Forest Road Sediment and Drainage Monitoring Project Report for Private and State Lands in Western Oregon

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Summary

This is the second report completed as part of a four-year project to investigate the effectiveness of forest road drainage practices designed to minimize sediment delivery to streams. This investigation is expected to yield a list of recommended road drainage and construction practices for private and public forest land managers and agencies that regulate forest management activities in western Oregon. This report summarizes data collected during the summer and fall of 1995 and 1996, years two and three of this project. Road drainage and sediment delivery data were analyzed in a regional context, as well as broken into categories based on best management practices (BMP's). A final technical paper will be produced at the end of this project.

Objectives

1. Develop field methods that determine the sediment delivery potential from forest roads.
2. Survey discharge structures and their potential for sediment delivery to waters of the state on forest roads in each of the five western Oregon georegions.
3. Develop a forest road inventory and erosion hazard inventory protocol for landowners.
4. Develop a road management guidebook.
5. Develop a technical issue paper for the Board of Forestry.

Background

Forest roads are recognized as the greatest potential source of accelerated erosion associated with forest management. The original intent of this four year monitoring project was to evaluate the effectiveness of Oregon's forest practice standards to minimize delivery of surface erosion from forest roads to waters of the state.

The February 1996 storm caused many landslides, channel changes, and other effects to natural resources and private property in northwestern Oregon. The storm was an unusual, but extremely important event that provided a unique opportunity to test the effectiveness of forest practices developed over the last two decades.

This report summarizes monitoring activities conducted during the summer and fall of 1995 and 1996. The data set reflects years when the relative importance of chronic surface erosion versus episodic landslide erosion as sources of sediment may have differed.

Methods

This report includes data that was collected during the summer and fall of 1995 and 1996. The method used to select areas to be surveyed differed each year. In 1995, all accessible roads within a randomly selected township, range and section were sampled to obtain at least 10 miles of road length. Where the randomly selected area (township, range and section) did not contain 10 miles of road, the sampling boundary was extended until that length of road was encompassed. Land in federal ownership, agricultural or urban landuse or dominated by large waterbodies was not sampled.

Areas sampled in 1996 were chosen using two different methods. First of all, three 10 square-mile areas of the highest landslide density observed after the February 1996 storm were selected non-randomly by the Oregon Department of Forestry (ODF) and are called the "red" zones. Secondly, areas of similar landscape, climate and geology but with low-landslide density were identified and three areas were randomly selected from these areas, one to pair with each of the "red" zones.

Forest roads in each of the five western Oregon georegions were sampled in 1995. During the 1996 survey, only three georegions were sampled (Coast Range, Interior, Western Cascades), thus the South Coast and Siskiyou georegions are represented by only the 1995 data. The Oregon forest practice rules (ODF 1997) use the term "geographic region" to describe large areas with similar climate, geomorphology and natural vegetation. There are five geographic regions in western Oregon:

1) Coast Range – Characterized by marine sandstone geology, high annual rainfall and steep coastal mountains.
2) Western Cascades – Characterized by volcanic geology, high annual rainfall and is generally mountainous.
3) Interior – The foothills on either side of the Willamette Valley.
4) South Coast – An area of unique geology and hydrology in Oregon that consists mainly of sheared metamorphic rocks and has the highest instantaneous maximum streamflows in the state.
5) Siskiyou – Highly variable geology and average annual rainfall ranges from 20 to over 100 inches.

Information gathered

The same methods were used to collect data in both 1995 and 1996 although the codes used for some road classifications and characteristics differed slightly. The data gathered included:

1) Road characteristics;
2) Condition of sample road segments (between surface discharge points); and
3) The location of surface water discharge points, including their potential to deliver sediment to waters of the state.

1) General Characteristics

The following data was collected to characterize the road:

a) Legal description (section, township, range) and name;
b) Forest practices maintenance status (active, inactive or vacated); and
c) Road surfacing material (clean rock, dirty rock or dirt).

2) Source Area

The source area of a surface water discharge point is the length of road draining to that point. Information was gathered for every road segment in the survey area. The information collected was used to evaluate the potential of the road to generate sediment for delivery to a surface water discharge point. This information was also used to evaluate road BMP's for erosion control and dispersal of surface waters.

The length and slope of each road segment was measured. Road design was categorized as crowned, insloped or outsloped. The condition of the ditch and the height and vegetative cover of the cutslope were also determined.

3) Discharge

Surface drainage points from the road include cross-drainage culverts, live stream crossings, waterbars, rolling dips, grade breaks, saddles, and random points of discharge. Information on drainage characteristics and potential sediment delivery at all surface drainage points was collected.

The diameter of all cross-drainage and live stream crossing culverts was measured. Culvert condition was estimated as the amount of the culvert inlet remaining open expressed as a percent. Where the culvert inlet was reduced, the cause was recorded as mechanical crushing, filling by debris or age related deterioration.

The culvert outlet or other discharge point was examined for evidence of sediment delivery to waters of the state. Discharge directly into a stream or a gully connected with a stream was rated a "yes" for delivery. Discharge points with either no evidence of erosion or deposition at the outlet or no evident pathway for sediment to enter the waters of the state were rated "no" for sediment delivery. All other discharge points rated "possible" for sediment delivery.

4) Data Collection

The length of each road segment was measured using a distance measuring instrument (DMI) that was installed in the vehicle and recorded distance in feet. A hip chain was used for distance measurements when roads could not be driven. A clinometer was used for slope measurements.

