Washington Road Sub-Basin Scale Effectiveness Monitoring First Sampling Event (2006-2008) Report

Kathy Dubé, Alice Shelly, Jenelle Black, Karen Kuzis

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

Cooperative Monitoring
Evaluation & Research

September 2010

CMER 08-801

Washington State Forest Practices Adaptive Management Program
Cooperative Monitoring, Evaluation, and Research Committee (CMER)
Report

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Prepared by:

Kathy Dubé, Alice Shelly, Jenelle Black, Karen Kuzis

Prepared for the
Cooperative Monitoring, Evaluation, and Research Committee (CMER)
of the

Washington State Forest Practices Board
Adaptive Management Program
Washington State Department of Natural Resources
Olympia, Washington

May 2010 **CMER 08-801**

Forest Practices Adaptive Management Program

The Washington Forest Practices Board (FPB) adopted an adaptive management program in concurrence with the Forests & Fish Report (FFR) and subsequent legislation. The purpose of this program is to:

> Provide science-based recommendations and technical information to assist the board in determining if and when it is necessary or advisable to adjust rules and guidance for aquatic resources to achieve resource goals and objectives. (Forest Practices Rules, WAC 222-12-045)

To provide the science needed to support adaptive management, the FPB made the Cooperative Monitoring, Evaluation and Research Committee (CMER) a participant in the program. The FPB empowered CMER to conduct research, effectiveness monitoring, and validation monitoring in accordance with guidelines recommended in the FFR.

Disclaimer

This technical report contains scientific information from a research study designed to evaluate the effectiveness of the Forest Practices Rules in achieving one or more of the Forests & Fish performance goals, resource objectives, and/or performance targets. The document was prepared for CMER and was intended to inform and support the Forest and Fish Adaptive Management Program. The project is part of the Roads Rule Group Road Sub-Basin Scale Effectiveness Monitoring Program, and was conducted under the oversight of the Uplands Processes Scientific Advisory Group (UPSAG).

This document has been reviewed by CMER and has been assessed through the Adaptive Management Program's independent scientific peer review process. CMER has approved this document for distribution as an official CMER document. As a CMER document, CMER is in consensus on the scientific merit of the document. However, any conclusions, interpretations, or recommendations contained within this document are those of the authors and may not reflect the views of all CMER members.

Proprietary Statement

This work was developed with public funding including contracts: PSC 05-386 and PSC 08-73. As such it is within the public use domain. However, the concept of this work originated with the Washington Department of Natural Resources (WDNR) and the authors; permission must be obtained from the originators to use the results in the way developed herein. Use of results without permission of WDNR and the authors may be deemed a violation of federal statures under preview of the Office of Research Integrity. As a public resource document, this work should be given proper attribution and be properly cited.

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Dubé, K., A. Shelly, J. Black, and K. Kuzis. 2010. Washington road sub-basin scale effectiveness monitoring first sampling event (2006-2008) report. Cooperative Monitoring, Evaluation and Research Report CMER 08-801. Washington Department of Natural Resources. Olympia, Washington.

This report was prepared under contact to the Washington Department of Natural Resources as part of Contacts No. PSC-05-386 and PSC-08-73.

Author Contact Information

Kathy Dubé
Watershed Professionals Network
kdube@watershednet.com

Alice Shelly
TerraStat Consulting Group
alice@blarg.net

Jenelle Black
Northwest Indian Fisheries Commission
jblack@nwifc.org

Karen Kuzis
ENVIRON International Corporation
kkuzis@Environcorp.com

Acknowledgements

Many thanks to the members of the UPSAG committee and all others who reviewed various work products throughout both phases of this project. Your comments and thoughts are appreciated. Reviewers included Julie Dieu, Mark Hicks, Doug Martin, Dick Miller, Bob Palmquist, Nancy Sturhan, Laura Vaugeois, Curt Veldhuisen, and the Independent Science Panel Review committee members. Jenelle Black performed the site selection process. Thanks also to the field crews who drove and walked all those road miles: Scott Hotchkiss, Pete Malinak, Matt Rourke, Jesse Saunders, Dan Thomas, and Brett Winterowd, and to Ted Hitzroth for GIS support.

ABSTRACT

New Forest Practice Rules for forest roads under Washington Department of Natural Resources (WDNR) jurisdiction were adopted in Washington State in 2001. Implementation of the road rules for existing roads is planned over a 15-year time horizon through the completion of Road Maintenance and Abandonment Plans (RMAP). The objectives of the Road Sub-Basin Scale Effectiveness Monitoring Program are:

- to determine if the road characteristics that affect runoff and sediment delivery to streams are improving through time as RMAP are implemented between 2001 and 2016; and
- to determine the extent to which roads on lands subject to WDNR forest practice rules meet the FFR performance targets.

Characteristics of forest roads in a total of 60 random four-square-mile sample units across the state were inventoried between 2006 and 2008, five to seven years after the forest practice rules were adopted. This is the first sample event planned for the Road Sub-Basin Scale Effectiveness Monitoring Program, and provides the first look at the current status of forest roads.

A high percentage of roads in the sample units across the state were reported to either have RMAP work complete, or already be up to current road rule standards, with over half of the sample units reported to have at least 85 percent of road length meeting standards. An average of 11 percent of the road network was hydrologically connected and assumed to deliver water and sediment to streams or wetlands. Across the state, 62 percent of the sample units met the Forests & Fish Report (FFR) hydrology performance target (miles of delivering road/miles of stream) and 88 percent of the units met the FFR sediment performance target (tons of delivered sediment/year/miles of stream).

Statewide, no relationship was found between length of road delivering in a sample unit and percent of roads in the unit reported to be up to standards; however, a statistically significant decreasing relationship was found between sediment delivery in the sample unit and percent of roads in the unit reported to be up to standards. These findings suggest that, while there may be locations where there is higher hydrologic connectivity or sediment input from roads, many roads show decreasing sediment inputs as they are brought up to standards.

Approximately ninety-five percent of the land sampled was owned by large industrial forest owners and state/local governments. The study was intended and designed to incorporate land owned by small forest landowners, but due to the sample site criteria and layout and their fragmented ownership patterns, little of that ownership type was able to be incorporated. Development of a companion study specifically designed to obtain access to and evaluate small forest ownerships could be pursued in order to characterize those lands.

It is recommended that the monitoring project continue with next planned monitoring period (planned interval of 5 years) to evaluate the expectation that, in general, roads conditions improve and they meet the performance metrics as they are brought up to FFR standards.

WASHINGTON ROAD SUB-BASIN SCALE EFFECTIVENESS MONITORING FIRST SAMPLING EVENT REPORT (2006-2008)

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1 Introduction

The Washington Department of Natural Resources (WDNR) implemented new Forest Practice Rules for forest roads under WDNR jurisdiction in 2001. The 2001 road rules were developed in the wake of the Forests & Fish Report (FFR) and are designed to improve many aspects of the road network by reducing the occurrence of road landslides, culvert plugging, and road surface erosion, and by eliminating barriers to fish passage. The resource objectives for roads include sub-basin scale performance targets for surface sediment and water diversion to the stream network associated with forest roads (Raines et al. 2005). The resource objectives and performance targets for road hydrologic connectivity to the stream network and sediment input to streams are linked because runoff is required to transport sediment from roads to streams. By limiting the delivery of sediment and excess water to streams, the road rules will help to protect water quality and aquatic resources. Implementation of the road rules for existing roads is planned over a 15-year time horizon through implementation of Road Maintenance and Abandonment Plans (RMAP) that concludes in 2016. After that time, all roads will be required to be maintained to forest practice rule standards.

As part of the Cooperative Monitoring, Evaluation, and Research (CMER) Committee mission, a number of different monitoring programs have been developed to evaluate the Forest Practice Rules. Monitoring projects are grouped by 'Rule Group' (roads, riparian, etc.) and include effectiveness and validation monitoring at several different scales (FY 2010 CMER WORK PLAN p.12). The Road Sub-Basin Scale Effectiveness Monitoring Project (Raines et al. 2005) was designed to determine the degree to which forest roads under the jurisdiction of Washington Forest Practices Rules are meeting the road surface erosion and hydrologic connectivity resource objectives. This monitoring project has been set up to document current road characteristics related to runoff and surface erosion from roads within randomly-selected four-square-mile sample units of forest land. Sample units are planned to be re-surveyed three times through 2016 to determine if road conditions are either meeting targets or improving with respect to surface erosion and hydrologic connectivity. This is a voluntary study relying on the cooperation of landowners and does not evaluate landowner compliance with the Forest Practices Rules.

This report describes the first data collection effort, conducted from 2006 to 2008. It includes the field protocols, quality assurance plan, and analysis of data collected during the first sampling effort. Trends in road performance can not be evaluated until after future revisits to these (and/or other) sample units.

1.1 Literature Summary

There is a large network of unpaved forest roads in Washington State that provides access to private and state-owned timberlands. While these roads provide many positive benefits, they can also be sources of runoff and sediment that have the potential to affect aquatic habitat and water quality where the roads are hydrologically connected to streams or wetlands. Because the documentation for the Washington Road Surface Erosion Manual (Dubé et. al 2004, Appendix A) provides a detailed narrative of past research, the following discussion is limited to a brief summary.

The characteristics of a road and where it is constructed on the landscape control how much sediment is produced and whether or not this sediment is delivered to a waterbody. Road characteristics that have a major influence on erosion rates include:

- Road segment length – longer lengths have more erosion (Mills et al. 2003)
- Road gradient – steeper roads have more erosion (Luce and Black 1999)
- Surfacing type and durability – surfacing with durable gravel or vegetation reduces erosion (Meyers 2007, Coe 2006, Mills et al. 2003, Foltz 1996, Burroughs and King 1989, Kochenderfer and Helvey 1987, Swift 1984, Reid and Dunne 1984)
- Traffic use – higher use, particularly during precipitation events, produces more erosion (Mills et al. 2003, Foltz 1996, Reid and Dunne 1984, Sullivan and Duncan 1981)
- Grading and rut development – rutting produces more erosion; disturbance from grading temporarily increases erosion (Meyers 2007, Sugden and Woods 2007, Foltz and Burroughs 1990, Burroughs and King 1989)
- Interception of cutbank sub-surface flow by the road ditch – more interception results in ditch erosion (MacDonald et al. 2001)

Factors that influence the delivery of sediment to streams include:

- Distance between runoff point and waterbody – shorter distances result in more delivery (Brake et al. 1997, Megahan and Ketcheson 1996, Swift 1985, Trimble and Sartz 1957)
- Hillslope gradient and number of obstructions between road and waterbody – steeper gradient hillside and/or fewer obstructions results in more delivery (Brake et al. 1997, Megahan and Ketcheson 1996)
- Volume of flow and erosion from road segment – higher runoff and/or erosion volumes results in delivery at greater distances (Ketcheson and Megahan 1996)

The present monitoring project collected information on all the road conditions that have a major influence on erosion as well as indicators of hydrologic connectivity between the road and a stream or wetland.

2 Monitoring Objectives

The Road Sub-Basin Scale Effectiveness Monitoring Project was developed by members of CMER to determine if road characteristics that affect runoff and sediment delivery to streams are improving through time and the extent to which roads meet the FFR performance targets (Table 1). Details of the monitoring design are in Raines et al. (2005).

Table 1. FFR Sediment Performance Targets for Roads

Measure	Performance Target: New Roads	Performance Target: Existing Roads
Road sediment delivered to streams	Virtually none	
RLEN - Ratio of road length delivering to streams/total stream length (mile/mile)		Not to exceed: East of Crest 0.08-0.12 Coast (Spruce) 0.15-0.25 West of Crest 0.15-0.25
RSED - Ratio of road sediment production delivered to streams/total stream length (tons/yr/mile)		Not to exceed: East of Crest 1-3 Coast (Spruce) 6-10 West of Crest 2-6

(Source: Forests & Fish Report, Schedule L-1, June 2000)

The performance targets for road hydrologic connectivity to streams (RLEN) and surface sediment delivery (RSED) were developed in 2000 to supplement qualitative road standards identified in the Forests & Fish Report (Table 1). Target values were derived from sediment production estimates for forest road networks across Washington inventoried as part of Watershed Analyses done during the 1990s. Watershed analysts compiled road sediment delivery within sub-basins of similar scale to this study, each of which was given an aquatic hazard rating of Low, Moderate or High. The ranges bracketed by the RLEN and RSED targets correspond to sub-basins rated Low hazard and the lower values rated Moderate hazard. The group chose to document the targets by a 'range' rather than a single value because they felt the scientific information available to quantify aquatic sensitivity to sediment was insufficient to support a single threshold value. Separate targets were developed for the western and eastern sides of the Cascades and the coastal zone to reflect differing precipitation rates and channel densities. Although sub-basins where road metrics are within the local target range are expected to have acceptably low impact levels, the target development group recommended initiating further sediment-sensitivity studies to evaluate and possibly refine the target values. Readers should also be aware that although road evaluation methods for this monitoring study are similar to those used for Watershed Analysis, there have been numerous minor changes to methodologies since target development that have changed road sediment estimates.

The FFR performance target for new roads, virtually no sediment delivered to streams (Table 1), was not specifically addressed in the monitoring design for this study. For all the metrics developed as part of the monitoring design, existing and new roads were evaluated together and compared to the regional FFR targets for existing roads (Table 1). A small number of new roads were present within some of the sample units. The lengths of hydrologically connected road and estimated road sediment delivered to streams were compiled and are reported separately for the new roads in Section 4.4.

Six monitoring questions were developed to provide feedback on how well improvements in road characteristics translate into changes in the target measures for sediment and hydrology at the sub-basin scale:

- Monitoring Question 1: What is the condition of forest roads at each sample event, specifically those attributes management can change relative to sediment production and delivery?

- Monitoring Question 2: Have road attributes that affect sediment production and delivery improved over time?
    - Hypothesis 2a: No reduction in road drainage connectivity to streams has occurred since the previous sampling event(s).
    - Hypothesis 2b: No improvement in road attributes that affect sediment production and delivery has occurred since the previous sampling event(s).

- Monitoring Question 3: What is the status of road performance measures for drainage connectivity and sediment delivery to streams at each sample event?

- Monitoring Question 4: What is the status of road performance measures relative to their targets, by performance target region, at each sample event?

- Monitoring Question 5: Have measures of road sediment performance improved over time?
    - Hypothesis 5a: No reduction in the road drainage connectivity performance measure has occurred since the previous sampling event(s).
    - Hypothesis 5b: No reduction in the road sediment delivery performance measure has occurred since the previous sampling event(s).

- Monitoring Question 6: Will roads judged to meet FFR road standards meet the performance targets?
    - Hypothesis 6a: There is no direct relationship between the percentage of the road system that is judged to meet road standards and the reported road drainage connectivity performance measures.
    - Hypothesis 6b: There is no direct relationship between the percentage of the road system that is judged to meet road standards and the reported road sediment delivery performance measures.

In order to assess these monitoring questions and hypotheses, a series of numerical monitoring measures was developed that include the primary road characteristics influencing the delivery of sediment and water from a road system to aquatic environments (Table 2). These monitoring measures will be computed and compared for each sample event to determine the trend in road conditions through time.

Table 2. Monitoring Questions/Hypotheses and Measures

Monitoring Questions or Hypothesis	Reported Monitoring Measures
Monitoring Question 1	1. Total road length draining to streams (road miles/sq mi) 2. Percent of road network draining to streams 3. Percent of road in each surface category 4. Percent of road in each traffic category 5. Percent of road in each cutslope cover category 6. Percent of drainage points by connectivity class 7. Percent of road in each road rutting category
Hypothesis 2a	1. Total road length draining to streams (road miles/sq mi) 2. Percent of road network draining to streams
Hypothesis 2b	1. Road surfacing index 2. Road traffic index 3. Cutslope cover index 4. Miles of delivering road with ruts interfering with drainage
Monitoring Question 3	1. Miles of forest road delivering to streams per miles of stream (road hydrology performance measure) 2. WARSEM modeled tons of road sediment delivered to streams per miles of stream per year (sediment performance measure)
Monitoring Question 4	1. Miles of forest road delivering to streams per miles of stream (road hydrology performance measure) divided by the performance target by target region 2.WARSEM modeled tons of road sediment delivered to streams per miles of stream per year (sediment performance measure) divided by the performance target by target region
Hypothesis 5a	Miles of forest road delivering to streams per miles of stream (road hydrology performance measure)
Hypothesis 5b	WARSEM modeled tons of road sediment delivered to streams per miles of stream per year (sediment performance measure)
Hypothesis 6a	Miles of forest road delivering to streams per miles of stream by percent of road length meeting FFR road standards
Hypothesis 6b	WARSEM modeled tons of road sediment delivered to streams per miles of stream per year by the percent of road length meeting FFR road standards

(Source: Raines et al. 2005)

3 Methods

The first sample event included two phases of work. The first phase (Phase I) included development of a detailed field protocol and QA/QC plan, training of the inventory crew, and sampling 14 blocks of land in 2006. The results of the Phase I samples were used to conduct a statistical power analysis to estimate the total sample size required for the first sample event, which resulted in a decision to use a sample size of 60. The second phase of the sample event was conducted in 2008 and included updating the field protocol, re-training, and sampling the remaining 46 sample units.

3.1 Project Coordination and Meetings

Several meetings between the contractor and CMER personnel were scheduled as part of the Phase I and Phase II work. Meeting minutes are included in Appendix A.

The Phase I Start-Up Meeting was held on December 14, 2005, to review the monitoring objectives and methods. The Phase I Second Unit Meeting was held on March 31, 2006, with the field crew to discuss any changes needed to the field protocol after sampling the first two sample sites. Attendance by project principal investigator Kathy Dubé at the October 24, 2006 CMER meeting satisfied the Phase I completion meeting and is documented in the CMER meeting minutes.

A kickoff meeting for Phase II was held on March 21, 2008, to review the Phase II objectives and methodology with UPSAG committee members. The Phase II Second Unit Meeting was held on May 23, 2008, following sampling of two Phase II units. The purpose of the Second Unit Meeting was to review data collection procedures and discuss any issues that came up with the survey crews. The Phase II Survey Completion Meeting was held on January 29 and continued on February 5, 2009 to discuss the sampling results, any issues that arose during the project, suggestions from the field crew for future sample events, and data analysis required to meet project goals.

3.2 Field Protocol Development

A standardized field protocol manual was developed to provide consistent methods for collecting road condition data (Appendix D). The Field Protocol was developed based on guidelines in the WARSEM manual (Dubé et al. 2004) and the information required in the monitoring design (Raines et al. 2005).

Several revisions to the 2006 field protocol document were made prior to the 2008 sampling based on suggestions by the field crews and to incorporate UPSAG requests. The following key changes were made and implemented during the 2008 sampling:

- Tread configuration (the percent of the road tread that drained to a particular drainage point being inventoried) was changed from three categories in 2006 [full (100%), half (50%), none (0%)] to five categories in 2008 (0%, 25%, 50%, 75%, 100%) at the suggestion of the field crews to better reflect conditions actually seen on the ground and to improve consistency between surveyors who were having a difficult time determining tread configuration in some cases.

- Delivery of ditch water across long, vegetated fillslopes was clarified to help improve consistency. If there was less than 50 feet of vegetated fillslope between the ditch outlet and the stream, 100% delivery is assumed. If there is more than 50 feet of vegetated fillslope between the ditch outlet and the stream, the delivery flowchart is used to determine delivery.

- Addition of a fifth delivery category to document road segments that closely paralleled streams or obvious and mapped wetlands but did not fall within another delivery category. This category was called "Parallel within 20 feet of a stream."

- Addition of a data field to document the length of road that is parallel within 20 feet of a stream. This includes cases where a segment may deliver directly, but the road closely parallels a stream and may be constructed in or occupying the floodplain.

- Updating the flowchart that provides guidance for delivery and breaking roads into segments to reflect changes to delivery categories.

The final 2008 field protocol is included on the data CD.

3.3 Quality Assurance/Quality Control Program

A Quality Assurance Project Plan (QAPP) was developed and implemented during the initial 2006 field season, and updated during the Phase II field season in 2008. The main elements of the QAPP include:

1. Standard field protocols
2. Data management procedures
3. Field crew training program
4. Quality controls during field data collection
5. Monthly field visits by management personnel
6. Duplicate crew surveys
7. Quantification of crew variability
8. Third party QA analysis
9. QA/QC reporting

Field inventory personnel were trained in the field protocol during three-day sessions prior to both the 2006 and 2008 field seasons; these included PowerPoint presentations and field training. In addition, the Principal Investigator and contractor project management personnel worked in the field with crew members during the course of the project to answer questions, review protocols, and discuss potential revisions and improvements to the protocol (“Field Assistance Visits”). Crew members also worked together for several days during the sampling season to discuss how they were making determinations in the field and improve the consistency of data collected (“Duplicate Crew Surveys”).

An assessment of crew variability was conducted during both the Phase I and Phase II field seasons to: 1) understand where field assistance and additional training were needed to minimize differences between observers; and 2) help to understand, if possible, how much of the total variance in monitoring results may be due to observer error. Three road sections were selected from a West of Crest sample unit in 2006 (Phase I) and three different road sections were measured in an East of Crest unit in 2008 (Phase II). The test lengths were chosen to represent the range of road use and maintenance conditions within each sample unit. The variability tests were conducted after initial training and again near the end of data collection. Each of the road sections was evaluated by each of the crew members using standard project data collection instructions and techniques.

A final version of the 2008 QAPP includes details of each of these elements and is included in Appendix B of this report. Appendix C is the QA/QC report for the project.

3.4 Sample Units

3.4.1 Sampling Frame

Sample units were selected in a stratified random manner from all forest practices rules-regulated (FFR) timberlands within the state. The number of units in each geographical performance target region was based on percent of FFR land area within each region:

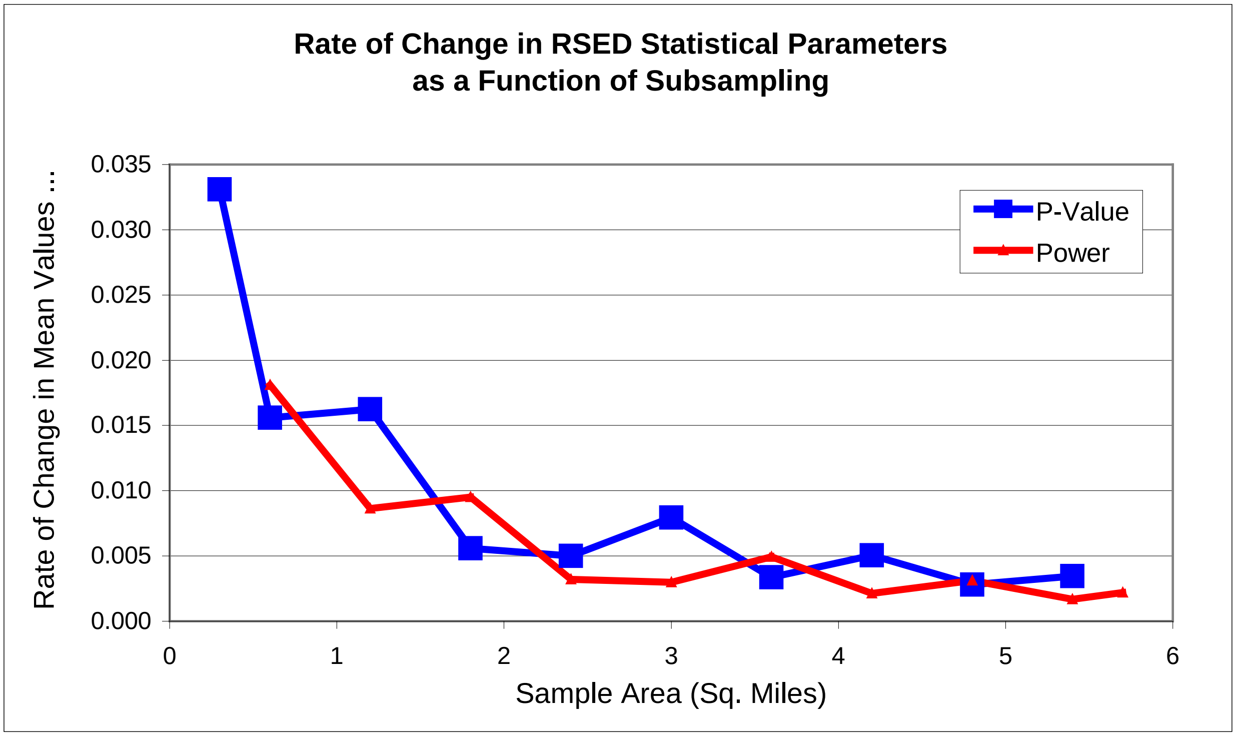
- Coastal Spruce = 11%
- East of Crest = 51%
- West of Crest = 38%

FFR land was estimated from the "CMERlands" GIS coverage developed by the Department of Natural Resources Forest Practices Division (Washington Department of Natural Resources 2005). The CMERlands coverage was developed from USGS "forested" polygon coverage (assessed from LandSAT imagery), Habitat Conservation Plan (HCP) areas, public land ownership coverages, and Native American land coverages. FFR lands were selected as those forestlands that were neither Federal, Tribal, nor covered by an HCP *plus* DNR HCP lands that were not within the habitat range of spotted owls or marbled murrelets and so are managed under normal forest practices rules (these occurred in eastern Washington). The "forested" designation was inclusive and often included land that was actually scrub-shrub steppe or rangeland as well as some agricultural land. These non-forest areas were further filtered out from individual sites during the site screening process. Property from small forest landowners was specifically included in this study.

3.4.2 Sample Size and Unit Area

This study is designed to evaluate trend, which entails evaluating differences in results from sample events spaced 5 years apart. The study is designed to resample the same units in each sampling event and to use paired t-test analyses to assess change (Raines et al. 2005). In order to estimate the number of samples required to obtain good statistical power for a paired t-test, a measure of variability among differences (e.g., future year metric minus current year metric for each sample unit) would be required. Since such an estimate will not be available until multiple years of data are collected, the power for a simple two-sample t-test was estimated instead. When measurements are correlated (i.e., same sites through time), the paired t-test has higher power than the two-sample t-test, so the estimated sample size should be more than adequate. Based on variability among parameters found during earlier watershed analyses, the study plan originally estimated a sample size of 60 units. With 60 units at each sampling time, the power was greater than 80% for detecting a change of 30% in RLEN and a change of 50% in RSED using a two-sample t-test. Thus, with a paired t-test for a paired sample, the power is expected to be even greater. Data from the 14 units sampled during Phase I were analyzed to refine this original estimate.

During Phase I, six-square-mile units (24 quarter sections) were used for sampling based on the average subbasin area in Watershed Analysis data (average area = 6.26 mi^2, n=60, SD = 3.96 mi^2; Raines et al. 2005). However, obtaining sites of this size proved to be very difficult and resulted in an unacceptably high site rejection rate (see next section), especially in those areas on the fringes of large industrial forestland blocks. Sampling such large areas was also very expensive due not only to the increased land area but to the fact that accessing many landowners and road systems greatly multiplied the sampling effort and costs. As part of an effort to reduce the sample unit rejection rate (by requiring fewer approved quarter sections) and to reduce costs, CMER analyzed the 2006 field data for the two main target metrics from the 14 Phase I sites using fixed area re-sampling (Figure 1).



