MONITORING STUDY GROUP
CALIFORNIA STATE BOARD OF FORESTRY AND FIRE PROTECTION

HILLSLOPE MONITORING PROGRAM

MONITORING RESULTS FROM 1996 THROUGH 2001

DECEMBER 2002
SACRAMENTO, CALIFORNIA
BOARD OF FORESTRY AND FIRE PROTECTION

HILLSLOPE MONITORING PROGRAM:
MONITORING RESULTS FROM
1996 THROUGH 2001
December 2002

by Peter H. Cafferata and John R. Munn
California Department of Forestry and Fire Protection

MONITORING STUDY GROUP

Tharon O'Dell, Chair	California State Board of Forestry and Fire Protection
Dr. Marty Berbach, Brad Valentine	California Department of Fish and Game
Pete Cafferata, John Munn, Clay Brandow	California Department of Forestry and Fire Protection
Dr. Rich Walker, Dr. Russ Henly	California Department of Forestry and Fire Protection—Fire and Resource Assessment Program
Syd Brown	California Department of Parks and Recreation
Mark Rentz	California Forestry Association
Tom Spittler, Trinda Bedrossian	California Geological Survey
Joe Blum	National Marine Fisheries Service
Nathan Quarles	North Coast Regional Water Quality Control Board
Gaylon Lee	State Water Resources Control Board
Doug Eberhardt	U.S. Environmental Protection Agency
Dr. Richard Harris	University of California Cooperative Extension
Richard Gienger, SSRC/HWC	Member of the Public
Rob DiPerna, EPIC	Member of the Public
Roger Poff, R.J. Poff and Associates	Member of the Public
Mike Anderson, Anderson Logging Company	Member of the Public
Peter Ribar, Campbell Timberland Management	Industrial Timberland Owner
Bernie Bush, Simpson Resource Company	Industrial Timberland Owner
Tom Shorey, Fruit Growers Supply Company	Industrial Timberland Owner
Robert Darby, Pacific Lumber Company	Industrial Timberland Owner

The Monitoring Study Group (MSG) is made up of members of the public, resource agencies (both state and federal), and the timber industry. The agencies listed above make up the MSG; the names listed above are the primary representatives for these agencies at MSG meetings. The MSG chair is appointed by the Board of Forestry and Fire Protection (BOF) and the group is staffed by CDF. Each agency and organization is responsible for determining the appropriate person to serve as a representative on the MSG (i.e., the BOF does not make formal appointments to the MSG).

Executive Summary

The Hillslope Monitoring Program has been evaluating the implementation and effectiveness of California forest practices since 1996. This project began with field inspection of 50 timber harvesting plans (THPs) in Humboldt and Mendocino Counties in 1996, and has continued with a statewide random sample of 50 plans in subsequent years. Non-industrial timber management plans (NTMPs) were added in 2001.

As part of the Program, detailed information has been collected during summer months on THPs that have gone through one to four winters after harvesting was completed. Site characteristics, erosion problems, and Forest Practice Rule (FPR) implementation were recorded for randomly located landings, watercourse crossings and for randomly selected road, skid trail, and watercourse protection zone segments. Data was also collected at the site of large erosion events that were identified in the THP or located while conducting the field work. Some information was recorded on non-standard practices and additional mitigation measures when they were applied at the study sites and transects. Observations of fine sediment transport during winter storms were not included in this program because of logistic and safety concerns. Additionally, evaluation of the THP review and inspection process was not included as part of the Hillslope Monitoring Program.

This report is based on the 295 THPs and 5 NTMPs sampled through 2001. About 63 percent of these plans were on large ownerships and 37 percent were classified as smaller ownerships (non-industrial timberlands and other types of ownerships). The Coast Forest Practice District contained 61 percent of the plans, while the Northern and Southern Districts had 26 and 13 percent, respectively. The monitoring data was collected and entered into an extensive database by experienced independent contractors who acted as third party auditors. An interim report of study findings was prepared for the California State Board of Forestry and Fire Protection in June 1999. This report updates the interim findings and offers several recommendations. Analysis completed on the data set to date has primarily been composed of frequency counts and has been limited by time and access to database analysts. Additional data analysis will be conducted in the future.

Implementation and effectiveness of the Forest Practice Rules were rated by the field team as conditions requiring application of the Rules were encountered on the study sites and transects, and as part of an overall evaluation following completion of the inspection. In both cases, implementation of the Rules applicable to a given subject area was rated as either exceeding the requirements of the Forest Practice Rules, meeting the requirements, minor departure from requirements, major departure from requirements, not applicable, could not determine, or could not evaluate (with a description of why). At erosion problem points, the source and cause of the feature was recorded, along with whether sediment had been transported to a watercourse.

Results to date show that implementation rates of the Forest Practice Rules related to water quality are high and that individual practices required by the Rules are effective in

preventing hillslope erosion features when properly implemented. Overall implementation ratings were greater than 90 percent for landings and for road, skid trail, and watercourse protection zone transects. Watercourse crossings had the lowest overall implementation ratings at 86 percent. Implementation of applicable Rules at problem points was nearly always found to be less than that required by the FPRs. These results, however, do not allow us to draw conclusions about whether the existing Rules are providing properly functioning habitat for aquatic species, since evaluating the biological significance of the current Rules was not part of the project.

To focus on areas where improvement in Rule implementation would provide the greatest benefit to water quality and where educational efforts are required, a list of 20 FPR requirements with the highest percentage of major departures is provided in the report. Three of these Rule requirements relate to roads, three to both roads and crossings, one to both roads and landings, one to skid trails, one to landings, ten to watercourse crossings, and one to watercourse protection zones.

Watercourse crossing problems are caused by a number of factors, including inherent uncertainties in determining and implementing site specific construction and abandonment needs, improper maintenance, the finite expected life of culverts, and high risk location for sediment delivery when stream discharge exceeds design discharge. The majority of the evaluated crossings were existing structures that were in place prior to the development of the THP, and frequent problems related to adequate design, construction, and maintenance were found. Crossings with culverts installed as part of the plan evaluated had a significantly lower rate of problem points per crossing, when compared to existing culverted crossings. Common problems included culvert plugging, stream diversion potential, fill slope erosion, scour at the outlet, and ineffective road surface cutoff waterbreaks.

The other main problem area identified by this program is erosion from roads caused by improper design, construction, and maintenance of drainage structures. Nearly half the road transects had one or more rills present and approximately 25 percent had at least one gully. Evidence of sediment transport to at least the high flow channel of a watercourse was found on 12.6 percent and 24.5 percent of the rill and gully features, respectively, with high percentages of delivery to Class III watercourses. These erosion features were usually caused by a drainage feature deficiency, and the FPRs rated at these problem sites were nearly always found to be out of compliance. Most of the identified road problems were related to inadequate size, number, and location of drainage structures; inadequate waterbreak spacing; and lack of cover at waterbreak discharge points. About six percent of the drainage structures evaluated along the road transects were found to have problems.

In contrast, watercourse protection zones were found to retain high levels of post-harvest canopy and surface cover, and to prevent harvesting related erosion. Mean total canopy exceeded FPR requirements in all three Forest Practice Districts and was approximately 80 percent in the Coast Forest Practice District for both Class I and II watercourses. Surface cover exceeded 75 percent for all watercourse types in the three districts. WLPZ width requirements were generally met, with major Rule departures recorded only about one percent of the time. The frequency of erosion events related to current operations in watercourse protection zones was very low for Class I, II, and III watercourses. Similarly, landings and skid trails were not found to be producing substantial impacts to water quality. Erosion problems on landing surfaces, cut slopes, and fill slopes were relatively rare. Rill and gully erosion features on skid trails were much less frequent than found on road transects, and sediment delivery to watercourses was also considerably lower.

Preliminary results on the use of non-standard practices and additional mitigation measures indicate the need for more thorough THP inspection to ensure proper implementation. A more focused monitoring approach, however, is needed to adequately examine the implementation and effectiveness of these practices. To date, the emphasis of the Hillslope Monitoring Program has been on evaluating the adequacy of standard Forest Practice Rules, and relatively little data has been collected for non-standard practices.

Ten recommendations are provided based on study findings to date. Six of these relate to training needs for CDF Forest Practice Inspectors, RPFs, Licensed Timber Operators, and personnel from other reviewing agencies (e.g., CDFG, CGS, and the Regional Water Quality Control Boards). Since watercourse crossings were found to be a significant problem area, voluntary, cooperative road management plans are recommended to effectively locate, prioritize, and schedule improvement work for high risk crossing structures. The results of this study also indicate a need to revise the Hillslope Monitoring Program to adequately sample additional mitigation measures and non-standard practices that are frequently added to THPs. Study revisions are also needed to monitor changes in the Forest Practice Rules that have occurred since July 1, 2000. Finally, it is recommended that the BOF and CDF continue to support the implementation and funding of instream monitoring projects designed to monitor compliance with Regional Water Quality Control Board Basin Plan standards.

Acknowledgements

We would like to thank all the landowners that granted access for the Hillslope Monitoring Program from 1996 through 2001. Large landowners participating were: Barnum Timber Company, Coombs Tree Farms, Congaree River Limited Partnership, Crane Mills, Eel River Sawmills, Fruit Growers Supply Company, Georgia-Pacific Corporation, Gualala Redwoods Company, Hawthorne Timber Company, J.H. Baxter Company, LaTour Demonstration State Forest, Louisiana Pacific Corporation, Mountain Home Demonstration State Forest, Miller-Rellim Company, Mendocino Redwood Company, Pacific Lumber Company, Pacific Gas and Electric Company, Red River Forest (managed by W.M. Beaty and Associates), Richard Padula, Roseburg Resources Company, Shasta Forest (managed by W.M. Beaty and Associates), Sierra Pacific Industries, Siller Brothers, Inc., Simpson Resource Company, Soper-Wheeler Company, Stimson Lumber Company, Strategic Timber Trust, Timber Products Company, and Wetsel-Oviatt Lumber Company. Small landowners who participated are too numerous to thank individually, but their cooperation is deeply appreciated. In addition to providing access to their properties, many of these landowners (both small and large) assisted our field teams by providing maps, gate combinations, keys, and other help in locating the sites.

Roger Poff, Cliff Kennedy, and Joe Hiss collected data on more than 90 percent of the THPs and NTMPs monitored and provided helpful comments and suggestions throughout the project. Natural Resources Management Corporation (NRM) collected field data in Humboldt County on 25 THPs in 1996.

Clay Brandow of CDF assisted in many aspects of the project, including the laborious task of screening THPs and NTMPs in Santa Rosa, Redding, and Fresno.

CDF's State Forests Research Coordinator Tim Robards provided very valuable assistance with database queries for the current report and his efforts are greatly appreciated. We would also like to thank Dr. Don Warner, California State University, Sacramento, for his valuable assistance with the Hillslope Monitoring Program database over the entire six year period. Don developed the database, modified it as requested, maintained it, and queried it for report generation. CDF's Forest Practice Database Coordinator Shana Jones queried the Forest Practice Database for the basic pool of THPs and NTMPs to randomly sample.

CDF Deputy Director for Resource Management Ross Johnson recognized the importance of the Hillslope Monitoring Program and provided the funding for individual contracts to collect the field data and enter the data in the database from 1996 through 2001. Individuals representing the various state and federal agencies making up the Monitoring Study Group helped design the study and supplied valuable guidance and oversight for the Hillslope Monitoring Program throughout the six year period. CDF Secretaries and Office Technicians in Santa Rosa, Redding, and Fresno provided assistance with screening potential THPs and NTMPs and copying the appropriate sections of the THP/NTMP files for field work.

Table of Contents

List of Figures

List of Tables

Appendix Tables

List of Abbreviations

ACL	Associated California Loggers
BMPs	Best management practices
BOF	California State Board of Forestry and Fire Protection
CDF	California Department of Forestry and Fire Protection
CDFG	California Department of Fish and Game
CDPR	California Department of Parks and Recreation
CFA	California Forestry Association
CGS	California Geological Survey
CLFA	California Licensed Foresters Association
CPSS	Certified Professional Soil Scientist
CSES	Critical Sites Erosion Study
EEZ	Equipment exclusion zone
EHR	Erosion hazard rating
ELZ	Equipment limitation zone
ESU	Evolutionarily significant unit
FLOC	Forest Landowners of California
FPA	Forest Practice Act
FPRs	Forest Practice Rules
HMP	Hillslope Monitoring Program
LTMP	Long-Term Monitoring Program
LTO	Licensed Timber Operator
LWD	Large woody debris
MAA	Management Agency Agreement
MCR	Modified Completion Report
MSG	Monitoring Study Group
NMFS	National Marine Fisheries Service
NTMP	Nonindustrial Timber Management Plan
NCRWQCB	North Coast Regional Water Quality Control Board
NTO	NTMP Notice of Timber Operations
PHI	Pre-Harvest Inspection
PMP	Pilot Monitoring Program
QA/QC	quality assurance/ quality control
RCD	Resource Conservation District
RG	Registered Geologist
RPF	Registered Professional Forester
Rules	Forest Practice Rules
RWQCB	California Regional Water Quality Control Board
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
THP	Timber Harvesting Plan
UCCE	University of California Cooperative Extension
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Department of Agriculture, Forest Service
WLPZ	Watercourse and lake protection zone

Introduction

Monitoring the impacts of forestry related activities on water quality is an important issue for California. Aquatic species continue to be listed as threatened or impaired by state and federal agencies, such as the state listing of coho salmon in August 2002. The Regional Water Quality Control Boards are considering how to address a legislatively mandated expiration of waivers on January 1, 2003, for silvicultural activities under the Clean Water Act. The listing of numerous North Coast watersheds as impaired waterbodies under Section 303(d) of the Clean Water Act and the implementation of Total Maximum Daily Load (TMDL) requirements are significant issues to numerous landowners. Additionally, debate continues on the appropriate protection measures needed along small headwater streams for adequate water quality protection. Scientifically credible monitoring data is needed to help resolve these issues and to reach sound conclusions regarding the impacts of current timber operations on water quality.

The purpose of the Hillslope Monitoring Program is to determine if California's Forest Practice Rules are adequately protecting beneficial uses of water associated with commercial timber operations on nonfederal lands in California. In June 1999, the California State Board of Forestry and Fire Protection's Monitoring Study Group presented an interim report documenting preliminary findings from its Hillslope Monitoring Program (CSBOF 1999). Additional data collected over the past three years is now sufficient for the preparation of a second report on the project. Hillslope monitoring will continue in the future, with refined protocols for improved tests of individual practice effectiveness. Continued monitoring is also needed to evaluate changes in the California Forest Practice Rules, the issues raised above, and the changing expectations of resource agencies and California's citizens.

The Hillslope Monitoring Program is not the only approach used in California to determine impacts of timber operations to water quality. Other efforts to evaluate how well California's Forest Practice Rules are implemented and how effective they are in protecting water quality include: 1) extensive inspection, enforcement, and monitoring by California Department of Forestry and Fire Protection Forest Practice Inspectors, and 2) research conducted as part of detailed watershed studies, such as the Caspar Creek watershed study. Each approach has its advantages and disadvantages. The Hillslope Monitoring Program described in this report complements these efforts, and when combined with the results from other monitoring efforts, conclusions can be reached regarding Rule implementation and effectiveness (Ice et al. 2002).

Specific objectives of the Hillslope Monitoring Program are: 1) implementation monitoring to determine if the Forest Practice Rules (FPRs) related to water quality are properly implemented, and 2) effectiveness monitoring to determine if the FPRs affecting water quality are effective in meeting their intent when properly implemented. Both implementation and effectiveness monitoring are necessary to differentiate between water quality problems created by non-compliance with a FPR, versus problems with the practice itself. The goal of effectiveness monitoring is to provide information on where, when, and in what situations problems occur under proper implementation (Tuttle 1995). Determining which Rules have the poorest implementation and effectiveness and the highest frequency of violations both provides input to the BOF on needed Rule changes and identifies training needs for: (1) CDF's Forest Practice Inspectors; (2) Registered Professional Foresters (RPFs) submitting THPs; and (3) Licensed Timber Operators (LTOs).

Background Information

California's modern Forest Practice Act (FPA) was adopted in 1973, with full field implementation occurring in 1975, and many monitoring efforts have taken place over the past two decades to learn more about the implementation and effectiveness of California's Forest Practice Rules in protecting water quality. These monitoring efforts complement the California Department of Forestry and Fire Protection (CDF) Forest Practice compliance inspection program that has been in place for over 25 years.

Under the FPA, Timber Harvesting Plans (THPs) must be submitted to CDF and approved for commercial timber harvesting on all non-federal timberlands. THPs are reviewed for compliance with the FPA and the Forest Practice Rules adopted by the Board of Forestry and Fire Protection (BOF), as well as other state and federal regulations protecting watersheds and wildlife. CDF, along with the Department of Fish and Game, Regional Water Quality Control Boards, and the California Geological Survey, conducts Pre-Harvest Inspections (PHIs) of proposed harvest areas to determine if plans are in compliance with the Act and FPRs. During PHIs, additional mitigation measures beyond the standard rules are often recommended based upon site-specific conditions. This report focuses on water quality issues, but the added THP mitigation also relates to habitat protection, public safety, and numerous other public trust resources. CDF also conducts inspections during active timber operations and the post-harvest period when logging is completed to assess compliance with the Act, the FPRs, and the specific provisions of the THP.

The State Water Resources Control Board (SWRCB) certified the Forest Practice Rules and review process as Best Management Practices under Section 208 of the Federal Clean Water Act in 1984, with a condition that a monitoring and assessment program be implemented. Initially, a one-year qualitative assessment of forest practices was undertaken in 1986 by a team of four resource professionals (Johnson 1993) that audited 100 THPs distributed across the state and produced the final "208 Report" (CSWRCB 1987). The team found that the Rules generally were effective when properly implemented on terrain that was not overly sensitive, and that poor Rule implementation was the most common cause of observed water quality impacts. They recommended several changes to the FPRs based on their observations.

Additional water quality monitoring projects in the 1980's related to the Forest Practice Rules include the Critical Sites Erosion Study (CSES), conducted within watersheds throughout northern California, and the North Fork phase of the Caspar Creek watershed study, located near Fort Bragg. Objectives of the CSES project were to determine site characteristics on THPs that could be used to identify potential large erosion features, and to identify management factors which may have been responsible for erosion events. This project collected data during 1985 and 1986 on management and site factors associated with existing mass wasting events on a random sample of 314 THPs covering over 60,000 acres (Durgin et al. 1989; Lewis and Rice 1989, Rice and Lewis 1991). A brief summary of the Caspar Creek watershed study findings is included in the following section under Summary of Related Studies.

