CMER Data Use Notification

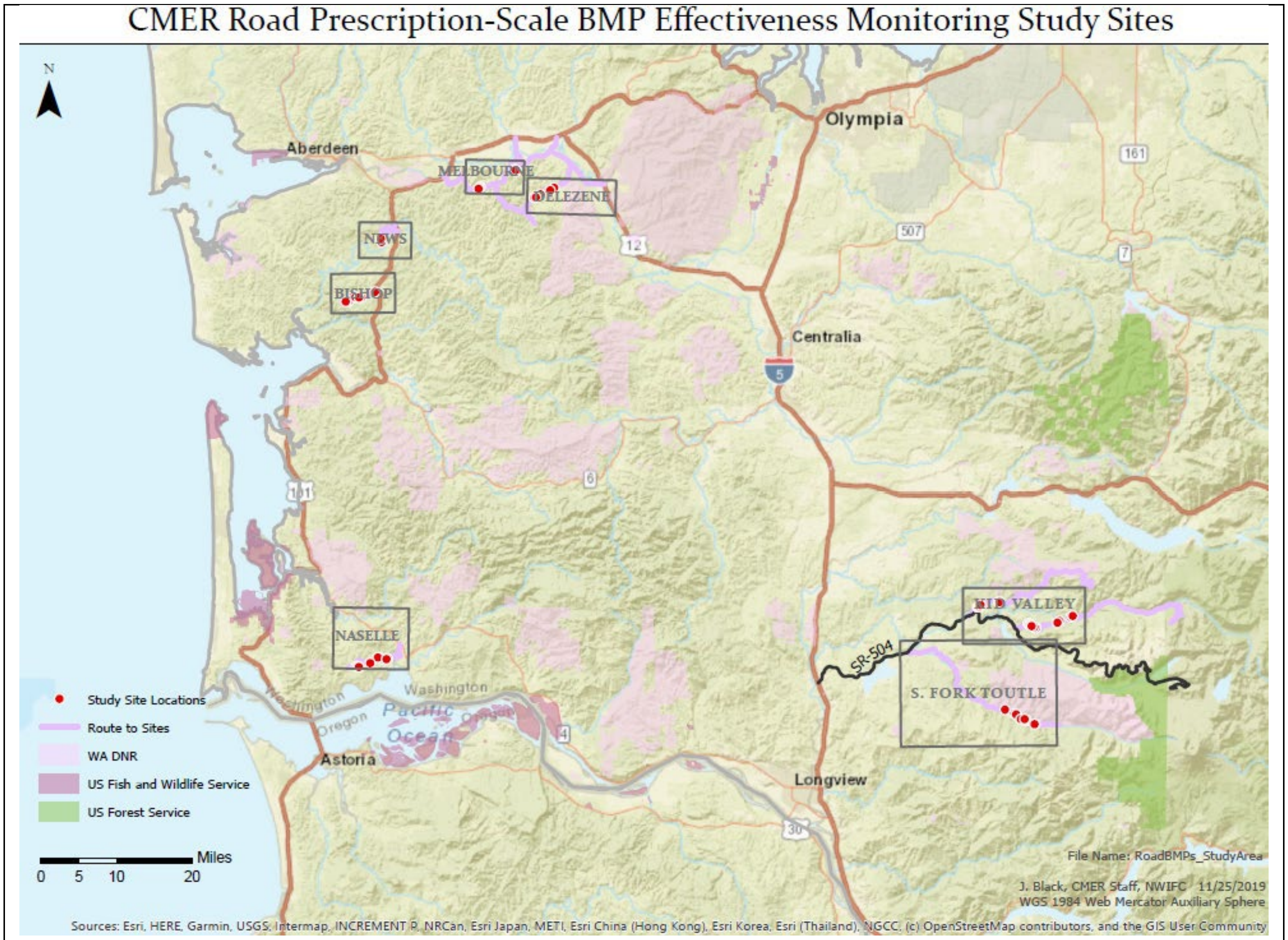
Proponent: Roads Project Team	**Date**: 17 December 2024
Contact: Charles Luce Charles.Luce@usda.gov (PI)	**PM**: Alexander Prescott alexander.prescott@dnr.wa.gov
Project Name/Issue: Road Prescription-Scale Effectiveness Monitoring Project	
Notification: Use of data collected during Prescription-Scale Effectiveness Monitoring Project major experiment the for a poster discussing the preliminary analysis of the data.	
Funding Source: NA	**Urgency**: High

