Turbulent flow structure upstream of an isolated boulder: Implications for sediment deposition

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Abstract In mountainous gravel-bed rivers, boulders stimulate the development of unique bed morphological features in their vicinity due to their effects on local flow structure. To better understand turbulent flow structure in the vicinity of boulders, volumetric particle image velocimetry (PIV) measurements were made in a laboratory flume upstream of an isolated and fully submerged spherical boulder. The mean velocity profile results help explain the sediment deposition observations made in earlier studies at similar conditions.

Keywords: turbulent flows, boulders, relative submergence, gravel-bed rivers, sediment deposition

Methods

The experimental setup and flow conditions are designed to mimic an isolated and fully submerged boulder in a gravel-bed river.

- An isolated boulder (55-mm diameter sphere) is mounted atop a rough, porous bed (18.5-mm diameter spheres)
- Boulder relative submergence, H_w/H_b = 2.18

Table 1: Experimental conditions.

H_w/H_b (-)	H_w (m)	U (m/s)	Fr (-)	Re (-)	Re_b (-)
2.18	0.12	0.822	0.76	3.9×10^5	4.5×10^4

A TSI, Inc. volumetric particle image velocimetry (PIV) system (Fig. 1) is used with four cameras and a dual-pulsed Nd:YAG laser. Three-component velocity vectors are measured within the laser-illuminated control volume.

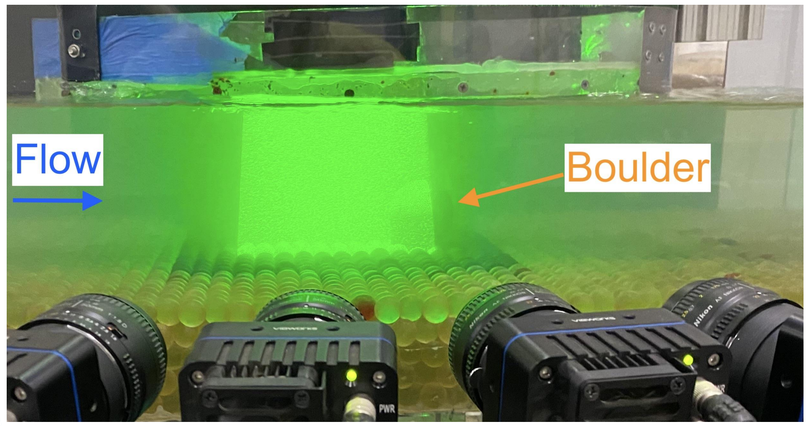

Figure 1: Photo of the volumetric PIV setup.

Results

Mean velocity profile results:

- Gradual flow deceleration (Fig. 2a)
- No near-bed flow recirculation (Fig. 2a). This helps explain limited sediment deposition observed at similar conditions (Papanicolaou et al., 2018)
- Inflection of $\overline{w}$ profiles at the stagnation height (Fig. 2b)
- Notable negative $\overline{w}$ near the bed suggests flow intrusion into the porous bed (Apsilidis et al. 2016)

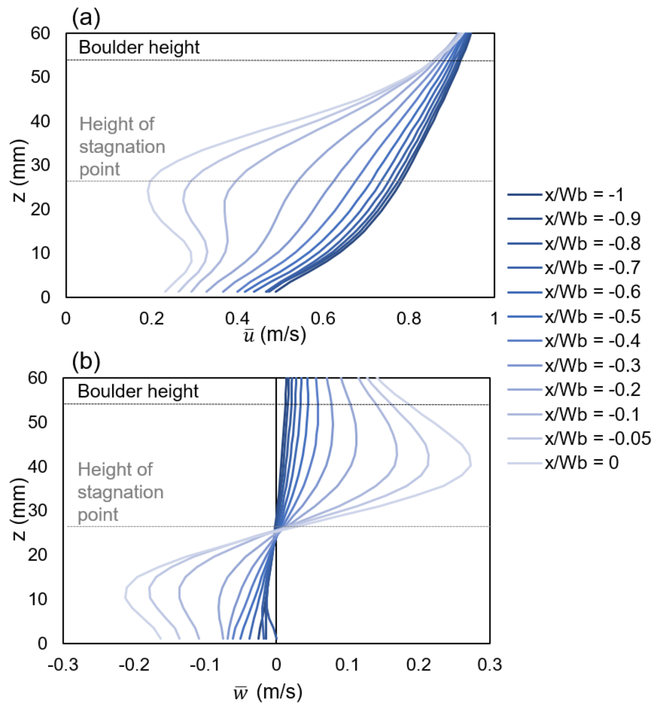

Figure 2. Mean velocity profiles near the boulder. (a) Streamwise velocity, $\overline{u}$; and, (b) vertical velocity, $\overline{w}$.

Conclusions

- For the present setup and conditions, no mean flow separation occurs upstream of the spherical boulder.
- Notable intrusion of surface fluid mass into the subsurface porous bed may occur near the boulder.

Future Research

- Comparisons with partially submerged conditions could help improve understanding of bed morphology around boulders in mountainous gravel-bed rivers

Figure 3. Boulder Creek, Boulder, Colorado, USA.

References

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