6th Annual Conference on Natural Channel Systems

Did it move?

Lessons Learned with Sediment Tracking

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Outline

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4. Methodology and Approach
5. Analysis and Results
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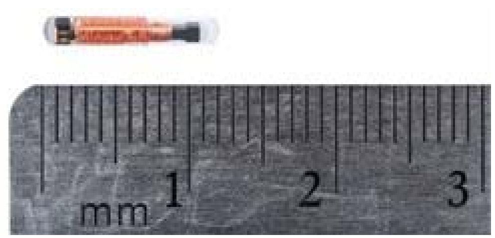
Introduction

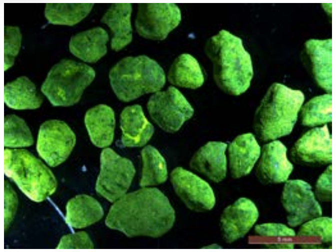
Substrate mobility is a key component of natural channel function

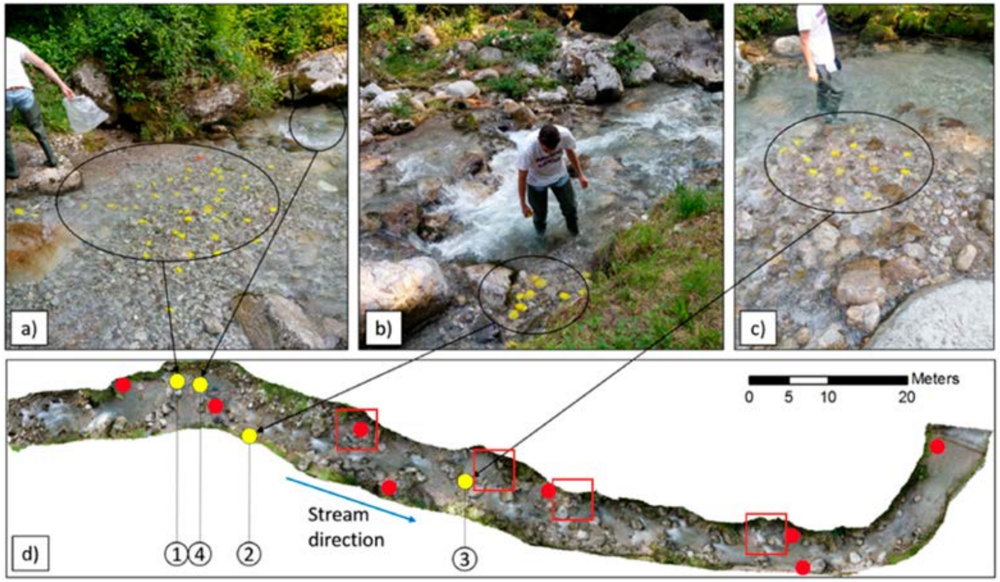
- Fluvial processes of erosion and deposition
- Ecological function of aquatic habitat conditions
- Implications for structures and erosion control measures
- Evaluation of the dynamic stability of channels
- Natural channel design

Particle Tracking Technology

- Passive integrated transponder (PIT) tags
- Radio-frequency identification (RFID)
- Artificial tracers
- Metal detection
- Reflective coatings







Objective

Examine the reliability of particle entrainment equations and methods for the purpose of characterizing existing conditions and restoration works

<u>Specific applications</u>

- Defining erosion thresholds
- Identifying substrate gradations for restoration projects
- Evaluate the stability of bed material on specific channels

Site Selection

Site Selection Criteria

- Rain/flow gauge data for flow monitoring
- Existing hydraulic model
- Sufficient depth and volume to mobilize particles

Site Selection

Methodology and Approach

Particle Tracking Challenges:

- Need to be identified under water
- Need to be identified under substrate (i.e. buried tracers)
- Need to identified over extended periods
  - Lifespan of particle tracing equipment
- Temporal and monetary constraints of the project

Methodology and Approach

Particle Preparation:

- Gradation of substrate, similar to existing conditions
- Weigh and measure particles for identification
- Implant particles with detectable metal
- Coat with reflective paint and assign identification number

Methodology and Approach

Site Installation:

- Place particles in channel at a reproducible origin
- Install flow monitor to establish hydraulic conditions specific to each site
- Longitudinal and cross-sectional surveys of local conditions

