Monitoring the Hydrologic and Geomorphic Effects of Forest Road Decommissioning and Road Improvements

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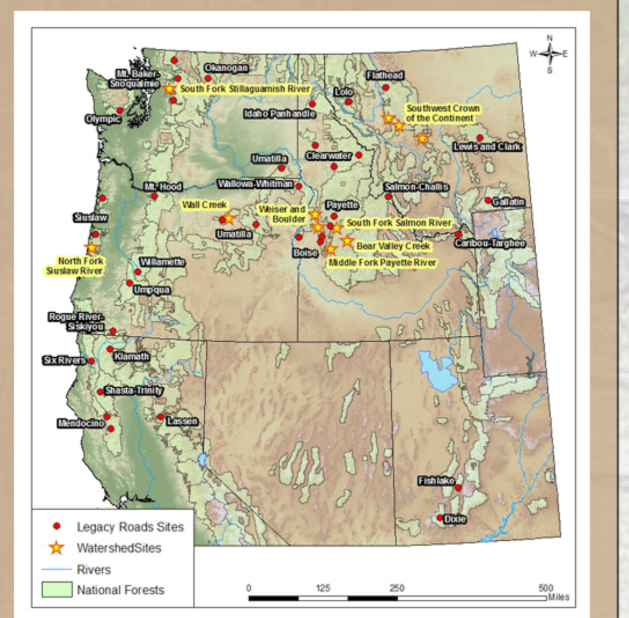
Forest roads are frequently a major source of fine sediment delivery and mass wasting in steep terrains. The U.S. Forest Service operates over 616,000 kilometers of forest roads in a wide variety of landscapes. The USFS Legacy Roads Program has been working to address the environmental impact of this 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 52 of these projects in order to establish the efficacy of the treatments over time and in a range of environments.

The Geomorphic Roads Analysis and Inventory Package (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. GRAIP is combined with other field observations to evaluate:

- Fine sediment delivery
- Excavated stream crossings on decommissioned roads
- Mass wasting risks
- Road surface erosion problems



Map of monitored Legacy Roads sites and other GRAIP studies.

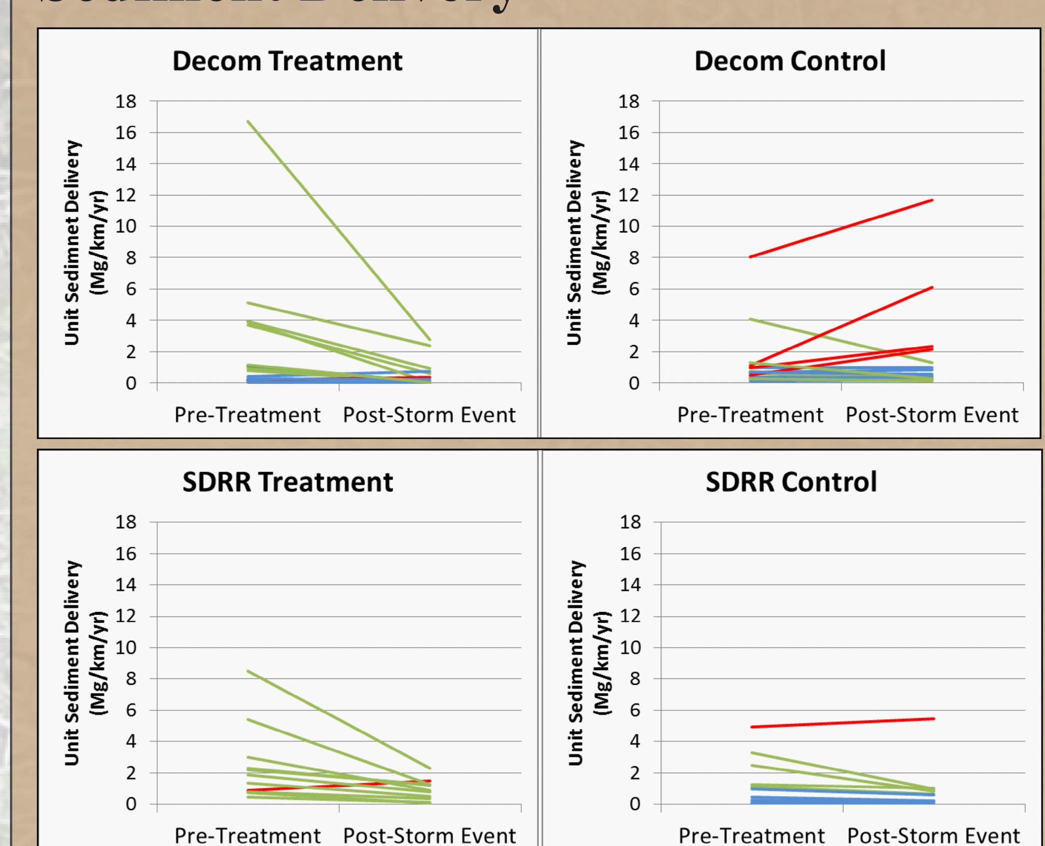
Objective: To quantify the effectiveness of decommissioning (n=15) and storm damage risk reduction (SDRR; n=11) road treatments at reducing risk to watersheds.