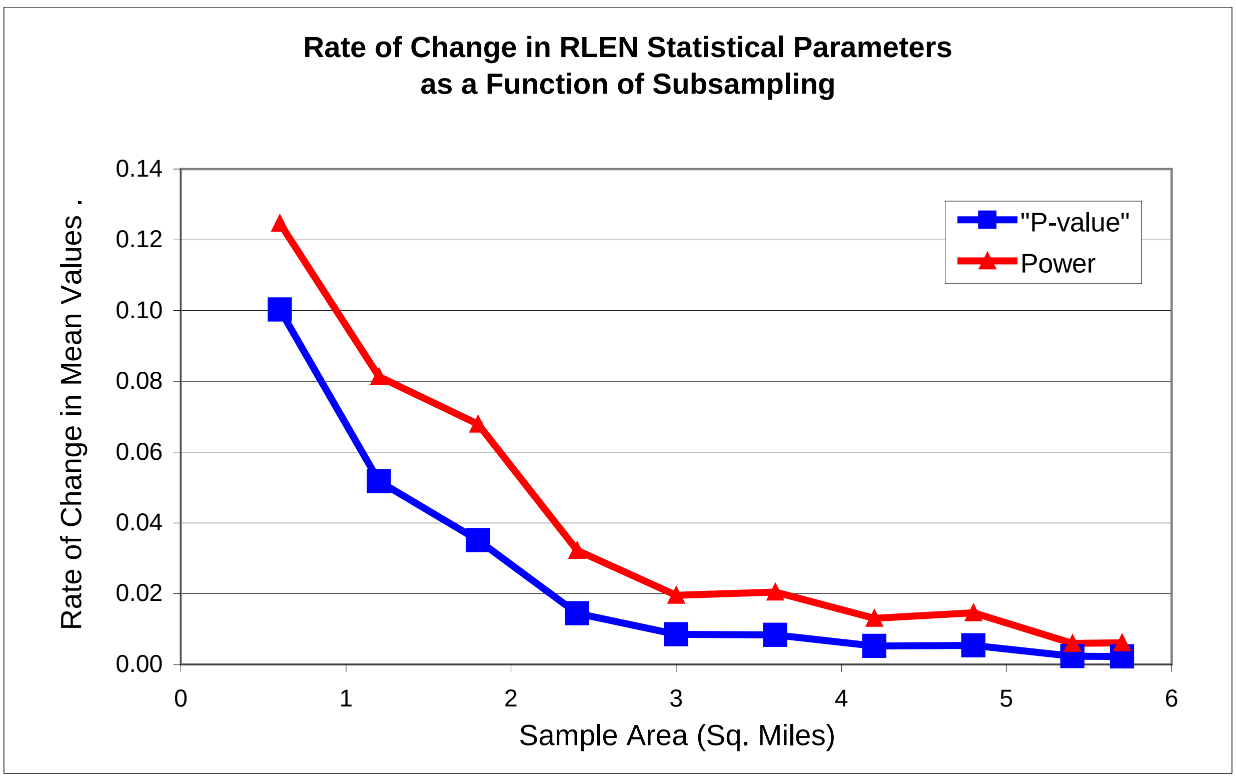


Figure 1(a) and 1(b). Change in the Mean Power and P-value for (a) RSED and (b) RLEN as the Area of Each Sample Unit from Phase I was Increased.

Based on this analysis, CMER determined that the sample size should remain at the original 60 but that the sample unit areas could be reduced to as little as three square miles and still provide the required certainty to assess trends (Figure 1). Three square mile units would still be within the standard deviation of the average Watershed Analysis subbasin area used as the basis in the study design. Sampling four-square-mile blocks would allow for some area attrition within blocks (due to ownership or land use changes incompatible with the study) in future years without having to remove the entire block from the sample. This is a very important point given the current trend of land development, the desire to gain information about small forest land management as well as large industrial land management, and the effort required to obtain and permit sample units that meet the study criteria. Therefore, UPSAG recommended and CMER and the Forest Practices Policy Committee approved the decision to retain the original sample size of 60 but reduce the sample unit areas to four-square miles. The results of the CMER analysis suggested that reducing the sample area from six- to four-square miles would reduce power by less than 0.5% for RSED and 2% for RLEN (the two primary metrics being tracked) while reducing the costs by approximately $175,000. For the final analysis combining data from Phases I and II, only the first 16 selected quarter sections from the Phase I units were used (see following section for a description of sample unit quarter section numbering) so that all units analyzed had the same area. The 240 square miles sampled represents 1.7 percent of the estimated 9.1 million acres of Forest Practice Rule land. If 60 of the original 6 square-mile units were inventoried, it would have been 2.5 percent of the total land area.

3.4.3 Site Selection

Initial unit selection followed the plan described in Raines et al. 2005 and began by randomly selecting section corners within the FFR land sample area. The potential sample unit consisted of a sixteen-square-mile block surrounding that section corner (Figure 2). Units were screened in the numerical order in which the corner was selected. As a unit was rejected, the next unit in the initial selection was evaluated until the total sample number was reached. Extra units were initially selected and screened to allow for further attrition as more refined site screening and permitting proceeded.

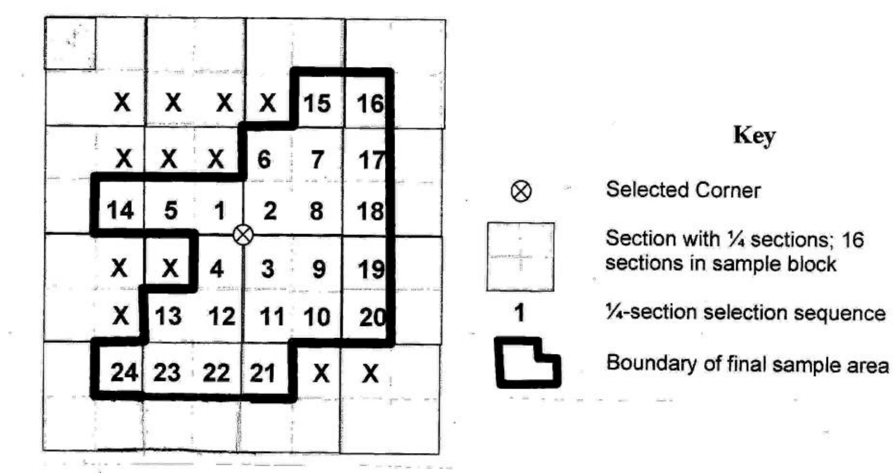


Figure 2. Sample Unit/Quarter Section Selection Process (from Raines et al. 2005).

The intent was to sample blocks of land that contained coherent networks of roads that were managed as forest roads under the forest practices rules. The first step in screening units entailed assessing the amount of FFR land within the block. If there was less than four square miles of FFR land, as designated from the GIS layers, the unit was discarded without further assessment. If there was enough FFR land, the unit was inspected to see if the FFR areas were laid out such that there was a contiguous block of FFR land of suitable size, or two large contiguous blocks that together would make up the requisite area. The objective of assessing blocks of contiguous road was the key factor. For example, in a few cases the unit spanned a large river, and large contiguous blocks on each side could be formed and were used to make up the unit. In other cases, large blocks could not be formed and the unit was rejected.

After the initial screening using the CMERlands FFR GIS layer, quarter sections within units were evaluated using aerial photos, land parcel ownership, personal knowledge, and field inspection. Typically, quarter sections in the unit that could be readily identified as non-usable were rejected in the table for that unit. Per the study design (Raines et al. 2005, Appendix A), quarter sections were discarded if they contained any unacceptable non-forest use (residence, quarry, fire station, commercial, etc.). Roads, power lines, and railroad rights of way were considered acceptable non-forest uses and quarter sections containing those were retained. UPSAG determined that properties containing small (e.g., one-room) hunting cabins would be retained in the sample since such a structure’s use did not fundamentally change the use of that forestland, nor did it particularly indicate the intention to develop the land further. On the other hand, quarter sections that consisted of land parcels less than 10 acres in size were assumed to be under development or likely to be developed by the next sample event and were rejected. Agricultural, scrub-steppe range land, and large water body inclusions were assessed on a case-by-case basis. If the non-forested area made up over half of the quarter section, that quarter was discarded.

Following the initial identification and recording of ineligible quarter sections, each potential quarter section surrounding the central section corner was evaluated in more detail in a clockwise spiraling pattern out from the selected section corner (Figure 2). If the quarter section was eligible, it was added to the potential sample unit in order (quarter section 1, 2, 3, 4, etc. in Figure 2) and numbered. Weeding out the clearly ineligible quarters first simplified the detailed assessment by allowing working unit maps to be created in the GIS and quarters numbered. Using those working maps, county assessor records of land parcel boundaries and ownership provided further information on land use and ownership for sites and quarter sections that passed the photo screening. Parcel information was obtained in several ways. County assessors were contacted and most provided their parcel data to us in a database, and, where they had it, a GIS layer. When it became available, the Statewide Parcel Database (RTI 2007) was used. Internet searches were used to verify parcel database information and to obtain information for those counties that did not provide information directly. Where graphical parcel data were not available, property legal descriptions were used to identify properties within quarter sections. Since this level of data screening was very time intensive, it was left until last and only applied to those quarter sections that passed previous screening. Parcel data were inspected to ensure there were no incompatible improvements on the properties and to obtain landowner contact information.

Landowners were then contacted to determine if they were interested in participating in the monitoring project. Contact was made via letter, by telephone, and by personal contact if somebody whom we knew also knew the landowner. If the owner was interested in participating, the quarter section was retained; if any owner within a quarter denied access, that quarter section was dropped and the next quarter section in the sequence was used. Additional criteria were applied to ensure that units were reasonably blocked up and did not have short segments of unrelated roads distributed across them (see Raines et al. 2005, Appendix A for more details).

3.5 Landowner Contacts

Landowners within each sample unit were contacted to provide permission to sample the roads, and to acquire the following information about roads within the unit:

- Landowner category (large or small by WDNR standards)
- Road name/numbering
- Traffic levels over past 1 year - landowner either provided average number of loads/day or selected traffic category from those provided in the Field Protocol for each road within the sample unit on their ownership
- Percentage of roads within the sample unit that the landowner considered up to current forest practice standards (either up to standards or RMAP has been implemented)
- Recent road maintenance activities (within last 5 years)
- Age of roads

This information was used for statistical analysis and in the WARSEM analysis.

3.6 Field Sampling

Roads in the selected sample units were inventoried from March – August, 2006 during Phase I (14 units) and from May – December, 2008 during Phase II (46 units). Field crews during both phases included five crew members; four of these crew members participated in both field seasons. One Phase I crew member was not available during Phase II and was replaced by another person. Details of the field sampling methods are included in the field protocol (Watershed Professionals Network 2006 and 2008).

During the field inventory, all forest roads in the sample unit were either walked or driven to collect information on the road condition. Forest road for the purpose of this study are as defined by the Washington Administrative Code (WAC) Chapter 222-16-010. On that basis, the following were not included in the inventory:

- Foot trails
- Skid roads
- Highways/county roads
- Officially orphaned or abandoned roads [defined in WAC 222-24-053(3) and (4)]
- Vegetated roads: non-drivable vegetated roads with over 90% cover on the tread were inspected for at least 200 meters to ascertain there was no evidence of erosion. Vegetated roadways with no traffic result in little surface erosion (Swift 1984). If no

evidence of erosion was found, the remainder of the road was not surveyed. Non-drivable roads with less that 90% vegetative cover were inventoried.

Roads were divided into segments by determining the hydrologic connectivity (drainage to streams or typed wetlands) for each portion of the road network. Delivery to streams/typed wetlands was classified as follows, based on studies of road sediment delivery and sediment trap efficiency as described in Appendices A and C of the WARSEM manual (Dubé et al. 2004), Ketcheson and Megahan (1996), and NCASI (2000):

0 – No delivery – the road or drainage structure outfall drains to the forest floor, with no evidence of sediment plumes reaching a stream or wetland

1 – Direct delivery – the road, ditch, or drainage structure outfall drains directly into a stream (e.g., at a stream crossing) or wetland

2 – 35% delivery – a sediment plume from the road drainage reaches a stream or wetland, or there is a constructed sediment trap that traps some sediment (Ketcheson and Megahan 1996, NCASI 2000)

3 – 10% delivery – a sediment plume from the road drainage ends between 1-20 feet from a stream or wetland (Ketcheson and Megahan 1996)

4 – Direct via gully – drainage from the road is delivered directly to a stream or wetland through a gully or landslide scar

5 – Road parallel to and within 20 feet of a water body – a road that does not fall into another delivery category (1-4) but parallels a stream or wetland (edge of tread is within 20 feet of stream/wetland/floodplain). This delivery category was added for Phase II field work; it was not delineated for Phase I roads.

The road network was broken into delivering and non-delivering segments that were generally delineated by drainage structures (culverts, bridges, ditchouts) and grade breaks. Figure 3 shows an example of a road system broken into segments; delivering segments that either drain directly to streams (e.g., segments 1, 2, 3, 5) or are in the 35% or 10% delivery categories (e.g., segments 4 and 6), or are closely parallel to a stream (e.g., segment 7) are numbered in the diagram.

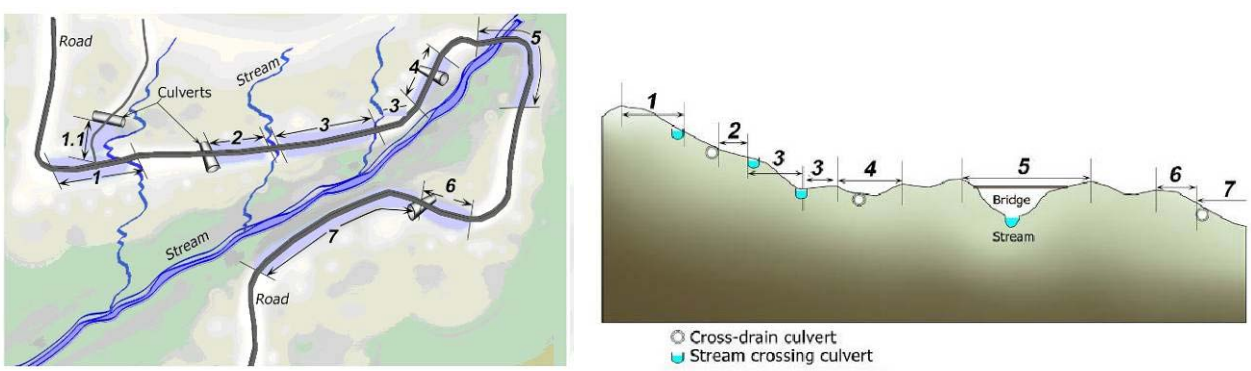


Figure 3. Example Road Segments
Map view (on left) and road profile (on right) show how roads were divided into delivering segments (numbered) and non-delivering segments (un-numbered).

For each delivering road segment, a GPS location was collected, and information on the characteristics of the road tread, cutslope, and ditch were collected and entered into the GPS (Table 3). A JAMAR RAC Plus I odometer was used in each vehicle to track stationing in feet (a string box was used for roads inventoried on foot). The location of each non-delivering culvert (e.g., ditch relief pipes) was also collected. No information on road characteristics was collected for non-delivering road segments since these segments do not contribute sediment to surface waters (Raines et al. 2005).

Table 3. Data Collected on Delivering Road Segments

Attribute	Possible Values	How Measured or Determined
Site ID	Text	Input site ID number.
Segment ID	Unique number; integer	The GPS unit assigns this number automatically.
Road Name	Text	Recorded on first/last segment of road, rest blank.
Group ID	Integer	Leave field blank unless this road segment drains to the same point as another segment; then assign both (or all) segments draining to the same point the same Group ID number (unique to those segments).
Surveyor	Name	Input surveyor name.
Weather	Clear Rainy Cloudy Snow	Determine average conditions for day.
Reference Point ID	Text	Record on first/last segment of road.
Segment Start Station	Number	Record JAMAR reading at start of segment.
Drainage Point Station	Number	Record JAMAR reading at drainage point.
Segment End Station	Number	Record station at end of segment (JAMAR reading or string box).
Drainage Point Type	Culvert Bridge Ditchout Drivable dip Sag point Other segment Other/unknown	Record type of drainage structure. Other segment – drains to other segment that delivers.
Structure Purpose	Stream crossing Relief, no gully Relief, gully No structure	Stream – defined bed and banks up and downstream of culvert Relief – no defined bed/banks Gully – defined bed/banks downstream but not upstream of culvert No structure – no structure observed
Delivery	0-none 1-direct or direct w/full trap 2-35% sediment 3-10% sediment 4-direct via gully or landslide scar 5-parallel within 20 feet	Determine delivery of ditch, drainage outfall, or road segment if outsloped based on flowchart “Guidance for delivery and breaking road segments” included in the field protocol.
Stream Adjacent Length	Length in feet	Measure length of road parallel and within 20 feet of a stream/wetland.
Culvert drop >9 inches?	Y/N	Is the vertical measurement between the water flowing out of the culvert and the water surface of the plunge pool more than nine inches? If stream is dry, measure from bottom of pipe to bottom of plunge pool.
Culvert downstream end countersunk?	Y/N	Is the downstream end of the culvert below the surrounding substrate?
Culvert upstream end countersunk?	Y/N	Is the upstream end of the culvert below the surrounding substrate?
Substrate extends through culvert?	Y/N	Look through culvert to determine if substrate extends the entire length of culvert.

Attribute	Possible Values	How Measured or Determined
Average Tread Width	Width in feet	Measure the full width of tread surface that could be driven on at 3-4 locations to nearest foot. Record average value (nearest foot).
Average Ditch Width	Width in feet	Measure width of ditch at 3-4 locations. Record average value (nearest foot).
Ditch Condition	P - recently pulled or graded E - scoured, eroding A - aggrading R - armored S – stable N/A	P – ditch has been recently pulled or graded E – ditch is eroding/incising. A – ditch is aggrading (full) R – ditch has been rocked/armored or is vegetated S – ditch appears stable (not eroding currently)
Maintenance Category	1-none recent 2-grading and/or ditch pulling only 3-other BMPs	Visually inspect the road to determine if maintenance has been completed recently (within last year).
Road Slope	<5% 5-10% >10%	Measure and record average gradient of tread with clinometer or estimate within slope class: <5% - flat or gently sloping road 5-10% - moderately sloped road segment >10% - steep road Average the gradient over entire segment. If the segment is a V-shaped stream crossing, estimate gradient on each side of crossing and average.
Surfacing	A-asphalt G-good gravel P-pitrun or worn gravel N-native	Determine surfacing on road tread. Use the following guidelines: Good gravel – a good gravel surface; little dust or fines on surface Pitrun or worn gravel – poor quality gravel surface; lots of fines or dust Native – dirt surface
Rutted?	No Yes/interfering Yes/not interfering	Are there ruts in road (over 2" deep)? If so, are they interfering with tread drainage?
Grassed tread?	Y/N	Is grass/vegetation covering more than 50% of tread surface?
Road Configuration (percent of tread width that drains to structure)	0% 25% 50% 75% 100%	Look at configuration of road prism. Evaluate the drainage path of water on the tread. Record the percent of the road tread drainage that delivers to the drainage structure to the nearest 25%.
Cutslope Average Height	25 ft 10 ft 5 ft 2.5 ft no cutslope	Average height of cutslope (slope length).
Cutslope Cover Density	90-100% 70-90% 50-70% 30-50% 10-30% 0-10% N/A	Determine the average percent of the cutslope area that is covered with vegetation, rock, leaf litter, or other non-erodible material.
Erosion Rating	High Low Default	Record rating only if obviously high (major cutslope raveling due to soil conditions) or low (bedrock). Otherwise record default.
Secondary segment?	Y/N	Record Y if this is a secondary segment – see field protocol for details.
Difficult segment?	Y/N	Indicates segment that is difficult or has complicated drainage.
Comments	Text	Note any unusual situations in the comment field.
Photo numbers	Text	Enter photo number from digital camera.
Date and time	yy/mm/dd hh:mm:ss	Automatically recorded by GPS unit.

3.7 Database Development

Concurrent with the development of the field protocol, an Access® database was prepared to store data collected during the road inventory. Data tables within the database include:

- Sample Unit Table – contains information about each sample unit.
- Landowner Table – contains contact information for each landowner.
- Road Segment Table – contains the information collected in the field, as well as modeled sediment delivery (from WARSEM) for each road segment that was determined to deliver to a stream, lake, or wetland.
- Non-Delivering Segment Table – contains information collected in the field for non-delivering drainage structures.

The database structure is included as an appendix to the Final Field Protocol.

3.8 Calculation of Monitoring Measures

Data for each sample unit and road segment was compiled for computation of monitoring measures and graphing. The monitoring measures for each of the monitoring questions or hypotheses listed above in Table 3 were computed for each sample unit based on the formulas shown in Table 4 below. Each monitoring measure was also compiled for the three geographical performance target regions (East of Crest, West of Crest, Coastal/Spruce) as well as for the entire state-wide sample. Statistical analyses are described in more detail in Section 3.8.1.

Table 4. Methods Used to Compute Monitoring Measures and Statistics

Monitoring Measure	Computation Method
MQ1.1, H2a.1 Total road length draining to streams (road miles/sq mi)	a. Un-weighted delivering road length[2] (mi)/Area of sample unit (sq mi)
	b. Weighted delivering road length[3] (mi)/Area of sample unit (sq mi)
MQ1.2 Percent of road network draining to streams	a. Un-weighted delivering road length[2] /Total surveyed road length[1]
	b. Weighted delivering road length[3] /Total surveyed road length[1]
MQ1.3 Percent of road in each surface category	Surveyed road length in each surface category[1] /Total surveyed road length[1]
MQ1.4 Percent of road in each traffic category	Surveyed road length in each traffic category[1] /Total surveyed road length[1]
MQ1.5 Percent of road in each cutslope cover category	Surveyed road length in each cutslope cover category[1] / Total surveyed road length[1]
MQ1.6 Percent of drainage points by connectivity class	Number of delivery points in each connectivity category / Total number of surveyed delivery points
MQ1.7 Percent of road in each road rutting category	Surveyed road length in each rutting category[1] /Total surveyed road length[1]
H2b.1 Road surfacing index	Road attribute index for surfacing (see [B] below)
H2b.2 Road traffic index	Road attribute index for traffic (see [B] below)
H2b.3 Cutslope cover index	Road attribute index for cutslope cover (see [B] below)
H2b.4 Miles of delivering road with ruts interfering with drainage	Surveyed length of roads[1] with ruts that were classified as interfering with drainage (mi)

Monitoring Measure	Computation Method
MQ3.1 Miles of forest road delivering to streams per miles of stream (road hydrology performance measure)	a. Un-weighted delivering road length[2] (mi) / Adjusted length of streams within sample unit[C] (mi)
	b. Weighted delivering road length[3] (mi) / Adjusted length of streams within sample unit[C] (mi)
MQ3.2 WARSEM modeled tons of road sediment delivered to streams per miles of stream per year (sediment performance measure)	WARSEM modeled tons of road sediment delivered to streams (tons/yr) / Adjusted length of streams within sample unit[C] (mi)
MQ4.1, H5a Miles of forest road delivering to streams per miles of stream (road hydrology performance measure) divided by the performance target by target region	a. Un-weighted delivering road length[2] (mi) / Adjusted length of streams within sample unit[C] (mi) divided by upper performance target: East of Crest = 0.12 West of Crest = 0.25 Coastal (Spruce) = 0.25
	b. Weighted delivering road length[3] (mi) / Adjusted length of streams within sample unit[C] (mi) divided by upper performance target
MQ4.2, H5b WARSEM modeled tons of road sediment delivered to streams per miles of stream per year (sediment performance measure) divided by the performance target by target region	WARSEM modeled tons of road sediment delivered to streams (tons/yr) / Adjusted length of streams within sample unit[C] (mi) divided by upper performance target: East of Crest = 3 West of Crest = 6 Coastal (Spruce) = 10
H6a Miles of forest road delivering to streams per miles of stream by percent of road length meeting performance standards	Data is displayed graphically
H6b WARSEM modeled tons of road sediment delivered to streams per miles of stream per year by the percent of road length meeting performance standards	Data is displayed graphically

A. Note that there are three different ways the length of road was used in the formulas in Table 4. Superscripted numbers in the right column apply to the following definitions:
   1. Total surveyed road length in the unit includes length of all roads surveyed (delivering and not delivering).
   2. Total delivering road length = the total (un-weighted) length of road that was in any delivering class (direct, direct via gully, 35% delivery, 10% delivery). Does not include non-delivering or stream-parallel length.
   3. Weighted delivering road length = total delivering road length (#2 above) for each segment multiplied by the delivery percent (100%, 35%, 10%) multiplied by the percent of the tread width delivering (100%, 75%, 50%, 25%, 0%).

B. Road Attribute Indexes for categorical values are computed using the following formula:

$$\frac{\sum \text{Surveyed road length in each attribute category}^{1} \text{ x WARSEM factor for that attribute category}}{\text{Total surveyed road length}^{1} \text{ x WARSEM factor associated with least amount of erosion for that attribute}}$$

C. Adjusted stream length = length of streams within each sample unit taken from WDNR GIS coverage x [number of road-stream crossings found in field / number of road-stream crossings in GIS]. This adjustment takes into consideration the fact that the GIS stream coverage may miss or have extra streams in many locations.

Note that the length of streams within each sample unit is included as part of the calculation of several of the monitoring metrics. The length of stream was based on the WDNR GIS stream layer, which is often not a true representation of actual streams on the ground. The road inventory crew checked each road/stream crossing within the sample unit to assess whether mapped and un-mapped streams were or were not present. The miles of streams in the GIS layer were then proportionally adjusted based on the actual number of stream crossings found within the unit versus the number of stream crossings in the GIS layer (see note C below Table 4). While this may not result in a completely accurate portrayal of stream miles, it was the most cost-effective method of adjusting stream miles within the scope of this project.

The length of road delivering to steams was measured in the field and included length in each of the delivering categories (direct, direct via gully, 35% delivery and 10% delivery). This length was used for comparison with the FFR length performance measure (RLEN, Table 1 above). The total delivering length metric does not take into account some strategies that landowners may use to reduce road connectivity such as crowning or outsloping a road, installing cross drains (if they are still within proximity to a stream), or sediment traps. For this reason, a weighted road length was computed for comparison with future monitoring events. The weighted delivering road length was computed based on the total delivering road length, delivery category, and percent of tread width draining to the delivery point (Table 4).

The multi-year, state-wide scale of the road effectiveness monitoring study precluded direct measurement of sediment production. For this reason, a modeling approach was chosen to estimate sediment production for the FFR sediment metric (MQ3.2, MQ4.2, H5b, and H6b). WARSEM was chosen to estimate sediment delivery for the following reasons (Raines et al. 2005):

1. WARSEM is closely related to the Road Surface Erosion Module calculations in the Washington Watershed Analysis Manual (Washington Forest Practices 1997) that was used to develop the FFR performance targets for sediment delivery;

2. WARSEM input variables include the important road attributes controlling road sediment production with categories that provide clear interpretation of improving trends;

3. Input data from WARSEM can be used in alternate models if the need arises; and

4. WARSEM is easy to use and is well suited for estimating sediment delivery for large datasets.

It is recognized that output from any road surface erosion model is not an accurate measure of sediment production or delivery at the scales of individual delivery points or individual road segments; however, models are useful for comparing trends in sediment production through time in response to changes in road conditions (Dubé et al. in press). The monitoring measures and statistics evaluated here include 15 different measures/indices; only two of these use WARSEM-generated numbers.

The Washington State Road Surface Erosion Model (WARSEM) was used to estimate the sediment production and delivery from each delivering road segment. The characteristic of each road segment (length, tread and ditch width, tread configuration, surfacing, road gradient, cutslope height and cover, traffic use, delivery, and Township/Range/Section location) were entered into WARSEM.

