Comparing Long-Reach vs. Conventional Skyline Design Options:

Impacts on Road Densities, Sediment Budgets, Economics and Silvicultural Options

Executive Summary

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Abstract

The operational and environmental impacts of a conventional and a long-span yarding approach to forest management were simulated and compared in T12N R14E in the Ahtanum valley West of Yakima, WA. The conventional approach produced higher revenues at lower costs as expected, but delivered no more sediment to the stream than the long-span, no-new-roads approach. The explanation for this counter-intuitive result can be found in the density of the road network and its proximity to the stream. The road network produced a tenfold sediment increase over background levels, which might suggest a program of elimination and/or surfacing of existing roads. Analysis of this case, however, suggests that the construction of a ridge-based road network will be both environmentally and economically superior. This approach of integrating cumulative environmental impacts into the landscape scale harvest and transportation planning appears promising for identifying management options for reducing salmonid habitat degradation.

Introduction

The Washington Department of Natural Resources (DNR) entered into an agreement with the federal government relating to the compliance with the federal endangered Species Act (16 US>C> 1531 et seq). As part of that agreement DNR developed a Habitat Conservation Plan (HCP) which would provide the framework for the management activities of its trust lands. Significant changes to timber sales requirements resulted. Rather than commit to a definite, upper limit on road densities, DNR agreed to provide for a comprehensive landscape-based road network management process. The major components of that process includes the minimization of the active road density and a site specific assessment of alternatives to new road construction such as extending yarding distances and their use where consistent with conservation objectives (DNR, 1997).

Impacts on salmonid habitat or water resources in general are influenced by activities in any one of the six general phases of road system development: planning (yarding distance – road densities/locations), design, construction, use, maintenance, and decommissioning. The planning aspect includes the trade-off of yarding distance – road densities and within this general framework the location of roads based on the particular topographic and geologic conditions. A clear understanding of a total and true cost accounting of the road transportation system has to include aspects of sediment generation and sediment delivery to the stream network.

The overall goal as stated in the HCP is to reduce road densities based on the assumptions that this is one of the significant factors that affect salmonid habitat. Road density reduction would be achieved through a combination of increased yarding distances and an aggressive road-decommissioning program. Both options (increased yarding distance, road decommissioning) have costs associated with them and both strategies will result in decreased road densities. However, as will be shown, neither strategy alone, or in combination may reduce the true agent of salmonid habitat degradation; sediment delivery.

What is needed is an integrative approach to road system development including new road construction. What is not quite clear are the cumulative effects of either or what a combined strategy has on the natural resources and habitat of sensitive species. Any comparative analyze should attempt to quantify road use patterns (and with it the economic trade-off) and include sediment budgets as the true agents of salmonid habitat degradation

Objectives

The objective of this study was to develop a framework for comparing the economic and environmental costs of conventional harvest systems versus a road minimizing option using a combination of long-reach skylines, helicopters, and conventional skyline systems. Each management plan would be assessed based on the economics and the resulting sediment budgets

1. Develop appropriate production and costing models for long-span cable yarding and review the appropriate information for long-reach ground systems.

2. Analyze the impacts and trade-offs of long-span yarding systems and reduced roading on total costs and revenues.

3. Assess the impacts of roads on sediment generation and delivery to salmonid habitat.

Approach

The project was organized along three major activities in order to address the issues mentioned earlier. First, a thorough literature search and assessment of current knowledge with regard to long-span cable yarding production and costs was carried out. This is an area where little information currently exists. The second activity developed the operational and economic parameters for a harvest and transportation plan comparison of a portion of the Ahtanum watershed. It s purpose was to develop a long-span yarding alternative with the resulting road system and compare the results (revenues and road densities) with the current harvest and transportation plan that had been developed by DNR harvest planners using conventional yarding systems and yarding distances. The third activity was to use the road systems (road use pattern and traffic loads) from each plan and develop the corresponding sediment budgets (sediment generation and delivery)

Results

Long-span cable yarding cost and production estimates

Most current harvest and road systems are based on a yarding technology with an upper limit of approximately 2000 ft external yarding distance (EYD). Available information shows a wealth of information for the conventional spans but very little information exists for the extended spans beyond 2000 ft

Long-span skyline systems (also referred to as Wyssen systems) developed primarily in Central Europe. The Swiss Federal Forest Research Institute developed a series of production and cost tables for the forest districts to be used in their production and cost appraisals based on a database that covered four years. They provided detailed information for corridor layout, system setup (rigging and move times) and production as a function of yarding distance.

