Oregon Department of Forestry
Best Management Practices
Compliance Monitoring Project

Executive Summary

OREGON DEPARTMENT OF FORESTRY
FOREST PRACTICES MONITORING PROGRAM
TECHNICAL REPORT 15

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The Oregon Department of Forestry (ODF) regulates forestry operations on non-federal land. Landowners and operators are subject to the Forest Practices Act and Rules when they conduct any commercial activity relating to the growing or harvesting of trees. The Oregon Forest Practices Act (FPA) was adopted in 1972 with the overarching objective to

> …encourage economically efficient forest practices that assure the continuous growing and harvesting of forest tree species and the maintenance of forestland for such purposes as the leading use on privately owned land, consistent with sound management of soil, air, water, fish and wildlife resources and scenic resources within visually sensitive corridors as provided by ORS 527.755 that assures the continuous benefits of those resources for future generations of Oregonians. (ORS 527.630 Policy, Oregon Forest Practices Act)

The Oregon Board of Forestry has been vested with exclusive authority to develop and enforce statewide and regional Forest Practice Rules. These rules are designed to address the resource issues identified in the FPA policy (sound management of forest, soil, air, water, fish and wildlife resources, and scenic resources). The Forest Practices Act and Rules are considered a Best Management Practices (BMPs) program. BMPs are defined as practices that are practical and effective at reducing non-point source pollution to standards compatible with water quality goals.

It is the responsibility of the ODF to monitor the effectiveness and implementation of BMPs in achieving that objective.

The Forest Practices Program is responsible for administering and monitoring the Forest Practice Rules. These rules are subject to revision as necessary based on the best available science and monitoring data. Such revisions shall maintain the policy of the FPA as described above. The rules have undergone many revisions since 1972. The most recent changes to the water protection rules were in 1994 and 1995.

Administration of the Forest Practice Rules is done through a balanced program of rule education, technology transfer, incentives, and enforcement. ODF employs 52 forest practice foresters (FPFs), stationed in 25 unit and district offices throughout the state. Through a series of inspections and field visits, FPFs work with landowners and operators to facilitate proper implementation and compliance with the Forest Practice Rules. Not all operations are inspected by FPFs due to extremely heavy workloads, therefore, FPFs prioritize operations to determine inspection schedules. Citation records are a valuable monitoring tool, but a statistically reliable sample of BMP compliance is needed to more precisely determine the degree to which the compliance program is producing the desired results and to identify areas of low compliance. Furthermore, more detailed information is needed on compliance rates of specific practices and rules and to quantify resource damage that occurs as a result of noncompliance.

Monitoring of these BMPs is the responsibility of the Forest Practices Monitoring Program. The monitoring program conducts a variety of projects designed to assess how well current BMPs are achieving their desired goals (effectiveness monitoring) and how well these BMPs are being properly implemented in the field (compliance monitoring).

BMP Compliance Monitoring Project

The ODF Forest Practices Monitoring Program implemented the BMP Compliance Monitoring Project (BMPCMP) to evaluate compliance with BMPs on non-federal forestland. The goal of the BMPCMP was to identify the statewide level of compliance with the Forest Practice Rules relating to the protection of water quality based on a statistically reliable sample. The purposes for this were to determine if adjustments to the administration of the compliance program are needed, identify areas where forest practice rule language can be clarified, and to identify where additional education and training is needed.

This project was conducted with the oversight of both internal and external review committees. These committees provided input and approval of the design, methods, and interpretation of results of this project over a four-year period. The first year of the project (1998) was a pilot study used to revise the site-selection and data collection protocols, determine the needed sample size, and provide preliminary compliance results. During the 1999 and 2000 field seasons, the final version of the BMPCMP was implemented.

A total of 189 harvest operations associated with waters of the state were surveyed for the final version of this project. Operation units were randomly selected and stratified statewide to account for regional differences in the numbers of notifications and types of practices implemented; differences between industrial, non-industrial, and other (generally government) landowners; and heightened concern for fish-bearing streams. Site selection was done so that sample distribution was proportionate to that of the total population of 1998 notifications. The exception to this was an intentional bias towards the selection of units associated with fish-bearing (Type F) streams in order to better assess those rules which would apply only to these sensitive and valued resources. The weakness of this stratification is that it may undersample steep terrain as these units are less likely to have Type F streams.