Results

The analysis addressed the following questions:

1) What is the proportion of the forest road system that potentially delivers sediment to streams;
2) What is the spacing of surface runoff discharge points;
3) What is the distance from stream crossing structures to the first drainage point upslope; and
4) What are the characteristics of forest road drainage systems and road segments where evidence of sediment delivery to waters of the state exists.

Summary of road survey information by georegion

Table 1: Summary of road survey information by georegion.

Georegion	Percent Road Grade	No. Road Segments	Sum of Length (ft)	Average Length (ft)	Percent of Length in Georegion
Coast Range	0 – 4	405	188,056	464	40
	5 – 8	246	129,861	528	27
	9 – 12	158	70,348	445	15
	13 – 18	182	79,357	436	17
	>18	30	5,212	174	1
	Total	1,021	472,834	463	100
Interior	0 – 4	496	198,977	401	40
	5 – 8	305	195,760	642	39
	9 – 12	113	70,815	627	14
	13 – 18	44	25,028	569	5
	>18	10	5,475	548	1
	Total	968	496,055	512	100
South Coast	0 – 4	138	37,530	272	28
	5 – 8	77	35,178	457	26
	9 – 12	77	33,661	437	25
	13 – 18	67	28,025	418	21
	>18	3	385	128	0
	Total	362	134,779	372	100
Siskiyou	0 – 4	135	27,432	203	38
	5 – 8	41	13,985	341	20
	9 – 12	52	18,449	355	26
	13 – 18	13	9,523	733	13
	>18	4	2,282	571	3
	Total	245	71,671	293	100
Western Cascades	0 – 4	319	123,545	387	37
	5 – 8	177	80,221	453	24
	9 – 12	104	52,614	506	16
	13 – 18	112	74,348	664	22
	>18	0	0	0	0
	Total	712	330,728	465	100
Entire Database	0 – 4	1,493	575,540	385	38
	5 – 8	846	455,005	538	30
	9 – 12	504	245,887	488	16
	13 – 18	418	216,281	517	14
	>18	47	13,354	284	1
	Total	3,308	1,506,067	455	100

Table 2: Summary of road survey information by georegion. ESS = Excessively spaced segment by Arnold's (1957) criteria for road drainage spacing. Y or P = "Yes" and "Possible" connectivity with waters of the state.

Georegion	Percent Road Grade	Percent Length in Georegion Rated (Y or P) for Sediment Delivery	Percent Length in Georegion ESS	Percent Length in Georegion ESS and Rated (Y or P) for Sediment Delivery
Coast Range	0 – 4	14	7	2
	5 – 8	10	12	4
	9 – 12	3	10	2
	13 – 18	6	13	5
	>18	0	0	0
	Total	33	42	13
Interior	0 – 4	8	4	1
	5 – 8	9	16	4
	9 – 12	4	12	3
	13 – 18	2	5	2
	>18	1	1	1
	Total	24	42	11
South Coast	0 – 4	8	0	0
	5 – 8	8	8	4
	9 – 12	6	16	4
	13 – 18	1	17	1
	>18	0	0	0
	Total	23	41	9
Siskiyou	0 – 4	13	2	0
	5 – 8	11	6	6
	9 – 12	17	14	8
	13 – 18	5	13	5
	>18	1	3	1
	Total	47	38	20
Western Cascades	0 – 4	17	2	1
	5 – 8	8	6	2
	9 – 12	5	11	4
	13 – 18	7	21	6
	>18	0	0	0
	Total	37	40	13
Entire Database	0 – 4	12	4	1
	5 – 8	9	11	4
	9 – 12	4	12	3
	13 – 18	5	12	4
	>18	1	1	0
	Total	31	40	12

1995 Survey Comparison

This report summarizes the combination of the 1995 and 1996 ODF forest road drainage and sediment delivery surveys. The 1995 data is summarized in a 1996 report to the Department of Environmental Quality (ODF 1996a). To the length of road surveyed in 1995, 61 miles (324,141 feet) were added to the Coast Range georegion, 72 miles (380,876 feet) were added to the Interior georegion and 28 miles (148,278 feet) were added to the Western Cascade georegion by the 1996 survey. No survey data was collected in 1996 in the Siskiyou or South Coast georegions. The number of surface drainage discharge points surveyed approximately doubled from 1,398 to 2,810.

Delivery to Streams

Of the 285 miles (1,506,067 feet) of forest road surveyed in the five georegions, 25 percent drained directly to streams and another 6 percent were rated "possible" for sediment delivery. A total of 31 percent of the road length surveyed had a "yes" or "possible" delivery rating. Within the georegions, the combined "yes" and "possible" ratings ranged from 23 percent of the length of roads surveyed in the South Coast up to 47 percent in the Siskiyou georegion.

Spacing of Drainage Systems

The spacing between surface drainage discharge points ranged from 0 feet (culvert installed at a high point in the road) to 7,516 feet. The average spacing between surface drainage discharge points was 455 feet for all georegions and ranged from 293 feet in the Siskiyou georegion to 512 feet in the Interior georegion. The average segment length of roads with a grade greater than 18 percent was 284 feet and increased to 538 feet on roads with grades of 5-8 percent.

The spacing between points of surface road drainage (road segment length between drainage points) was compared with the spacing recommended by Arnold (1957). Arnold's spacing criteria was developed based on experience in the Western Cascades. The spacing of inventoried drainage structures was compared with Arnold's recommended spacings for a silt-loam soil and a 1-2 in/hr rainfall intensity.

