Is watershed response to flood events impacted by forestry and roadbuilding activity and the time since such activity?

Seventy years of watershed response to floods and changing forestry practices in western Oregon, USA

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Topic Summary

What are the watershed and stream reach level responses to forestry practices, flooding, and geomorphic change? Do these responses differ over five time periods associated with specific harvest practices or flood events? Scientists surveyed in four reaches of Lookout Creek, a steep, forested watershed in the H.J. Andrews Forest on the west slope of the Cascade Range in Oregon. Data were collected on scouring or aggradation, woody debris influx or efflux, and reworked channel area.

Did flood magnitude have the greatest influence on geomorphic responses?

- Geomorphic response, such as debris slides, to flood events were more greatly influenced by the closeness in time to road construction and clearcuts, and by past land movements and forest dynamics than by the magnitude of flood events.
- During the most recent time period there was no harvest or road building activity and regrowth in former clearcuts reached ages of 40-70 years. Although the third largest flood of record occurred during this period, no debris flows were observed.

What factors impacted slide occurance and sediment aggradation?

- The vast majority of slides in Lookout Creek during the study originated from roads, clearcuts, and earthflow toes. Within channels, sediment aggradation was caused by the effects of major floods interacting with the disturbance effects of clearcuts and associated roads.

Can watershed response be best understood using one theoretical approach?

- Watershed level responses to forestry practices are complex. Several theoretical approaches (process domains, stochastic forcing, disturbance cascades, and sediment and wood budgets and routing) may together more fully explain changes in forested watersheds than any of these approaches individually.

Which factors impact sedimentation and wood loading?

- Watershed response varied with geologic history and geomorphic activity (land movement) among the watershed sub-areas, or process domains. Channel sediment load and aggradation depended on the type and amount of sediment in the basin and its proximity to the streambed.
- Forest condition and dynamics are also important factors related to sedimentation and wood loading. Clearcuts and young plantations likely contribute more sediment to streams while older

plantations and old growth contribute large woody debris (disturbance cascades, sediment and wood budgets).

Are these processes affected by human impacts?

- The effects of geophysical and biological processes were influenced by human impacts, such as road building and the beginning or ending of forest harvest regimes. The interaction between flood events and disturbance is an example of stochastic forcing.

As a manager, how can I use this information now and how can it help us in the future?

- This approach, which uses a synthesis of current and historical data may help managers predict watershed level impacts and responses to changing climate or fire regimes, which may in turn inform management plans.
- Future attempts to investigate or predict watershed response to disturbance must take into account the local geologic, geomorphic, and biological dynamics, as well as the history of land movement and the accumulation and availability of sediment and wood.

Research Approach/Methods

- Lookout Creek watershed was divided into three zones, a glacially-sculpted zone, an earthflow-dominated zone, and a debris slide and debris flow-dominated zone to assess how logging and road building impacted landscape response to flooding.
- The authors spatially compiled historical vegetative cover data with logging and road building activity to map historic land use change. They also calculated the cumulative density of roads and the cumulative percent of the watershed that was clearcut.
- They assembled and mapped an unpublished dataset of landslides in the watershed to analyze spatial and temporal patterns of landslide volumes and locations relative to clearcuts and roads and natural landforms.
- The researchers used channel surveys to calculated cross-sectional scour and deposition through time and specifically in response to flood events. They calculated cumulative net deposition and changes in thalweg elevation since 1978 for each survey section.
- For years with 75% of cross-sections surveyed, they used linear regression to investigate the relationship between reach-averaged reworked area and unit-area peak flow.