In 1988, the Board of Forestry, CDF, and the SWRCB entered into a Management Agency Agreement (MAA) that required the BOF to improve forest practice regulations for protection of water quality based on needs described in the "208 Report." At this point, the SWRCB approved final certification of the FPRs as Best Management Practices. The U.S. EPA, however, withheld certification until the conditions of the MAA were satisfied, one of which was to develop a long-term monitoring program (LTMP).

In response to the MAA conditions, the BOF formed an interagency task force, later known as the Monitoring Study Group (MSG), in 1989 to develop this long-term monitoring program that could test the implementation and effectiveness of FPRs in protecting water quality. With public input, the MSG developed a LTMP with both implementation and effectiveness monitoring components, and conducted a pilot project to develop appropriate techniques for both hillslope and instream monitoring (CSBOF 1993). CDF has funded this monitoring program since 1990.

From 1989 to 1999, the MSG was an "ad hoc" committee which met periodically to: 1) develop the long-term monitoring program, and 2) provide guidance to CDF in implementing the program. The MSG was designated as an Advisory Committee to the Board of Forestry and Fire Protection in January 2000. The MSG continues to refine the long-term monitoring program testing the effectiveness of California's Forest Practice Rules and provide oversight to CDF in implementing the program.

The primary goal of the MSG's monitoring program has been to provide timely information on the implementation and effectiveness of forest practices related to water quality for use by forest managers, agencies, and the public. CDF and BOF chose to place more initial emphasis on hillslope monitoring for the Long-Term Monitoring Program because it can provide a more immediate, cost effective and direct feedback loop to resource managers on impacts from current timber operations when compared to instream monitoring (particularly channel monitoring which involves coarse sediment parameters) (Reid and Furniss 1999). As stated in Robben and Dent (2002), it is usually easier to identify a sediment source and quantify the volume of sediment it produced, when compared to measuring sediment in the watercourse and tracing it to the source.

The components of the Long-Term Monitoring Program are described in the MSG's Strategic Plan (CSBOF 2000) adopted by the BOF in 2000. This program is robust—utilizing a combination of approaches to generate information on Forest Practice Rule implementation and effectiveness related to water quality. The major components of the program include: 1) continuation of the Hillslope Monitoring Program, 2) use of CDF Forest Practice Inspectors to collect hillslope monitoring data on a random sample of completed THPs as part of a Modified Completion Report (MCR), 3) development of scientifically credible monitoring plans for cooperative watershed monitoring projects in selected basins to provide instream monitoring data, and 4) development and/or funding of selected monitoring projects that can answer key questions about forest practice implementation and effectiveness.

To date, considerable information has been collected by projects conducted as part of each of these components of the Long-Term Monitoring Program. A summary of what has been learned so far as part of the Modified Completion Report monitoring process is included in the following section of this report. One cooperative instream monitoring project has been started in the Garcia River watershed. The first phase of the project provided a watershed assessment and instream monitoring plan (Euphrat et al. 1998). The second phase was implementation of the instream monitoring plan to document baseline habitat conditions, which will allow examination of long-term trends to determine if instream conditions are improving. A final report documenting baseline measurements made in 1998 and 1999 for parameters such as water temperature, canopy and shading, gravel composition and permeability, large wood loading, sediment source areas, fish surveys, channel cross sections, and thalweg profiles was produced in 2001 (Maahs and Barber 2001). In 2002/2003, smaller scale cooperative instream monitoring projects are planned in Mendocino County with Campbell Timberland Management/ Hawthorne Timber Company, and in the Sierra Nevada/Cascade province with Sierra Pacific Industries.

Additionally, numerous monitoring projects have been supported, or are currently being supported, by CDF that provide critical information related to monitoring techniques and/or answer key questions regarding forest practice implementation and effectiveness. Examples of these projects include:

- Testing Indices of Cold Water Fish Habitat—Knoop (1993)
- V-Star Tests in Varying Geology— Lisle (1993), Lisle and Hilton (1999)
- Erodible Watershed Index--McKittrick (1994)
- Evaluation of Road Stream Crossings (Flanagan et al. 1998)
- Sediment Storage and Transport in the South Fork Noyo River Watershed, Jackson Demonstration State Forest (Koehler et al. 2001)
- Sediment Composition as an Indicator of Stream Health (Dr. Mary Ann Madej, USGS, and Dr. Peggy Wilzbach, HSU; in progress)
- Central Sierra Nevada Sediment Study (Dr. Lee MacDonald, CSU; in progress)
- Caspar Creek Watershed Study—Ziemer 1998, Lewis et al. 2001 (Dr. Robert Ziemer, USFS-PSW (retired), Dr. Thomas Lisle, USFS-PSW, in progress)

Final reports for completed projects, as well as other earlier monitoring reports and papers, detailed information on the Modified Completion Report monitoring process, the MSG Strategic Plan, and agendas for upcoming MSG meetings are available online at:
http://www.fire.ca.gov/bof/board/msg_geninfo.html

Over 100 papers and reports documenting findings from the Caspar Creek Watershed Study are available online at:
http://www.rsl.psw.fs.fed.us/projects/water/caspubs.html

Summary of Other Related Studies

Several recently completed and ongoing monitoring efforts are related to the hillslope monitoring work reported on in this document. Many of the findings in these studies are similar to and support results described in this Hillslope Monitoring Program report.

Colorado State University, Department of Earth Resources— Central Sierra Nevada Sediment Study. Dr. Lee MacDonald and Drew Coe, Colorado State University, Fort Collins, CO (MacDonald and Coe 2001; Coe and MacDonald 2001; Coe and MacDonald 2002)

The objective of this research is to quantify natural and anthropogenic hillslope erosion rates for use in a spatially-explicit cumulative watershed effects model. Study sites are on the Eldorado National Forest and Sierra Pacific Industries land in the Central Sierra Nevada. Approximately 150 sediment fences were installed in the summers of 1999 and 2000 to measure sediment production and sediment delivery to the stream network (Figure 1). Silt fences were installed in areas subjected to different management activities, including undisturbed sites, across three geologic types (volcanic, granitic, and metamorphic) and different elevation zones. Sediment production rates were measured for three winter periods (hydrologic years 2000 through 2002). The first winter was the wettest of the three years, while the second winter was drier and colder. The third winter was intermediate in terms of total precipitation and the duration of snow cover.

Data analysis is currently nearing completion, although several progress reports and presentations have described some of the initial key findings. The results have shown that native surface roads are the primary anthropogenic source of sediment. High rates of sediment production have also been documented for high severity wildfires and areas used for off-highway vehicles. Most harvest units and areas burned at low severity produced relatively little sediment. Overall, there was a large degree of variability between sites within a given management category as well as between years. For example, sediment production rates in the first year were 3 to 11 times higher than the sediment production rates for the second winter, and this is due in large part to the lower amounts of precipitation and more consistent snow cover.

Data from the first winter showed that, on average, native-surface roads generated approximately seven times as much sediment as harvest units and landings. These results led to a greater focus on sediment production from native surface roads. Data from the next two winters indicated that recently-graded native surface roads produced twice as much sediment as comparable segments that had not been graded. Road surface area, slope, annual precipitation, elevation, and grading (i.e., recently graded vs. ungraded) were the primary controls on road sediment production. The product of road surface area and road gradient was the single best predictor of road surface erosion, and this explained from 40 to 65% of the variability within a given year. Rocked roads produced only 2-4% as much sediment as comparable native surface roads. Relative to the other factors, soil type was not an important control on sediment production from the native surface roads. However, the limited data suggest that erosion rates from harvest units on granitic soils can be as much as an order of magnitude larger than the erosion rates from harvest units on volcanic soils.

A survey of 285 road segments as defined by specific drainage outlets (e.g., waterbar, rolling dip, or culvert) indicated that approximately 18% of the segments (20% of the total surveyed length) had gullies or sediment plumes that reached to within 10 m (33 ft) of a stream channel. Road crossings accounted for 58% of the road segments that were connected to the stream network.

Overall, the highest sediment production rates were often associated with insloped road segments located downslope of areas with shallow, impermeable bedrock. Because the product of area and slope was a dominant control on road segment sediment production, the older roads with inadequate drainage produced much more sediment per unit area than roads that followed current drainage specifications. Hence the best means to reduce erosion rates from native surface roads is to alter the road surface by rocking, decreasing the product of area and slope by improving and maintaining road drainage, and avoiding areas with shallow bedrock that increase sideslope drainage and increase ditch runoff. Areas with shallow bedrock also appear to facilitate the generation of extended gullies that can link roads to the stream network. These segments, together with road crossings, account for nearly all of the road-derived sediment that is being delivered to the stream network.

Figure 1. Example of one of 147 sediment fences installed to measure sediment production rates in the central Sierra Nevada Mountains (photo by Drew Coe used with permission).

US Forest Service—Pacific Southwest Region—Best Management Practice Evaluation Program. Brian Staab, USFS, Vallejo, CA (Staab 2002)

The U.S. Forest Service's (USFS) Best Management Practices (BMP) Evaluation Program in California is focused on hillslope monitoring of BMP implementation and effectiveness. Preliminary results indicate that USFS silvicultural BMPs are generally implemented and effective. Statewide, average implementation and effectiveness rates from 1992-2001 were both approximately 87% (n=2900 random evaluations). Yearly rates of BMP implementation and effectiveness ranged from 83% to 91% and 78% to 92%, respectively. Effectiveness rates were above 85% every year except 1997. Implementation and effectiveness rates, respectively, for specific silvicultural BMPs were as follows: streamside management zones: 82%/79% (n=248); skid trails: 84%/91% (n=276); suspended yarding 97%/90% (n=87); landings: 90%/95% (n=373); timber sale administration (n=62): 95%/98%; special erosion control and revegetation: 84%/96% (n=57); meadow protection: 93%/95% (n=121); road surface, drainage and slope protection: 87%/84% (n=238); stream crossings: 86%/80% (n=259); control of sidecast: 81%/89% (n=185); servicing and refueling: 95%/97% (n=38); in-channel construction practices: 92%/61% (n=115); temporary roads: 91%/88% (n=120); rip rap composition: 91%/82% (n=22); snow removal: 85%/87% (n=163); pioneer road construction: 96%/56% (n=25); management of roads during wet periods: 92%/85% (n=61); prescribed fire: 77%/95% (n=231); vegetation manipulation: 89%/96% (n=93); and revegetation of surface disturbed areas: 84%/76% (n=85).

Oregon Department of Forestry—Best Management Practices Compliance Monitoring Project: Final Report. Joshua Robben and Liz Dent, ODF, Salem, OR (Robben and Dent 2002)

The ODF Forest Practice Monitoring Program implemented the BMP Compliance Monitoring Project to evaluate compliance with BMPs on non-federal forestlands in Oregon. This was a three year statewide project, with the first year (1998) being a pilot study to develop and test protocols. A total of 189 harvest operations were randomly selected, using criteria that favored selection of units with fish-bearing waters. At the selected units, harvesting practices, roads, skid trails, stream crossings, riparian management areas, wetlands, etc. were evaluated for compliance with 150 Forest Practice Rules designed to protect water quality and fish habitat. Monitoring was completed by a former Forest Practices Forester who rated individual BMP applications as compliant or noncompliant. The type and magnitude of resulting riparian and channel impacts were recorded for noncompliant practices.

A total of approximately 13,500 BMP applications were evaluated and the overall compliance rate was 96.3%. Specific practices that were found to have the poorest compliance (less than 96% compliance and five or more noncompliance practices) are: slash piling within waters of the state (89.6%), removal of petroleum-related waste from the unit (82.0%), stream crossing fill stability (84.3%), road surface drainage design (86.5%), road surface drainage maintenance (94.2%), restrictions on felling of trees into small streams (83.1%), skid trails not located within 35 feet of Type F streams (91.5%), skid trails located so that stream water will not flow onto the skid trail (92.5%), removal of temporary crossings (47.8%), protection of other wetlands (69.8%), prior approval requirements (90.4%), and written plan requirements (77.1%).

Approximately 500 noncompliant practices were recorded and 185 of these were administrative requirements not directly affecting water quality. About 65% of the noncompliant practices either had impacted water quality or had the potential to impact riparian and channel conditions in the future. The greatest source areas of sediment delivery were from 36 noncompliant road construction and maintenance practices. To improve BMP compliance, the results of this monitoring work are being presented to landowner groups, operator workshops, and Oregon Department of Forestry conferences. Additionally, the results are being used to clarify guidance language, develop additional implementation tools, and guide future monitoring work.

California Department of Forestry and Fire Protection—Modified Completion Report Monitoring Progress Report. Clay Brandow, CDF, Sacramento, CA (Brandow 2002)

As part of the CDF's Forest Practice Program, the Department's Forest Practice Inspectors collect hillslope monitoring data for areas of the landscape that have been found in previous monitoring work to be either particularly sensitive to disturbance or having significant impacts to water quality. For each THP evaluated, a randomly selected road segment (1000 feet), a randomly selected WLPZ segment (200 feet), and two randomly located watercourse crossings are rated for FPR implementation at the time logging is completed. Effectiveness of erosion control facilities and crossing design/construction are rated a second time for the same road segment and crossings during an Erosion Control Maintenance inspection after one to three overwintering periods. Rating implementation immediately following logging and effectiveness after stressing winter storms follows the guidelines suggested by Lewis and Baldwin (1997) in a statistical review of the Hillslope Monitoring Program. Sample size is a random selection of 12.5% of THPs undergoing Work Completion Report field inspections. As of September 2002, 132 THPs have been sampled, with 101 having a Class I or II WLPZ. Class I WLPZ total canopy has averaged 83% in the Coast District and 68% in the inland (Northern and Southern) districts. Class II total canopy has been similar, with 83% and 69% in the Coast and inland districts, respectively. For the road segments to date, 15% of evaluated stretches have had at least one departure from the FPRs. Most of the departures have related to waterbreak spacing, waterbreak discharge into cover, and waterbreak construction. Additionally, 145 crossings have been sampled, and FPR departure rates have been found to be low (contrary to Hillslope Monitoring Program results). This may be due to: 1) fewer overwintering periods; 2) differences in monitoring forms, rating categories, and reviewer opinions; and 3) requirement for major problems to be fixed prior to plan completion report approval.

US Forest Service—Pacific Southwest Research Station—Caspar Creek Watershed Study. Dr. Robert Ziemer, Chief Research Hydrologist (retired), Redwood Sciences Laboratory, Arcata, CA; Dr. Thomas Lisle, Research Hydrologist, Redwood Sciences Laboratory, Arcata, CA. (Ziemer 1998, Lewis 1998, Cafferata and Spittler 1998, Lewis et al. 2001, Lewis 2002)

Results from the Caspar Creek watershed study located near Fort Bragg, California show that improved forestry practices after 1974 have significantly reduced sediment yields in the past two decades. Selection logging conducted prior to the implementation of the modern Rules in the South Fork of Caspar Creek produced from 2.4 to 3.7 times more suspended sediment compared to that produced by clearcutting in the North Fork under the modern Rules. Suspended sediment monitoring in the North Fork of Caspar Creek following clearcut harvesting of almost half the watershed in three years under the modern Forest Practice Rules showed that annual sediment loads increased 123-269% in the tributaries. At main-stem stations, however, increased loads were detected only in small storms and there was little effect on annual sediment loads. Most of the suspended sediment generated at the North Fork weir resulted from one large landslide that occurred in January 1995.

The overall conclusion from the Caspar Creek watershed study is that logging operations conducted under the modern Forest Practice Rules produce much less sediment than logging in the early 1970's prior to the implementation of these Rules. Unit area sediment loads from four storm events in hydrologic year 2001 show that sediment yields are higher in several South Fork tributary watersheds, without disturbance for almost 30 years, than was found in clearcut tributary basins in the North Fork that were logged approximately 10 years ago. Much of this difference is attributed to poor design, construction, and maintenance of pre-modern Forest Practice Rule roads, landings, and skid trails.

Road rehabilitation work was conducted during the summer of 1998 on three miles of old road constructed along the South Fork in 1967. A total of 33 watercourse crossings were abandoned, removing a total of approximately 28,500 cubic yards of fill material. Surveys of the abandoned crossings have shown that downcutting following large winter storm events, including a 40-year recurrence interval event the first winter following excavation, has resulted in 854 cubic yards of sediment, or three percent of the total amount of sediment removed, being washed downstream. Most of this material came from three crossings. Approximately 500 cubic yards were lost from one abandoned crossing on the mainstem of the South Fork, primarily from upstream residual deposits of sediment above an old splash dam built in the 1860s. The other two problem crossings each lost 50 to 70 cubic yards of sediment due to downcutting at the crossing site. Little additional downcutting has occurred after the first winter following excavation (W. Baxter, CDF—Jackson Demonstration State Forest, Fort Bragg, CA, personal communication).

Study Design

Overview

The Hillslope Monitoring Program began in 1993 with a pilot project designed to develop and test monitoring procedures. Dr. Andrea Tuttle and CDF began the process by modifying previously developed U.S.D.A. Forest Service hillslope monitoring forms developed for the Pacific Southwest Region (USFS 1992). Modifications were made to allow detailed information to be recorded for locations within Timber Harvesting Plans (THPs) that were felt to present the greatest risk to water quality--roads, skid trails, landings, watercourse crossings and watercourse and lake protection zones (Tuttle 1995). The forms developed for the U.S. Forest Service monitoring program did not adequately identify the specific requirements of the Forest Practice Rules. As a result, these initial forms were either substantially modified (i.e., watercourse crossings and landings) or completely re-written (i.e., transect evaluations were developed for roads, skid trails, and watercourse and lake protection zones). Dr. Tuttle and CDF prepared new forms for practices that are unique in the FPRs, and developed methods for measuring and identifying features related to Rule implementation and effectiveness. Harvest units were not included because few of the Rules apply to these areas and previous studies had shown that most of the erosion features were associated with the more disturbed sites (Durgin et al. 1989).

As part of the hillslope component of the Pilot Monitoring Project, Monitoring Study Group members identified all of the separate Forest Practice Rule requirements that could be related to protection of water quality. This resulted in a list of over 1300 separate items, including plan development, the review process, and field application requirements. This list was then pared down to 191 Rule requirements that are implemented during the conduct of a Timber Harvesting Plan and can be evaluated by subsequent field review. Many of the Rule sections with multiple requirements were broken down into their separate components for field evaluations.[1] FPRs related to cumulative watershed effects and the THP review process were not included because they could not be evaluated using an on-the-ground inspection of the THP area. The overall goal of the Hillslope Monitoring Program has been to collect data that can, over time, provide information on: 1) how well the Rules are being implemented in the field, and 2) where, when, and to what degree problems occur—and don't occur—under proper implementation (Tuttle 1995).