The erosion and delivery calculations in WARSEM are based on a set of empirical relationships that were developed from research on road erosion (Dubé et al. 2004). The model uses the following formulas to calculate road surface erosion:

> Total Sediment Delivered to a Stream from each Road Segment (in tons/year) = (Tread & Ditch Sediment + Cutslope Sediment) x Road Age Factor
>
> Tread & Ditch = Geologic Erosion Factor x Tread Surfacing Factor x Traffic Factor x Segment Length x Road (Tread + Ditch) Width x Road Gradient Factor x Rainfall Factor x Delivery Factor
>
> Cutslope = Geologic Erosion Factor x Cutslope Cover Factor x Segment Length x Cutslope Height x Rainfall Factor x Delivery Factor

The value for each factor in the equations is selected by WARSEM based on the road characteristics collected in the field and entered for each individual road segment. The delivery categories assigned in the field (100%, 35%, and 10%) correspond directly to WARSEM delivery factors.

3.8.1 Statistical Analysis

The statistical analysis relevant to monitoring questions 1, 3, and 4, and hypothesis 6 followed the methods discussed in the Monitoring Design (Raines et al., 2005). The following are clarifications and modifications to the statistical analysis methods described in that document. Arithmetic means, medians, and standard deviations of the unit results are provided for each region. The statewide median is simply the median across all 60 units. The statewide mean and standard deviation are weighted means of the regional results, weighted by sample size. Some discussion as to the appropriateness of the arithmetic mean as an estimate of statewide metrics is necessary

Sample units of roughly equal land area were selected randomly in three geographic regions, proportional to the estimated land area subject to FFR rules. However, the sampling design within each region can be looked at as a cluster sample, where each unit is a cluster of roads (or streams, depending on the metric being estimated). Some units have many roads or streams while others have few roads or streams, so the clusters differ in size with regard to the amount of road or stream. Typically, when calculating a landscape average, larger clusters (i.e., units with more roads) should have greater weight than smaller clusters if one wants to infer results to additional stream- or road-miles. However, Washington state forestlands are tracked, assessed, and managed on an area-basis rather than on a road- or stream-mile basis. We need to be able to infer results to additional land area, not road- or stream-mile. Therefore it was decided that the unit-by-unit averages (i.e., not weighted by length of road or stream) were more relevant as management summaries of results. These averages are biased estimates of state-wide means of road characteristics with less precision than if samples were weighted by and inferred to road mile.

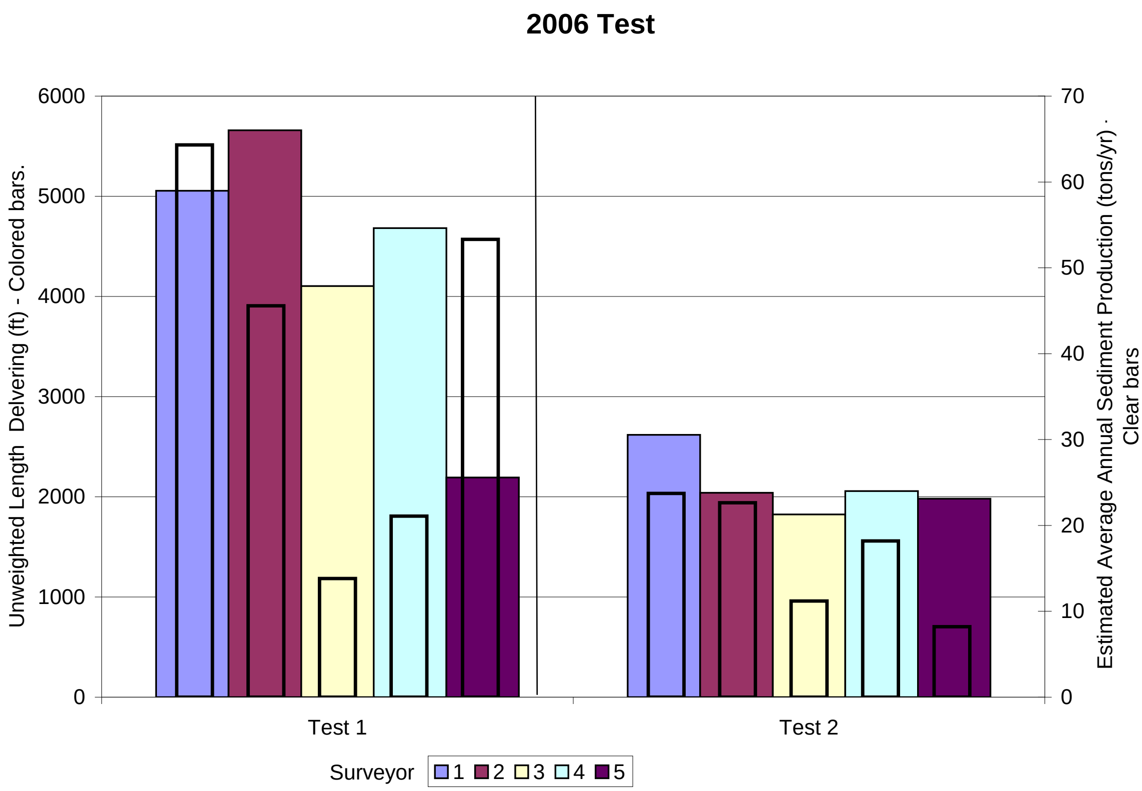
For hypothesis 6, the Monitoring Design states that linear regression will be used to determine if there is a relationship between the percentage of the road system that is judged to meet road standards and two reported metrics. Because the metrics are not normally distributed or transformable to normal distribution, a nonparametric (Kendall's tau; Conover 1980) regression/correlation test was used instead. Using the nonparametric test also loosens the assumption of linear regression that the x-variable is measured without error. For the nonparametric test, it is only necessary that the x-variable is ranked properly, which seems to be a reasonable assumption.

4 Results and Discussion

4.1 Crew Variability Test

The crew variability test originally had two goals: 1) to target areas for training to improve consistency; and 2) to provide a quantitative estimate of crew variability for delivering length and sediment yield.

The test was optimized to provide feedback to and guide training for field crews for quality assurance purposes. The test results were very helpful to target areas for further training. From the results of the first test in 2006, project management personnel targeted field assistance and additional discussion with field crew members on assessing delivery (using the flowchart developed for this purpose), using a clinometer to measure road gradient, determining configuration (full/half/none) with care, and developing a common understanding of surfacing between field workers in each unit. During the 2008 season, these measurements continued to be stressed, along with protocols for determining delivery over fillslopes and deciding if a drainage swale was considered a stream or not. Road variables influencing the sediment production that varied most among observers included delivery, gradient, portion of tread delivering, and surfacing. Several of the roads in the 2008 test unit were outsloped, which means that the road drains over the fillslope to the stream. These types of road drainage systems are prevalent in Eastern Washington roads. Determination of delivery in these cases is particularly difficult, and was one reason for the high variability between observers during the 2008 testing. Field crew members who were used to surveying Westside road systems with pronounced ditch systems were looking at delivery from the poorly developed/short ditch systems on the Eastside (2008 test unit) roads. Field crew members who normally surveyed Eastside road systems were considering delivery over the fillslopes. The post-test discussions led to a common way to look at outsloped Eastside road systems (delivery over fillslopes) and should have further reduced variability for this metric after the test. In general, there is less variation in results during the second test each field season than in the first test, suggesting that results became more consistent with continued training and working together during the duplicate crew surveys (Figure 4).



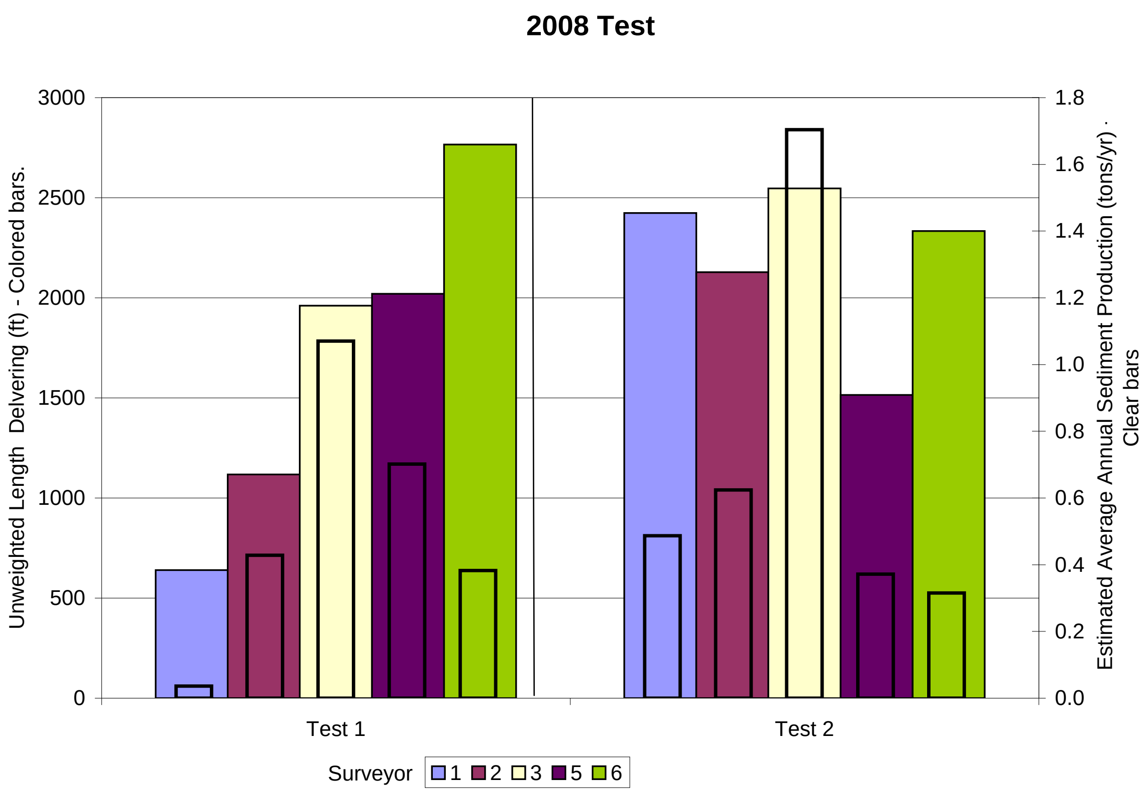


Figure 4. Length Delivering and Sediment Production by Surveyor for 2006 and 2008 Tests.

Because the crew variability tests were optimized for quality assurance and training purposes, the results are not useful for estimating measurement error for the entire project. While it is possible to calculate the amount of variance among surveyors based on the 2006 and 2008 test results, it is not appropriate to apply the results to the data collected in an entire sample unit for several reasons:

- The variability in delivering length and calculated total sediment production among observers on a single segment or section of road is quite large relative to differences among road segments. However, the variability among sums of road segments, which are being used for the larger project will be lower because they are sums (or averages), which have lower theoretical variance (i.e., the variance of a mean is reduced proportionally to the sample size). Since the crew variability study measured only a small length of road (1.4-2.4 miles) in relation to the total road miles in a sample unit (average 23 miles/unit), it was not appropriate to extrapolate the results to entire units.

- Crew variability differed from the first to the second test (Figure 4) and from 2006 to 2008. In addition, crew members sampled different amounts of roads in different regions across the state. This would complicate efforts to apply appropriate variance estimates to all the sample units across the state and through time.

- During subsequent sampling events, the Monitoring Design specifies that the same study sites will be re-sampled. Since trends between sampling events will be based upon change of only those variables that can be modified by management practices within each sample unit, there will be fewer variables with the potential for observer error.

For the study results, these crew variability results imply that differences observed through time (particularly for only two time periods) could be purely due to observation error. Therefore, strong interpretation of data results should only be made after consistent changes through time (after repeated measurements) have been observed. Minimizing observer variability is important to this and subsequent monitoring periods. Consideration of ways to minimize variability should be stressed during both the planning and implementation phases of future monitoring events.

4.2 Sample Units

This first sampling event provides information on the current (2006-2008) status of forest roads on lands subject to Washington Forest Practice Rule across the state. A total of 60 four-square-mile sample units were inventoried (Figure 5). The units were distributed by performance target geographical region based on the relative proportion of forest practice rule lands within each region (East of Cascade Crest = 30 sample units, Coastal/Spruce = 7 sample units, and West of Cascade Crest = 23 sample units).

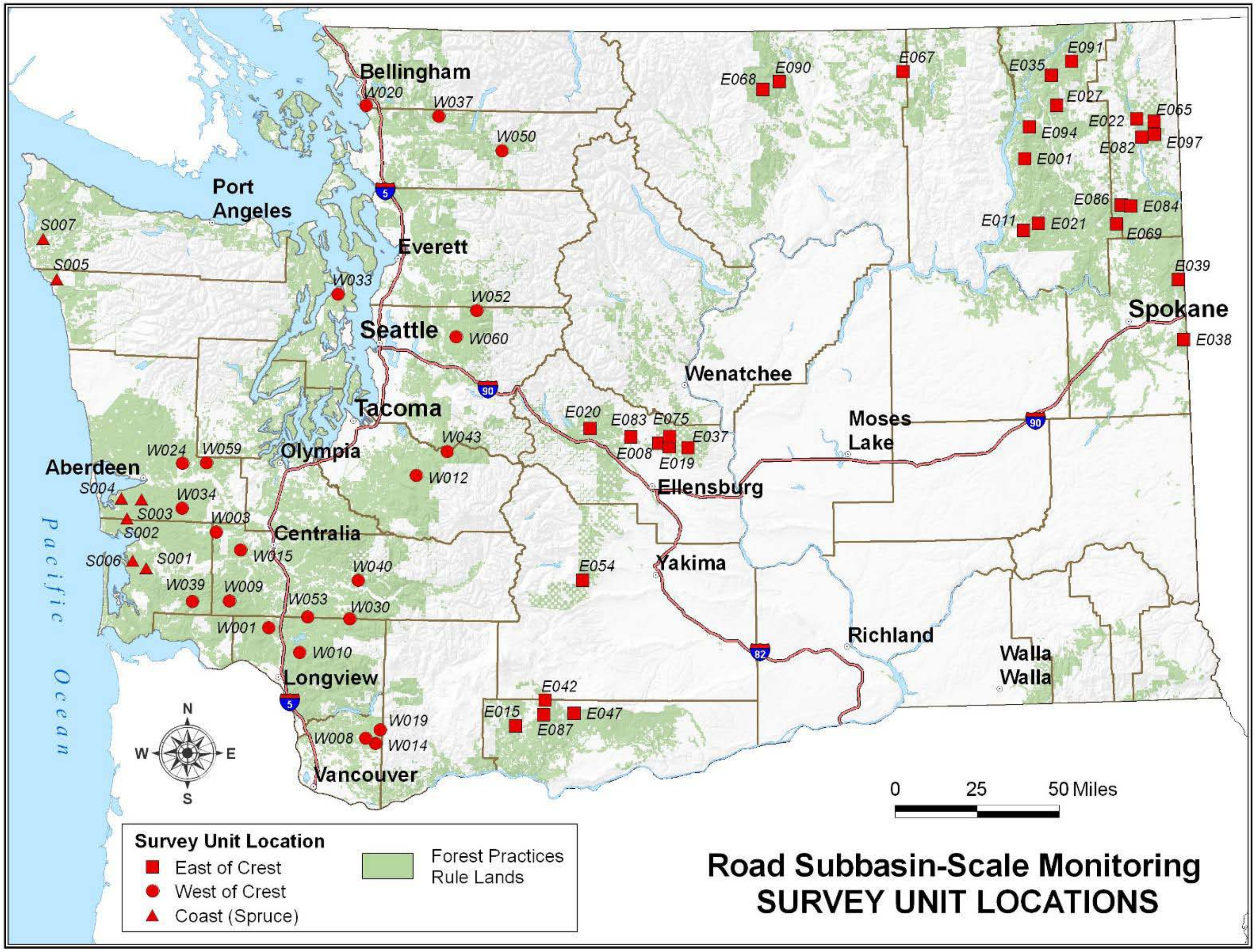


Figure 5. Location of Road Monitoring Sample Units.

Sample units beginning with the letter "E" are east of the Cascade crest, "W" are west of the Cascade crest, and "S" are in the Coastal Spruce zone.

4.2.1 Sample Unit Selection and Rejection

As described in Section 3.4.3, sample units initially selected for study were screened to ensure that each unit included four square miles of relatively contiguous blocks of FFR-regulated lands with acceptable uses, and that land owners granted access to their lands for the study. Of 164 sample units originally selected, 37% were rejected in the initial assessment due to lack of FFR land, and 14% were rejected because the FFR land was not contiguous enough to create blocks large enough to meet study unit criteria (Table 5). Units rejected at this first stage of screening were not assessed in enough detail to specify particular reasons for the lack of FFR land. In later stages of screening, where individual quarter sections were assessed, 3% of the units were rejected because of too much agricultural or other non-forest area; 6% due to development at various levels; 3% due to landowner denial; and one unit due to inaccessibility as the result of a large storm in southwest Washington.

Table 5. Potential Study Unit Rejection Reasons and Rates

Reason for Rejection	Number of Units	Percentage of Total Sites Assessed (n=164)
Not enough FFR	61	37%
Not enough contiguous FFR	23	14%
Development	10	6%
Agricultural land, non-forest	4	3%
Landowner denial	5	3%
Inaccessibility	1	1%
Total Rejected	104	63%

No sample units selected for use in the Southeastern part of the state around the Blue Mountains met the sample unit criteria and had enough of those landowners willing to grant access. Several units were initially identified in that region, but they were all rejected. Private forestland in the Blue Mountain area forms a narrow band between the agricultural and rangeland and the National Forest. Moreover, the forested areas tend to be in the valleys that weave among the agricultural land on plateaus and hillsides. The roads in these areas are agricultural roads and are not designed or maintained as forest roads under the forest practices rules and so they were not accepted into study units. These factors made it very difficult to compile a block of FFR land of the necessary size in that region.

Roads sampled include those owned by twenty-one large landowners, thirty small landowners, three state agencies, and four municipalities. The sampled area is dominated by large landowner and State forest land properties, which constitute approximately ninety-five percent of the sampled area. Although property from small forest landowners was specifically included in this study, small forest ownerships are underrepresented (by area) in the final sample. Across the state it is estimated that 40 percent of FFR land is owned by small landowners (landowners having an average harvest of less than 2 million board feet annually; Rogers and Cooke 2009). However, most of the small forest landowner properties occur on the margins of developed areas and include houses or agricultural lands that were incompatible with study site criteria. This intermingling with qualifying forest lands was the largest cause for rejection of individual quarter sections. Lack of landowner cooperation also contributed to the low acceptance rates of quarter sections containing lands belonging to small forest landowners. CMER studies rely on voluntary participation by landowners. Although many small forest landowners were willing to cooperate, any one uncooperative landowner resulted in rejection of the entire quarter section for that unit. The end result is that, despite the relatively high number of participating small forest landowners, small forest parcels make up less than five percent of the sampled area. All large forest landowners and government entities approached participated in this study.

Because small non-industrial forest ownerships (by land area) were under-represented, this study likely does not adequately reflect road conditions on small forest ownerships and should not be used to infer road conditions on those ownerships. The high rejection rate for these has convinced us that either a change in the sampling design or a companion study specifically designed to obtain access to and evaluate small forest ownerships would be required to provide an accurate assessment of the status of roads on those lands.

4.2.2 Sample Unit Results

Table 6 summarizes the number of miles of road surveyed and miles of stream in each sample unit, the un-weighted and weighted length of road delivering to streams/wetlands, and the estimated sediment delivering to streams and the FFR sediment performance metrics.

Note that one East of Crest survey units had no streams. As a result, there were no delivery points in this unit, and no data on road conditions were collected. This unit has 0 miles of road delivering and appears as a blank on the bar charts in Section 4.3.

Table 6. Summary of Data Collected by Sample Unit

Area	Miles of Road Surveyed	Surveyed Road Density (mi/sq mi)	Adjusted Stream Length (mi)	Stream Density (mi/sq mi)	Un-weighted Road Length Delivering (mi)	Weighted Road Length Delivering (mi)	WARSEM Calculated Delivered Sediment (tons/yr)	RLEN - Un-weighted Miles of Road Delivering/ Stream Length (mi/mi)	Weighted Miles of Road Delivering/ Stream Length (mi/mi)	RSED - Sediment Delivered/ Stream Length (tons/yr/mi)
Sample units located East of Crest	27.3	7.12	5.2	1.35	1.51	0.94	1.4	0.3	0.18	0.28
	25.0	6.26	4.0	1.01	0.66	0.30	0.4	0.2	0.07	0.10
	26.0	6.50	5.6	1.40	0.83	0.52	0.7	0.1	0.09	0.13
	24.3	6.14	8.3	2.09	5.32	3.58	13.4	0.6	0.43	1.62
	20.5	5.15	3.9	0.98	1.83	1.24	2.2	0.5	0.32	0.57
	18.1	4.53	7.5	1.89	1.49	0.70	6.9	0.2	0.09	0.92
	29.8	7.16	3.0	0.72	1.25	0.68	1.0	0.4	0.23	0.34
	13.4	3.39	4.0	1.01	0.08	0.01	0.2	0.0	0.00	0.04
	14.1	3.51	0.0	0.00	0.00	0.00	0.0	0.0	0.00	0.00
	5.7	1.46	7.9	2.04	0.06	0.01	0.0	0.0	0.00	0.00
	13.9	3.47	1.9	0.48	0.10	0.01	0.0	0.1	0.01	0.01
	22.3	5.42	8.2	2.00	2.66	1.77	1.9	0.3	0.22	0.23
	2.7	0.69	7.6	1.90	0.08	0.01	0.0	0.0	0.00	0.00
	26.2	6.71	17.0	4.37	2.33	1.99	10.7	0.1	0.12	0.63
	17.0	4.10	7.4	1.78	0.70	0.33	0.8	0.1	0.05	0.11
	19.8	4.93	14.5	3.62	4.33	3.46	14.6	0.3	0.24	1.01
	20.1	5.05	3.9	0.98	1.19	0.32	3.6	0.3	0.08	0.92
	22.2	5.63	8.9	2.26	0.66	0.07	0.6	0.1	0.01	0.06
	4.1	1.05	10.9	2.79	0.27	0.10	0.1	0.0	0.01	0.01
	10.7	2.67	23.2	5.79	1.64	1.64	3.5	0.1	0.07	0.15
	25.3	6.31	4.3	1.07	1.50	0.59	1.2	0.4	0.14	0.28
	16.6	4.10	5.5	1.37	0.32	0.03	0.1	0.1	0.00	0.02
	21.9	5.49	8.6	2.14	1.67	1.01	4.6	0.2	0.12	0.53
	10.9	2.67	13.9	3.40	0.38	0.22	0.2	0.0	0.02	0.02
	31.1	7.46	13.6	3.26	1.58	1.03	7.6	0.1	0.08	0.56
	17.2	4.32	9.0	2.27	1.08	0.92	1.9	0.1	0.10	0.21
	15.5	3.83	5.3	1.31	0.08	0.07	0.1	0.0	0.01	0.01
	20.4	5.48	5.4	1.45	0.23	0.05	0.3	0.0	0.01	0.06
	20.9	5.37	9.9	2.54	0.41	0.28	0.5	0.0	0.03	0.05
	14.9	3.71	6.0	1.50	0.44	0.04	0.2	0.1	0.01	0.04
Units in Coastal/Spruce	25.9	6.50	24.2	6.06	4.09	1.93	117.9	0.2	0.08	4.88
	15.3	4.28	59.9	16.75	0.98	0.55	29.3	0.0	0.01	0.49
	25.2	6.32	11.0	2.75	0.71	0.23	173.9	0.1	0.02	15.83
	25.2	6.39	6.7	1.69	0.67	0.30	1.8	0.1	0.05	0.27
	27.8	6.95	48.9	12.23	6.21	2.86	224.9	0.1	0.06	4.60
	29.0	7.19	24.1	5.96	3.69	1.77	30.9	0.2	0.07	1.28
	21.6	5.60	27.2	7.05	4.55	2.34	102.4	0.2	0.09	3.77

Table 6. Summary of Data Collected by Sample Unit (continued)

Area	Miles of Road Surveyed	Surveyed Road Density (mi/sq mi)	Adjusted Stream Length (mi)	Stream Density (mi/sq mi)	Un-weighted Road Length Delivering (mi)	Weighted Road Length Delivering (mi)	WARSEM Calculated Delivered Sediment (tons/yr)	Un-weighted Length of Road Delivering/ Stream Length (mi/mi)	Weighted Length of Road Delivering/ Stream Length (mi/mi)	Sediment Delivered/ Stream Length (tons/yr/ mi)
Sample units located West of Crest	28.8	7.27	17.4	4.41	7.08	4.42	217.3	0.4	0.25	12.45
	29.9	7.63	26.8	6.85	4.78	2.36	407.6	0.2	0.09	15.19
	26.4	6.56	13.0	3.23	4.89	2.79	60.6	0.4	0.21	4.65
	33.0	7.63	15.5	3.60	7.35	3.76	137.0	0.5	0.24	8.82
	29.2	7.35	21.1	5.31	7.93	2.05	30.2	0.4	0.10	1.43
	22.9	5.83	22.7	5.78	3.13	1.20	26.1	0.1	0.05	1.15
	17.1	4.33	23.5	5.94	3.35	1.12	73.9	0.1	0.05	3.15
	27.7	6.95	4.6	1.16	1.72	0.60	7.6	0.4	0.13	1.66
	27.2	6.74	14.5	3.58	6.64	2.91	93.5	0.5	0.20	6.47
	14.6	3.79	15.8	4.11	1.86	1.00	9.7	0.1	0.06	0.62
	26.4	6.79	13.7	3.53	0.73	0.22	7.5	0.1	0.02	0.55
	26.0	6.51	18.7	4.69	5.96	2.02	47.6	0.3	0.11	2.54
	22.7	5.71	4.6	1.17	0.49	0.17	0.4	0.1	0.04	0.09
	25.4	6.41	22.6	5.71	3.25	0.93	24.3	0.1	0.04	1.07
	8.9	2.44	59.2	16.22	4.37	2.35	205.6	0.1	0.04	3.48
	20.6	5.64	14.3	3.91	5.69	2.35	163.7	0.4	0.16	11.47
	24.2	6.26	4.3	1.12	0.63	0.24	1.5	0.1	0.05	0.35
	24.7	6.31	19.2	4.90	4.74	2.07	266.0	0.2	0.11	13.88
	23.4	5.86	10.0	2.51	1.75	0.90	28.5	0.2	0.09	2.85
	24.8	6.09	23.9	5.86	3.21	0.79	39.9	0.1	0.03	1.67
	21.3	5.32	11.1	2.78	4.42	2.04	13.5	0.4	0.18	1.22
	25.4	6.43	32.6	8.25	0.49	0.26	7.6	0.0	0.01	0.23
	24.3	6.16	24.5	6.20	6.53	3.61	68.9	0.3	0.15	2.82

Road density (miles of road/square mile of area), is commonly cited as a metric for the impacts of roads on streams. Although data from sample units suggest a generally positive correlation between road density and the length of road hydrologically connected to streams (Figure 6), and the predicted sediment input to streams (Figure 7), there is not always a direct correlation due to other contributing factors. The location of the road network in relation to the stream network, as well as road condition and traffic levels are important factors for determining the relative effect of roads on streams, aquatic habitat, and water quality.

