Advances in the measurement of mud flocs within turbulent suspensions in both the laboratory and field (Abstract: EP51C-1653)

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Introduction

Predicting the size and settling velocity of sediment under the influence of flocculation is crucial for the accurate prediction of mud movement and deposition in sediment transport modeling of environments such as agricultural streams, large coastal rivers, estuaries, river plumes, boundary currents, and turbidity currents.

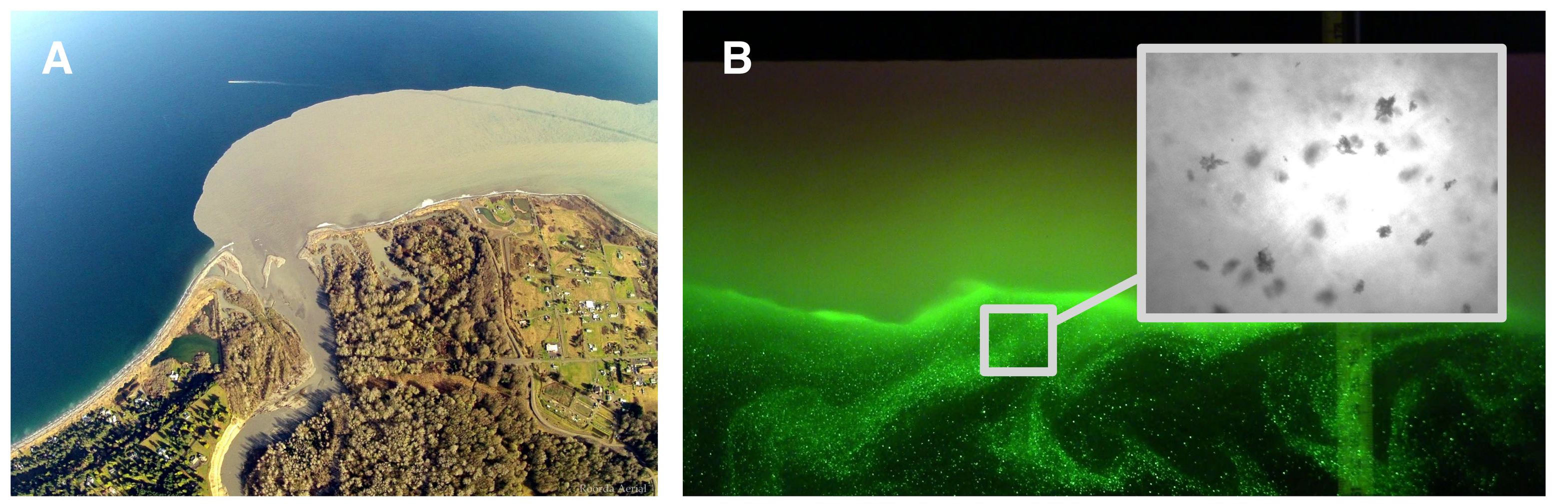

Figure 1: Muddy sediment flocculates in natural environments (such as in river plumes). Predicting mud settling velocity depends strongly on predicting the size of mud flocs. (A) the Elwha River plume, and (B) profile of sedimentation from a vertically stratified plume.

