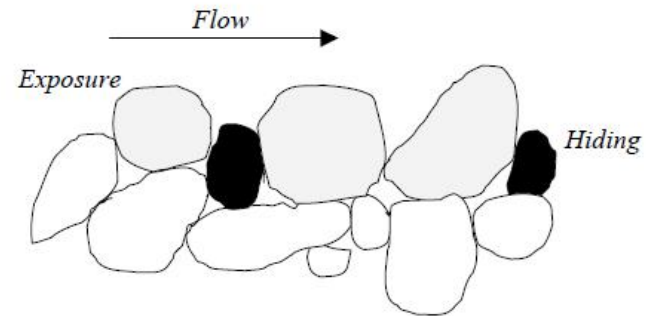# Transport of sand mixtures:
Laboratory experiments and numerical modelling

Joep van der Zanden, Jebbe van der Werf, Jan Ribberink,
Bart Vermeulen, Tom O'Donoghue, Dominic van der A

Sand mixtures – why?

- Many coastal regions comprise *mixed* rather than *uniform* sediments

- Transport rates mixed sediments can differ substantially from uniform sediments

- Sediment mixing effects in engineering models (e.g. Delft3D) included in a relatively simple way

- Applicability models questionable for e.g. coastal nourishments and dune erosion during storm events

- Better understanding and engineering modeling of the transport of sand mixtures, based on detailed experimental data
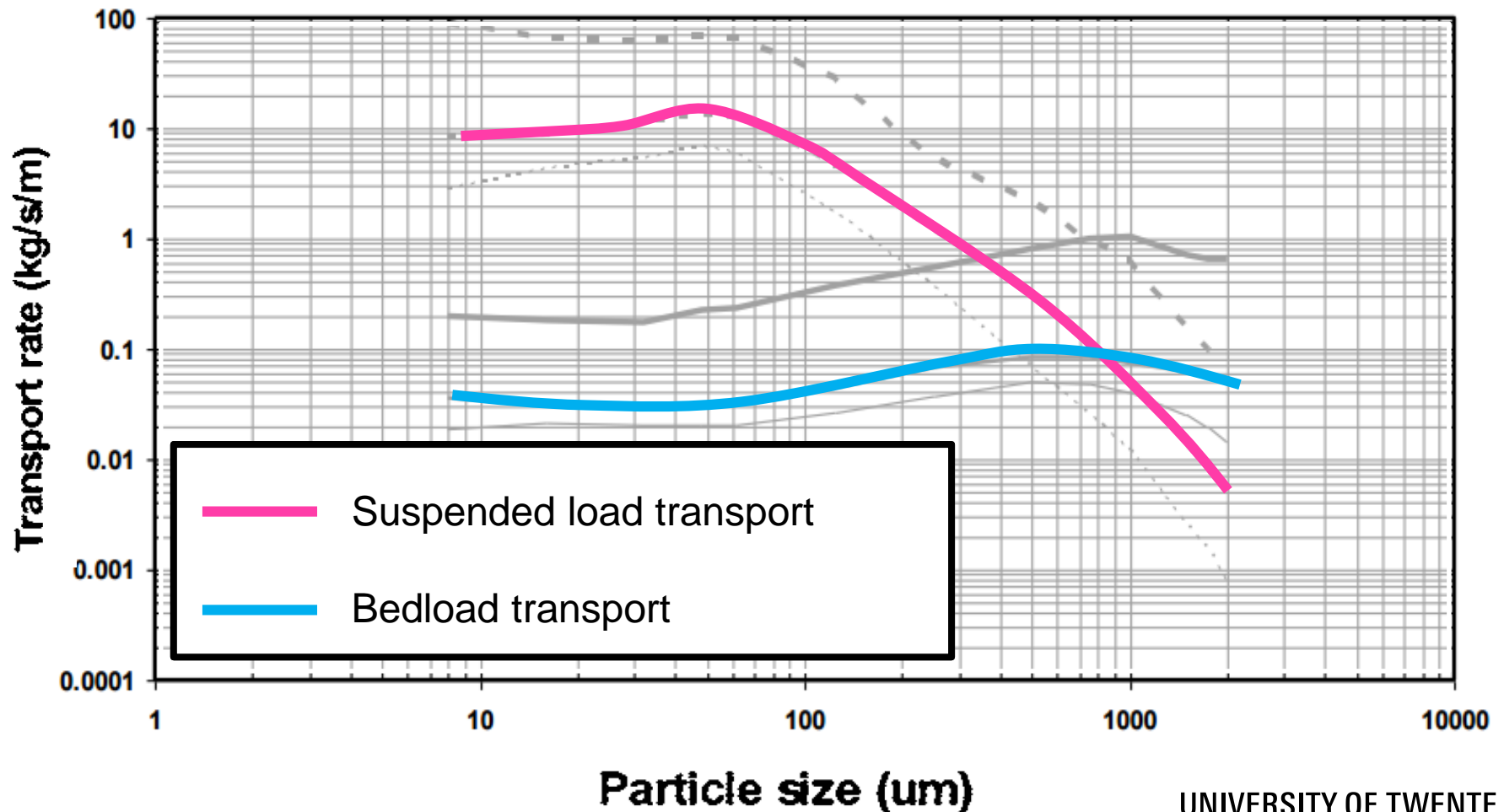
Mixed sediment effects

Non-linear dependence of sediment transport on particle diameter (especially for suspended load)

