Geomorphic response to peak flow increases due to forest harvest activities, Western Cascades, Oregon

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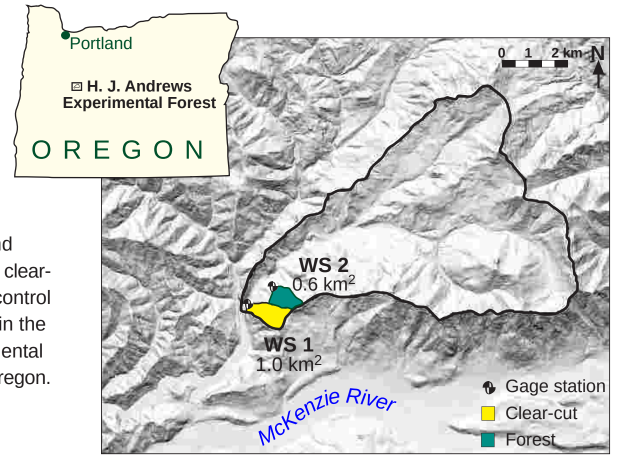
Introduction

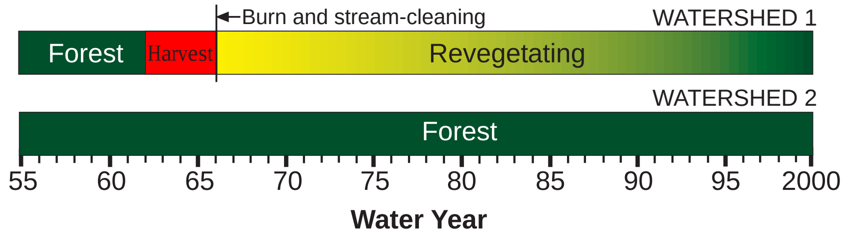
A persistent and often contentious debate surrounds evaluating effects of forest harvest activities on streamflow. Despite decades of paired-watershed studies at small experimental catchments world-wide, the jury is still out on the magnitude, persistence, and mechanisms responsible for peak flow changes following timber harvest. Recent studies examining long-term streamflow data from the H.J. Andrews Experimental Forest have reached conflicting conclusions on the magnitude and causes of peak flow changes (*Jones and Grant*, 1996, 2001; *Thomas and Megahan*, 1998, 2001; *Beschta et al.*, 2000; *Jones*, 2000). But no studies have evaluated the geomorphic response to observed peak flow changes-- a question of great interest in interpreting potential downstream consequences of forest management on channels and ecosystems.

Since the relation between sediment transport and discharge typically follows a power law, small increases in discharge can translate into large increases in sediment transport. But interpreting the geomorphic effects of peak flow increases is confounded by the fact that timber harvest typically influences both the hydrologic regime and sediment supply of a watershed, making it difficult to isolate the peak flow effect alone. Here we report on a novel approach to this problem using paired-watershed data to predict streamflow response in the absence of cutting. We combine this predicted hydrology with observed relations between discharge and sediment transport to disentangle the relative effects of changes in hydrology and sediment supply. Results indicate that while peak flow increases alone can account for modest increases in both suspended and bedload transport, the peak flow effect is dwarfed by the increased supply of sediment that accompanied timber harvest.

Study Area



We use streamflow and sediment data from the clear-cut Watershed 1 and control Watershed 2, located in the H.J. Andrews Experimental Forest in Blue River, Oregon.

