INFLUENCES OF OFF-HIGHWAY VEHICLES ON FLUVIAL SEDIMENT REGIMES

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Abstract: A wealth of research quantifies forest road erosion and resultant sedimentation impacts on stream water quality; however, little is known about the impacts of off-highway vehicles (OHV) on stream sedimentation. We monitored OHV impacts on sediment for a trail system in northern Georgia. Suspended and bed load sediment transport in a control and OHV impacted stream were significant and both experienced massive transport following torrential rains. Bed load transport capacity was similar for the OHV and control stream. Sedimentation in the OHV stream occurred in the sand and gravel size classes. Suspended sediment concentrations and transport on the OHV stream was many times greater than the control stream.

INTRODUCTION

Multiple use management of USDA Forest Service (USFS) National Forests includes OHV use on designated trails that must comply with federal law. National Forests in the southern Appalachians are within a few hours drive of millions of potential OHV users (Figure 1).

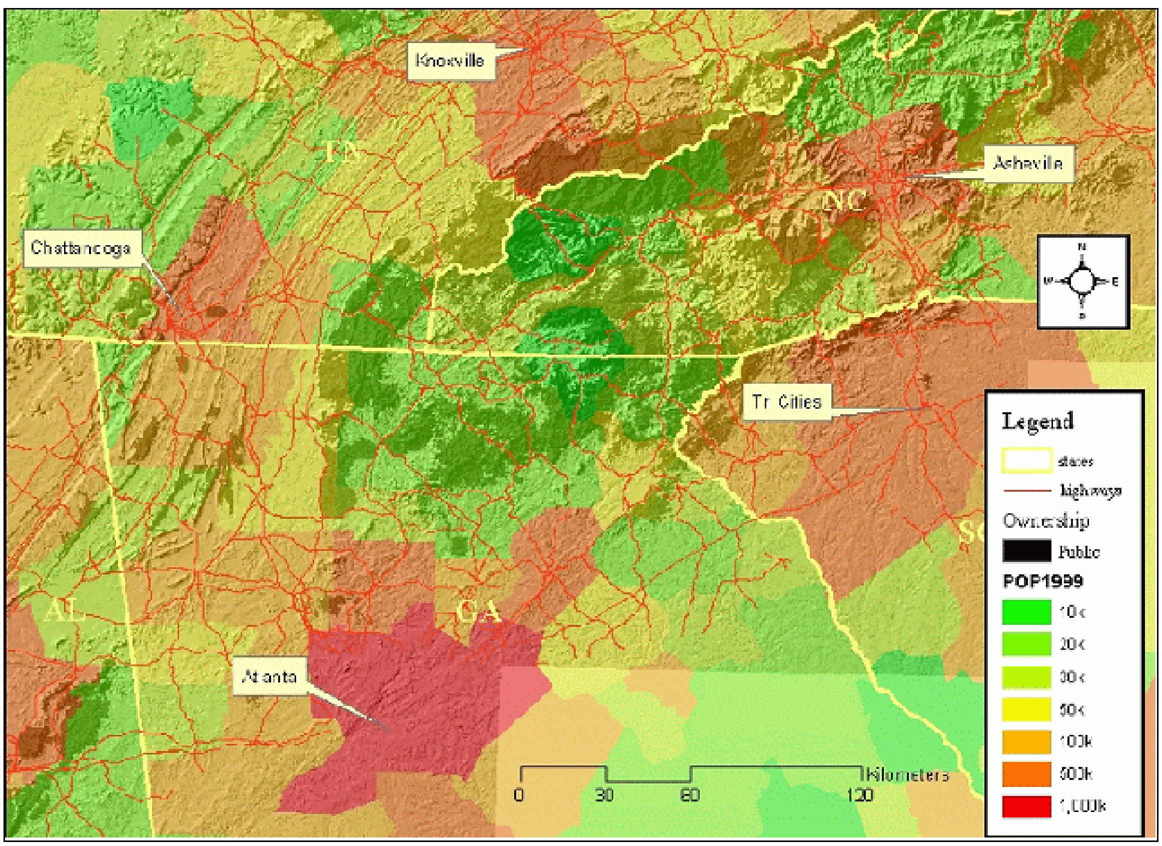


Figure 1 Population distribution on a per county basis for the southern Appalachians. Note, county borders are not indicated for neighboring counties (e.g., Atlanta metropolitan area is actually numerous counties).