Table 3: Arnold's (1957) recommended forest road drainage spacings for a silt loam soil receiving 1-2 inches/hr of rainfall.

Slope Class	Excessively Spaced Segment (ESS) Criteria (ft)
0 – 4	1500
5 – 8	865
9 – 12	480
13 – 18	335
>18	250

Of the road length surveyed, 40 percent were in segments that were longer than Arnold's spacing criteria. This value was consistent throughout the georegions, ranging from 38 percent in the Siskiyou georegion to 42 percent in the Coast Range georegion.

Of the total length of excessively spaced segments (ESS), 88 percent have slopes between 5 and 18 percent. Thirty-one percent of the length of ESS's is in the 13-18 percent road grade class. Of the total road length surveyed, 12 percent was classified as both ESS and rated "Yes" or "Possible" for sediment delivery to waters of the state.

Figure 1 shows the ratio of the average road segment length to the maximum length according to Arnold's criteria by road grade category and georegion. On average, segment lengths remain below the limits set by Arnold's criteria except in the 13 – 18

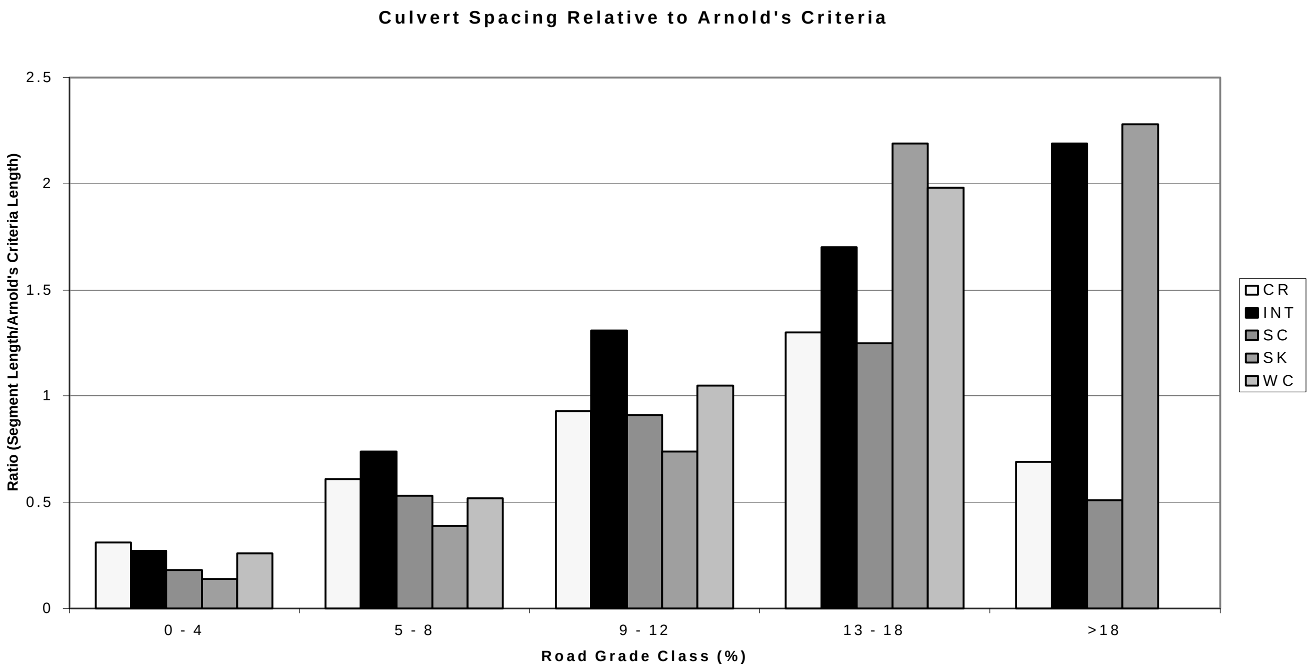

Figure 1: Ratio of segment length to Arnold's criteria recommended length expressed as an average by road gradient class and georegion. CR = Coast Range, INT = Interior, SC = South Coast, SK = Siskiyou and WC = Western Cascades.

percent road grade category where the average of all georegions is at least 25 percent and up to 119 percent greater. Though the Coast Range had the highest percent of road segments exceeding Arnold's spacing criteria, Figure 1 suggests that the spacing criteria was not exceeded by very much. The georegions that exceed the criteria by the most, on average, are the Interior and Siskiyou georegions.

Distance Above Stream to First Drainage

Table 4: Summary of stream-crossing segment data.

