HAUL ROUTING: AN OVERLOOKED FACTOR IN ENVIRONMENTALLY DRIVEN ROAD DECOMMISSIONING

Finn Krogstad and Peter Schiess
Doctoral Candidate and MCMC Professor of Forest Engineering, respectively, College of Forest Resources
Box 352100, University of Washington, Seattle, Washington 98195

ABSTRACT – Stream sedimentation concerns might probably be incorporated into the road design process as a simplified, intuitive *thumbnail* model. Road Density (RD) and Stream Crossing Density (SCD) however guide designers towards minimizing minor, unused spur roads that have minimal sediment impacts. Crossing Area Served (CAS) on the other hand, focuses design attention towards the most heavily traveled segments, tending to shift them away from the stream network and towards a ridge alignment. A case study suggest that CAS better identifies areas of high sediment delivery and the design options that reduce this sediment.

INTRODUCTION

Sediment from forest roads can impact riparian habitat (WFPB, 1997). Several tools exist for modeling sediment delivery to streams. The Washington Forest Practices Board (1997) specified a fairly simple process for incorporating soils, haul, precipitation, alignment, width, etc. This has been incorporated into a user friendly GIS program (Glass, 2000) into which the relevant GIS data is fed, and which allows estimation of sediment produced by alternate forest management options. An even more detailed approach would be to model sediment production and delivery at each crossing (Elliot, et al., 1994). These models can be incorporated into the design process by running them on alternate road designs to identify the option that delivers the least sediment to the stream and to identify the problem areas that deliver high concentrations of sediment.

The best way to fix a problem however is to avoid it. If the environmental analysis can be moved from the evaluation phase to the design phase, then these problems can be avoided rather than just estimated/mitigated. To be useful in the design phase, a model must be simple enough to be intuitively *seen* on the base map. Just as no complicated calculation are required to *see* that a steep slide slope will require costly excavation/compaction and a steep adverse grade will drive up haul costs, simple *thumbnail* sediment models are needed if sediment minimization is to be incorporated into road design. Such a thumbnail model will necessarily sacrifice accuracy for intuitiveness, but this is unavoidable in a move from evaluating sediment problems into actually avoiding them.

ROAD DENSITY

One such simplified metric of road impact is road density (road length per area ownership). The simplicity of this method (more roads are bad; fewer roads are good) allows rapid conceptual evaluation of many possible access options. It guides the design towards better options, which is better than having to pick the better of two poor options.

Road density (RD) can also be used at the landscape level to evaluate alternate road network options to identify the one with the lowest impact, and even to compare impacts of road networks across ownership.

The simplification that allows intuitive application of this thumbnail model makes it necessarily less accurate than one of the detailed models above. The question is thus, not whether road density is an accurate predictor of road impact, but whether it guides the design towards better options. The problem with using road density to guide management becomes evident when it is combined with operational objectives. While road density penalizes roads according to their length, the operational value of roads is the area that they access and thus the traffic they carry. Combining the objectives of reducing road density while maintaining access to the woods results in the elimination of road segments that are not being used (Figure 1). The roads that are not being used however produce only a small fraction the total network sediment total however, so their elimination has minimal impact on the total sediment production of the road network. This is not a site-specific problem, but rather a general problem whenever these two goals are combined.

HAUL TRAFFIC AND EROSION

The reason that road density guides design towards the wrong management options is that while the road network is evenly distributed over the landscape (Figure 3), the traffic and thus the erosion is not evenly distributed (Figure 5). Vehicular traffic and thus traffic related erosion is the result of a number of transits, each going from some point to another. Trips commonly start from some place off map, follow some pat to some point on the landscape, and then return off map. There are generally several possible routes to reach a given point, but it can be argued that routes are chosen to optimize transit or minimize time. This disturbance is intrinsically uneven since the only reason a vehicle would enter a piece of road is if it provided the best

access to the destination point. Since disturbance increases with traffic volume (WFPB, 1997), the distribution of sediment production is similarly unevenly distributed.

Figure 1. Minimizing road density while maximizing operational value results in the decommissioning of unused roads producing minimal sediment (upper photo) while maintaining heavily trafficked roads producing most of the sediment (lower photo).

STREAM DELIVERY AND CROSSING DENSITY

Sediment erosion however is not the same as sediment delivered to the stream network. If sediment laden road runoff is routed across the forest floor, then it can slow or even infiltrate, leaving behind the sediment it carries. The further that road runoff has to travel to get to the stream (Figure 2), the less likely it is to deliver to the stream (Ketcheson and Megahan, 1996).