Methods

The effectiveness of road treatments were measured using a before-after-control impact design (BACI). The GRAIP outputs and associated field observations were used as indicators of the state of risk.

A ~6 km 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, and again after a greater-than 7 year recurrence interval storm event.

Sediment Delivery



Compared to the control roads, both decommissioning and SDRR treatments were effective at reducing sediment delivery to streams at most sites. This is due to decreases in sediment production and disconnection of roads from streams, with the former dominating SDRR roads.

Sediment delivery was calculated for each segment of road according to observations and the following equation (*Luce and Black 1999, Cissel et al. 2012*):

$$E = B \times L \times S \times V \times R$$

E is the erosion for each road segment (kg/yr)
B is the base erosion rate (kg/m)
L is the road length (m) contributing to the drain point
S is the slope of the road contributing to the drain point (m/m)
V is the vegetation cover factor for the flow path
R is the road surfacing factor

Road treatments have met or exceeded sediment production and delivery, and hydrologic connectivity expectations for both decommissioning and SDRR roads, with the exception of sediment production on SDRR roads.

Expected Changes in Connectivity and Sediment, Pre-Treatment to Post-Storm Event

	Decommissioned Roads	*SDRR Roads*	*Control Roads*
Δ Road-Stream Hydrologic Connectivity	large decrease	small to moderate decrease	small increase
Δ Sediment Production from Road Surfaces	small to moderate decrease	small decrease	small increase
Δ Sediment Delivery from Road Surfaces	large decrease	small to moderate decrease	small to moderate increase

