Flume experiments on gravel bed load transport in unsteady flow – preliminary results

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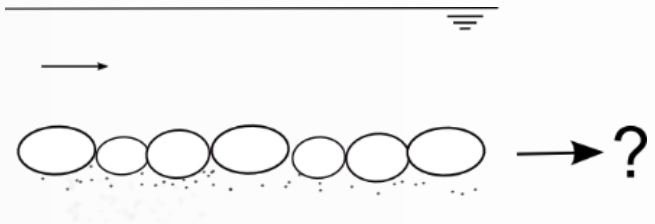
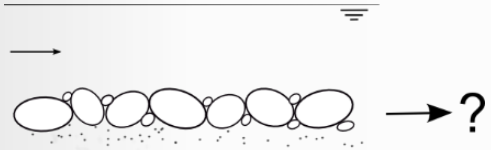
Outline

1. Motivation and objectives
2. Experimental set-up
3. Results of experiments and data treatment
4. Analysis of results
5. Summary

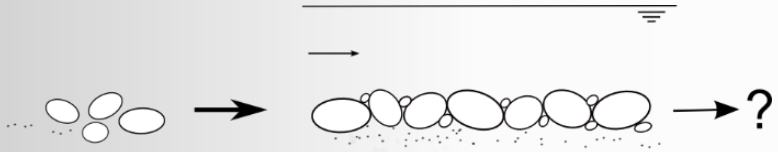
Motivation



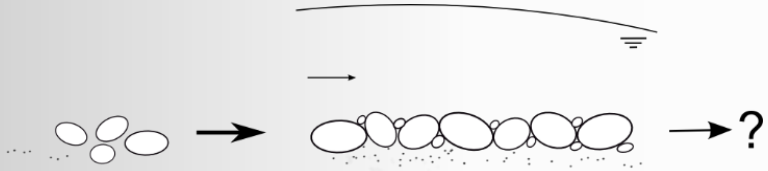
Factors affecting bed load rate



Spatial arrangement of sediment grains: coarsening, armoring -> partial transport



Rate of sediment supply from upstream



Non-uniformity and unsteadiness of flow

Objectives

Objective 1

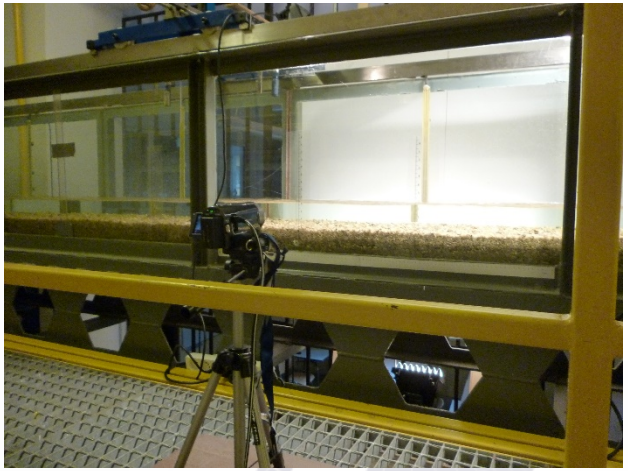
analyse to what extent **sediment supply** affects bed load transport in unsteady flow

Objective 2

examine **variability of bed load rate** in unsteady flow in comparison with bed load rate in steady flow