The observed North American experiences with Wyssen-type cable systems appeared well correlated with Central European experiences as far as cycle times were concerned. Production was primarily a function of distance and did not vary with silviculture such as clearcut or selective cut. By increasing log lengths production could be increased without impacting cycle times. In most, if not all cases turns were usually fully suspended making the yarding cycle independent of ground or stand conditions. Currently there are no Wyssen systems working on the U.S. West coast. A Wyssen system was used on a Plum Creek Co. timber sale near Cle Elum WA in 1998. One Wyssen system is currently operating near Boston Bar, BC, Canada.

Production data for slackline operations with yarding distances beyond 2000 ft EYD are rare. Only one reported study was found documenting performance over 4000 ft. Average turn times of 9.02 minutes were reported for an AYD of 1300 ft. The production rates reported were not significantly different for uphill and downhill (gravity) yarding. However, in general practice the downhill yarding was discouraged because of the high level of engineering and fieldwork required to insure full suspension of turns.

European long-span skylines systems differ from their North American counterpart in horsepower rating and therefore line speeds. The effect of line speeds on cycle times is shown in Figure 1. Over comparable distances (< 1000 ft) cycle times for the conventional tower yarders are half the time for the Wyssen systems indicating the effect of line speeds. Cycle times for the Swiss and the Hensel model (North American experiences) are very close for the uphill yarding operation and differ by about 15% for the downhill operation. Downhill yarding results in faster cycle times than for uphill yarding for the Wyssen systems because of higher speeds that are attainable with gravity inhaul due to the load. Full suspension, however, is critical. The cycle times for the tower yarder are about 60% of the cycle times reported for the Wyssen system operating in the downhill direction.

