Effect of geometrical configuration of sediment replenishment on the development of bed form patterns in a gravel bed channel

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EGU2016-6208

Introduction

Dams interrupt the longitudinal continuity of river reaches since they store water and trap sediment in the upstream reservoir (Fig. 1a, 1b). **Sediment replenishment** is used for **restoring** the **continuity** in rivers and for reestablishing the sediment regime. Artificial deposit of finer sediments are placed along these disturbed reaches (Fig.1c).

Objective

A **new** approach with **multiple** sediment **replenishment** is herein performed. The effect of different **geometrical configurations** of sediment replenishment on the evolution of the bed morphology by systematic laboratory experiments is evaluated.

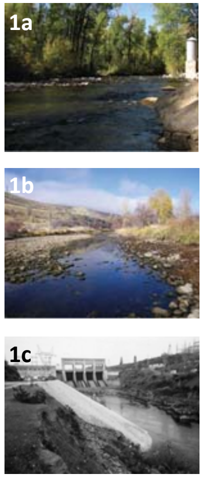


Figure 1: (a, b) river condition upstream and downstream the Echo Dam, Utah (USA); (c) sediment replenishment below Keswick Dam along the Sacramento river (USA) [photo by Kondolf G.M.]

Experimental installation

Channel dimensions: 15*m* long, 2.5*m* wide and 0.7*m high*, divided in 2 identical channel (Fig. 2b).

Trapezoidal cross-section (Fig. 2c).

Data sets: laser and camera, on a moveable carriage (Fig. 2a).

Water depth=replenishment height

Ratio 100% of submergence (Fig. 2c).

Constant discharge during the entire test (3 hours duration).

Replenishment on both banks, with a constant volume of 0.007m^3.

Grain size replenishment:

$d_{60}<d_{mr}<d_{80}$ (Fig. 2e), according to ecological needs for alpine fishes.

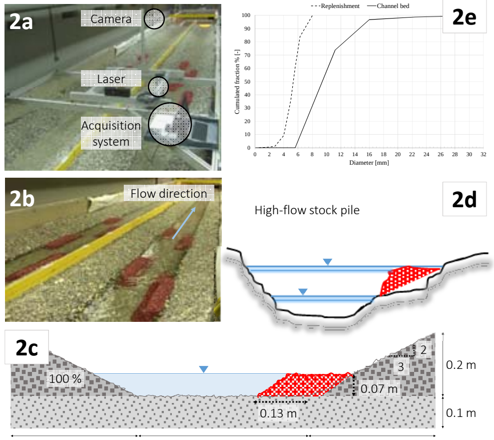


Figure 2: (a) channel instrumentation, (b) replenishment of volume on channels, (c) cross-section and flow condition, (d) replenishment placement, (e) grain size distribution for bed and replenishment

Configurations and parameters

Alternated (B, C and E) and parallel (A, D and F) replenishment configurations (Fig. 3). Following the tested parameters:

$$CS\ [\%] = \frac{\sum(A_{or})}{\sum(A_{oi})}$$ → Covered surface

$$NDC\ [\%] = \frac{C_b - C_{b,min}}{C_{b,max} - C_{b,min}}$$ → Compactness

$$OCR_x\ [\%] = \frac{\sum(Red\ grains\ along\ x) * pixel\ area}{w}$$ → Occupation ratio

The area of interest A_{oi} corresponds to the channel bed (0.4*m* x 10*m*) and A_{or} corresponds to the area covered by red grains. C_b, $C_{b,min}$ and $C_{b,max}$ refer to the bed form connecting bounderies as proposed by Bribiesca (1997).

The channel width, w, is equal to 0.4*m*. The observational length is indicated as x, and corresponds to 10*m*.