The California Division of Mines and Geology (now known as the California Geological Survey) assisted with the hillslope pilot program and provided detailed geomorphic mapping for two of the watersheds used for the pilot work (Spittler 1995). The California Department of Fish and Game completed the pilot project work for the instream monitoring component of the program (Rae 1995). The Pilot Monitoring Program was completed during 1993 and 1994, and final reports were prepared in 1995. Pilot

[1] The Forest Practice Rules referred to in this report, including all the tables, are based on the Rules in effect in 1994. Changes to the FPRs since that time have affected the letters and numbers assigned to some individual Rules, but the listed Rules remain in effect in the same Rule Section.

Monitoring Program Manager Gaylon Lee of the SWRCB prepared a summary document that included a detailed description of what had been learned about hillslope monitoring and made recommendations for the long-term program (Lee 1997).

Site Selection

Data collection for the BOF/CDF Hillslope Monitoring Program began in 1996 with a stratified random sample of 25 THPs in both Humboldt and Mendocino Counties to collect information from watersheds with coho salmon habitat, due to the proposed federal listing of that species.[2] Contracts were developed with the Resource Conservation Districts (RCDs) in each county, and the RCDs hired Registered Professional Foresters (RPFs) to collect the required field data on THPs that had over-wintered for a period of one to four years. Natural Resources Management Corporation (NRM) was the contractor hired by the Humboldt County RCD, while R.J. Poff and Associates was hired by the Mendocino County RCD. Stratified random sampling was utilized to select the THPs for work completed in 1996. Using erodibility ratings developed as part of a study completed by the California Division of Mines and Geology (now the California Geological Survey) (McKittrick 1994), approximately 50 percent of the THPs evaluated were included in the areas designated as having high overall erosion hazard, 35 percent were included in the moderate category, and 15 percent were included in the low erosion hazard rating.[3]

From 1997 through 2001, field data was collected from a statewide random sample of 50 THPs each year. These THPs were not stratified based on the CGS erodible watershed categories utilized in 1996. While only a fraction of all completed THPs were evaluated, the random sample design ensured that the results were representative of all the THPs harvested during the same period. Beginning in 2001, Nonindustrial Timberland Management Plan (NTMP) Notices of Timber Operations (NTOs) (or NTMP projects) were included as part of the sample because of the growing number of NTMPs statewide, and a lack of information regarding rule implementation and effectiveness on these projects. NTMPs are long-term management plans for small nonindustrial timberland owners. When a portion of the area covered by the NTMP is to be harvested, an NTO is submitted to CDF for review and is valid for one year following approval.

CDF's RBASE Forest Practice Database was queried from 1996 through 1998 in Santa Rosa, Redding, and Fresno to produce a combined list of potential THPs meeting the completion and acceptance dates (approximately 2,500 THPs were in the population).

---

[2] Coho salmon were listed by the NMFS as threatened for the Southern Oregon/Northern California Coasts Coho ESU in 1997.

[3] This project rated large (e.g., 50,000 acre) watersheds on their inherent erodibility, excluding land use impacts. Variables input into a GIS model included precipitation, slope, and geology. A low, moderate or high rating was assigned to each factor. Numbers were summed to create an ordinal display of relative susceptibility of watersheds to erosion.

Beginning in 1999, CDF's new Oracle Forest Practice Database system was queried in Sacramento to generate the list of potential THPs and, in 2001, NTMP NTOs, with appropriate completion and acceptance dates.

These queries produced a preliminary, randomized list of THPs and NTMP NTOs to evaluate. Individual THP and NTMP files were then reviewed at CDF's regional offices in Santa Rosa, Redding, and Fresno to determine whether the individual plans met the criteria for when the logging was completed, the length and types of watercourses present, yarding system(s) utilized, plan or project size, and wildland classification described below. THPs eliminated from the preliminary list were replaced with the next THP meeting the above criteria, keeping the original percentages for each CDF Forest Practice District (i.e., Coast, Northern and Southern) established in the random sort.[4] The statewide sample, therefore, is very similar to the distribution of THPs CDF receives at each of its three Forest Practice District offices.

Specifically, THPs and NTMP NTOs were included in the study if they met the following criteria:

1. The THP had been filed and completed under the Forest Practice Rules adopted by the BOF after October 1991 (when the most recent WLPZ rules were implemented prior to adoption of the Threatened and Impaired Watersheds Rule Package in July 2000).

2. The THP was not accepted by CDF after the adoption of the July 2000 Threatened and Impaired Watersheds Rule Package.

3. The plans had been through at least one, but not more than four winters, since logging was completed. To ensure that plans met this requirement, the CDF Work Completion Report for the entire THP must have been signed by a CDF Forest Practice Inspector, and the date used to determine the one to four over-wintering periods was the date supplied by the RPF that indicated when all the logging was completed on the THP. This length of over-wintering provided the opportunity for erosion control measures to be tested by wet-weather prior to the field evaluation of effectiveness.

4. The THP or NTMP NTO was primarily composed of wildlands (e.g., it was not a campground or golf course). Also, the THP or NTMP NTO could not be a road-right-of-way-only plan.

5. The THP or NTMP NTO was not entirely helicopter logged and had significant components of either ground based tractor logging and/or cable yarding systems.

[4] If this were not done, a much higher percentage of THPs would have been selected from the Coast Forest Practice District, since many more of these plans have the required watercourse length.

6. The THP or NTMP NTO had at least 500 continuous feet of a Class I or II watercourse present, or the project boundary was a distance from the Class I or II watercourse that would correspond to what the Forest Practice Rules would prescribe for a WLPZ for that watercourse type and slope.

7. The THP was at least 5 acres in size.

8. The THP was not previously sampled.

Permission for THP access was first requested in a letter written by CDF and then with follow-up telephone calls made by the contractor for those plans where a response was not received. CDF stressed that there was no possibility of legal actions as a consequence of the field inspection, since no citations or violations could be issued by our contractor. Where permission was not granted, the next THP on the list was used. Permission was received from large industrial owners for all but one THP. In contrast, more than 50 percent of the selected THPs on small, nonindustrial timberlands were excluded from the study because of either an inability to locate the landowner, sale of the parcel, or denial of access. This resulted in the study being weighted toward the industrial timberlands.

Starting in 2000, to prevent additional bias in the sample towards large industrial forest landowners, large forest landowner THPs that were rejected due to a lack of access were replaced with other large landowner plans, and small landowner plans were replaced with other small landowner THPs. Large landowners were arbitrarily defined as having combined ownership in California of at least 6,000 acres based on a list of landowners and their ownership size developed by CDF Forest Practice Program staff. This practice was largely successful, but a few large industrial plans were still needed at the last moment when small non-industrial landowners changed their mind about access.

When permission for access was received for 50 THPs and NTMP NTOs, a final list of projects was developed and copies of the THPs and NTMPs were made by the CDF Regional Offices for the contractor. The contractor was supplied with copies of the Pre-Harvest Inspection reports, Amendments, Notices of Violations, and Final Work Completion Reports (including maps). Alternate THPs were supplied for each Forest Practice District in 1999, 2000, and 2001 in addition to the 50 THPs and NTMP NTOs. This was necessary to provide alternate plans for situations where field inspection revealed that the THP would not be acceptable for monitoring (e.g., all the roads had their drainage structures removed for more recent logging activities).

Data Collection

The monitoring work was conducted by independent contractors who acted as third party auditors (Figure 2). CDF developed the bid package, advertised the bid package, accepted bids from qualified contractors, and hired the qualified contractor with the lowest bid for each year from 1997 through 2001. To qualify, bidders must have met the following requirements:

1. The Contractor must have been a Registered Professional Forester (RPF) in the state of California. The Contractor could employ assistants who were not Registered Professional Foresters who worked under the supervision of the RPF and the on-site team conducting each THP or NTMP NTO must have included at least one RPF and one earth scientist (note that one person meeting both requirements could fill this role).

2. The Contractor must have had experience in the development, implementation, and evaluation of THPs on private timberlands within the state of California.

3. The Contractor must have had a working knowledge of the California Forest Practice Rules and experience with tractor and cable logging operations.

4. The Contractor's team must have had experience evaluating hillslope erosion problems, and must have had at least one member who was an earth sciences specialist with soil science or geology expertise and who had experience working with forested environments. To meet this criteria, one of the team members must have been either a **Certified Professional Soil Scientist** (CPSS) (as designated by the American Registry of Certified Professionals in Agronomy, Crops, and Soils) or a **California Registered Geologist** (RG) (as designated by the Board for Registration of Geologists and Geophysicists).[5]

5. The Contractor must have had an extensive background in monitoring, including experience with on-site monitoring to evaluate the impacts of timber operations on water quality.

The contractor for each of these contracts from 1997 to 2001 was R.J. Poff and Associates. Mr. Roger Poff was the U.S.D.A. Forest Service North Sierra Zone Soil Scientist and was stationed on the Tahoe National Forest from 1980 to 1993. He is both a Certified Professional Soil Scientist and a Registered Professional Forester (RPF) in California. Assisting Mr. Poff were Mr. Cliff Kennedy, an RPF in California, and Mr. Joe Hiss, the principles of High Country Forestry.[6]

Field work was conducted during the spring, summer, and fall months. During the site inspections, data was recorded by the contractor on paper field forms supplied by CDF. Detailed information was collected on: 1) randomly located road, skid trail, and watercourse protection zone segments; randomly located landings and watercourse crossings; 2) large erosion events (e.g., mass wasting features) where they were encountered, and 3) non-standard practices and additional mitigation measures when they were utilized at the randomly sampled locations. A set of forms was provided for each of these subject areas, with sub-sections for site information, non-standard practices and additional mitigation measures, rule implementation, and rule

[5] From 1997 to 1999, the bid package specified that the one of the members of the field team must be either a RG, CPSS, or a Certified Professional Erosion and Sediment Control Specialist (CPESC).

[6] Mr. Chris Hipkin, RPF, assisted R.J. Poff and Associates in 1996 in Mendocino County.

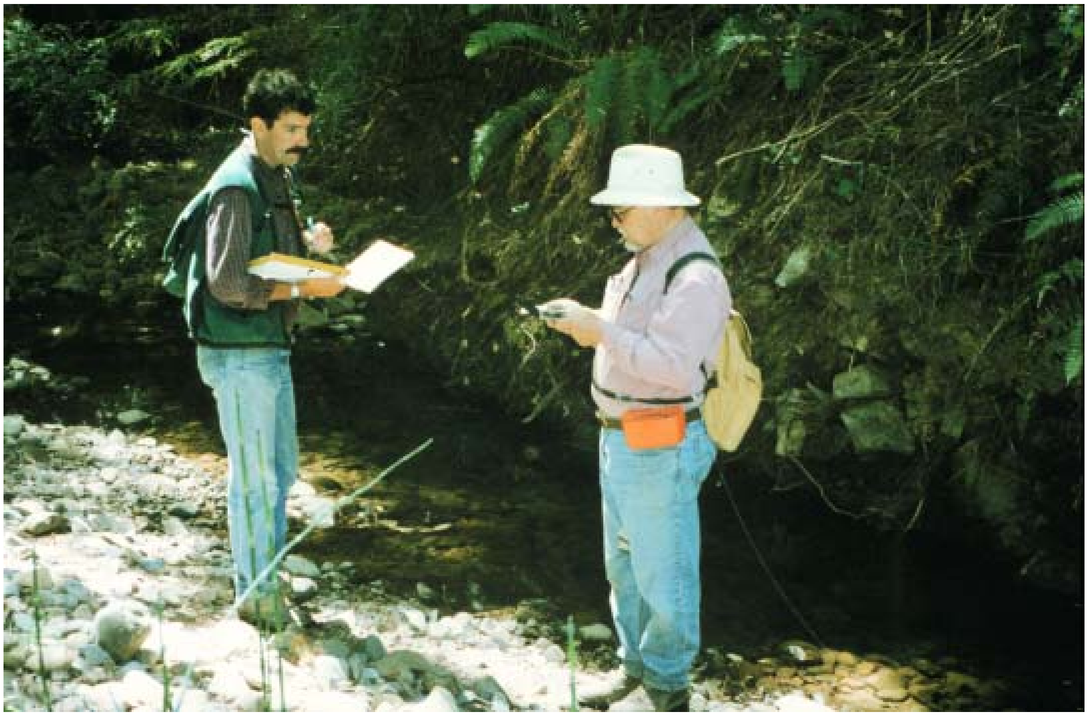

Figure 2. Field data was collected by highly qualified independent contractors who acted as third party auditors. Cliff Kennedy and Roger Poff are shown collecting field data in Mendocino County.

effectiveness. Direct observation of fine sediment delivery to stream channels during storm events was not attempted with this dry season program.

A Hillslope Monitoring Program database was developed in Microsoft Access for Windows (Microsoft Office 97) and runs on a personal computer. It is a relational database, approximately 30 megabytes in size without data. The data collected in 1996 was entered into the database by CDF. From 1997 to 2001, data was entered into the database by CDF's contractor. A preliminary set of queries were developed for the interim report prepared in 1999 (CSBOF 1999). These queries and additional, new queries were utilized for the current report.

Quality Assurance/Quality Control (QA/QC)

Quality assurance consists of actions to ensure quality data collection and analysis, while quality control is associated with actions to maintain data collection and analysis quality consistent with study goals through checks of accuracy and precision. The quality assurance program was composed of three components: 1) minimum qualifications for the contractor (see above), 2) a detailed training program, and 3) protocols provided in a field instruction package. New contractors were trained in the field by CDF Forest Practice personnel who developed the field sampling procedures and a detailed set of instructions on the Hillslope Monitoring Program procedures was provided.

The quality control program was composed of the following components: 1) self-evaluation, 2) CDF review, and 3) independent review. Under self-evaluation, it was stressed that the contractor ensure that the forms were completed satisfactorily and that the features were mapped prior to leaving the field site. CDF field inspections were “front-loaded”, meaning that more field inspections were completed early on in the program compared to later years. CDF remeasured selected transects for canopy measurements in made in 1996 and found that the canopy measurements reported by the contractors were approximately seven percent higher than the internal estimate. The CDF average for three transects in Humboldt County and three transects in Mendocino County was 77.4 percent (measured with a spherical densiometer). The contractor’s measurement for these transects was 84.8 percent.

For independent review, a random sample of 10 THPs were chosen in 1997 for quality control work. Dr. Stephen Daus and Mr. Michael Parenti were hired by CDF to complete the field work for these THPs a second time to test the repeatability of the process. Three plans were located in the Coast Forest Practice District, three in the Northern District, and four in the Southern District. Eighteen WLPZ transects were evaluated (14 Class II watercourses and four Class I watercourses). The average canopy cover measured with a spherical densiometer by the Daus/Parenti team for the WLPZ transects was 70.7 percent. The corresponding average canopy measurement for the same 10 THPs by the R.J. Poff and Associates team was 64.4 percent. A paired T Test revealed that these means of these two groups are significantly different at alpha <0.05.

Site Characteristics

Of the 300 plans evaluated, 295 were THPs and five were NTMP NTOs. Most of the THPs in the sample were accepted by CDF in the early to mid-1990’s and the harvesting was completed by the mid to late 1990’s (Figure 3). None of the THPs evaluated were approved under the new July 2000 Threatened and Impaired Watersheds Rule Package.

The THPs and NTMP NTOs sampled from 1996 through 2001 are displayed by Forest Practice District in Table 1. About 60 percent of the plans were from the Coast Forest Practice District. The distribution of large and small landowners is displayed in Table 2, and approximately 60 percent were on timberlands owned by large landowners. Figure 4 shows the general location of the projects which were monitored. Table 3 displays the distribution of THPs and NTMP NTOs by county. Slightly more than half the plans were located in Humboldt and Mendocino Counties. The average size of the THPs classified as being filed by large landowners was 441 acres, while the average size of the THP filed by small landowners was 169 acres. Considering both categories, the overall average size was 341 acres. In total, the 300 projects covered 102,260 acres.

Table 1. Distribution of THPs and NTMP NTOs by Forest Practice District.

Forest Practice District	THPs/NTMP NTOs	Percent
Coast	183	61
Northern	78	26
Southern	39	13

Table 2. Distribution of THPs and NTMP NTOs by landowner category.

Landowner Category	Number of THPs/ NTMP NTOs	Percent of THPs/ NTMP NTOs
Large landowner	189	63
Small landowner	111	37

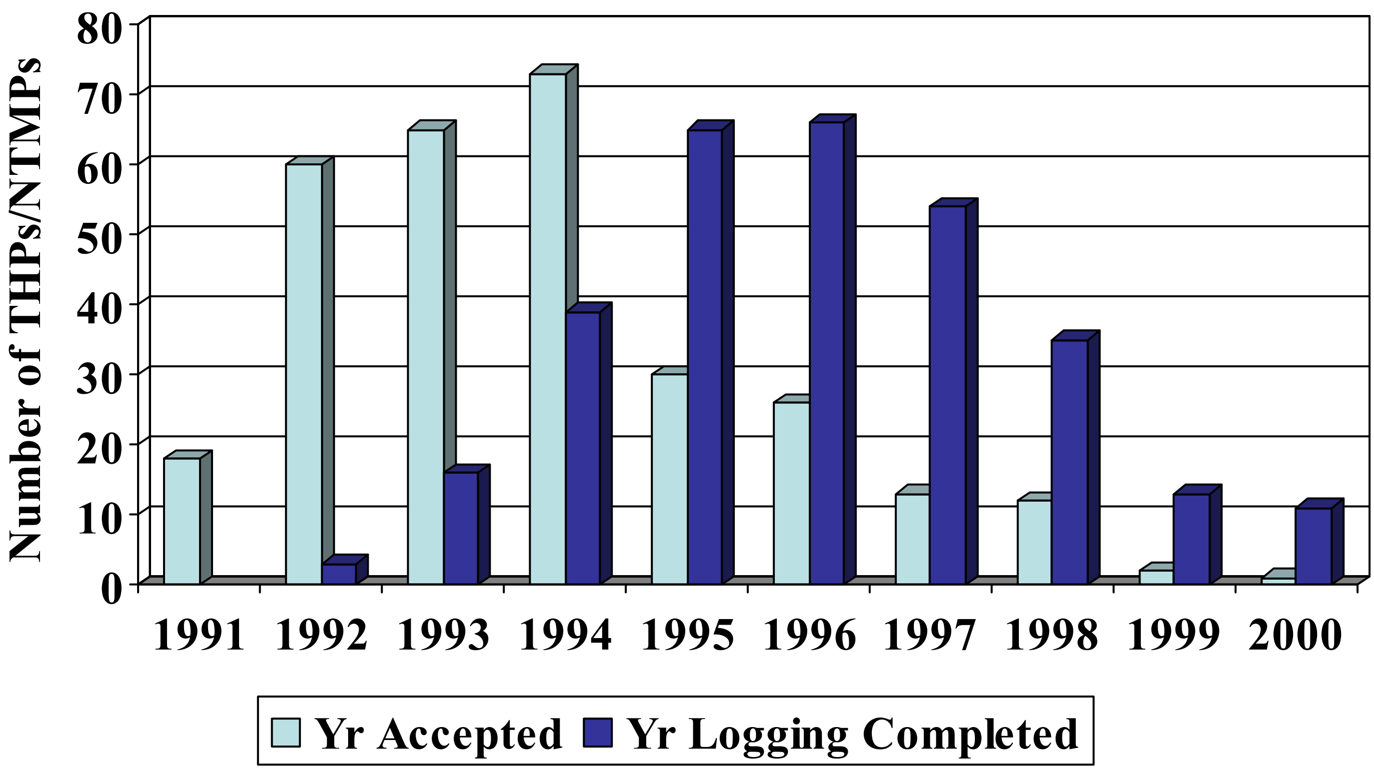

Figure 3. Distribution of when THPs and NTMP NTOs were accepted by CDF and when the logging was completed.