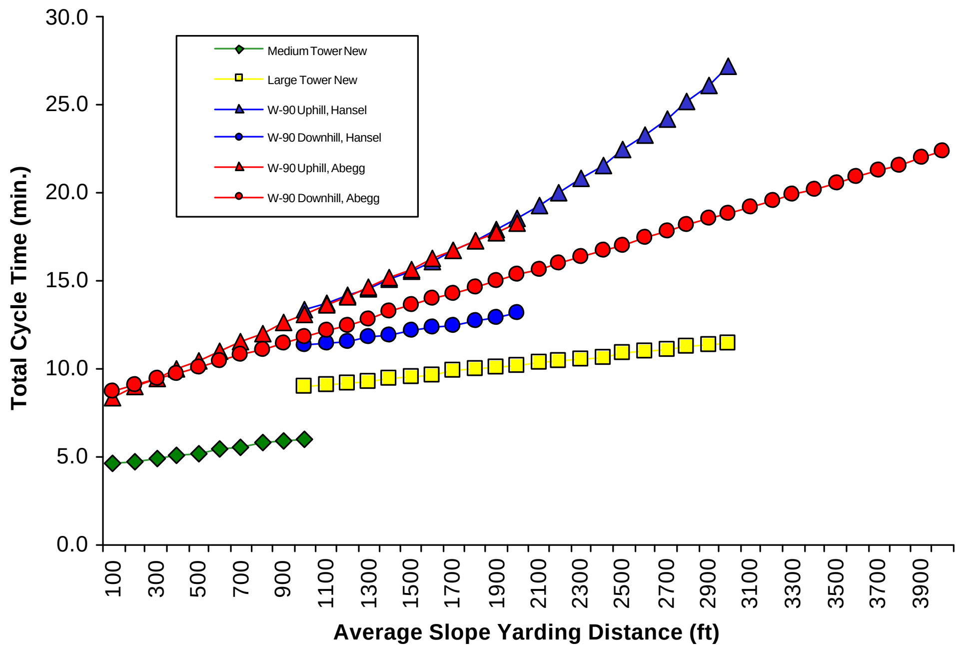

Figure 1. Total cycle times for uphill and downhill yarding for three long-span and one conventional span systems; a Wyssen system(Swiss conditions-Abegg and PNW conditions-Hensel) a large tower yarder and a conventional-span yarder

The results revealed higher production costs for EYD >2000 ft. This is in agreement with surveys of logging contractors who clearly showed a preference for yarding distances less than 1000 ft. Reasons were increased rigging times and the increased risk for operational delays. In general, optimal AYD increased with increasing rigging times and/or decreasing harvest volumes (MBF/acre) and log/turn size.

To explore the effect of silviculture on yarding costs two cases were considered. The first case was typical of a regeneration cut of second-growth forests, 50-60 years old with an average volume of 35 MBF/acre and log size of approximately 120 BF/log resulting in a turn size of 6200 lbs. Stump-to-truck cost for a conventional system with an AYD of 600 ft was $103.-/MBF. A comparable large tower system in the same silvicultural situation had stump-to-truck costs of $124.- and $136.-/MBF for AYD's of 1000 and 2000 ft respectively compared with $116.- and $119.-/MBF for a Wyssen system.

The second case was a selection cut in older stands with log sizes of 20 -22 inch (167 BF/log and payload of 9000 lbs. (indicative of east-side condition) and volume removals of 15 MBF/acre. Production costs for a large tower yarder were $116.- and 117.-/MBF for AYD's of 1000 and 2000 ft. Decreasing volumes with increased turn size (such as in selection cuts) had the effect of increasing the optimal AYD. Noticeable was the impact it had on making yarding costs almost independent of distance. Long-span production costs of $116 to 117.-/MBF (AYD's of 1000 – 2000 ft) compared favorably with conventional systems despite higher volume and shorter yarding distances ($103.-/MBF, AYD = 600 ft). Piece or turn size played an important role. With the longer cycle times opportunities exist to maximize payloads in a similar fashion as with helicopter yarding and therefore minimize the impact of distance on yarding costs.

Long-span systems appeared promising as an appropriate alternative where silvicultural goals included significant dispersed or aggregated retention. In both cases rigging requirements would increase while at the same time reduce the available, total extraction volume but not necessarily the log and turn sizes. Long-span systems had comparable costs to conventional systems, if applied under appropriate silvicultural conditions. Such silvicultural goals might help long-span yarding systems because of the interaction of total volume available, piece size and rigging time requirements.

Scheduling and Network Analysis

The Ahtanum is characterized by its checkerboard ownership pattern where various other landowners are involved, each with different land management goals. To reduce those impacts a township was selected for further analysis where DNR had substantial (although no exclusive) ownership. The original harvest and transportation plan developed by DNR harvest planners was adjusted to reflect the new planning boundaries. However, the stated goals and harvest volume targets were used in the adjusted areas (**Error! Reference source not found.**).