Georegion	Road Grade	Stream Crossing Segments Rated "Y" or "P" for Sediment				
		No. Segments	Total Segment Length (ft)	Avg. Segment Length (ft)	Percent of Total "Y" or "P" Length Upslope of Stream Crossings	Percent of Total "Y" or "P" Length Upslope of Stream Crossings and ESS
Coast Range	0 – 4	99	45,301	458	29	8
	5 – 8	73	37,274	448	23	13
	9 – 12	13	13,855	543	5	5
	13 – 18	33	5,071	561	12	16
	>18	1	111	111	0	0
	Total	219	106,642	487	69	42
Interior	0 – 4	89	31,228	351	26	4
	5 – 8	55	36,749	668	31	18
	9 – 12	19	13,855	729	12	14
	13 – 18	8	5,071	634	4	5
	>18	1	507	507	0	1
	Total	172	87,410	508	73	42
South Coast	0 – 4	40	9,407	235	30	0
	5 – 8	15	9,640	643	30	21
	9 – 12	11	5,625	511	18	14
	13 – 18	3	1,093	364	3	3
	>18	0	0	0	0	0
	Total	69	25,765	373	81	38
Siskiyou	0 – 4	10	1,309	131	4	0
	5 – 8	6	4,157	693	12	26
	9 – 12	5	2,653	531	8	14
	13 – 18	1	2,566	2,566	8	22
	>18	1	856	856	3	7
	Total	23	11,541	502	35	69
Western Cascades	0 – 4	72	27,663	384	24	0
	5 – 8	47	19,364	412	17	6
	9 – 12	23	13,351	580	11	13
	13 – 18	27	18,260	676	16	22
	>18	0	0	0	0	0
	Total	169	78,638	465	68	41
All Georegions	0 – 4	310	114,908	371	25	4
	5 – 8	196	105,559	539	23	14
	9 – 12	71	42,540	599	9	11
	13 – 18	72	45,515	632	10	13
	>18	3	1,474	491	0	0
	Grand Total	652	309,996	475	67	42

Of the 88 miles (462,108 feet) of road segments that were rated as either "Y" or "P" for sediment delivery to waters of the state, 67 percent (309,996 feet) were immediately upslope of live stream crossings. This percentage ranges from 35 percent of all "Y" or "P" rated road segments in the Siskiyou georegion to 81 percent in the

South Coast georegion. The first two segments upslope of live stream crossings accounted for 74 percent of the length connected to waters of the state, though this proportion ranged from 90 percent in the South Coast georegion to 41 percent in the Siskiyou georegion. The average length of road segments that were rated "Y" or "P" and were located upslope of stream crossings was 475 feet for the whole database, 373 feet for the South Coast georegion and 502 feet for the Siskiyou georegion. This average length is only 20 feet more than the average road segment length for the entire database.

Road segments that were rated "Y" or "P" for sediment delivery, were directly upslope of stream crossings and were excessively spaced comprised 9 percent of the entire database. These excessively spaced segments constitute 42 percent of segments rated "Y" or "P" for sediment delivery that are adjacent to streams, which is not substantially different from the proportion of excessively spaced road segments in the entire road survey database (40 percent). Thus, the occurrence of drainage spacing that exceeds Arnold's spacing criteria is similar for both segments rated "Y" or "P" for sediment delivery upslope of stream crossings and for elsewhere in the road network. However, the small sample size of this group of data suggests that such conclusions be drawn with caution.

Drainage System Characteristics

There were 2,810 surface drainage discharge points surveyed that drained 3,308 road segments (some surface drainage discharge points drained two road segments). Of these surface drainage discharge points, 714 (25 percent) were cross-drain culverts, 498 (18 percent) were live stream-crossing culverts and 18 (1 percent) were bridges. Additional drainage points included 306 waterbars, 305 ditch relief points, 210 grade breaks and 54 "other" drainage features. Non-engineered surface drainage occurred at 398 points and represented 14 percent of the data.

The majority (58 percent) of the drainage points rated "Y" or "P" for sediment delivery to waters of the state were live-stream crossing culverts. Another 19 percent of the drainage points that delivered to streams were cross-drain culverts. Non-engineered or random drainage points were less than 10 percent of the drainage points that delivered sediment to streams. The average road segment length that was drained by cross-drain culverts or live-stream crossing culverts was not appreciably different from the average for the entire database.

Over half (56 percent) of the live-stream crossing culverts were completely open and 10 percent were at least 51 percent obstructed. The degree of obstruction ranged from 91 percent of live-stream crossing culverts in the South Coast georegion that were completely open to 39 percent in the Coast Range georegion. Only 46 percent of all cross-drain culverts were completely open and 14 percent were at least half blocked. Nineteen percent of the cross-drain culverts surveyed in the Siskiyou georegion were completely open and 28 percent at least half blocked as compared to 78 percent being completely open in the South Coast georegion. However, this data represents a small sample size of cross-drain culverts and live-stream crossing culverts in the Siskiyou georegion compared to the other georegions.

Table 5: Summary of road drainage features inventoried.

Drainage Type	Number	Percent
Cross-Road Culvert (Single)	714	25
Cross-Road Culvert (Multiple)	3	0
Stream-Crossing Culvert (Single)	498	18
Stream Crossing Culvert (Multiple)	10	0
Bridge	18	1
Ditch Relief	305	11
Water Bar	306	11
Non-Engineered Relief	398	14
Grade Break	210	7
Road Junction	290	10
Outsloped Road Construction	4	0
Other	54	3
Total	2,810	100

Table 6: Summary of road segment data by drainage feature type for the entire database and for segments definitely or possibly connected to waters of the state.