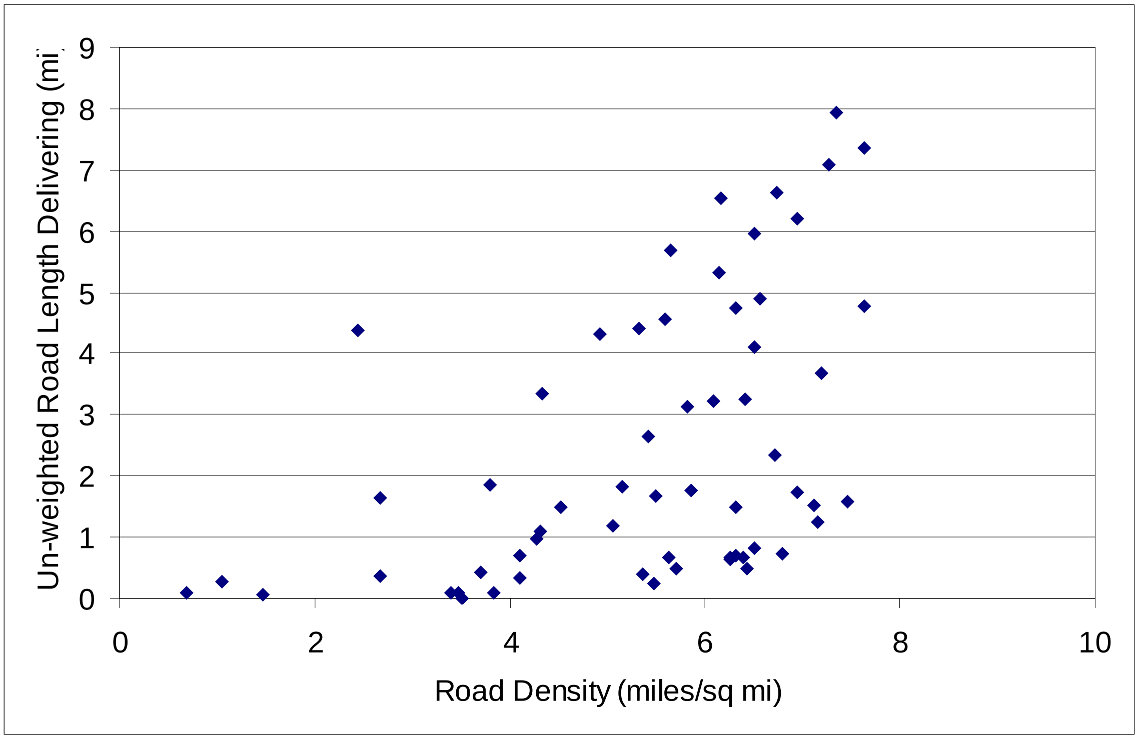


Figure 6. Un-weighted Road Length Delivering in Sample Unit vs. Road Density.
Includes all sample units across state

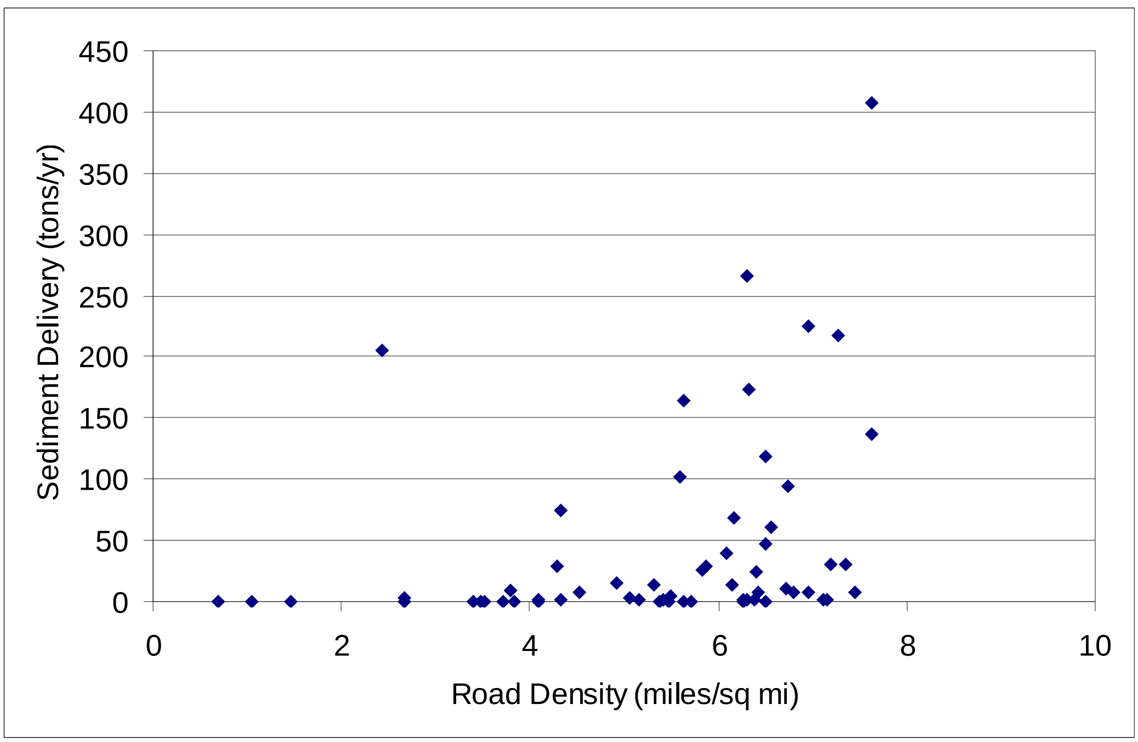


Figure 7. Estimated Sediment Delivered to Streams in Sample Unit vs. Road Density.
Includes all sample units across state

The total length of road delivering to streams was measured in the field and included both direct and indirect (35%, 10%) delivery categories, and so includes road segments where some of the strategies land managers use to reduce the amount of road runoff and sediment draining to streams – such as crowning or outsloping a road, installing a sediment trap, or installing a cross-drain culvert with partial delivery – have been applied. In order to understand the magnitude of the difference such measures may make, a weighted delivering length was also calculated that takes into consideration delivery percentage and percent of road tread delivering to each drainage point. Figure 8 shows the comparison of un-weighted (total delivering length) and weighted road length. Across the state, the weighted road length delivering was an average of 45% of the un-weighted road length delivering.

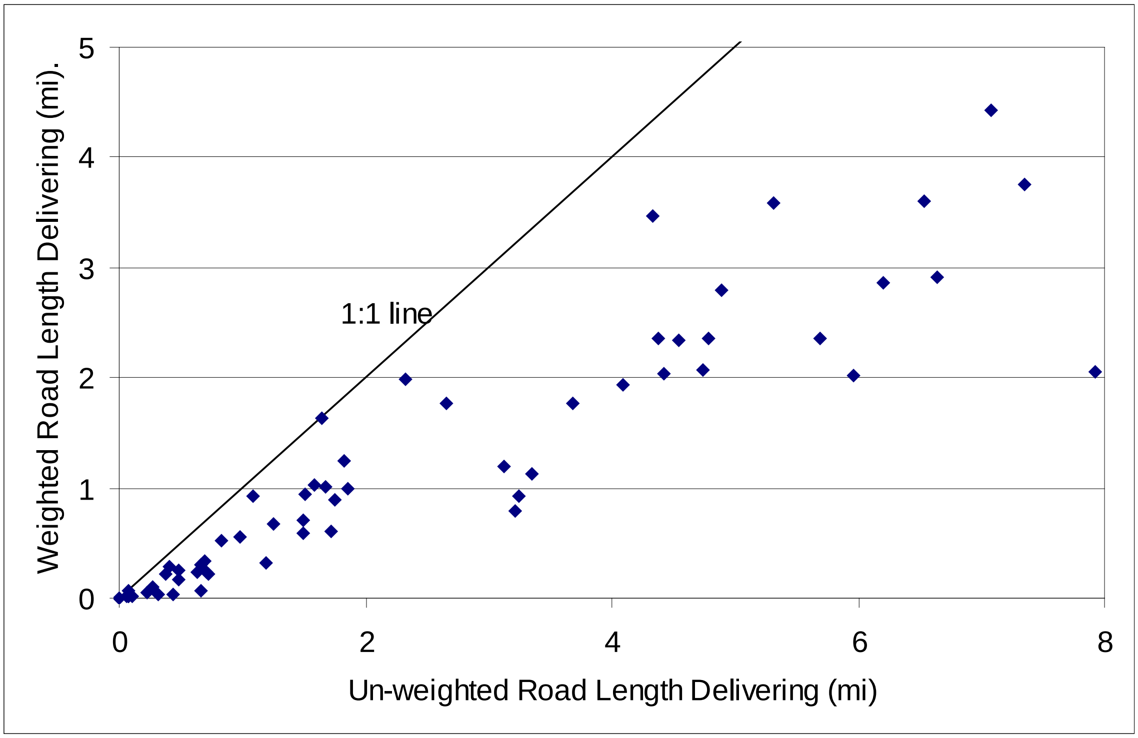


Figure 8. Un-weighted vs. Weighted Road Length Delivering for the Sample Units.
Includes all sample units across state

Road managers are also interested in which parts of their road system are delivering the most sediment. Figure 9 shows the length of road in four sediment yield categories (average annual delivered sediment in tons/yr at a drainage point) in each of the sample units. The majority of the road system in the units had either no sediment delivery, or less than one ton/yr of delivery to streams. A small portion of road drainage points in some of the Coast and West of Crest units had over 3 tons/yr of sediment delivery. Targeting segments with higher sediment yields for road maintenance and improvements may be a cost-effective method to reduce total delivery of road surface erosion to streams.

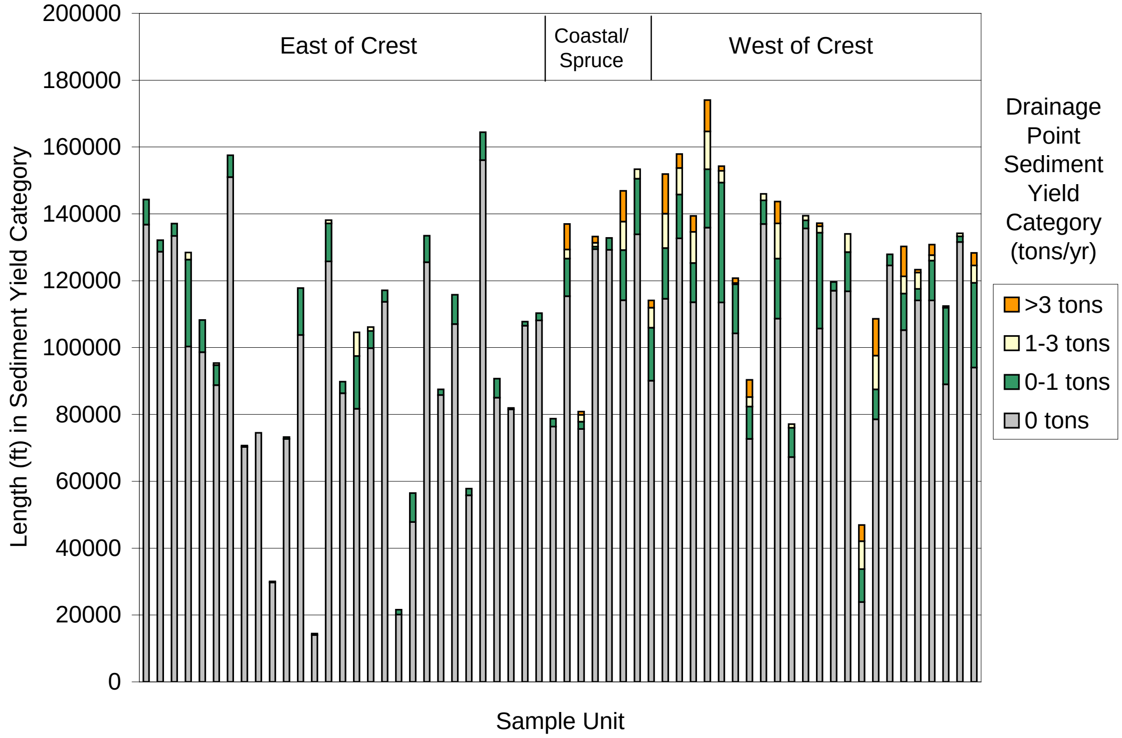


Figure 9. Length of Road by Sediment Yield Category in Each Sample Unit Showing Overall Variability Among Sites.

4.3 Monitoring Questions and Measures

Six monitoring questions/hypotheses, each with one or more metrics, were developed in the study plan to determine the status of forest road characteristics that relate to water and sediment delivery to streams. The mean median, and standard deviation of the monitoring measures listed in Table 2 (above) were computed for each geographic target region as well as state-wide (Table 7). The following sections describe the results for each of the monitoring questions/hypotheses.

Table 7. Mean, Median and Standard Deviation of Monitoring Measures by Region and State.

Monitoring Question or Hypothesis			East of Crest n=30			Coast/Spruce n=7			West of Crest n=23			Statewide n=60		
			Mean	Median	Stand. Dev.	Mean	Median	Stand. Dev.	Mean	Median	Stand. Dev.	Mean	Median	Stand. Dev.
MQ1, H2a	1a. Total un-weighted road length delivering per unit area (road miles/sq mi)		0.29	0.19	0.31	0.76	0.91	0.55	1.00	1.11	0.59	0.62	0.40	0.47
	1b. Total weighted road length delivering per unit area (road miles/sq mi)		0.18	0.08	0.24	0.36	0.44	0.26	0.44	0.51	0.30	0.30	0.23	0.27
	2a. Percent of road network delivering (un-weighted length/length inventoried)		6%	4%	6%	12%	13%	8%	17%	19%	11%	11%	7%	8%
	2b. Percent of road network draining to streams (weighted length/length inventoried)		4%	2%	5%	6%	6%	4%	8%	7%	6%	5%	4%	5%
	3. Percent of road in each surface category (based on total length delivering)	Asphalt	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	2%
		Good gravel	8%	0%	22%	23%	20%	13%	15%	15%	13%	12%	2%	18%
		Pitrun/worn gravel	14%	8%	18%	67%	73%	16%	77%	77%	20%	44%	48%	19%
		Native	74%	89%	32%	10%	9%	10%	8%	3%	14%	42%	25%	24%
	4. Percent of road in each traffic category (based on total length delivering)	Very heavy	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Heavy	0%	0%	0%	9%	0%	22%	0%	0%	0%	1%	0%	8%
		Mod Heavy	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Moderate	0%	0%	1%	7%	0%	12%	7%	0%	14%	4%	0%	10%
		Light	8%	0%	21%	3%	0%	4%	8%	0%	12%	7%	0%	17%
		Occasional	84%	100%	32%	81%	84%	22%	85%	92%	18%	84%	100%	26%
		None	5%	0%	20%	0%	0%	0%	0%	0%	0%	2%	0%	14%
	5. Percent of road in each cutslope cover category (based on total length delivering)	90-100 %	41%	36%	34%	45%	53%	15%	61%	65%	20%	49%	56%	27%
		70-89 %	16%	15%	15%	23%	21%	8%	14%	11%	11%	16%	15%	13%
		50-69 %	12%	5%	16%	11%	8%	9%	7%	4%	8%	10%	5%	13%
		30-49 %	4%	0%	9%	4%	4%	4%	3%	1%	6%	4%	0%	8%
		10-29 %	3%	0%	8%	2%	0%	4%	1%	0%	1%	2%	0%	6%
		0-9 %	0%	0%	1%	2%	0%	4%	0%	0%	0%	0%	0%	1%
		N/A	20%	16%	18%	13%	13%	14%	14%	13%	12%	17%	13%	15%
	6. Percent of drainage points by connectivity class	Direct	47%	49%	34%	55%	52%	13%	58%	57%	19%	52%	53%	27%
		Direct via gully	4%	0%	6%	8%	9%	5%	9%	9%	8%	6%	3%	7%
		35% Delivery	10%	9%	10%	24%	23%	9%	22%	20%	17%	16%	14%	13%
		10% Delivery	34%	19%	35%	13%	14%	7%	10%	8%	8%	23%	12%	25%
		Stream Parallel	2%	0%	5%	0%	0%	1%	2%	0%	4%	2%	0%	5%
	7. Percent of road in each road rutting category (based on total length delivering)	Not Rutted	92%	100%	20%	88%	98%	22%	98%	100%	4%	94%	100%	16%
		Rutted - Interfering	4%	0%	6%	8%	0%	16%	1%	0%	2%	3%	0%	7%
		Rutted - Not Interfering	2%	0%	5%	4%	0%	6%	1%	0%	2%	1%	0%	4%

Monitoring Question or Hypothesis		East of Crest n=30			Coast/Spruce n=7			West of Crest n=23			Statewide n=60		
		Mean	Median	Stand. Dev.	Mean	Median	Stand. Dev.	Mean	Median	Stand. Dev.	Mean	Median	Stand. Dev.
,MQ3, H5a H5b	1a. Un-weighted miles of forest road delivering per miles of stream (road hydrology performance measure)	0.16	0.11	0.16	0.11	0.13	0.06	0.24	0.18	0.14	0.19	0.14	0.14
	1b. Weighted miles of forest road delivering per miles of stream (road hydrology performance measure)	0.09	0.07	0.11	0.05	0.06	0.03	0.11	0.09	0.07	0.09	0.07	0.09
	2. WARSEM modeled tons of road sediment delivered per miles of stream per year (sediment performance measure)	0.30	0.12	0.39	4.44	3.77	5.38	4.25	2.54	4.73	2.30	0.56	3.47
MQ4	1a. Un-weighted miles of forest road delivering per miles of stream (road hydrology performance measure) divided by the performance target by target region	1.33	0.88	1.34	0.46	0.51	0.23	0.96	0.71	0.57	1.09	0.67	1.01
	1b. Weighted miles of forest road delivering per miles of stream (road hydrology performance measure) divided by the performance target by target region	0.76	0.60	0.89	0.21	0.23	0.12	0.42	0.36	0.30	0.56	0.35	0.65
	2. WARSEM modeled tons of road sediment delivered per miles of stream per year (sediment performance measure) divided by the performance target by target region	0.10	0.04	0.13	0.44	0.38	0.54	0.71	0.42	0.79	0.37	0.15	0.53

4.3.1 Monitoring Question 1

What is the condition of forest roads at each sample event, specifically those attributes management can change relative to sediment production and delivery?

MQ 1.1 and H2a1 Total road length draining to streams per unit area (road miles/sq mi)

The total length of road draining to streams per unit area sampled provides a measure of the length of road that is hydrologically connected to streams in each sample unit (Figure 10). Across the state, half of the sample units had less than 0.4 miles/sq mi of delivering road. Units in the West of Crest and Coast/Spruce geographic zones had more weighted road length delivering than those in the East of Crest zone, as would be expected given the overall lower stream densities in the East of Crest sample units.

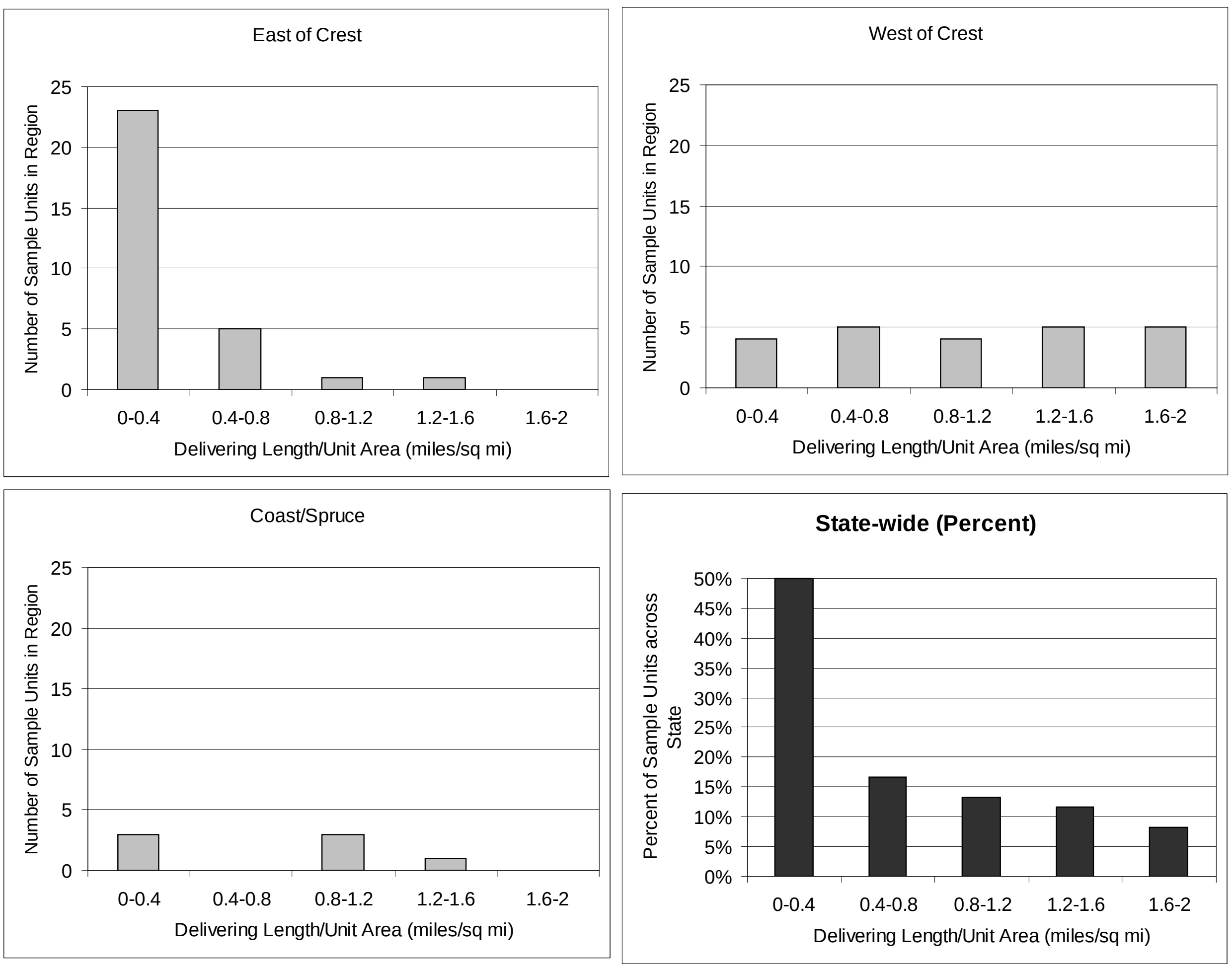


Figure 10. MQ1.1 Total Road Length Delivering to Streams per Unit Area.

MQ 1.2 and H2a2 Percent of road network draining to streams

The percentage of the road network draining to streams was calculated using the un-weighted length of road delivering. Across the state, more than half of the sample units had less than 10 percent of the road network delivering (Figure 11). As with MQ1.1 (length of road delivering), units East of the Cascade Crest had the lowest percent of the road network delivering to streams and units in the West of Crest region had the highest percent of the road network delivering.

State-wide, an average of 11 percent of the surveyed road length delivered to streams, either directly, via a gully, or partially through an indirect sediment plume pathway across the forest floor. The percent of connected road network can vary greatly among watersheds based on values reported in other studies, although it should be noted that the survey methods and definitions of road connectivity between different studies make direct comparison of results complex. Martin (2009) reports an average of 12 percent of the surveyed road length on private timberlands was hydrologically connected in a landowner-conducted survey of 1,047 miles of road throughout Washington. Watershed Analyses conducted in the 1990's on timberlands owned by Boise Cascade ranged from 3 to 57 percent connectivity, with watersheds in drier, inland areas of Washington, Oregon, and Idaho having 3 to 17 percent connectivity and watersheds in wetter areas (e.g., Coast Range of Oregon) having 45 to 57 percent connectivity (Domoni Glass, personal communication). A survey of roads in the Sierra Nevada Mountains of California by Coe (2006) found 25 percent connectivity, and a survey in the Oregon Cascades by Wemple et al. (1996) reports 57 percent connectivity (although 24 percent of this was connected via gully without confirmation that the gully reached a stream).

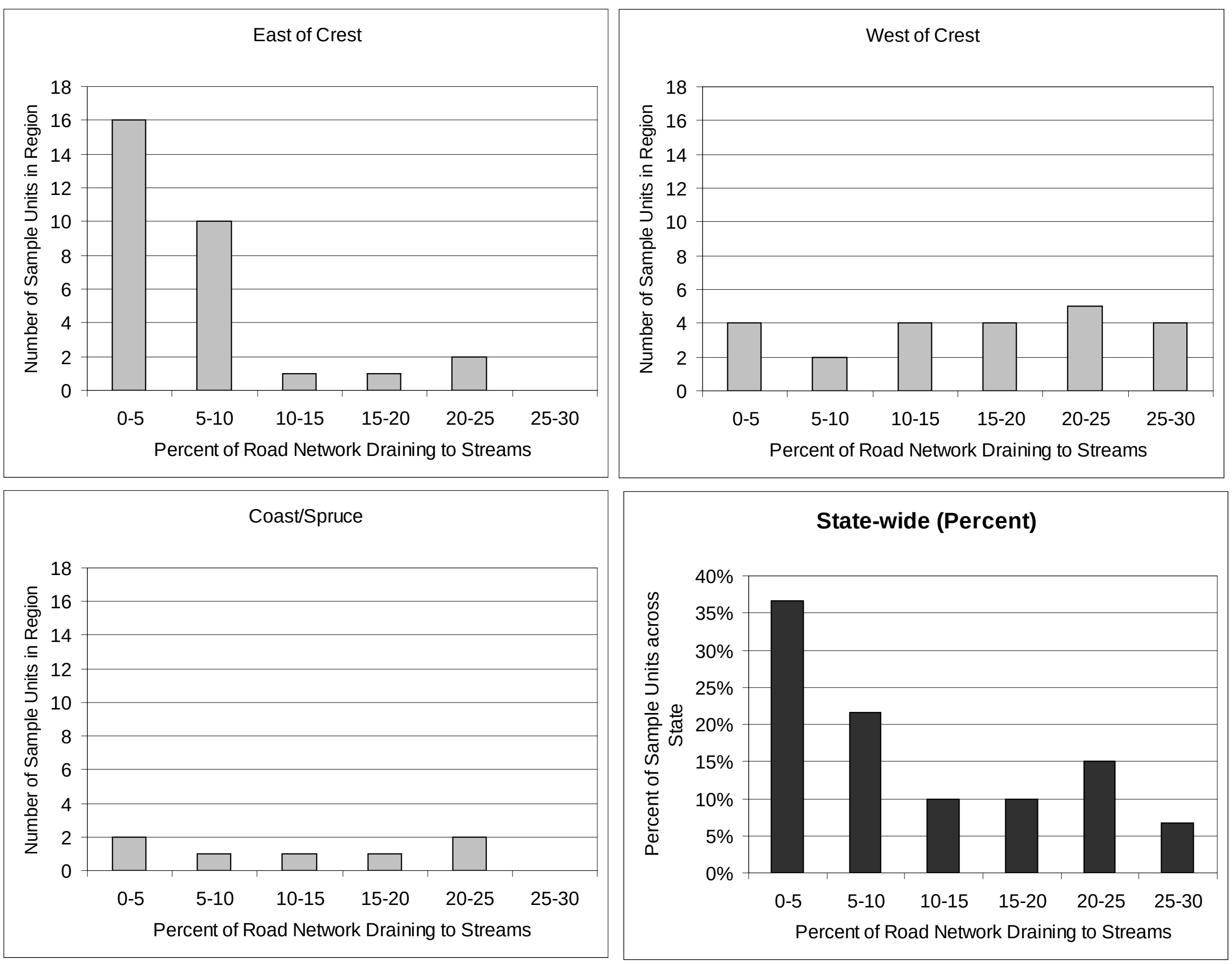


Figure 11. MQ1.2 Percent of Road Network Draining to Streams.