At selected harvest unit sites, practices and features within that unit (harvest practices, roads, skid trails, riparian management areas, wetlands, etc.) were evaluated for compliance with 150 Forest Practice Rules designed to protect water quality and fish habitat. Please visit http://www.odf.state.or.us/FP/fpmp/default.htm to view the detailed protocol for this project. Stream-crossing structures (bridge, culvert, or ford) were evaluated for fish passage and 50-year stream-flow event capacity using a separate selection process and field protocol. These detailed stream-crossing results are discussed in a report titled *Compliance with Fish Passage and Peak Flow Requirements at Stream Crossings* (Paul, Dent, and Allen, 2001). The stream crossing protocol and final report can be found online at http://www.odf.state.or.us/FP/fpmp/default.htm.

For the BMPCMP, compliance was evaluated for the application of all BMPs relating to water quality on each unit. Each unit was surveyed by a former forest practices forester who evaluated all individual BMP applications as either “compliant” or “noncompliant." A seasonal field crew collected numeric data which was used to quantify compliance for those practices with numeric standards (eg., basal area retention standards in a riparian management area). When noncompliance practices were found, the type and magnitude of resulting riparian and channel impacts were recorded.

BMPCMP Findings

Monitoring Question 1: Compliance Rates. *How often did operators comply with BMPs described in the forest practice rules pertaining to water protection, road construction and maintenance, harvesting, and high-risk sites?*

Unit-Level Compliance

Compliance rates for individual units ranged from 78.8% to 100% (Figure 1) and averaged 96.1%. The majority of units (76%) had at least one noncompliant practice of some sort, and 40% had at least one noncompliant practice that resulted in an impact to riparian and channel conditions.

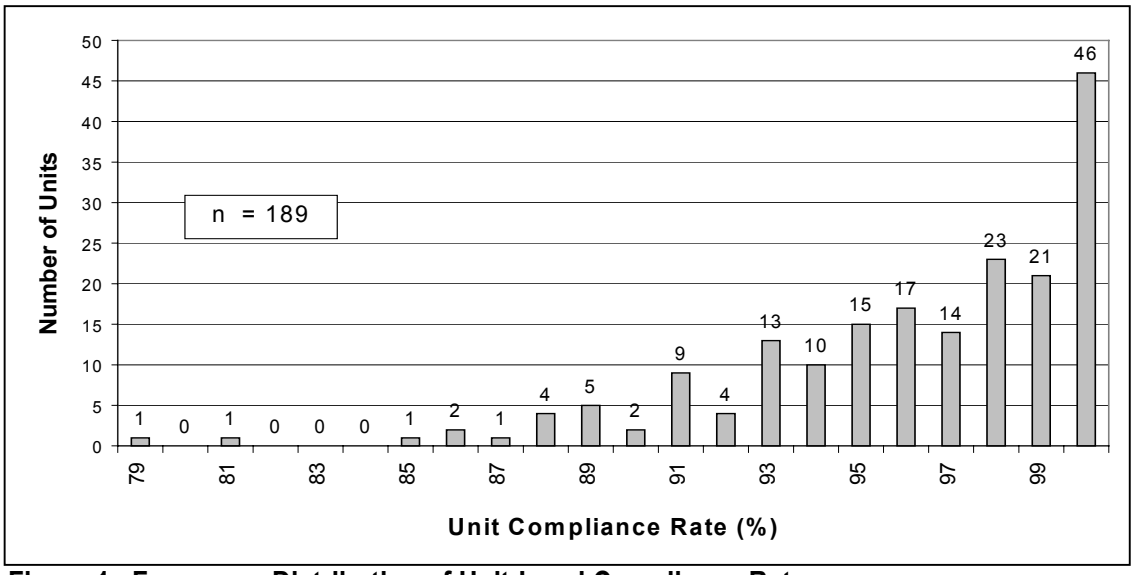

Figure 1. Frequency Distribution of Unit-Level Compliance Rates

The results of this project appear to compare favorably with those reported in other states, although they cannot be compared directly because state rule requirements differ and survey methodologies varied. Oregon's Forest Practice Rules are one of the most detailed and extensive sets of mandatory forestry BMPs in the nation. While it was common to find compliance issues when units were evaluated strictly, it would be an oversimplification to rate compliance solely on existence of a compliance issue of any kind on a unit. An accurate representation of compliance must account for the high numbers of BMPs applied to each unit (average of 71), the specific sources of noncompliance, and impacts to riparian and channel conditions (units had an average of 98.7% of practices with no impact).

Rule-Level Compliance

Compliance was 96.3% for the 13,506 BMP applications reviewed across all 189 units. Of the 502 total noncompliant practices surveyed, 185 (1.4%) were with administrative rules only, 147 (1.1% of all applications) were potential resource issues, and 170 (1.2%) had an impact to riparian or channel resources. These applications were broken into 11 rule sections (Table 1), with section compliance ranging from 69.8% for protection measures for other wetlands, to 100% for rules related to reforestation and operations near waters of the state (WOS).