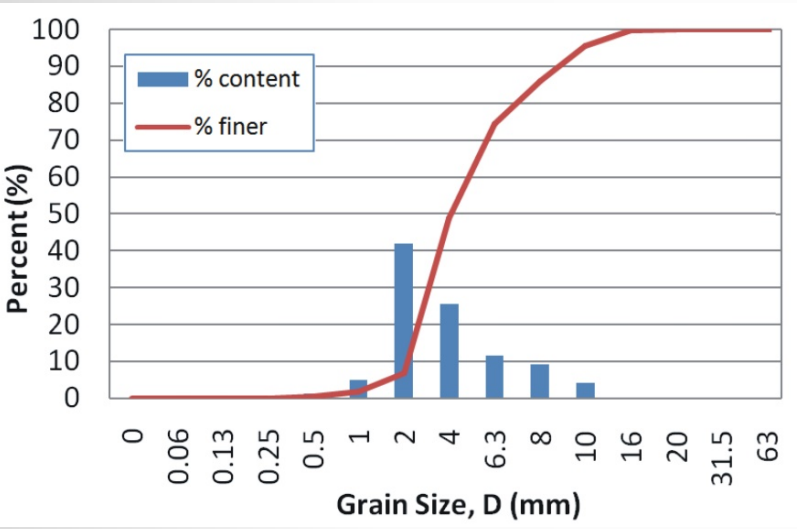
Objective 3

analyse **changes in grain size distribution** after experimental tests



Hydraulics Laboratory of University of Agriculture in Kraków

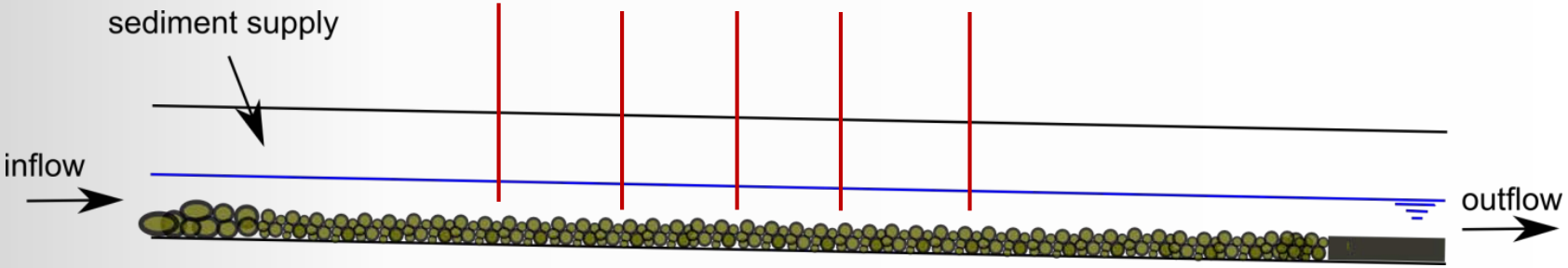
Set - up



