Sediment Trap Efficiency

Objectives and Expected Significance

The objective of this parameterization experiment is to determine the efficacy and efficiency of a commonly used best management practice (BMP) in the logging industry: sediment traps. Using a rapid and inexpensive experiment, we will develop an efficiency curve—a relation of the fractional reduction in sediment flux to how full the sediment trap is—that can be used to inform landowners whether and when these BMP are performing in the expected manner. In addition, samples taken during the experiment will provide information about the sizes of particles that are captured in or flow past the trap at differing flow rates.

Background and Motivation

Sediment traps are ubiquitous in industrial lands. A typical sediment trap is dug out by an excavator at the end of a ditch line as a final treatment of water quality before sediment-laden water from the road and ditch line is released to a water body; for longer ditch lengths, multiple sediment traps may be dug at periodic intervals. The traps vary in size but, on average, are approximately 4 cubic feet. The Washington Department of Natural Resources Forest Roads Guidebook (2018) states that sediment traps must be frequently monitored and maintained to keep them functioning properly.

As common as sediment traps are, though, few data are available regarding their efficacy (e.g., Dube et al., 2004). Fortunately, the basic principle governing the behavior of sediment traps is the settling of particles (i.e., sediment) as the velocity of water is temporarily slowed (see Figure 1). Conceptually, this design contrasts particle-settling-time versus water-residence-time. While such a design could be tested in a real ditch with trials over the course of several years, a more cost-effective approach can be used for bounding expected performance in a lab-like setting. We propose a more active experimental format to test the performance of this treatment rapidly and inexpensively. Furthermore, the Major Experiment of this Project has implemented sediment traps as one of the field-tested BMPs, and those results can be compared to the findings of this Parameterization Experiment.

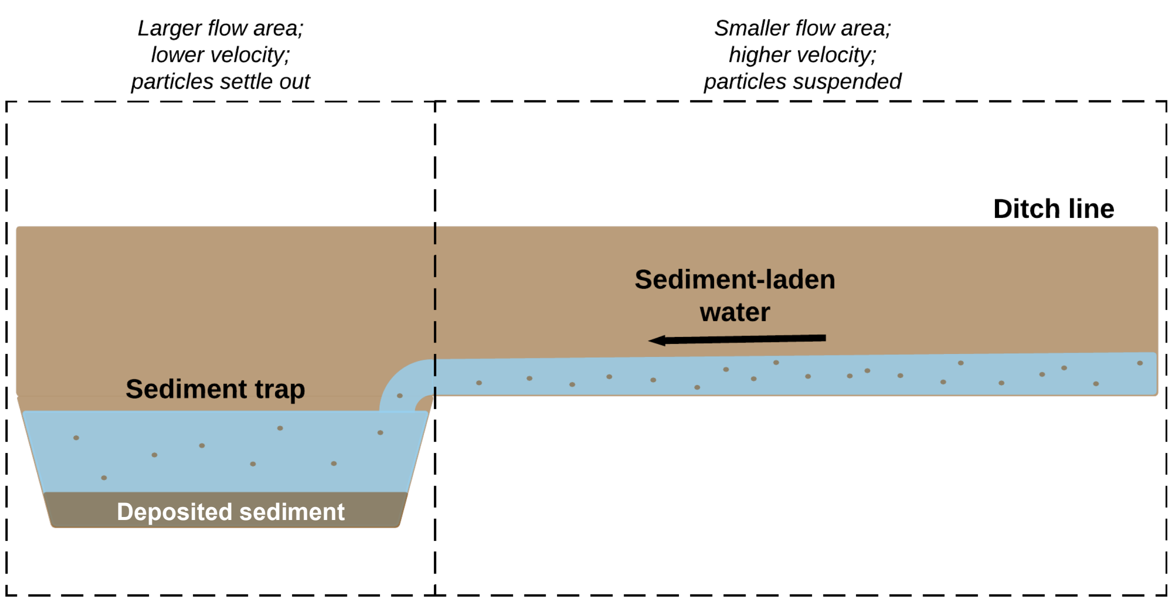

Figure 1. Ditch line with sediment trap schematic. In the ditch line, the flow area is small, which means the velocity of the sediment-laden water is high. Once this water hits the sediment trap, the velocity decreases because the flow area increases, thus allowing the sediment particles to settle out.

Experimental setup

This experiment is set to take place in June, 2024, and will be conducted in a location with readily available water and capacity to weigh sediment[1].

The basic design is shown in Figure 2. We will use half of an oil barrel on its side as the sediment trap (approx. 25 gallons or 3.3 cubic feet). It will be cut with 2-inch higher sides at the flume end, so that water flow remains relatively smooth and all flows out the exit end, best resembling an actual sediment trap in a ditch. The half-barrel will be set nearly level with a 10- to 15-foot length of 20-inch wide wooden flume set on a 3% grade feeding it. The flume will be fed water by a sediment-free water source (e.g., a tank used for filling fire trucks). Pre-sieved sediment from the siltstone lithology in the Major Experiment will be introduced into the flume for the water to carry to the trap. The sediment trap will be suspended from an automotive engine hoist and weighed using a hanging scale.