Data Description: The PI and other members of the Project Team, principally Dr. Luce from the US Forest Service, are preparing a poster discussing preliminary results from one year of the Roads Prescription-Scale Effectiveness Monitoring Project's major experiment. This poster, currently titled, *The effectiveness of combined erosion control approaches for logging roads*, presents the effects of varying ditch streampower (slope times flow), traffic levels, ditchline treatment roughness, and road rock toughness. This poster will be presented at the American Geophysical Union Fall meeting in a poster session on geomorphologic process associated with restoration and management of forest lands.

Below are the figures and tables that are expected to be used for the poster. The figures will be drawn from the 2024 interim report and slide presentation to CMER and are expected to be used without additional modification. Additional photographs may be added to illustrate data collection and covariates.

- Figure 1 presents a map of the field sites.
- Figure 2 presents a map of the field sites.
- Table 1 presents covariates considered in the analysis.
- Figure 3 presents a conceptual illustration of sensitivity of traffic and rock quality interactions.
- Figure 4 presents a conceptual illustration of sensitivity of traffic and ditch treatment interactions.
- Figure 5 presents a graph illustrating the model quality.
- Figure 6 presents sensitivity of sediment production to contextual variables and treatments.

Three additional Roads Project team members will be presenting materials associated with previously CMER approved data use notifications. All details and abstracts are provided with this document.



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Figure 1. Map of field site locations in Washington state.

Figure 2: Field data collection setup. The upper figure shows the road surface routing water to the ditch and the collection trough. Water and sediment then are routed through a culvert pipe to the sediment tub. The lower figure shows the platform with the sediment tub collecting road sediment, the tipping bucket measuring discharge and the suspended sediment tank(SST) sampling the fine sediment that is not settled in the tub.

Table 1: *List of Measurements and Covariates considered in this analysis. Other measurements have been made, but this subset represents the ones of preliminary utility and interest.*

Basic site, flow, and sediment information
- Monthly runoff, liters
- Slope
- Geology (Volcanic and Siltstone Provinces)
- Monthly average stream power (flow*slp)
- Suspended load (fine sediment)
- Mass trapped in tub (coarse sediment)
- Total sediment

Road surface disturbance
- Number of trucks in a month
- Number of cars in a month
- Number of trucks on days with at least 0.1 in of rain
- Number of cars on days with at least 0.1 in of rain
- Number of trucks on days with at least 0.25 in of rain
- Number of cars on days with at least 0.25 in of rain
- New road-grading occurred during the month (T-F variable)
- Fraction of trucks on days with >0.1 inch of rain
- Fraction of trucks on days with >0.25 inch of rain

Rock quality and ditch treatment covariates
- Degradation score, resistance to degradation when wet
- Fraction of shear stress partitioned to sediment grains