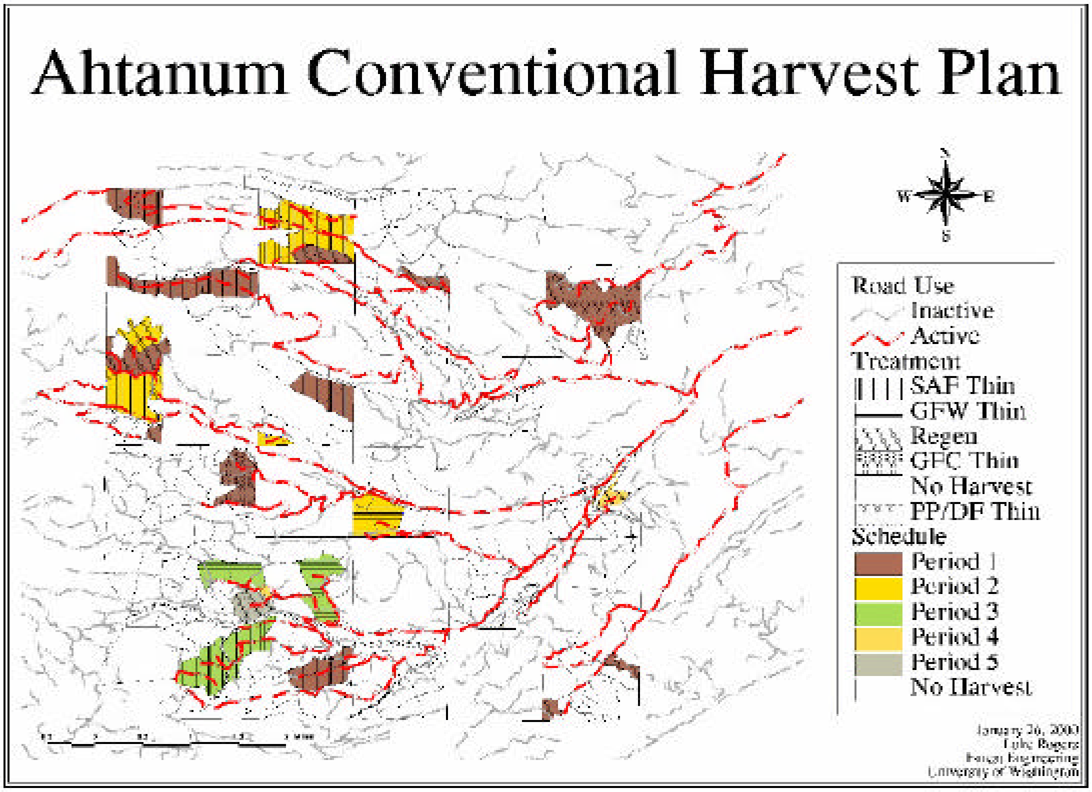

Figure 2. Harvest schedules and road use pattern for the conventional plan over five periods (as developed by DNR). Shown are the harvest areas (by period and silvicultural harvest method) and resulting road use pattern. Non-DNR ownership is usually characterized by an absence of setting boundaries. A total of 19.6 km (12.2 miles) of new roads were constructed with 18.5 km (11.5 miles) on DNR land. A total of 1032 ha (2551 acres) are scheduled for harvest of which 823 ha (2031 acres) are as partial cut and 210 ha (520 acres) as regeneration cut over a 25-year time span (5 planning periods).

The long-span management plan had as its stated goal the reduction of overall road densities. This could be achieved by extending the yarding distances beyond the conventional reach (>2000 feet) and/or by not allowing any new road construction. We chose to use both goals. In order to approach the extremes of extending conventional yarding distances beyond 2000 feet we specified that any setting not currently served by an existing road would be harvested by helicopter (Figure 3).

The HCP dispersal and NRF habitat requirements as well as the late seral stage requirements agreed upon with local tribes were adhered to for the area-adjusted base plan (DNR's conventional plan) and the long-span plan. Target volumes for both plans were set at 10 MMBF for the first three periods and then 1 MMBF for periods 4 and 5 as stated in DNR's original base plan. The software used for scheduling and network analysis was SNAP 3.19.