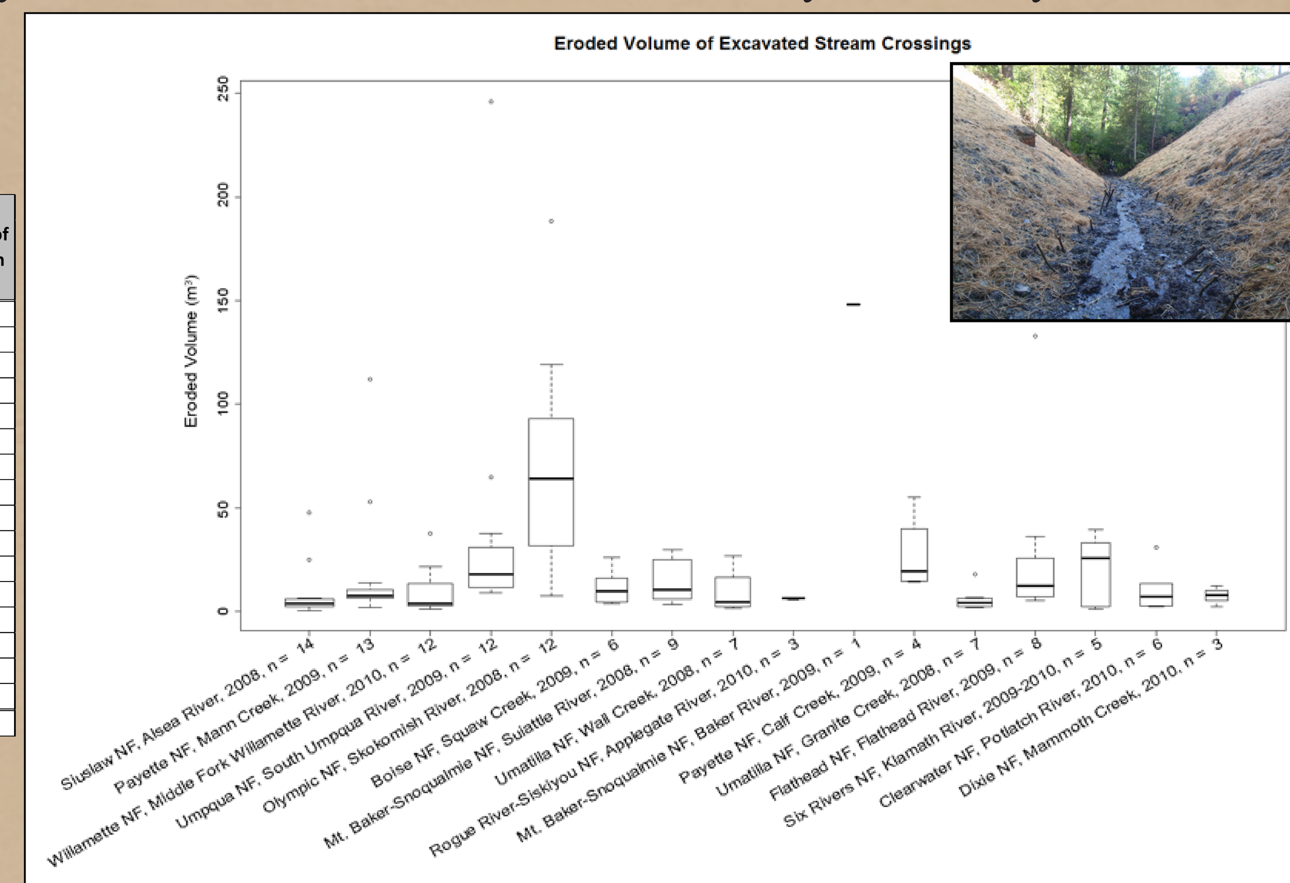
Changes in Connectivity and Sediment, Pre-Treatment to Post-Storm Event

	Decommissioned Roads (n = 15)		SDRR Roads (n = 11)	
	Treated Roads (97.4 km)	*Control Roads (92.5 km)*	*Treated Roads (85.6 km)*	*Control Roads (71.1 km)*
Δ Road-Stream Hydrologic Connectivity	-12.5 km (-62%)	+1.2 km (+6%)	-0.9 km (-3%)	no change (-0.1%)
Δ Sediment Production from Road Surfaces	-451 Mg/yr (-56%)	-68 Mg/yr (-10%)	-418 Mg/yr (-53%)	-281 Mg/yr (-49%)
Δ Sediment Delivery from Road Surfaces	-208 Mg/yr (-79%)	+47 Mg/yr (+35%)	-125 Mg/yr (-61%)	-34 Mg/yr (-34%)
Δ Unit Sediment Delivery from Road Surfaces	-2.1 Mg/km/yr (-79%)	+0.5 Mg/km/yr (+34%)	-1.5 Mg/km/yr (-61%)	-0.4 Mg/km/yr (-34%)

Excavated Stream Crossings

Excavated stream crossings on decommissioned roads have had their culvert infrastructure removed. The channel and remaining road fill are recontructed to closely mimmick the natural channel and valley. We surveyed the excavated crossings to determine the shape of the new crossing, erosion present, and the risk of further erosion (*Black et al. 2012*).