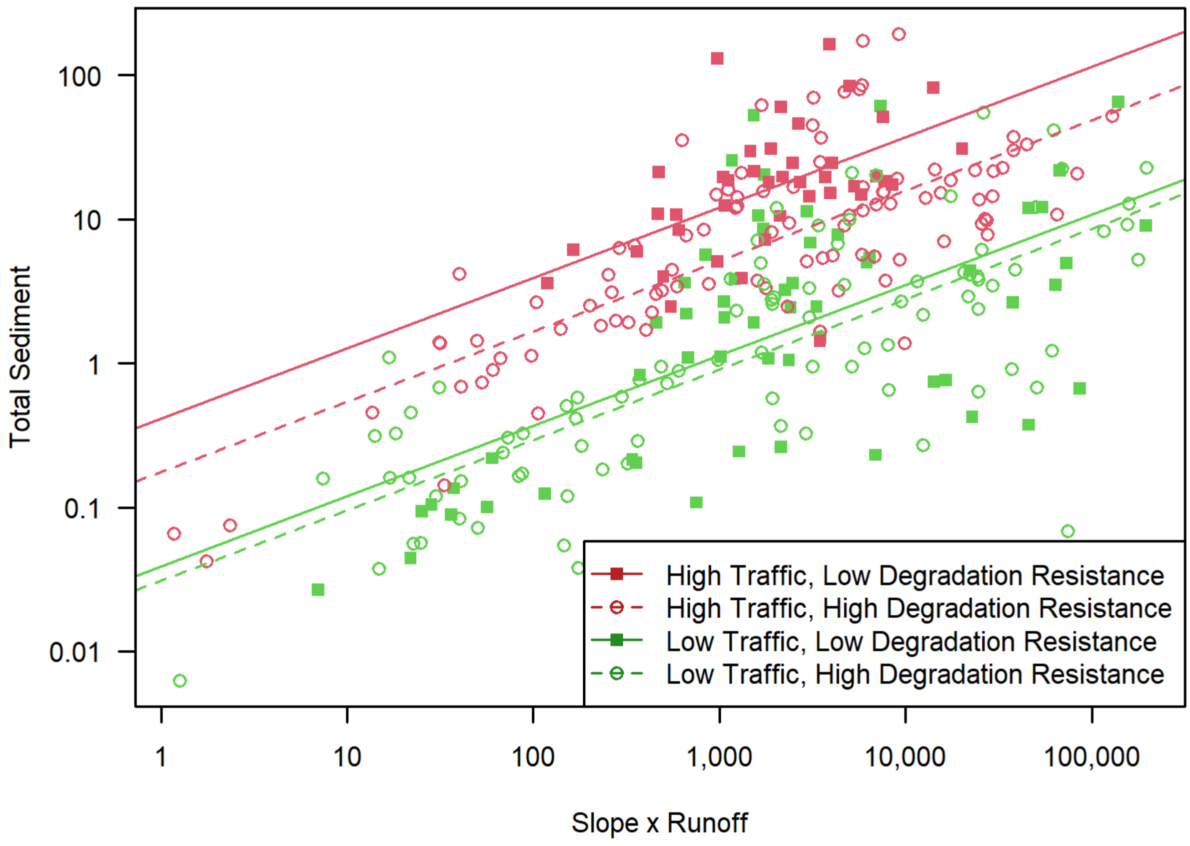


Figure 3: Conceptual plot of sensitivity to streampower contingent on classified traffic and rock degradation resistance.