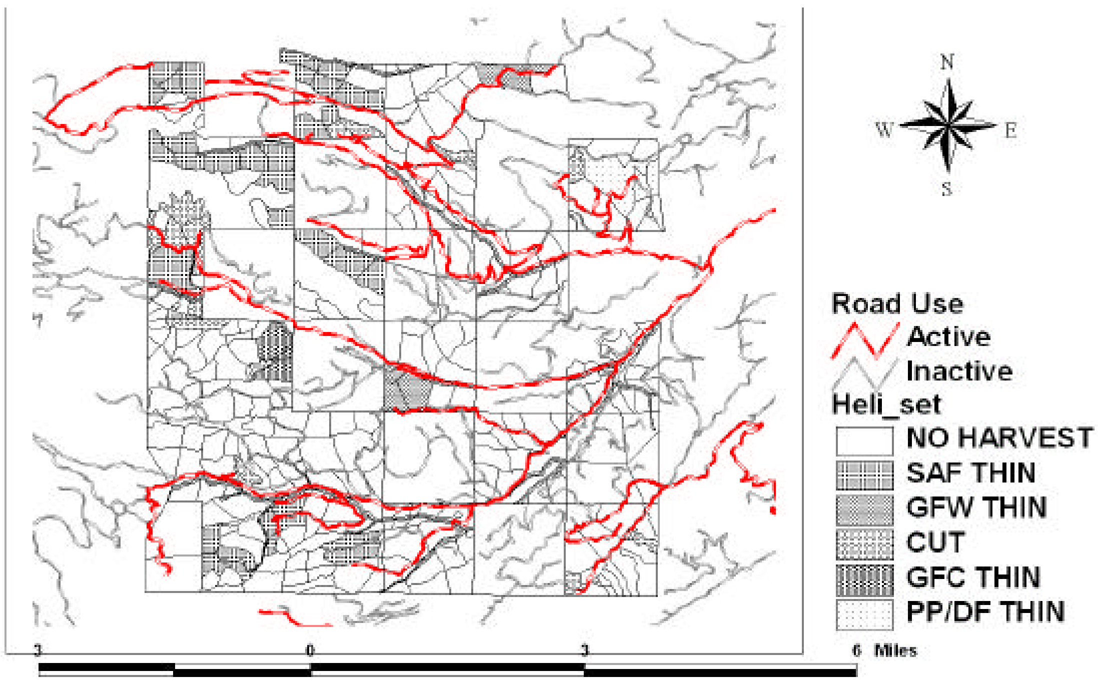

Figure 3. SNAP analysis for the long-span. Shown are the harvest areas (by period and silvicultural harvest method) and resulting road use pattern. Non-DNR ownership is usually characterized by the absence of setting boundaries. Note the absence of any new road construction. A total of 1035 ha (2557 acres) are scheduled for harvest of which 873 ha (2158 acres) as partial cut and 161 ha (399 acres) as regeneration cut over a 25-year time span (5 planning periods).

The results for the two management plans are shown in Table 1. Neither plan is able to meet the stated harvest volumes without violating any of the adopted HCP or adjacency requirements. Harvest volumes achieved were about 56,600 m^3 (10 MMBF) over the five periods for both plans. The helicopter use and related harvest patterns reveal some interesting aspects. The conventional plan never used a helicopter despite its potential availability. Targeted volumes could be achieved within the other constraints without resorting to the more expensive yarding method. It was more cost-effective to build additional roads and utilize a larger road system. The conventional plan used a total of 137.6 km (85.5 miles) versus the 83.2 km (51.7 miles) of existing road length in the long-span version. In the long-span plan, helicopters had to be used in order to meet stated harvest goals from areas that were not constrained by other requirements such as adjacency, seral stage and HCP requirements. As a result the long-span plan tried to meet stated harvest goals by harvesting more areas in closer proximity to existing roads resorting to smaller tree sizes and lower standing volumes. More mature stands further removed from the existing road network proved economically not viable because of the high yarding costs brought about by long cycle times resulting overall in lower values for the timber harvested.

Table 1. Results from the scheduling and networking analysis for the two management plans. Shown are the harvest systems utilized, road uses and road construction requirements together with costs and revenues. Note that the long-span plan requires no new road construction. Table 2. Results from the scheduling and networking analysis for the two management plans. Shown are the harvest systems utilized, road uses and road construction requirements together with costs and revenues. Note that the long-span plan requires no new road construction.