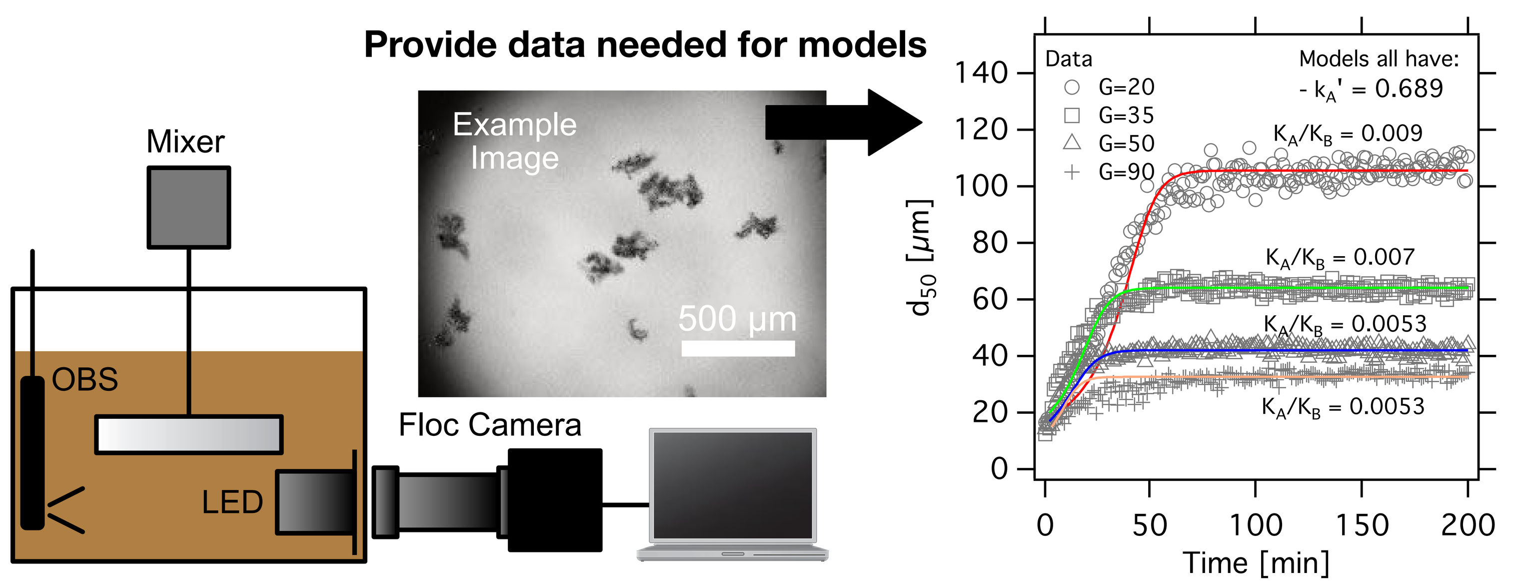

Figure 2: Hi-fidelity floc size measurements are needed to understand the factors that influence the change in flocs size. Such data can build understanding and allow for the development and calibration of floc size models.

Measurement of flocs with camera systems generally provide the best avenue for preserving floc structure and obtaining accurate information about true floc sizes. However, capturing images of flocs in swirling turbulent flows can be difficult and often limited to suspensions where concentrations are low (< 100 mg/L). As a result, models that account for the influence of flocculation on mud settling velocity are based on sparse data that often present non-congruent functionality in floc size and settling velocity with basic influencers such as suspended sediment concentration.

Study Aim

Here we present developments in image acquisition systems that allow for measurement of floc size distributions **in turbulent suspensions approaching 500 mg/L**. At the heart of these developments are the introduction of a simple flow-through cell, modern digital sensor technology, and automated image processing. The combination of these elements allows for high-resolution times series of floc size populations to be measured in turbulent suspensions over a broader range of mud concentration without the need to transfer samples to a separate imaging container.