Drainage Feature	Entire Database				Possible and Positive Sediment Delivery to Channels					
	Discharge Length (ft)				Drainage Feature (DF)		Discharge Length			
	No. Rd. Seg-ments	Total Length (ft)	Avg (ft)	% of Total	No. DF	% of Total (of DF)	No. Rd. Seg.	Total Length (ft.)	Avg. (ft.)	% of Total (of DF)
Cross-Road Culvert (Single)	861	424,269	493	28	158	5 (18)	181	89,544	495	6 (19)
Cross-Road Culvert (Multiple)	4	2,601	650	0	2	0 (0)	2	601	301	0 (0)
Stream-Crossing Culvert (Single)	619	292,015	472	19	493	15 (58)	613	287,277	469	19 (62)
Stream Crossing Culvert (Multiple)	15	11,097	740	1	10	0 (1)	15	11,097	740	1 (2)
Bridge	22	11,629	529	1	13	0 (2)	14	5,762	412	0 (1)
Ditch Relief	324	180,046	556	12	22	1 (3)	23	11,812	514	1 (3)
Water Bar	309	67,429	218	4	55	2 (6)	55	11,994	218	1 (3)
Non-Engineered Relief	499	164,588	330	11	74	2 (9)	89	32,168	361	2 (7)
Grade Break	285	141,913	498	9	4	0 (0)	6	2,526	421	0 (1)
Road Junction	299	190,434	637	13	14	0 (2)	15	7,228	482	0 (2)
Outsloped Road Construction	4	1,109	277	0	0	0 (0)	0	0	0	0 (0)
Other	67	18,937	282	1	9	0 (1)	11	2,099	191	0 (0)
Total	3,308	1,506,067	455	100	854	31 (100)	1,024	462,108	451	31 (100)

Table 7: Inlet of all surveyed stream-crossing and cross-drainage pipes as a percent of the original open area.

% Open	Entire Database	Streams		Cross Drains		Coast Range	Streams		Cross Drains	
		#	%	#	%		#	%	#	%
0		29	6	41	6		21	12	16	11
1 – 24		12	2	34	5		5	3	7	5
25 – 49		10	2	22	3		6	3	4	3
50 – 79		80	16	156	22		20	12	36	25
80 - 99		88	18	125	18		53	31	24	17
100		279	56	336	46		68	39	57	40
Total		498	100	714	100		173	100	144	100

% Open	Interior	Streams		Cross Drains		South Coast	Streams		Cross Drains	
		#	%	#	%		#	%	#	%
0		5	4	13	7		1	2	2	2
1 – 24		3	2	9	5		1	2	1	1
25 – 49		1	1	5	3		1	2	0	0
50 – 79		23	21	52	26		1	2	8	7
80 - 99		15	12	29	15		1	2	16	13
100		71	59	89	45		48	91	96	78
Total		121	100	197	100		53	100	123	100

% Open	Siskiyou	Streams		Cross Drains		Western Cascades	Streams		Cross Drains	
		#	%	#	%		#	%	#	%
0		1	5	2	6		1	1	8	4
1 – 24		0	0	4	13		3	2	13	6
25 – 49		0	0	3	9		2	2	10	5
50 – 79		3	16	2	6		30	23	58	27
80 - 99		3	16	15	47		16	12	41	19
100		12	63	6	19		80	61	88	40
Total		19	100	32	100		132	100	218	100

Fifty-five percent of all live-stream crossing culverts that were observed to be partially blocked were blocked by sediment and another 19 percent of those culverts were partially crushed. These same factors were responsible for the blockage of cross-drain culverts as well, with 60 percent of the blockages due to sediment and 26 percent due to crushed openings. However, only 19 percent of this data is from the South Coast and Siskyiou georegions. Thus, the dominant mechanisms that caused culvert blockage come predominately from the Coast Range, Interior and Western Cascade georegions which may not adequately represent other georegions.

Road Segments That Deliver Sediment

In previous sections, it was reported that 31 percent of the total road length was rated as “Y” or “P” for delivery of sediment to waters of the state. Twelve-percent was classified as both delivering sediment (“Y” and “P”) and being excessively spaced. Of the road segments rated to deliver sediment (“Y” and “P”), the percent of length in ESS’s was identical to the percentage of the entire database (40 percent). Sixty-seven percent of the length of segments rated as “Y” or “P” for sediment delivery were adjacent to stream crossings, but the average length of these segments was not different from the average segment length for the entire database. Excessively spaced segments were not more common in the road segments adjacent to stream crossings either. What follows is an analysis of other characteristics of road segments rated to deliver (“Y” or “P”) sediment to streams.

The greatest number of road segments rated to deliver sediment (“Y” or “P”) were on midslope roads (Figure 2) (72 percent) and the least number were on ridgetop roads (7 percent). It is likely, however, that the surveyors classified only the extreme cases as valley and ridgetop roads, artificially increasing the number of segments classified as midslope. Fifty-one percent of the length of road segments rated as “Y” or “P” for sediment delivery were upslope of midslope live-stream crossing culverts and 36 percent had road grades between zero and eight percent. Midslope roads also comprise 74 percent of all roads, but the proportion of midslope roads that are rated to deliver sediment (30 percent) is not different from the overall average of 31 percent. However,