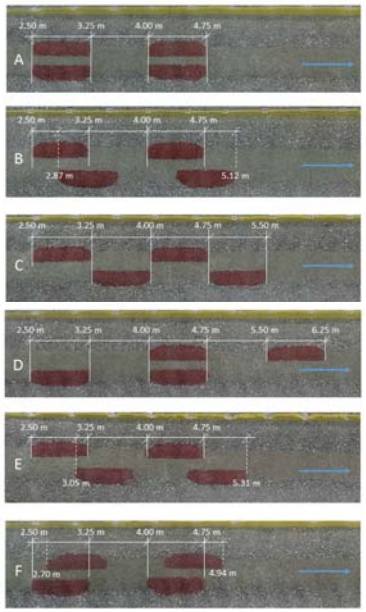
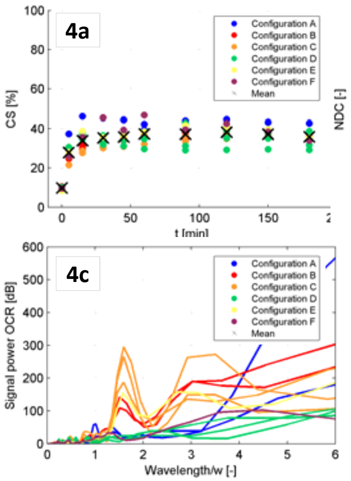


Figure 3: (from the top) performed configurations at EPFL. Replenishment length of 0.75m, height of 0.07m and width of 0.13m per each volume. Distance along the channel length. Flow direction from left to right.

Results

The **CS** values varies between 20% and 40%. The highest value are obtained for configuration B (Fig. 4a). The **NDC** of bed forms is higher for configurations B and C (Fig. 4b). The **OCR** distributions show peaks of denser replenishment areas for **alternated configurations**. Smoother distributions result for parallel replenishment geometries (Fig. 5b).

The Welch's function, applied to the OCR-signal, show a more pronounced periodicity for alternated configurations (Fig. 4c). The **wavelength** of these bed forms is equal to the **replenishment length**.



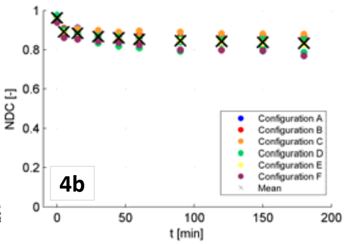


Figure 4: (a) covered surface CS, (b) compactness NDC, (c) power spectrum density of OCR-signal; for all the configurations and ratio of 100% submergence

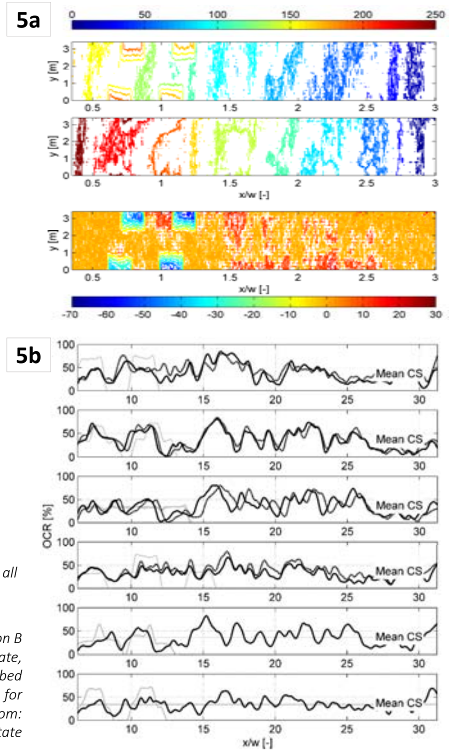


Figure 5: (a) laser measurements for configuration B and ratio of 100% submergence: (top) initial state, (middle) final state after 3 hours, (bottom) bed elevation changes;(b) occupation ratio distribution for all the configurations (from top to bottom: A,B,C,D,E,F). Gray line initial state, black line final state

Conclusions

The **erosion** of the replenishment is mainly occurring during the first **45 minutes**, for then decreasing and attending an equilibrium state. A ratio of **100% submergence** of replenishment volume is necessary to obtain a complete volume erosion and transportation of eroded grains (Fig. 5a). The replenishment material is spread on the entire channel bed applying parallel configurations of volumes.

Parallel configurations can be useful for obtaining a diffuse **bed fining**. More compacted cluster and bigger portion of the channel bed are affected when placing alternated configurations.

Alternated replenishment configuration may be preferred in order to **reestablish bed form** morphology downstream of dams since they enhance the creation of bed pattern. These bed forms can be used as new **spawning grounds** by fishes.

References

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Acknowledgements

This research is funded by the Federal Office for the Environment, Switzerland.