Delivery of sediment to the stream network is more likely when routed down roadside ditches directly into the stream. Much like overland flow however, sediment delivery in roadside ditches is more likely to be delivered to the stream (rather than routed across the forest floor) for road segments closest to the stream. Given that both ditch and overland delivery is highest near streams, this stream proximate road segment might be approximated by the road-stream crossing itself (Figure 3).
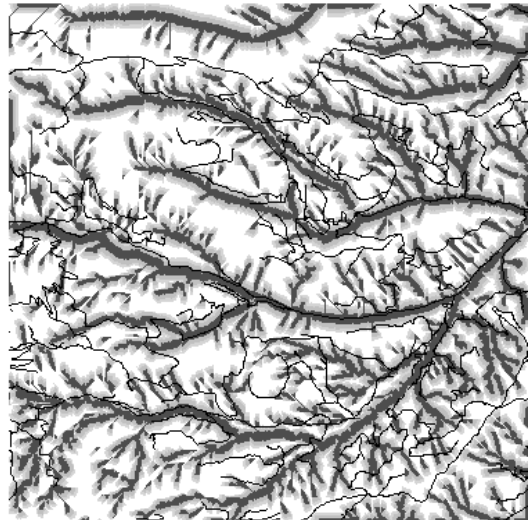

Figure 2. Sediment from the roads (black lines) is delivered to the streams with probability (shading) that decreases with distance from the stream.
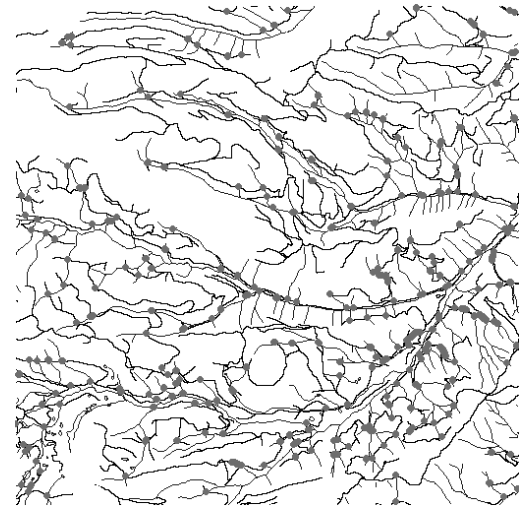

Figure 3. The road segments in Figure 2 with high probability of delivering sediment to the stream network can be approximated by just the points (dots) where the road (black) crosses the stream network (gray).

Making a simplifying assumption that all stream crossings deliver comparable amounts of sediment, allows stream crossings to be viewed as another thumbnail model of sediment delivery to the stream network. Dividing the number of road-stream crossings by the area of the ownership gives a Stream Crossing Density (SCD) in units of area^{-1}. SCD is similar to RD in that more roads produces more road density and thus the possibility for more road stream crossings. SCD however has the advantage that road segments that avoid streams produce fewer crossings and thus lower SCD than road networks that ignore or even follow streams.

The problem with using SCD as a metric of road impact is the same as using RD. If forest managers are told to decommission roads so as to reduce the number of stream crossings in an ownership, they will choose to decommission roads and road crossings that are not being used and are thus not producing sediment.

CROSSING AREA SERVED

This artificial incentive to decommission unused roads and crossings can be eliminated by weighting roads according to their projected use. This will balance the operational value of a road with the environmental cost of the sediment it produces. The erosion at each crossing is a function of the amount of traffic across that crossing, which in turn is a function of the volume of timber accessed by that crossing, which in turn is a function of the area served by that crossing.

Road sediment delivery to the stream network can thus be modeled according to the area served by each crossing (Figure 4). This Crossing Area Served (CAS) thumbnail is simple and intuitive like RD and SCD, but unlike them, requires the designer to envision the approximate area that each crossing will serve. Like the SCD, the CAS will tend to push alignments away from the valley bottoms and towards the *ridges* running between. But unlike the SCD, it will focus this stream *aversion* on the main haul routes and will devalue the impacts from the spur roads.
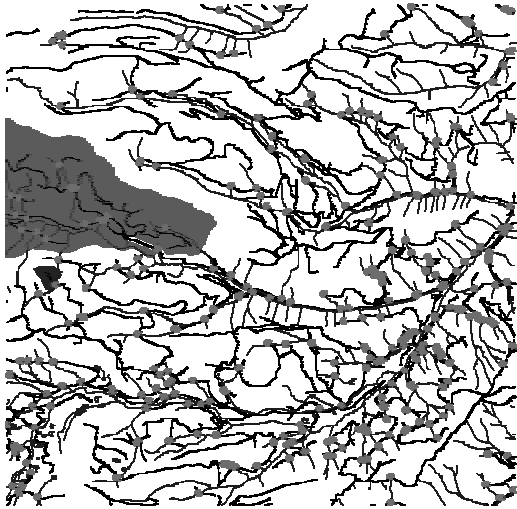