Testing the flow-through cell in the laboratory - Setup

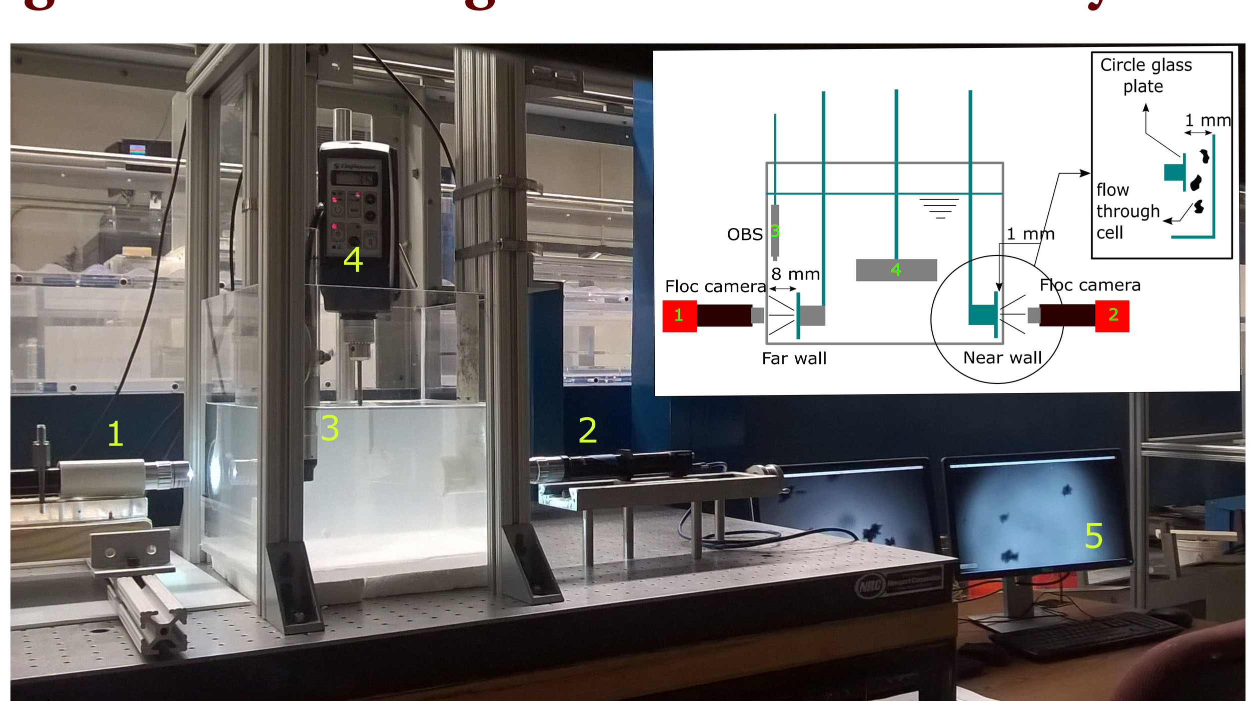

Figure 3: Setup for testing of the "Near Wall" flow-through cell.