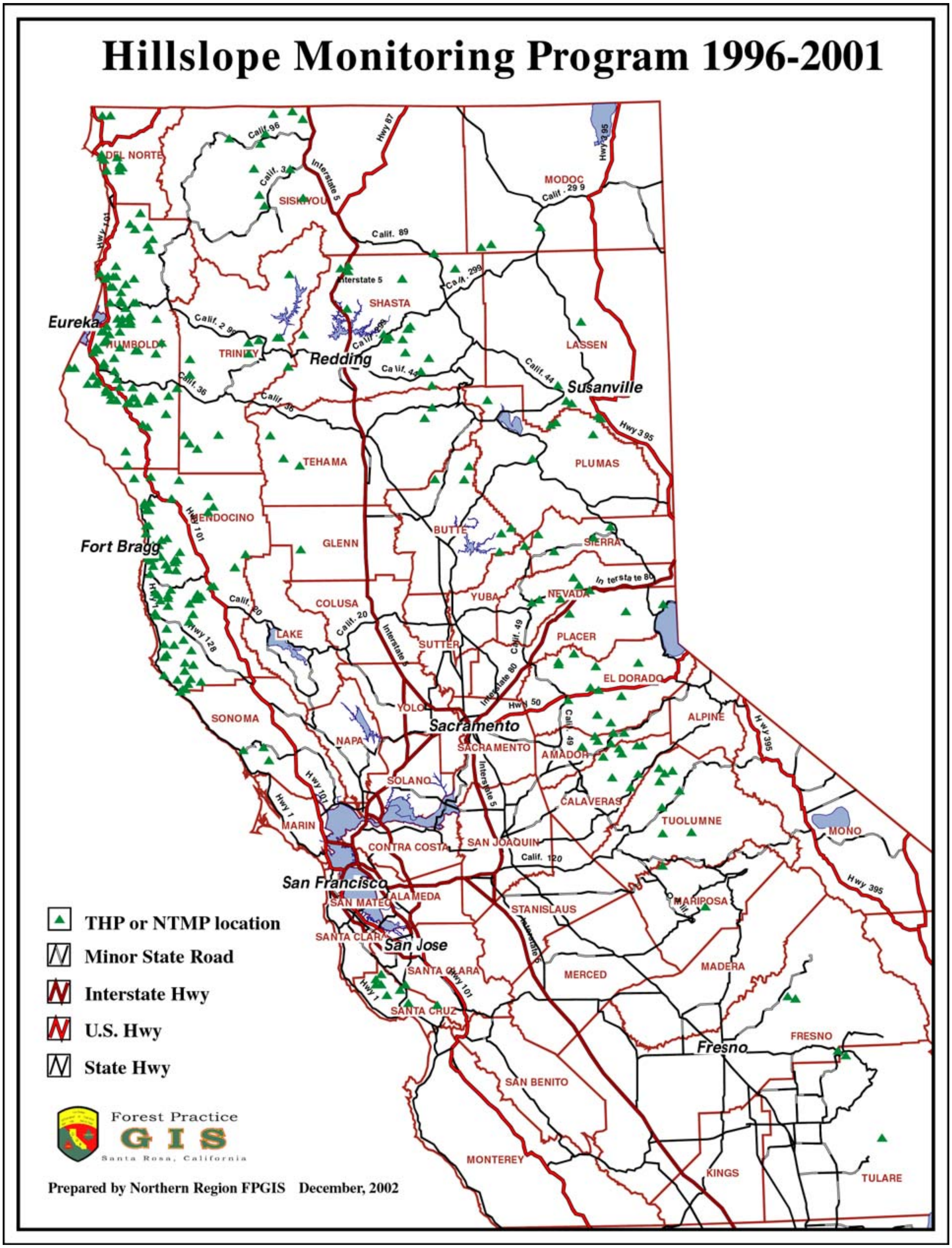

Figure 4. General location of THPs and NTMPs monitored from 1996 through 2001.

Table 3. Distribution of THPs and NTMP NTOs monitored from 1996 through 2001 by county.

County	North Coast THPs: 1996	Statewide THPs: 1997- 2001	Statewide NTMPs: 2001	Total Number of Projects
Coast Forest Practice District				
Del Norte		11		11
Humboldt	25	52	4	81
Mendocino	25	48	1	74
Santa Clara		2		2
Santa Cruz		7		7
Sonoma		4		4
Trinity		4		4
District Total	50	128	5	183
Northern Forest Practice District				
Butte		6		6
Glenn		1		1
Lassen		7		7
Modoc		3		3
Nevada		5		5
Placer		4		4
Plumas		4		4
Shasta		18		18
Sierra		3		3
Siskiyou		12		12
Tehama		5		5
Trinity		9		9
Yuba		1		1
District Total	0	78	0	78
Southern Forest Practice District				
Amador		6		6
Calaveras		8		8
El Dorado		10		10
Fresno		3		3
Mariposa		2		2
Tulare		2		2
Tuolumne		8		8
District Total	0	39	0	39
Totals	**50**	**245**	**5**	**300**

Methods

GENERAL INFORMATION

Five sample features were evaluated within each THP or NTMP NTO: roads, skid trails, landings, watercourse crossings, watercourse protection zones (i.e., WLPZs, ELZs, and EEZs). Two samples of each of these features were evaluated within each selected THP or NTMP NTO if possible. Large erosion events were inventoried where they were encountered on the THP or NTMP project. Additionally, non-standard practices and additional mitigation measures were evaluated when they applied to randomly located sample features.

Conducting the evaluations involved both office and field activity. Office work needed to prepare for the field evaluations included:

- Determining the plan location and access routes.

- Reading the THP or NTMP/NTMP NTO to identify and become familiar with Review Team requirements, alternatives, in-lieu practices, additional mitigations, and addenda in the approved plan.

The following items were completed either in the office or in the field:

- Filling out "Site Information" sheets for each sample site with information that could be obtained from the THP or NTMP NTO document.

- Laying out the road transect grid and WLPZ transect grid for selection of sample transects, as described under “Site Selection” below.

SITE SELECTION

Selection of specific sample areas began with marking approximate 500 foot road segments on all roads on the THP or NTMP NTO map. Each of these segments was assigned a number. A random number table or generator was then used to identify one of the segments. From this point, a coin was flipped to determine direction of travel along the road until a landing was encountered. This randomly selected landing was used for the landing sample. Where more than one road entered or exited the landing, coin flips were used to identify a road transect that began where the selected road left the landing. Coin flips were also used to determine the direction of travel to the first available skid trail transect. Watercourse crossing sites were selected as either the first crossing encountered during the road transect or, if no crossing was encountered, the first crossing along a road selected by a coin flip. Finally, the point on a Class I or Class II watercourse closest to the landing was used as the starting point for the WLPZ transect, and direction of travel along the WLPZ was determined by a coin flip. Either

GPS readings or topographic maps were used to record site locations with UTM coordinates.

FIELD ACTIVITIES COMMON TO ALL SAMPLE AREAS

The first step in the field work was to finish filling out Site Information sheets. This was followed by an effectiveness evaluation of pertinent features that presented an erosion or water-quality problem to permit calculation of the relative proportion of problem to non-problem areas.

Sample area field evaluations were designed to provide a database "sketch" of the sites and transects that were inspected. The resulting detailed information was used to estimate the proportion of Rule or water quality problems in the whole population of similar features. This also allowed evaluation of Forest Practice Rule implementation and effectiveness for protection of water quality and identification of problems requiring revisions or additions to the Forest Practice Rules.

At "problem" sites (such as cut bank failures, gullies, excessive grades, and Rule violations), the problem type, erosion, and sediment delivery codes were recorded and a Rule implementation evaluation was conducted. Any rills, gullies, mass failures, or sloughing features that were encountered as part of the transect and site inspections were followed to determine whether sediment from these erosional features reached a watercourse protection zone or stream channel.[7] The presence of rills, gullies or deposited sediment at the edge of the high flow channel was sufficient to class the sediment as having entered that portion of the stream.

After the field review had been completed, an evaluation of all the Rules was conducted based upon the <u>overall</u> frequency of problem sites and Rule violations found along the transect as a whole. Implementation of the Forest Practice Rules applicable to a given subject area was rated as either exceeding the requirements of the Forest Practice Rules, meeting the requirements, minor departure from requirements, major departure from requirements, not applicable, could not determine (evidence is masked), or could not evaluate (with description of why).

Major departures were assigned when there was a substantial departure from Rule requirements (e.g., no or few waterbars installed for entire transect), or where sediment was delivered to a watercourse. Minor departures were assigned for slight Rule departures (e.g., WLPZ width slightly less than that specified by the Rule).[8]

---

[7] Rills, gullies, mass failures, and cutbank/sidecast sloughing are defined in the glossary.

[8] Minor and major departures from Forest Practice Rule have similar impact to water quality for watercourse crossings since sediment is assumed to enter the watercourse for both categories.

ROAD AND SKID TRAIL TRANSECT METHODS

Transects

The location of road and skid trail transects on the THP or NTMP NTO were determined using procedures described under Site Selection. Roads or skid trails that were not used as part of the THP or NTMP project being evaluated were not included. The starting point for the transect was the point at which the road or skid trail narrowed to its “normal width” and was outside of the influence of operations on the landing. Where a road forked, the transect followed the road that was of the same general type of construction and level of use. Where a skid trail forked, the branch that continued in the same basic direction (up-hill or down-hill) as the transect to that point was followed. If there were no clear differences, a coin flip was used to determine direction. The direction that was chosen was described in the comments section of the data form to provide a record for follow-up inspections or re-measurement, if required.

At the start of a transect, a measurement string was tied to a secure object, the string box counter was set to zero, and the location of the starting point was described in the comments for future reference. The road or skid trail was walked in the pre-determined transect direction for a distance of 1000 feet or to the end, whichever occurred first.[9]

If the total road distance was less than 800 feet, another transect on a different road segment was started from the landing without resetting the string box counter, and measurements were continued to obtain a total transect length of 1000 feet.

The minimum skid trail transect length was 500 feet. If needed, this distance could be made up of several segments. Skid trails were randomly selected from those entering the landing, where possible. If a skid trail was not available at this location, the nearest trail that brought logs to the measured road segment was used. Skid trail transects were no shorter than the length of trail requiring two waterbars. If the total skid trail distance was less than 300 feet, the transect was continued from the most recently passed trail intersection. Where there was no intersection, the transect was continued from the landing without resetting the string box counter, and the transect was continued in this fashion up to a maximum distance of 1000 feet. If there was less than 500 feet of skid trail, the available trail length was sampled and an explanatory comment was included. If there were no skid trials (i.e., the plan was entirely cable or cable/helicopter yarded), this was noted at the start of one of the skid trail forms.

Data Recording

The general procedure for linear transects was to record the starting and ending distance to each feature as it was encountered. On roads, for example, the beginning and ending point of all features (e.g., inside ditches, cut banks, location of waterbreaks,

[9] Note that main-line logging roads were not sampled if drainage structures had been removed to facilitate log hauling from more recent timber operations. This type of road (i.e., native surfaced primary road with waterbars) was probably under sampled as a result of these more recent operations.

cross drains, etc.) were recorded, regardless of whether or not they presented a water quality problem. Consecutive numbers were assigned to each feature, which, in combination with the THP and transect numbers, became a unique database identifier for that feature. Then codes were entered to indicate the type of feature and any associated drainage problems, erosion source area, erosion causes, and sediment production, plus information about road or trail gradient, sideslope steepness, and dimensions of erosion features. A feature date code was included for all erosion features, features with drainage problems, and other features related to Rule requirements to indicate if the feature was created by the current THP or NTMP project.[10]

LANDING METHODS

Site Identification

The landing to be evaluated was located as previously described under Site Selection. Landing selection was important because it became the basis for locating random sites for the other sample features.

Landing Surface

The entire landing surface was inspected for rills and gullies. Gullies were defined as being six inches or greater in depth and of any length. The total length of all gullies and their average width and depth were recorded on the data forms. Sample points for rills were located along a single transect that bisected the landing into two roughly equal parts perpendicular to the general direction of surface runoff in 1996. The percentage of the landing surface drained by rills was estimated for 1997 through 2001. To be counted, rills had to be a least one inch deep and 10 feet long. Both rills and gullies were inspected to determine whether they continued for more than 20 feet past the toe of the landing fill slope, and gullies were followed to determine if sediment had been delivered to the nearest WLPZ and channel.

Cut Slopes (if present)

The face of the cut slope was inspected for evidence of slope failures, rilling, and gullying. The path of any transported sediment was traced to determine the quantity and whether material was transported to a drainage structure(s) on the landing.

[10] Number codes that were used to indicate erosion and problem feature date were: 1-feature created by current THP; 2-feature predates and was affected by current THP; 3-feature predates and was not affected by current THP; 4-cannot determine feature date; and 5-feature created after THP but was not affected by THP. For example, 1-R indicated that a rill was created by the current THP or NTMP project.

Fill Slopes (if present)

The toe of the fill slope was inspected for evidence of slope failures, rilling, and gullying. Rills or gullies that were not caused by drainage from the landing surface were traced to determine whether they extended to a downslope channel. All slope failures were evaluated to determine the total amount of material moved and whether it reached a watercourse channel.

WATERCOURSE CROSSING METHODS

Site Identification

A watercourse crossing site was established at the first crossing encountered on the road or skid trail transects, which was also noted as a feature on the transect. If no crossing was encountered as part of the transects, the first crossing beyond the end of the road transect was used for this evaluation.

Once the crossing had been identified, the next step was to determine the length of road to be included in the drainage evaluation. This was done by walking in both directions from the crossing and identifying the points where runoff from the road surface, cuts, and fills no longer carried toward the stream crossing. The road length for evaluation also included the cut-off waterbar that should route water away from the crossing.

Fill Slopes

The crossing fill slope was evaluated to determine whether it had vigorous dense cover or if at least 50 percent of its surface was protected by vegetation, mulch, rock, or other stable material. The presence and frequency of rills, gullies, and cracks or other indicators of slope failure were noted, and the size of rills and slope failures was recorded.

Road Surface

The type and condition of road surfacing was assessed and was evaluated for ruts from vehicles and, if ruts were present, whether they impaired road drainage. The presence, frequency and length of rills and gullies on the road surface were also determined along with average gully size and surface drainage conditions. The presence, condition, and effectiveness of cutoff waterbars and inside ditches were evaluated, along with evidence of ponding or other water accumulation on the road.

Culverts

The stream channel at both the culvert inlet and outlet was examined for evidence of scouring. The current degree of plugging at the upstream inlet was assessed along with the diversion potential in case the culvert eventually becomes plugged.   Alignment of the culvert, crushing of the inlet and outlet, and degree of corrosion were also evaluated. Pipe length and gradient were determined and evidence of piping around the culvert was identified.

Non-Culvert Crossings (e.g., Rocked Class III crossings)

The crossing was examined to determine the type and condition of armoring and whether downcutting or scouring at the outlet was occurring. Crossing approaches were evaluated to determine if they had been maintained to prevent diversion of stream overflow down the road should the drainage structure become plugged.

Removed or Abandoned Crossings (where applicable)

Removed crossings were examined to determine whether the restored channel configuration was wider than the natural channel and as close as feasible to the natural watercourse grade and orientation. The location of excavated material and any resulting cut bank was assessed to determine if they were sloped back from the channel and stabilized to prevent slumping and minimize erosion. The crossing was also evaluated for the following conditions:

- Permanent, maintenance free drainage.
- Minimizing concentration of runoff, soil erosion and slope instability.
- Stabilization of exposed soil on cuts, fills or sidecast that prevents transport of deleterious quantities of eroded surface soils to a watercourse.
- Grading or shaping of road surfaces to provide dispersal of water flow.
- Pulling or shaping of fills or sidecast to prevent discharge of materials into watercourses due to failures of cuts, fills or sidecast.

WATERCOURSE PROTECTION ZONE (WLPZ, ELZ, EEZ) TRANSECT METHODS

Transects

Two Class I or II WLPZs were sampled on each THP or NTMP project, when available (transects may have been shorter than 1000 feet, but must have been at least 500 feet to be included). These WLPZ segments were located along the nearest, accessible Class I or II watercourse relative to the selected landing sites. When WLPZs were present near only one of the selected landings, both segments were selected from this location. And where there was only one WLPZ on the THP, both segments could have been located along the same watercourse but, where possible, should have represented different conditions (e.g., different stream classes, stream gradients, sideslope gradients, adjacent logging methods, etc.).

For Class I waters, two 1000 foot long transects were sampled parallel to the stream within the WLPZ. One of these was a "mid-zone" transect located between the watercourse bank and the up-slope boundary of the WLPZ. The other was a "streambank" transect located immediately along the stream bank and parallel to the mid-zone transect. For Class II watercourses, only the mid-zone transect was used.

Beginning in 2000, Class III watercourses were included in the Hillslope Monitoring Program. Two Class III watercourses were sampled on each THP or NTMP project, when available. One 300 foot long transect parallel to the watercourse was established for each Class III evaluated. These segments were located along the nearest, accessible Class III watercourse relative to the selected landing sites. The transect was located either: 1) approximately 25 feet from the watercourse where no WLPZ had been established, or 2) where there was a designated protection zone (i.e., WLPZ, ELZ, or EEZ), along the “mid-point” of the designated zone. Class III monitoring protocols were developed in 1999 during a pilot project involving the THPs sampled as part of the 1999 Hillslope Monitoring Program work (Poff and Kennedy 1999).