Table 1. Compliance Rates for Rule Sections

Rule Division	Section Description	Rule Applications	Compliance Rate
629-610	Reforestation (RMA reforestation only)	36	100.0
629-615	Treatment of Slash	1,157	98.2
629-620	Chemicals and Petroleum Products	696	94.3
629-625	Road Construction and Maintenance	2,495	97.6
629-630	Harvesting	6,876	98.1
629-640	Vegetation Retention Along Streams	833	96.4
629-645	Protection Measures for Significant Wetlands	42	88.1
629-655	Protection Measures for Other Wetlands	96	69.8
629-650	Protection Measures for Lakes	0	N/A
629-660	Operations Near WOS	186	100.0
All	Administrative Requirements	1,089	83.0

Monitoring Question 2: Stream Crossing Fish Passage and Peak Flow. *Have stream crossing structures on newly constructed and/or reconstructed roads been designed and installed according to ODF guidelines regarding fish passage and the 50-year peak stream flow event?*

These issues could not adequately be evaluated by the sampling design and survey constraints of this project. A supplemental study was implemented concurrently with this to more accurately address peak flow capacity and juvenile fish passage for newly constructed or reconstructed stream crossings. Results of this project are detailed in ODF Technical Report 14, *Compliance with Fish Passage and Peak Flow Requirements at Stream Crossings* (ODF, 2002[A]). This document can be found online at http://www.odf.state.or.us/FP/fpmp/default.htm.

Monitoring Question 3: Compliance Rates and FPF Inspections. *How do the statistical sample results compare with results based on forest practice foresters (FPF) inspections? Is there a correlation between number of FPF inspections and compliance rates? How statistically representative are the results of this project?*

Forest Practices Forester (FPF) Inspections

The Forest Activities Computerized Tracking System (FACTS) and a civil penalties database were queried for inspection and citation rates for the period of 1995 through 2001. These data are based on the number of citations issued relative to the number of operations that have been inspected by an FPF. Inspection compliance rates during this period showed little fluctuation, with 96.3 to 98.2% of annual operations inspected receiving a citation during this period (Figure 2). The power of these data is in the sheer number of operations assessed. For example, around half of the roughly 18,000 operations completed each year received at least one FPF inspection.

While these results provide a gage for the level of compliance during this period, they cannot be directly compared to compliance rates identified by this study for several reasons. The sample of operations inspected by an FPF consists of prioritized operations within significant time and resource limitations. Conversely, the sample for this project was completely randomly selected and stratified by stream and ownership classes, with an access denial rate of around 4%. FPF inspections also include all applicable

forest practice rules, not just the water-related rules that were the focus of this project. It is also important to note that this project had three people collecting data to evaluate operations at a very strict and technical level of rule compliance. Many of the practices considered noncompliant may not have necessarily warranted a citation.

Although direct correlation between FPF inspections and findings from this project could not be measured with this data, the similar overall compliance rates supports the effectiveness of FPF inspections relative to the findings of this study.

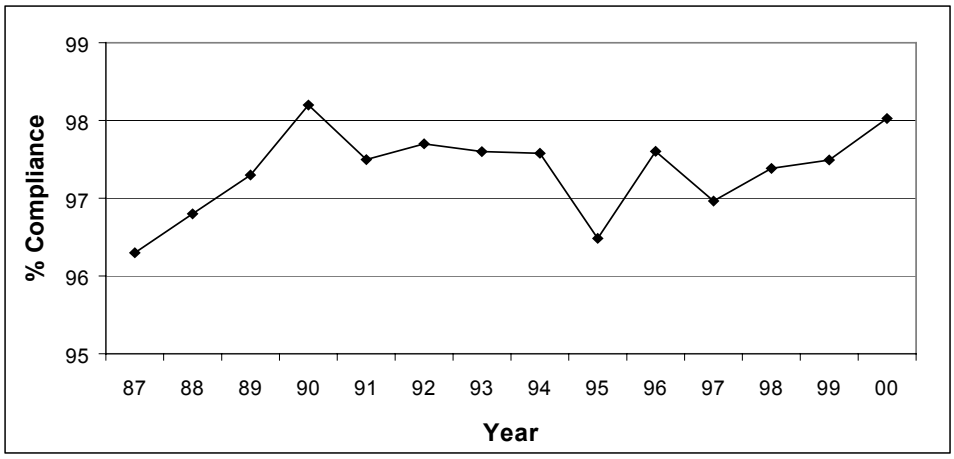

Figure 2. 1987-2000 FPF Inspection Compliance Rates
Rates are based on operations inspected and citations issued for 1987 through 2000.