Particle Tracking

Sediment Tracers

- 55 tracers per site
- Multiple transects

Sequentially monitored for displacement using GPS equipment

Monitoring Water Level

Hydrologic Regimes
- Hydrographs
- Rating curves

Relating particle movement with channel hydraulics

Analysis

Incipient Motion: When sediment movement first begins!

$$\tau = \tau^{*}(s-1)\rho g D$$

Shear Stress

$$\tau^{*} = \frac{\tau_o}{(s-1)\rho g D}$$

Shield's number (dimensionless)

$$\tau_c = \tau_c^{*}(s-1)\rho g D$$

Critical Shear Stress

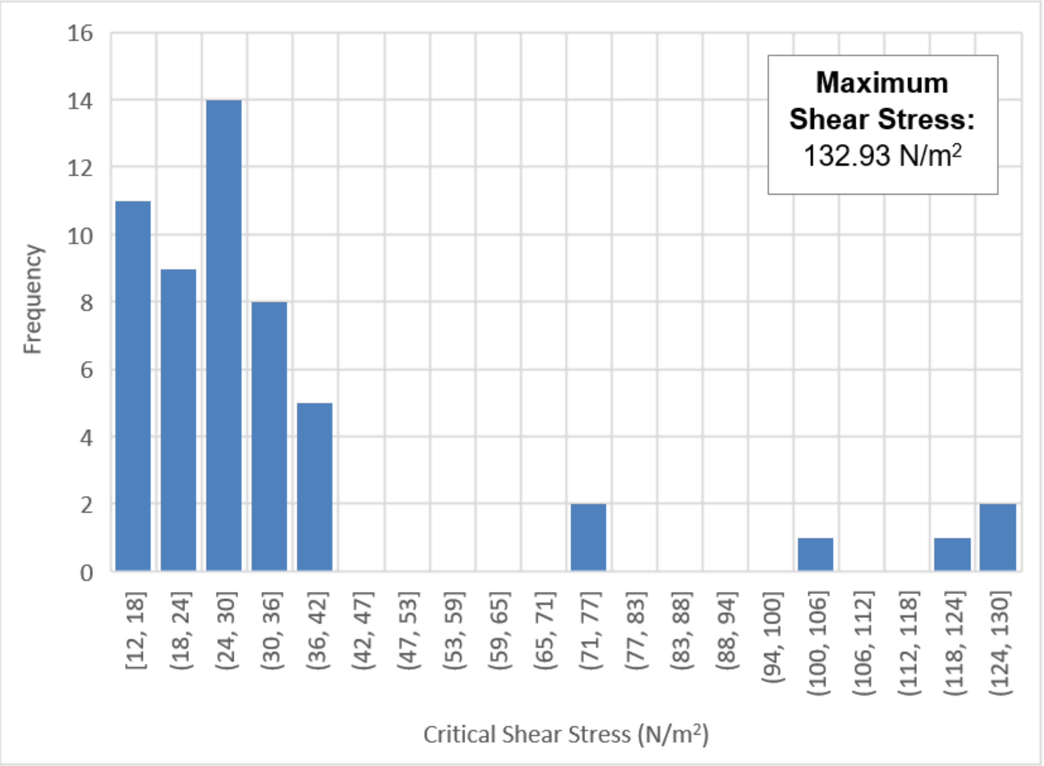
Grain motion is driven by shear stress (force per unit area)