Mixed sediment effects

Non-linear dependence of sediment transport on particle diameter (especially for suspended load)   Van Rijn (2007)
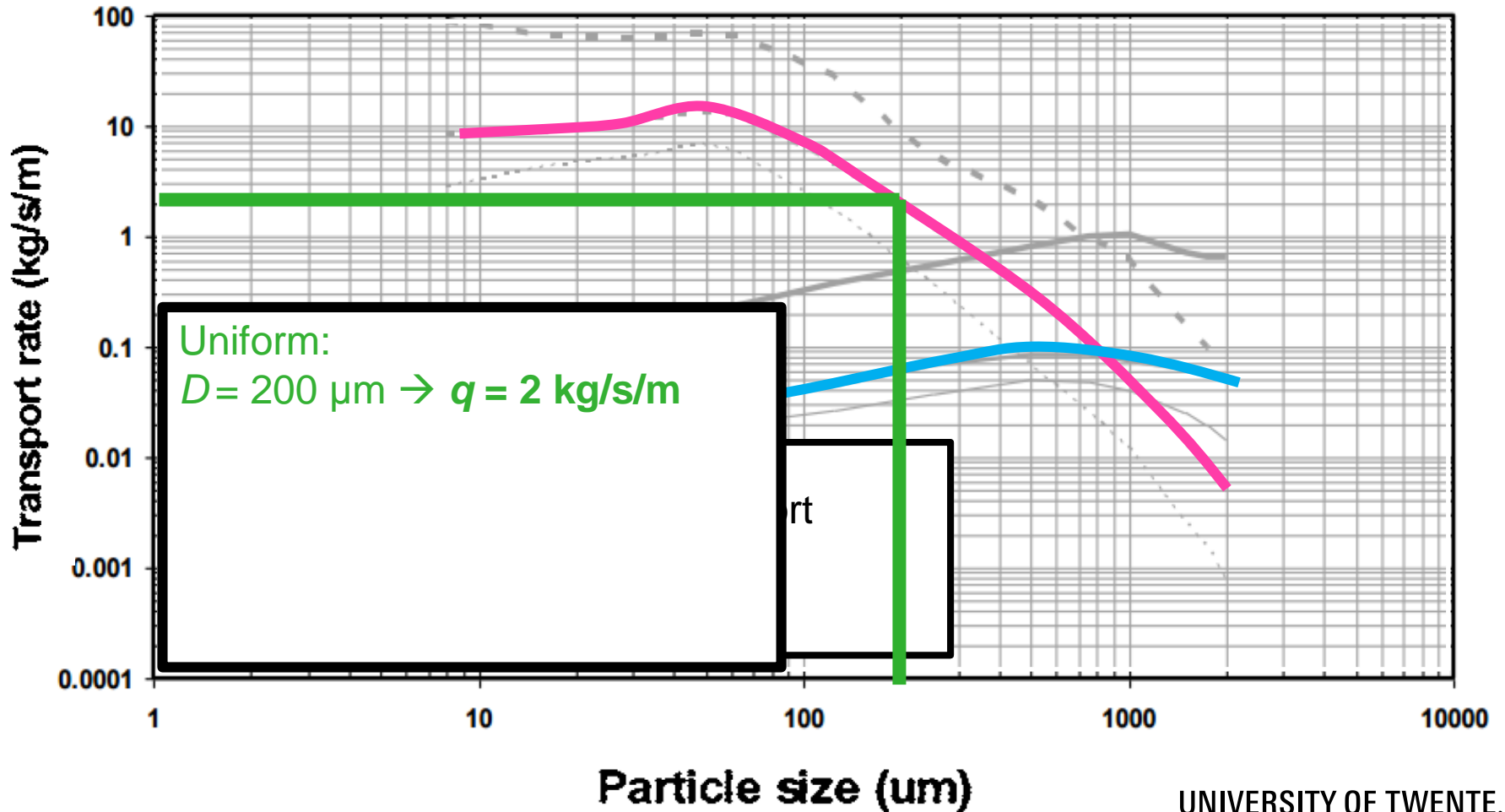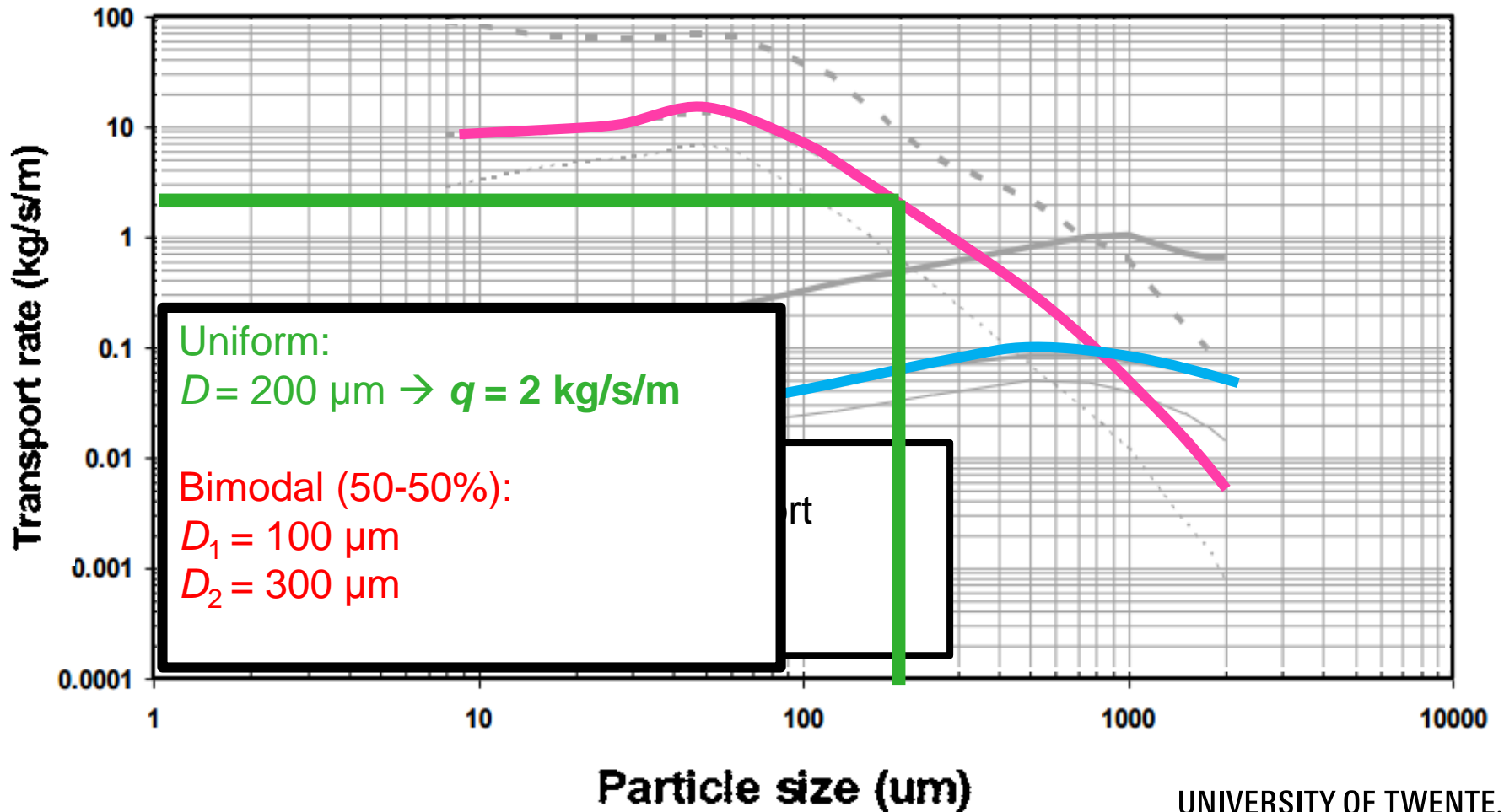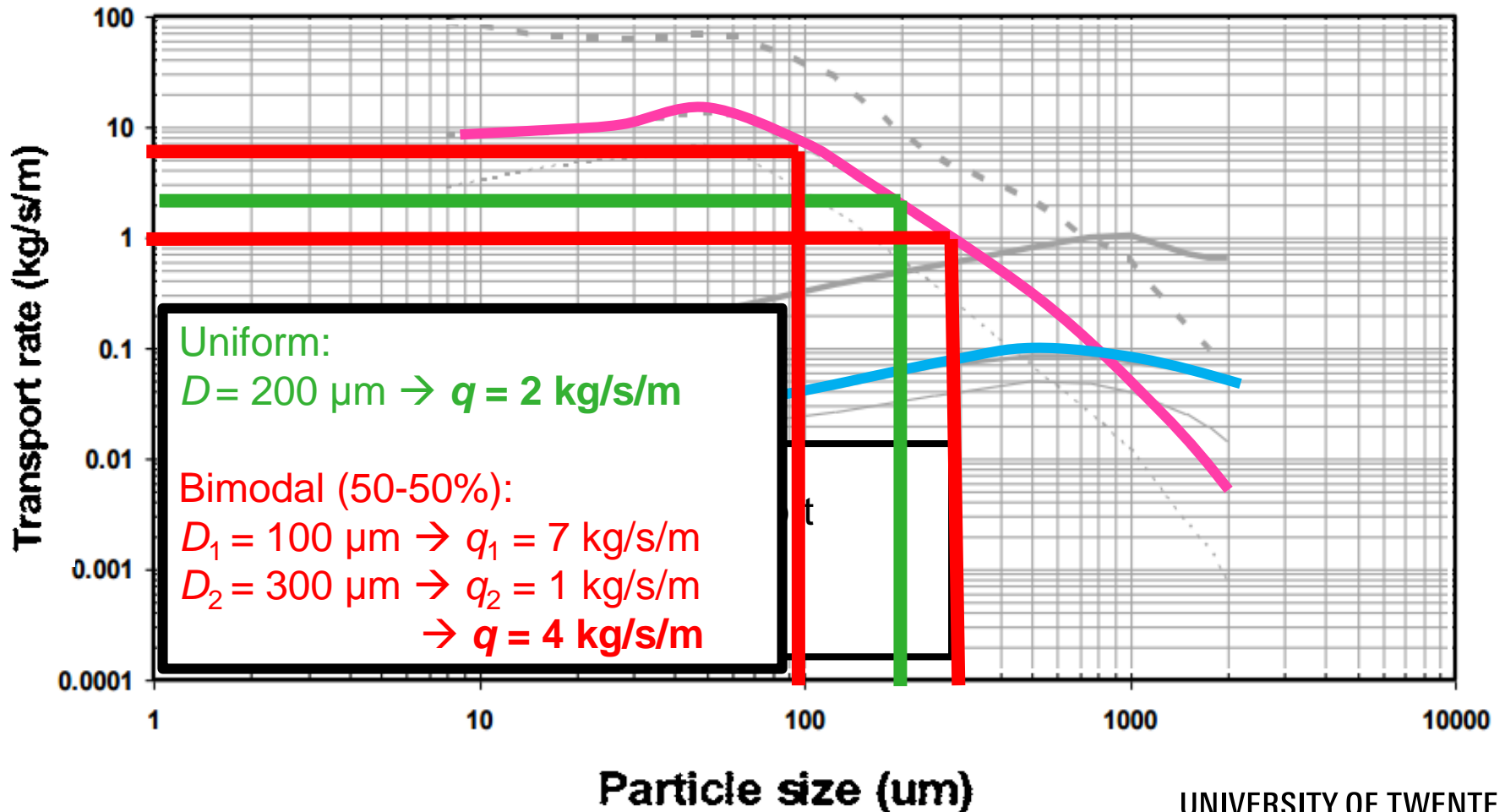
Mixed sediment effects