Data Recording

Within the transects, groundcover and canopy cover were evaluated at regular intervals and at disturbed sites where timber operations had exposed more than 800 continuous square feet of mineral soil. Several other factors were also evaluated wherever they occurred, such as sediment delivery to the channel, streambank disturbance, and channel conditions.

Parameters measured or estimated in the mid-zone transect for Class I and II watercourses included groundcover at every 100 feet, canopy cover at every 200 feet with a spherical densiometer (from 1996 to 1998),[11] WLPZ width at every 200 feet (concurrent with canopy measurement and whenever there was a change in sideslope class), and sediment to the channel wherever it occurred. Measurements in the Class I watercourse streambank transect included canopy cover at 200 foot intervals, disturbance to streambanks wherever it occurred, and other stream related features. In addition, Rule implementation was evaluated continuously along both transects, and any Rule requirements or discrepancies were noted as a feature and were included in the implementation evaluation.

From 1999 to 2001, the canopy sampling method for Class I and II watercourses was changed from use of the spherical densiometer (Figure 5) to use of the sighting tube (Figures 6 and 7). This change was based on findings from a recent study that the sighting tube provides unbiased estimates of true canopy cover, while the densiometer does not (Robards et al. 2000). The procedure for estimating canopy was as follows:

[11] In 1996, the spherical densiometer was used as suggested by Lemmon (1956). The Strickler (1959) modification, which requires counting only 17 grid intersections, was used in 1997 and 1998 to reduce bias.

- Estimate the length of the WLPZ segment to be evaluated to the nearest 100 feet (maximum length was 1000 feet and minimum length was 500 feet). A 200 foot segment was randomly selected from the number of feet in this estimate.

- Canopy was estimated at 44 to 56 systematically located points throughout the 200 foot transect, where the number of points was based on the WLPZ width at the site. Sighting tube lines were run by “zig-zagging” back and forth across the WLPZ (i.e., up and down the hillslope) (see Figure 8).

- A random starting point for the first canopy point was used to reduce sampling bias.

- After leveling the sighting tube in both horizontal and vertical directions, a “hit” or a “miss” was recorded for that point depending on whether the small dot in the center of viewing area appeared to be touching or not touching some form of vegetation.

- The percent canopy for the transect was determined by the total number of “hits” for the transect divided by the total number possible (44 to 56).

The general procedure for recording watercourse protection zone transect data and the use of codes was similar in format to the methods used for roads and skid trails, but with features that were specific to watercourse protection zone conditions and Rule requirements. As with roads, the starting and ending distance to each feature was recorded along with a unique identification number and information about feature type, erosion causes, dimensions of erosion features, and sediment deposition. Additionally, a feature date code was included for all erosion features and other features related to Rule requirements to indicate if the feature was created by the current THP or NTMP project (see footnote number 10).

Groundcover was estimated in an area with a diameter of approximately one foot located directly in front of the observer’s boot toe, where adequate cover was defined as "living plants, stumps, slash, litter, humus, and surface gravel (minimum diameter of 3/4 inch) in amounts sufficient to break the impact of raindrops and serve as a filter media for overland flow.”

Features did not need to intersect the transect line to be included. This was necessary because dense vegetation and other obstructions in watercourse protection zones make following a straight line transect impractical, so the location of the transect line will be biased by access within the zone and some extensive watercourse protection zone features might not intersect the transect. An example of this situation would be a road running parallel to, but not on, the transect.

The Class I and II WLPZ measurements began at one end of the mid-zone transect and included a continuous record of the beginning and end points of features encountered along the transect for a distance perpendicular to the end of the mid-zone transect and proceeded in the opposite direction toward the starting point of the mid-zone transect.

Figure 5. Concave spherical densiometer used for canopy measurements from 1996 to 1998 (the Strickler (1959) modification was utilized in 1997 and 1998 to reduce bias).

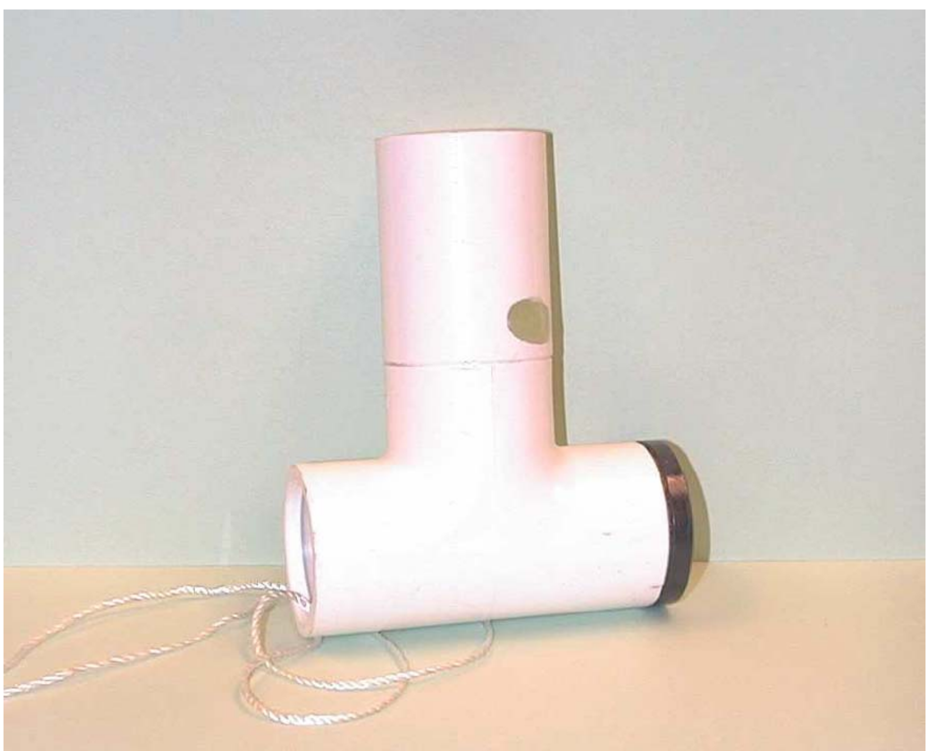

Figure 6. Close-up view of the sighting tube.

Figure 7. The sighting tube in use in the field. This instrument was utilized for obtaining an unbiased estimate of canopy cover from 1999 through 2001.

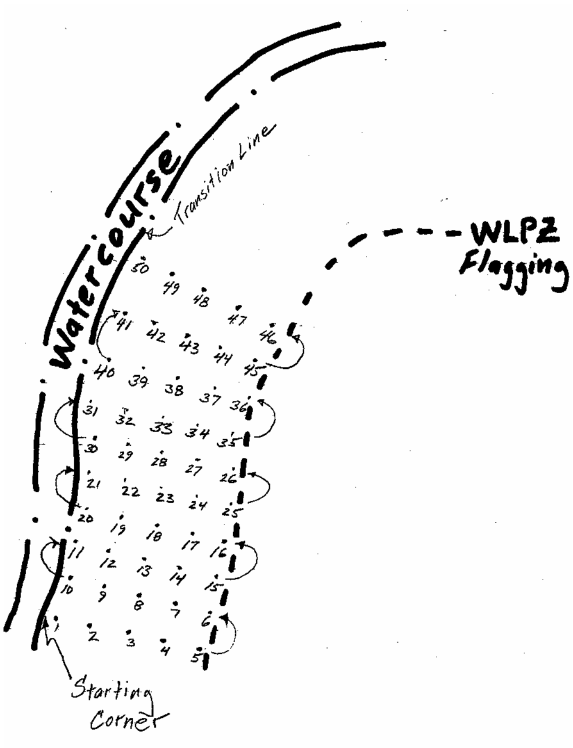

Figure 8. Example of the systematic grid used for a 125-foot WLPZ to determine canopy cover with a sighting tube for a randomly selected 200 foot reach of Class I or II watercourse (total number of sighting tube points varied from 44 to 56 depending on WLPZ width). Diagram drawn by Mr. Clay Brandow, CDF, Sacramento.

For Class III watercourses, ground cover was evaluated every 100 feet, including end points, and at the mid-points of disturbed sites. ELZ, EEZ, or WLPZ widths were determined every 100 feet, including end points. Erosion features were recorded and sediment delivery to channels was documented where it occurred. Canopy was not measured, but where canopy was retained, it was noted with the appropriate code.

LARGE EROSION EVENT EVALUATION METHODS

Erosion events that created voids larger than 100 cubic yards were assessed whenever they were encountered on the THP on NTMP project. For watercourse crossings that had failed, a large erosion event was defined as greater than 10 cubic yards. These sites were identified during the standard site evaluations, while traveling within the THP, or as a result of information provided in the THP or by landowners or managers. Data collected included the location, size, and type of feature; site conditions; and an evaluation of the causal connections between the feature and specific timber operations, along with any applicable Forest Practice Rules. Features were classified as gullies, shallow debris slides, debris torrents, deep seated rotational failures, streambank failures, or catastrophic crossing failures. This process was modified significantly in 1997 based on information provided by the Hillslope Monitoring Program contractors who completed the field work in Mendocino and Humboldt Counties during 1996.

If more than five large erosion events were discovered on a THP or NTMP, only the first five were required to be completely evaluated by the field team. For additional events, only the location, type, and estimate of the cause were briefly noted.

NON-STANDARD PRACTICES AND ADDITIONAL MITIGATION MEASURE METHODS

In addition to completing the site information, implementation, and effectiveness sections of the field forms, the field teams also filled out a form for non-standard practices and additional mitigation measures, for each of the five subject areas.[12] Non-standard practices include in-lieu and alternative practices. These site specific practices and/or additional mitigation measures often did not apply at the randomly selected transects and features, so the totals reported are a relatively small sample that does not include all of the types of practices that were included in the THPs and NTMP projects.

For each of the five evaluation areas (roads, skid trails, landings, watercourse crossings, and watercourse protection zones), four questions were asked:

1. Was an alternative, non-standard, or in-lieu practice approved on the THP or NTMP NTO?

[12] Non-standard practices, alternatives, in-lieu, and exception practices are defined in the Glossary.

2. Were additional mitigation measures beyond the standard Rules included in the approved THP or NTMP NTO?

3. Where present on the sample transect or feature, have the alternative measures been implemented as described in the THP or NTMP NTO?

4. Provide comments on the implementation and effectiveness of the alternative practices.

The field team provided brief qualitative answers to these questions where they were applicable to the randomly located sites being evaluated.

TOTAL SAMPLE SIZE FOR THE PERIOD FROM 1996 TO 2001

If qualifying features had been found for all the THPs and NTMP projects sampled (and all the plans had been tractor yarded), the total sample size would have equaled the "maximum possible" number illustrated in Table 4. The actual sample size, however, is lower (as shown in Table 4) because numerous smaller plans did not have two of each feature to sample and many of the plans were entirely yarded with aerial systems (i.e., cable or cable/helicopter).

Table 4. Potential and actual sample sizes for the Hillslope Monitoring Program from 1996 through 2001.

	Road Segments	**Skid Trail Segments**	**Landings**	**Watercourse Crossings**	**Class I and II WLPZs**[13]	**Class III ELZs, EEZs, WLPZs**
Maximum Possible	600	600	600	600	600	200
Actual Number Sampled	568	480	569	491	501	182

[13] This column includes three Class IV watercourses.

Results

The results of the Hillslope Monitoring Program reported here are organized using the following major categories: roads, skid trails, landings, watercourse crossings, watercourse protection zones, large erosion events, and non-standard practices/additional mitigation measures. The results are generally displayed in a manner similar to that used in the earlier interim Hillslope Monitoring Program Report (CSBOF 1999).

Roads

From 1996 through 2001, 568 randomly located road transects were evaluated, covering a total of approximately 550,200 feet or 104.2 miles. Over 80 percent of the road transects were classified as seasonal roads (Table 5). About 23.4 percent of the road length surveyed had been surfaced with rock. Approximately 81 percent of the road transects monitored were existing roads built prior to the current plan; 19 percent of the transects were classified as new roads.

As part of the road transects, the field team rated the implementation and effectiveness of applicable Forest Practice Rules as they were encountered and as part of an overall evaluation following completion of the transect. In the overall evaluation of road transects, a total of 59 questions were answered in the field based on 46 Forest Practice Rule sections, since some FPRs were broken down into separate components. The majority of the Rules had high percentages (i.e., greater than 90 percent) of cases where implementation ratings either met or exceeded the standard Rule requirements. When considering all the Forest Practice Rules related to roads, the implementation rate where the Rules were met or exceeded was **93.2** percent. For the Forest Practice Rules where the sample size was adequate[14], 23 Rule requirements were found to have combined minor and major departures greater than five percent (Table 6).

Table 5. Percentages of road segment type.

Road Segment Type	Percent
Permanent	10
Seasonal	84
Temporary	4
Combination	2

[14] The results reported here are based on at least **30** observations where the field team assigned an implementation rating of exceeded rule requirement, met requirement, minor departure from requirement, or major departure from requirement. Thirty observations represents five percent or more of the implementation ratings available for each major category (i.e., roads, skid trails, landings, watercourse crossings, and watercourse protection zones).

Table 6. Road related Forest Practice Rule requirements with more than five percent departures based on at least 30 observations from the overall transect evaluation where implementation could be rated (note that some Rule sections are divided into components and the table is ordered by the percentage of total departures).

Forest Practice Rule	Description	Total Number	% Total Departure	% Minor Departure	% Major Departure
923.4(c)	waterbreaks maintained to minimize erosion	458	24.2	22.1	2.2
914.6(f)	where waterbreaks do not work—other erosion controls installed	214	19.2	15.0	4.2
923.1(f)	adequate numbers of drainage structures to minimize erosion	567	18.3	13.6	4.8
923.2(h)	size, number, and location of structures sufficient to carry runoff water	564	17.6	12.2	5.3
914.6(c)	waterbreak spacing according to standards in 914.6(c)	452	17.5	14.8	2.7
914.6(g)	waterbreaks have embankment of at least 6 inches	438	17.4	14.6	2.7
923.1(a)	landings on roads greater than ¼ acre or requiring substantial excavation must be shown on the THP map	243	15.2	3.7	11.5
923.2(h)	size, number, and location of structures sufficient to minimize erosion	565	15.2	11.2	4.1
914.6(g)	waterbreaks cut to depths of at least 6 inches	443	15.1	12.6	2.5
923.2(b)	sidecast minimized for slopes greater than 65% and distances greater than 100 feet	66	13.6	13.6	0.0
923.2(o)	discharge onto erodible fill prevented	510	13.1	9.2	3.9
923.2(d) Coast District	fills constructed with insloping approaches, berms, rock armoring, etc.	192	13.0	8.3	4.7
923.2(m)	sidecast extending greater than 20 feet treated to avoid erosion	202	11.9	4.5	7.4
914.6(f)	waterbreaks built to discharge into cover	464	11.4	9.3	2.2
923.2(d) Northern/ Southern	breaks in grade for drainage are located above and below through-fill, or other measures provided to protect the fill	222	11.3	8.6	2.7
923.6	wet spots rocked or otherwise treated	318	10.4	9.7	0.6
923.2(l)	trash racks, etc. installed where appropriate	173	9.2	6.4	2.9
923.2(p)	waterbars installed according to 914.6	401	8.7	6.5	2.2
923.4(j)	drainage ditches maintained to allow flow of water	306	8.5	8.2	0.3
923.1(d)	slopes greater than 65%, 50% within 100 feet of WLPZ--treat soil	93	7.5	5.4	2.2
923.4(c)	erosion controls maintained during the maintenance period	177	5.6	4.5	1.1
923.1(g) (3)	insloped roads-adequate number of ditch drains installed	237	5.5	4.6	0.8
923.4(e)	roadside berms removed or breached	513	5.5	5.3	0.2

The Rules with the highest percentages of total departures were related to waterbreak maintenance; use of other erosion control measures when waterbreaks are not effective; use of adequate numbers of drainage structures to minimize erosion; sufficient size, number, and location of drainage structures to carry runoff water; and waterbreak spacing. All the Rules evaluated had major departure percentages of less than five percent except for three: 1) if the landing on road was greater than ¼ acre or had substantial excavation, it must be shown on THP map; 2) sidecast extending greater than 20 feet must be treated to avoid erosion, and 3) the size, number, and location of drainage structures must be sufficient to carry runoff water.

A total of 1,132 erosion features were noted on the road transects. These features included rilling, gullying, mass failures, cutbank/sidecast sloughing, and other erosion types. Gullies were defined as erosion channels deeper than six inches, while rills were defined as small surface erosion channels that: 1) were greater than two inches deep at the upslope end when found singly or greater than one inch deep where there were two or more, and 2) were longer than 20 feet if located on a road surface or of any length when located on a cut bank, fill slope, cross drain ditch, or cross drain outlet. Mass failures were defined as downslope movement of soil and subsurface material that occurs when its internal strength is exceeded by the combination of gravitational and other forces. Mass erosion processes include slow moving, deep-seated earthflows and rotational failures and rapid, shallow failures on hillslopes (debris slides) and in downstream channels (debris torrents). Sloughing was defined as shallow, surficial sliding associated with either the cutbank or fill material along a forest road or skid trail, with smaller dimensions than would be associated with mass failures.

The distribution of erosion features is displayed in Table 7. Total erosion volumes from cutbank/sidecast sloughing, mass failure, and gullying is estimated to be roughly 3,600; 76,200; and 2,500 cubic yards, respectively.[15] This equates to approximately 790 cubic yards per mile.[16] Of the mass failures, one feature (450 feet x 270 feet x 15 feet) accounted for 88.6 percent of the total mass failure volume.[17] Without including this large feature, the average erosion volume is reduced to 142 cubic yards per mile. These estimates are based on the volumes of voids remaining at the hillslope locations, not the amount of sediment delivered to watercourse channels. Table 7 also shows the

---

[15] Note that rilling volumes were not determined. Erosion from rilling is generally a much smaller component of total hillslope erosion when compared to that from mass wasting and gullying. For example, Rice et al. (1979) found that rilling accounted for only three percent of the total hillslope erosion following tractor logging in the South Fork Caspar Creek watershed. Rice and Datzman (1981) reported rill erosion to be eight percent of the total erosion measured in northwestern California.

[16] Measuring only erosion voids of 13 cubic yards or more, Rice and Lewis (1991) reported that the average road erosion rate measured in the Critical Sites Erosion Study was 524 cubic yards/mile for their North Coast analysis unit (rain-dominated portions of the North Coast with redwood and Douglas-fir).

[17] This mass wasting feature was classified as a deep seated rotational failure on 70 percent slopes and located in the Northern Forest Practice District. Management related factors included waterbar discharge onto erodible material and subsurface water concentration.

number of erosion features recorded in the first three year period (1996 through 1998) and the second three year period (1999 through 2001). For all types of erosion features, the numbers are lower for the 1999 through 2001 period. Possible reasons for this difference are presented in the Discussion and Conclusions section of this report.