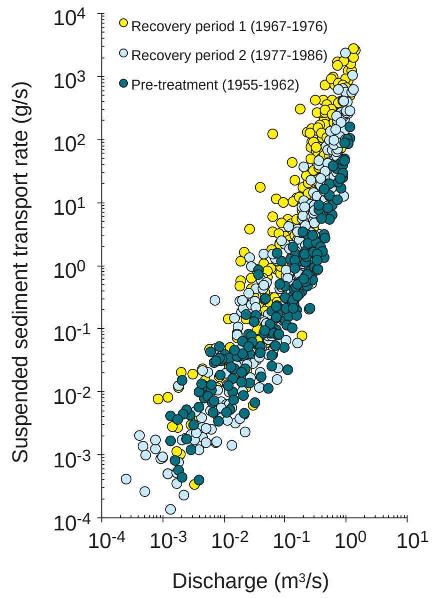


Data

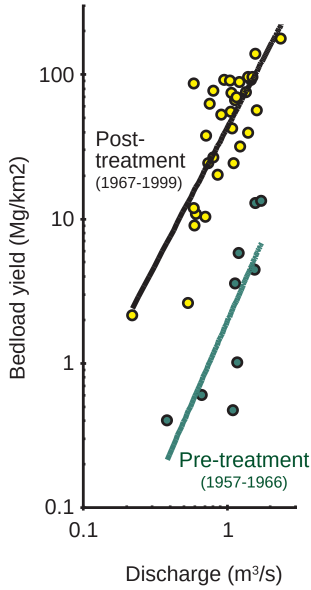
Sediment transport = *f* (Discharge, Time since harvest)

Sediment Data

Vertically-integrated suspended sediment grab samples were taken throughout the pre-treatment period and through 1988 following treatment in pint bottles; samples were screened, dried, and weighed. Annual bedload accumulation in a settling pond below the gauge station was surveyed annually during the summer low flow, and converted to mass using a bulk density of 1.0 g/cm3.



Pre- and post-treatment sediment rating curves for Watershed 1 demonstrate both the steepening of the Q/Qs relation following cutting, reflecting increased sediment supply, and the return towards the pre-treatment curve with time since treatment. Both the discharge and time dependencies are utilized in calculating suspended sediment flux.

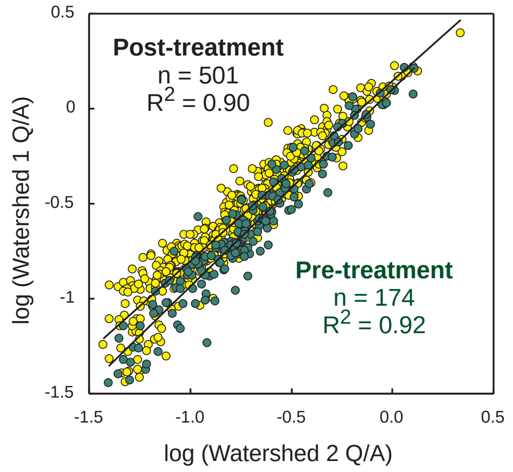


Regression of pre- and post-treatment annual bedload yields against *maximum* annual peak flow. Although smaller flows during the year transport bedload, annual resolution of bedload data limits refinement of bedload transport relation.

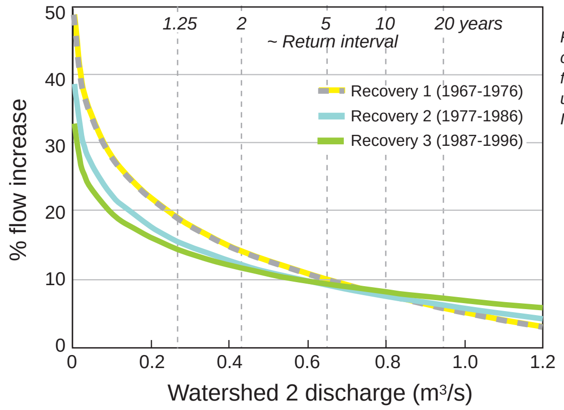
Flow data

Δ Peak Flow = *f* (Discharge, Time since harvest)

Pre- and post-treatment regressions of matched unit peak flows for Watershed 1 (treated) versus Watershed 2 (control) shows declining post-treatment response with increasing event size.



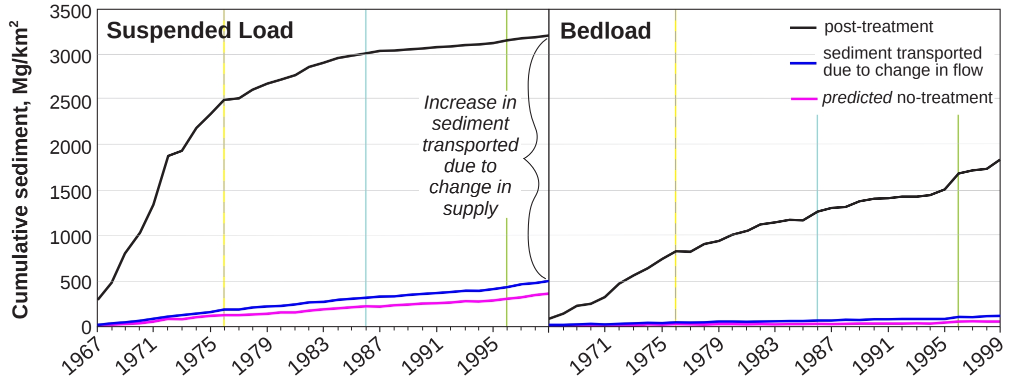
Increase in Watershed 1 peak flow following clearcutting relative to the control discharge for three 10-year recovery periods calculated as the percent difference between pre- and post-treatment WS 1 unit discharges predicted from the regression equations.