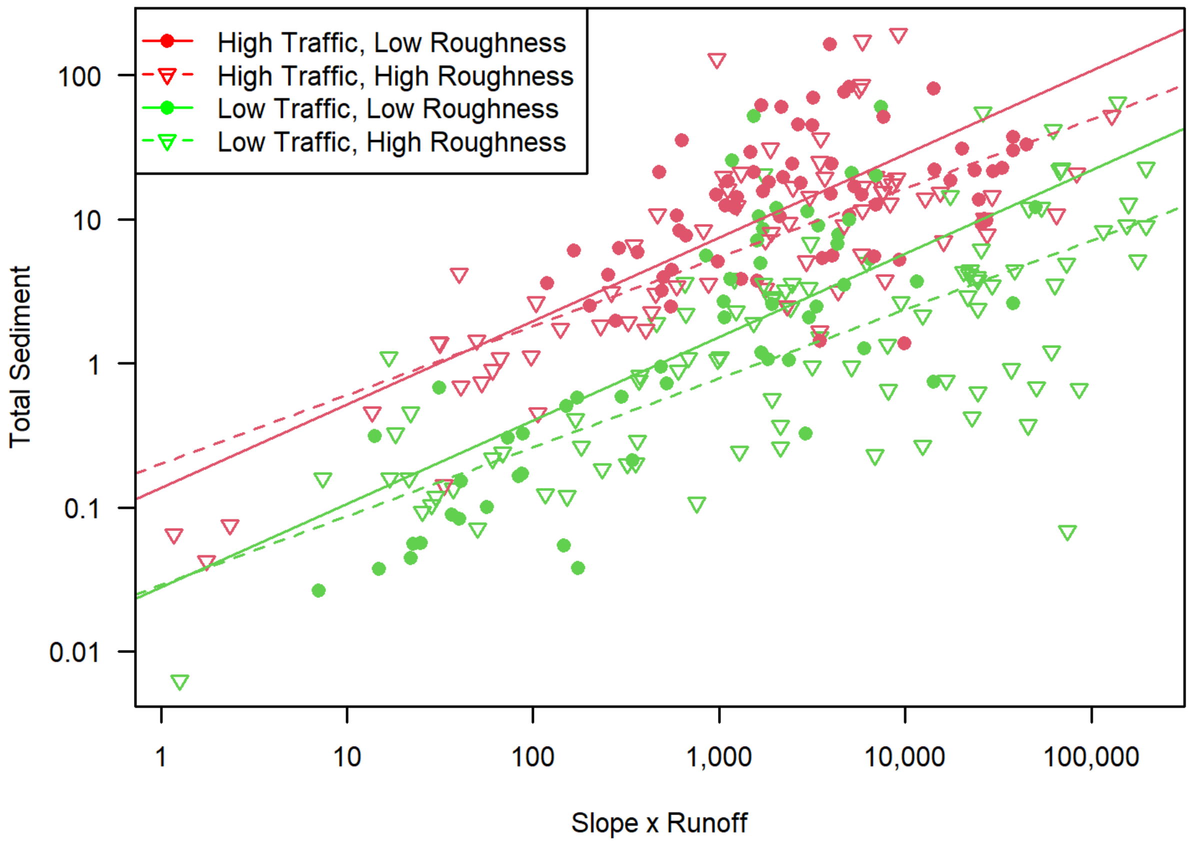


Figure 4: Conceptual plot of sensitivity to streampower contingent on classified traffic and ditchline treatment roughness.