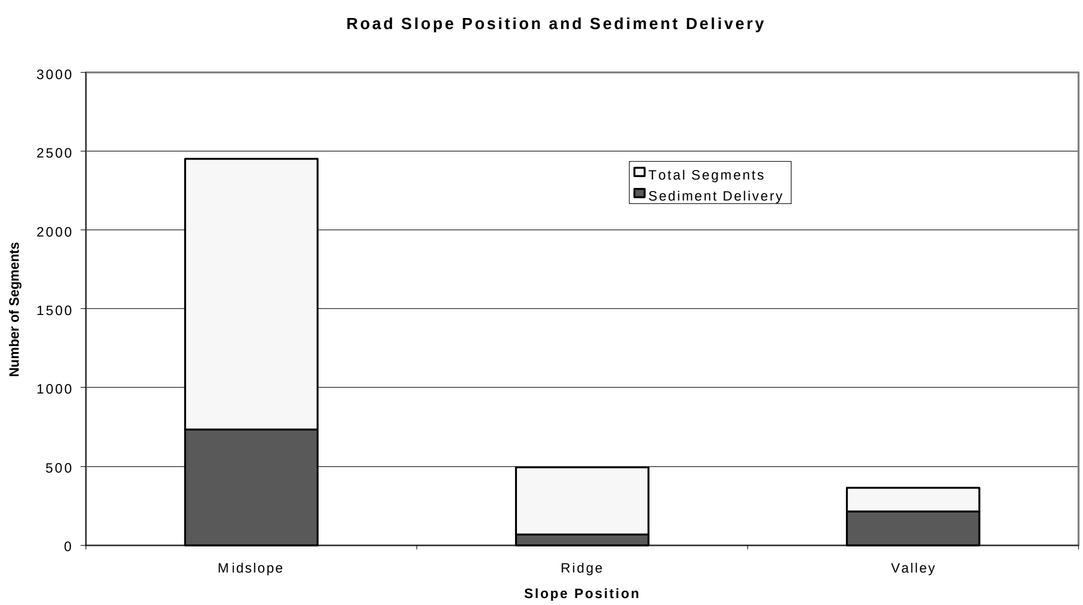

Figure 2: Connectivity with waters of the state by road location.

59 percent of all valley bottom roads deliver sediment to streams although they constitute only 11 percent of the database. This suggests that locating roads parallel and directly

adjacent to or crossing streams increases the potential for sediment delivery. These trends hold across all georegions except the Siskiyou georegion where midslope roads still have the greatest number of drainage points that directly deliver to waters of the state but only 20 percent of midslope road segments rated to deliver sediment were associated with live-stream crossing culverts. In this georegion, waterbars accounted for 36 percent of the midslope sediment sources, 17 percent were non-engineered drainage points and 16 percent were cross-drain culverts.

Any relationship between road prism construction (crowned, insloped, outsloped, other) and sediment delivery varied substantially between georegions. Thus, conclusions regarding such a relationship are difficult. Additionally, crowned roads made up 78 percent of the length of all roads surveyed and all construction types were not represented in all georegions. Less than 20 percent of the length of road draining to streams in all georegions had potholes or ruts. Relationships with sediment delivery may have been obscured by inconsistencies in the classification of road prism construction and surface condition between the 1995 and 1996.

Seventy-two percent of midslope road segments rated to deliver sediment ("Y" or "P") had cutbank heights at least five feet high as compared to 60 percent of midslope segments not rated to deliver sediment. The type of road surfacing material did not differ from other midslope roads, with approximately 80 percent of all roads being surfaced by dirty rock. The occurrence of culvert blockage and culvert outlet conditions did not differ between midslope road segments rated to deliver sediment and the entire data set. Overall, no clear pattern in differences of road surface material or condition, increased culvert obstruction or culvert outlet erosion emerged with midslope road segments rated to deliver sediment even though cutbank heights were slightly greater.

Approximately 60 percent of all roads rated "Y" or "P" for sediment delivery to streams of the South Coast and Siskiyou georegions were less than 300 feet long (Figure 3). In the other georegions, 60 percent of the segments were greater than 300 feet long. Since only 41 percent of road segments rated to deliver sediment in the Siskiyou georegion occur within the first two road segments upslope of stream crossings, this suggests that non-stream crossing drainage structures in this georegion have greater connectivity with streams than in other georegions despite shorter road segments.

Excessively Spaced Segments (ESS)

As reported in previous sections, 40 percent of the total length of roads surveyed had excessive spacing between surface drainage points compared to Arnold's spacing criteria. This is identical to the proportion of ESS within the subset of road segments rated to deliver sediment ("Y" or "P") to waters of the state. The proportion of ESS within road segments both rated to deliver sediment and were upslope of live-stream crossing culverts was not different from that value for the entire database (42 percent). The proportion of road length rated to deliver sediment within ESS and non-ESS segments was also identical (31 percent). This suggests that using Arnold's criteria for drainage spacing is not a reliable best management practice by itself to reduce connectivity between road drainage points and streams.