Non-linear dependence of sediment transport on particle diameter (especially for suspended load)
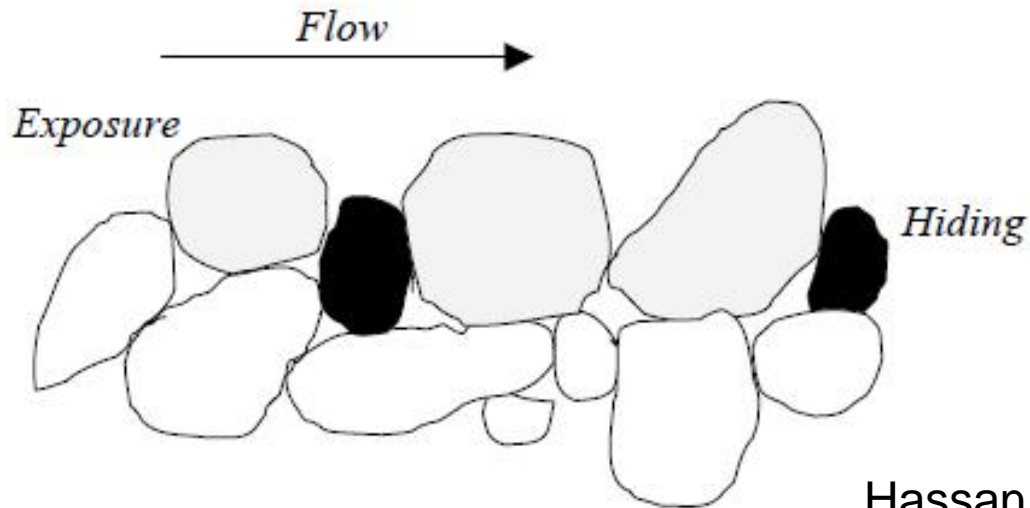
Van Rijn (2007)

Uniform:
D = 200 μm → q = 2 kg/s/m

Mixed sediment effects

Non-linear dependence of sediment transport on particle diameter (especially for suspended load)   Van Rijn (2007)

Uniform:
D = 200 μm → **q = 2 kg/s/m**

Bimodal (50-50%):
D_1 = 100 μm
D_2 = 300 μm

Mixed sediment effects

Non-linear dependence of sediment transport on particle
diameter (especially for suspended load)   Van Rijn (2007)

Uniform:
D = 200 μm → **q = 2 kg/s/m**

Bimodal (50-50%):
D_1 = 100 μm → q_1 = 7 kg/s/m
D_2 = 300 μm → q_2 = 1 kg/s/m
                → **q = 4 kg/s/m**