While roads have been identified as a significant source of sediment in southern Appalachian streams (Riedel, et al, 2003), no research has investigated the influence of OHV trails and OHV use on stream sedimentation. While OHV trails are similar to roads, OHV trails have not been regularly maintained. In the southern Appalachians, average annual rainfall often exceeds 230 cm per year (Riedel, 2006) and fine grained micaceous soils are extremely sensitive to erosion (Riedel and Vose, 2005). Given these conditions, OHV trail has the potential to cause significant stream sedimentation in this region (Figure 2).

Figure 2 Typical erosion from an OHV trail in the southern Appalachians and resultant stream sedimentation.

The extent of OHV trail erosion on stream sedimentation in this region unknown (Riedel, et al, 2004). Given the widespread existence of illegal OHV trails, the extent of OHV trails on National Forests is also unknown. Consequently, Coweeta Hydrologic Laboratory and the Southern Region of the USFS initiated a study of erosion and sedimentation on an OHV Trail in the Chattahoochee National Forest of NE Georgia (Figure 3). This study was not designed to be a rigorous investigation of basic scientific principles; rather, the primary goal was to simply test and demonstrate field methods that may be easily used to rapidly assess and document the effects of OHV trails and OHV use on stream sedimentation.

Three sites were instrumented in a combined control vs. treatment and upstream vs. downstream design. We employed this approach as it allowed for determination of local and downstream impacts of OHV trails on stream sediment budgets. This was important because the Clean Water Act mandated cumulative effects (both offsite, and through time) be addressed when determining the impacts of a management activity on designated uses of water resources. The three sites were (Figure 3);

Site A: “OHV” treatment watershed (65 ha) with numerous trails and stream crossings,
Site B: “Control" watershed (35 ha) with no historic road or OHV impacts,
Site AB: “Downstream” watershed (104 ha) representing cumulative effects of site A.

OHV trails were in use during the study and no attempts were made to offset rider behavior, trail use or access to the trails. The trails affecting the sites in this study were official trails, and there were no illegal trails upstream of the sample sites.

METHODS

<u>Discharge and Suspended Sediments:</u> We installed automated pumping samplers and stage recorders on each study stream to monitor stream stage and collect water quality samples (Wagner, et al., 2000). We anchored inlets and pressure transducers to 1 m rebar pins driven into the streambed. Pressure transducers were placed in PVC stilling wells to minimize wave action.