Flood frequency for the control basin was predicted from maximum annual flow using a Log-Pearson Type III distribution.

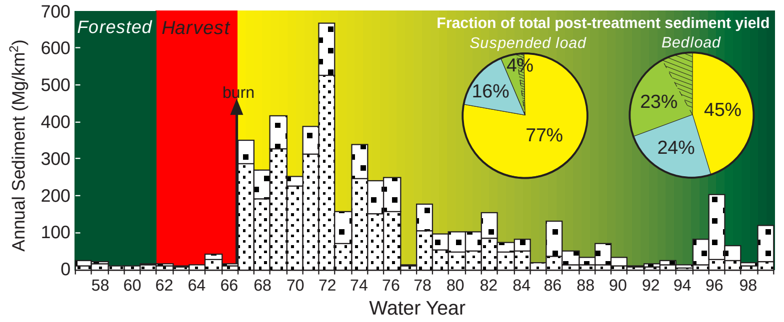
Results

Cumulative post-treatment suspended and bedload yield through time for three scenarios: 1) observed post-cut hydrology and sediment rating curves (black); 2) observed post-cut hydrology with pre-cut sediment rating curve, showing effect of increased peak flows alone (blue); and 3) predicted no-cut hydrology with pre-cut rating curve (pink). Changes in flow alone can account for almost doubling the total sediment output in the 32 years following harvest, but this amount is dwarfed by the increase caused by changes in sediment supply following havest.

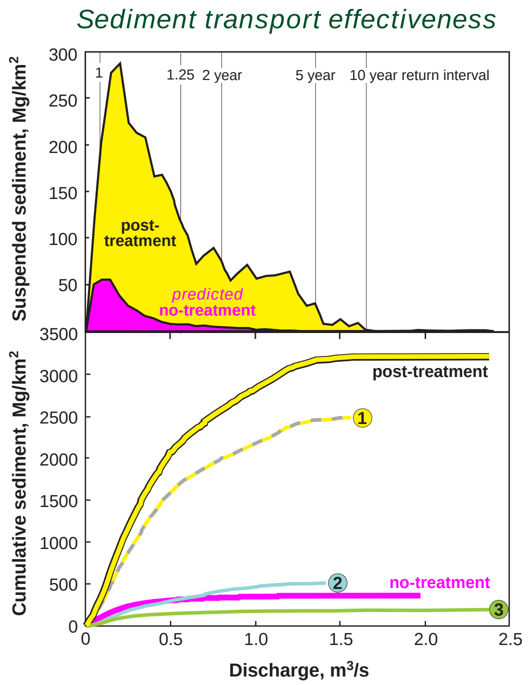


Annual suspended ⊡ and bedload ☐ yields from Watershed 1 reveal the initial increase and roughly exponential decline in sediment output following treatment. Suspended sediment yields returned to pre-treatment levels in the first two decades following treatment, but bedload remained elevated. Pie graphs show the percent of suspended and bedload transported during three 10-year post-treatment recovery periods: 1-10 yrs, 11-20 yrs, 21-30 yrs.