Statistical Representation

The precision level of the unit-level compliance results can now be calculated with the equation originally used to determine the needed sample size. Using sample size (n), population size (N), and unit-level compliance rate (P), the equation (Freese, 1962) can be solved to give the precision level (E) of these results:

$$n = \frac{1}{\frac{E^2}{(4)(P)(1-P)} + \frac{1}{N}} \quad \text{or} \quad E = [(1/n-1/N)*4*P*(1-P)]^{\wedge 1/2}$$

With a sample size of 189 units surveyed, a population of 4,075 notifications, and an average unit-level compliance rate of 96.1% for the units sampled, the precision level is 0.028. The average compliance rate of the sampled units is therefore representative of the entire population with 97.2% confidence. This confidence level is actually somewhat higher than 97.2% because the identified population greatly overestimates the number of qualifying units. Qualified units were completed operations with a 1998 notification, harvested under the forest practices rules, and associated with some waters of the state. About one-half of the identified notifications reviewed during site selection either did not meet these criteria or did not actually occur.

As well as meeting these criteria, units were selected based on ownership class and stream type stratifications. These results are likely not representative of units selected with different criteria or stratifications. As well, confidence levels cannot be calculated for individual rules surveyed, as this site-selection process likely influenced the sampling rate and distribution of specific practices.

Monitoring Question 4: Areas of Highest and Lowest Compliance. *Are there particular rules that consistently have a higher or lower level of compliance? If the latter, can the guidance and/or rule language be modified to improve compliance? Are there educational and training opportunities/materials regarding those rules?*

Compliance and Sample Size

It is important to first note the role of sample size when assessing the significance of compliance rates for individual rules. It is difficult to assess the scope of a compliance issue in cases where a BMP was applied so few times that one or two noncompliant practices resulted in a low compliance rate. Closer examination shows that average compliance results were highly correlated to sample size, with average compliance much higher for those BMPs applied more often (Table 2). Rules with 1 to 10 total applications (37 rules) had an average rule compliance of 72%, while rules with 11 to 100 total applications (49 rules) had an average rule compliance of 94%, and rules with more than 100 total applications (43 rules) had an average rule compliance of 96%.

Table 2. Average Compliance Rates for Rules Based on Number of Times Applied

Number of Times Rule Applied	Number of Rules	Total Number of Rule Applications	Average Rule Compliance
1-10	37	194	72%
11-100	49	2,685	94%
>100	43	10,627	96%

This trend is encouraging for two reasons: the low compliance results for some rules with small sample sizes is possibly not representative of the larger population; and proper understanding, interpretation, and administration of forest practice rules appears to improve the more they are conducted, as those practices most frequently applied to the landscape were generally most likely to meet BMP compliance.

Areas of Higher Compliance

Given the sample size considerations discussed above, these results still allow for the identification of areas of higher and lower compliance. There were 50 individual rules (39%) with 100% compliance and 72 rules (56%) with 98% or higher compliance. Because of these high numbers, high compliance is identified below for rule groups which have 98% or higher compliance.

- RMA Reforestation Timing (610-040): 100% compliance for two rules (36 applications)
- Chemical Applications (620-400): 98.4% compliance for three rules (129 applications)
- New Road Location (625-200): 100% compliance for three rules (240 applications)
- New Road Prism Design (625-310): 99.4% compliance for seven rules (320 applications)
- Rock Pits (625-500): 100% compliance for five rules (85 applications)
- General Yarding Practices (630-100): 99.5% compliance for three rules (407 applications)
- Cable Yarding near WOS (630-700): 99.7% compliance for five rules (376 applications)
- Landings (630-200): 99.8% compliance for four rules (3,472 applications)
- Vegetation Retention for Type N and D Streams (640-200): 98.8% compliance for eight rules (83 applications)

The general vegetation retention rules for Type F streams (640-100) are not listed above, but are worth mentioning here. Compliance was 97.1% for these six rules, however, the average rates of retention of

RMA vegetation were quite high. All 41 no-harvest prescription Type F RMAs in partial cut units had at least 100% of the required buffer retained. The 52 Type F RMAs with this prescription in clear-cut units had an average of 117% of the required buffer retained. The 62 RMAs with a basal area prescription had an average of 202% of the standard target retained (although only a portion of the basal area above the standard target was likely harvestable due to the limitation of other rules). These prescriptions made up 93% of the total length of Type F RMA surveyed.