Critical shear stress is that which is needed to initiate particle movement

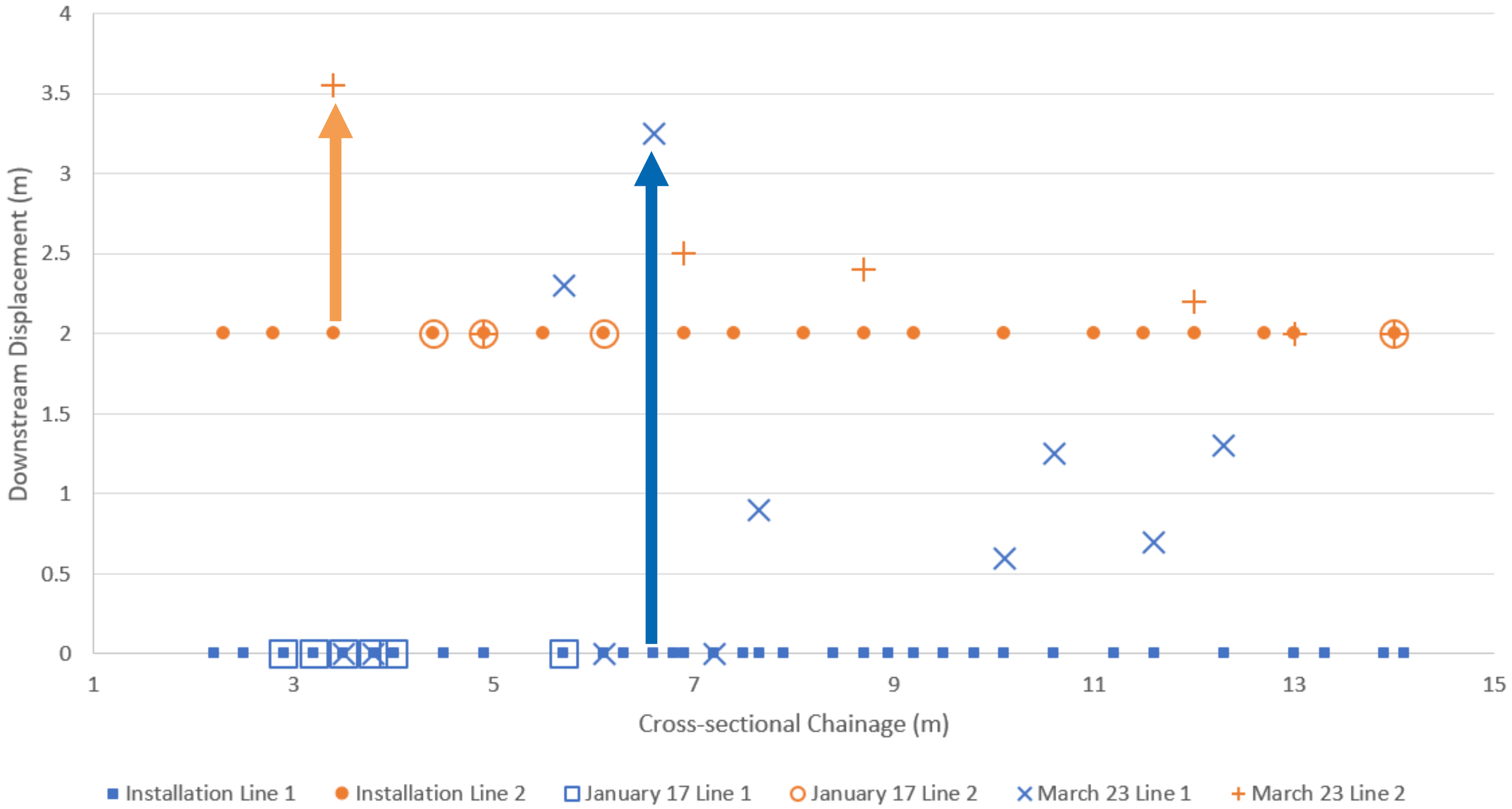
Theoretical Displacement

Comparing what would theoretically move using widely used sediment particle movement equations