MQ 1.3 Percent of road in each surface category

The type and quality of road surfacing has an effect on how well the road holds up to traffic use and the amount of sediment produced from the road surface. Good quality, durable gravel surfacing holds up better and produces less sediment than native-surfaced roads. Poor quality or pitrun gravel produces an intermediate amount of sediment.

Surfacing on inventoried roads was classified into one of four categories: Asphalt, good gravel, pitrun/worn gravel, and native (unsurfaced). Since gravel surfacing breaks down with traffic use, there is a continuum from good gravel to worn gravel. This phenomenon is particularly evident on heavily traveled mainline gravel roads. Good gravel was differentiated from pitrun by visually determining if the gravel particles were clearly visible or if the gravel particles were embedded in fines. For consistency, at the start of each sample unit field crews assessed the condition of surfacing on the roads and agreed upon the surface type.

Surfacing in the East of Crest units was primarily native; pitrun/worn gravel dominated Coast/Spruce and West of Crest roads (Figure 12).

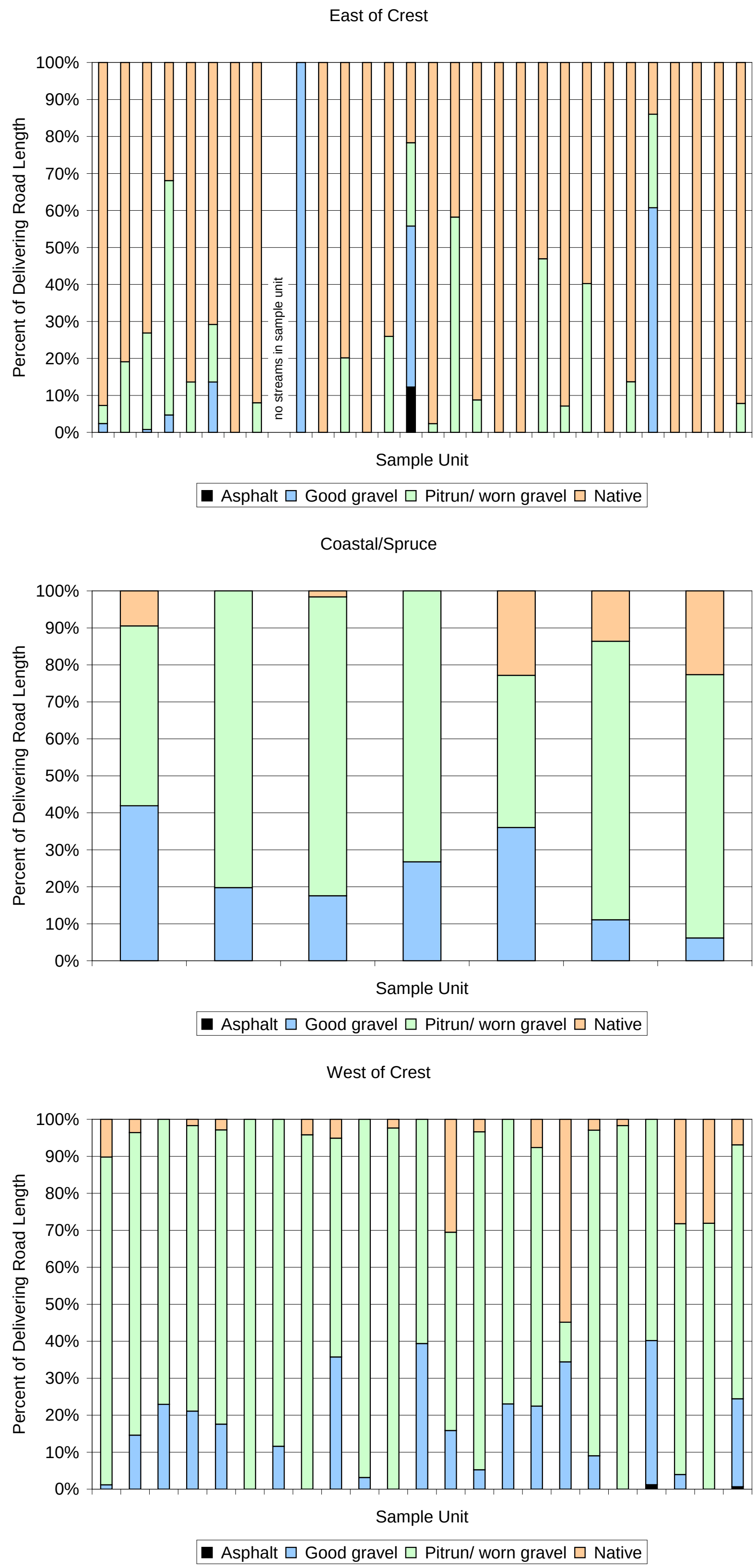


Figure 12. MQ1.3 Percent of Delivering Road Network by Surfacing.
This information is also included in numerical format in Table 7.

MQ 1.4 Percent of road in each traffic category

Traffic on unpaved roads has been shown to increase sediment production as the road surface is broken down into fine-grained particles that can be eroded by surface runoff, and passage by truck tires produces a pumping action that brings fines to the surface.

Landowners reported the daily average traffic use over the past year on their roads within each sample unit. Traffic levels were grouped into categories based on WARSEM traffic categories (none, occasional, light, moderate, moderately heavy, heavy, and very heavy). Traffic use on most of the road network sampled across the state was occasional, with a daily average of less than 1 log truck/day (Figure 13). Several of the units in each of the geographic areas had some roads with light use (1-2 log trucks/day) or moderate use (3-4 log trucks/day). Two of the units in the Coast/Spruce zone had roads with heavy traffic (4-5 log trucks/day); these units included mainline roads in areas of recent active hauling. Traffic use in each sample unit is open to change between sample periods as traffic patterns shift to accommodate haul from different harvest units through time.

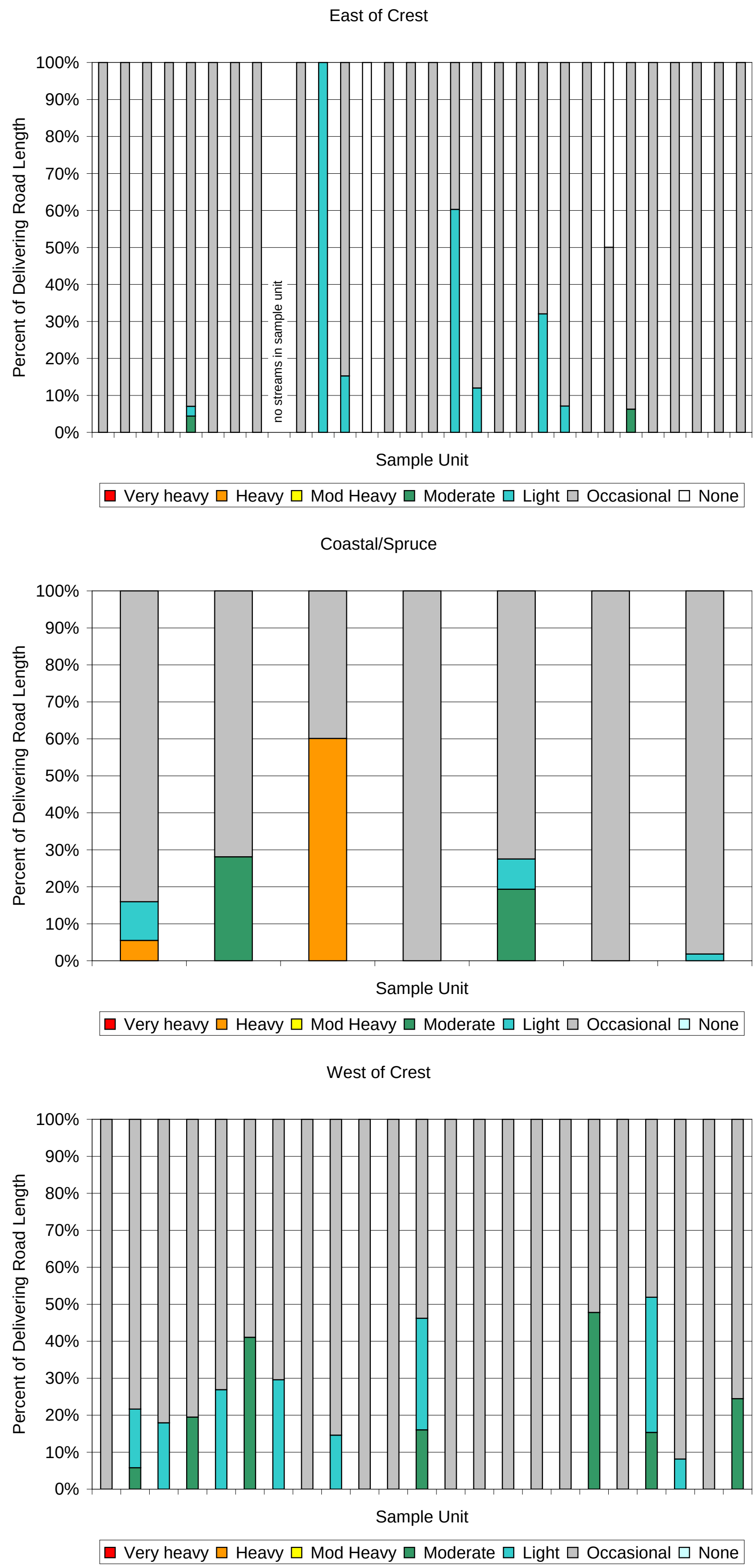


Figure 13. MQ1.4 Percent of Road Network by Traffic Level.
This information is also included in numerical format in Table 7.

MQ 1.5 Percent of road in each cutslope cover category

The percent of rock or vegetative cover on cutslopes influences the erosion rates on the cutslope. Cutslope cover data was collected in 10% cover increments on all delivering road segments. Higher cover categories would be expected to have less erosion from the cutslope. Some road segments had no cutslope; a cover rating of ‘n/a’ was used for these segments.

Cutslope cover varied widely, but in general there was more cover on West of Crest and Coast/Spruce road segments than on East of Crest segments (Figure 14). This is expected due to denser vegetation coverage from higher precipitation rates on the West side of the state.

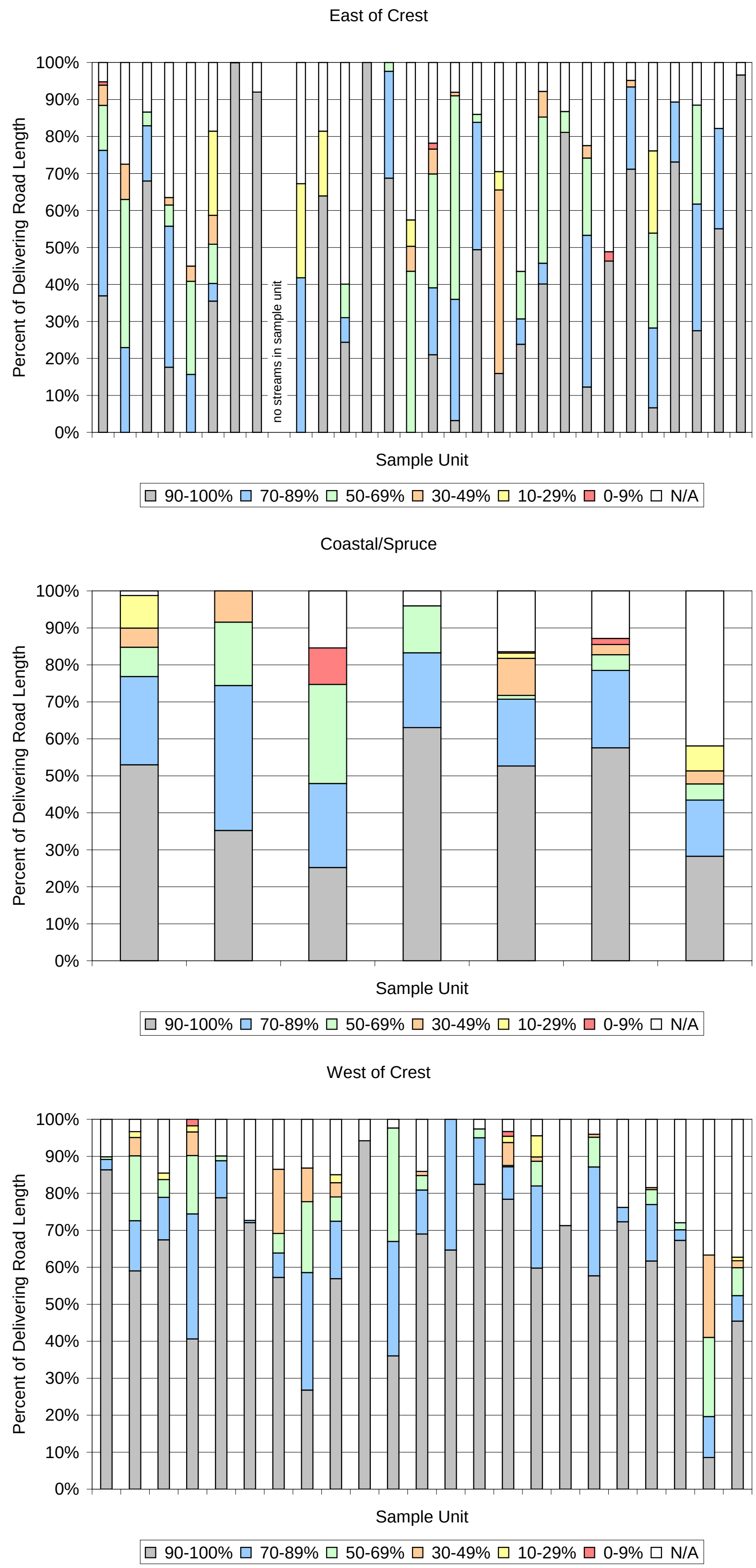


Figure 14. MQ1.5 Percent of Road Network by Cutslope Cover Category.
This information is also included in numerical format in Table 7.

MQ 1.6 Percent of drainage points by connectivity category

Forest roads can alter surface runoff patterns in a watershed by intercepting groundwater via the cutslope or collecting runoff on the relatively impermeable tread. If the drainage from the road prism enters a stream or wetland, it can route water and sediment to the stream at a different rate than without the road in place.

Road drainage connectivity was assessed by assigning each road segment into one of six delivery categories:

- No delivery (no data was collected on these segments)
- Drains directly into stream channel/typed wetland
- Drains directly into stream channel/typed wetland via a gully
- 35% delivery to a stream/typed wetland
- 10% delivery to a stream/typed wetland
- No evidence of delivery, but road parallels within 20 feet of a stream/wetland

The percent of delivering points in each delivery category varied widely between sample units (Figure 15). The location of roads in relationship to streams in each sample unit played a large role in delivery, as did grading and placement of cross-drain culverts and drainage dips near streams.

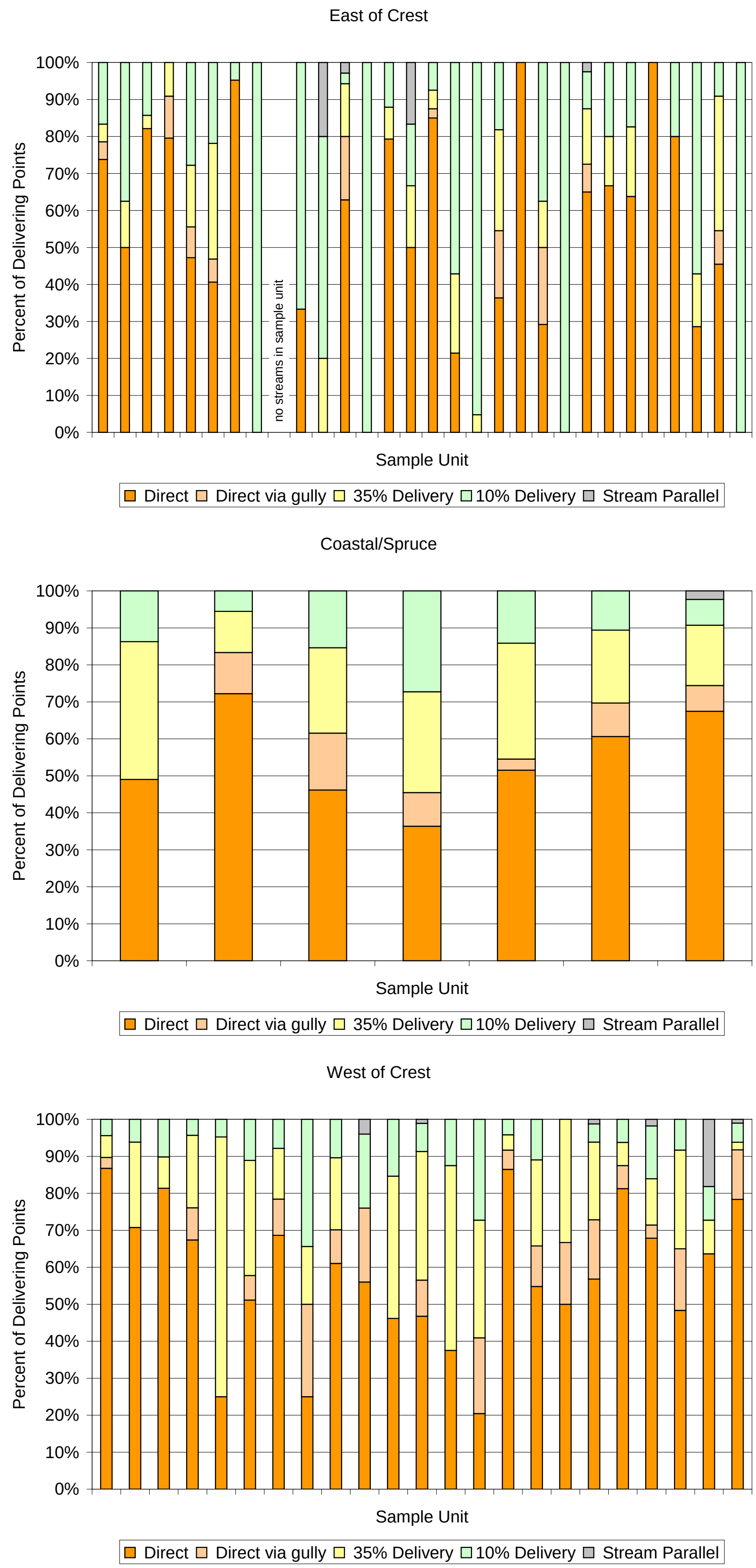


Figure 15. MQ1.6 Percent of Drainage Points by Connectivity Class.
This information is also included in numerical format in Table 7.

MQ 1.7 Percent of road in each road rutting category

Ruts in the road surface can result in increased erosion by channeling drainage into a concentrated flow path. In addition, ruts can change the intended drainage pathway on the road surface by capturing water on an outsloped or crowned road and directing it down the road tread to a stream instead of allowing it to disperse across the fillslope. Ruts can be formed by traffic on soft road surfaces, such as saturated native surfaced roads, or by concentrated water running down long, steep (over 10%) sections of road. For the present study, ruts were defined as wheel indentations over two inches deep and classified into three categories: no ruts, ruts not interfering with tread drainage, and ruts interfering with drainage.

Over half of the sample units had no ruts on delivering road segments, and most of the units had no ruts on over 90% of the delivering road length (Figure 16). A few units in the East of Crest and one in the Coast/Spruce regions had ruts on up to 40% of the delivering road length.

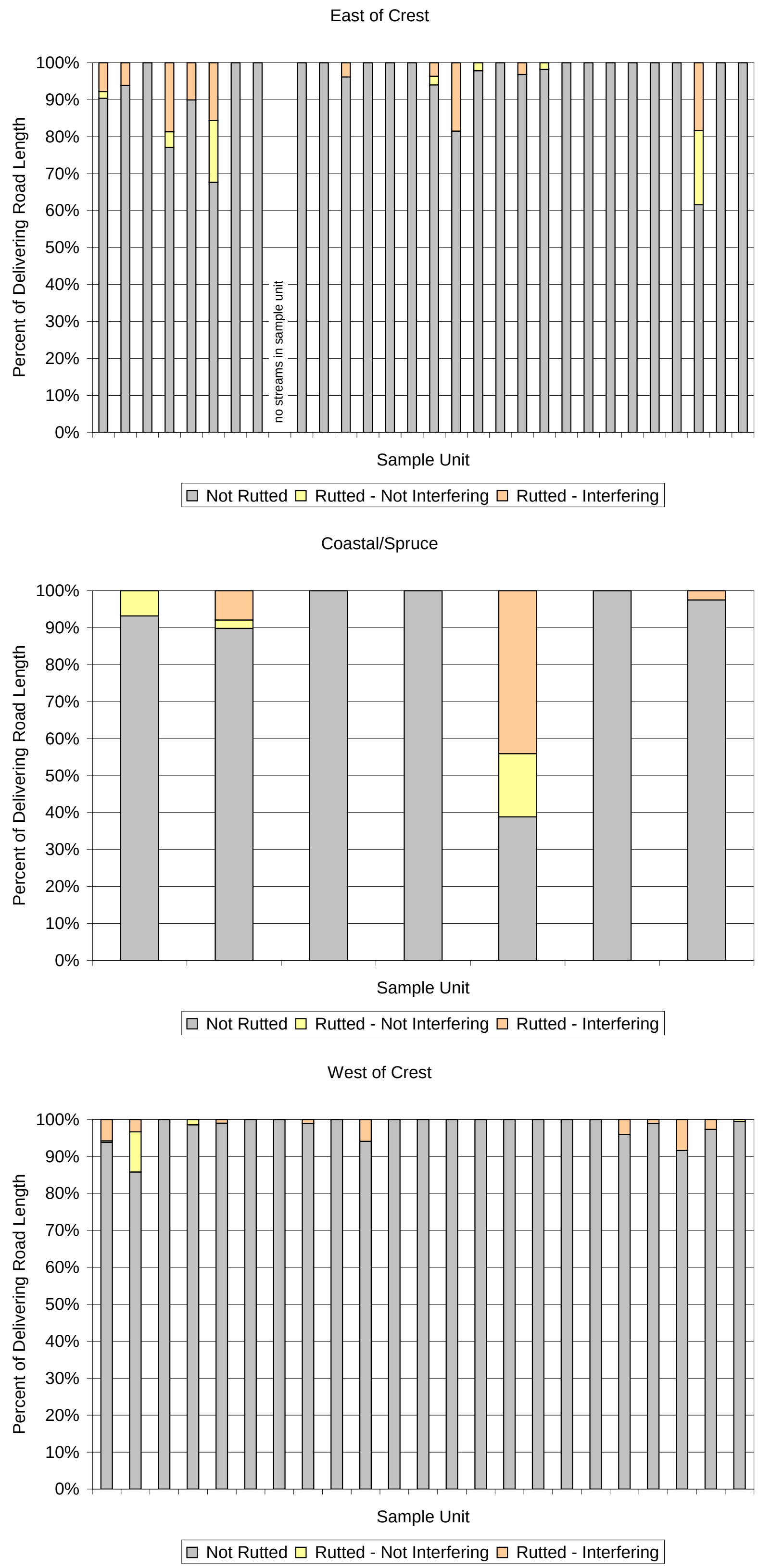


Figure 16. MQ1.7 Percent of Delivering Road Length by Rutting Category.
This information is also included in numerical format in Table 7.

4.3.2 Monitoring Question 2

Have road attributes that affect sediment production and delivery improved over time?

Note that this question will be answered through comparison with future sample event results; data for the first sample event are presented here.

H2b1 Road surfacing index

The road surfacing index is a combined/weighted metric that is computed by multiplying the length of road in each road surfacing class by the WARSEM numerical factor for that class and dividing the sum of all classes by the total length x lowest numerical WARSEM factor for road surfacing. A lower road surfacing index indicates that relatively less erosion would come from roads in that unit based on the distribution of surfacing in the unit.

Units in the East of Crest region had higher surfacing indices than units in the Coast/Spruce or West of Crest regions. This distribution reflects the higher percentage of roads with native surfaces in East side units (Figure 17).

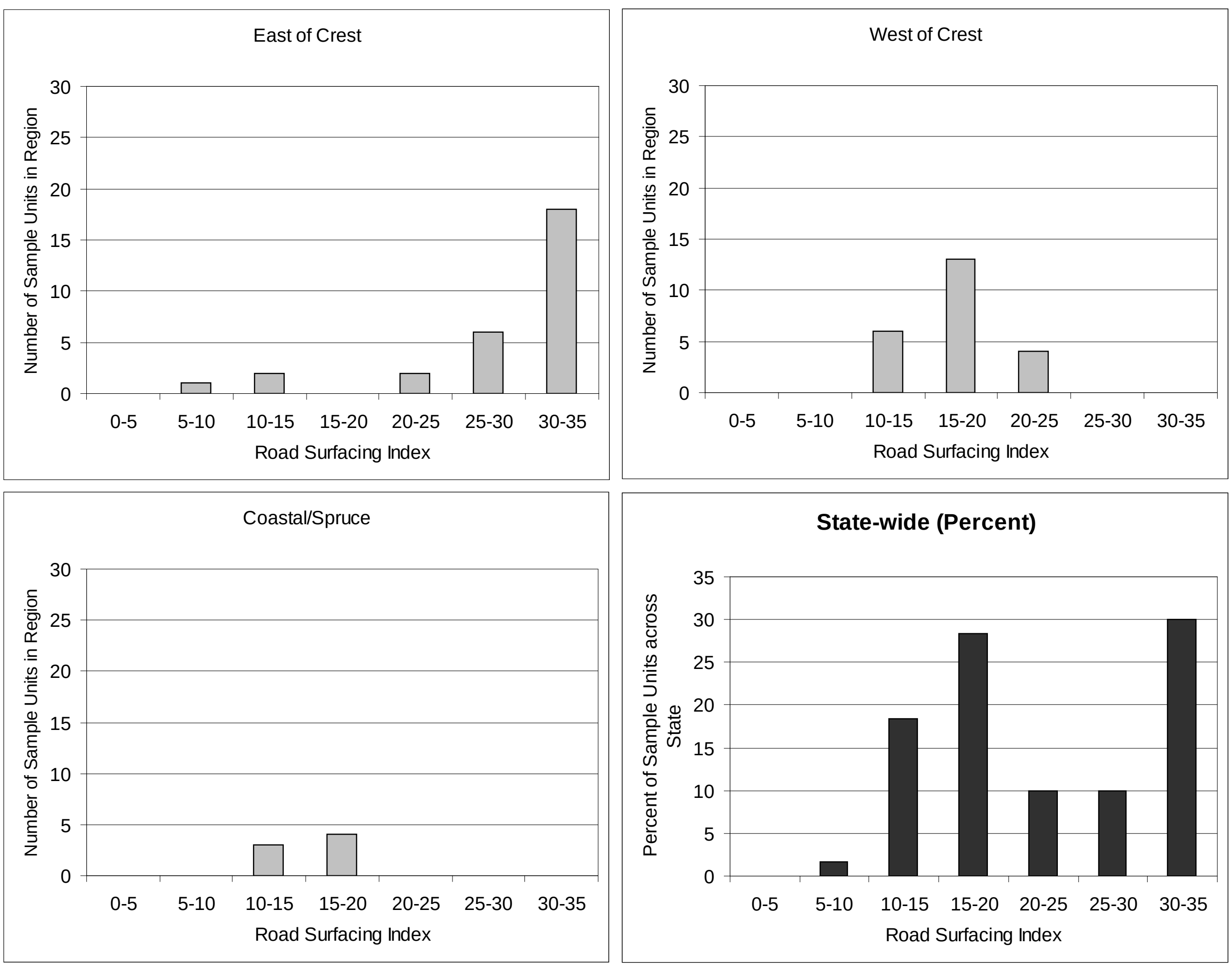


Figure 17. H2b1 Road Surfacing Index.