Testing the flow-through cell in the laboratory - Data

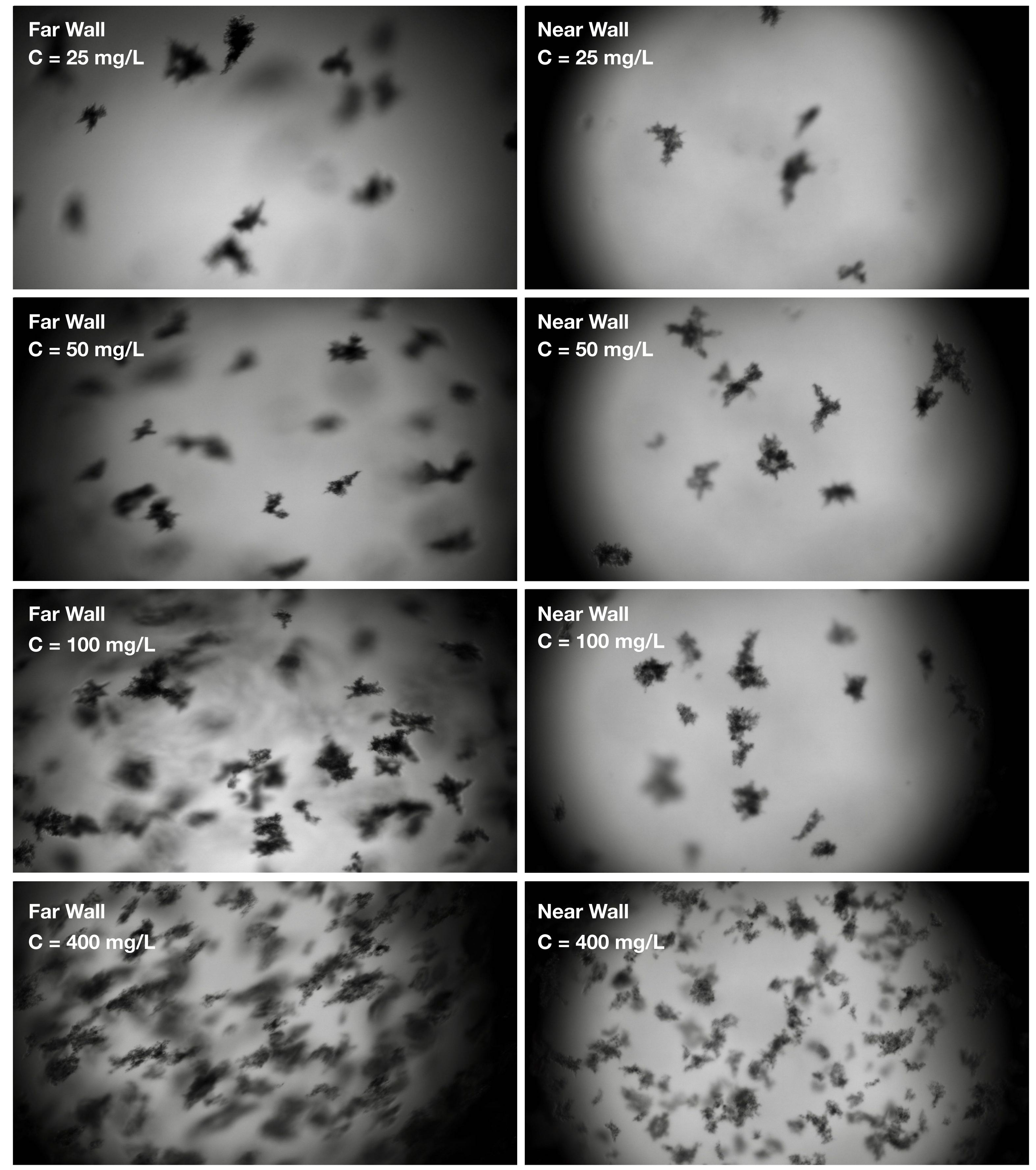

Figure 4: Images of flocs in a well mixed suspension using the Near Wall (new method) and Far Wall (old method) setups under different suspended sediment concentrations. At about 100 mg/L, it becomes difficult for automated image processing schemes to identify and measure individual flocs in the Far Wall setup (lefthand column of images). This problem is alleviated with the small flow-through cell created with the Near Wall method (righthand column of images).