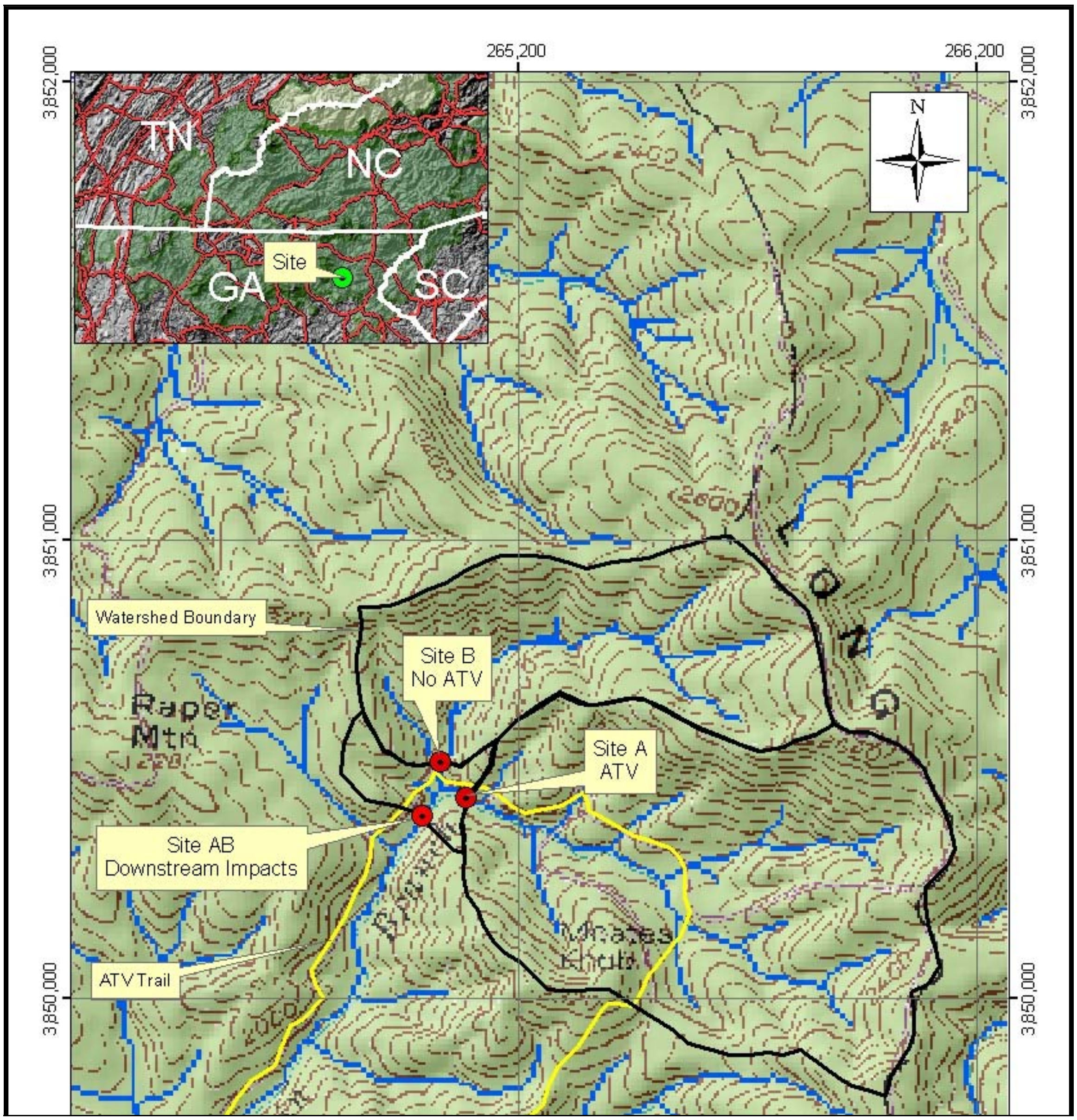


Figure 3 Location of OHV study sites. Here, ATV indicates all terrain vehicles (OHV).

Stage was recorded every 15 minutes and automatically corrected for variations in atmospheric pressure. Stage readings were validated weekly by manually surveying stage to each benchmark and measuring discharge (Buchanan and Somers, 1969). We developed stage discharge rating curves for each sampling site and programmed the pumping samplers to monitor stream flow using these rating curves. Samplers pumped samples to capture stream water quality during baseline conditions and storm flow conditions. The baseline regime collected samples on a flow proportional basis - sampling frequency increased with flow, whereas during storm flow, samples were pumped on a time proportional basis. We checked for bias in sampling via the fixed-point inlets using a DH-48 depth-integrated grab sampler to simultaneously collect depth-integrated grab samples on a weekly basis (Thomas, 1985). We then compared these to a simultaneously pumped sample. Total suspended solids (TSS) were analyzed to 1.5 μm by vacuum filtration (USGS, 1978a). Solids were combusted in a muffler furnace to determine clastic sediment as ash-free dry weight (USGS, 1978b).

