

How Does Decommissioning Forest Roads Affect Hydrologic and Geomorphic Risk?



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Introduction

Forest roads are frequently a major source of fine sediment delivery and mass wasting in steep and wet landscapes. Compacted road surfaces generate direct runoff and infiltrated shallow subsurface flow from hillslopes. Roads discharge runoff through engineered and non-engineered structures, resulting in changes in sediment transport and delivery to hillslopes and channels, and can change the timing and location of runoff generation. The USDA Forest Service operates over 616,000 kilometers of forest roads in a wide variety of landscapes. The USFS Legacy Roads Program has been working to address the environmental impact of this large road network by decommissioning or upgrading roads that historically have caused water quality impacts. The Legacy Roads Monitoring Project has developed a method and is monitoring a sample of 46 of these projects in order to establish the efficacy of the treatments over time and in a range of environments (Figure 1).

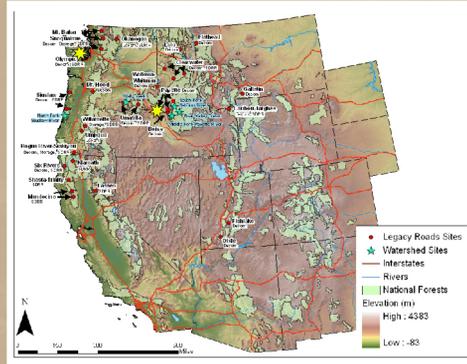


Figure 1. Locations of Legacy Roads Monitoring sites within the western U.S.

The Geomorphic Roads Analysis and Inventory Package (GRAIP) (Prasad 2007, <http://www.fs.fed.us/GRAIP>) is a GPS based road inventory paired with a set of GIS tools designed to quantify the most common hydrologic and geomorphic problems associated with forest roads.

- **Fine sediment production** is predicted based on an empirical relationship between road length, road slope, a road surfacing factor, a vegetation cover factor, and a base erosion rate, as established by Luce and Black (1999).
- **Sediment delivery and hydrologic connectivity** to the channel are predicted by modifying the sediment production at a drainage location based on observations of sediment transport across the hillslope.
- **Slope stability** is assessed using a version of SINMAP 2.0 (Pack et al. 2005), modified to account for road surface runoff. A factor of safety metric, called the Stability Index, is calculated that can be calibrated to determine areas where road drainage may result in a high risk of shallow landsliding.
- **The risk of gully initiation** below a drainage location is evaluated using the Erosion Sensitivity Index (*ESI*) (Istanbulluoglu et al. 2003). Observed road related gullies are used to establish a value of ESI_{crit} , the value above which the risk of gully initiation increases significantly. Drain point *ESI* values are compared to ESI_{crit} to identify areas with a high risk of gully formation. $ESI = L \times S^2$, where *L* is the road length contributing to the drain point, and *S* is the slope of the hillslope below the drain point.

Objectives

The goal of the Legacy Roads Monitoring Project is to quantify the effectiveness of road treatments, such as decommissioning, at reducing risk to watersheds. We use a combination of the GRAIP method and other field observations to measure changes due to treatments in fine sediment production and delivery to streams, hydrologic connectivity, slope stability, and gully initiation risk. We address the question, do decommissioned forest roads continue to concentrate water during large storm events, and if so, to what effect? Additionally, we examine the stability of the excavated stream crossings.

Methods

The effectiveness of road decommissioning treatments were measured using a before-after-control impact design (BACI). The GRAIP (<http://www.fs.fed.us/GRAIP>) outputs and associated field observations were used as indicators of the state of risk.

A 4 mile sample of road was inventoried for both treatment and control sites. Control sites were selected based on their proximity and similarity to treated sites with respect to road construction methods, maintenance levels, geology, and hydrologic regimes. Each study site was inventoried before road treatments occurred, after treat-

Mann Creek Watershed, Idaho

This watershed is located in southwestern Idaho and flows into the Weiser River (Figure 2). A rain-on-snow event occurred on June 2, 2010 that resulted in an 8 year flood event in the nearby town of Cambridge, ID (Figure 3). Earlier events in the season affected an elevation band lower than these sites.