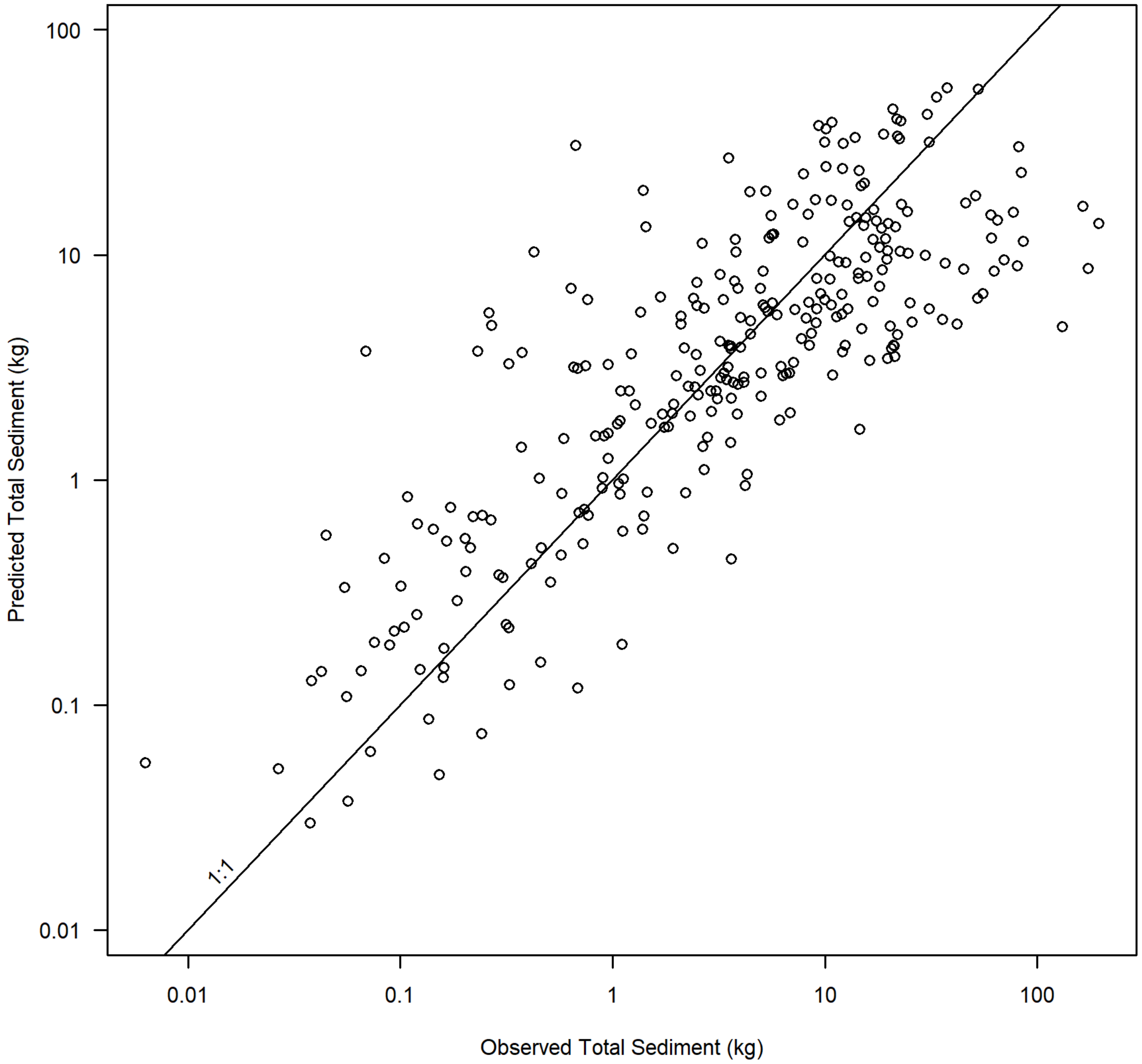


Figure 5: Plot of predicted vs observed results using leave-one-site-out (75-fold) cross validation.