Areas of Lower Compliance

There were also 10 specific BMPs identified as having the most significant compliance issues (less than 96% compliance and five or more noncompliant practices). These were: slash piling near WOS, removal of petroleum-related waste, stream crossing fill stability, road surface drainage, felling of trees into small Type N streams, skid trails near WOS, removal of temporary crossings, protection of other wetlands, prior approval requirements, and written plan requirements. These are detailed individually below in order of rule number.

- Mechanical Slash Piling near WOS (615-200 [4]). The placement of mechanically-piled slash in WOS or where it can enter WOS was an issue on 8 of the 77 applicable units (89.6% compliance). Five of these noncompliant practices were slash piled within or on the banks of small Type N streams and three were slash piled in "other" wetlands less than 8 acres in size. Discussions with operators over the course of implementing this project revealed that non-compliance resulted from two factors: operators did not realize that these protection requirements extended to small Type N streams and "other" wetlands, or operators had difficulty identifying small, ephemeral features during the dry season. Discussions of these results with ODF field staff, landowners, and operators have already begun to raise awareness of this issue.

- Removal of Petroleum-Related Waste (630-400 [3]). The removal of petroleum-related waste from the unit following completion of the operation was noncompliant on 34 of the 189 units surveyed (82.0% compliance). These materials (oil filters, grease tubes, and motor and bar oil containers) were generally located at landings, and while none were found to have delivered to WOS, they represent a possible risk to future soil and water quality. Noncompliance was considered to be the result of poor post-operation clean-up practices.

- Stream Crossing Fill Stability (625-320 [1bC]). The design of new stream crossings so that fill and erosion to a channel are prevented was not achieved for 8 of the 51 new crossings surveyed (84.3% compliance). Fill erosion on those eight crossings was attributed to two design issues: over-steepened fills, which enter the channel through ravel or shallow failures, and drainage-caused rutting over ineffectively stabilized fill material.

- Road Surface Drainage (625-330 [1] and 625-600 [2]). Road surface drainage designs that effectively disperse runoff and minimize erosion and proper maintenance of that road surface drainage are critical for resource protection. Compliance with these rules was 86.5% (drainage design) and 94.2% (maintenance), with 31 total noncompliant practices on 171 units with roads. These two rules were considered together because distinguishing compliance issues between ineffective drainage designs and maintenance levels was often extremely difficult. Non-compliance was generally due to a combination of ineffectively designed drainage systems that broke down quickly and did not receive the subsequent required maintenance. These conditions resulted in routing of excessive runoff across the

road surface for great distances, causing erosion and instability. There were 11 cases of sediment delivery attributed to poor drainage design and 10 attributed to a lack of maintenance.

- Felling of Conifers into Small Type N Streams (630-600 [2]). Compliance for felling conifers away from streams and preventing damage to channels was 83.1% on 189 units. The 32 noncompliant practices surveyed were nearly all from the felling of conifers across or into small Type N channels or, to a lesser extent, felling into small wetlands. Fifteen of these resulted in significant slash in WOS, one to channel bed and bank disturbance, and one to sediment delivery to a WOS. Low compliance rates for limiting slash accumulations in Type N steams (630-600 [3b]) and leaving slash where it will not enter WOS (600-400 [1]) were considered to generally result from these noncompliant felling practices. Discussion with operators and ODF field staff while implementing this project revealed that noncompliance was generally associated with interpretation of this rule's application to small Type N streams and other wetlands, especially those which were dry during the time of harvest. Discussion of these results with ODF field staff, landowners, and operators has already begun to raise awareness of this issue.

- Skid Trails Near WOS (630-800 [8] and 630-800 [9]). Harvesting rules also require that skid trails on 106 units not be located within 35 feet of Type F streams (91.5% compliance) and be located so that stream water will not flow onto the skid trail (92.5% compliance). Noncompliant practices consisted of nine units with skid trails located within 35 feet of a Type F stream and eight units with skid trails located within a length of a small Type N stream channel. These resulted in eight cases of channel bed or bank disturbance and six cases of sediment delivery to WOS. Discussion with operators indicated that noncompliance was generally the result of skid trail location rules not adhered to because of operational concerns.

- Removal of Temporary Crossings (630-800 [4e]). The removal of temporary crossing structures following completion of an operation and placement of fill material where it will not enter WOS was done properly for only 11 of 23 temporary crossings surveyed (47.8% compliance). Noncompliant practices include five crossings with fill not removed, two with fill only partially removed, and five with fill material removed but placed where it eroded back into the stream channel. Non-compliance was considered to be simply the result of poor post-operation clean-up practices.

