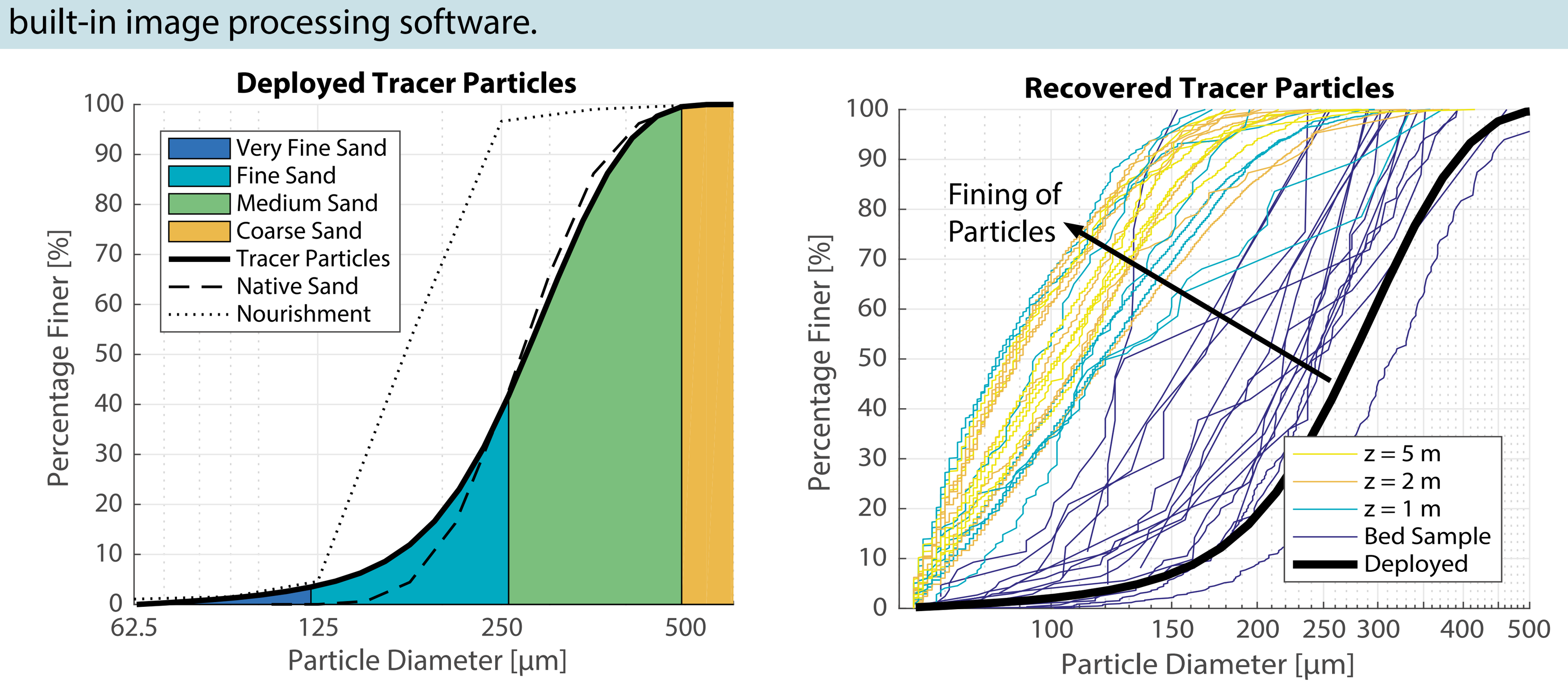

Figure 2. (a) Particle size distribution of deployed tracer sediment, native seabed sediment, and sediment from the recent nourishment. (b) PSD of tracer recovered from the seabed and suspended magnets at z=1, 2, 5 m.

3. Preliminary Results

Tracer Recovery

Tracer particles were recovered from over 60 of approximately 200 samples, despite the occurrence of conditions likely to mobilize 99% of the deployed particles. Although hydrodynamic measurements suggest an eastward tidal residual flow, the spatial pattern of the recovered tracer indicates that transport is highly dispersive, likely due to wave action.

Grain Size Distribution

Among samples collected in the first 4 days after deployment, there is a general trend of fining and improved sorting behaviour with increasing distance from the source. Samples recovered from the suspended magnets show an upward fining trend in grain size through the water column.