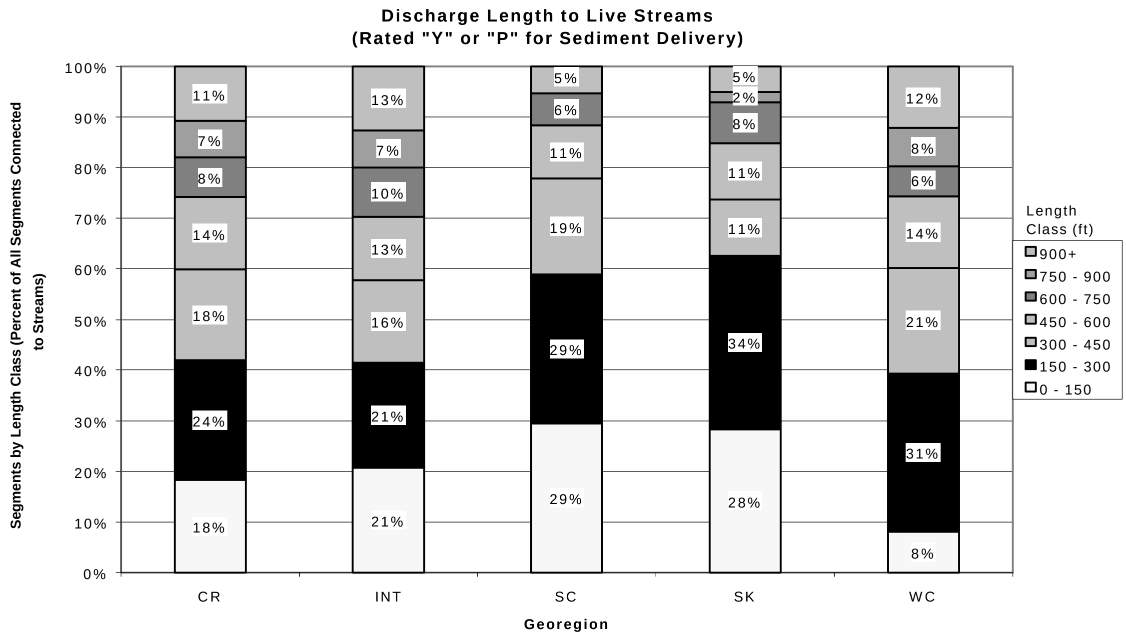

Figure 3: Connectivity with waters of the state by segment length class.

Like segments rated to deliver sediment ("Y" or "P"), the majority (80 percent) of ESS were located on midslope roads except for the Siskiyou georegion where 45 percent were midslope, 37 percent were valley bottom roads and 19 percent were on ridges. The Western Cascades georegion also differs slightly from the norm with only 68 percent of ESS on midslope locations and 23 percent on ridges. Within each slope location, the highest percentage of ESS occurs with midslope or ridge top road locations although the Siskiyou georegion again differs with valley bottom and ridge top roads having the greatest proportion of ESS.

Any relationship between road prism construction (crowned, insloped, outsloped, other) and ESS varied substantially between georegions. Thus any conclusions regarding this relationship are difficult because crowned roads made up 78 percent of the length of all roads surveyed and not all construction types were found in all georegions. Less than 15 percent of the length of ESS in all georegions had road surfaces with potholes or ruts. Except for the South Coast georegion where road surfaces classified as "Other" were common, the majority of ESS had smooth surfaces. This suggests that long distances between drainage points does not in itself lead to poor road conditions.

There is no indication that the amount of culvert inlet blockage differs or that cutting or fillslope failures are more common below culvert outlets of excessively spaced segments as compared to the entire database. Road surfacing material and cutbank height distributions also do not differ from that of the entire database.

Discussion

In contrast to accepted road construction BMP's, the average road segment length, both for the entire database and above stream crossings, increased with increasing road grade. Only the Coast Range georegion deviated from this trend with average road segment lengths generally decreasing with increasing road grade.

Of the entire length of road segments sampled, 31 percent were definitely or possibly connected to waters of the state and thus potentially delivered sediment. This ranged from 24 percent in the Interior to 47 percent of the road length sampled in the Siskiyou georegion. Sixty-seven percent of segments rated as delivering sediment ("Y" or "P") to waters of the state were immediately upslope of live-stream crossings. The first two segments upslope of live-stream crossings accounted for 74 percent of the total segment length rated to deliver sediment ("Y" or "P"). This trend is consistent for all georegions except the Siskiyou georegion where 59 percent of the segments rated to deliver sediment are farther than two road segments away from live-stream crossings. Waterbars, cross-drain culverts and non-engineered drainage points were a high proportion of the road segments rated to deliver sediment in this georegion. Because of the sheer number of roads classified as midslope, most road segments rated to deliver sediment occur in midslope locations although valley bottom roads had the highest proportion of road segments connected with streams.

When the 1996 and 1995 data are combined, the result is an overall lower estimated proportion of road connectivity with streams (31 vs. 39 percent). The greatest difference was in the Interior georegion where the 1995 survey had estimated 40 percent of the road length was rated "Y" or "P" to deliver sediment versus the 24 percent observed in the combined data. The difference in road connectivity with streams in the Coast Range and Western Cascade georegions differed by 6 and 12 percent, respectively.

These stream-connectivity values are lower than the value of 57 percent reported by Wemple et al. (1997) in a study of channel network extension by forest roads in the western Cascades of Oregon. Reid and Dunne (1984) reported an even higher value of 75 percent stream connectivity in the Clearwater basin of Washington. The values in this report, however, do compare well with the 34 percent connectivity reported by Bilby et al. (1989) in southwest Washington and the 39 percent value estimated for the Kilchis watershed in northwest Oregon (ODF 1996b).

The spacing of surface road drainage discharge points that were in excess of Arnold's spacing criteria occurred on 40 percent of the road length sampled. This percentage was consistent across georegions and within the subset of road segments directly upslope of live-stream crossings. However, excessive segment lengths were most common in the 13 – 18 percent road grade class. The Interior and Siskiyou georegions had the largest average segment lengths that exceeded Arnold's spacing criteria. Again, the greatest number of excessively spaced segments were classified as being on midslope locations, although most ESS in the Siskiyou georegion were on ridge top and in valley bottom locations. The proportion of road segment length rated to deliver sediment (“Y” and “P”) was also constant at 31 percent regardless of whether drainage points were excessively spaced or not. Only 12 percent of the entire database was both rated to deliver sediment to streams and observed to have excessive drainage point spacing.

Piehl (1988) in a review of 515 cross-drain culverts in the Oregon Coast Range found that culvert spacing on state and private lands were 1.4 and 1.7 times that recommended by Arnold (1957) as opposed to the average of 0.6 observed in this inventory. However, the 42 percent of the total road length that exceeded Arnold’s spacing criteria found by the ODF road drainage and sediment delivery survey in the Kilchis watershed agrees with the 40 percent reported in this study (ODF 1996b).