shaded green area represents 1997-99 yields



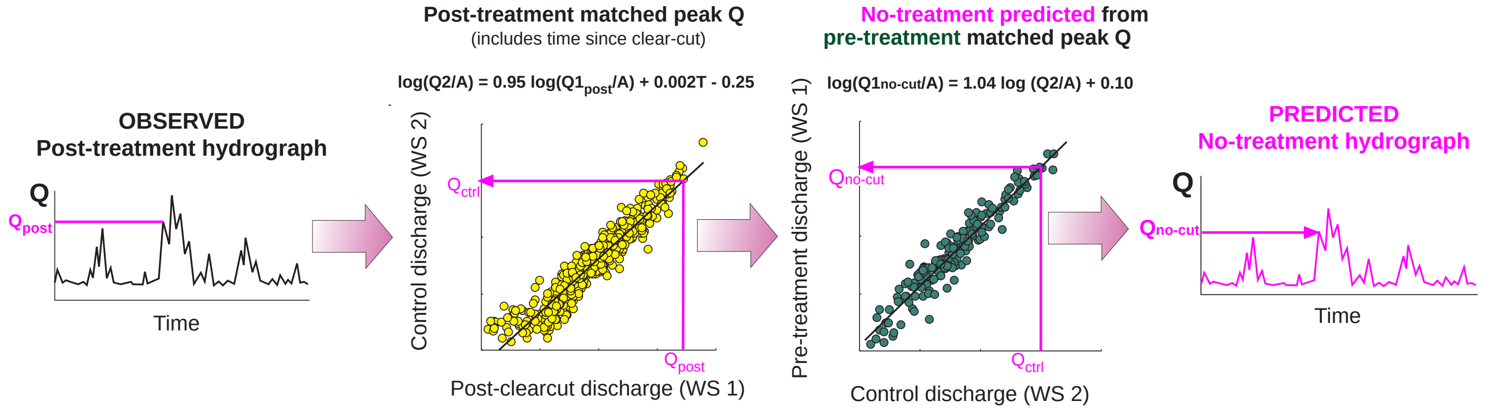
Sediment transport effectiveness



Comparing the density function of Watershed 1 suspended sediment yields versus discharge for the estimated post-treatment and predicted no-treatment scenarios shows a dramatic increase in the effectiveness of all flows following treatment. Although the maximum effective discharge for the two scenarios is similar, the shape of the two curves suggests that larger flows were more effective following treatment. Slopes of the cumulative density functions for the 3 recovery periods relax over time, indicating that the shift in effectiveness towards higher flows only occured immediately following treatment.

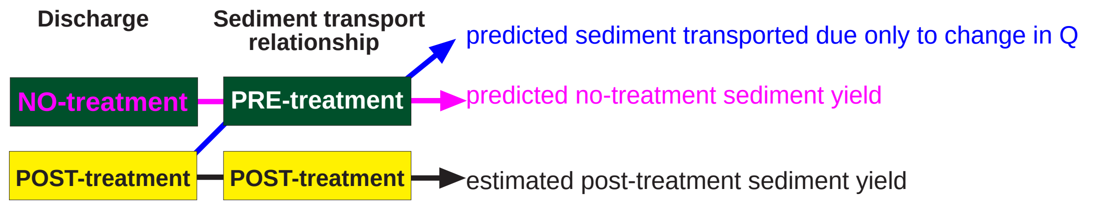
Approach

1. Using matched peak discharges from Watersheds 1 & 2 from before and after logging, we predicted a hydrograph for Watershed 1 had the basin not been clearcut.



2. The observed (post) and predicted (no-cut) hydrographs were multiplied by the pre- and post-treatment sediment rating curves to calculate continuous sediment discharges.

3. Integrating the continuous sediment discharges through time gives the total sediment transported in Watershed 1 post-treatment, predicts the amount that would have been transported if the basin was left in its natural state, and estimates how much sediment was transported due solely to change in discharge and not increased sediment supply.



Conclusions

Long-term paired streamflow and sediment data from small experimental catchments permit disentangling the separate effects of increased sediment supply and increased peak flow on sediment transport following timber harvest.

- Results demonstrate that increases in peak flow following forest harvest produce modest increases in total sediment yield, but this effect is dwarfed by the increased sediment supply.
- Sediment yields following forest harvest generally decline exponentially over time as revegetation limits the sediment supply, but the recovery rates for suspended and bedload differ. Suspended sediment yields from Watershed 1 declined to pre-harvest levels within ~20 years of harvest, yet bedload yields remained elevated 30+ years.
- Clearcutting increases the effectiveness and changes the distribution of sediment transporting flows. Under forested conditions, sediment supply is quite limited and small, frequent flows are the most effective in terms of total transport. We hypothesize that immediately following treatment, dramatic increases in sediment supply enhances the effectiveness of larger flows.
- Changes in peak flow following forest harvest do not appear to have a significant effect on the sediment transport regime of clearcut basins. The most significant geomorphic effects of harvest-induced hydrologic changes may be a higher frequency of mass movements due to increased water availability on hillslopes and roads.

References and Acknowledgments

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