Shear Stress Analysis

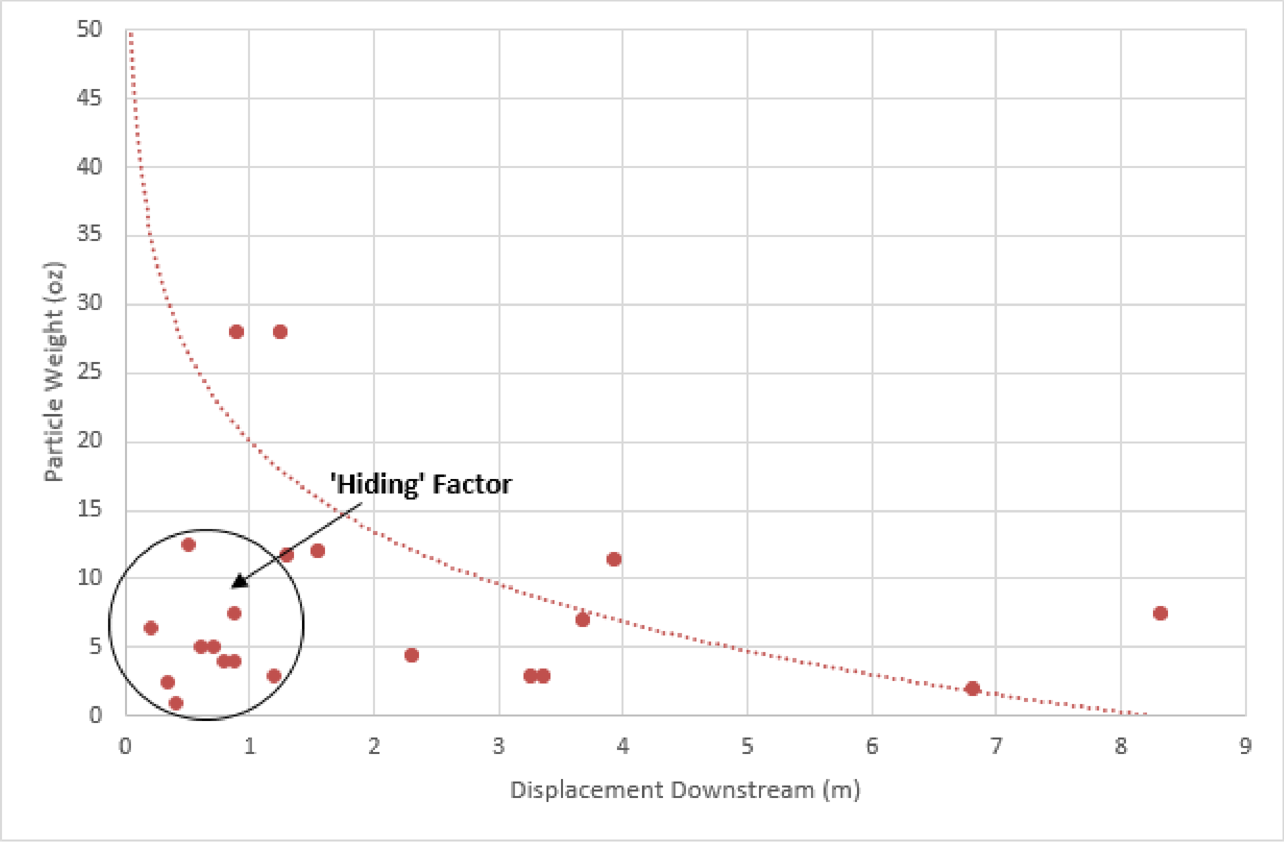


Particle Displacement



Particle Displacement

Relative form of bed substrate stability?



Influencing Factors

- Impact of ice conditions
- Local bed grade
- ‘Hiding’ factor
- Substrate integrity
- Timespan between mobilizing flow events

Conclusions/Observations

1. Critical shear stresses calculated for particles installed were exceeded by the maximum boundary shear stresses.
   - Corroborated current practice for use of tractive force equations using a conservative Shield's value

Bed state	Shields parameter, θ
Overloose (no structure)	0.05
Normal (weak structure)	0.06
Underloose (strong structure)	0.07
Underloose (very strong structure)	0.08

2. Not every particle moved! A portion of the sample remained stationary, suggesting stability.
3. The anticipated relationship between particle mass and downstream displacement was not consistent.

Conclusions/Observations

4. The size of a particle is relative to those surrounding it, which can influence the exposure to forces that can initiate displacement.
5. Over time, tracer particles were ‘buried’ and stabilized with fine substrate deposited by natural channel processes; and as such became established within the existing bed matrix.
6. Significant influence of local channel conditions (i.e. cross-section and gradient); variance in HEC-RAS model outputs (under-prediction in shear stress values)

Lessons Learned

- A well established bed veneer will resist entrainment beyond what current assumptions can predict
- The local hydraulics can be vastly distinct from modelled hydraulic values (conventional flood model)
- ‘Loose’ particles can gain stability under the ‘hiding factor’
- Additional sediment tracking would be beneficial to establish seasonal impacts

Thank you.