		5-period Total
	Conventional Plan	
Volume harvested	112 $/MBF	10,688 MBF
Roads used **Existing**	47 $/MBF	**74** miles
Roads used **New roads**	37 $/MBF	**11.5** miles
Yarding costs	197 $/MBF	$ 1,200,000
Haul costs	269 $/MBF	$ 507,00
Construction costs		$ 396,000
Total Costs		$ 2,104,000
Revenues		$ 2.880,000
	Long-span alternative (no new roads)	
Volume harvested	202 $/MBF	9218 MBF
Roads used **Existing**	47 $/MBF	**51.7** miles
Yarding costs	**0**	$ 1,861,000
Haul costs	249 $/MBF	$ 431,000
Construction costs	251 $/MBF	**0**
Total Cost		**$** 2,294,000
Revenues		**$** 2.310,000

Delivered Sediment

The harvest and haul activities identified by SNAP, provided a unique opportunity to estimate sediment production for the two options and delivery to the stream network. The topography was divided into a grid, and information relevant to sediment production and delivery (e.g. local slope, distance to stream, road surfacing) were recorded for each cell. The Washington Forest Practices watershed analysis manual was used as the basis of a GIS program to estimate sediment production and delivery from each grid cell. Road usage was estimated from SNAP's timber haul estimates (MBF/period). Vegetation on cut and fill slopes was assumed to increase by 1% per year, while all existing were assumed to be 30% vegetated at the start of the simulation. Harvest related soil disturbance was assumed to produce 810 tons/acre during the period of harvest. Overland filtering/delivery to streams was estimated by assuming that half the sediment was filtered every 90'.

Table 3. Sediment Delivered to the Stream Network (tons/year) is estimated for each management plan, study period, and source area. Concentrating haul onto native surface roads in close proximity to the stream network results in a tread volume that dwarfs all other sources.

Period	**1**	**2**	**3**	**4**	**5**	**mean**
Conventional Plan						
Background	747	747	747	747	747	747
Harvest	26	21	5	2	3	11
Cut Slopes	380	371	350	318	314	347
Fill slopes	184	177	167	151	150	166
Tread	7471	6423	4375	3466	4291	5205
Long Span (no new roads)						
Background	747	747	747	747	747	747
Harvest	30	23	4	4	0	12
Cut Slopes	354	330	303	276	276	308
Fill slopes	175	164	151	137	137	153
Tread	9658	7444	4498	3069	3069	5548

The results of this analysis are summarized in Table 3. Contrary to expectations, the long-span (no new roads) option actually produced more total sediments than the conventional harvest/transportation plan. The no-new-roads option produced less sediment from cut and fill slopes, but this reduction was dwarfed by haul related erosion from the tread surface. In the long-span case SNAP routed more of the long-span haul along roads in proximity to the stream network. The resulting increase in total sediment delivery does not represent a failure of the long-span system, but rather that usage of specific roads is far more significant than road density.

These estimates of delivered road sediment are much higher (~7Xbackground) than those predicted by Ahtanum Watershed Analysis report (~3Xbackground), even though similar methodology and numbers are used. The main difference between this study and the watershed analysis report is that this study used SNAP outputs to identify traffic loads and patterns (Figure 2).