Fine sediment production was predicted to decrease from 137 tonnes/yr before treatment to 60 tonnes/yr post-treatment. Sediment delivery to streams was predicted to decrease from 42 tonnes/yr to 1 tonne/yr. Post-storm event, modeled sediment production on the treated road was 38 tonnes/yr, and delivery was 0.27 tonnes/yr (Table 1).

Table 1.	Pre-Treatment	Post-Treatment	Post-Storm Treatment	Pre-Storm Control	Post-Storm Control
Sediment Production (tonnes/yr)	137	60	38	145	117
Sediment Delivery (tonnes/yr)	42	1	0.27	17	42
% Sediment Delivery	31%	2%	1%	11%	36%
Delivering Road Length (m)	3000	77	63	3262	4396
% Delivering Road Length	37%	1%	1%	38%	59%

One new gully formed on and below the surface of a treated road where the road crossed a swale post-storm event. Nine new gullies formed on control roads on the fillslope and hillslope below. Before the storm event, the surface of the control roads were 13% rutted; after the storm, 52% of the road surface was rilled and eroded. Road surface erosion and new gullies and landslides were measured to be 314 tonnes on the treated road after the large storm event. Control roads had 1,703 tonnes of new gully and landslide erosion after the storm event (Table 2). These sediment sources were all observed to deliver to streams.

Table 2. Post-storm obs.	Treatment Roads	Control Roads
Road Surface Erosion (tonnes)	29	-
Gully Erosion (tonnes)	0.80	4.9
Landslide Erosion (tonnes)	285	1698
Total Measured Erosion (tonnes)	314	1703

Pebble counts were conducted at each of the excavated stream crossings after the treatment was applied, and then again after the storm event. The crossings were at various states of adjustment following the storm event and spring runoff. The higher-order channels followed the expected response, where excess fines left in the crossing following excavation were being, or had been, removed. This indicates that the bedload more closely resembled that of the natural channel upstream of the crossing (Figure 4). Three of the 1st-order channels crossings showed an opposite pattern where the bedload had become significantly finer after the storm event, but also remained significantly finer than upstream reaches. Some likely reasons include a lack of significant adjustment, entrapment of fines by large anchor clasts, or scour through the disturbed sediment into undisturbed colluvium (Figure 5).

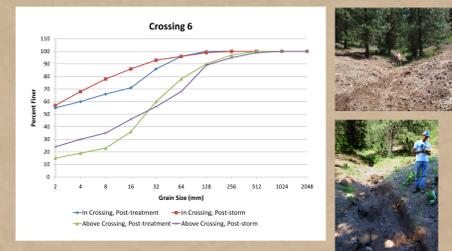


Figure 4. Grain sizes by % for a large stream crossing. Photo before treatment (top) and after treatment (bottom).

ments, and when possible, after a greater-than 7 year recurrence interval storm event. Control sites were inventoried before treatment and, where possible, at the post storm stage.

	Mann Creek, Idaho	Skokomish River, Washington
Precipitation	25-75 cm	254 cm
Geology	Basalt	Basalt veneered by glacial deposits
Elevation	1463-1830 m	245-550 m
Land Use	Timber harvest, grazing and historic mining	Timber harvest
Treatments	Stream crossing fill removal, culvert removal, road prism recontouring	Stream crossing fill removal, culvert removal, road prism recontouring, road surface tilling

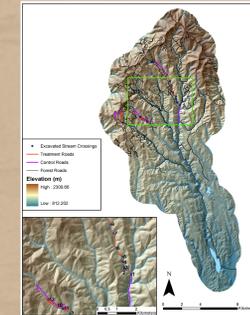


Figure 2. Mann Creek watershed, study locations.

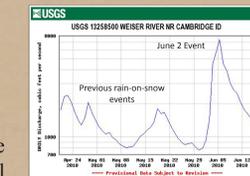


Figure 3. Stream gauge showing the major event on June 2.



Figure 4. Grain sizes by % for a large stream crossing. Photo before treatment (top) and after treatment (bottom).