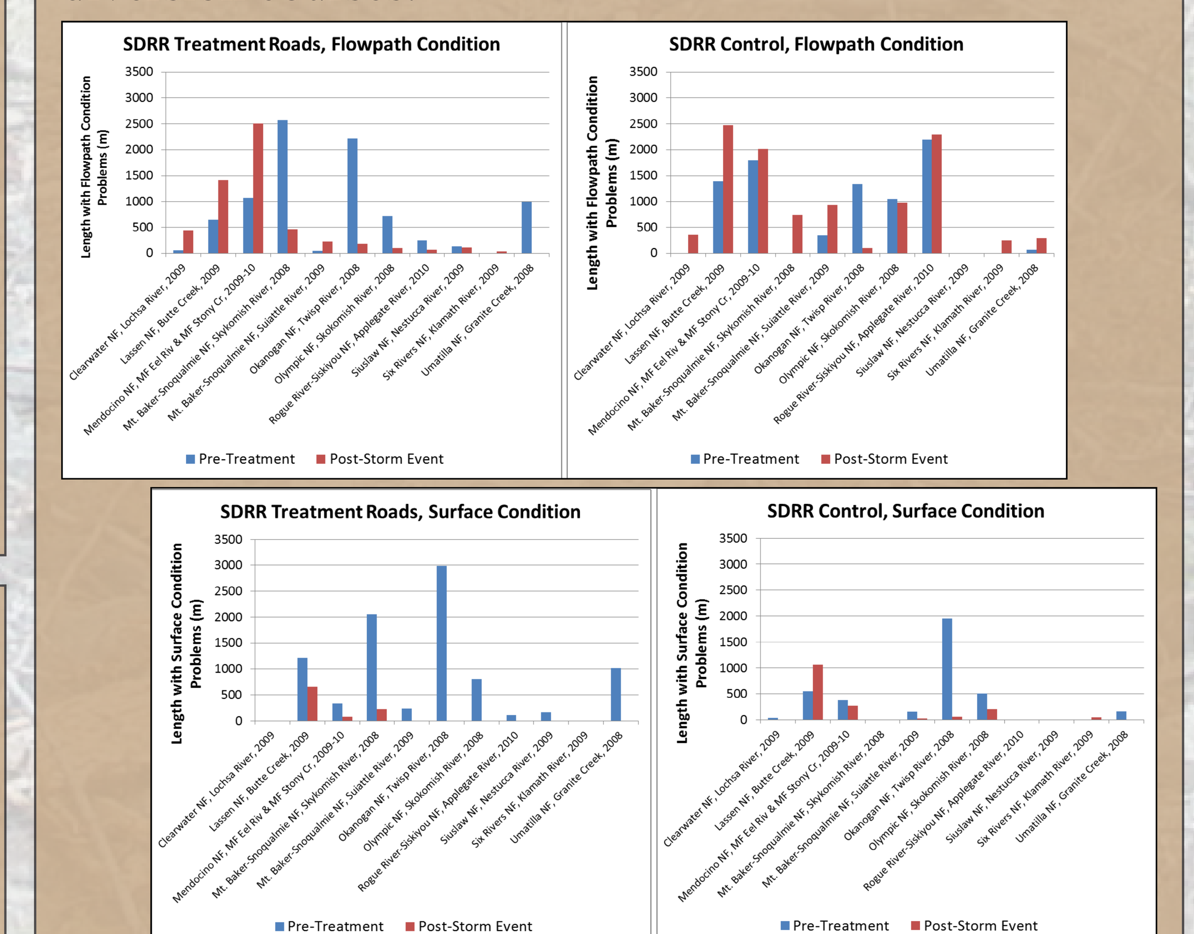
Site	Volume of Fill Removed: Total Volume (m^3)	Volume of Fill Removed: Mean Volume (m^3)	Volume of Erosion in Crossings: Total Volume (m^3)	Volume of Erosion in Crossings: Mean Volume (m^3)	Mean Depth of Erosion (m^3)
Boise NF, Squaw Creek, 2009	3,040	510	70	10	0.5
Clearwater NF, Potlatch River, 2010	3,490	580	60	10	0.3
Dixie NF, Mammoth Creek, 2010	780	260	20	10	0.3
Flathead NF, Flathead River, 2009	12,990	1,620	230	30	0.4
Mt. Baker-Snoqualmie NF, Baker River, 2009	1,500	1,500	150	150	0.6
Mt. Baker-Snoqualmie NF, Suiattle River, 2008	10,220	1,140	130	10	0.4
Olympic NF, Skokomish River, 2008	63,990	5,330	830	70	0.8
Payette NF, Calf Creek, 2009	4,140	1,040	110	30	0.6
Payette NF, Mann Creek, 2009	8,140	630	250	20	0.4
Rogue River-Siskiyou NF, Applegate River, 2010	1,840	610	20	10	0.1
Siuslaw NF, Alsea River, 2008	28,250	2,020	120	10	0.2
Six Rivers NF, Klamath River, 2009-2010	6,790	1,360	100	20	0.5
Umatilla NF, Granite Creek, 2008	2,940	420	40	10	0.2
Umatilla NF, Wall Creek, 2008	3,360	480	70	10	0.3
Umpqua NF, South Umpqua River, 2009	22,850	1,900	490	40	0.4
Willamette NF, Middle Fork Willamette River, 2010	7,550	630	110	10	0.4
Total	**181,890**	**1,490**	**2,790**	**20**	**0.4**