Figure 4. The area accessed by each crossing can be rapidly identified. While each dot looks identical, the number of settings served is not.

The CAS can also be employed at the landscape level to evaluate the total sediment impact of a road network. Summing the area served by all the crossings in an ownership, and dividing by the area of the ownership, gives a non-dimensional (area/area) measure of road sediment impact. This landscape CAS is much like the basal area index (sum of stem basal areas over stand area) or leaf area index (sum of the area of all the leaves over stand area). Landscape CAS can then be intuitively viewed as the number of streams that the 'average' log crosses in leaving the ownership. The lower the CAS, the fewer streams each log crosses, the less sediment impact a given operation will have.

EVALUATION

The utility of the alternate thumbnail models can be evaluated by using them to compare two alternate road network options on four subsections of an existing road network. While not predicting sediment volumes, a useful thumbnail model would be expected to rank the design option by stream sediment impacts and to rank the subsections of the study area by stream sediment impact and thus by mitigation needs.

A 36 mi^2 mixed ownership block on the Eastern side of the Cascade Mountains in Washington State, USA was chosen as a study area. Instead of developing two unrelated road options for the study area, the existing road network (Figure 5) was specified as Option 1, and an Option 2 (Figure 6) was created by adding a few road segments that would route traffic away from the existing stream-proximate main haul roads.
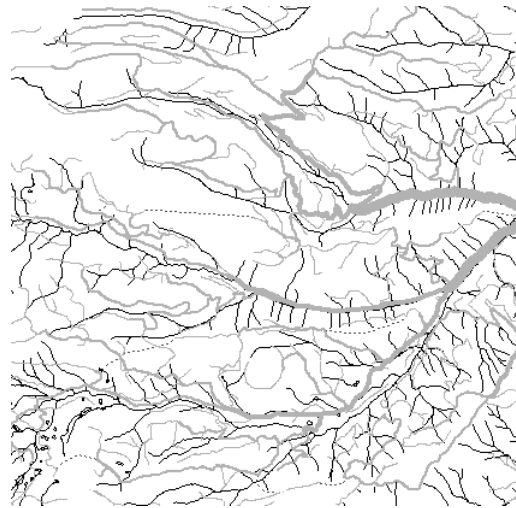

Figure 5. The original Option 1 haul routing (gray lines) is represented as line thickness and overlain on the stream network (black lines). The additional routes proposed by Option 2 are shown dotted.

Ideally, the resulting thumbnail metrics would be compared to observed delivered sediment volumes. The stochastic nature of sediment delivery, their limited duration, and the scarcity of such data sets however precluded their use in this study. Instead, one of the detailed road sediment models (SEDMODL) was used to estimate delivered sediment volumes, against which the simplified thumbnail models would be evaluated. Lacking good data on the design standards and surfacing of the existing road network, they

were all assumed to be designed as secondary roads with pitrun surfacing. Traffic volume was assumed to be proportional to the area served by each road, as estimated from shortest path calculations using the costpath function in ArcInfo.
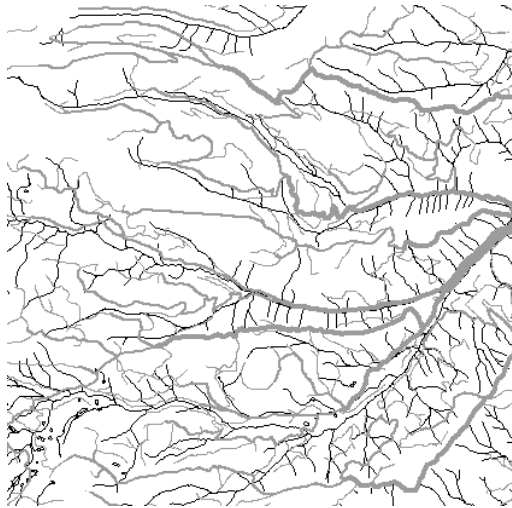

Figure 6. The revised haul traffic (Option 2) made possible by adding a few roads (show in Figure 6) that provide shorter access along roads with fewer stream crossings.

