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Near-field of an experimental turbidity current triggered by an impinging water jet – a preliminary assessment

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Keywords — physical modelling, water injection dredging, sediment management

Introduction

The construction of dams in rivers impacts the environment at small to large temporal and spatial scales, and the impacts caused by the changes in sediment fluxes are a major concern. Although efforts have been made to develop more sustainable sediment management techniques, their poor predictability often hinders effective application. With this research, we aim at quantifying key sediment and hydrodynamic processes of an idealized and reduced-scale version of the water injection dredging technique, which can be applied to sustain sediment bypassing through dams. The application of this technique consists of (Winterwerp et al 2002) a) water injection into the bed, typically by a moving boat equipped with a jet array; b) mobilization and suspension of sediment from the bed; c) formation of a turbidity current that can transport sediment to distal areas by natural means. The processes involved in the application of this technique are commonly divided into spatial units, here defined as: injection and impact zone (position A, Figure 1), near-field (position B, Figure 1), and far-field (positions C, D, and E, Figure 1). Within a framework to link the momentum and sediment fluxes between two of these areas, injection and near-field (e. g. Sequeiros et al 2009), the first preliminary results on the near-field characterization of a laboratory experiment are here presented.

Methodology

The experimental setup (Figure 1) consists of a 4 m long, 2 m deep, and 22 cm wide flume; a hydrodynamic diffuser device exiting in a rectangular shape 3 cm high and 20 cm wide, approximately reproducing 2D jet boundary conditions; and a one meter deep deposit (ρ_{bulk} ~ 737 kg/m^3, i.e. 737 kg of sediment per m^3 of deposit) built with lightweight sediment ($\rho_{sediment}$ = 1581 kg/m^3; D50 = 0.222 mm[1]) and constant slope (α = 0°). To measure velocity and concentration profiles, four Ultrasonic Velocity Profilers (UVPs), one Acoustic Doppler velocimetry (ADV), and two Conductivity Concentration Meters (CCMs) were placed at four longitudinal locations. For the experiment presented in this piece of work, the jet boundary conditions were: discharge = 3 l/s and impinging angle = 45°.

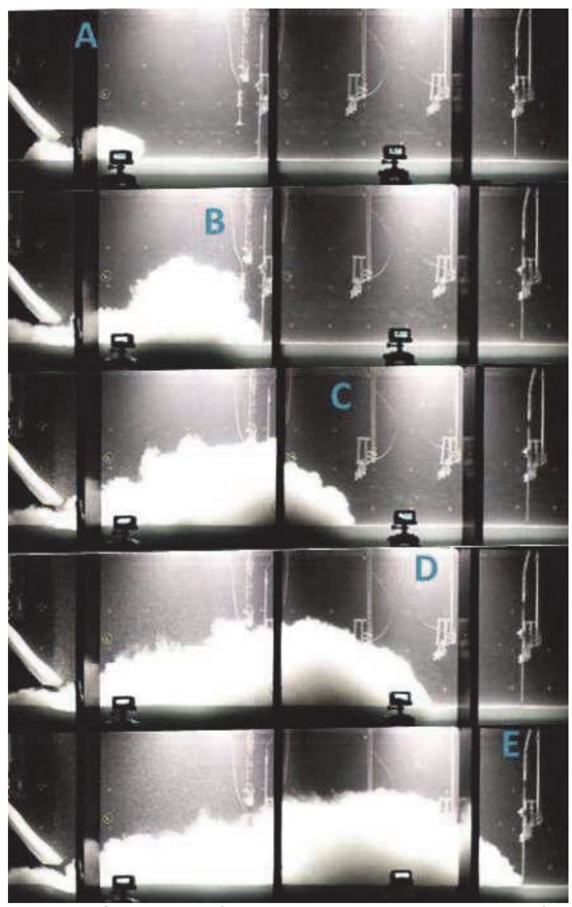

Figure 1. Snapshots of the experimental setup instants after the experiment started (A), and after approximately 5 (B), 10 (C), 15 (D) and 20 (E) seconds after the first snapshot.

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[1] Approximately, 4% of the grain sizes are between 0.150 - 0.180 mm, 76% between 0.180 - 0.250 mm, and 19% between 0.250 - 0.300 mm.

Preliminary results

In Figure 1, the development of the turbidity current after the jet impingement is shown in a sequence of snapshots (A to E). Downstream the near-field, the head of the turbidity current travelled with a velocity of ~ 8.5 cm/s. The impact zone at approximately the instant when the snapshot E was taken is shown in greater detail in Figure 2. Roughly, an erosion rate of 40 g/s (across the width of the flume) at the impact zone, triggered a turbidity current with a mean velocity profile at the near-field as shown in Figure 3.

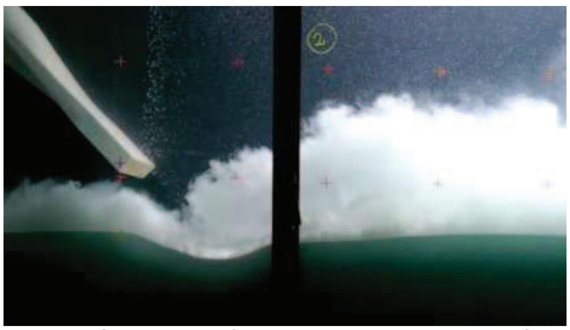

Figure 2. Scour result after approximately 23 seconds from the start of the experiment (snapshot E, Figure1).

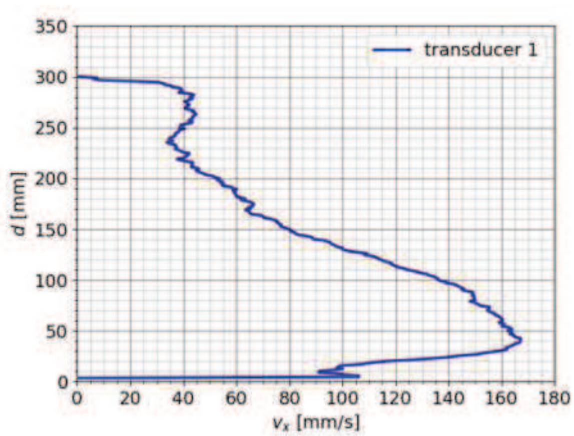

Figure 3. Mean velocity profile at position B (Figure 1). The velocities were averaged from t ~ 7 s (snapshot B, Figure1) to t ~ 23 s (snapshot E, Figure 1) from the start of the experiment.

Current and future work

Current and future research aim to characterize the near-field turbidity currents triggered in various initial (bed slope) and boundary conditions (jet discharge and impinging angle) and to link these near-fields with the injection characteristics.

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