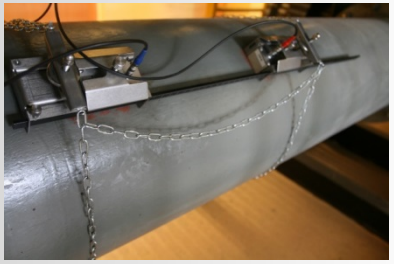
Fine gravel

d_{50} = 4.9 mm, d_{max} = 18.0 mm

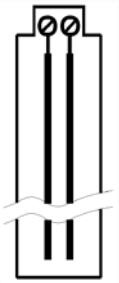
Set - up



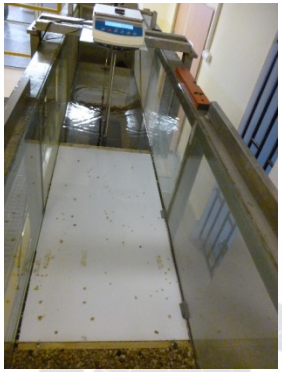
Ultrasonic flowmeter



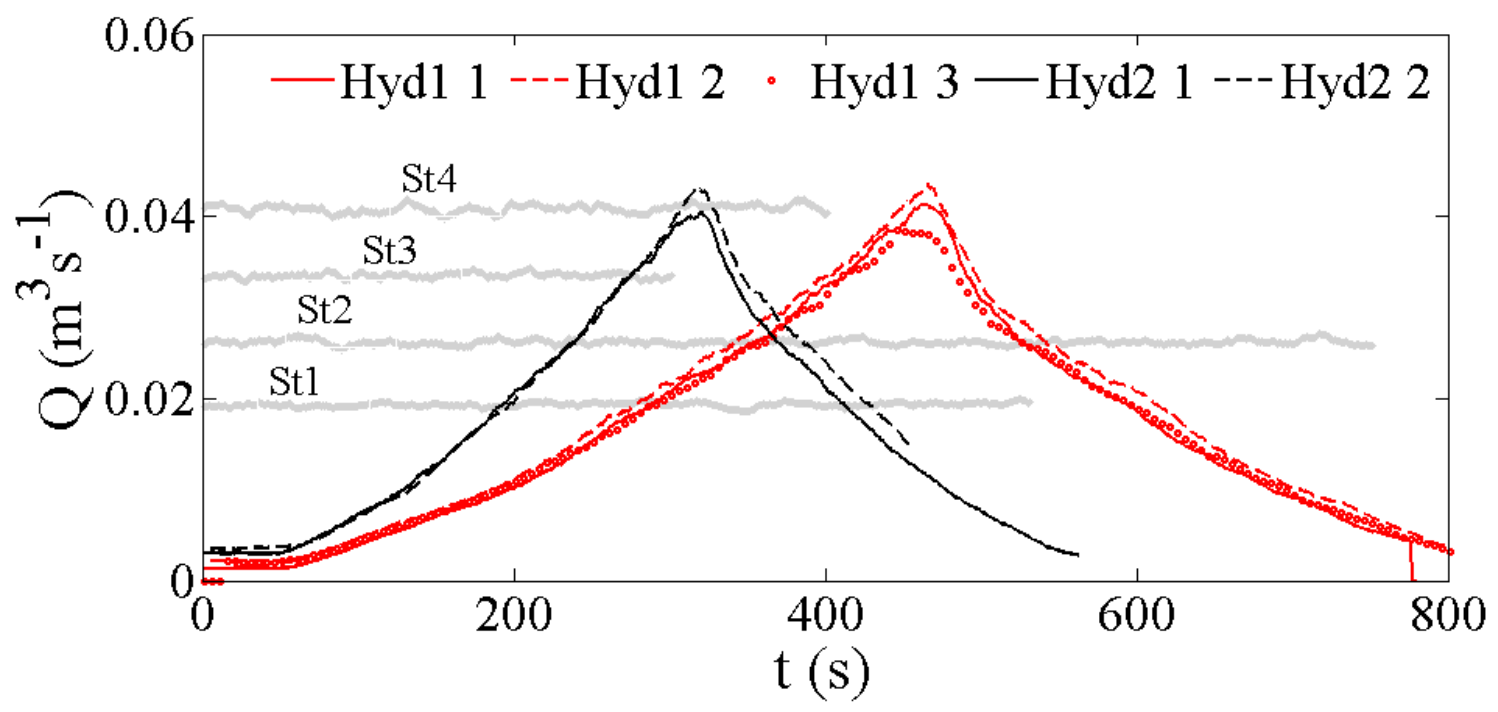
Resistive gauges