- Protection of Other Wetlands (655-000 [2a & 3]). This rule required protection of soil and water quality for activities along 96 wetlands less than 8 acres ("other" wetlands), seeps, or springs. Compliance was 69.8%, with 29 noncompliant practices in the form of harvesting machinery driven through wetlands, wetlands used as landing areas, trees yarded through wetlands, and slash piled in wetlands. Discussion with landowners, operators, and ODF field staff over the course of implementing this project revealed that noncompliance was generally the result of interpretation of this rule's application to these small wetlands and their identification during the dry season. These discussions have already begun to raise awareness of this issue.

- Prior Approval Requirements. Compliance was evaluated for 13 rules located in several divisions that require department approval for a variety of specified activities. No written prior approval documentation was found for 48 of the 492 activities for which it was required (90.4% compliance). Noncompliance with these requirements was strictly an administrative issue and was not an indicator of compliance for related resource-protection rules. Discussions with landowners, operators, and ODF field staff revealed that the practices addressed by these rules were often considered or discussed with

ODF personnel during the operation, with the compliance shortcoming simply being one of written documentation. Compliance also appears to be closely related to how familiar operators and landowners are with the requirements in question. The two most commonly applied prior approval rules averaged 203 applications each and 97.2% compliance. The remaining 11 rules averaged only eight applications each and 55% compliance.

- Written Plan Requirements. Compliance was evaluated for eight rules located in several divisions that require that detailed information be documented in a written plan for a variety of specified activities. Documentation of adequate information in a written plan was lacking for 136 of 593 total activities for which it was required (77.1%). Noncompliance with these requirements was strictly an administrative issue and not an indicator of compliance for related resource protection rules. Discussions with landowners, operators, and ODF field staff revealed that these requirements were often considered or discussed with the FPF during or before the operation, with the compliance shortcoming being one of written documentation. Noncompliance also occurred in many cases where a written plan was submitted but did not contain a sufficient level of detail to describe activities in question. Compliance issues generally appeared to be the result of a lack of clear understanding of what specific details are required to be in a written plan (This was especially true for providing fish passage. See ODF Technical Report 14).

Monitoring Question 5: Resource Impacts of Noncompliance. *When BMP compliance is inadequate, to what extent are quality and function of riparian areas, stream channels and/or fish habitat compromised?*

Of the 502 total noncompliant practices surveyed, 185 (37%) were with administrative requirements not directly affecting riparian and channel conditions, 147 (29%) had the potential to impact riparian and channel conditions in the future, and 170 (34%) had an observed impact to riparian and channel conditions. The 170 observed impacts resulted from noncompliant practices associated with a range of forest practices rules (Table 3). Each of these instances was categorized as one of four types: significant harvesting slash accumulations below a high water line, significant damage or removal of riparian vegetation, physical alterations of channel bed or banks without sediment delivery, or sediment delivered below a high water line.

<u>Slash Accumulations</u>
Fifty-three noncompliant harvesting slash accumulations were deemed significant enough to impair the water quality of a stream or wetland. These accumulations resulted from trees not felled directionally away from small Type N streams and small wetlands (40), slash on slopes above streams was not disposed of or placed to prevent it from entering the channel after harvest (7), or mechanically-piled slash was placed below a high water line (6). In all these cases, the loading of fine harvesting slash greatly exceeded natural levels.

Table 3. Riparian and Stream Channel Impacts of Noncompliant Practices

Slash = Significant accumulations below a high water line, Vegetation = significant damage or removal of riparian vegetation, Alteration = physical alterations of channel bed or banks without sediment delivery; Sediment Delivery to WOS numeric columns are categorical estimates of volume of sediment delivered in cubic yards.

				Sediment Delivery to WOS (yd3)			
Rule Sub-Section	Slash	Vegetation	Alteration	0-1	1-10	10-100	>100
Reforestation (RMAs only)							
Treatment of Slash	6				1	1	
Chemical and Other Petroleum Products							
Chemical Applications		2					
Petroleum Products							
Road Construction and Maintenance							
Road Location							
Road Prism Design					1		
Steam Crossing Design			2		8	2	
Road Drainage Design				4	7		
Road Waste and Stabilization				4			
Road Drainage Maintenance				5	4	1	
Road Vacating							
Rock Pits							
Harvesting							
General Yarding Practices						1	1
Felling and Harvesting Slash	38		1				
Cable Yarding Near WOS					1		
Ground Equipment Near WOS				2		1	
Harvesting Waste	7			2		3	
Landings							
Skid Trails			8	4	4	1	
Temporary Crossings				5	5	2	
Vegetation Retention Along Streams							
Vegetation Retention - Type F RMAs		23					
Veg. Retention - Type N and D RMAs		1					
Significant Wetlands		2					
Other Wetlands	2	2		2	3		1
Stream Channel Changes							
Total	53	30	11	28	34	12	2