Mixed sediment effects

Hiding and exposure effects:
- Increased mobility coarser grains
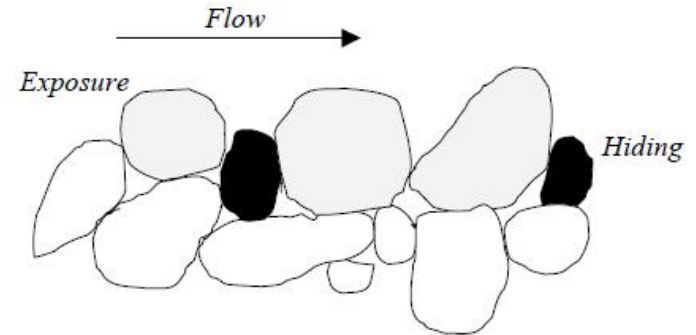- Reduced mobility finer grains
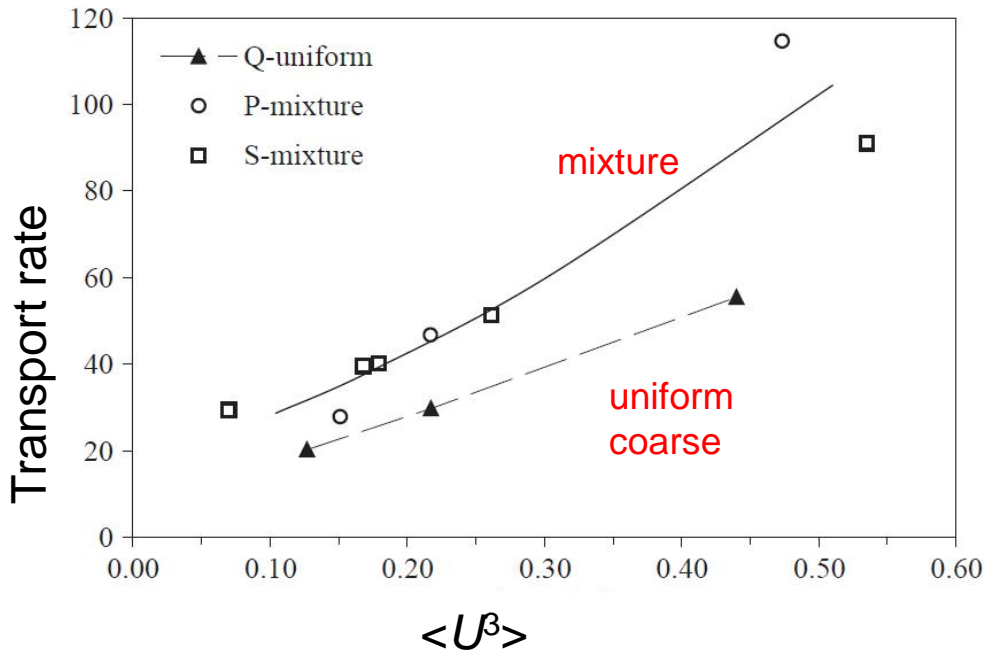

Hassan (2003)

Mixed sediment effects

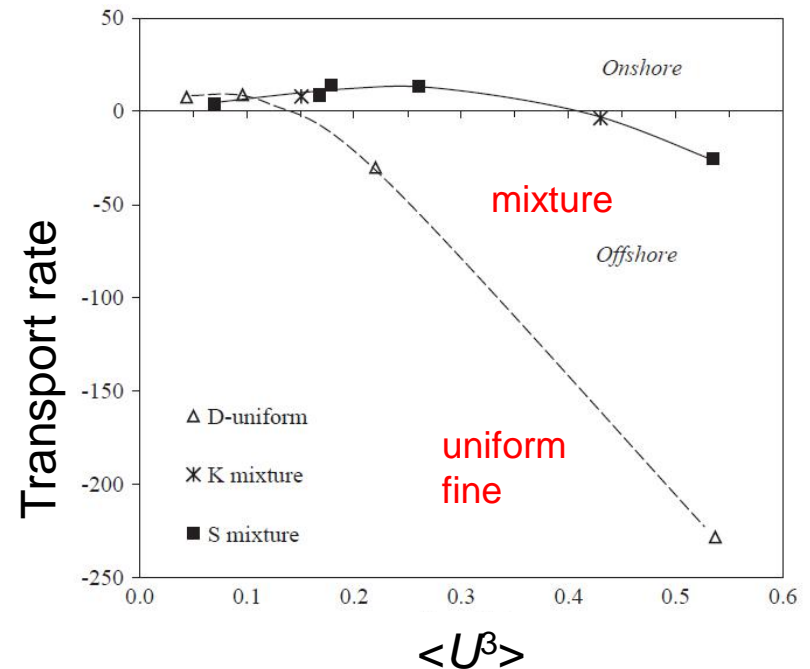**Hiding and exposure** effects:
- Increased mobility coarser grains
- Reduced mobility finer grains

Transport of **coarse** fraction (0.97 mm)
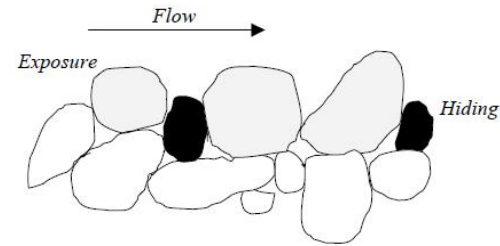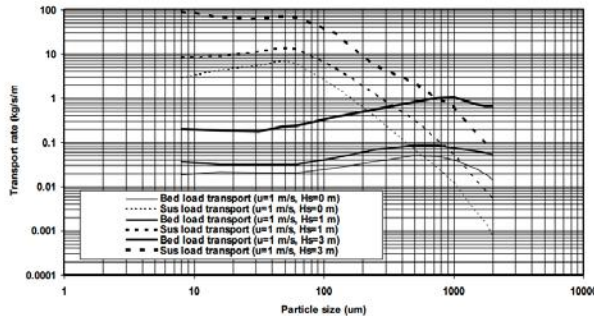in a **finer** mixture (0.13, 0.34, 0.97 mm)

Transport of **fine** fraction (0.13 mm)
in a **coarser** mixture (0.13, 0.34, 0.97 mm)