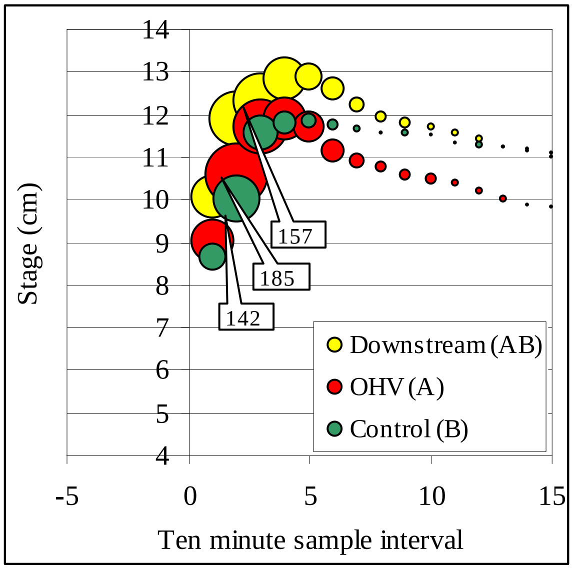
Bed Load and Bed Material Sediments: Multiple pebble counts were replicated along each site. At least one hundred particles were measured with each sample. "Blindfolded" sampling was used to minimize sampling bias. Measurement of the intermediate particle axis to approximately 1 mm was obtained with a pebble chart and ruler. Sand particles smaller than this were simply lumped as fine sand. Silt size particles were determined using the "feel" method (Brady, 1990). Bed load transport was sampled across a range of flows using a Helley-Smith bed load sampler. Stream stage and discharge were simultaneously recorded. To track scour and deposition on each site, we installed multiple transects of scour and deposition pins (Figure 4).

Figure 4 Example showing scour and deposition pin transect – note: pins are elevated to show locations. Actual pins were installed nearly flush with streambeds to minimize flow disturbance.

Each pin consisted of a 12mm washer on a 9 mm x 0.5 m rolled steel pin. Pins were installed by drilling through stream bed armor into bedrock. Each pin was capped with a small nut to prevent the washer from being removed during high flows. We allowed multiple storms to reestablish stream bed sediments following installation of the pins. Then, we measured washer elevations and sediment deposition to quantify stream bed scour and deposition on an event basis. Scour and deposition pins were only used during the summer months. Data obtained in autumn were not useful as organic debris accumulated on the pins causing irregular scour and deposition in the transect area surrounding the pins.

RESULTS

Suspended Sediment: There was strong hysteresis in suspended sediment data for all sites (Figure 5a, Figure 5b). Peak suspended sediment concentrations over the study period were 30% and 10% higher for the OHV and Downstream sites, respectively. Over the course of samples, suspended sediment yields averaged 18% and 15% higher (Figure 6).



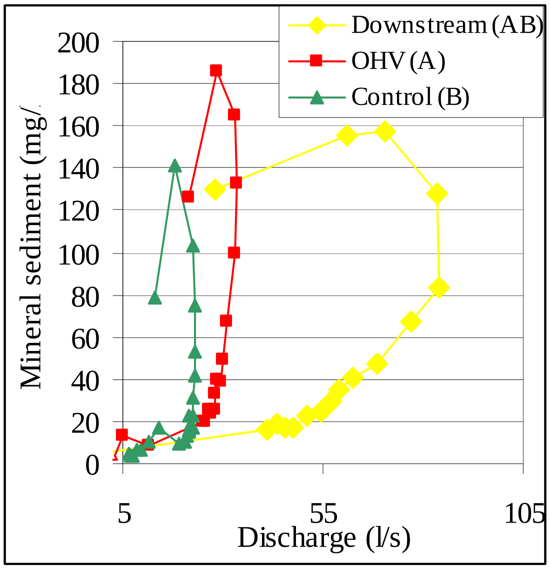


Figure 5a Sedigraph showing concentrations of sediment during a storm event. Bubble size indicates relative concentration and numbers show peak concentrations (mg/l).
Figure 5b: Sediment hysteresis loops for each site.