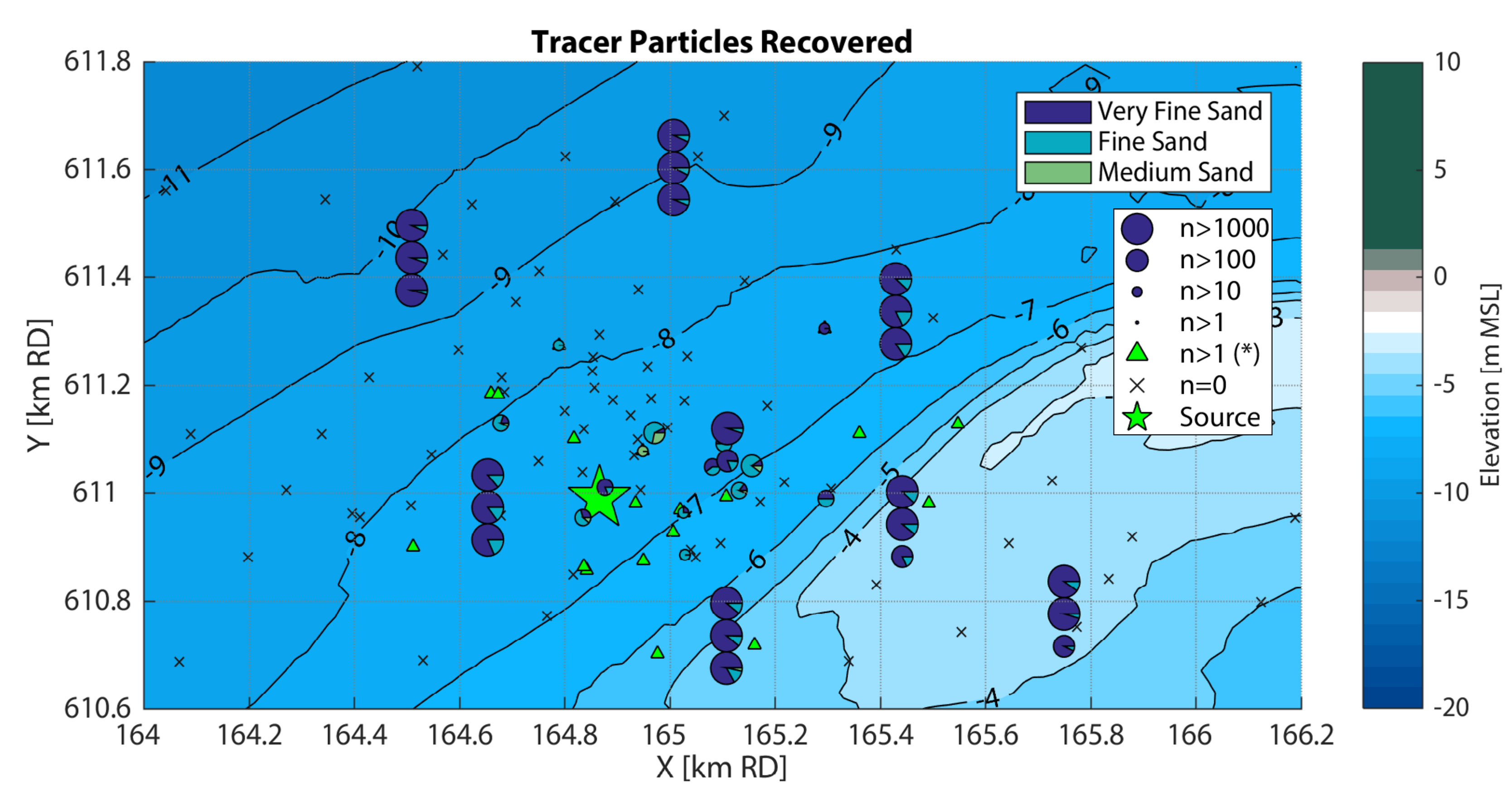

Figure 4. Spatial distribution of tracer recovered in the first 4 days after deployment with pie charts indicating the relative fraction of a particular sediment class. The green triangles marked "n>1 (*)" denote samples with visible tracer particles whose particle size distribution has not yet been measured.

