Threshold for Everglades Sediment Entrainment Determined by Flow Enhancement in a Field Flume

Judson W. Harvey*, Gregory B. Noe, Laurel G. Larsen, Daniel Nowacki* and *Raymond Schaffranek*
[1]National Research Program, U.S. Geological Survey, Reston, VA, USA

Conditions for mobilizing organic Everglades sediment were determined in an experimental flume facility constructed by the USGS at a site in the central Everglades (Water Conservation Area 3A, 26° 03′ 23.7″ N, 80° 42′ 19.2″ W). The experimental flume is 7.3 meters long and 1 meter wide with boundary walls constructed of PVC sheets inserted into peat and supported by vertical and horizontal sections of angle iron on the exterior, which protected the interior vegetation, peat, and flocculent organic sediment from disturbance. The flume was aligned parallel to the dominant flow direction in a Nymphaea odorata slough with the upstream end left open. At the time of the experiment the average water depth in the flume was 31.7 cm. To enhance flow the downstream end of the flume was sealed and water was pumped water from three withdrawal wells just upstream of the end wall. After monitoring for entrainment of suspended sediment at the ambient flow speed (0.38 cm s^{-1}) the end wall was emplaced and flow speed was elevated in four steps (each lasting approximately 50 minutes) to the four higher speeds (1.73, 3.32, 6.37, and 6.05 cm s^{-1}). Flow speeds are based on duplicate velocity profiles acquired at a distance of 4.4 m downstream using two acoustic Doppler velocimeters (ADV) deployed side-by side (to the left and right of the centerline of the flume).

During each of the sequential flume runs at a different velocity the entrainment of sediment was monitored with two instruments, the first being a laser diffraction particle size analyzer (LISST-100a) deployed vertically such that a measurement was made in the middle of the water column (16 cm above the flocculent detrital sediment bed) that quantifies particles between the sizes of 1.25 and 250 μm. The second instrument was a digital floc camera viewing at 8 cm above the bed that quantifies particles larger than 14.50 μm. We also sampled suspended sediment by pumping water from three depths in the water column, followed by 0.2 μm pore size filtering and gravimetric analysis.

Under ambient Everglades flow (prior to flow enhancement) the mass-weighted and volume-weighted concentrations of suspended sediment were very low (0.51 mg L^{-1} and 0.43 μL L^{-1}, respectively), and the mean particle size of suspended sediment was 24 μm. Enhancement of flow velocity had the effect of increasing the volume concentration of suspended sediment by approximately a factor of five and the mean particle size by approximately a factor of three by the end of the experiment. Two distinct periods of elevated suspended sediment concentration were apparent: an early entrainment pulse during the first and second elevated flows and a late pulse during step four. The LISST detected an increase in the mean diameter of smaller particles from 24 μm at ambient flow to 66 μm at the first elevated flow velocity, and ultimately to 75 μm at the highest elevated flow velocity. The digital floc camera detected an increase in mass-weighted mean diameter for larger particles from 160 μm at ambient flow to 305 μm at the third elevated flow velocity, and ultimately to 279 μm at the highest elevated velocity. Suspended particle size differences and suspended particle concentration frequency differences between the pulses indicated that suspended sediment was entrained on the first elevated velocity step was from a source of relatively small organic particles associated with epiphyton on plant stems. The relatively large particles of flocculent detrital matter from the bed were not entrained until the third elevated velocity step. The smaller size class of particles detected by the LISST was the

dominant contributor to total suspended sediment concentrations at ambient and higher flows. The pool of stored particles in the smaller size-class also is apparently very large because there is only limited evidence of depletion during the experiment. Entrainment of the class of larger floc particles from the bed becomes significant to total volume-weighted concentrations between a threshold velocity of 3.3 and 6.4 cm s^{-1}. Our field flume experimental data were consistent with recent numerical modeling of bed shear stress (predicted threshold = 1.0 x 10^{-2} Pa bed shear stress at a velocity of 5.2 cm s^{-1} in water 32 cm deep) and was also consistent with laboratory flume entrainment experiments.

A summary of experimental finding and implications for restoration include:

- Average ambient velocities in the Everglades are typically on the order of 0.3 cm s^{-1} at our site in WCA-3A and 0.7 cm s^{-1} in Shark Slough with a few locations averaging over 1 cm s^{-1}. Our field flume experiment with enhanced flow determined that relatively fine particles associated with plant stems begin to be entrained at a flow velocity between 0.38 and 1.73 cm s^{-1}, in other words, at flow velocities that are characteristic of the present-day Everglades. Fine suspended particles are important in carbon and phosphorus transport and cycling, although their role in ridge and slough landscape processes remains uncertain.
- Entrainment of the larger particles of floc from the sediment bed began at substantially higher velocities (between 3.3 and 6.4 cm s^{-1}) that are rarely measured in the present-day Everglades. Although a detailed assessment of velocities expected in a restored Everglades may not yet be available, we suspect that the relatively high velocities for floc entrainment reported above are likely only be reintroduced for short periods of time and possibly only in small areas of a restored Everglades, i.e. similar to the velocity increases expected from severe storms.

Contact Information: Judson Harvey, National Research Program, U.S. Geological Survey, 12201 Sunrise Valley Drive, Reston, VA 20192 USA, Email: jwharvey@usgs.gov