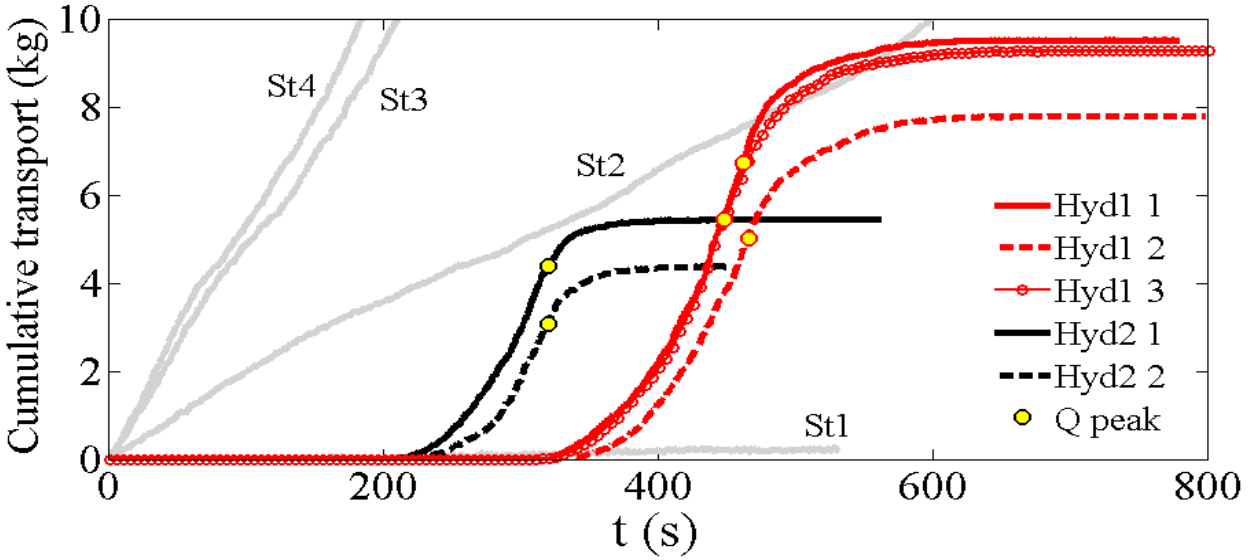
Trap and weighing scales



Experimental tests

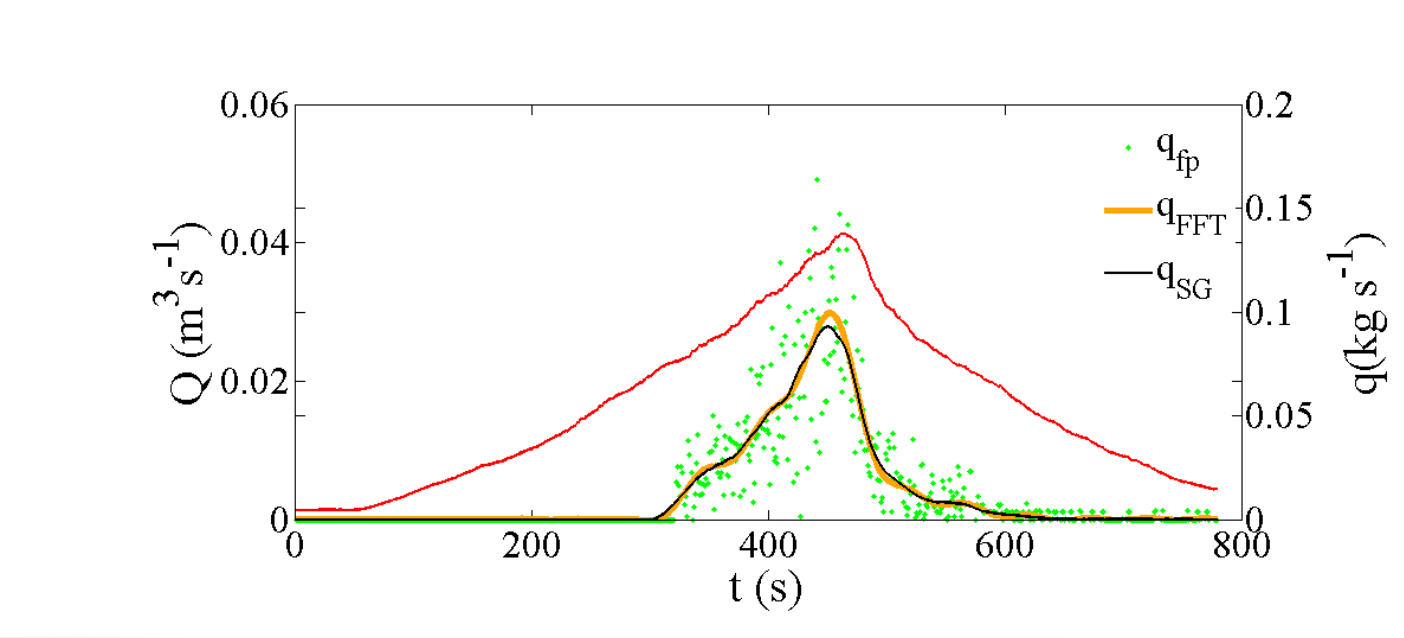


Results: cumulative transport



	Hyd1_1	Hyd1_2	Hyd1_3	Hyd2_1	Hyd2_2
Wsup (kg)	13.46	11.59	18.19	10.6	8.33
Wt (kg)	9.505	7.787	9.280	5.444	4.383