RESULTS

As might be expected, the minor road additions that distinguish Option 1 from Option 2 resulted in a slight increase in both road and stream crossing density (Table 1). The Crossing Area Served metric however recognized that less area was being served by the existing stream proximate main haul roads, resulting in reduction in delivered sediment volume. When the study area is quartered, the same pattern is seen in each quarter (Table 2). Additionally, the CAS metric does a much better job in identifying the Southeast and particularly the Northeast sections as areas of high traffic and thus sediment delivery. These results are particularly noticeable when plotted against the sediment volumes predicted by SEDMODL (Figure 7).

Table 1. The road density and stream crossing density metrics show a slight preference (have lower values) for Option 1, but crossing area served agrees with the results of the detailed SEDMODL in showing a significant reduction in Option 2 resulting from the revised haul routing shown in Figure 6.

	Option 1	Option 2
Road Density *(mi/mi²)*	6.39	6.57
Stream Crossings *(mi⁻²)*	8.11	8.14
Crossing Area Served	13.3	8.4
SEDMODL *(tons/yr)*	928	678

Table 2. Dividing the study area into quarters and running each metric for both options yields results similar to Table 1 for each quarter. CAS also correctly ranks the sections according to road sediment impact.

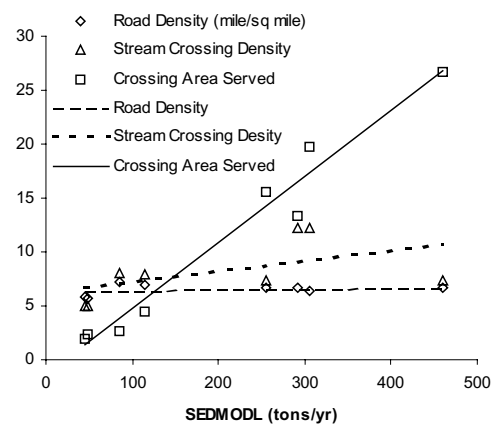|	NW		NE		SW		SE	
	#1	**#2**	**#1**	**#2**	**#1**	**#2**	**#1**	**#2**
Road Density (mi/mi^2)	**5.7**	5.9	6.6	6.6	**6.9**	7.2	**6.4**	6.6
Stream Crossings (mi^{-2})	5.0	5.0	7.3	7.3	**7.9**	8.0	12.2	12.2
Crossing Area Served	2.4	**2.0**	26.7	**15.5**	4.4	**2.7**	19.7	**13.4**
SEDMODL (tons/yr)	48	**46**	460	**255**	115	**85**	305	**292**

Figure 7. Plotting the data from Table 2 shows a strong agreement between Crossing Area Served and the detailed SEDMODL, but the considerable variation in predicted sediment volumes is poorly reflected by Road Density and Stream Crossing Density.

CONCLUSION

A single case study can not conclusively demonstrate the superiority of a model, so further testing is needed. It should also be remembered that CAS is not intended to model other road impacts such as landsliding or habitat fragmentation. None the less, the theoretical appeal and experimental success of CAS suggests that it may be possible to begin including stream sediment concerns into road design and avoiding rather than just measuring such impacts.

ACKNOWLEDGEMENTS

CITATIONS

Elliot, W.J.; R.B. Foltz, and M.D. Remboldt 1994. Predicting sedimentation from roads at stream crossings with the WEPP model. Pap. Am. Soc. Agric. Eng. 94-7501/94-7512.

Glass, D. 2000. Where is all that dirt coming from and what can we do about it? Use of **SEDMOD** to estimate delivery of sediment to streams. In: Slaughter-Charles-W (editor). Western watersheds; science, sense, strategies; proceedings of the seventh biennial Watershed Management Council conference. Water Resources Center Report - Centers for Water and Wildland Resources. Pages 128-129.

Ketcheson, G. L. and Megahan W.F., 1996. Sediment production and downslope sediment transport from forest roads in granitic watersheds. USDA Forest Service, Intermountain Research Station, Research Paper, INT-RP-486. 11 pp.

Washington (State) Forest Practices Board, 1997. Board manual: standard methodology for conducting watershed analysis under chapter 222-22 WAC, version 4.0, Washington Forest Practices Board, Olympia, Washington.