Skokomish River Watershed, Washington

This watershed is located on the southeastern section of the Olympic Peninsula in Washington state, and drains into the Puget Sound (Figure 6). Treatments for this site were applied in 2008.

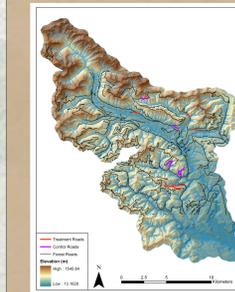


Figure 6. Skokomish River watershed, study locations.

Fine sediment production was predicted to increase from 41 tonnes/yr to 48 tonnes/yr, due to the change from a compact gravel surface to an unconsolidated native soil surface. Sediment delivery decreased from 27 tonnes/yr to 5 tonnes/yr, and hydrologic connectivity decreased from 3,474 m of the road length to 1,032 m, due to the removal of concentrated drainage features from the road (Table 3, Figure 7). Most of the connected length after treatment was routed through stream crossings.

Table 3.	Pre-Treatment	Post-Treatment	Change
Number of Drain Points	85	179	94
Sediment Production (tonnes/yr)	41	48	7
Sediment Delivery (tonnes/yr)	27	5	-22
% Sediment Delivery	65%	11%	-81%
% Delivering Road Length	49%	18%	-70%

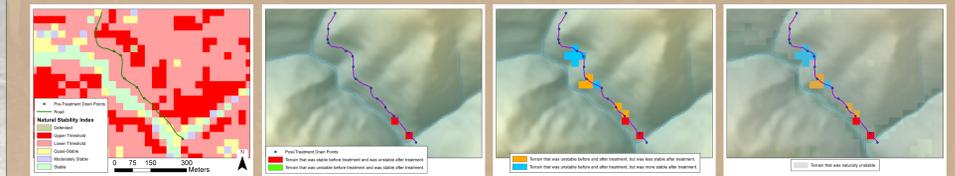


Figure 8. Changes in stability index risk due to decommissioning treatments.

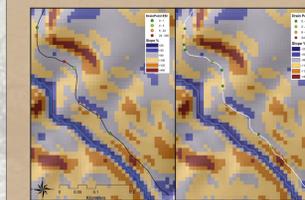


Figure 9. Risk of gulying below drain points, before treatment (left), and after treatment (right).

Before treatment, gully risk was elevated at 34% (29 of 85) of the drain points (Figure 9). The treatments increased drainage frequency resulting in 18% (32 of 179) of the drain points having elevated gully risk. Actual performance of the restoration treatments may exceed these predictions, as less runoff is expected on unconsolidated and outsloped surfaces.

Risk of stream crossing blockage and overtopping was eliminated at all crossings, as culverts and associated deep fills were removed. Over 4,000 m³ of stream crossing fill was removed during the decommissioning work.

Conclusions

Hydrologic and geomorphic response were significantly reduced by high-intensity road decommissioning treatments at Mann Creek. Sediment delivery was expected to decrease significantly by 93% from before the treatment to after the storm event. Hydrologically connected road length was observed to decrease significantly, from 3,000 m to only 63 m. Observed erosion on the treatment roads after the storm was 314 tonnes, while 1,703 tonnes were observed on the untreated control roads. Excavated stream crossings appear to be undergoing expected adjustment, except where stream order is very low.

Similarly, the high-intensity treatments applied at the Skokomish River have reduced watershed risks. Sediment delivery was expected to decrease by 81%, and the hydrologically connected road length by 70%. Slope stability risk was distributed over the hillslope, probably resulting in slightly lower risk. Uncertainty remains around gully risk. Risks associated with stream crossing were nearly eliminated.



Figure 7. Fine sediment delivery to stream channels pre-treatment road.

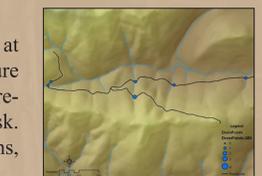


Figure 10. Risk of stream crossings being blocked by debris and overtopping, pre-treatment road. All risk was removed by the treatments.

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