H2b2 Road traffic index

The road traffic index is a combined/weighted metric that is computed by multiplying the length of road in each road traffic class by the WARSEM numerical factor for that class and dividing the sum of all classes by the total length x lowest numerical WARSEM factor for traffic. A lower road traffic index indicates that relatively less erosion would come from roads in that unit based on the distribution of traffic use in the unit.

Units in the East of Crest region had lower traffic indices than units in the Coast/Spruce or West of Crest regions (Figure 18). One unit in the Coast/Spruce zone had very heavy traffic on a mainline with many delivery points.

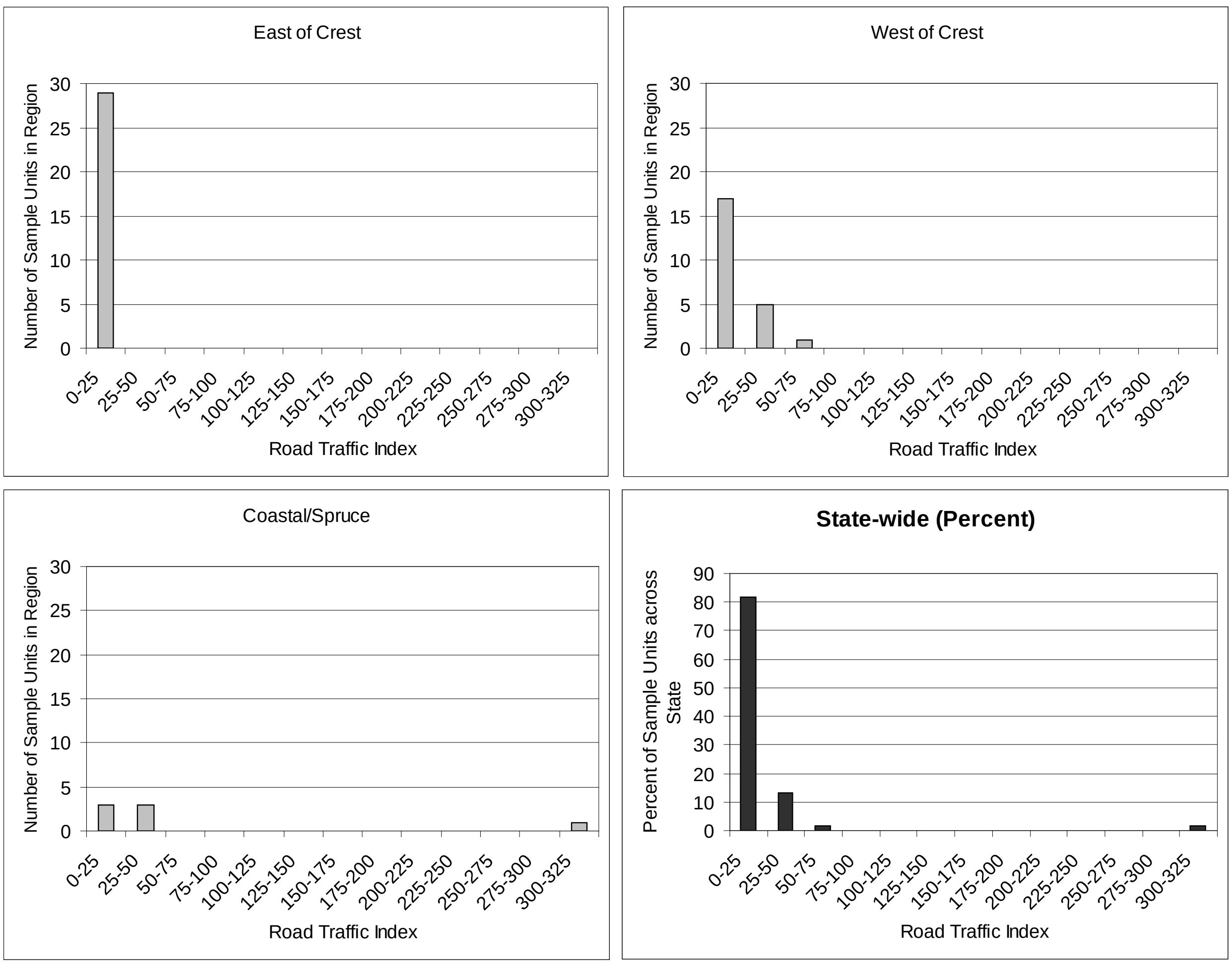


Figure 18. H2b2 Road Traffic Index.

H2b3 Cutslope cover index

The cutslope cover index is a combined/weighted metric that is computed by multiplying the length of road in each cutslope cover class by the WARSEM numerical factor for that class and dividing the sum of all classes by the total length x lowest numerical WARSEM factor for cutslope cover. A lower cutslope cover index indicates that relatively less erosion would come from roads in that unit based on the distribution of cutslope cover in the unit.

Cutslope cover indices are relatively evenly distributed between 0.5-3 in East of Crest units, with a slight skew toward lower indices in Coast/Spruce and West of Crest units (Figure 19).

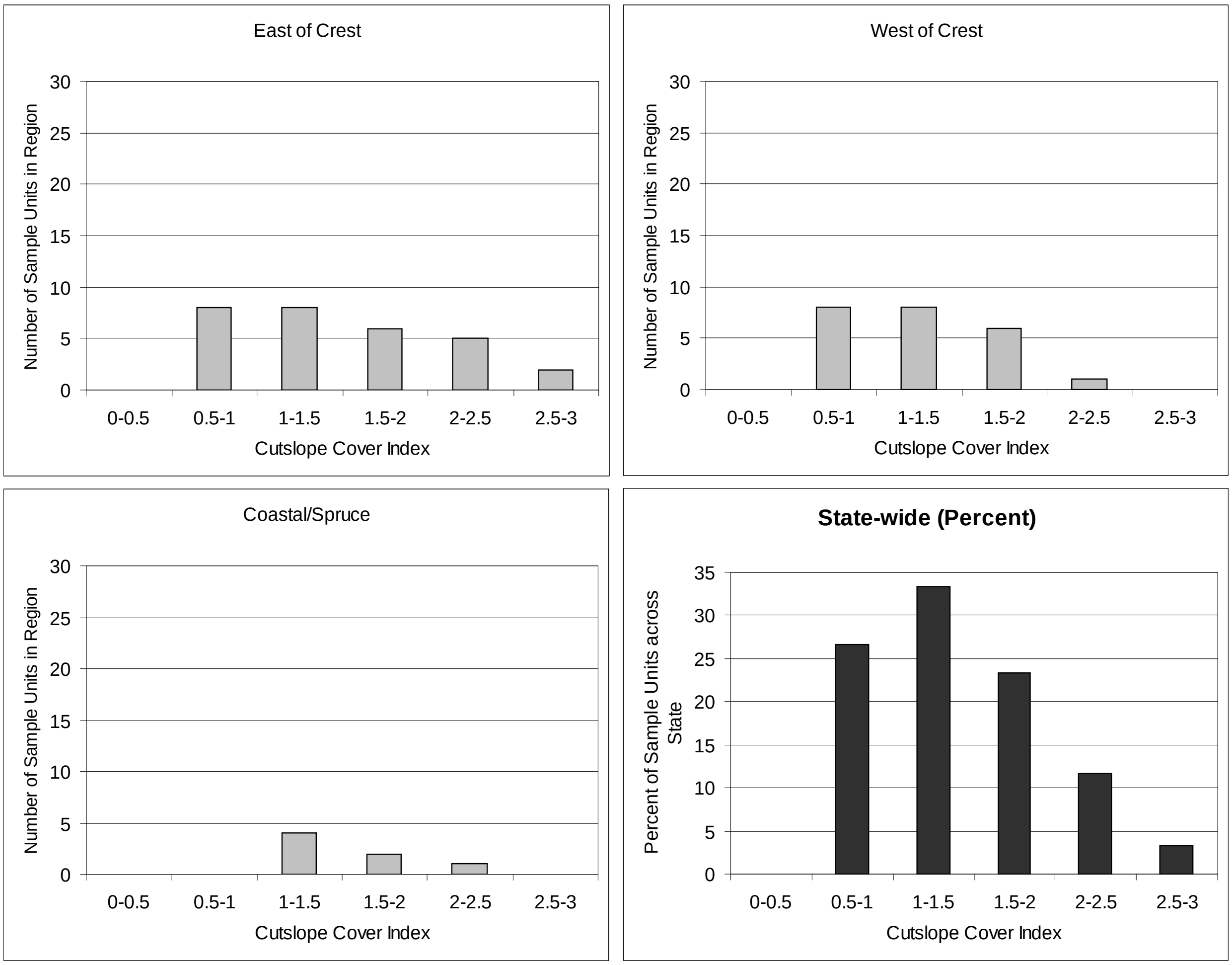


Figure 19. H2b3 Cutslope Cover Index.

H2b4 Miles of delivering road with ruts interfering with drainage

The distribution of units by miles of delivering road with ruts that were determined to interfere with drainage is shown in Figure 20. Less than 0.2 miles of roads with interfering ruts were found in the majority of units, although a few units had a relatively large number of rutted roads.

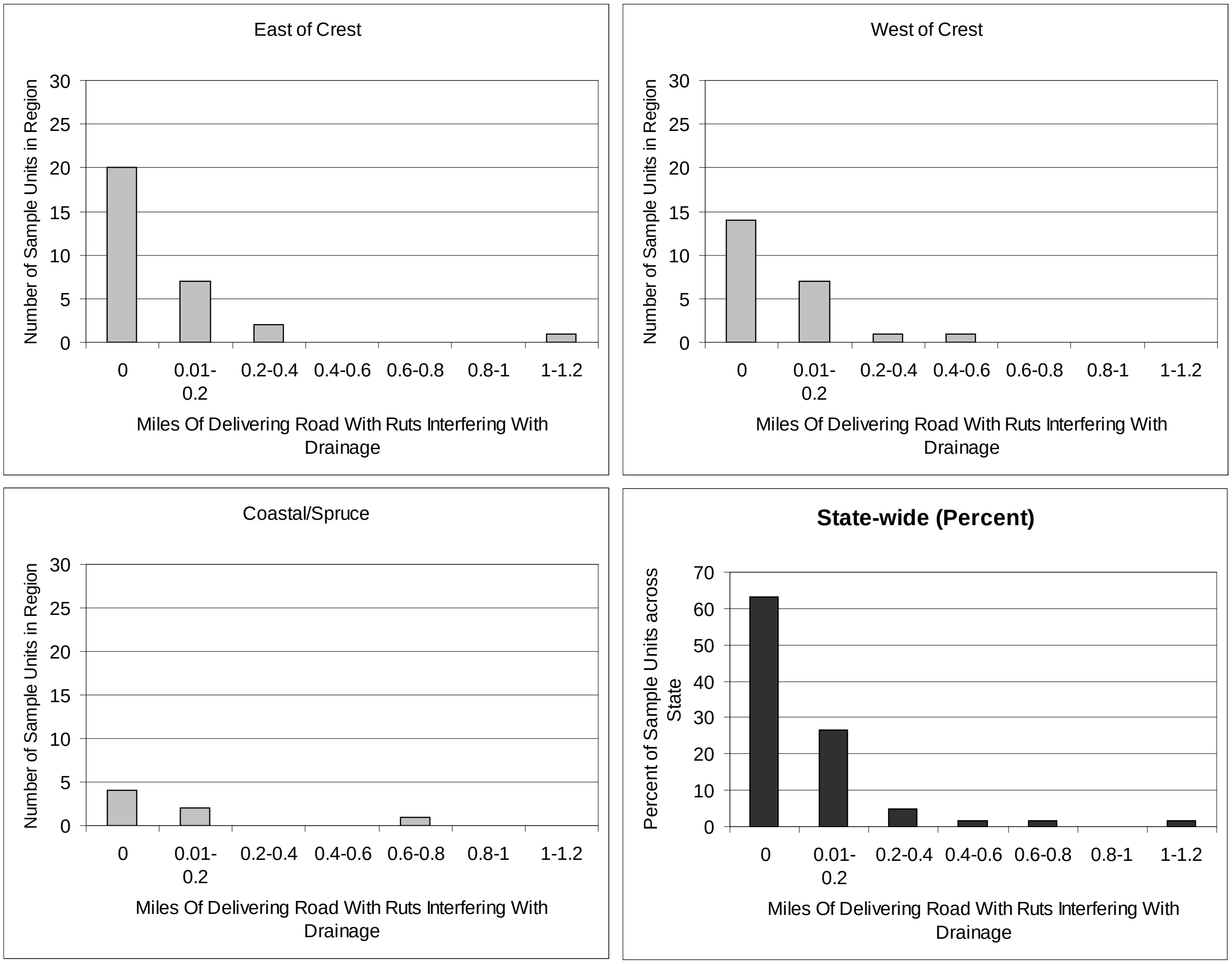


Figure 20. H2b4 Miles of Delivering Road with Ruts Interfering with Drainage.

4.3.3 Monitoring Question 3

What is the status of road performance measures for drainage connectivity and sediment delivery to streams at each sample event?

MQ 3.1 and H5a Miles of forest road delivering to streams per miles of stream (road hydrology performance measure)

Schedule L-1 of the Forests & Fish Report provides two performance measures with targets for existing roads. The first is a measure of the hydrologic connectivity of the road system in relation to the stream density in a sample unit (RLEN), and was calculated as the miles of road delivering to streams per miles of stream in each sample unit. The higher this number is, the more road network drains to streams in the unit. Sample units in the East of Crest region had less road delivering/miles of stream than units in the Coast/Spruce or West of Crest regions.

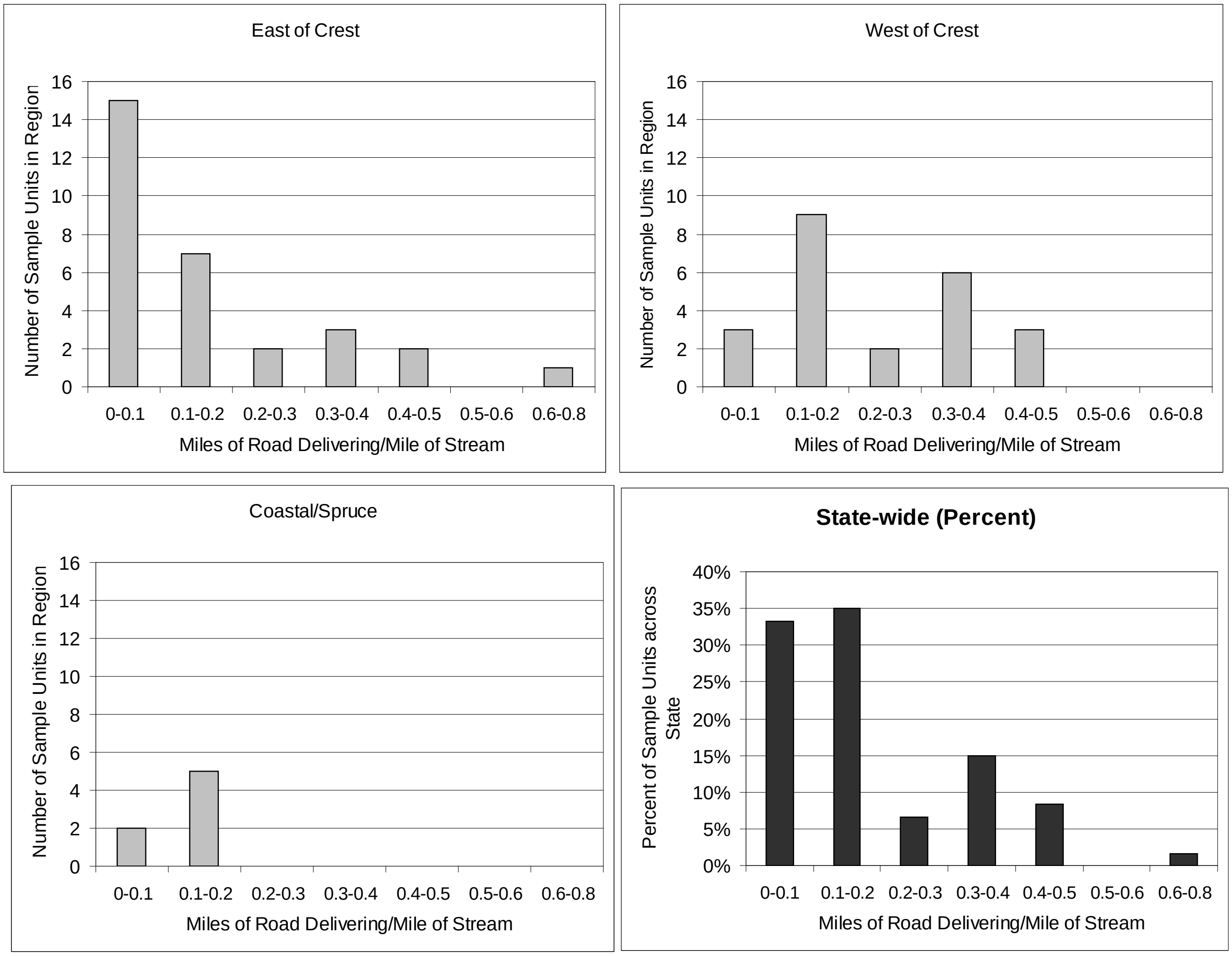


Figure 21. MQ3.1 Miles of Delivering Road per Mile of Stream (FFR Hydrology Performance Measure).

Figure 22 shows the cumulative percentages of sample units as a function of miles of road connected to the stream network per mile of stream (RLEN) for each region and statewide. These graphs can be thought of as counting the number of units (or percentage of study units) that have RLEN values less than or equal to the value on the x-axis. For instance, it can be seen in Figure 22 that 68 percent of the sample units had RLEN values of less than 0.2 mile of delivering road per stream mile. The range of each regional target (upper and lower target) is also shown on the graph so that the percentage of sample units meeting either the upper or lower end of the target range can be determined for each region.

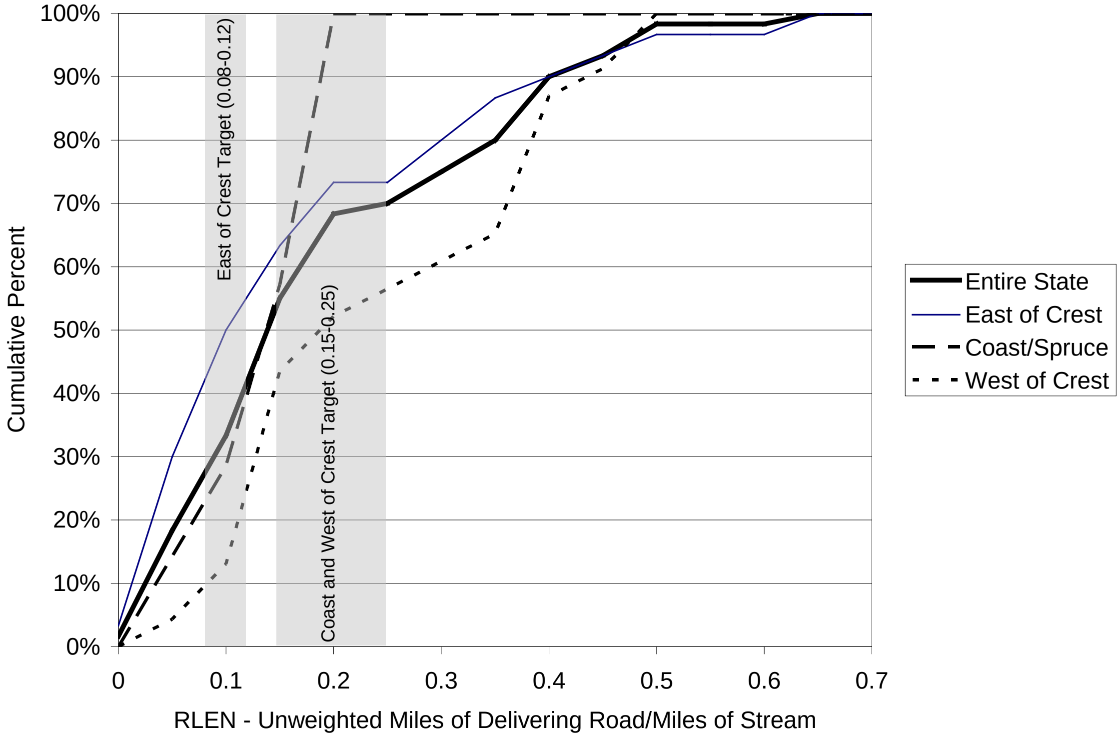


Figure 22. MQ3.1 Cumulative Percent of Sample Units, Miles of Delivering Road per Mile of Stream (RLEN).

MQ 3.2 and H5b WARSEM modeled tons of road sediment delivered to streams per mile of stream (road sediment performance measure)

The other FFR performance measure is tons of road sediment delivered to streams per mile of stream. This metric focuses on the relative amount of sediment delivered to streams in the sample unit. All sample units in the East of Crest region had less than 2 tons of sediment/mile of stream (Figure 23). Most units in the Coast/Spruce zone had less than 6 tons/mile, and units in the West of Crest region varied the most, with up to 16 tons/mile

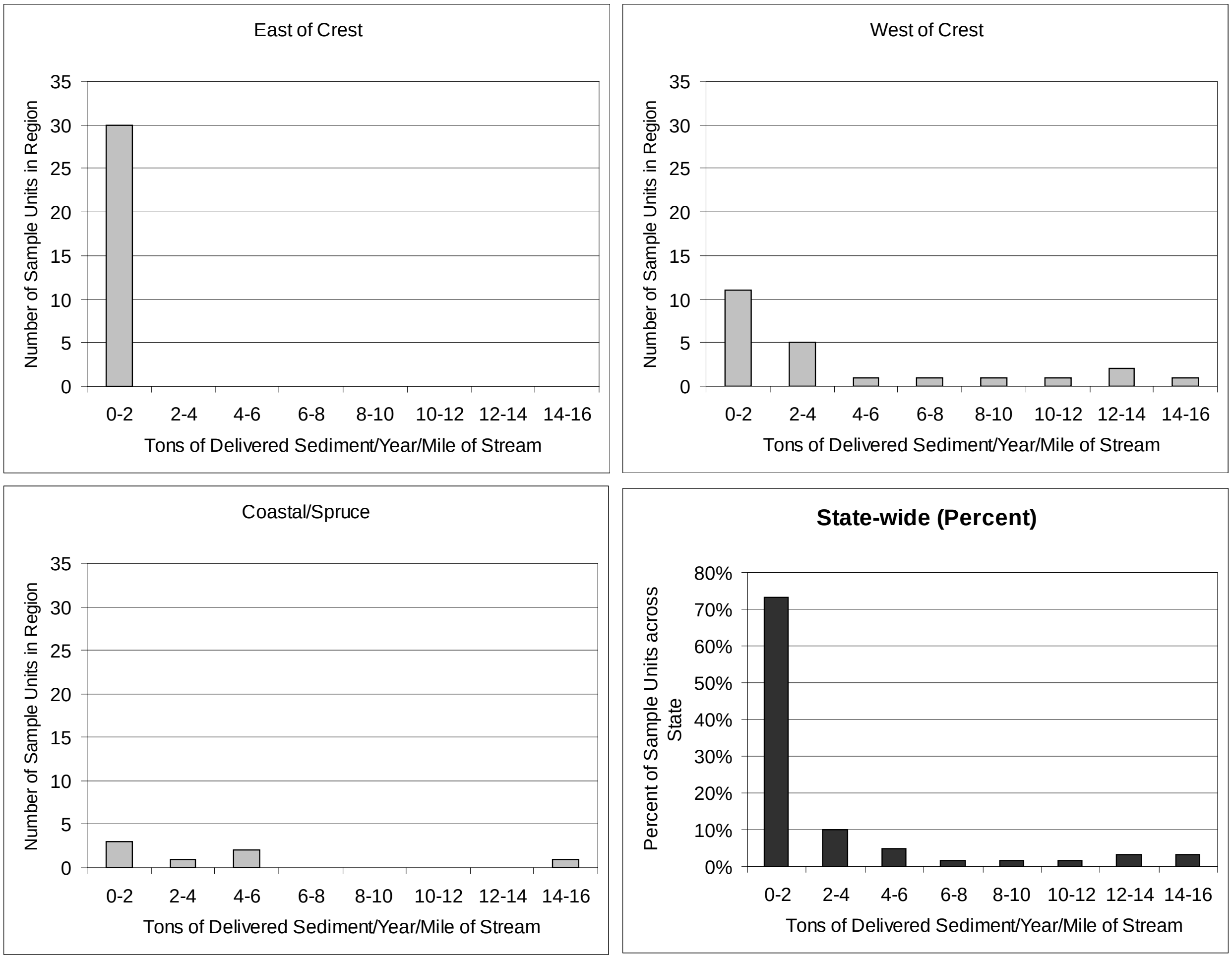


Figure 23. MQ3.1 Sediment Delivered/Year per Mile of Stream (FFR Sediment Performance Measure).

Figure 24 shows the cumulative percentages of sample units as a function of sediment delivered per mile of stream (RSED). The range of each regional target (upper and lower target) is also shown on the graph so the percent of sample units meeting either the upper or lower end of the target range can be determined for each region.

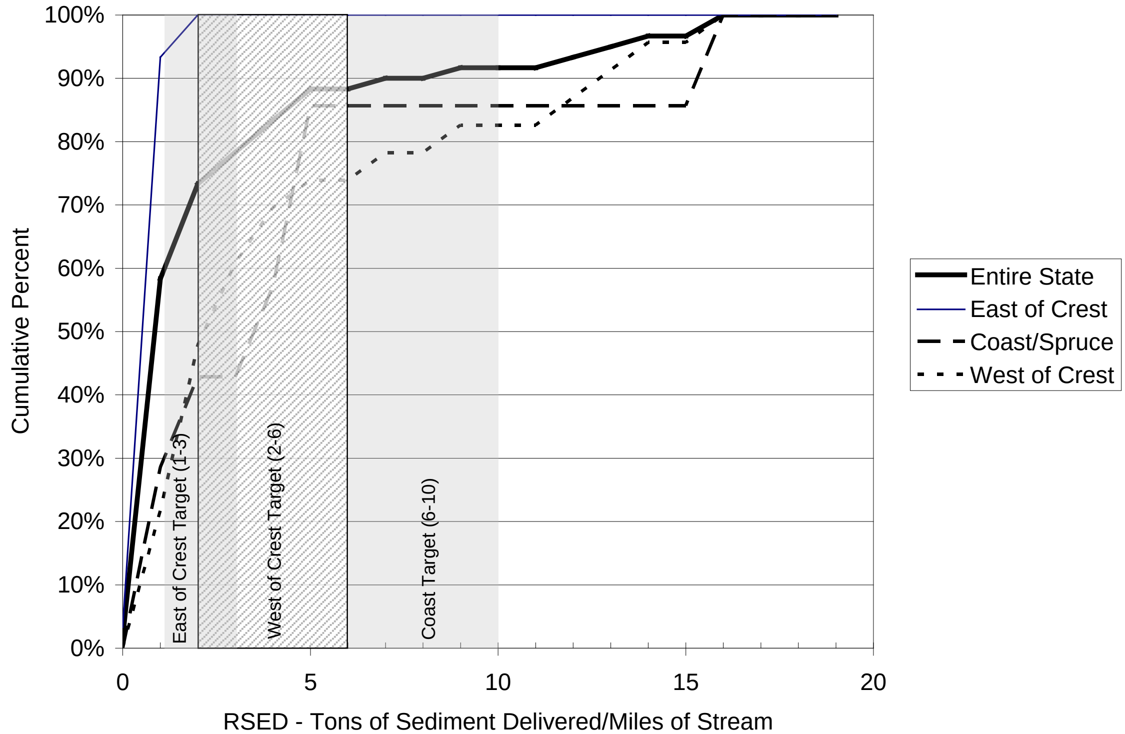


Figure 24. MQ3.1 Cumulative Percent of Sample Units, Tons of Delivered Sediment per Mile of Stream (RSED).