4. Conclusions & Next Steps

Conclusions

- **Large quantities of tracer were recovered** in a highly dynamic environment
- Magnetic character of tracers makes them **easier to recover** in the field and process in the laboratory
- Tracer approach enables **tracking of differential transport** (per grain size) from a specific location
- Sediment transport on the ebb-tidal delta is **highly dispersive**
- Tracer becomes both **finer and better-sorted** further from the source and higher in the water column
- This can be explained by the **preferential suspension** of finer sediment classes (Figure 5)
- Behaviour of tracer suggests that **nourishment sand** will also be highly dispersive

Next Steps

- Compare grain size of tracer with other particles retrieved via grab sample and magnet
- Comparison of suspended grain sizes from magnets with nearby LISST measurements
- Numerical particle tracking model calibration and validation

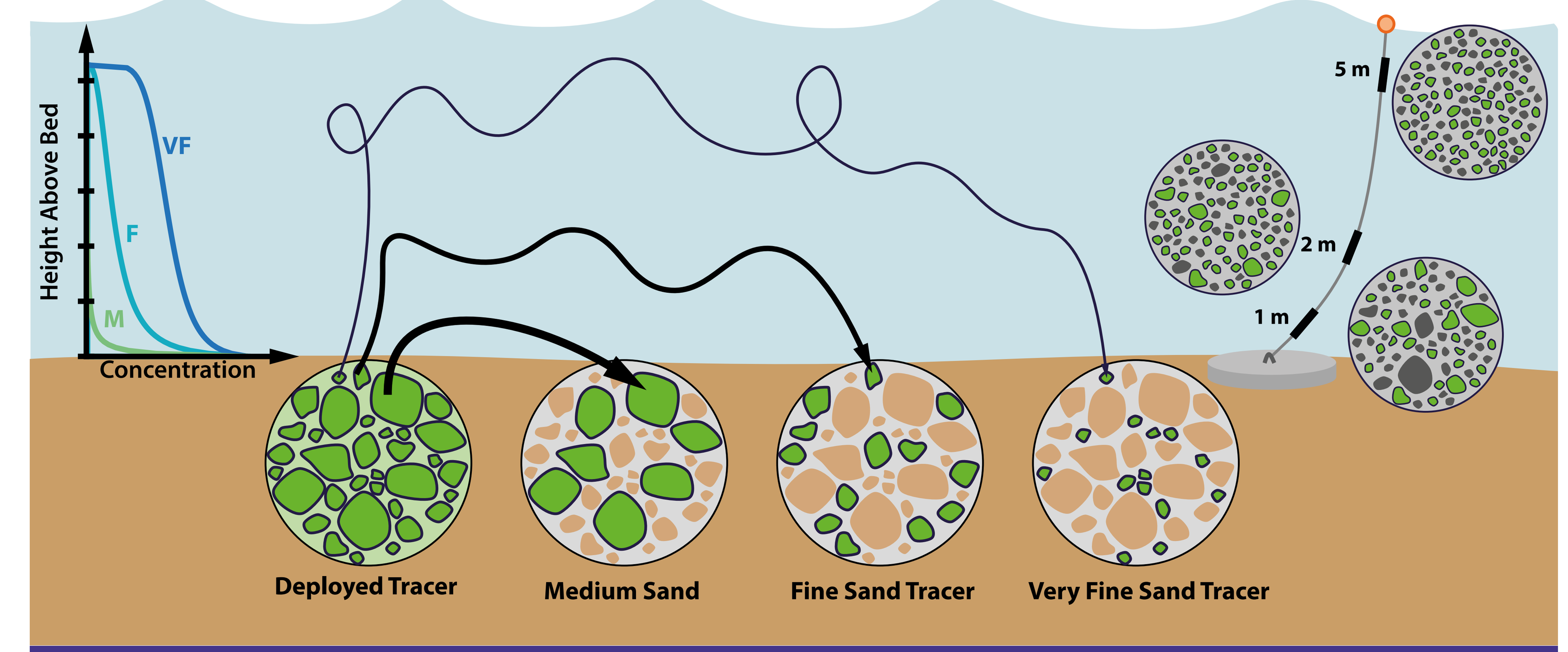

Figure 6. Conceptual diagram indicating dispersal of tracer on the seabed and in the water column. Finer grains are preferentially resuspended and transported further than coarser grains, which travel more often as bedload.

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Contact:
Stuart Pearson
s.g.pearson@tudelft.nl

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