Hassan & Ribberink (2005)
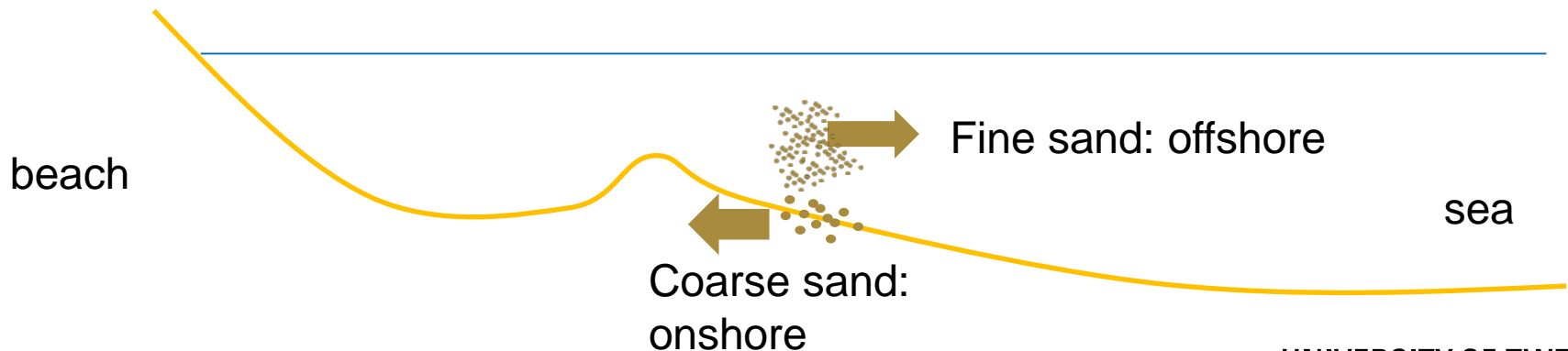
Cross-shore sorting

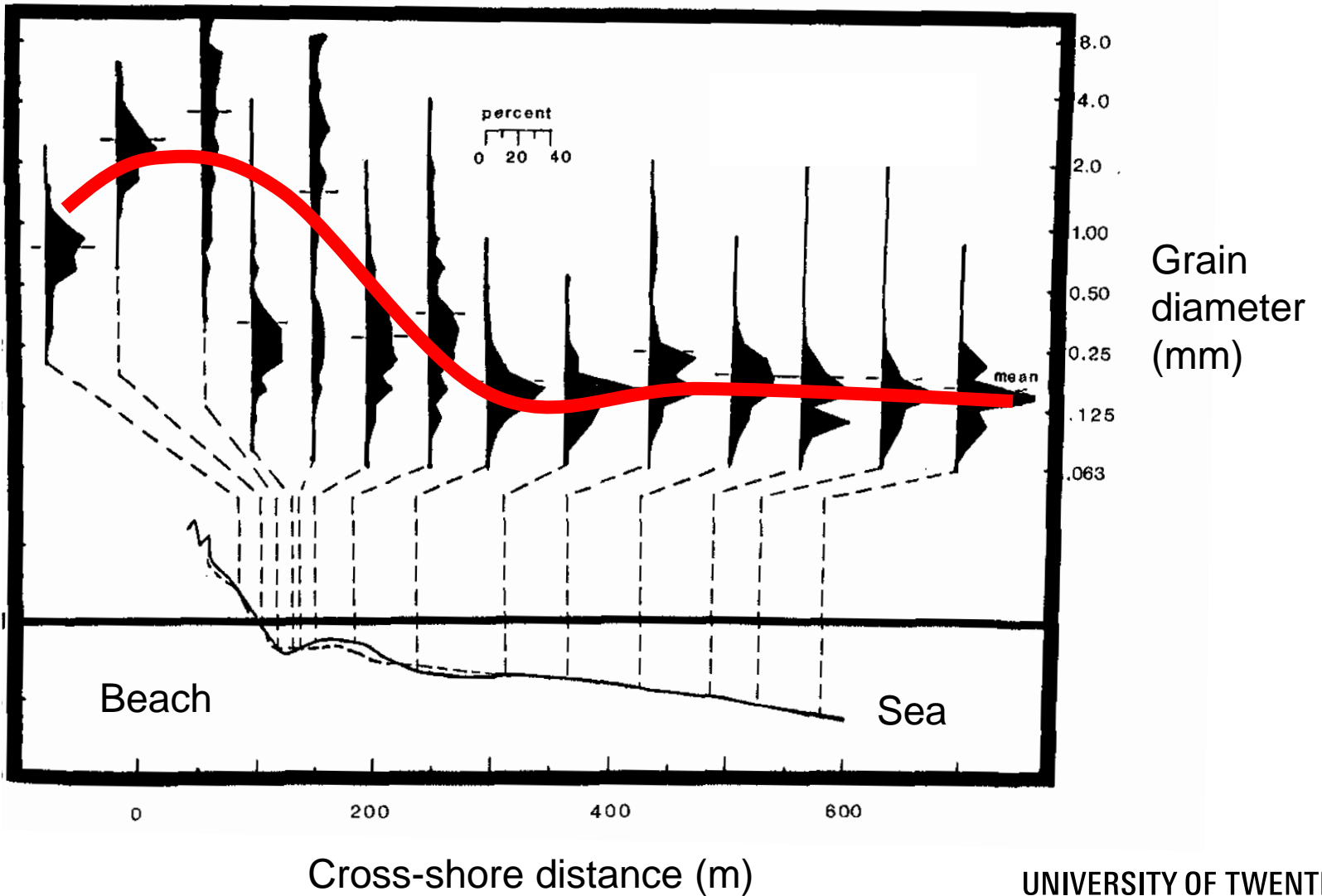- Non-linear dependence sand transport on grain diameter

- Hiding/exposure effects

Cross-shore sorting

beach

Fine sand: offshore

sea

Coarse sand: onshore

Cross-shore sorting

Richmond and Sallenger (1984)

Grain diameter (mm)