4.3.4 Monitoring Question 4

What is the status of road performance measures relative to their targets, by performance target region, at each sample event?

MQ 4.1 Miles of forest road delivering to streams per miles of stream (road hydrology performance measure) divided by the performance target by target region

Monitoring Question 4.1 looks at the road hydrology performance measure in each unit in relationship to the upper limit of the performance target for that region. If the ratio of the measure/target is one or less, the unit meets the target. If the ratio is greater than one, the unit exceeds the target.

Across the state, 62 percent of the sample units meet the sample hydrology target (Figure 25). The sample unit that far exceeded the standard (East of Crest Unit, 5-6 bin) had a large number of mid-slope roads resulting in numerous stream crossings despite the moderate overall stream density.

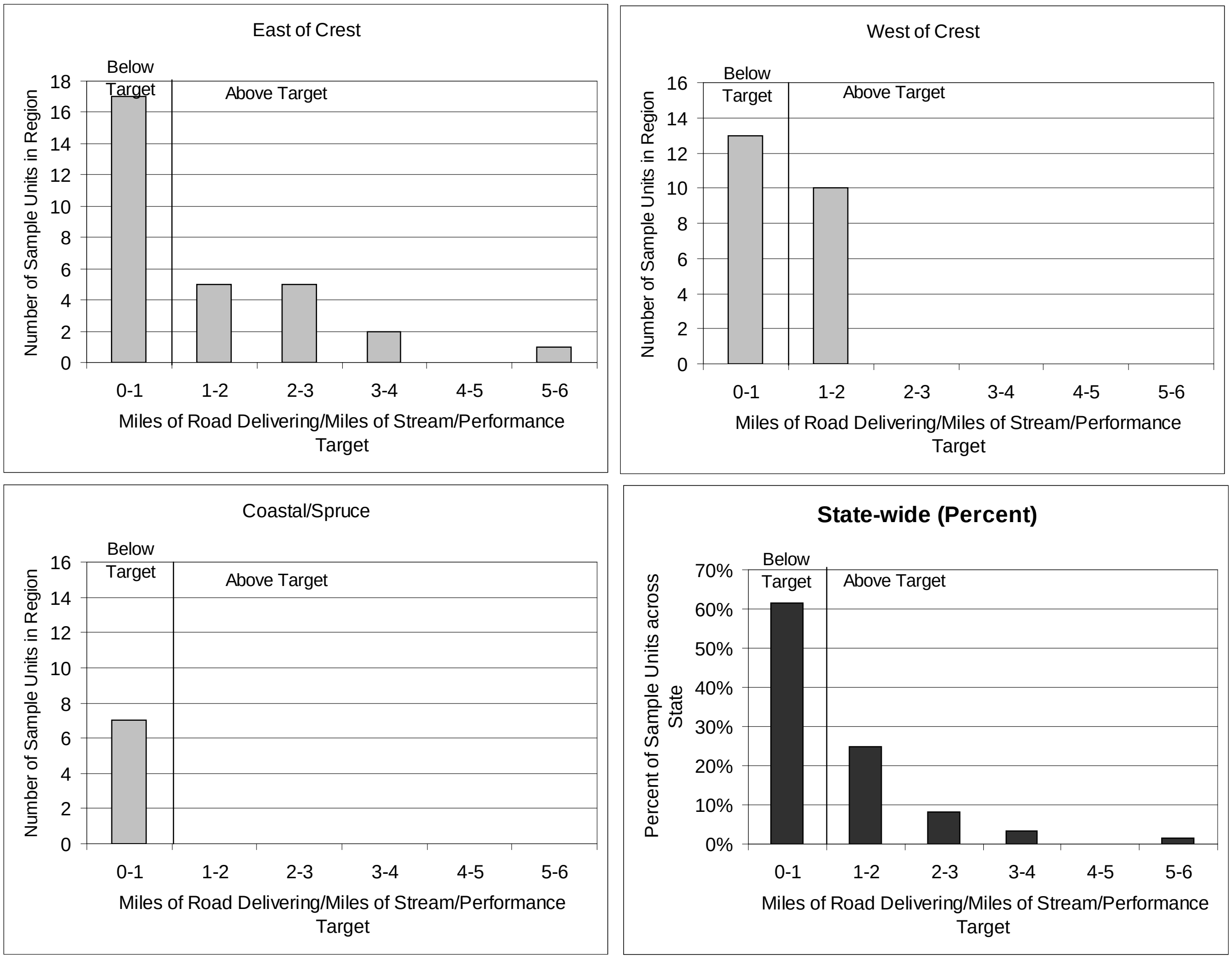


Figure 25. MQ4.1 Miles of Delivering Road per Mile of Stream Divided by Regional Performance Target.

MQ 4.2 WARSEM modeled tons of road sediment delivered to streams per miles of stream (road sediment performance measure) divided by the performance target by target region

Monitoring Question 4.2 looks at the road sediment performance measure in each unit in relationship to the upper limit of the performance target for that region. If the ratio of the measure/target is one or less, the unit meets the target. If the ratio is greater than one, the unit exceeds the target.

Across the state, 88 percent of the sample units meet the sediment target (Figure 26). All sample units in the East of Crest region meet the target. One unit in the Coast/Spruce region and several in the West of Crest region do not meet the target.

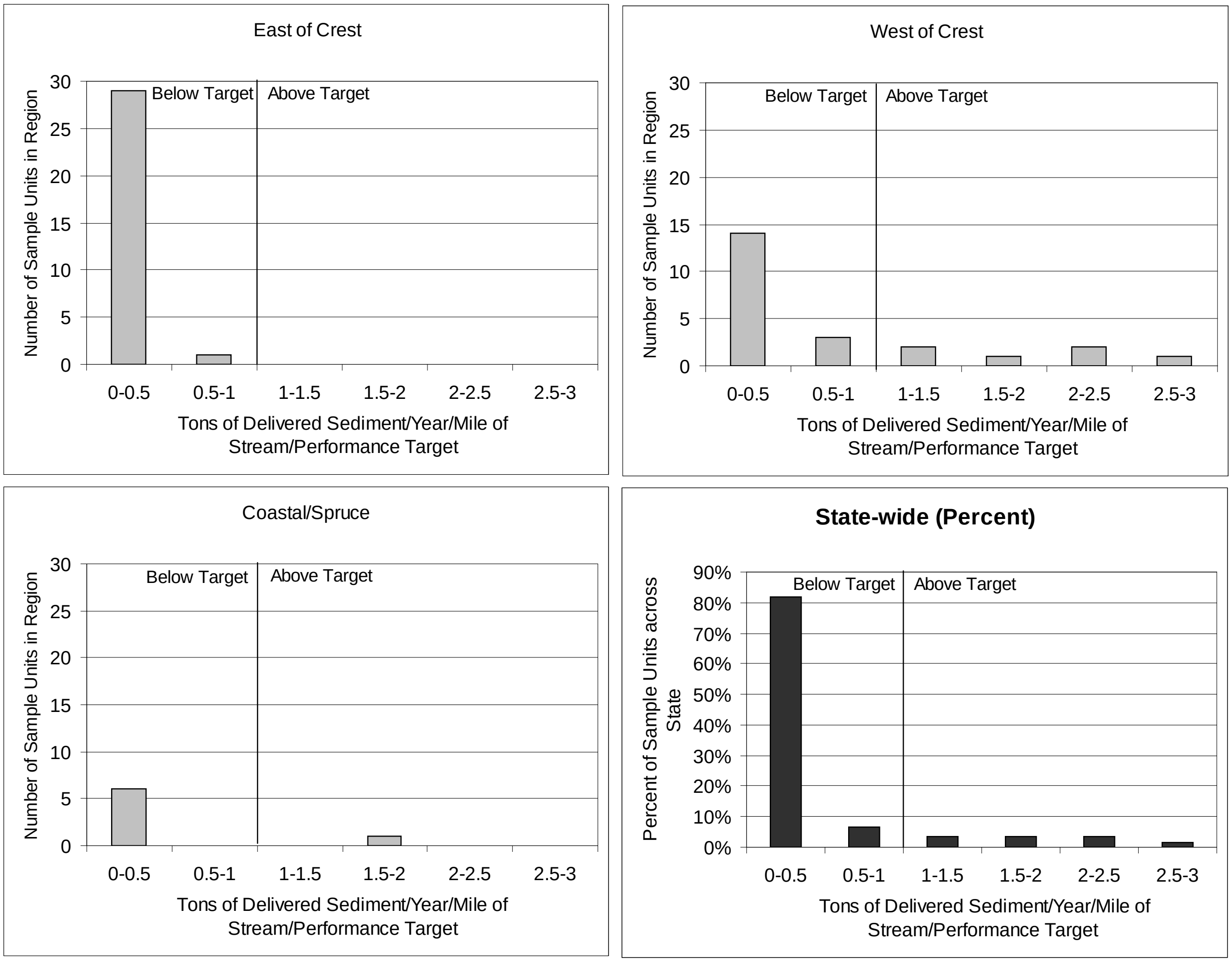


Figure 26. MQ4.2 Sediment Delivered/Year per Mile of Stream Divided by Regional Performance Target.

4.3.5 Monitoring Question 5

Have measures of road sediment performance improved over time?

This monitoring question will be assessed through comparison of the initial and subsequent sampling events.

4.3.6 Monitoring Question 6

Will roads judged to meet FFR road standards meet the performance targets?

In order to assess how much of the road system in each sample unit either had RMAP work completed or was up to current road standards, each landowner was asked the percentage of roads on their lands in the unit that they consider to be up to standards. This measure was compiled for each sample unit by combining the percent of roads reported to meet standards from each landowner by the percent of the road system on their land in each sample unit. As this metric was based on landowner judgment and was not verified by field crews, it should be regarded as an estimate rather than a precise measurement. Figure 27 shows the percent of sample units by the percent of roads reported to be up to current road standards for each region and across the entire state. Overall, a high percentage of roads were reported to be up to standards, with over half of the units reporting that at least 85 percent of the roads meet standards. Percent of roads meeting standards was highest in the East of Crest region, and lowest in the West of Crest region.

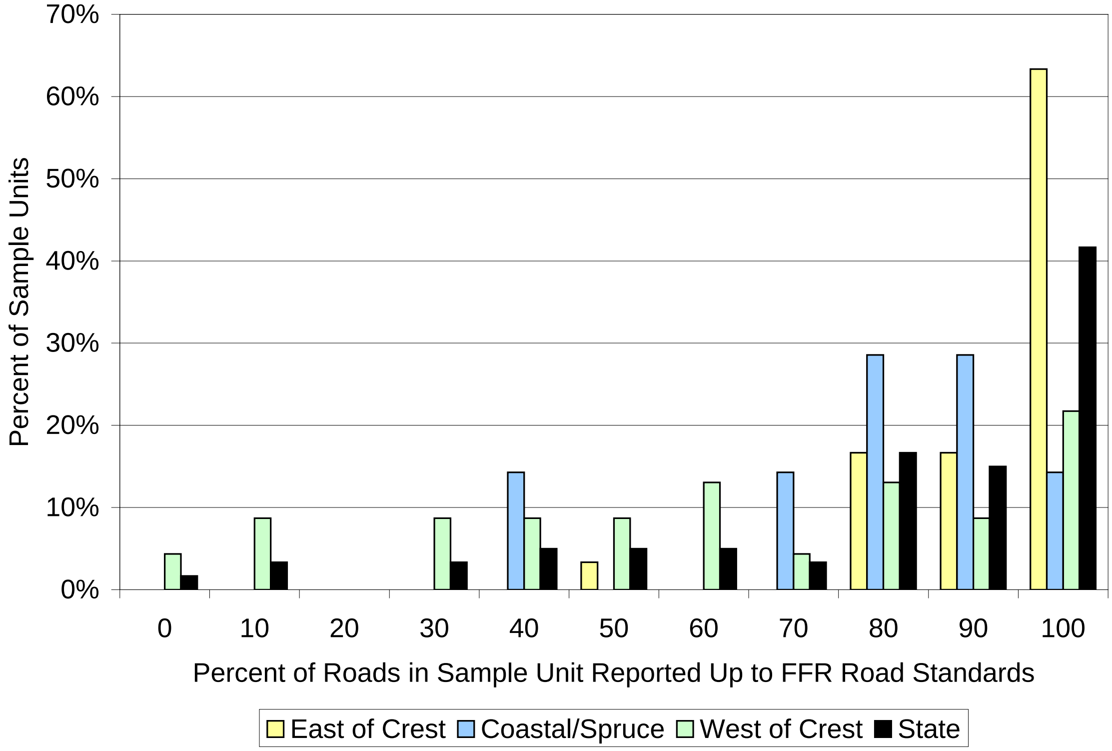


Figure 27. Percent of Sample Units with Percent of Roads Reported to be up to FFR Road Standard

H6a Miles of forest road delivering to streams per miles of stream (road hydrology performance measure) vs. percent of road length in each unit meeting FFR road standards

H6b WARSEM modeled tons of road sediment delivered to streams per miles of stream (road sediment performance measure vs. percent of road length in each unit meeting FFR road standards

The FFR performance metrics for road length delivering (MQ3.1) and sediment delivery (MQ3.2) were calculated for each sample unit, divided by the FFR performance target for that metric (shown in Table 1) and plotted by the percent of roads within the sample unit that were reported by landowners to meet current road rule standards. This relationship between percent roads meeting performance standards and the ratio of each sample unit performance measure to the regional target are displayed in Figures 28 and 29.

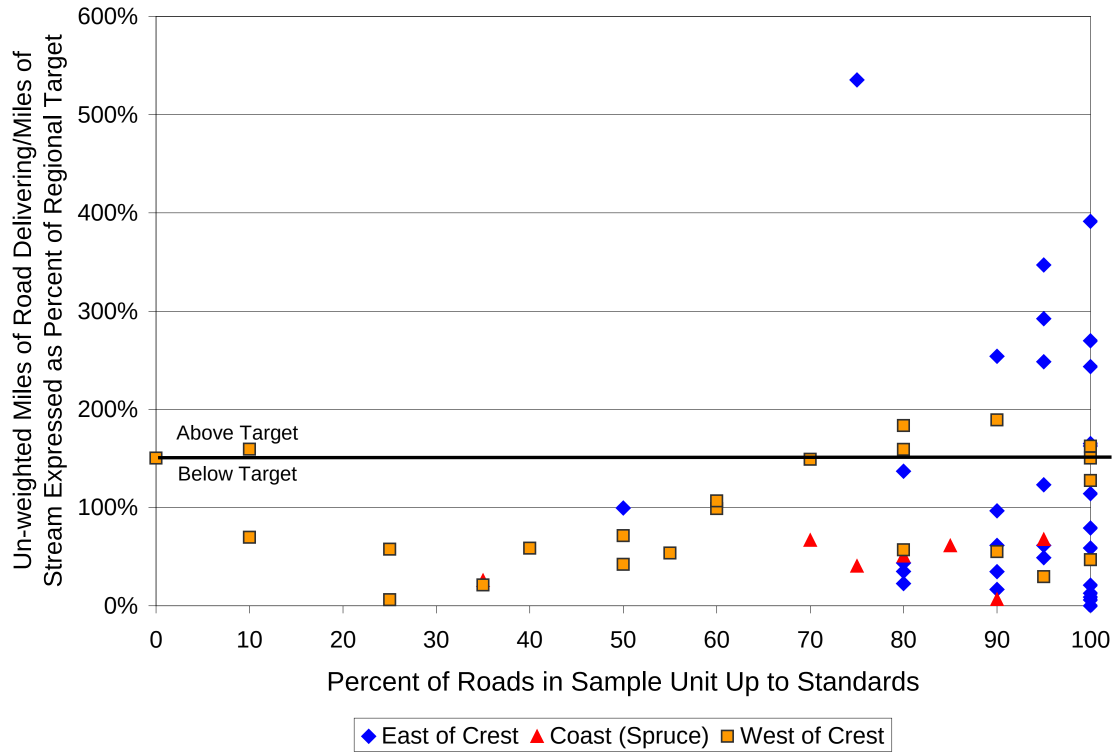


Figure 28. Miles of Delivering Road/Miles of Stream (MQ3.1) Expressed as Percent of Regional Target vs. Percent of Road Miles in Sample Unit Reported to be up to Standards.

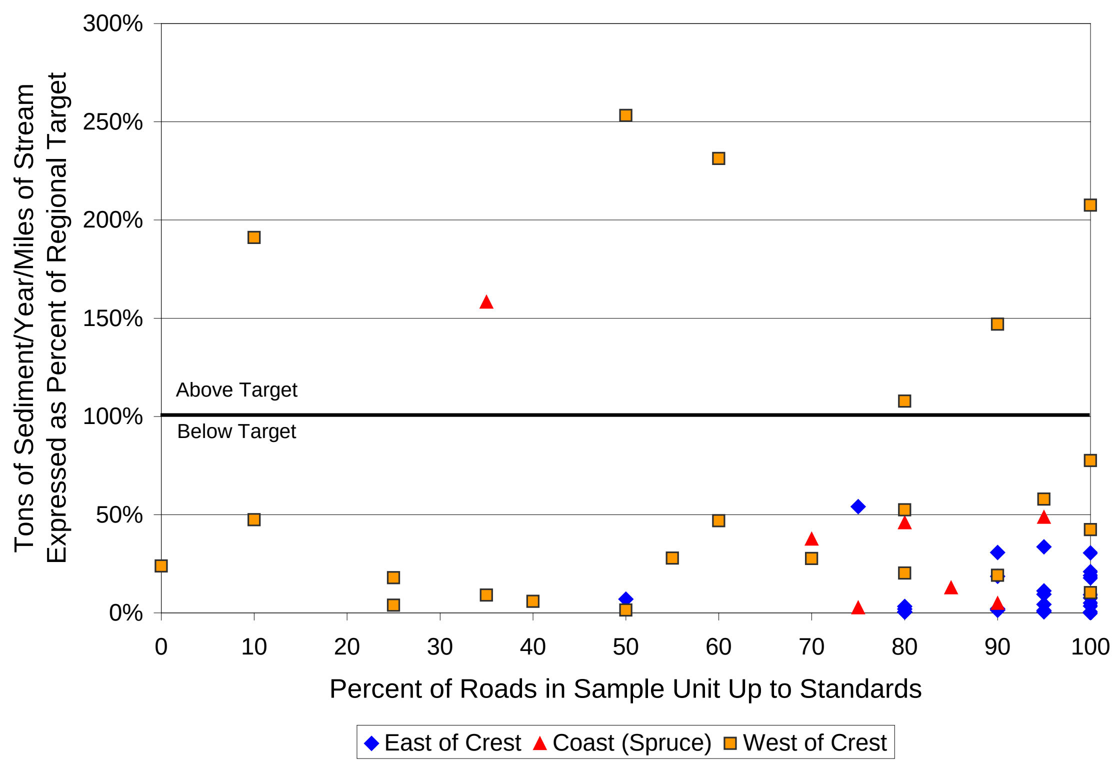


Figure 29. Tons of Delivered Sediment/Miles of Stream (MQ3.2) Expressed as Percent of Regional Target vs. Percent of Road Miles in Sample Unit Reported to be up to Standards.

For MQ3.1, length of road delivering, there is no evidence of a relationship with the reported percent of roads up to standards (one-tailed Kendall's trend test $p = 0.327$). This may reflect a general RMAP objective of prioritizing road maintenance on road sections with the highest need for maintenance/repairs.

All of the Coast/Spruce zone units met the road mile delivering target, but in the East of Crest and West of Crest zones only 57 percent of the units met the road mile delivering target. This was true even though 93 percent of the units reported more than 80 percent of their roads were up to standards. The reported percentage of roads up to standards varied widely for the Coastal and West units. The sample unit that far exceeded the standard (East of Crest Unit, 535 percent of standard) had a large number of mid-slope roads resulting in numerous stream crossings despite the moderate overall stream density.

For MQ3.2, sediment delivered, there is a significant monotonic decrease in sediment delivered with increase in percent of roads meeting performance standards within the sampling unit ($p = 0.0028$). The regional results for sediment delivery are quite different than the road length delivering results, with all of the East of Crest units meeting the sediment performance target, and 74 percent of the West of Crest units and 86 percent of the Coastal/Spruce units meeting the target.

The reasons for the differences in meeting delivering length and sediment targets between the different geographic regions are likely due to a combination of factors, including a much lower stream density on East of Crest units (metrics are divided by miles of stream in each unit), and much lower precipitation on the Eastside resulting in lower calculated sediment production in those units. It is also possible that landowners prioritized roads for RMAP work and upgrades to first work on those areas with roads that they judged to need the most improvements.

It should also be noted that in some of the selected sample unit areas it will be much more difficult to meet the target values as beacause of the location of the existing roads in relation to the stream network. For example, areas with a ridgetop road system (Figure 30 left side) have a much lower density of road/stream crossings (blue squares) and therefore a much lower chance for long lengths of delivering roads than a unit with primarily midslope and valley bottom roads (right side of Figure 30). Moreover, some geologic materials and soils are more erodible than others and/or more prone to gullying.

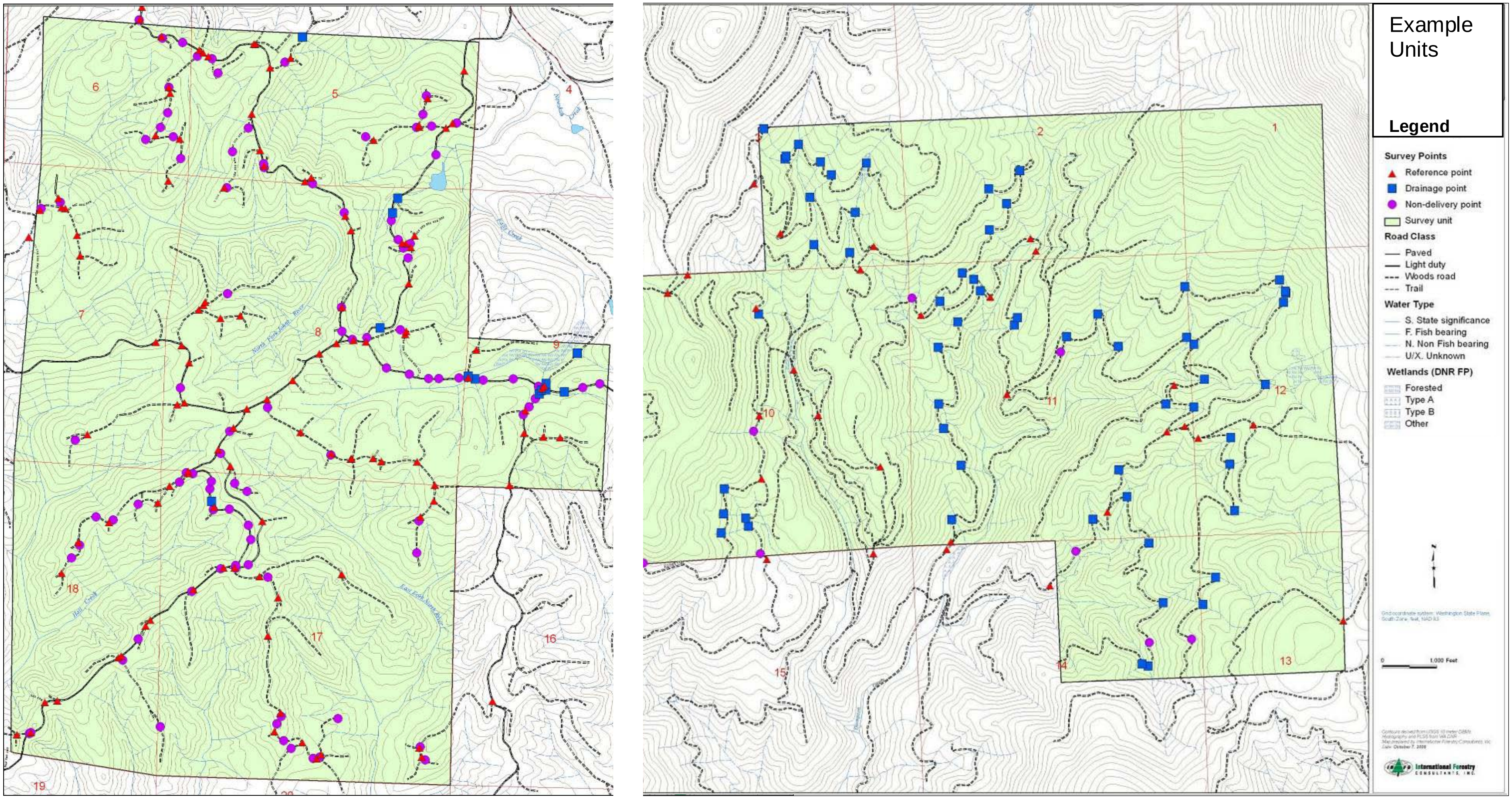


Figure 30. Sample Unit Maps Showing Difference in Delivery Between Units with Ridgetop Roads (left) and Midslope/Valley Bottom Roads (right)

4.4 New Roads Evaluation

While the majority of this study evaluates road effects collectively at the sub-basin scale, the data set also allows site-scale evaluation of new roads. A total of 11.8 miles of new roads, defined as being constructed within two years of the field sampling, were present within 11 of the sample units; these units were distributed among all three rule regions. The FFR performance target for sediment delivered to streams from new roads is “virtually none” (see Table 1 in Section 2 above), which does not lend itself to objective determination of success or failure. Despite the subjective target and small sample size, this evaluation provides an initial assessment of new roads built under post-2000 Forest Practices Rules.

Table 8 summarizes the miles of new road length and estimated sediment delivery from new roads in each of the 11 sample units. Delivery from the new roads varied greatly – five of the units with new roads had no delivery from the new road segments, while between 1 and 79 percent of the new road length in the remaining six units delivered to streams. The specific location of the new roads determined whether or not the road segments were hydrologically connected to streams. In several units, the new roads were a number of short spurs off existing roads and did not cross streams. However, in four of the units the new roads were midslope roads constructed in locations without previous road systems; these crossed many small drainages and did drain to streams. In the two units with the highest percentage of new delivering (72 and 79 percent), it did not appear that measures were taken to minimize the length of new road connected. The average length of road connected at drainage structures in these two units was 838 and 942 feet respectively. It did appear that an effort was made to minimize connectivity in the other units, with the average length of connected road at each crossing less than 250 feet in all but one of the remaining units. Across all the sample units, 17 percent of the new roads were hydrologically connected compared to 11 percent of all roads sampled across the state.