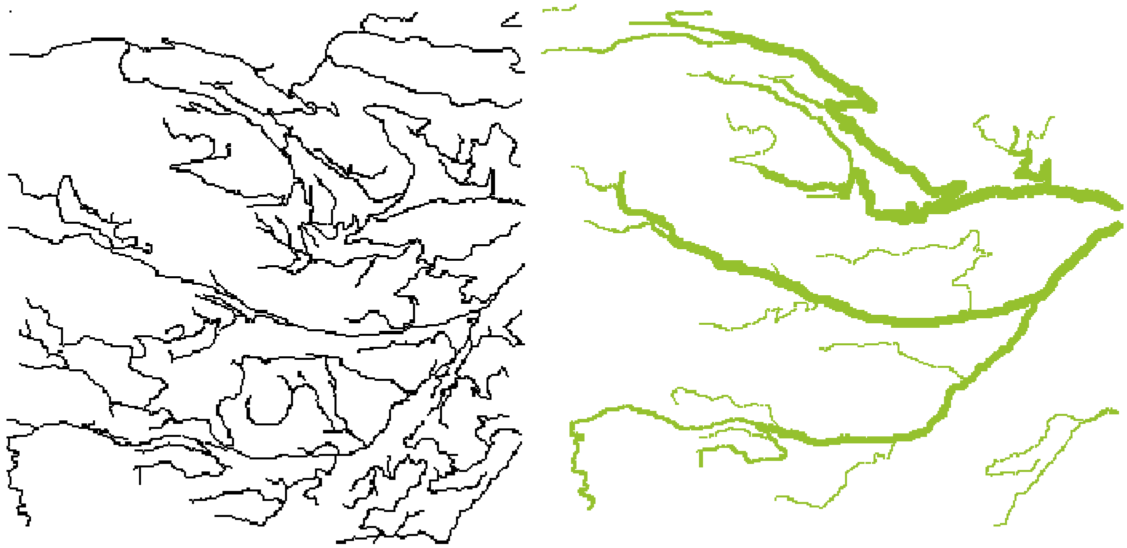

Figure 2. Twenty-five years of haul in the long-span option. While the road network covers the entire planning area (**Error! Reference source not found.**), haul is concentrated along a relatively few roads. Thicker lines indicate more haul volume.

The reason that minimizing road density did not reduce road sediment is that the existing road network (Figure 3) routes most of the haul traffic (Figure 2) onto roads that closely parallel the stream network (Figure 3). The problem with using road density to describe road impacts is that the vast majority of the road network gets little or no haul, and the vast majority of the haul traffic goes over relatively few road segments. This concentration of haul volume over roads located very close to streams produces the large tread derived sediment load, which in turn dwarfs the sediment produced on all other roads and all other sediment sources in Table 3.

A traditional program of road density reduction would eliminate many unused spur roads, which being unused would thus not be the ones producing the sediment. According to the watershed analysis manual, applying a thick gravel to this native surface road network would eliminate 80% of the tread sediment production but the remaining 20% of the tread related sediment will still approximately double the background sediment. In fact, even if every road in the study area were paved, the cut and fill slopes alone would still provide more than 50% of background levels.