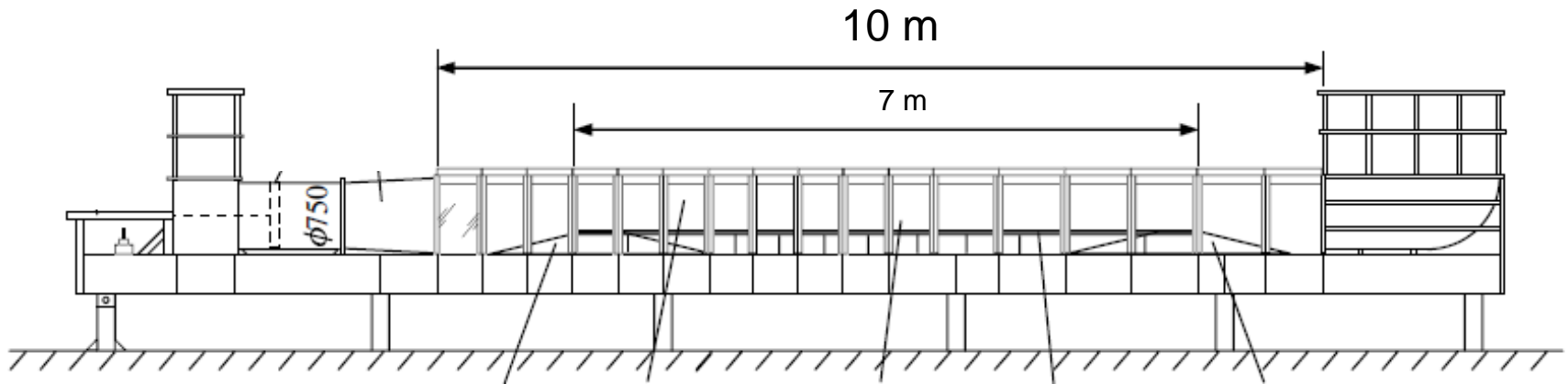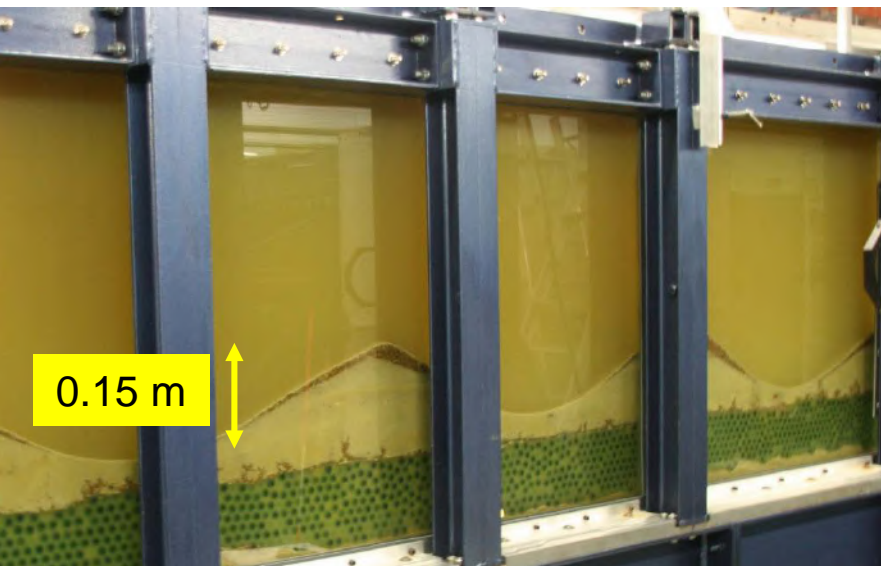Cross-shore distance (m)

Local sorting patterns (PhD Davide Boscia, U.Aberdeen)

- Oscillatory flow tunnel measurements
- Bimodal sediment (D = 0.16 and 1.5 mm)
- U = 0.5 – 1.2 m/s
- Full-scale