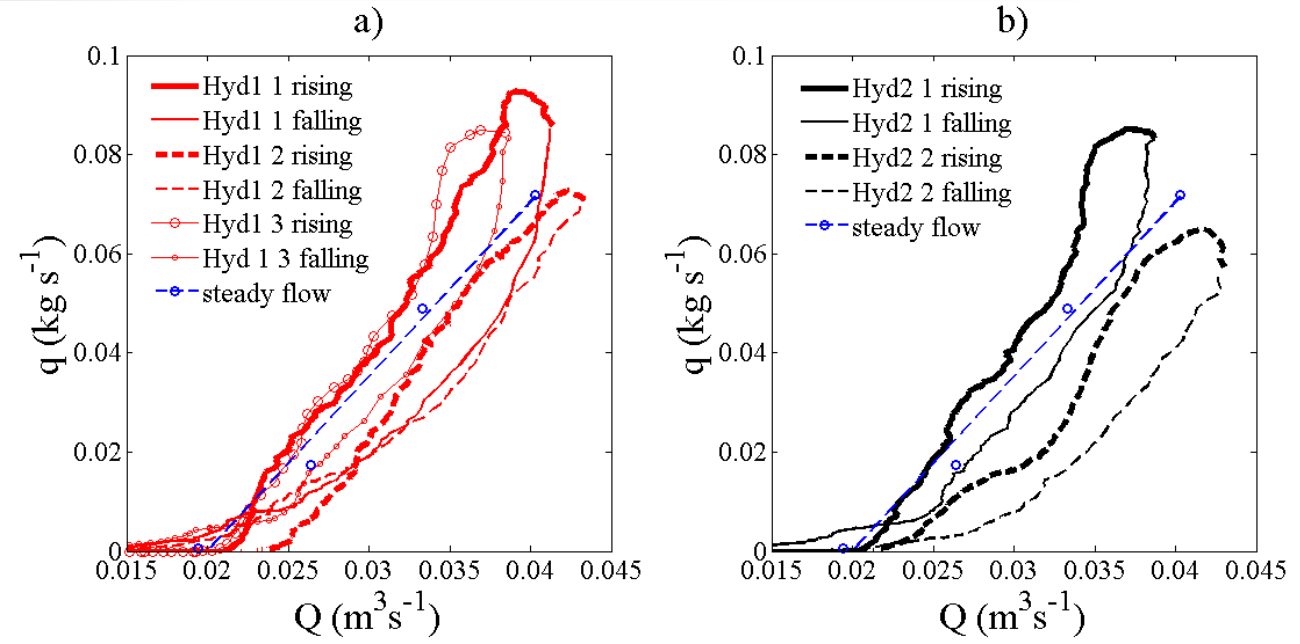
Results: bed load rate



Evaluation methods:

- q_{fp}: four-point difference quotient
- q_{FFT}: fast Fourier transform applied to q_{fp}
- q_{SG}: Savitzky – Golay filter

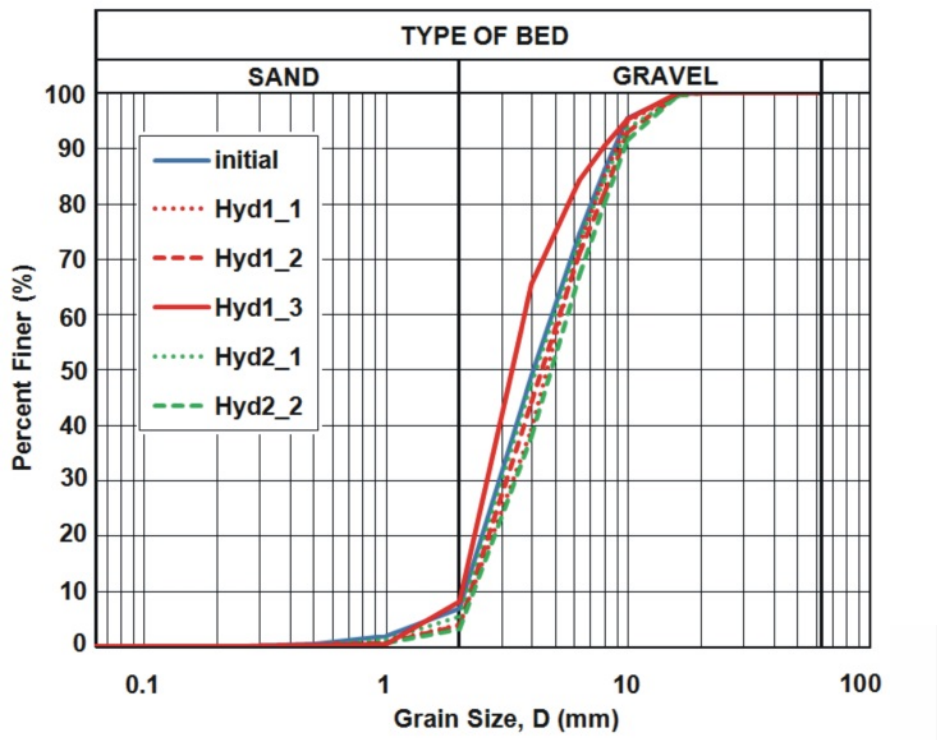
Results: bed load rate vs. flow rate



- clockwise hysteresis - maximum bed load rate in a rising limb of hydrographs
- bed load rates during Hyd1_2 and Hyd 2_2 are below bed load rate for the same discharge in steady flow. This may be explained by too small amount of supplied sediment in these unsteady flow tests