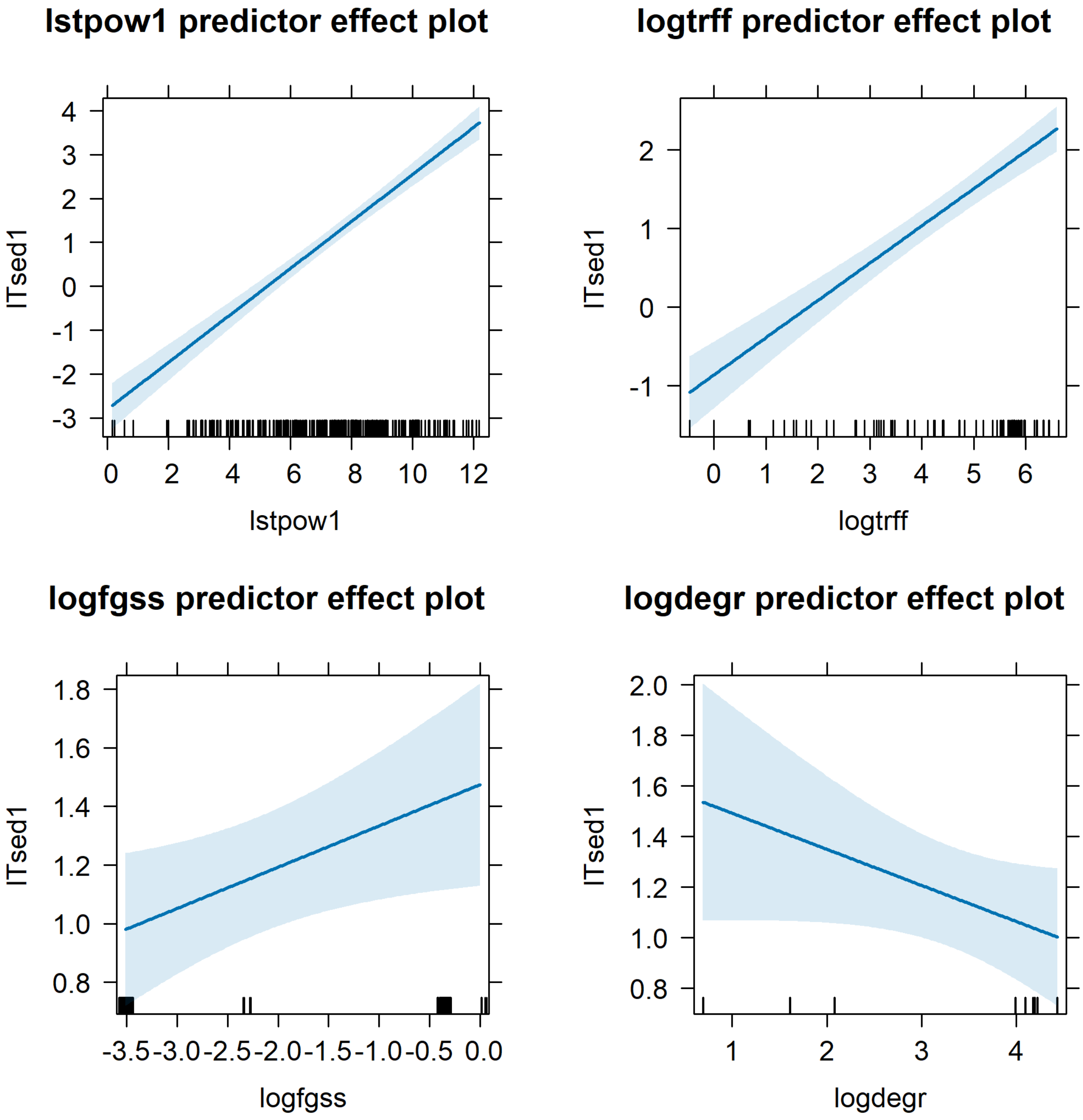


Figure 6: Sensitivity plot for full equation showing the relative effects of each covariate on the sediment yield (lTsed1), all axes are log transformed variable values. Recall that the rock degradation resistance score (degr) has higher quality with higher scores, and the fractional grain shear stress (fgss) partitioning is greater on bare ditches than on highly vegetated

AGU Annual Conference 2024

Abstracts submitted by Roads Project members

Microtopography Abstract

Examining the Effects of Rutting on Forest Road Flow Pathways and Erosion Potential

Authors: Amanda Danielle Alvis, Charles H Luce, Friedrich Knuth, Lauren Wittkopf, David E Shean, Gregory Stewart, and Erkan Istanbulluoglu

Notes:

- This abstract is being presented as an Oral Presentation.
- A data use notification regarding this information was presented to CMER in April 2024. A paper on this topic was submitted for publication to *ESPL* in September 2024, was rejected from *ESPL* in October 2024, then was submitted for publication to *Hydrological Processes* in November 2024.

Heavily trafficked unpaved forest roads are some of the largest sources of anthropogenic fine sediment in nearby streams. The generation of fine sediment through traffic is often made worse by road surface deformation. Ruts are one of the most common types of surface deformation seen on unpaved forest roads. Historically, the rate and magnitude of rut development have been studied using cross-sectional analyses. While elevational cross sections are a straightforward way to examine the development of ruts, this type of analysis lacks spatial distribution. More recently, remote sensing techniques, such as structure-from-motion (SfM), have demonstrated their utility in detecting ruts on forest roads but applications of these data are limited. Here we use SfM to examine the development of ruts on forest roads in a spatially comprehensive manner. We carried out a small-scale field experiment at two field sites in western Washington using unoccupied aerial vehicles (UAVs) to obtain digital elevation models (DEMs) of mainline logging road surfaces over three seasons. These UAV-derived DEMs were used in an elevation change analysis and in a simple flow routing model to examine the evolution of ruts, especially with respect to the road surface flow pathways and erosion potential. We found that: (1) the relationship between rut incision and time since grading was nonlinear at both sites for all seasons with sufficient data; (2) as ruts develop, the overall flow pathways shift down-road; and (3) the erosion potential of our road surfaces tended to increase as ruts developed. Our results demonstrate the expanded utility of using UAV-derived DEMs for analysis of rut evolution over cross-sections alone. Additionally, our results give us insight into how rutting may affect the utilization of erosion control treatments in roadside ditch lines and the sediment yield of the road surface.

Ditch Line Hydraulics Abstract

Quantifying Erosion Control Treatment Effectiveness in Roadside Ditch Lines Using Additional Roughness

Authors: Tom Black, Amanda Danielle Alvis, Charles H Luce, Erkan Istanbulluoglu, Julie Joslyn Dieu, and Jenelle Black

Notes:

- This abstract is being presented as a Poster Presentation.
- A data use notification regarding this information was presented to CMER in April 2023, and a paper on this topic was subsequently published in *ESPL* in January 2024.