Keywords channel adjustment, disturbance cascade, harvesting, large wood, process domains, sediment supply, stochastic forcing, long-term harvest and flood data, road building

Images

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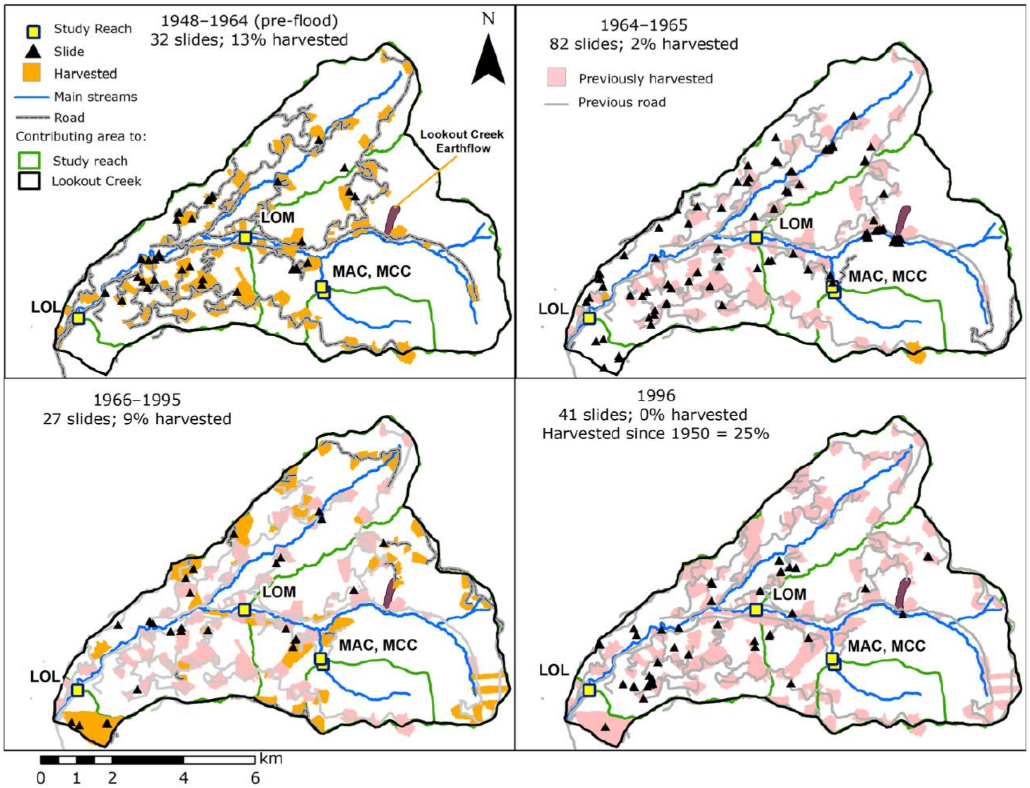

Figure 3 in Goodman et al. 2023. Spatial distribution of clearcuts (orange polygons for current period, pink for previous period) and inventoried debris slides and stream-side slides >75 m3 (black triangles) for four periods demarcated by large floods: 1948–November 1964; 1964–1965; 1966–1995; and 1996. Instrumented cross-sections (yellow squares) in Lookout Creek are indicated with their contributing watershed areas (green lines). Source: Swanson (2014) and H.J. Andrews Experimental Forest (2019).