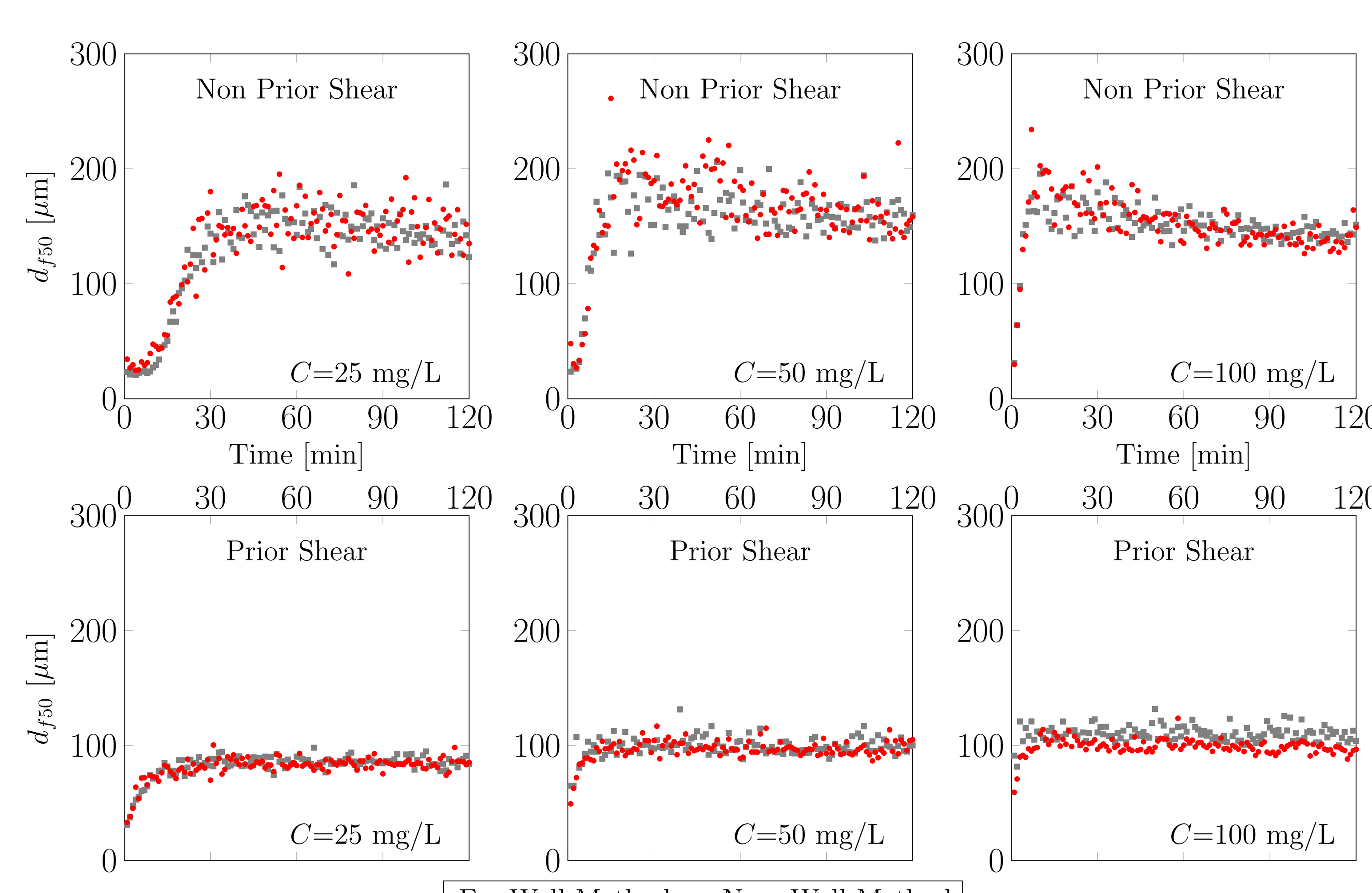

Figure 5: Time series of the floc size d_{f50} from both the Near and Far wall setups at different concentrations and initial conditions. The data shows that the two methods are comparable — indicating that the flow-through cell does not modify the floc size as they pass through the cell.

Field camera system

That basic elements of the laboratory system (digital sensor + microscope lens + backlighting + flow-through cell) was adapted for field by modifying a GoPro Hero 5 to accommodate a c-mount lens and waterproofing the package. The GoPro was chosen for its excellent sensor, internal power supply, relative low cost, and built-in controller and data storage abilities. As with the labatory camera, the field system uses an objective lens (Bausch and Lomb 2.25x0.04) to provide magnification up to 1.0 μm/pixel with a field of view of 3 x 4 mm. Illumination is provided by a battery-powered LED, and an adjustable flow-through cell is used to limit the number of particles between the light source and camera sensor.