Results: grain size distribution

- The percent finer decreases and mean grain size increases for 4 out of 5 hydrographs
- These changes are probably due to washing out of sand fraction which decreases about 1.5÷3.7%
- Hyd1_3 deviates form others: percent finer increases and grain size decreases
- Hyd1_3 has the highest sediment supply, content of sand fraction increase about 1.2%



Summary

Objective 1 - sediment supply

The bed load transport is very sensitive to sediment supply

Objective 2 - variability of bed load rate

The relation between bed load rate in unsteady flow and bed load rate in steady flow equilibrium conditions depends to large extent on sediment supply

Objective 3 - changes in grain size distribution

Sediment tends to coarsen except the experiment with excessive sediment supply

Thank you for attention

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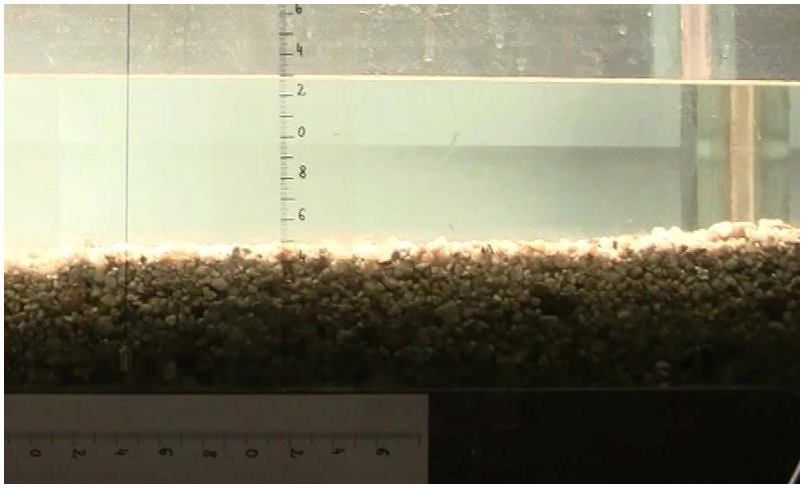
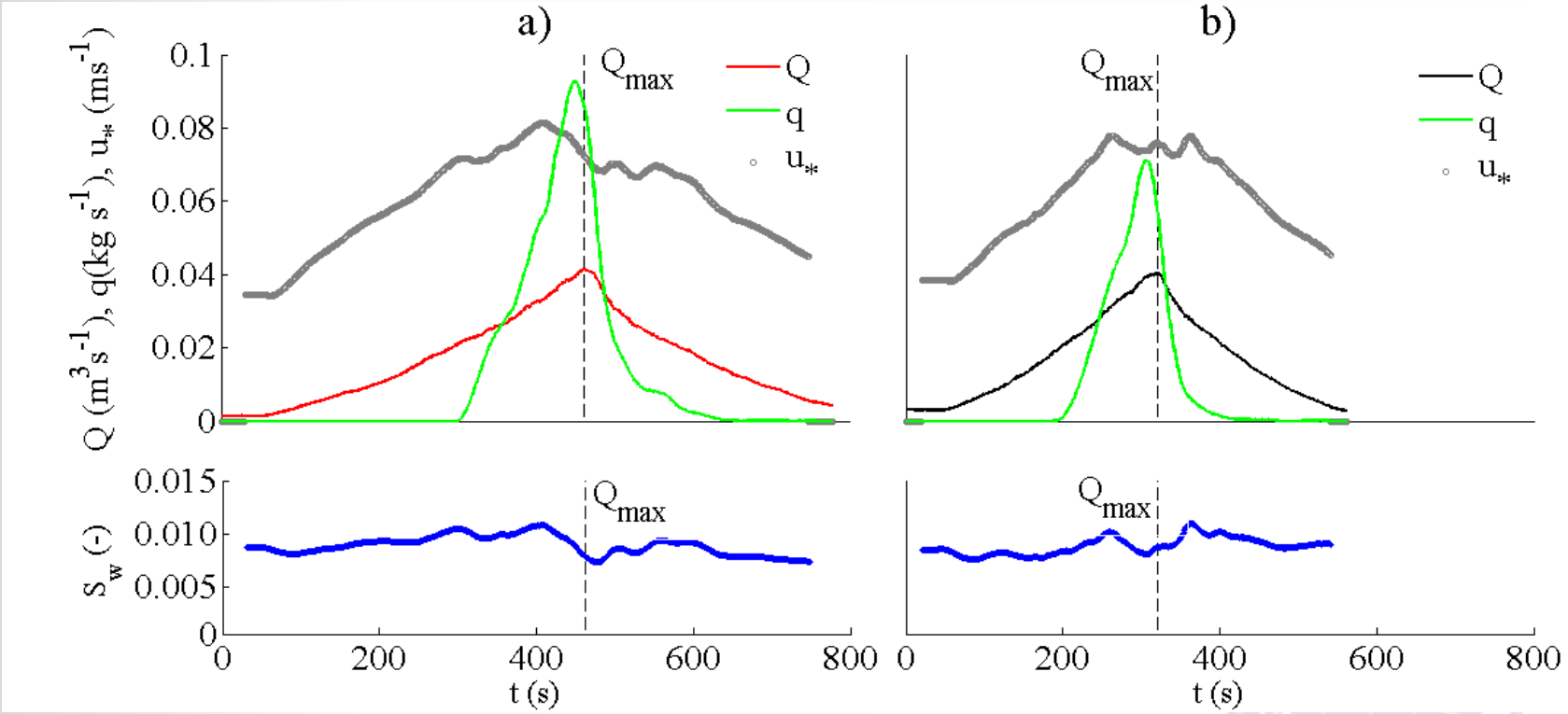
Problems