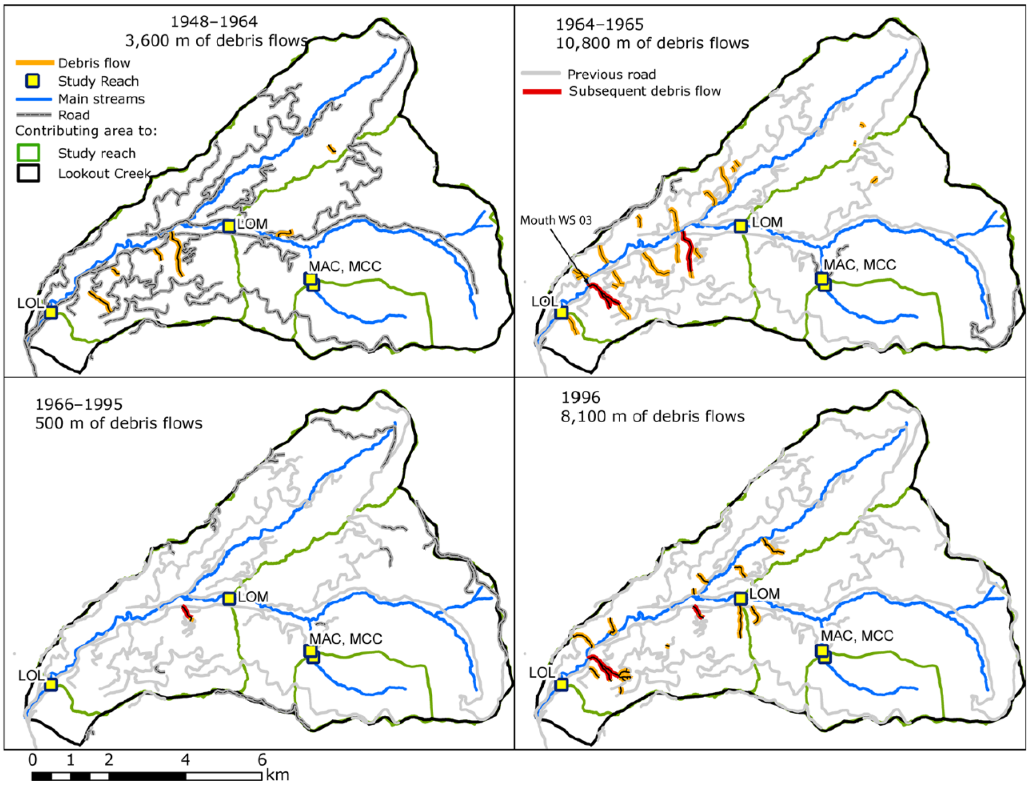

Figure 4 in Goodman et al. 2023. Spatial distribution of debris flows (orange lines for current period and red lines for subsequent debris flows in a channel segment with one or more prior debris flows) and roads (dark grey lines for current period, light grey lines for previous period) for four periods demarcated by large floods: 1948–November 1964; 1964–1965; 1966–1995; and 1996. Instrumented cross-sections (yellow squares) in Lookout Creek are indicated with their contributing watershed areas (green lines). Sources: Snyder (2000) and Swanson (2014).

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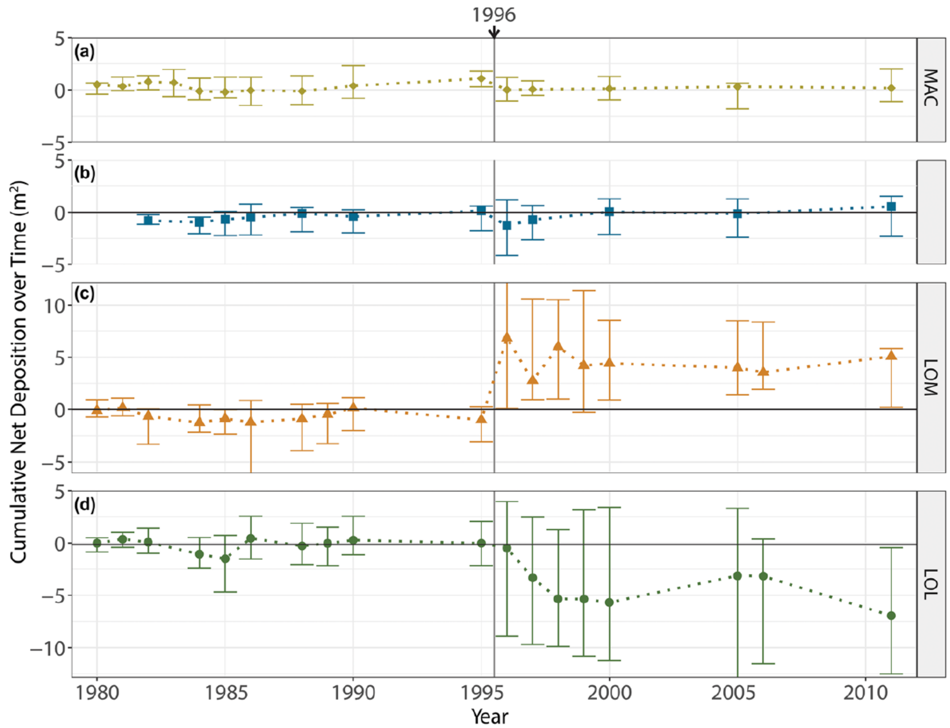