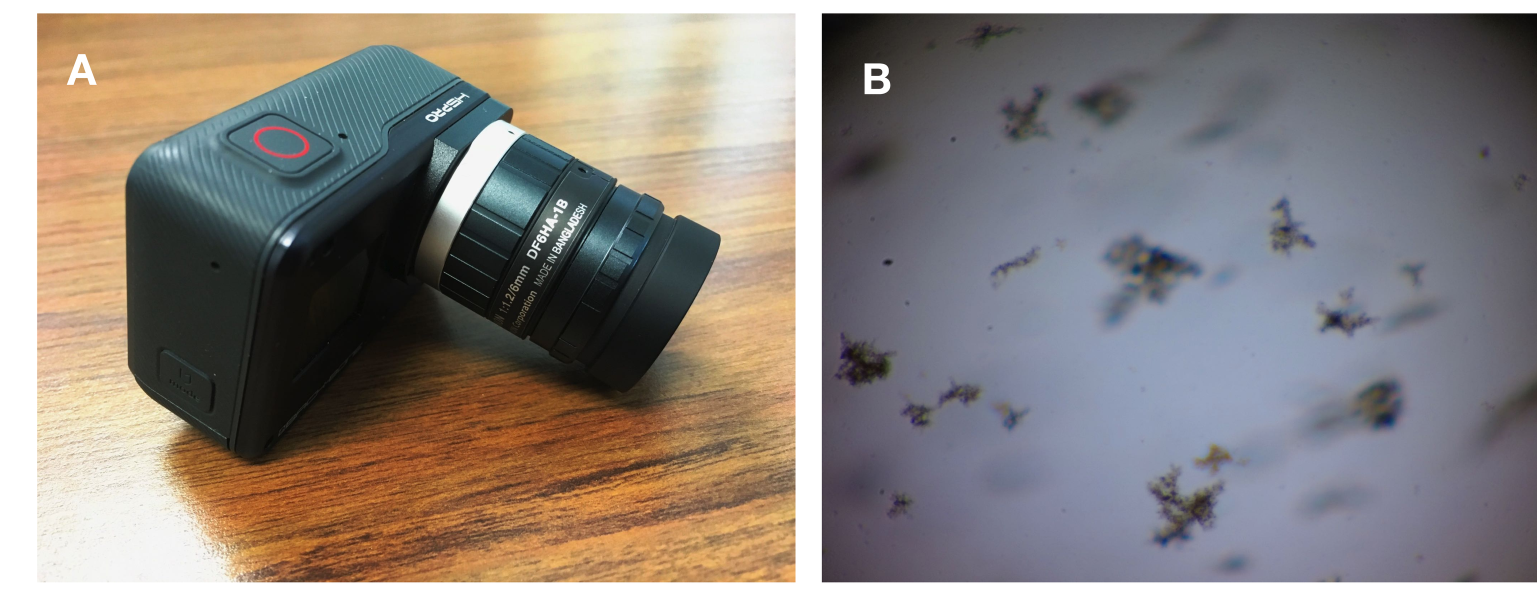

Figure 6: (A) GoPro Hero 5 with a c-mount lens. (B) image captured with the GoPro and Bausch and Lomb 2.25x0.04 lens in a laboratory mixing tank.

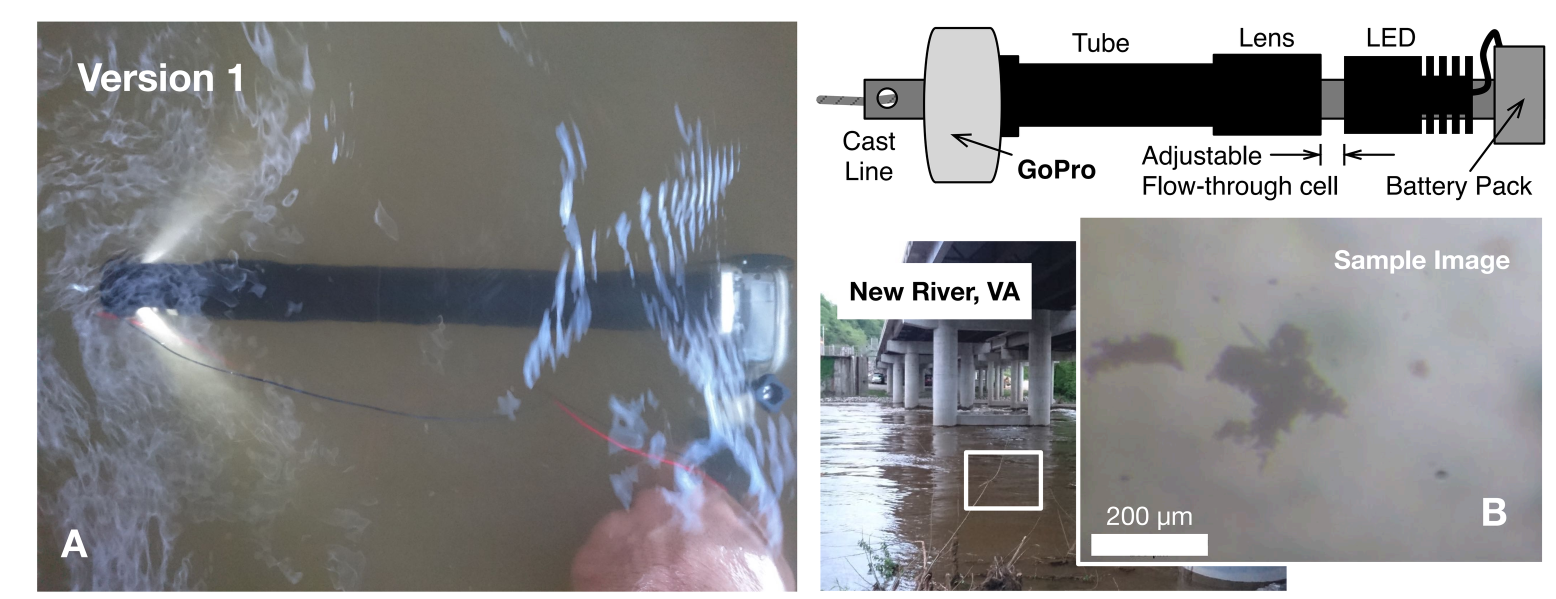

Figure 7: A first test of the GoPro system in the field. The test was conducted on the New River near Radford, VA during a moderate flow event. For this test the camera was held by hand under the water and the light was powered by an external power supply. The system can easily be completely self contained (no communication or power lines needed) by attaching a batter back for the light source. The system has been tested to a water depth of 12 m for 24 hrs.