The beneficial and detrimental effects of this material on water quality and channel dynamics is not yet fully understood or quantified. It is believed, however, that large accumulations of fine organic material in streams and wetlands can have the following potential impacts: elevated water temperatures due to artificially widened channels and slowed flows, reduced dissolved oxygen as material decomposes, alteration of channel hydrology and increased erosion, reduced potential for vegetation establishment, short-term retention of sediment, and elevated debris torrent hazard.

Research on clear-cut first- and second-order streams in western Washington (Jackson *et al*., 2001) found several significant short-term effects of heavy slash loading. These include large increases in the amount of fine sediment retained in these channels, shading of channels from direct solar radiation, and reduction of amphibian populations.

Riparian Vegetation Damage

Thirty of the noncompliant practices surveyed resulted in significant damage or removal of riparian vegetation that was required to be retained by the forest practices rules. The retention of vegetation along streams and wetlands is required to maintain water quality, fish and wildlife habitat, and bank stability. The majority of these (23) were failures to fully meet the vegetation retention requirements when harvesting in Type F RMAs. Other noncompliances were for aerial chemical applications to riparian vegetation (2) and with vegetation retention requirements when harvesting along significant wetlands (2), other wetlands (2), and a Type N RMA (1).

Alteration of Bed or Banks

Eleven noncompliant practices resulted in channel alterations with no observable sediment delivery to a stream or wetland. This physical alteration of channel beds or banks can result in immediate and long-term impacts to water quality through altered hydrology, soil compaction, and elevated erosion potential. Most were associated with machinery operated within a channel, either from ground skidding of logs (8) or excessive activity within a channel while constructing a stream crossing (2). The remaining alteration was the result of trees felled into a small Type N streambed.

Sediment Delivery

Seventy-six observations of sediment delivered to a stream or wetland resulted from a wide range of noncompliant practices (Figure 3). The impacts of sediment delivery vary greatly depending on the volume of delivery, stream size, channel morphology, and other site conditions, but in some cases can cause severe resource impacts. These situations can mean unstable slopes and the loss of forest soils, as well as impaired water quality through increased stream temperatures and lowered dissolved oxygen, hindered fish migration and feeding ability, mortality of aquatic invertebrates, and deposition of fine materials which can alter channel hydrology and bury spawning gravels.

Because these surveys were conducted during the dry season, observations of past sediment delivery and estimations of delivery volume were likely to be under-representative of actual erosion rates. The volume of sediment delivered to WOS was estimated within broad categories. Of the total (76), 28 were estimated to be less than 1 cubic yard, 34 were 1 to 10 cubic yards, 12 were 10 to 100 cubic yards, and two were greater than 100 cubic yards (Figure 4). The first of these two largest cases was from poor yarding practices on steep slopes that caused several large shallow failures. The second (on the same unit) was from improper ground skidding within a wetland.

It is important to note that the estimated volume of delivered sediment is not necessarily a measurement of the magnitude of impact that this delivery may have had on the stream channel. The degree to which a volume of delivered sediment will impact a channel can vary greatly depending on the presence of fish and other aquatic species, stream size, channel morphology, habitat conditions, delivery timing, and other factors. The two cases of sediment delivery of greater than 100 cubic yards, for example, were to a small Type N stream and a wetland of less than one acre. Neither of these streams had fish populations, however, such large amounts of sediment delivery to these small features have drastic hydrology and morphology impacts, such as long-term aggradation of the channel downstream.

The greatest source areas of sediment delivery were from 36 noncompliant road construction and maintenance practices. Specific sediment source areas were ineffective road drainage design (11), inadequate road drainage maintenance (10), eroding stream crossing fill (10), unstabilized road waste (4), and an unstable road prism design (1). The other main sources of sediment delivery were from 32 noncompliant harvesting practices. Specific source areas were poorly removed temporary crossings (11), ineffectively drained skid trails near streams (9), unstablized harvesting waste (5), harvesting equipment operated in stream channels (3), yarding gouges on steep slopes (2), trees felled into a channel (1), and

trees yarded through a stream channel (1). The remaining delivery observations were from infractions of small wetland protection requirements (6), and slash-piling machinery operated in WOS (2).