Table 8 shows the percentage of road transects with one or more erosion features of a given erosion type. Almost half the road transects had at least one rill, roughly a quarter of the transects had one or more gullies, and about four percent had at least one mass failure.

When an erosion problem feature or other type of problem (such as inadequate waterbar construction, tension cracks in the road surface, etc.) was discovered, implementation of the applicable Forest Practice Rule(s) was also rated for that problem point. A total of 40 Rule requirements were rated for implementation at problem sites along the road transects. Of these, 21 Rules were associated with approximately 95 percent of the problem points (Table 9). The most commonly cited Rules were: 1) sufficient size, number, and location of drainage structures to carry runoff water, 2) adequate numbers of drainage structures to minimize erosion, and 3) sufficient size, number, location of drainage structures to minimize erosion. As was reported in the interim Hillslope Monitoring Program report (CSBOF 1999), the vast majority of problem

Table 7. Road transect erosion features related to the current THP or NTMP project.

Erosion Feature	Number of Features 1996-1998	Number of Features 1999-2001	Total Number of Features 1996-2001
Cutbank/sidecast Sloughing	80	48	128
Mass Failure	18	12	30
Gullying	148	120	268
Rilling	478	225	703
Other Erosion Features	3	0	3
Totals	727	405	1,132

Table 8. Percent of road transects with one or more erosion features associated with the current plan for selected types of erosion features.

Erosion Feature	Percent of Transects with One or More Features
Sloughing	12.2
Mass Failures	3.9
Gullying	25.5
Rilling	48.9

points recorded along the road transects were judged to be due to either minor or major departures from specific Rule requirements. When considering all the implementation ratings assigned at problem points, only about two percent were associated with situations where the Rule requirements were judged to have been met or exceeded and 98 percent were associated with departures from Rule requirements.

Table 9. Problem point implementation ratings that account for approximately 95 percent of all the Forest Practice Rule requirements rated along road transects.

Forest Practice Rule	Description of Rules Rated for Implementation at Problem Points	Number of Times FPR Cited	Meets/ Exceeds Rule (%)	Minor Departure (%)	Major Departure (%)
923.2(h)	size, number, and location of structures sufficient to carry runoff water	452	0.2	80.8	19.0
923.1(f)	adequate numbers of drainage structures to minimize erosion	438	2.7	78.8	18.5
923.2(h)	size, number, and location of structures sufficient to minimize erosion	401	4.7	78.3	17.0
914.6(f)	waterbreaks built to discharge into cover	236	0.0	87.3	12.7
914.6(c)	waterbreak spacing according to standards in 914.6(c)	234	5.1	78.6	16.2
923.2(o)	discharge onto erodible fill prevented	217	0.0	85.7	14.3
914.6(g)	waterbreaks have embankment of at least 6 inches	186	0.0	86.6	13.4
923.4(c)	waterbreaks maintained to minimize erosion	186	0.0	75.3	24.7
914.6(g)	waterbreaks cut to depths of at least 6 inches	166	0.0	84.3	15.7
923.2(p)	waterbars installed according to 914.6	89	6.7	74.2	19.1
914.6(f)	where waterbreaks do not work--other erosion controls installed	67	0.0	73.1	26.9
923.4(l)	soil stabilization on cuts, fills, sidecast	59	1.7	83.1	15.3
923.4(m)	inlet/outlet structures/additional structures have been maintained	38	0.0	84.2	15.8
923.2(m)	sidecast extending greater than 20 feet treated to avoid erosion	31	0.0	22.6	77.4
923.4(j)	drainage ditches maintained to allow flow of water	28	10.7	85.7	3.6
914.6(f)	waterbreaks built to provide unrestricted discharge	26	0.0	80.8	19.2
923(d)	road located to avoid unstable areas	24	0.0	87.5	12.5
923.4(c)	erosion controls maintained during maintenance period	20	0.0	70.0	30.0
914.6(f)	waterbreaks built to spread water to minimize erosion	19	0.0	68.4	31.6
923.2(g)	excess material stabilized so as to avoid impact	19	0.0	36.8	63.2
923.2(k)	road constructed without overhanging banks	19	0.0	100.0	0.0

The results displayed in Table 9 may be biased by the design of the program. Lewis and Baldwin (1997) suggested in their statistical review of this project that implementation should be rated immediately following the completion of logging and prior to stressing storm events to provide an unbiased assessment of whether a practice was implemented correctly. That is, it is likely that some percentage of the problem points might not have been classed as Rule departures if they had been evaluated at the end of timber operations. CDF's Modified Completion Report monitoring will provide information on implementation following harvesting that may help us address this concern. The logistics and funding of the current version of the Hillslope Monitoring Program did not allow for two site visits by the contractor.

The data collected along road transects allows us to determine the proportion of problem features versus non-problem features, particularly for road drainage structures. The counts of existing road drainage structures with and without problem points is displayed in Table 10. For the total population of waterbreaks evaluated, approximately seven percent did not conform to Rule requirements or had an associated erosion feature. Rolling dips and culverted cross drains had deficiencies about five percent of the time. Note that multiple types of Rule requirement violations are possible at each drainage structure with a problem. Therefore the number of drainage structures with problems will be less than the counts for major and minor Rule departures. Additionally, the number of structures with problems is lower than the counts for Rule departures since Rule implementation was rated whenever there was an erosion feature present, regardless of whether or not it was associated with a specific drainage structure.

Table 10. Counts of drainage structures evaluated along road transects with and without problem points.

Drainage Structure Type	Total Number	Number with No Problems	Number with Problems	Percent with Problems
Waterbreaks	1,879	1,756	123	6.5
Rolling Dips	605	578	27	4.5
Leadoff Ditch	315	309	6	1.9
Culvert Cross Drain	306	291	15	4.9
Other Drainage Structure	39	38	1	2.6
Totals	3,144	2,972	172	5.5

The source, cause, and depositional area associated with the recorded erosion features were also documented during the evaluations of the road transects. The different erosion types and their dominant source areas are displayed in Table 11. Cutbank and sidecast sloughing features were primarily associated with road cut slopes, with a smaller component coming from fill slopes. Mass failures were mostly associated with fill slopes below roads. Gullying had many source areas, but was most commonly

Table 11. Number of source location codes and the number delivering sediment to the high or low flow channel for the recorded erosion features associated with the current THP or NTMP NTO on road transects.

Source Area	Sloughing		Mass Failure		Gullying		Rilling	
	#[1]	# with delivery[2]	#[1]	# with delivery[2]	#[1]	# with delivery[2]	#[1]	# with delivery[2]
Cut Slope	68	1	6	0	4	1	5	2
Fill Slope	17	5	15	9	54	18	30	5
Hillslope Above Road	4	0	6	2	7	3	10	1
Hillslope Below Road	1	0	0	0	0	0	0	0
Road Surface	1	0	2	1	45	18	542	66
Waterbar Ditch	0	0	0	0	7	1	5	3
Waterbar Outlet	1	0	0	0	96	12	61	6
Inside Ditch	0	0	0	0	20	4	15	3
Rolling Dip Ditch	0	0	0	0	3	3	5	1
Rolling Dip Outlet	0	0	0	0	26	4	7	0
Other Erosion Source	0	0	0	0	5	2	6	0
Totals	**92**	**6**	**29**	**12**	**267**	**66**	**686**	**87**

[1]Totals in Table 11 differ from Table 7 because of missing source code data.
[2]Corrected for missing data.

associated with waterbar outlets, fill slopes, and the road surface. Rilling, in contrast, was almost always associated with the road surface.

The causes of the recorded erosion features are shown in Table 12. Dominant causes for cutbank and sidecast sloughing included the cutslope being too tall, unstable terrain, the cutslope being too steep, steep side slopes, and unstable fill. The most commonly cited causes of mass failures along the road transects were unstable terrain, unstable fill, and steep side slopes. Approximately 85 percent of the gullies recorded were judged to be caused by drainage feature problems. Similarly, about 70 percent of the rills documented were coded as being associated with drainage feature problems. When rills occurred with road drainage structures (i.e., waterbreaks, rolling dips, lead off ditches) located somewhere along the length of the rill, the rill ended at the drainage structure 57 percent of the time. Highly erodible surface material and steep road gradient were also frequently cited causes of rilling.

Because drainage feature problems are the major cause associated with gullying and rilling on the road transects (Table 12), additional detail for this category is shown in Table 13. For gullying, cover (drainage structure did not discharge into vegetation, duff, slash, rocks, etc.) and spacing of drainage features (too far apart) were the most frequently cited problems. Inappropriate spacing of drainage structures was cited approximately 60 percent of the time for drainage feature problems associated with rilling. Also commonly recorded were inappropriate location to capture surface runoff and inadequate cover. Mass failures were usually not associated with drainage feature problems. When they were, inadequate cover and cross drain culvert shotgun outlets without adequate armoring at the point of discharge were the most frequent codes cited.

Similarly, cutbank or sidecast sloughing was usually not associated with a drainage feature problem. When it was, traffic impact on drainage structure function was the most frequently recorded problem.

Table 12. Number of recorded erosion cause codes related to development of identified erosion features associated with the current THP or NTMP NTO on road transects (note that multiple cause codes can be assigned to a single erosion feature).

Erosion Cause	Sloughing		Mass Failure		Gullying		Rilling	
	Number	%	Number	%	Number	%	Number	%
Fill Slope too Long	1	1	0	0	0	0	1	0
Cut Slope too Steep	20	17	3	6	2	1	1	0
Cut Slope too Tall	35	29	5	9	0	0	2	0
Drainage Feature Problem	3	3	4	8	239	85	538	72
Highly Erosive Surface Material	8	7	3	6	16	6	99	13
Steep Side Slopes	13	11	9	17	1	0	15	2
Unstable Fill	13	11	12	23	5	2	1	0
Unstable Terrain	22	18	13	24	1	0	1	0
Rutting	0	0	0	0	3	1	27	4
Steep Road Gradient	0	0	0	0	5	2	52	7
Other Erosion Cause	4	3	4	7	8	3	13	2
Totals	119	100	53	100	280	100	750	100

Table 13. Number of drainage feature problems associated with erosion features on road transects (note that multiple drainage feature problem codes can be assigned to a single erosion feature).

Drainage Feature Problem	Sloughing		Mass Failure		Gullying		Rilling	
	Number	%	Number	%	Number	%	Number	%
Blocked Ditch	2	9	0	0	4	1	6	1
Cover	4	17	2	29	142	34	86	10
Flow	3	13	0	0	9	2	7	1
Shotgun Outlet without Armoring	1	4	2	29	2	0.5	2	0
Location Inappropriate	2	9	0	0	81	20	110	13
Spacing	2	9	0	0	129	31	480	57
Divert	0	0	0	0	12	3	42	5
Runoff Escaped	0	0	0	0	5	1	7	1
Maintenance	0	0	1	14	11	3	47	6
Plugged Inlet	0	0	1	14	2	0.5	0	0
Rolling Dip Break	0	0	0	0	3	1	4	0.5
Height	0	0	0	0	0	0	3	0.5
Traffic	5	22	1	14	3	1	34	4
Other	4	17	0	0	10	2	7	1
Totals	23	100	7	100	413	100	835	100

Whether sediment actually reached a watercourse from the erosion features found along the road transects is of critical concern to the protection of beneficial uses of water. Figure 9 shows the percentage of identified erosion features that delivered sediment to channels. Since winter documentation of fine sediment delivery to streams was not possible with this program, the percentages of sediment delivery to the high or low flow channel displayed in Figure 9 are likely to underestimate total sediment delivery. The field team attempted to document the closest approach of sediment from a given erosion feature to the watercourse it was directed toward, using field evidence remaining in the dry spring, summer, and fall months. This evidence included: 1) fine and coarse sediment deposition on the forest floor, and 2) rill or gully discharge directly into the high or low flow channel.

The sediment delivery percentages to the high flow channel are similar to those reported in the interim Hillslope Monitoring Program report, after the evaluation of 150 THPs (CSBOF 1999). In that report, it was stated that the percentage of sloughing, mass failures, gullying, and rilling features delivering sediment to the channel was 6 percent, 47 percent, 18 percent, and 13 percent, respectively. Following the evaluation of 300 projects, the percentages of sediment delivery to the high or low flow channel for sloughing, mass failures, gullying, and rilling features are 6.2 percent, 39.3 percent, 24.5 percent, and 12.6 percent, respectively (Figure 9). No sediment was transported to the channel for 93.8 percent of the sloughing features, 60.7 percent of the mass wasting features, 75.5 percent of the gullies, and 87.4 percent of the rills. Of the rills that delivered sediment to watercourses, 70.2 percent delivered to Class III watercourses. For gullies that delivered sediment, 49.2 percent input sediment to Class III watercourses. Sediment delivery data was not reported for 4.8 percent of the rilling features, 1.1 percent of the gullies, 6.7 percent of the mass failures, and 23.4 percent of the sloughing events.

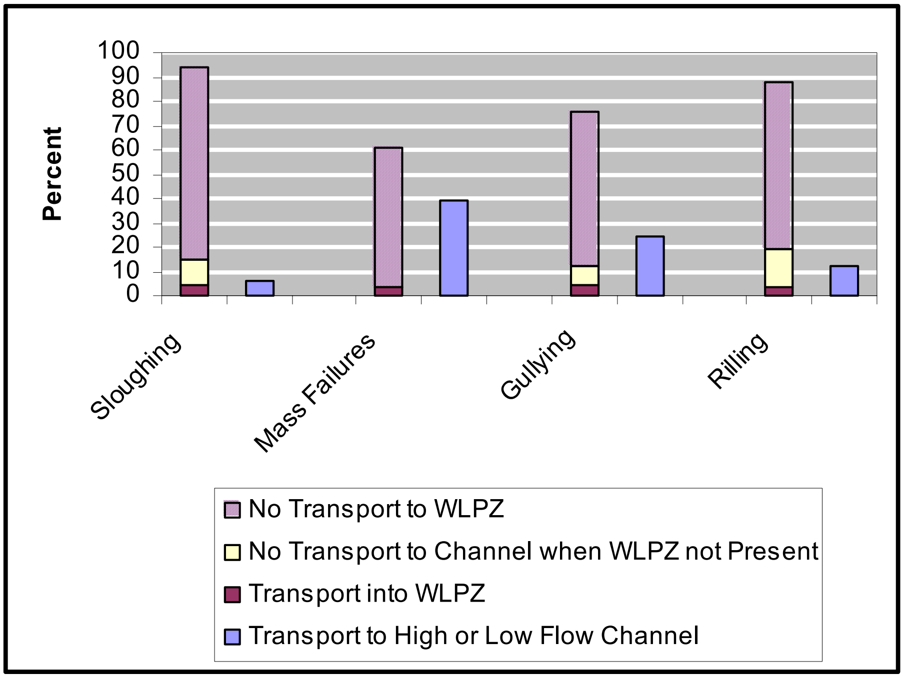

Figure 9. Percent of erosion features with dry season evidence of delivered sediment to the high or low flow channel of a watercourse from road transect erosion features related to the current THP or NTMP NTO.

Skid Trails

From 1996 through 2001, 480 randomly located skid trail transects were evaluated, covering a total of approximately 352,000 feet or 66.7 miles. The time of logging operations for approximately 90 percent of the skid trail transects was judged to be the dry season, with eight percent classified as winter operations, and two percent as either a combination of the wet and dry seasons or unknown. The silvicultural systems associated with the sampled skid trail transects were: 33% selection, 14% alternate prescription, 13% clearcut, 10% shelterwood, 9% commercial thinning, 5% transition, 4% seed tree, 2% sanitation salvage, and 2% rehabilitation, with 8% having combinations of silvicultural systems.[18] Data was not recorded on whether the skid trails were existing prior to the operation of the plan or created as part of the current project. The overall sample size (480 skid trails) is considerably lower than that for road transects because some of the THPs were entirely cable yarded. Field procedures and forms for skid trails are similar to those used for roads, so the results are presented in a similar manner.

As part of the skid trail transects, the field team rated the implementation and effectiveness of applicable Forest Practice Rules as they were encountered, and as part of an overall evaluation following completion of the 500 to 1,000 foot transects. A total of 26 questions were developed to answer in the field based on 22 Forest Practice Rule sections, since some Rules were broken down into separate components. In the overall evaluation of skid trail transects, the Rules were met or exceeded **95.1** percent of the time. For Forest Practice Rules where the sample size was adequate (i.e., 30 observations), seven Rule requirements were found to have combined minor and major departures greater than five percent (Table 14). The highest percentage of total departures from Forest Practice Rule requirements were for Rules requiring the installation of other erosion control structures where waterbreaks cannot disperse runoff, waterbreak spacing, and waterbreak maintenance. All the Forest Practice Rules evaluated had major departure percentages of less than five percent except for one: waterbreak spacing equals the standards specified in 14 CCR 914.6 (934.6, 954.6).

A total of 203 erosion features were found on the skid trail segments. The number of these features for each erosion type and observation period is shown in Table 15. Rilling accounted for more than 70 percent of the number of features. The total erosion volumes from cutbank/sidecast sloughing, mass failures, and gullying is estimated to be roughly 5, 1100, and 400 cubic yards, respectively. As was the case for the road transects, these volume estimates are based on the dimensions of voids remaining on the hillslopes, not the amount of sediment delivered to watercourse channels. Also similar to what was reported for the road transects, the number of erosion features for all types of erosion were lower in the period 1999 through 2001 than from 1996 to 1998. Possible reasons for this difference are given in the Discussion and Conclusions section of this report.

[18] Some skid trails were obliterated during site preparation activities.

The percentage of skid trail transects that had one or more erosion features of a given erosion type is shown in Table 16. Approximately 20 percent of the transects had at least one rill recorded, about seven percent had one or more gullies, and one percent had at least one mass failure.

Table 14. Skid trail related Forest Practice Rule requirements with more than 5 percent total departures based on at least 30 observations from the overall transect evaluation where implementation could be rated (note that some of the Rule sections are separated into components and the table is ordered by the percentage of total departures).

Forest Practice Rule	Description	Total Number	% Total Departure	% Minor Departure	% Major Departure
914.6(f)	where waterbreaks cannot disperse runoff, other erosion controls installed as needed	158	20.3	17.7	2.5
914.6(c)	waterbreak spacing equals standards	467	19.3	13.7	5.6
923.4(c)	waterbreaks maintained to divert runoff water	444	10.6	9.9	0.7
914.6(g)	waterbreaks have embankment of 6 inches	445	7.4	6.1	1.3
914.6(e)	waterbreaks installed for natural channels	219	6.4	3.7	2.7
914.6(g)	waterbreaks cut to minimum depth of 6 inches	445	5.8	4.7	1.1
914.6(c)	waterbreaks installed at 100 foot intervals on cable roads	213	5.6	4.2	1.4

Table 15. Skid trail transect erosion features related to the current THP or NTMP project.