Bed Material and Bed Load Sediment: Stream beds in the OHV and Downstream sites included 3 fold more sand than the Control site (Figure 7). Differences in fine gravel and gravel were not significant. While bed load transport capacity (kg/s) was highest for the OHV site, transport on a per unit area basis was identical for the OHV and Control sites (Figure 8). Bed load transport capacity was sufficient to mobilize sand and fine gravel during typical events.

While extreme flows caused by Hurricane Ivan mobilized the entire streambeds, the beds returned to a form similar to that before being scoured (Figure 9).

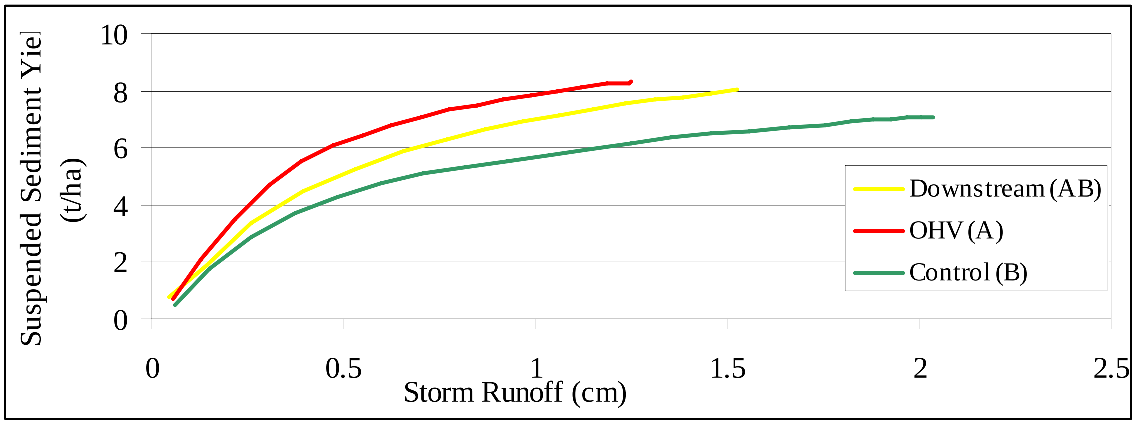


Figure 6 Example of suspended sediment yield over a single storm event.

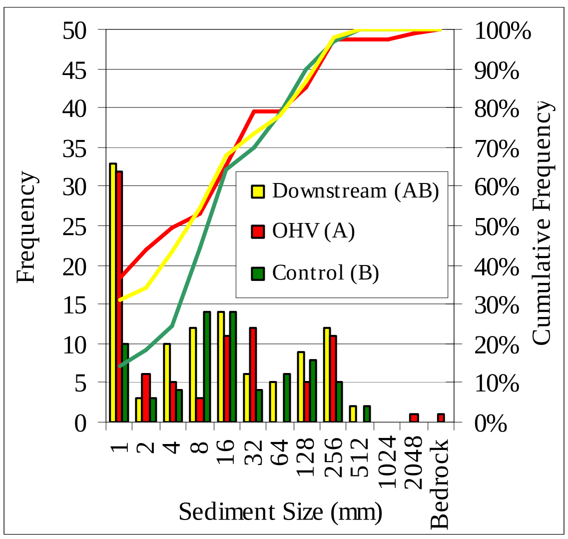


Figure 7 Particle size distributions of stream bed sediments.

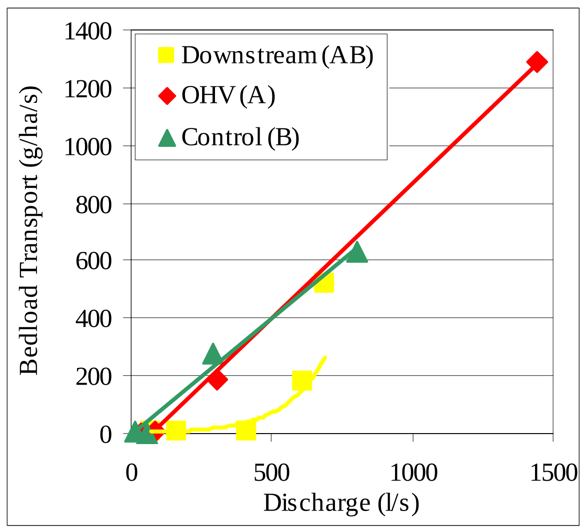


Figure 8 Bed load sediment transport for each reach.