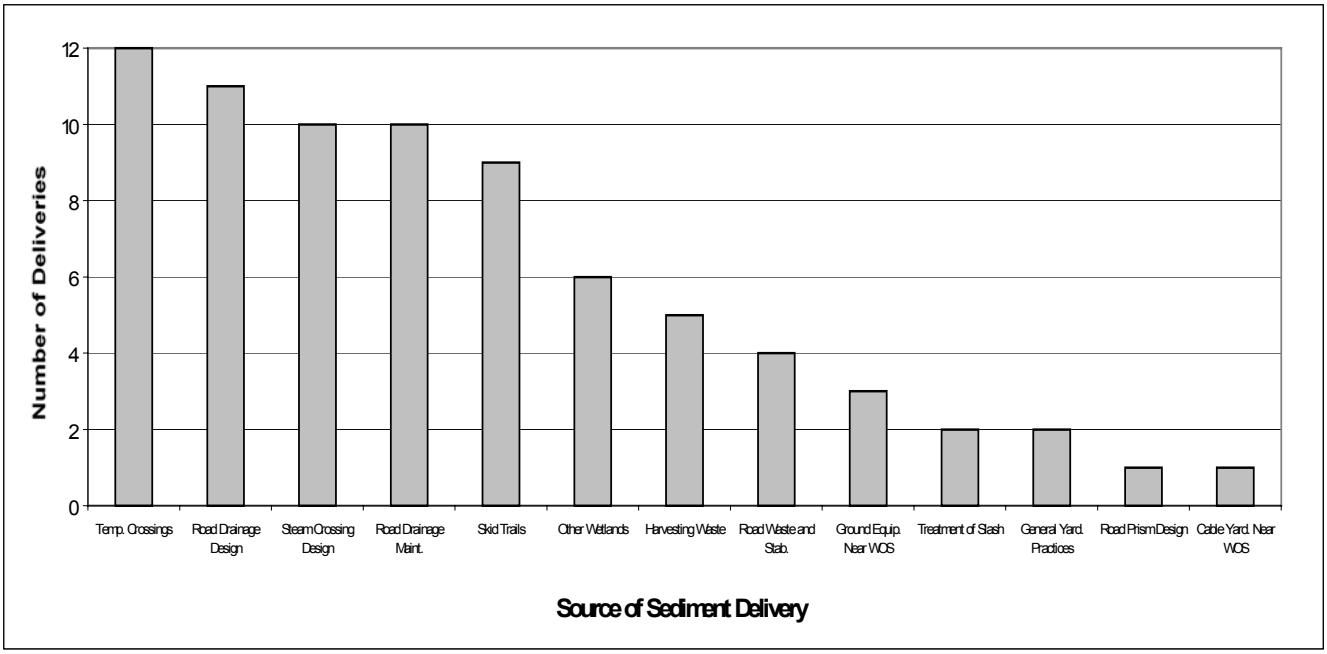

Figure 3. Distribution of Sediment Delivery Sources

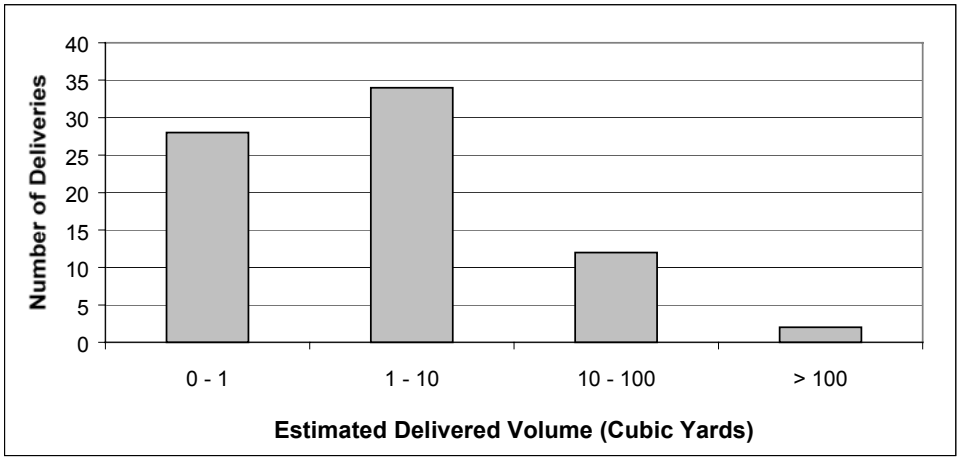

Figure 4. Distribution of Sediment Delivery Volumes from Noncompliant Practices

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