Figure 9 in Goodman et al. 2023. Median (dots) and interquartile range (bars) of cumulative net deposition (m2) relative to 1978 (1981 for MCC) at (a) MAC, (b) MCC, (c) LOM, (d) LOL. Vertical line indicates the flood of 1996.

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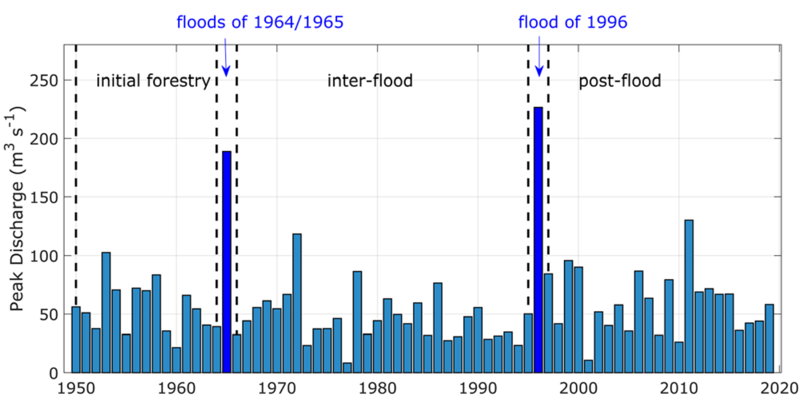

Figure 2 in Goodman et al. 2023. Annual peak flows by water year at Lookout Creek gage (no. 14161500), 1950 to 2020. Channel cross-sections were monitored from 1978 to 2011. The three highest peak flows at Lookout Creek from 1950 to 2020 were: February 1996 (227 m3/s or 3.7 m3/s/km2, return period 72 years), December 1964/January 1965 (189 m3/s or 3.0 m3/s/km2, return period 36 years), and January 2011 (130 m3/s or 2.1 m3/s/km2, return period 24 years) (Figure 2, Table S5).

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Figure 5 in Goodman et al. 2023. Photographs of debris flow deposits on the road passing by the mouth of the Watershed 3 stream (entering from the upper right) where it reaches Lookout Creek (lower left) (see location in Figure 4). (a) Pile of large wood delivered by the third pulse of multiple debris flows from watershed 3 on the night of 22–23 December 1964. Two previous pulses occurred during the night and early morning of 21–22 December (Fredriksen, 1965). Thirty-two landslides moved an estimated 30 000 m3 of sediment (300 m3/ha) in the watershed. Twenty-nine of the 32 landslides were adjacent to stream channels, and 93% of the material originated from roadrelated slides (Fredriksen, 1970). (b) Deposit from debris flows on the night of 6–7 February 1996 showing fewer very large wood pieces in 1996 compared to 1964. Note human figures for scale indicated by white arrows. Photo credits: 1964, Dick Fredriksen; 1996, Al Levno.