Combining the 1995 and 1996 databases resulted in an increase in the proportion of road length in excess of Arnold’s spacing criteria (40 vs. 36 percent), except within the Western Cascade georegion where a decrease of 4 percent occurred. The greatest increase (15 percent) was observed in the Coast Range geogregion while the Interior georegion increased by 13 percent.

Non-engineered road drainage points accounted for only 14 percent of the sampled drainage points and less than 10 percent of drainage points connected to streams. Most connectivity with streams occurred at live-cross stream or cross-drain culverts, representing 43 percent of the sampled drainage points. Over half (56 percent) of the live-stream crossing culverts were completely open, although this was true for only 40 percent of the cross-drain culverts. In the South Coast georegion, 78 percent of cross-drain culverts were completely open, although in the Siskiyou georegion almost half were at least 80 percent blocked. However, the 32 cross-drain culverts sampled in the Siskiyou georegion may be insufficient to base conclusions on. Sediment and crushing of the culvert inlet were the most common blockage factors. Only 19 percent of the drainage points sampled were in the South Coast and Siskiyou georegions. Thus, the primary culvert blockage factors identified were dominated by processes most common in the Coast Range, Interior and Western Cascade georegions.

Piehl et al. (1988) also found sediment deposition and physical damage or denting to be the most common factors reducing culvert inlet capacity. The 1995 Oregon Department of Forestry road drainage and sediment delivery survey, which makes up 43 percent of this inventory’s road length, and the Kilchis Watershed survey also identified these two factors as the main contributors to reduced culvert capacity (ODF 1996a, ODF 1996b). Piehl et al. (1988) reported a damage rate of 74 percent, but this inventory found only 60 percent of cross-drain culverts in the Coast Range to have reduced intake capacities. The greatest difference in culvert condition observed with the increased sample size of the 1995 survey in the Coast Range, Western Cascade and Interior georegions was a slight reduction in the proportion of culverts completely open and an increase in the proportion of culverts only 50 – 79 percent open.

Approximately 60 percent of road segments rated to deliver sediment ("Y" or "P") in the South Coast and Siskiyou georegions were less than 300 feet long. In contrast, the same proportion of road segments rated to deliver sediment in the other georegions were greater than 300 feet long. The Siskiyou georegion has a relatively low proportion of stream-crossings, thus this suggests that road segments not linked to stream crossings have a higher degree of connectivity with streams compared to the other georegions despite short segment lengths. This may be partly explained by the high degree of obstruction of cross-drain culverts and thus the potential for re-routing the flow from several segments onto one drainage point.

The two subsets of road segments rated to deliver sediment and excessively spaced segments were further investigated for special characteristics. No patterns of road prism construction, surface material or condition, frequency or degree of culvert blockage or culvert outlet erosion were observed with these subsets.

As previously noted, the two years of data compiled in this report represent time periods both before and after the February, 1996 flood. Conceivably, then, differences in some parameters (i.e. connectivity between drainage points and streams, culvert blockage) that exist between findings in this report and the 1996 report (ODF 1996a) that summarizes the 1995 data may be related to flood impacts. A storm event of that significance might be expected to increase the proportion of road segments connected to streams although the value of this parameter was actually observed to decrease. More in line with the expected consequences of a flood event was a slight increase in the proportion of culverts with inlets only 50 – 79 percent open. It is not at all clear, however, that such differences are related to the 1996 flood or simply reflect different inventory crews, different site selection methods, or different locations sampled.

Recommendations

Stream crossing segments still exhibit the greatest connectivity with and thus the highest potential for sediment delivery to streams. Management practices that either reduce that connectivity or maximize the filtering of water from the road prism would help diminish the potential for sediment delivery to streams. Valley bottom roads also show a high degree of connectivity with streams and would benefit from the same practices.

This survey and others show that sediment blockage and crushing of the culvert inlet are the most common factors reducing the capacity of stream- and road-crossing culverts. Road-crossing culverts in the Siskiyou georegion have a substantial proportion (28 percent) with inlet capacities reduced by at least half. Construction and maintenance practices that maintain clear and undamaged culverts should alleviate these problems.

This survey provides information as to the spatial extent of sediment delivery to streams, but it gives no indication of the amount of sediment being produced. Estimating sediment production would be a difficult and highly inaccurate addition to this survey protocol. Several factors have being linked, however, to sediment production from road surfaces including surface material, surface condition and traffic levels (Bilby et al. 1989, Foltz and Burroughs 1990, Reid and Dunne 1984). The survey protocol currently incorporates all of these parameters except traffic level. Reid and Dunne (1984) estimated that heavily used roads produced 130 times the sediment of an abandoned road. Including a rough estimate of traffic level in the survey protocol, such as heavy, moderate, light, or abandoned, might help landowners to prioritize road segments or drainage points for maintenance or repair.

As no difference in the proportion of connectivity with streams was observed between excessively- and non-excessively spaced road segments this suggests that Arnold's spacing criteria in itself is not sufficient as a means of reducing connectivity with streams. Further investigation of the relationship between road segment length, grade class and sediment production may be necessary to determine the ideal use of such criteria as a best management practice.

Enough data has been collected in the Coast Range, Western Cascade and Interior georegions to support the general conclusions made regarding road drainage and sediment delivery potential in these georegions. Further surveys should be conducted in the South Coast and Siskiyou georegions, however, to validate the stated characteristics of these georegions. In particular, it would be valuable to confirm the high degree of connectivity between streams and relatively distant road segments in the Siskiyou georegion and the responsible process or processes.

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