- Keeping water surface slope
- Water depth measurement
  - Difficulties during flow,
  - Variation with changing bed elevation,
  - Erosion along centerline of a channel,
- Choice of supply option:
  - no supply –> excessive erosion -> problems with water slope,
  - manual supply – how to assess the appropriate rate of supply?
- How to compare with steady flow equillibrium conditions?
- Repeatability

Problems: water surface slope and friction velocity



$$S = I - \frac{1}{g}\frac{\partial U}{\partial t} + \frac{U}{gh}\frac{\partial h}{\partial t} + \left(\frac{U^2}{gh} - 1\right)\frac{\partial h}{\partial x}$$

g – gravitational acceleration [m/s^2]

h – flow depth [m]

R – hydraulic radius [m]

U – mean velocity [m/s]

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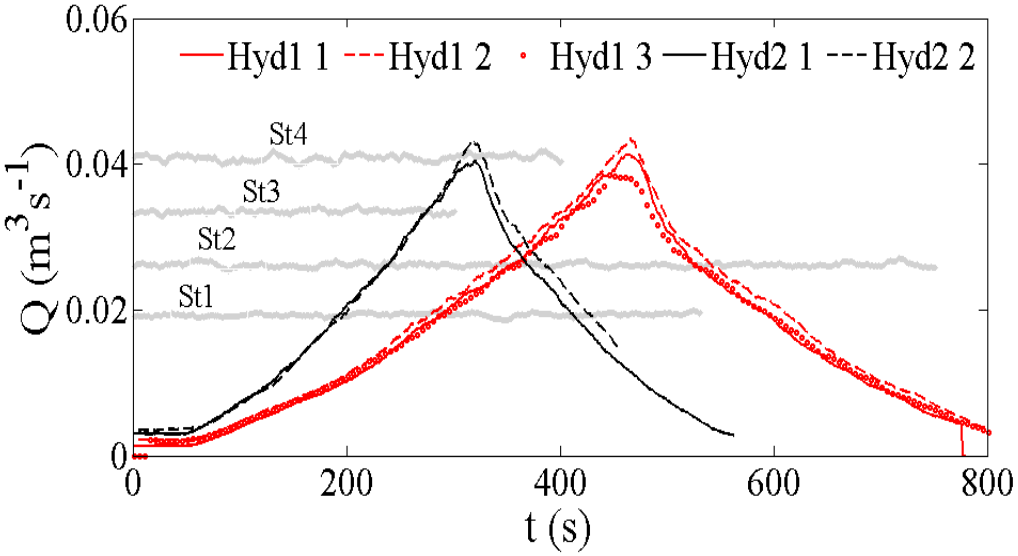
Experimental tests