Erosion Feature	Number of Features 1996-1998	Number of Features 1999-2001	Total Number of Features 1996-2001
Cutbank/sidecast Sloughing	3	1	4
Mass Failure	6	1	7
Gullying	35	12	47
Rilling	104	41	145
Totals	148	55	203

Table 16. Percent of skid trail transects with one or more erosion features associated with the current plan for selected types of erosion features.

Erosion Feature	Percent of Transects with One or More Features
Sloughing	0.8
Mass Failures	1.0
Gullying	6.7
Rilling	19.2

As with the road transects, when an erosion feature or other problem was found along the skid trail transects, implementation of the applicable Forest Practice Rule(s) was rated for that problem point. A total of 12 Rule requirements were rated for implementation at skid trail problem sites. Of these, nine Rules were associated with over 95 percent of the problem points (Table 17). All but one of these problem points were related to either minor or major departures from specific Forest Practice Rule requirements. Therefore, only about 0.2 percent of problem points were associated with situations where the Rule requirements were judged to have been met or exceeded, and 99.8 percent were associated with minor or major departures from Rule requirements.

Table 17. Problem point implementation ratings that account for over 95 percent of all the Forest Practice Rule requirements rated along skid trail transects.

Forest Practice Rule	Description of Rules Rated for Implementation at Problem Points	Number of Times FPR Cited	Meets/ Exceeds Rule (%)	Minor Departure (%)	Major Departure (%)
914.6(c)	waterbreak spacing equal standards	106	0.0	87.7	12.3
914.6(g)	waterbreaks have embankment of 6 inches	72	0.0	95.8	4.2
923.4(c)	waterbreaks maintained to divert water	62	0.0	100.0	0.0
914.6(f)	if waterbreaks do not work, other structures stall be installed	48	0.0	91.7	8.3
914.6(g)	waterbreaks cut to minimum depth of 6 inches	48	0.0	100.0	0.0
914.6(f)	waterbreaks allow discharge into cover	42	0.0	100.0	0.0
914.6(f)	waterbreaks--unrestricted discharge	42	0.0	100.0	0.0
914.6(f)	waterbreaks spread water to minimize erosion	25	0.0	92.0	8.0
914.6(g)	waterbars placed diagonally	24	4.2	95.8	0.0

The proportion of skid trail drainage features with and without problems is shown in Table 18. Nearly all these drainage structures were waterbreaks, and approximately four percent of them did not conform to Rule requirements or had an associated erosion feature. The number of waterbreaks with specific associated problems is much lower than the total counts of Rules rated for implementation at problem points (Table 17) because: 1) multiple Rule deficiencies are possible at each drainage structure with a problem, and 2) Rule implementation was rated at each erosion feature on a skid trail transect, whether or not it was associated with a specific drainage structure.

Table 18. Counts of drainage structures evaluated along skid trail transects with and without problem points.

Drainage Structure Type	Total Number	Number with No Problems	Number with Problems	Percent with Problems
Waterbreaks	2,940	2,830	110	3.7
Rolling Dips	51	50	1	2.0
Other Drainage Structure	1	1	0	0
Totals	2,992	2,881	111	3.7

As with the road transects, the source, cause, and depositional site associated with a recorded erosion feature was documented during the evaluation of skid trail transects. Cutbank and sidecast sloughing originated entirely from cut slopes, while mass failures were mostly associated with cut and fill slopes (Table 19). Over 90 percent of rilling features and two-thirds of gullying events were associated with the skid trail surface. About 24 percent of the skid trail gullies were related to waterbreak ditches or outlets.

Table 19. Number of source location codes and the number delivering sediment to the high or low flow channel for the recorded erosion features associated with the current THP or NTMP NTO on skid trail transects.

Source Area	Sloughing		Mass Failure		Gullying		Rilling	
	#	# with delivery	#	# with delivery	#	# with delivery	#	# with delivery
Cut Slope	4	0	2	0	0	0	0	0
Fill Slope	0	0	2	0	0	0	0	0
Hillslope Above Road	0	0	0	0	2	0	1	0
Skid Trail Surface	0	0	1	0	31	5	123	5
Waterbar Ditch	0	0	0	0	4	0	3	0
Waterbar Outlet	0	0	1	0	7	1	4	0
Inside Ditch	0	0	0	0	1	1	1	0
Rolling Dip Ditch	0	0	0	0	1	0	0	0
Rolling Dip Outlet	0	0	0	0	0	0	1	0
Totals	4	**0**	6	**0**	46	**7**	133	**5**

Erosion cause codes associated with the skid trail transects are displayed in Table 20. Mass failures on skid trails were mostly related to unstable terrain and unstable fill. Drainage feature problems contributed to gullying approximately 65 percent of the time, with highly erodible surface material and steep trail gradient each being cited about 10 percent of the time. Drainage feature problems were related to rilling features about 70 percent of the time, with highly erodible surface material and steep trail gradient contributing to the cause of about 15 percent and eight percent of the rills, respectively.

A summary of drainage feature problems found on skid trails is shown in Table 21. Cutbank/sidecast sloughing and mass failures were not found to be related to drainage feature problems. Approximately half of the drainage feature problems related to skid trail gullying were attributed to inadequate spacing of drainage structures, with another 20 percent related to inappropriate locations of the drainage structures to capture surface runoff. Similarly, almost 60 percent of the drainage feature problems related to rilling were attributed to inadequate spacing, with 17 percent related to inappropriate locations of the drainage structures and 12 percent associated with the inability of the drainage structure to divert runoff fully off the trail surface.

Table 20. Number of recorded erosion cause codes related to development of identified erosion features associated with the current THP or NTMP NTO on skid trail transects (note that multiple cause codes can be assigned to a single erosion feature).

Erosion Cause	**Sloughing**		**Mass Failure**		**Gullying**		**Rilling**	
	Number	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
Cut Slope too Steep	1	20	0	0	0	0	0	
Cut Slope too Tall	1	20	0	0	0	0	0	
Drainage Feature Problem	0	0	0	0	35	65	101	70
Highly Erosive Surface Material	2	40	1	8	5	9	22	15
Steep Side Slopes	1	20	2	15	2	4	2	1
Unstable Fill	0	0	3	23	3	5	1	1
Unstable Terrain	0	0	6	46	0	0	0	0
Rutting	0	0	0	0	0	0	1	1
Steep Skid Trail Gradient	0	0	0	0	5	9	12	8
Organic Matter in Fill	0	0	0	0	1	2	0	0
Other Erosion Cause	0	0	1	8	3	6	6	4
Totals	5	100	13	100	54	100	145	100

Table 21. Number of drainage feature problems associated with erosion features on skid trail transects (note that multiple drainage feature problem codes can be assigned to a single erosion feature).

Drainage Feature Problem	Sloughing		Mass Failure		Gullying		Rilling	
	Number	%	Number	%	Number	%	Number	%
Angle	0	0	0	0	0	0	2	1
Cover	0	0	0	0	7	12	5	3
Flow	0	0	0	0	2	4	0	0
Location Inappropriate	0	0	0	0	11	19	28	17
Spacing	0	0	0	0	26	46	92	56
Divert	0	0	0	0	5	9	19	12
Runoff Escaped	0	0	0	0	0	0	1	1
Maintenance	0	0	0	0	3	5	7	4
Height	0	0	0	0	0	0	1	1
Traffic	0	0	0	0	2	3	5	3
Other	0	0	0	0	1	2	4	2
Totals	0	0	0	0	57	100	164	100

The percentage of inventoried skid trail erosion features related to current operations that had dry season evidence of sediment reaching the high or low flow channel of a watercourse is shown in Figure 10. The percentages of sediment delivering features for sloughing, mass failures, gullying, and rilling features are 0, 0, 13.0, and 3.8 percent, respectively. Sediment delivery data was not reported for 8.3 percent of the rilling features, 2.1 percent of the gullies, 14.3 percent of the mass failures, and 0 percent of the sloughing events. No sediment was transported to the channel from any of the sloughing features or mass failures, 87 percent of the gullies, and 96.2 percent of the rills. For gullies that delivered sediment, 83.3 percent delivered sediment to Class III watercourses. All of the sediment delivered to channels from skid trail rills went to Class III watercourses. The proportions of erosion features delivering sediment from skid trails are considerably lower than that reported from similar types of erosion features found on the road transects (Figure 9).

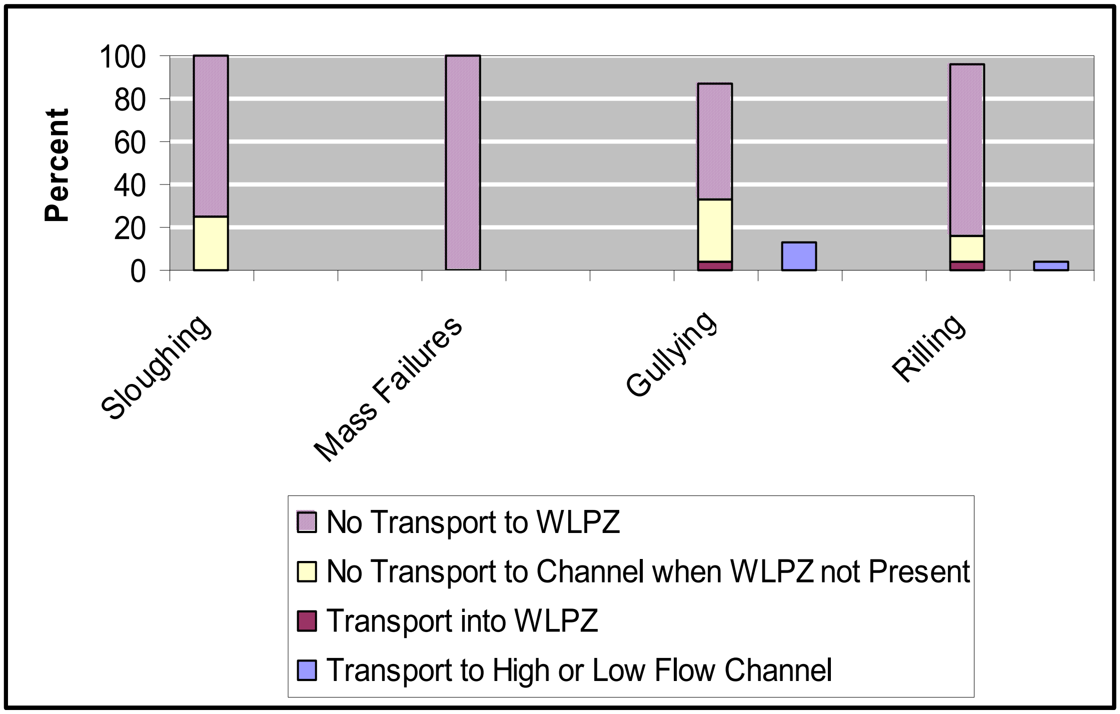

Figure 10. Percent of erosion features with dry season evidence of delivered sediment to the high or low flow channel of a watercourse from skid trail transect erosion features related to the current THP or NTMP NTO.

Landings

A total of 569 landings were evaluated from 1996 through 2001. Landing location and construction characteristics evaluated by the field team included: slope position, distance to the nearest watercourse, sideslope steepness, construction date, size, and fill dimensions. Landings were constructed on a ridge top, a "nose of a ridge", or above a break in slope about 85 percent of the time (Figure 11). Approximately 52 percent of the landings were more than 300 feet from the nearest watercourse receiving drainage off the landing, 31 percent were 100 to 300 feet away, 10 percent were from 50 to 100 feet, and seven percent were less than 50 feet from the nearest watercourse. Two percent of the landings were constructed on slopes greater than 65 percent, seven percent of the landings were on slopes from 46 to 65 percent, 35 percent of the landings were on slopes from 31 to 45 percent, and 56 percent of the landings were on slopes from 0 to 30 percent. Approximately 69 percent of the landings monitored were existing landings built prior to the current plan; 31 percent of the landings were classified as new features. About 88 percent of the landings were less than or equal to ¼ acre in size (Figure 12). Approximately 69 percent of the landings had a maximum fill thickness of 0 to five feet, 24 percent had a maximum thickness of six to 10 feet, and seven percent had a maximum thickness of greater than 10 feet.

Implementation and effectiveness of applicable Forest Practice Rules were rated both at problem points and for the whole landing for 23 separate requirements based on 20 FPR sections. Overall implementation related to landings was rated following complete inspection of the landing and its cut slope and fill slope areas. In the overall evaluation, the Rules were met or exceeded **93.5** percent of the time. For Rule requirements with at least 30 observations, four were found to have more than five percent major and minor departures (Table 22). The Rule with the highest percentage of major departures and total departures was 14 CCR 923.1(a) [943.1(a), 963.1(a)], which requires an RPF to map landings greater than ¼ acre in size or those requiring substantial excavation. A major departure from the Rule requiring treatment of fill material when it has access to a watercourse was assigned to four percent of the landings, and ten percent were judged to have either a minor or major departure from the Rule requiring adequate numbers of drainage features.

As with the road and skid trail transect evaluations, the field team rated the implementation and effectiveness of landing related Rules at specific problem points (Table 23). A total of 106 problem points were recorded under the general categories of landing surface, landing surface drainage, landing cut slopes, and landing fill slopes. About 89 percent of the landings had no problem points assigned. On the remaining 11 percent, approximately one-third of the problem points were related to rills or gullies that were formed from concentrated runoff below the outlet of a drainage structure on the surface of the landing. Problem points are fairly evenly distributed among the remaining 10 sources displayed in Table 23, but the sum of fill slope erosion problems is nearly as large the number of problems related to concentrated runoff from surface drainage structures.

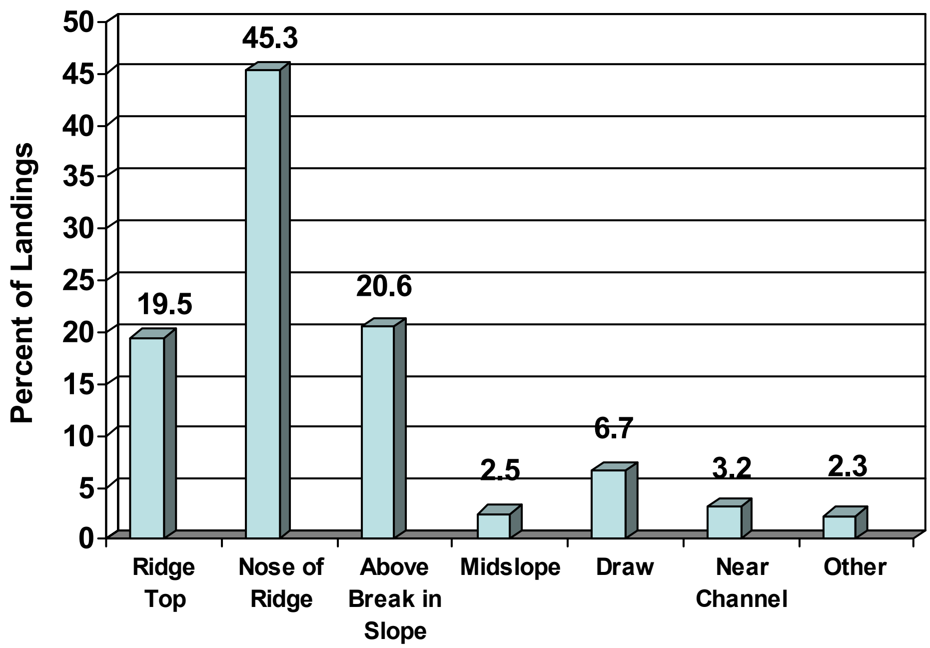

Figure 11. Distribution of landing geomorphic locations.

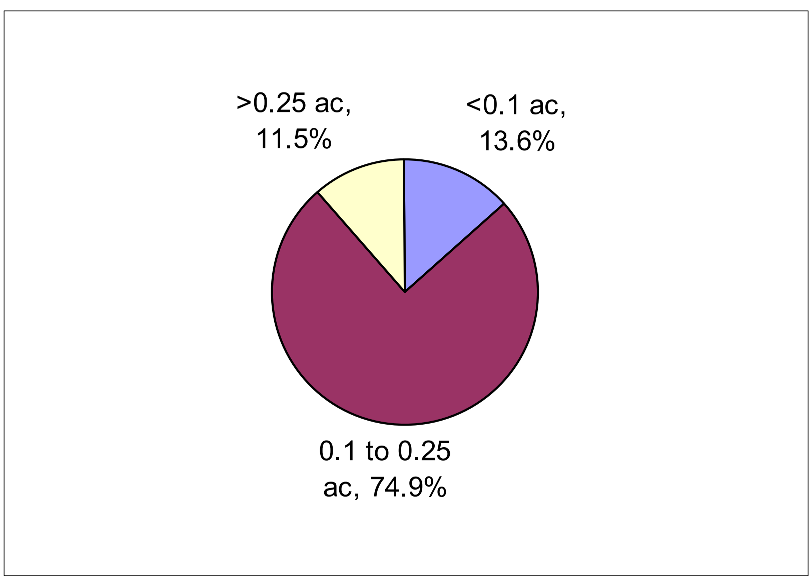

Figure 12. Landing size.

Table 22. Landing related Forest Practice Rule requirements with more than five percent total departures based on at least 30 observations from the overall evaluation where implementation could be rated (note that some of the Rule sections are separated into components and the table is ordered by the percentage of total departures).

Forest Practice Rule	Description	Total Number	% Total Departure	% Minor Departure	% Major Departure
923.1(a)	landings greater than 1/4 acre or requiring substantial excavation--shown on THP map	220	17.3	6.4	10.9
923.5(f)(4)	fill extending 20 feet with access to watercourse--treated	93	11.8	7.5	4.3
923.1(f)	adequate numbers of drainage structures	549	10.0	8.0	2.0
923.6	wet spots rocked or treated	154	5.8	5.8	0.0

At each problem point, the Forest Practice Rule(s) associated with that problem was rated for implementation (Table 24). Only 14 CCR 923.1(f) [943.1(f), 963.1(f)], which requires adequate numbers of drainage structures on landings to minimize erosion on landing surfaces, sidecast, and fills, was cited frequently. All of the problem points found on landings were judged to be caused by either minor or major departures from specific Forest Practice Rule requirements.