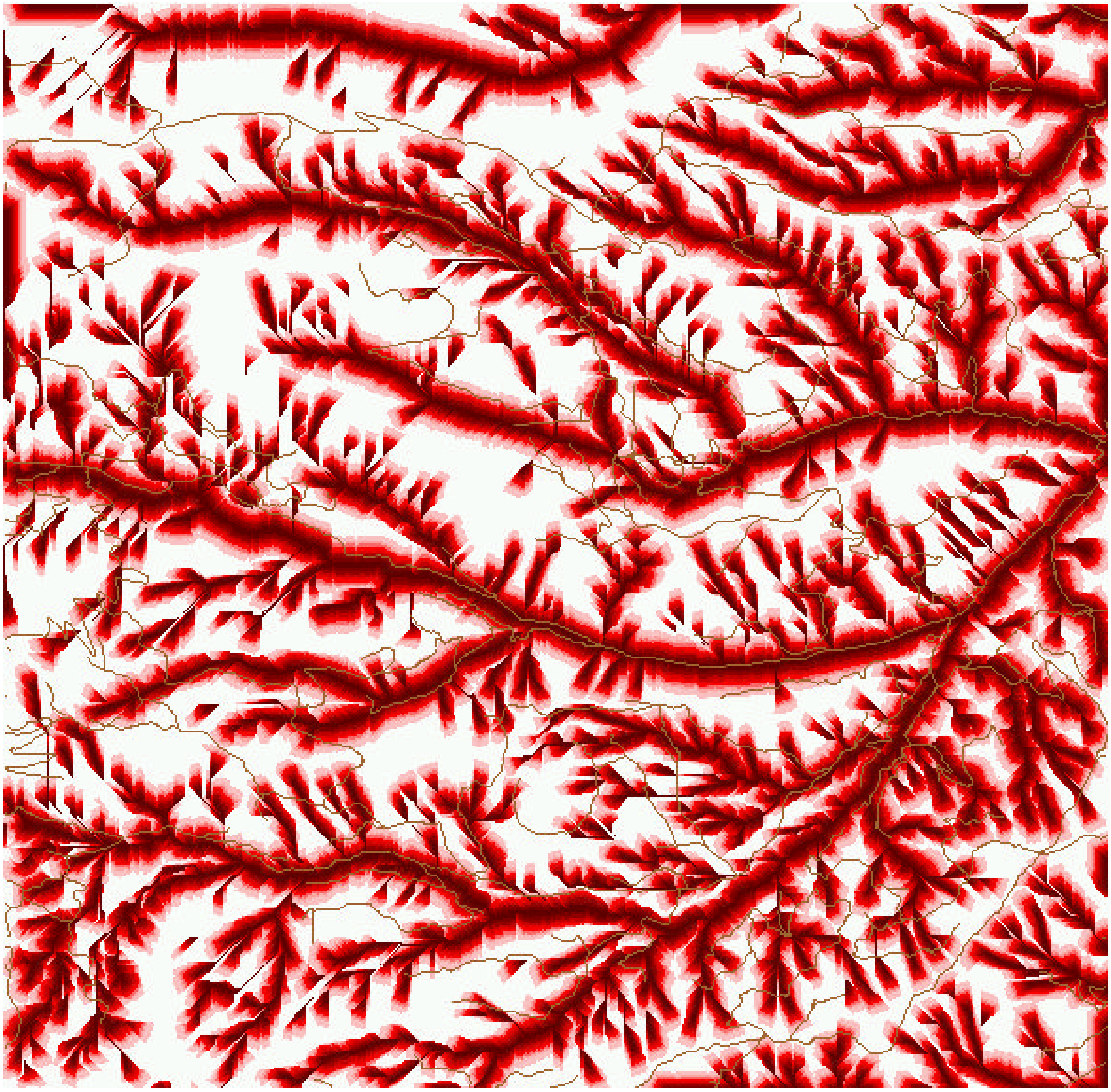

Figure 3. Sediment delivery and the existing road network. While areas near streams have near 100% delivery (darker areas), a large fraction of the landscape has <0.1% delivery (white areas), in which road networks can be constructed that will deliver almost no sediment to the stream network. Examples of such ridge road networks exist in the Northwest and Southeast portions of the planning area.

An alternative approach to reducing delivered sediment is suggested by Figure 3 in which long linear segments of the study area can be identified that deliver little or no sediment to the road network. A network of primary and secondary roads following this ridge network (and crossing the stream network only rarely) would deliver almost no sediment to the stream network, even if native surfaced. Assuming that rock accounts for half the cost of a new rocked road, then for the same cost as rocking a mile of existing road, it is possible to build a mile of ridgeline road, with much less sediment delivery.

These results show that sediment budgets and their spatial origins are most critical to effectively address salmonid habitat impacts. As shown here and in the Hoodsport analysis, road density management in isolation is not an effective tool to management impacts. To the contrary, uninformed road de-commissioning might result in no improvement at all.

Conclusion

Effective management to improve salmonid habitat depends on a clear understanding of the agents of sediment generation and delivery. Both processes are directly linked to transportation issues (both yarding and truck haul) which include the earlier stated six general phases of road system development. Paradoxically as it may sound, new road construction may actually improve salmonid habitat by routing traffic over less sensitive roads. However, such a solution is only possible in the context of comprehensive harvest and transportation planning at the landscape or watershed level, which includes cumulative assessment tools, among them a sediment budget. As part of a different project, we are pursuing such an approach.