Actively used forest roads generate large amounts of fine sediment from the road surface, which can have a deleterious effect on nearby aquatic habitats. To help mitigate the impacts of this generated fine sediment, forest roadside ditch lines are built to capture and redirect road runoff. Such ditch lines typically have erosion control treatments installed therein. The effectiveness of roadside ditch line erosion control treatments is usually presented as fixed fractional reductions in sediment yield. Fixed fractional reductions, however, depend on local calibrations that are not easily transferable to other contexts or conditions. Here we use additional flow roughness induced by erosion control treatments as a metric to help estimate treatment effectiveness in varying contexts. We investigate its utility in small-scale field experiments in western Washington. We measured the physical characteristics of each ditch including shape, soil texture, and slope. We observed flow velocities and sediment concentrations for each treatment using three discharge rates. We then used the concept of shear stress partitioning to relate sediment yield from the ditch line erosion treatments to grain shear stress, which is a function of flow roughness (Manning's n) of the respective treatment. We found that 1) a given erosion control treatment produced consistent Manning's n values across multiple replications and sites, with a bare ditch (no treatment) yielding the lowest roughness (n=0.05) and a densely-wattled ditch yielding the highest roughness (n=0.75); 2) increases in Manning's n yielded decreases in sediment load for all flows; and 3) adding erosion control treatments of any type resulted in reductions in sediment yield of greater than 95% for all flows. Our results demonstrate how additional flow roughness can be used as a general metric to help evaluate the effectiveness of ditch line erosion control treatments for a variety of physical conditions.

Modeling Abstract

Conceptualization of a process-based model for traffic-induced forest road erosion

Authors: Erkan Istanbulluoglu, Amanda Danielle Alvis, Charles H Luce, Julie Joslyn Dieu, Tom Black, and Jenelle Black

Notes:

- This abstract is being presented as a Poster Presentation.
- A paper including some of this information was published in *Environmental Reviews* in October 2022. The remaining information was part of Dr. Alvis' dissertation, which was completed in June 2024.

Traffic is one of the major drivers of sediment production on unpaved forest roads. Four main traffic-induced sediment production processes—pumping, crushing, scattering, and rutting—have been described in the literature. Pumping occurs when fine sediments are forced upward towards the surface of the road by traffic. Crushing is caused by traffic breaking down larger sediment into finer sediment. Scattering is the lateral displacement of larger sediments armoring the road surface, exposing the finer sediment below. Rutting is the channelization of flow on the road surface along the wheel paths as a result of traffic. Current forest road erosion models do not adequately represent these processes and their interactions based on conservation principles. Here we develop a continuous, three-layer model that represents sediment generation, storage, and vertical exchange within a road prism and surface sediment transport by runoff erosion, driven by traffic frequency and rainfall magnitude and moderated by surface roughness. This model is implemented in western Washington state where sediment yields and surface change have been monitored in several experimental logging road segments. When adequately parameterized for road surface material and climate conditions, our model shows potential to advance understanding of road erosion mechanisms and improve forest road management to reduce suspended sediment production from logging roads.

Major Experiment Abstract

The effectiveness of combined erosion control approaches for logging roads

Authors: Charles H Luce, Tom Black, Julie Joslyn Dieu, Amanda Danielle Alvis, Erkan Istanbulluoglu, and Jenelle Black

Notes:

- This abstract is being presented as a Poster Presentation.
- A data use notification regarding this information is to be presented to CMER in December 2024.

Silt-laden runoff from forest roads degrades the sublime water quality and fish habitat for which forests are prized. Consequently, aquatic conservationists and forest land managers share an interest in approaches to reduce erosion from forest roads, and many techniques have been applied to mitigate road erosion. Despite active innovation in approaches to prevent erosion, evaluation of different treatment approaches in the context of actively used forest haul, and particularly the combined effects of multiple treatment types, e.g. improved surfacing and ditchline protection, is largely absent from the literature. Here we apply multiple regression and machine learning approaches to analyze erosion from 75 road-segment plots in western Washington commercial forests to assess the effects of factors related to road location, traffic, gravel quality, and ditchline erosion control measures. Primary drivers of erosion from the plots were traffic volume and road gradient multiplied by runoff, which confirms and improves the physical understanding of previous work. Both stronger road surfacing gravel and increased ditchline roughness decreased road erosion substantially, each roughly halving sediment production when treatments are applied at their strongest level relative to more commonly applied treatment levels/quality. The effects appeared to be largely independent of one another so that improving both surfacing and ditchlines had a cumulative benefit. Surprisingly, there was no clear signal from the effect of variations in how many truck passes occurred under wet vs dry conditions, despite previous work documenting large turbidity increases during wet weather haul. This points to a need to understand ongoing rock crushing and storage of fines within the roadbed even when conditions are not saturated.