As the new channel adjusts, some erosion is expected at excavated stream crossings. While the mean volume eroded for all sites was low relative to previous findings (Cook and Dresser 2010), a few sites had significantly higher eroded volumes. Volumes may vary with precipitation, channel sizes (bigger streams erode more and wider channels inherently have more volume), natural slopes, or with design and implementation standards (matching the excavation to the natural channel and valley). Eroded volumes were 15% of the total that could be expected to erode over time as the untreated crossings failed.

SDRR Road Surface Erosion

Road surface and flowpath condition problems include gullies, rills, buried ditch lines, ruts, and stream diversion courses.

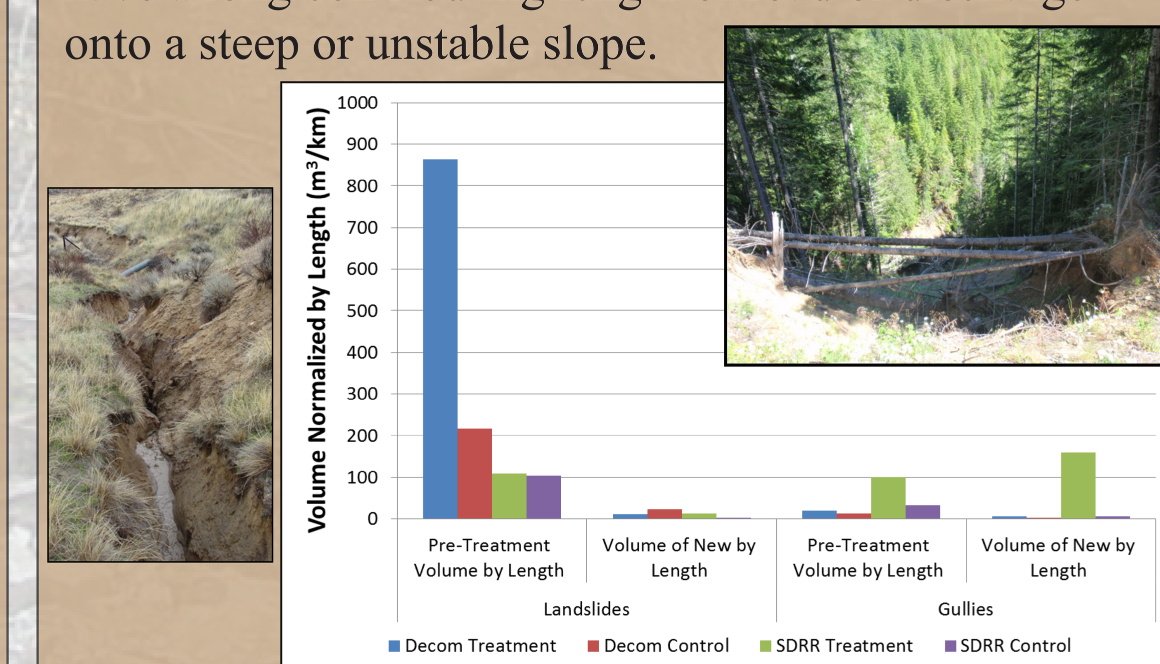


Site Type	Length of Road Treated (m)	Surface Condition Problems: %, Pre-Treatment Length	Surface Condition Problems: %, Post-Storm Event Length	Surface Condition Problems: Δ Length (m)	Surface Condition Problems: % Change Length	Flowpath Condition Problems: %, Pre-Treatment Length	Flowpath Condition Problems: %, Post-Storm Event Length	Flowpath Condition Problems: Δ Length (m)	Flowpath Condition Problems: % Change Length
SDRR Treatment	85,990	10%	1%	-7,970	-89%	10%	6%	-3,140	-36%
SDRR Control	68,310	5%	2%	-2,080	-56%	12%	15%	2,250	27%

Road surface and flowpath condition problems were both successfully addressed by the SDRR treatments. Control roads experienced an increase in flowpath condition problems, and a decrease in surface condition problems. The decrease was much smaller than that of the treated roads.

Mass Wasting