Sediment delivery from the new road segments was relatively minimal in eight of the 11 units (Table 8). Sediment delivery ranged from 0 to 136.5 tons/year. Note that the WARSEM computation of sediment delivery for new roads includes a factor for road age, with 10 times more sediment produced from a road constructed within the past year as an old road (see WARSEM technical documentation, Dubé et al. 2004). Therefore, the average of 18 tons/mile/year of sediment computed from new roads cannot be directly compared with the average of 2.1 tons/mile/year of sediment produced from existing roads across the state. Measurements of sediment produced from newly constructed roads shows erosion rates decline quickly and reach rates similar to older roads within 2-3 years (Ketchenson et al. 1999, Luce and Black, 1999, Grace 1999, Swift 1984, Dryness 1975, Megahan 1974, Megahan and Kidd 1972).

Table 8. Summary of New Roads by Sample Unit

Region	Miles of New Road in Unit	Un-weighted New Road Length Delivering (mi)	Percent of New Road Length Delivering	WARSEM Calculated Delivered Sediment (tons/yr)	Delivered Sediment per mile of new road (tons/mile/yr)
East of Crest	0.86	0	0%	0	0
	1.54	0.02	1%	0.04	0.03
Coastal Spruce	1.59	0.17	11%	17.3	10.9
	0.40	0	0%	0	0
	2.79	0	0%	0	0
	0.23	0.18	79%	4.9	21.5
	1.04	0.37	35%	51.2	49.4
West of Crest	0.44	0.32	72%	1.8	4.1
	0.43	0	0%	0	0
	2.29	1.00	44%	136.5	59.7
	0.19	0	0%	0	0
Total for New Roads	11.8	2.1	17%	211.8	18.0
Total for All Roads Evaluated Across State (new and old)	1283	147	11%	2,699	2.1

5 Summary and Recommendations for Future Sample Events

New Forest Practice Rules for forest roads under WDNR jurisdiction were adopted in Washington State in 2001. Implementation of the road rules for existing roads is planned over a 15-year time horizon through the completion of Road Maintenance and Abandonment Plans. The objectives of the Road Sub-Basin Scale Effectiveness Monitoring Program are:

- to determine if the road characteristics that affect runoff and sediment delivery to streams are improving through time as RMAP are implemented between 2001 and 2016; and
- to determine the extent to which roads on lands subject to WDNR forest practice rules meet the FFR performance targets (Table 1).

Characteristics of forest roads in a total of 60 four-square-mile stratified random sample units across the state were inventoried between 2006 and 2008, five to seven years after the forest practice rules were adopted. This is the first sample event planned for the Road Sub-Basin Scale Effectiveness Monitoring Program, and provides the first look at the current status of forest roads.

A high percentage of roads in the sample units across the state were reported to either have RMAP work complete, or already be up to current road rule standards, with over half of the sample units reported to have at least 85 percent of road length meeting standards. An average of 11 percent of the road network delivered to streams or wetlands. Across the state, 62 percent of the sample units met the Forests & Fish Report (FFR) hydrology performance target (miles of delivering road/miles of stream) and 88 percent of the units met the FFR sediment performance target (tons of delivered sediment/year/miles of stream). These results include new and existing roads combined.

Statewide, no relationship was found between length of road delivering and percent of unit reported to be up to standards; however, a statistically significant decreasing relationship was found between sediment delivery and percent of roads up to standards. These findings suggest that, while there may be locations where there is higher hydrologic connectivity or sediment input from roads, overall across the state there is a trend of decreasing sediment input as roads are brought up to modern standards.

Based on the findings of this first sample period, the following recommendations are made for future monitoring events:

- Continue with the next planned monitoring period (planned interval of 5 years) to confirm the findings that, in general, roads conditions improve and they meet the performance metrics as they are brought up to FFR standards.

- Continue to stress measures to minimize observer variability. To help reduce observer variance, minimize the number of field crew members to the extent practical. Five crew members were used during this first sample event. Training, duplicate crew surveys, and continued training through the field season are important to help minimize variance due to observer error.

- Re-evaluate the most effective method to conduct observer variability testing prior to the next sampling period. One addition to the existing methods that may prove helpful is to have the project leader survey the test road segments to use as a benchmark for observer variability. This could point out which attributes are most prone to variability, indicating that more training or guidance is needed.

- As specified in the Study Design, the same study units are planned to be re-sampled during subsequent sample events. Prior to the next sampling period, methods for re-sampling units (Field Protocol, Section 4.11) should be thoroughly discussed to specify how field crews will determine if each road attribute has changed (or not) between sampling events.

- Prior to the next planned sample event, methods for sampling should be discussed with a statistician regarding variables that will be or will not be re-sampled for each unit. Also, the method for analyzing changes should be carefully considered prior to sampling.

- Consider developing a companion study specifically designed to obtain access to and evaluate road conditions on small forest ownerships.

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Appendix A. Meeting Minutes

WDNR Road Sub-Basin Scale Effectiveness Monitoring
Phase I Kickoff Meeting Minutes
Wednesday, December 14 1 PM

Attendees: Kathy Dubé, Mary Raines, Curt Veldhuisen, Jenelle Black
By conference call: Karen Kuzis, Julie Dieu, Dawn Hitchens, Nancy Sturhan

1. Introduction and Meeting Purpose (Jenelle Black)

Purpose of meeting was to review the objectives and proposed methodology for the road sub-basin scale effectiveness monitoring project so contractor (WPN) and UPSAG committee members have shared vision of how project will proceed.

2. Goals and Objectives of Monitoring Project (Jenelle Black)

Jenelle reviewed goals in RFQQ:

- Provide a way to measure if the FFR road rules are having a positive effect on the condition of roads on forested lands in Washington.
- This assessment will establish baseline condition – assessment will be repeated at 5 year increments (separate project)
- Current project will develop methods and protocols for assessment methodology (spelled out in the monitoring design), develop crew training materials, train crew, and survey the first group of road sites (anticipated to be 17 – 20 sites)
- QA/QC procedures are quite involved and are also part of this project – objective is to provide statistically valid sample and be able to judge amount of error associated with field measurements
- Survey protocol will also include fish passage questions from ISAG. For reporting purposes, these can be included in a separate table in the database, linked to information collected on that drainage structure.

The group discussed the responsibilities of team members:

- On the DNR/CMER side, Jenelle Black is project manager. UPSAG team members will be available to review documents and guide process, as requested by the DNR/CMER project manager. Dawn Hitchens will handle contract/billing questions. Nancy Sturhan will be available to answer any policy questions.
- The WPN team will divide work among Kathy Dubé (technical issues, protocol, training), Karen Kuzis (contract/billing and logistics), and Mary Raines (QA/QC lead).

3. Field Protocol and Training (Kathy Dubé)

Kathy said that most of the data collection methods are clear, but she had a few questions on ways to deal with segments that are unusual, particularly as far as delivery and road drainage configuration. After some discussion, the group decided Kathy is going to list the questions/special situations and provide a suggested approach to addressing the situations.

UPSAG will review these and come to agreement about how they will be handled. Question also came up as to how the FFR metric of miles of road/miles of stream will deal with partial delivery segments. This is really a policy issue. WPN will provide suggestions and UPSAG again will make final determination.

Marking segments in field – Kathy has a list of several methods for monumenting the starting points of road segments that could be used depending on landowners and logistics: GPS, odometers, paper base maps with notes, and photos. Julie Dieu said that after experimenting with several different methods, they have found that putting metal tags on the base of trees/stumps near the top of the cutslope is a good way to deal with this. Use aluminum nails. Scratch info into tag, or use plastic tags and write on both sides (UV rays fade writing). The group decided that several methods should be available and planned for, depending on the site and any landowner constraints. As long as the method used for each monument is well-documented, the use of multiple methods is not expected to be a problem.

Nancy Sturhan asked who will make changes to the WARSEM code. Marc McCalmon has been designated as the person to do this. He worked on the original WARSEM code and currently works for WDFW. There were some concerns about whether or not he would have time to do this or if we needed an alternate person available. Nancy/Jenelle will work on scheduling this with Tim Quinn (Marc's boss). We anticipate 1 week of Marc's time, in January or February.

Training Location - Several sites were discussed. Jenelle said it would be nice if we could use one of the actual monitoring sites – maybe Skagit or Grays Harbor area – for training. Kathy also mentioned a DNR-owned property near Seattle that was used for the WARSEM project that might be available. We discussed that it might be hard to find an Eastside site that was snow-free at time of training – may need to hit that site later in Spring, as the crews start to work on that side.

Training Date – targeting February

How many DNR/UPSAG members and who can or do want to attend the training? Jenelle was going to do some inquiry about who (from where) may want to attend. Curt said he may attend one day. Kathy said up to 12 people in the field portion of the training is OK – as many as want can attend the first day (classroom).

Julie Dieu mentioned that in her experience, having crew members train the next generation of field crew was the most effective method (job shadow for a week or so – worked well).

4. QA/QC Program (Mary Raines)

Mary asked if the training materials and field protocols part of the QA/QC document or if they are separate documents that reference the other? The group said either way would work as long as they are integrated. Kathy and Mary are going to coordinate development, probably separate documents which will tier off of each other. In response to a question by Mary, the QAPP should include the methods and statistical tests for evaluating operator variability.

Jenelle expressed an expectation that the QA process will include methods for identifying and correcting problems and errors at all levels in data collection and processing, and that tracking operator variability throughout the process rather than just at the beginning and end of data collection would be one way to do this. This suggestion will be taken into consideration during the QAPP development if practical, but it is not specified in the contract.

5. Field Surveys (Kathy Dubé)

Site selection status – Sites have been identified but status is unclear. Jenelle is working on this. UPSAG members may be able to help? Jenelle is going to follow-up and determine what needs to happen to let WPN know which sites to sample.

Protocol needs to include how to determine what's a road vs. a cat road. On Westside, rocked vs. native can be helpful. Also, gradient over 18%.

6. Reporting

Kathy will have Specific Questions on Field Approach by Jan 3rd – maybe a Draft Field Protocol. Mary will have outline of QAPP by Jan 3rd. UPSAG Meeting is Jan 10th

Jenelle will provide a list of UPSAG meeting dates so we can plan monthly report submissions (normally meetings are first Tuesday of each month; will let us know if different). We will plan to send in monthly reports on last Tuesday of month.

WDNR Road Sub-Basin Scale Effectiveness Monitoring
Phase I Second Unit Meeting Notes

Date: March 31, 2006

Time: 8 AM

Purpose: Discuss any changes to field protocol necessary based on first two field sites (S001, S002)

Personnel: Dan Thomas, Jesse Saunders, Matt Rourke, Brett Winterowd, Pete Malinak, Karen Kuzis, Jenelle Black, Mary Raines, Kathy Dubé

Discussion Topics:

1. Any comments on delivery flowchart (attached file)? No – looks good, is working.

2. Changes to either the GPS data dictionaries or the paper data forms made during first week (see Road Form short.xls):
   - New form (Road log) for keeping track of mileage on each road segment completed.
   - Added Begin Reference Point ID on Reference Point form (GPS and paper)
   - Changed Road Name to text on Williamson's data dictionary
   - Minor tweaks such as adding S002
   - Begin RP is set to "1" as a default – it can be easy to forget to input this number. Dan will look into flagging this in a manner so it can't be missed as easily.

3. GPS road line feature does not need to be run if there is a good road layer in GIS. Only run a road line if it's a new road (not on map) or the road layer looks obviously wrong based on the orthophotos.

4. One item that is hard to rate in the field is road maintenance category. It's hard sometimes to determine what is "recent" in the field – within the last year? Last 5 years? Discussed that recent maintenance is within last five years, and the objective is to break out RMAP activities from normal maintenance. Normal maintenance includes surfacing, grading, and ditch cleaning. Other BMPs includes anything else such as new culverts, sediment traps, etc. that are intended to bring roads up to current/RMAP standards.

5. Vegetated ditchlines tended to trap quite a bit of sediment, but "vegetated" is not called out as a separate ditch condition. (Kathy noted we don't have much research data on this, but it's obvious if there is future research, this could change. Vegetated ditches do not transport sediment in the same way as "stable" ditchlines. We group these conditions under "stable" in the database.) Keep as "stable" for now.

6. At road intersections, note road junction road name in comments field on Reference Point form.

7. At stream crossings with no culvert apparent (e.g. Humboldt, or a ford) we will put in a new field called “Other/unknown” in the Drainage Structure Type field.

8. Brett asked about surfacing in the situation where there was a lot of leaf litter/organic matter over what used to be gravel. He recorded it at pitrun. We all agreed.

9. QA/QC going OK; checking records at end of day, and correcting items after conversion to a shape file.

10. Deliverables for each unit includes (2 hard copies of each plus an electronic file where applicable):

    - Copy of field maps (marked with your name - small maps as well as large map)
    - Copy of any data sheets (we used a few where the GPS wasn't recording satellites)
    - Report of road miles surveyed (road log - field form) so we know how many miles we get paid for
    - Photos (hard copies and electronic)
    - Final Maps (Ted produces these - marked with intersection/culvert/drainage points, streams, roads, project boundary - electronic file as well as hard copies)
    - Copy of GPS data files (convert to shape files and give to Ted - and Kathy will load the road segment data into the road database to run WARSEM - only need electronic copy of these)

11. It is most helpful to have completed the landowner interview ***<u>BEFORE</u>*** the field crews are on the ground to get:

- Keys,
- Directions to field unit,
- ROAD NAMES and GIS layers
- Any access issues (or areas to be careful of)
- Road maintenance levels

WDNR Road Sub-Basin Scale Effectiveness Monitoring Phase II
Kickoff Meeting Minutes
Friday March 21, 2008 9 AM

Attendees (conference call): Jenelle Black, Julie Dieu, Kathy Dubé, Dawn Hitchens, Karen Kuzis, Laura Vaugeois, Curt Veldhuisen

7. Introduction and Meeting Purpose

Purpose of meeting was to review the objectives and proposed methodology for Phase II of the road sub-basin scale effectiveness monitoring project so contractor (WPN) and UPSAG committee members have shared vision of how project will proceed.

8. Updates to Methods

a. Wetlands

Current protocol includes delivery to Type A and B wetlands. Jenelle mentioned that there is a new wetland layer on the DNR website (date 12/2007) that Ted should use for making field maps. She also mentioned that we should continue to note delivery to any un-mapped but obvious typed wetlands that are apparent from the orthophoto coverage. and make notes in the comment field during the inventory if there are wetlands we see on the ground and we cannot easily determine if they are Typed wetlands or not. We will discuss wetlands during training. There is interest from other CMER groups on the data we are collecting pertaining to wetlands.

b. Roads next to streams

There was discussion of how to handle roads that run alongside streams and wetlands (and through wetlands). Currently the protocol looks at delivery from drainage structures (constructed or not) and includes some amount of delivery if a sediment plume ends within 20 feet of a stream. Jenelle was concerned that we are not capturing any information on roads that have dispersed runoff and may deliver some sediment. Existing research and observations suggest that dispersed runoff may only transport sediment 10-15 feet from road. Concern was also expressed that we remain consistent with methodology from first set of sample units (Phase I). Consensus: An additional delivery category will be added – category 5 – for road segments that would have been classified no delivery (category 0) but that are along or through a stream or wetland and the edge of the road tread is within 20 feet of a stream/floodplain or typed wetland. The begin/end station and all other road attributes will be collected for these segments.

9. Site Selection/Landowner Contacts

a. Blue Mountains

Jenelle said that sites in the Blue Mountains area are tricky because there are cultivated ag lands on the hilltops and some inter-fingering forest lands in valleys/north slopes. Farm roads are commonly used for hauling, and are not being maintained as forest roads. UPSAG decided not to include the forest roads in the monitoring; consequently many of the potential units in this are have dropped out.

b. Description of site selection process for report
   Jenelle will write a description of the site selection process that will be included either within the text or within an appendix of the final report.

c. Procedure for sites in “December 2007 storm” area
   We discussed the procedure to use for units within the area hit hard by the December 2007 storm (SW Washington). There is concern that there may be enough damage that access either to the unit or on roads within the unit would be extremely difficult and beyond what any of us had budgeted for (both slides and blowdown). The pros and cons of sampling sooner (capture storm damage – but is it representative?) vs. later (storm damaged roads may be freshly fixed, but more likely to be able to access roads) were discussed. Consensus: Check with landowners of these sites soon to determine extent of problem (possibly also look on the air photos UPSAG will be obtaining for the mass wasting study?). Then check back with UPSAG to determine how to proceed.

d. Landowner letter
   Jenelle has updated the landowner letter and will send it out Monday to landowners in units we anticipate to be sampling soon – rest of landowners as they are identified.

10. Field Training/Testing Methods and Plan

a. Training currently scheduled for April 14-15 in units near Ellensburg
b. Then crews will complete 1-2 units in Ellensburg area (April 16-17…) with Kathy/Jenelle/Karen available for ride-alongs.
c. Second Unit meeting after they complete these units and are still in area
d. First Variability Test at end of week (April 18). Kathy will run through roads selected for testing to make sure any ambiguous items (such as weird road junctions) are cleared up before test and will flag start/stop locations.
e. Training will include PowerPoint presentation and then field training (first with paper, then GPS/Jamars). Will include last year’s training plus discussion of wetlands, roads next to streams, any other revisions. OK to discuss differences between observers we found from last year’s variability testing.

11. QA/QC Methods and Plan

a. Field Assistance Program (ride-alongs). Kathy/Jenelle/Karen – will ride along first week of field sampling, also available second week as needed if questions (Jenelle gone April 21-22). Then ride along one day/sampling month with each crew member for duration.
b. Replicate surveys. Try to schedule several during first 2 weeks of inventory, plus others throughout sampling season. Williamson crew found it helpful to do a quick check at the beginning of each unit to confirm surfacing calls, any other issues they saw with unit.
c. Third Party QA/QC. Karen will do this. Objective is to make sure crew members are following field methods and QA/QC protocols.
d. Data Cross-check. Each member checks data at end of day (issue with INFO not having enough time last year – going too fast – will discuss with them). Also check at end of

each unit; Kathy performs final QA/QC to ensure all data fields filled in, all photos, maps, etc. are in file. Will use unit check off list as we did last time.

e. Will provide general feedback to crew members on areas of concern following first variability test (no site specific information that could bias test at end of project).
f. Will make sure notes from each replicate survey and field assistance program visit are distributed to all crew members so they can see what items were discussed.

12. Field Crews

Have 5 field crews from Phase I plus one new field crew member (Amanda Ogden) to help Williamson crews.

13. Sampling Plan

Sampling will start in units near Ellensburg in conjunction with training/testing. Many west side units should be clear of snow and ready to go – we'll be checking on access as noted in 3.c. above. Williamson would like to go on Eastside units – will be checking snow/mud conditions.

WDNR Road Sub-Basin Scale Effectiveness Monitoring Phase II
Second Unit Meeting Minutes
Friday May 23, 2008

Attendees Kathy Dubé, Scott Hotchkiss, Pete Malinak, Jesse Saunders, Dan Thomas, Brett Winterowd, (via conference call) Jenelle Black, Karen Kuzis

14. Introduction and Meeting Purpose

Purpose of meeting was to review the data collection procedures from the training, first, and second sample unit, and discuss any issues that came up in field assistance visits or replicate crew surveys to date.

15. Discussion

a. When is a skid trail vs. a road?
Contract says inventory roads, not skid trails (roads = driven on by logging trucks). Sometimes the distinction is not obvious, particularly if skid trails are constructed/graded. Came across examples in E008 - unit was harvested in last 5 years – making skid trails more obvious. The skid trail in question was graded and looked like a road for part of its length, but like a skid trail for last half of length and has not received maintenance. The manual says the roads only count if constructed to be driven on by trucks. Brent noted a reliable factor for identifying roads vs. skid trails are the location of landings and slash piles. If there is no landing at the end it probably wasn't used as a road. Crews will have to use some judgment in gray areas. The situation is most likely to arise in areas that have been harvested more recently.

b. Spring and seeps were observed in numerous cut slopes – when is it a stream?
Some are obvious seeps starting in a cut slope and forming a channel downstream (often in road ditch) which is then defined as gully. If there is an obvious upslope channel then it is a stream.

The definition was more difficult where water was coming out a bit above the cut slope. Kathy and the crews decided if the water and channel looks like it start is within 10-20 ft of cut slope and is associated with the ground disturbance at the cut slope, it should be classified as a seep. If the channel is further up the hill and cut into native material call it a stream.

c. When should you note sediment delivery that is not necessarily related to the roads being surveyed?
Jenelle observed a landing constructed on a spring complex that delivered and mitigation measures weren't working. She also noted skid trails constructed and filled in type 5 channels diverting water down skid trail to the stream. She had made notes of these situations on the map. After consideration she thought we might not want to attribute non-road related problems to specific landowners in notes or on the maps. Better approach would be to keep a list of observed sediment delivery sources not necessarily related to roads in a separate notebook and pass the information onto Kathy and Jenelle. If needed this can be communicated to landowners informally by Jenelle and if similar conditions are

observed in more than one location may be noted in the report as item for future consideration. If we find sediment sources not related to roads keep notes on separate paper don't make specific notes on field forms and maps.

d. Surfacing
Remember to agree on surfacing at beginning of the unit.

e. Monuments
Put monument tags at the base of the trees – do not make them too obvious as targets.

f. Recording Non-Delivering Stream Adjacent Roads
Dan at INFO is concerned this was not included in the original Scope of Work and will likely take more time especially in units with a high density of streams and wetlands. May need a change on work order.

Kathy noted the 1st unit had two additional segments non delivering segments they had to stop at 3 other segments measuring the distance. The 2nd unit 2 segments which were delivering and would be recorded anyway.

Jenelle noted if crews are driving along a road adjacent to stream they should be getting out and looking at the stream/road adjacent to the stream to assess delivery anyway. Dan noted if the segment is not delivering you don't need to make a segment.

Dan also noted on the Westside wetlands dam water and there are lots of wetlands adjacent to roads where they will need to add segments. Kathy noted the difference is adding segments even if no delivery. Dan will evaluate how long it takes to add the new segments to address Jenelle's concern that they would have been stopping and looking at these areas anyway.

Kathy noted a quick review showed 2,000 to 4,000 feet stream adjacent road in each unit. The team will have a call with Dan after they complete the Hancock Unit (W043) next week to discuss how much work this actually added.

g. Consistency Issue - Delivery
Kathy told the crews they need to get in the habitat of following the delivery flow chart to stay consistent.

16. Other items discussed after meeting – field crews please note

a. Powerline roads
Issue came up in E037 regarding powerline roads. Roads used just for powerline access are not subject to DNR regulations. Roads used for both powerline and timber haul are. Jenelle suggested checking with landowners in these units to determine which roads to survey/not survey.

b. GPS point at end of road
Dan said he normally takes a GPS point at the end of the road to mark the end point of survey for Ted.

c. Blocked roads

Jenelle said field crews should remember protocol on blocked roads. Walk road out with string box for 200 meters. If 90% veg cover on road, can stop. If less than 90% veg cover, keep walking to end (or point where 90% cover for 200 meters). Note blockage, how far you went/if vegetated on map.

17. Next Steps

Today the crews are heading to complete variability testing in Unit E083.

Next week (5/27 to 30) Info will sample W043 (Hancock) and the following week (6/2 to 6/6) they will be in Forks for Units S007 and S005.

Williamson starting June 2nd at a unit to be determined. Possibly E069? depending on permissions.

WDNR Road Sub-Basin Scale Effectiveness Monitoring Phase II
Phase II Survey Completion Meeting Minutes
Thursday January 29, 2009
8 AM via conference call

Attendees Kathy Dubé, Jesse Saunders, Dan Thomas, Brett Winterowd, Jenelle Black, Karen Kuzis, Ted Hitzroth

Meeting Purpose

Purpose of meeting was to discuss sampling results, any issues that arose during the project and the analysis of sample data required to meet project goals.

Items Discussed

1. Phase II Field Sampling
    a. Any issues or suggestions for next time? Any specific things noted in field that should be considered for analysis of particular units (i.e., most roads were vegetated so we didn't survey very far; lots of pulled culverts)
        - Add a new field in the non-delivering point file for presence of BMPs (some non-delivering culverts didn't deliver because landowners had done a great job with BMPs – should be noted)
        - Add a method to show if a road is not surveyed, and why. Note these roads on field map, and why not surveyed (e.g., vegetated, blocked, not found on ground). Add this information into GIS road layer (line feature attributes) and map. One reason this is important is because number of stream crossings in GIS vs. found in field is used to adjust miles of stream in unit (FFR metric)
        - Logistics:
            - Fro efficiency, define unit, contact landowners as far in advance as possible.
            - Good for field crews to know contacts, who has keys. Can be an issue on Eastside where some landowners don't know which locks are on which gates.
        - Training/documentation ideas:
            - Describe Eastern/Western WA road differences and how to classify them (ditches, etc.)
            - Definition of a stream, disconnected stream.

2. Post-Sampling Processing
    a. Any issues or suggestions for next time?
        - Add Point ID for non-delivering culverts
        - Add lat/longitude into Access database for each point so that other users can download into hand-held GPS units

3. QA/QC Protocols (training, management visits, replicate surveys/ride-alongs, crew variability assessment)
    a. Any issues or suggestions for next time?

- Make sure that field crews review data at end of day to help catch incorrect entries (particularly stationing that's way off)
- Training:
    - o Stress how to define a stream in the field, and include training on methods for disconnected streams.
    - o Include differences between Eastern and Western WA road construction techniques and how to code (for example, presence/absence of ditches, outsloped roads).
    - o Start field training with easier sites, then move onto more complex sites
    - o Maybe base training in Cle Elum area and include one field day on E WA roads, one field day on W WA roads.
- Crew variability – might get better measure of variability if easier road segments were used instead of confusing ones.

4. Data Analysis
    a. Database Entry
        - How to deal with new fields – stream adjacent – with 2006 data? Add new field into Access database, populate with -8888 for 2006 data to indicate that no data was collected in 2006
    b. Selection of 4 square mile area for 2006 data units
        - Jenelle will send a clipped coverage to Ted, Ted will send Kathy a file listing points that are in/out of 4 square mile area.

At this point the call was ended and Kathy, Jenelle, and Karen discussed the following items on Thursday February 5.

    c. Database update:
        - add fields for latitude/longitude for each point
        - pull Qsecs 17-24 from 2006 data into separate data tables within database.
    d. Statistical analysis (operator variability, Monitoring Design Table 10 Questions – MQ1, MQ3, MQ4) – Alice is unpacking in her new location; she said that she can do analysis at end of February.

5. Report Outline, Schedule
    a. Proposed outline, work products
        - Audience: assume there will be readers who do not know about CMER, monitoring program.
        - Intro – can get text from study design, RFP
        - Map – just put dot for each unit to show general area
        - Do not report results by unit in report (unit by unit summary in Access database)
        - Summarize results by region, large vs. small landowners
        - Summary – list monitoring questions and summary answers
        - Recommendations for future sampling events, scientific study. No policy recommendations.

b. Schedule – draft report end of February

6. CMER Presentation
   a. Abstract due 2/18
   b. Draft PowerPoint to Jenelle by 2/27 (review 3/2 in Olympia)
   c. Final PowerPoint to Jenelle by 3/16
   d. CMER Science Conference 3/18 – Kathy presents in Olympia
   e. CMER meeting presentation April 28?

Appendix B. Quality Assurance Project Plan (QAPP)

The Quality Assurance Project Plan is available electronically on the data CD.

Appendix C. QA/QC Report

The QA/QC Report is available electronically on the data CD.

Appendix D. Field Protocol

The 2008 field protocol is available electronically on the data CD.