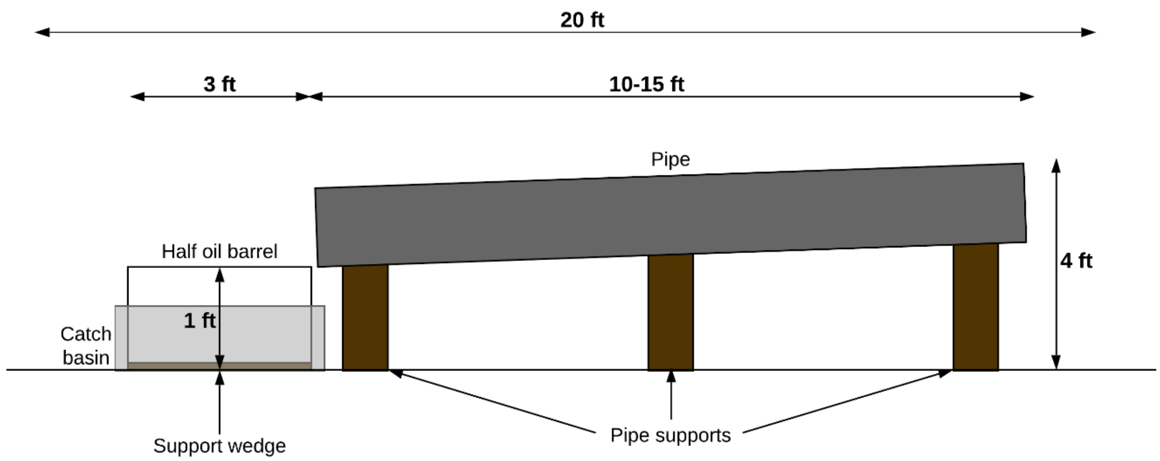

Figure 2. Experimental setup schematic.

Approach

1. Prior to running any water
    a. Dry and sieve sediment to obtain fraction of sediment finer than 2 millimeters
        i. We will sample the sediment for grain size distribution (GSD) prior to sieving
        ii. We will need approximately 5 cubic yards of sediment to be assured of sufficient sieved sediment for the experiment
2. Short experimental runs of one to four hours each will be carried out for 3, 10 and 50 gallons per minute (50th percentile flow is 2.3 gpm; 92nd percentile flow is 10 gpm; 99th percentile flow is 50 gpm)
    a. The changing weight will be used to estimate the capture efficiency of the sediment trap for each of these flows
    b. After the flow stops, a 20-minute settling time will be allowed, followed by a turbidity measurement, sampling of the turbid water, siphoning off the water, and sampling of the settled sediment for particle size analysis
    c. Sediment will be introduced at a rate of 5 grams per liter

3. Efficiency versus available volume experiments will be conducted at a flow rate of 10 gpm
    a. Fill the sediment trap half full with sorted gravel and interstitial sand, then measure efficiency as before. Do this again starting from three-quarters fill.

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[1]Most likely the Rayonier Pacific Resource Unit in Forks, WA.

b. The changing weight will be used to estimate the capture efficiency at that flow, and to determine the final (i.e., asymptotic) efficacy when the sediment trap is full.
c. After the flow stops, a 20-minute settling time will be allowed, followed by a turbidity measurement, sampling of the turbid water, siphoning off the water, and sampling of the settled sediment for particle size analysis.
d. Sediment will be introduced at a rate of 5 grams per liter.

Analysis

This experiment will give us data regarding sediment trap efficiency both instantaneously and over time. During the experimental runs, the sediment trap will be weighed continuously, which will give us an idea of how much sediment is held within the trap at any given time. These data will enable us to construct efficiency curves to see how the trap's efficiency changes, both for different flows and over time as it fills.

At the end of each experiment, the sediment in the trap will be weighed to give us an estimate of the trapped mass. The total mass—the mass of the sediment placed in the flume—will be based on the weight of the sediment along with the moisture content taken from 5 samples (placed in soil tins for lab analysis). The ratio of the trapped mass to the total mass is the sediment trap efficiency over time. This piece of the analysis will allow us to inform landowners when to empty their traps (i.e., empty the trap once it has hit 75% capacity to ensure continuous operability).

These experimental results will be interpreted by comparison of the tested particle sizes against particle size distributions captured in the tubs and actual ditchline sediment traps of the Major Experiment.

Equipment

- 10-15 feet of 20-inch-wide plywood or metal flume on 3% grade,
  - Flume roughness elements, plastic,
- Flume supports,
- Custom modified half an oil barrel,
- Automotive engine hoist
- Weighing apparatus, hanging scale
- Sieving apparatus,
  - Vibrating motor,
  - Screens,
  - Sediment introduction apparatus
- 5 cubic-yard of sieved sediment from siltstone lithology.
  - Approximately 5 cubic yards before sieving.
- Water flow meter and flow dissipator
- Box fans for soil drying.
- Tarp

References

Dubé, K., W. Megahan and M. McCalmon, 2004. Washington Road Surface Erosion Model, Manual and Appendices. For: Cooperative Monitoring, Evaluation and Research (CMER) Committee, Adaptive Management Program of the Forests & Fish Habitat Conservation Plan, Washington State. 56 p. Appendices A-E.

Forest Roads Guidebook, 3rd ed. WADNR, Olympia, WA, USA, 2018.