Shallow landslides and gullies that meet a minimum threshold for size are measured or estimated to determine volume. Even after a storm event, most sites did not have any new mass wasting events. Gullies often initiate below new drainage points when they have a long contributing length of road or discharge onto a steep or unstable slope.



Site Type	Length of Road (km)	Landslides: Pre-Treatment Volume (m^3)	Landslides: Number of New	Landslides: Volume of New (m^3)	Landslides: % New Volume of Pre Volume	Gullies: Pre-Treatment Volume (m^3)	Gullies: Number of New	Gullies: Volume of New (m^3)	Gullies: % New Volume of Pre Volume
Decom Treatment	97	84,150	12	1,000	1%	1,930	20	590	30%
Decom Control	92	20,050	6	2,110	11%	1,210	23	140	11%
SDRR Treatment	86	9,270	5	1,030	11%	8,650	59	13,680	158%
SDRR Control	71	7,380	4	10	0.2%	2,340	30	380	16%

Decommissioning treatments, which prevent roads from concentrating water in large volumes, were successful at reducing risk from both gullies and landslides. SDRR treatments, which leave water concentrated and may discharge at new locations, were less successful, particularly in relation to new gully formation.

Conclusions

• Fine sediment delivery was reduced 79% by decommissioning, and 61% by SDRR.

- Overall, both treatment types were effective compared to control roads.
- Exceptions: new gullies on SDRR roads, large erosion volumes at some excavated stream crossings, localized increases in flowpath condition problems.
- Further work to determine fine-scale causes behind these increases and reductions, as well as examine BMPs and develop tools for managers to use to prevent problems and further reduce impacts and risk to watersheds from forest roads.

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