DISCUSSION AND CONCLUSIONS

The results of this study, while preliminary, clearly indicate OHV trail use produced elevated concentrations and loadings of both suspended and fine bed load sediments in the OHV and Downstream reaches. Bed load transport for the Control and OHV sites was controlled by hydraulics (slope and depth). Hence, after accounting for watershed size, bed load transport capacity was similar between the two reaches. What appeared to be reduced transport capacity on the downstream reach was caused by two phenomena. First, flow on the downstream reach was the sum of the upstream reaches; e.g., when the upstream reaches contribute 200 and 300 l/s of runoff for Site A and B, respectively, Downstream (AB) flowed at > 500 l/s. Second, the Downstream (AB) reach had a lower slope so for a given flow, it had a lower transport capacity. Despite having sufficient bed load transport capacity, the OHV site (A) had elevated loading of fine bed load sediments in the sand and fine gravel size ranges. While these sediments were readily flushed out by storm events, they were quickly replaced with sediments eroded from the OHV trails. Thus, implantation of OHV trail best management practices and runoff treatment methods that prevent sediments from reaching the stream would allow the stream to clear itself of excess sediments in the stream bed.

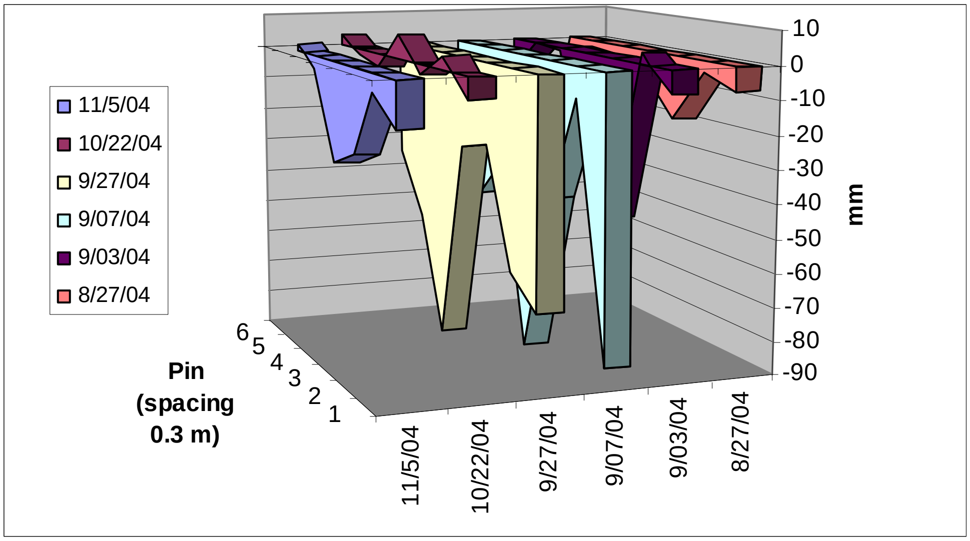


Figure 9 Scour and deposition of the stream bed at OHV Site A. Negative and positive values indicate event scour and deposition on a per event basis. Relative throughput of bed load sediment through the reach can be inferred from the area of each curve. The pre and post stream bed cross section elevations were quite similar following each event (no significant net change in bed elevation). October and November data are inaccurate from debris on pins.

The results indicate that simply collecting grab samples of water quality would not accurately characterize the impacts of OHV trails on stream sedimentation because the observed increases in suspended sediment loading came during storm events. Storm event sampling was necessary to characterize suspended sediment impacts. Bed load transport, stream bed scour and stream bed deposition were similar for the reaches. Only particle size analysis of stream bed sediments was useful in documenting OHV impacts on bed load / bed material load sediments.

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