10 m

7 m

$\phi750$

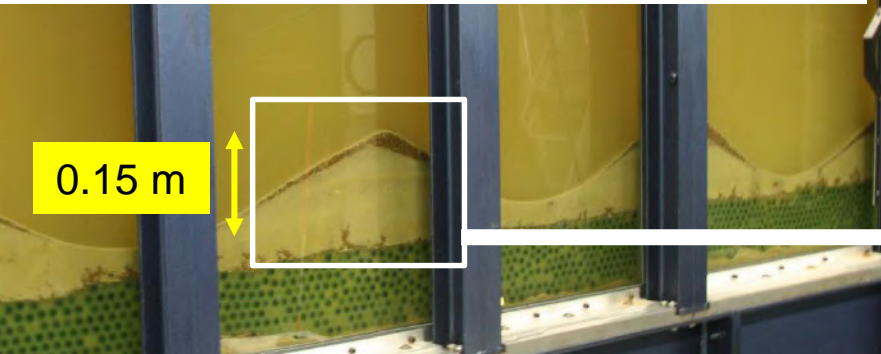# High velocity forcing: large ripples

0.15 m

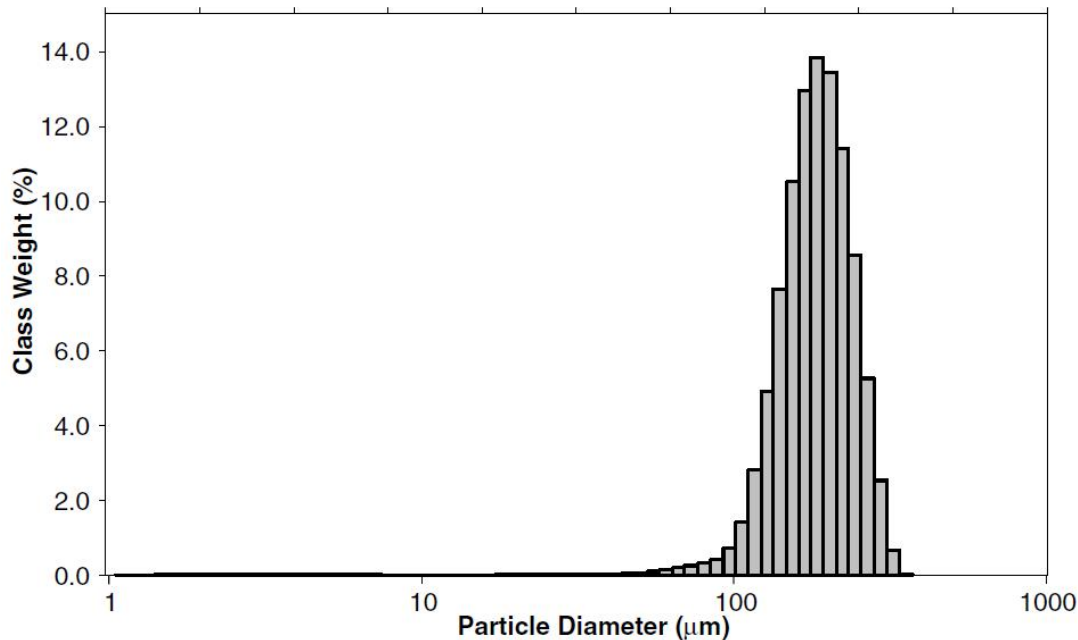# High velocity forcing: large ripples

➔ Vertical sorting
    Coarse top layer (armour layer)
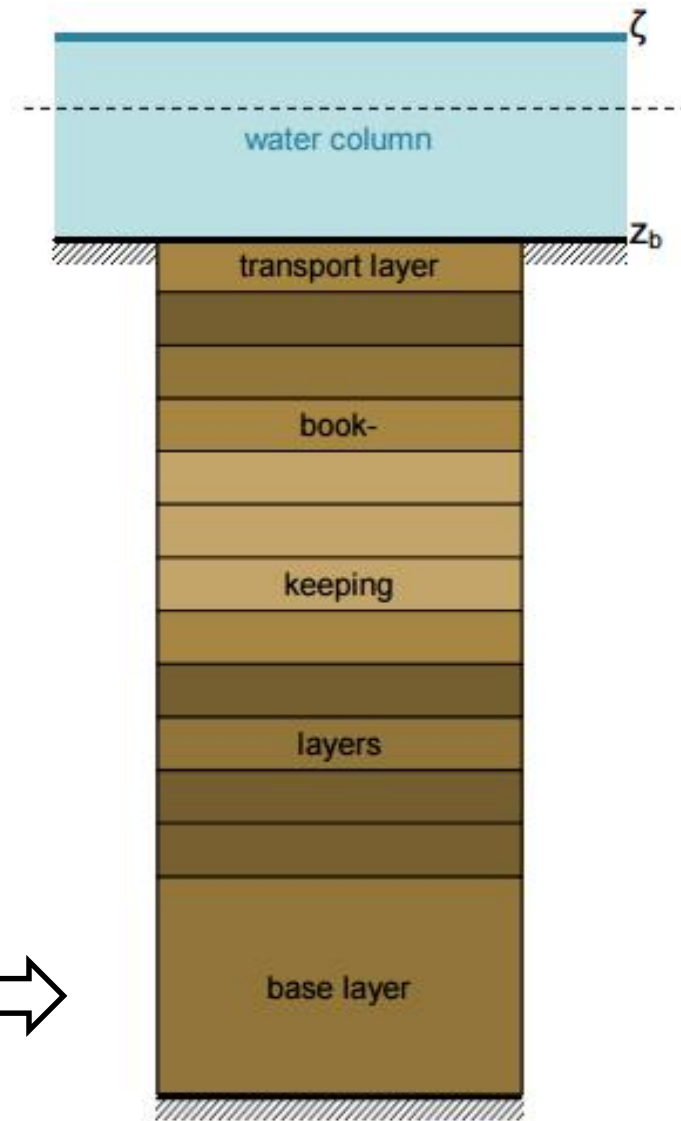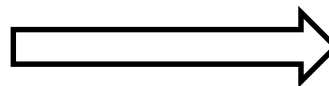➔ Size segregation ripple crest/trough

0.15 m

Delft3D modelling

- Sand transport following Van Rijn (2007)
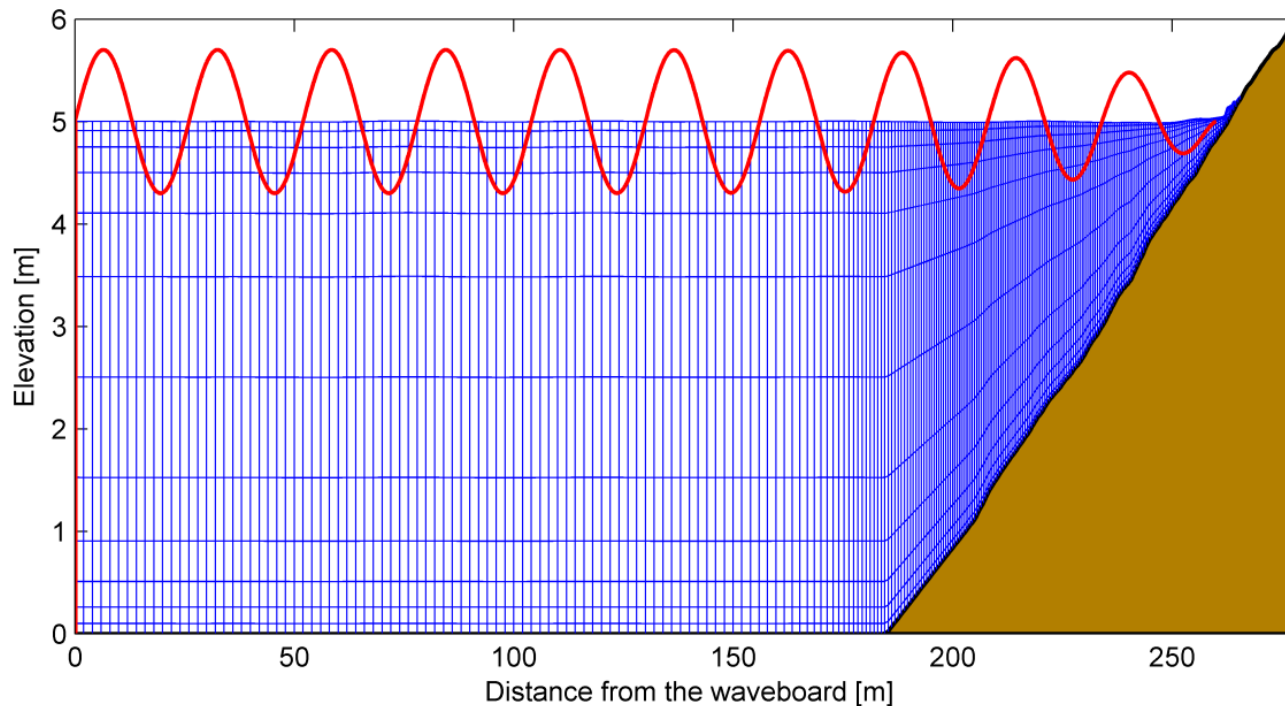 - Total transport is the sum of N size classes

- Mixing effects included:
  - Multi-layer bed stratification model
  - Hiding/exposure effects