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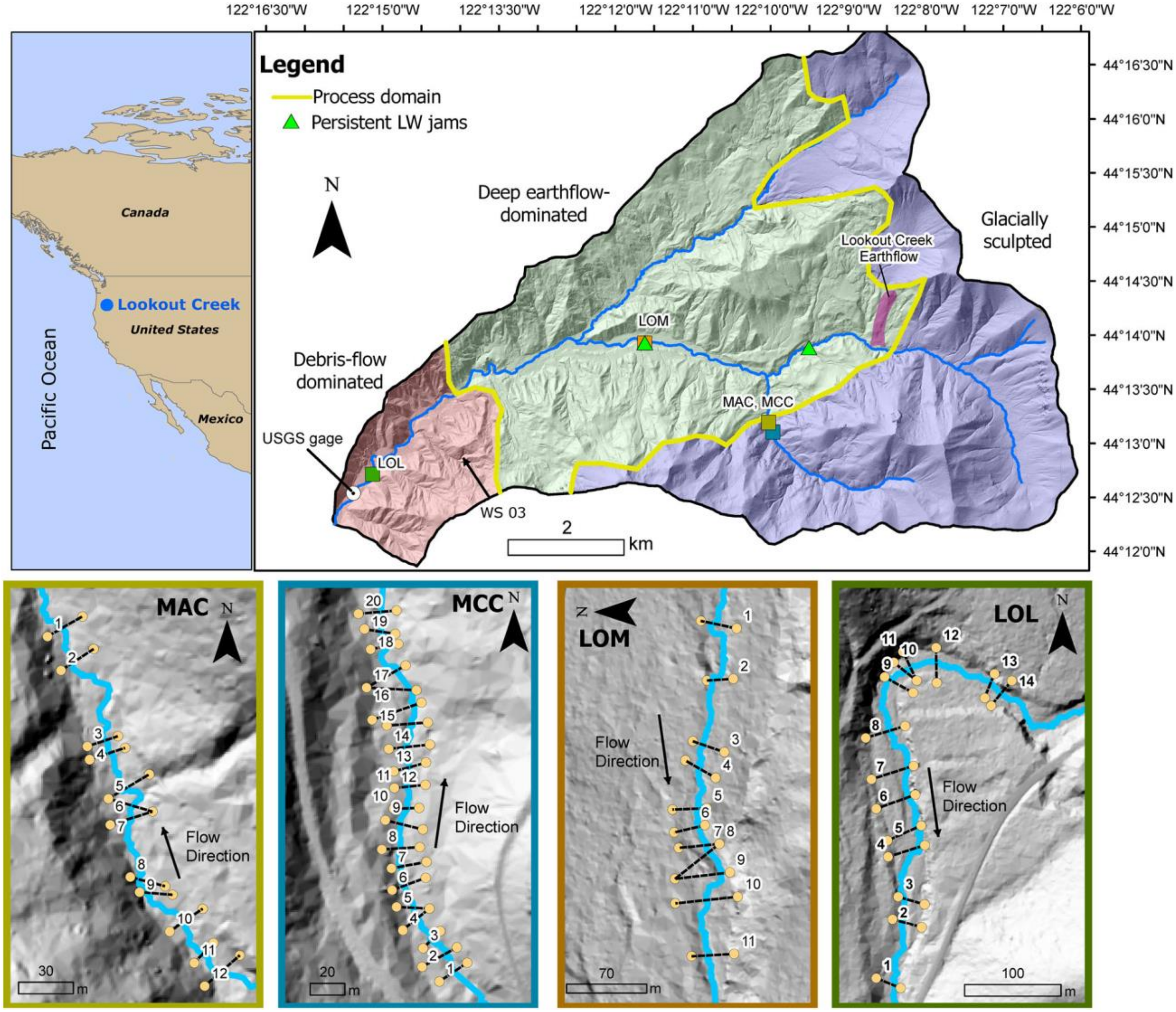

Figure 1 in Goodman et al. 2023. Location of Lookout Creek in western Oregon, USA (top left). Shaded relief of LiDAR bare-earth imagery of Lookout Creek, showing three litho-topographic zones (bounded by yellow lines, see text), location of the USGS gage (no. 14161500), locations of two persistent wood jams (green triangles, Figure S1), locations of study reaches (coloured squares) (top right), and location of watershed 3 (WS 03). Details of LiDAR bare-earth topography, locations of monitored cross-sections, and direction of flow (arrows) in four study reaches: Mack Creek old growth (MAC), Mack Creek clearcut (MCC), Middle Lookout (LOM), and Lower Lookout (LOL) (bottom panels).