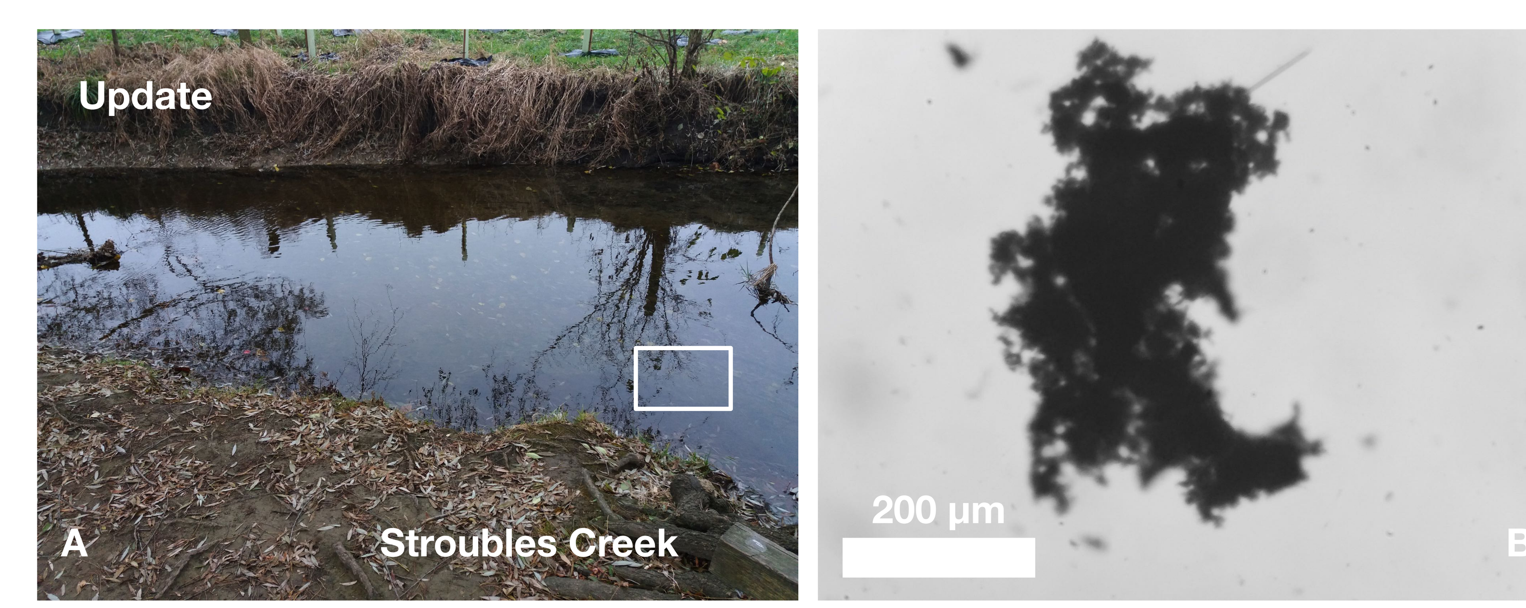

Figure 8: A modified flow-through cell was developed to allow for sharper images of flocs. (A) sampling location on Stroubles Creek near Blacksburg, VA. (B) Large freshwater floc imaged by the camera.

Key Findings

1. The flow-through cell can provide better floc imaging conditions without transfering flocs to a separate imaging or settling chamber. This preserves the floc size and structure, thereby allowing for more accurate measurements of floc size, and it allows for higher temporal resolution data.
2. Laboratory testing of the thickness of the flow-through cell showed that the gap thickness has no impact on floc size as long as the gap is 4 to 5 times larger than the average floc size.
3. The flow through cell allows for *in situ* measurements in concentrations up to ≈ 500 mg/L.
4. A modified GoPro Hero 5 serves as an excellent foundation for a field-ready floc camera.