▪ Comparison against Hannover wave flume data: 2 erosive wave cases; moderately sorted sand with $D_{50} = 0.3$ mm
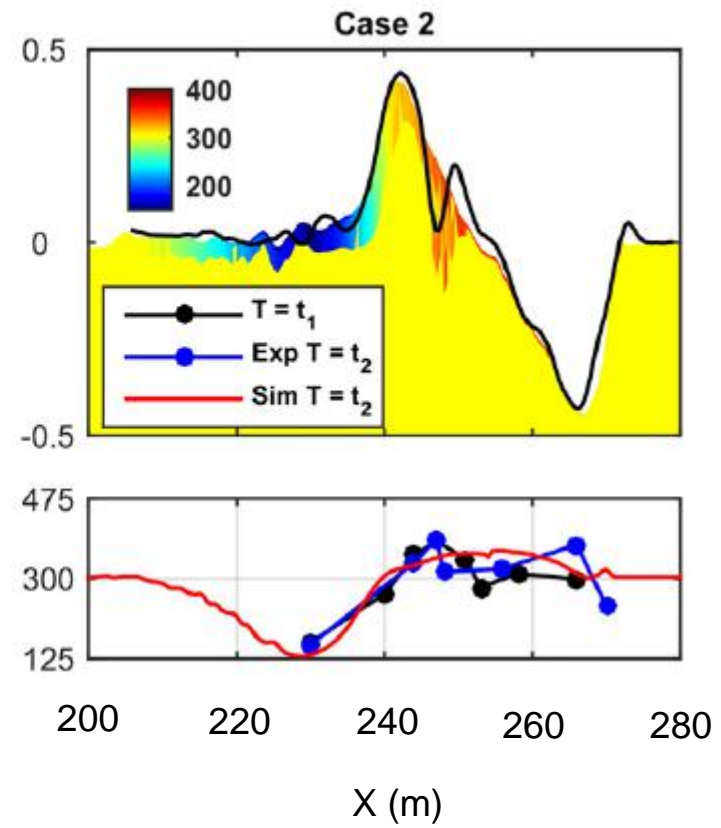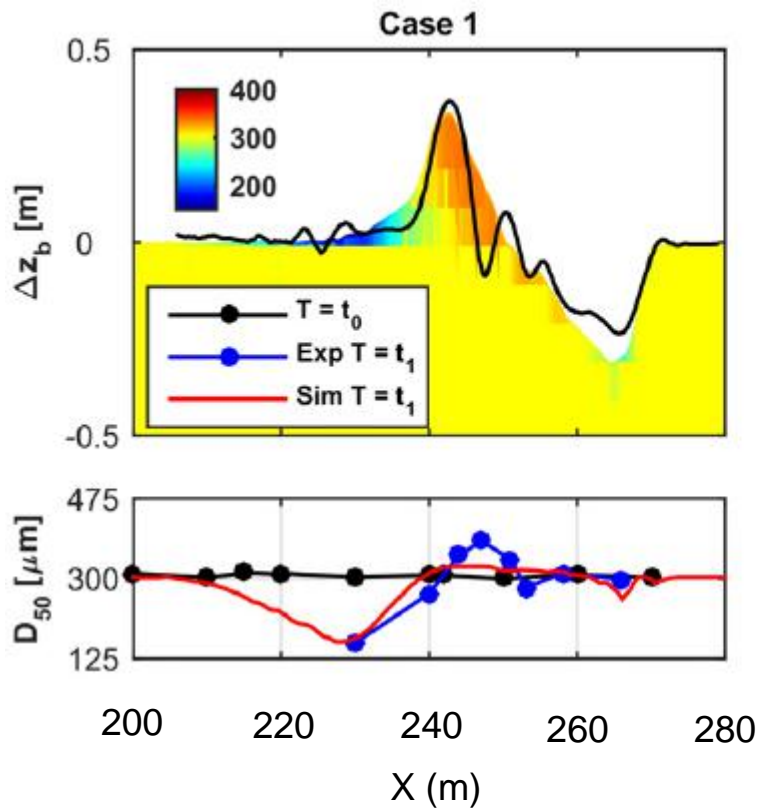

Broekema *et al.* (2016)

UNIVERSITY OF TWENTE.

Delft3D validation   (Broekema et al., 2016)

▪ Comparison against Hannover wave flume data: 2 erosive wave cases; moderately sorted sand with D_{50} = 0.3 mm

Modelling mixed sediment transport: discussion

- Lab (e.g. Broekema et al., 2016) and field (Huisman et al., 2018 → Sand Motor) simulations suggest that Delft3D can reproduce grain sorting

    - But: (heavy) calibration required!

Possible improvements:

- Hiding/exposure parameterizations (now based on fluvial research)

- Bed armouring not accounted for

- Uncertainties in grain and bedform roughness

- Other user input = appreciated!

Data availability - for wave-driven flows, few measurements of:

    - Net transport rates for strongly non-uniform sediment

    - Transport processes (suspension, fluxes, sheet flow)

Upcoming work

- STENCIL experiments in Hannover wave flume (also exps in Barcelona)
  - Different mixtures of fine (0.15 mm) and coarse (0.97) sand
  - Regular and irregular wave conditions (H = 1-1.5 m, T = 7 s)
  - April-June 2018
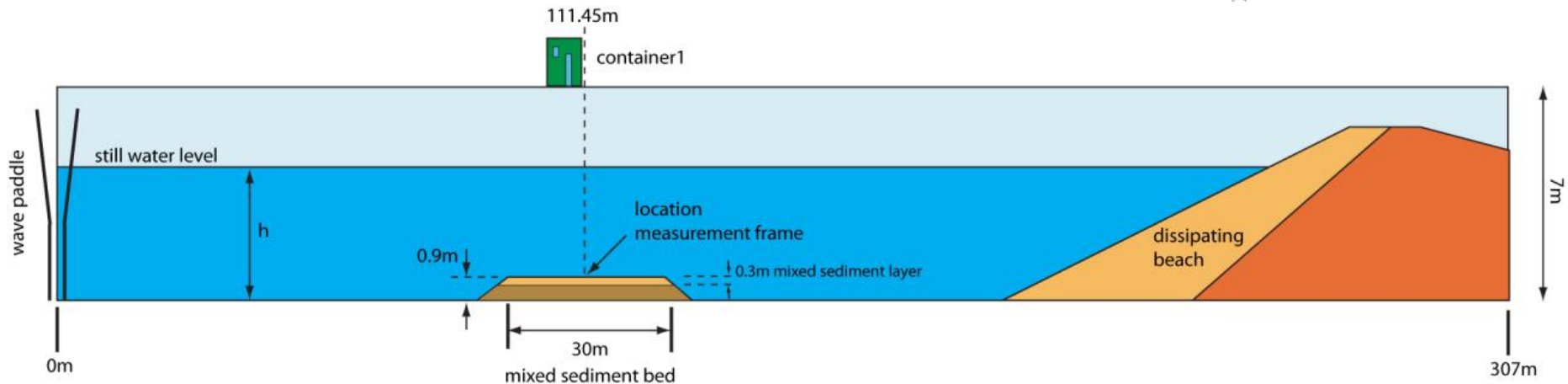
Take home

- **Mixture effects on sand transport:**
  - Non-linear dependence on particle size
  - Hiding/exposure

- **Sorting:**
  - Shoreward coarsening
  - Vertical stratification, bed armouring
  - Grain size segregation around bedforms

- **Sand transport models:**
  - Limited validation (oscillatory flows/waves)
  - Delft3D can reproduce general sorting patterns, when calibrated
  - ➔ Future experiments to further improve transport models for mixtures

Thanks!

Questions??

Photo: Davide Boscia,
U. Aberdeen