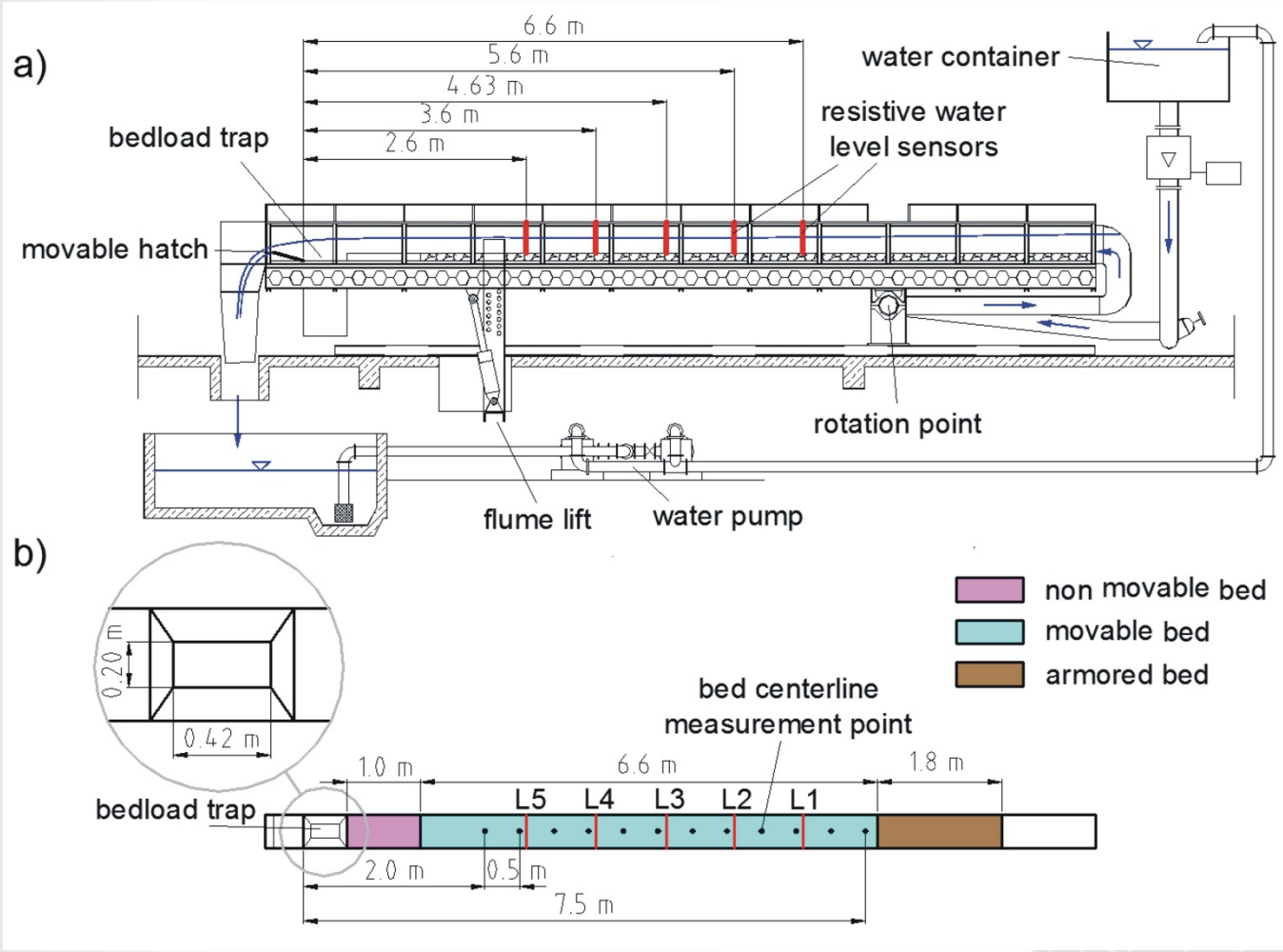
Unsteady flow

	Hyd1_1	Hyd1_2	Hyd1_3	Hyd2_1	Hyd2_2
Q_{max} (m^3h^{-1})	149.0	156.6	156.7	145.8	154.8
h_{max} (m)	0.096	0.100	0.096	0.096	0.103

Steady flow

	St1	St2	St3	St4
Q (m^3h^{-1})	70.0	95.0	120.0	145.0
h (m)	-	0.078	0.085	0.097

Set - up


a)
6.6 m
5.6 m
4.63 m
3.6 m
2.6 m
water container
resistive water level sensors
bedload trap
movable hatch
rotation point
flume lift
water pump
b)
non movable bed
movable bed
armored bed
0.20 m
0.42 m
bed centerline measurement point
1.0 m
6.6 m
1.8 m
bedload trap
L5
L4
L3
L2
L1
2.0 m
0.5 m
7.5 m