An overall effectiveness rating for each of the potential problem types listed in Table 23 was also completed for each landing. The complete summary of the landing effectiveness questions is displayed in Table A-1 in the Appendix. About 2.5 percent of the landings monitored had significant gullying on the landing surface. Of the landings with fill slopes (approximately two/thirds of the landings evaluated), about eight percent had gullies on the fill slopes and roughly three percent had slope failures that transported more than one cubic yard of material. For the landings with cut slopes (approximately 52 percent of the landings evaluated), roughly two percent had gullies on the cut slopes and about seven percent had slope failures with more than one cubic yard of material transported.

The landing evaluation also included a determination of the final location of sediment deposition originating from landing surfaces and fill slopes (Figure 13). Erosion features from two percent of the fill slopes produced sediment that entered channels, and another four percent of the time it reached the WLPZ. Similarly, erosion features from two percent of the drainage structures on the landing surfaces produced sediment that entered watercourses, and another six percent of the time it reached the WLPZ.[19]

Table 23. Distribution of problem points recorded at landings. Note that one landing can have multiple problem points.

Landing Area	Problem Type	Problem Count
Landing Surface	Rilling	8
	Gullying	9
Landing Surface Drainage	Erosion resulting from the drainage runoff structure or ditch	34
	Sediment movement from drainage structure	9
Landing Cut Slopes	Rilling	6
	Gullying	4
	Slope failures	5
Landing Fill Slopes	Rilling	8
	Gullying	8
	Slope failures	10
	Sediment movement to nearest channel	5
Total		106

Table 24. Problem point implementation ratings that account for 95 percent of all the Forest Practice Rule requirements rated at landings.

Forest Practice Rule	Description of Rules Rated for Implementation at Problem Points	Number of Times FPR Cited	Meets/ Exceeds Rule (%)	Minor Departure (%)	Major Departure (%)
923.1(f)	adequate numbers of drainage structures	63	0	76.2	23.8
923.5(f)(3)	landing sloped/ditched to prevent erosion	11	0	81.8	18.2
923.5(f)(2,4)	fill extending 20 feet with access to a watercourse--treated	9	0	33.3	66.7
923(g)	minimize cut/fill on unstable areas	6	0	0.0	100.0
923.1(d)	slopes greater than 65% or 50% within 100 feet-treated	6	0	50.0	50.0
923.5(f)(1)	slopes greater than 65% or 50% within 100 feet-treat edge	4	0	25.0	75.0
923.8	abandonment-minimize concentration of runoff	3	0	100.0	0.0

[19] Note that these ratings were only applied to landings where the appropriate features were present. For example, if no fill slopes were present, landing fill slope effectiveness questions were not answered. In total, 377 landings had fill slopes and 294 had cut slopes out of the 569 landings evaluated.

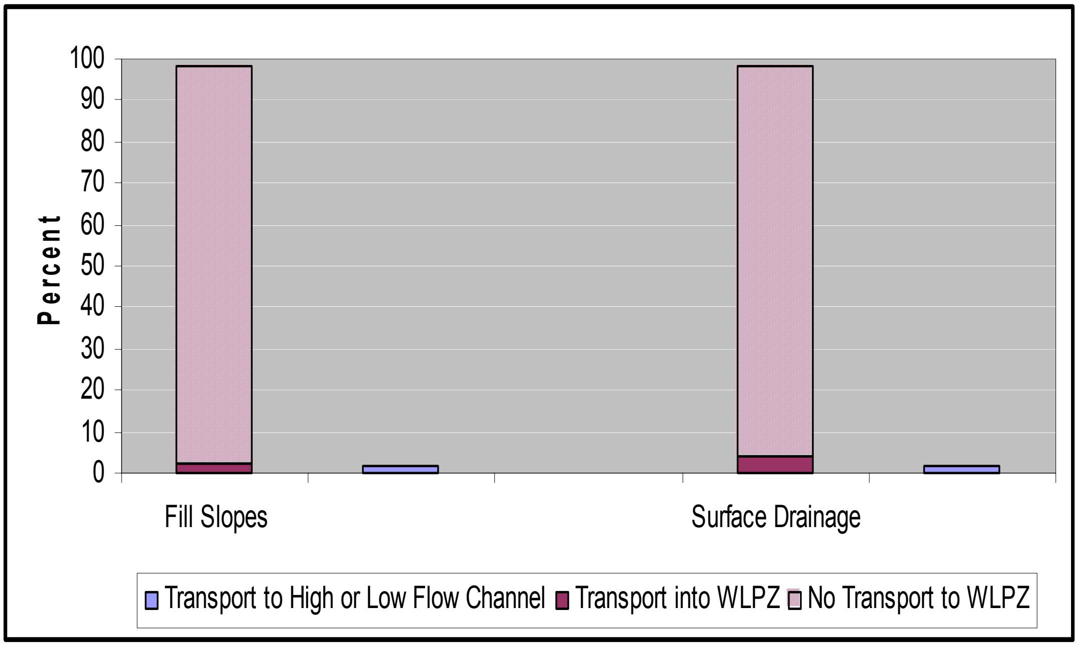

Figure 13. Percent of landing features related to the current THP or NTMP project that had dry season evidence of sediment delivered to either the WLPZ or the high/low flow channel of a watercourse.

Watercourse Crossings

A total of 491 watercourse crossings were evaluated from 1996 through 2001. Approximately 68 percent of these crossings had existing culverts (Figure 14), 12 percent were abandoned or removed road crossings, nine percent were fords, six percent were skid trail crossings, and two percent had bridges (Figure 15). The distribution of culvert sizes is displayed in Figure 16. The majority of pipe sizes are relatively small, reflecting the sampling criteria that favored choosing crossings located along road transects, which were often located above the break in slope near ridgelines. Approximately 64 percent of the crossings were existing road-related structures built prior to the beginning of the current plan; 18 percent were new road features; 12 percent were abandoned or removed crossings for roads; and six percent were removed, existing ford, or new skid trail crossings. Seventy-three percent of the crossings were associated with seasonal roads, 16 percent with permanent roads, four percent with temporary roads, six percent with skid trails, and less than one percent with abandoned roads. Forty-seven percent of the crossings were located in Class III watercourses, 46 percent in Class II drainages, six percent in Class I's, and less than one percent in Class IV watercourses.

Figure 14. Typical watercourse crossing sampled in the Hillslope Monitoring Program. This culvert was a crossing included in the sample for the 2002 field season.

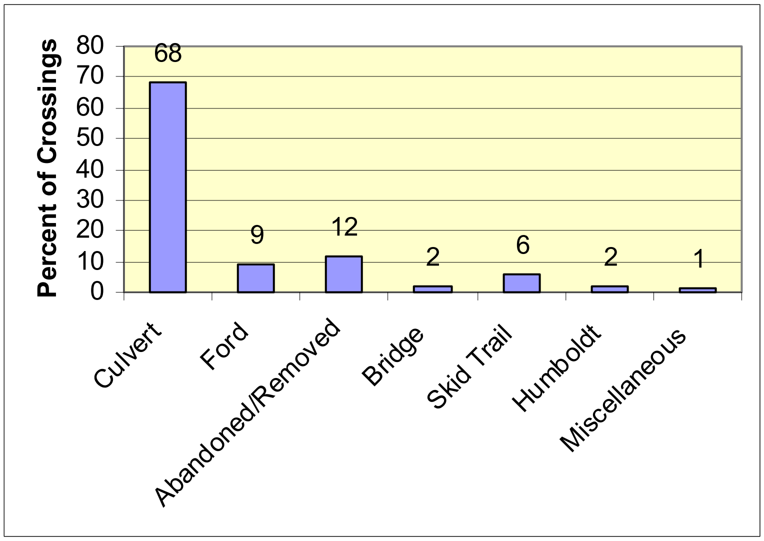

Figure 15. Distribution of watercourse crossing types evaluated from 1996 through 2001. The total number of crossings was 491.

Implementation and effectiveness of applicable Forest Practice Rules were rated both at problem points and for the whole crossing for 27 separate requirements from 24 Rule sections. Overall implementation of Rules related to watercourse crossings was rated following the complete inspection of the crossing, including the fill slope areas and the road segments draining to the crossing. In the overall evaluation, the Rules were met or exceeded **86.3** percent of the time. For Rule requirements with at least 30 observations, 21 were found to have more than five percent major and minor departures (Table 25). The Rules with the highest percentages of total departures were 14 CCR **923(o)** [943(o), 963(o)], **923.2(h)** [943.2(h), 963.2(h)], and **923.2(d)** [943.2(d), 963.2(d)], which prohibit discharge onto fill without appropriate energy dissipators; require appropriate size, numbers, and locations of structures to minimize erosion; and require fills across channels to be built to minimize erosion, respectively. Nine Rules had major departure percentages of more than five percent, which is substantially more than were found for the other hillslope areas (roads, skid trails, landings, and watercourse protection zones). Additional requirements with high levels of departures included Rules dealing with crossing diversion potential and proper crossing abandonment.

The field team rated the implementation and effectiveness of FPRs at problem points for specific components of watercourse crossings when they were encountered during the field inspection (Table 26). A total of 482 problem points were recorded under the general categories of crossing fill slopes, road surface drainage to the crossing, culverts, non-culverted crossings, removed or abandoned crossings, and road approaches at abandoned crossings. Problem points were identified on 45 percent of the crossings, indicating that deficient crossings often had more than one problem point. The most frequent problems were: culvert plugging, diversion potential, fill slope gullies, scour at the outlet of the culvert, ineffective road surface cutoff waterbreaks, and fill slope mass failures.

To determine if the high overall rate of crossing problems is coming from older crossings or continuing under current Rules, the database was queried to separate results from existing crossings, newly installed crossings, abandoned/removed road crossings, and skid trail crossings (Table 26). This revealed that the 88 new crossings had 68 total problem points, the 313 existing crossings (including culverts, fords, Humboldt crossings, and bridges) had 366 problem points, the 61 abandoned/removed road crossings had 43 problem points, and the 29 skid trail crossings had five problem points, which gives average values of 0.77, 1.17, 0.70, and 0.17 problem points per crossing for new, existing, abandoned/removed, and skid trail crossings, respectively.

A two-sample T test was used to test the difference between the means of the number of problem points for existing and new **culverted** crossings (the results are displayed in Table 27). This analysis revealed that the average of 0.77 problem points for new culvert crossings is significantly different (<0.01) than the average of 1.22 problem points at existing culverted crossings. However, problem points related to diversion potential, fill slope gullies, culvert plugging, and cut-off waterbreaks on roads draining to the crossing were still relatively common at new culvert crossings.

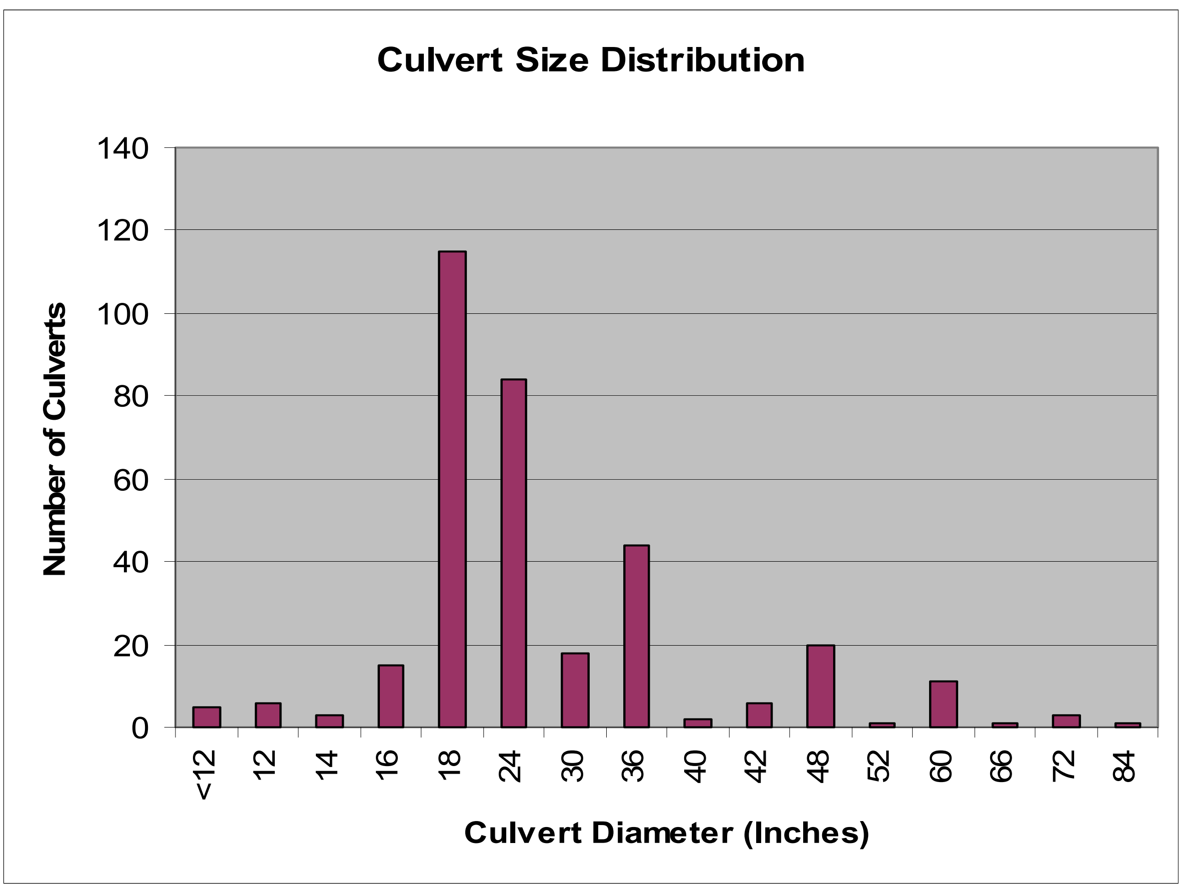

Figure 16. Culvert size distribution for watercourse crossings with pipes.

Table 25. Watercourse crossing related Forest Practice Rule requirements with more than five percent total departures based on at least 30 observations from the overall evaluation where implementation could be rated (note that some of the Rule sections are separated into components and the table is ordered by the percentage of total departures).

Forest Practice Rule	Description	Total Number	% Total Departure	% Minor Departure	% Major Departure
923.2(o)	no discharge on fill unless energy dissipators present	388	23.7	11.1	12.6
923.2(h)	size, number, and location of structures minimizes erosion	394	20.6	9.4	11.2
923.2(d) Coast	fills across channels built to minimize erosion	295	19.0	9.2	9.8
923.4(n)	crossing/approaches maintained to avoid diversion	403	16.6	12.7	4.0
923.4(1)	trash racks installed where there is abundant LWD	89	15.7	13.5	2.2
923.8	abandonment—minimize concentration of runoff	65	15.4	10.8	4.6
923.(c)	waterbreaks maintained to divert into cover	339	15.3	12.1	3.2
923.3(e)	crossing/fills built to prevent diversion	398	14.6	9.0	5.5
923.4(d)	crossing open to unrestricted passage of water	480	14.2	10.2	4.0
923.4(d)	trash racks installed where needed at inlets	78	14.1	10.3	3.8
923.8(d)	abandonment--pulling/shaping of fills	61	13.1	3.3	9.8
923.8(c)	abandonment--grading of road for dispersal	63	11.1	6.3	4.8
923.3(d)(2)	removed--cut bank sloped back to stop slumping	63	11.1	4.8	6.3
923.8(b)	abandonment--stabilization of exposed cuts/fills	63	11.1	6.3	4.8
923.3(d)(1)	removed--fills excavated to reform channel	64	10.9	7.8	3.1
923.2(h)	size, number, location of structures sufficient to carry runoff	394	10.7	3.6	7.1
923.8(e)	abandonment--fills excavated to reform channel	59	10.2	5.1	5.1
923.4	trash racks in place as specified in the THP	80	10.0	10.0	0.0
923.8(e)	abandonment--cutbanks sloped back	59	6.8	0.0	6.8
923.4(f)	50-year flood flow requirement	372	5.4	3.8	1.6
923.2(e)	throughfills built in one-foot lifts	39	5.1	2.6	2.6

Table 26. Distribution of problem points recorded for existing, new, abandoned, and skid trail watercourse crossings. Note that one crossing can have multiple problem points.

Crossing Feature	Problem Type	Existing Crossings (n = 313)	New Crossings (n = 88)	Road Abandoned/ Removed (n = 61)	Skid Trail Removed/ Ford (n = 29)	Totals
Fill Slopes	Vegetative cover	11	4	1	0	16
	Rilling	24	4	0	0	28
	Gullies	35	10	1	1	47
	Cracks	5	2	0	0	7
	Slope failure	28	4	2	0	34
Road Surface Draining to Crossing	Rutting	10	1	2	0	13
	Rilling	6	2	2	1	11
	Gullies	5	1	3	0	9
	Surfacing of approaches	5	2	2	1	10
	Cut-off waterbar	29	6	2	1	38
	Inside ditch condition	11	0	0	0	11
	Ponding	7	4	0	0	11
Culverts	Scour at inlet	5	0	NA	NA	5
	Scour at outlet	35	3	NA	NA	38
	Diversion potential	38	10	NA	NA	48
	Plugging	45	9	NA	NA	54
	Alignment	2	1	NA	NA	3
	Degree of corrosion	3	0	NA	NA	3
	Crushed inlet/outlet	8	0	NA	NA	8
	Pipe length	1	0	NA	NA	1
	Gradient	26	2	NA	NA	28
	Piping	10	1	NA	NA	11

Crossing Feature	Problem Type	Existing Crossings (n = 313)	New Crossings (n = 88)	Road Abandoned/ Removed (n = 61)	Skid Trail Removed/ Ford (n = 29)	Totals
Non-Culvert Crossings	Armoring	9	1	1	0	11
	Scour at outlet	5	1	1	0	7
	Diversion	3	0	0	1	4
Removed or Abandoned	Bank stabilization	NA	NA	5	0	5
	Rilling of banks	NA	NA	1	0	1
	Gullies	NA	NA	5	0	5
	Slope failure	NA	NA	2	0	2
	Channel configuration	NA	NA	5	0	5
	Excavated material and cutbank	NA	NA	3	0	3
	Grading and shaping	NA	NA	3	0	3
Road Approaches at Abandoned Crossings	Grading and shaping of road surface	NA	NA	2	0	2
Totals		**366**	**68**	**43**	**5**	**482**

Table 27. Distribution of watercourse crossing types and average numbers of problem points assigned for each crossing type.

Crossing Type	Number of Crossings	Number of Problem Points	Average Number of Problem Points/ Crossing
Existing Culvert	251	306	1.22*
New Culvert	83	64	0.77*
Existing Ford	40	39	0.98
New Ford	4	4	1.00
Abandoned/Removed (road)	61	43	0.70
Abandoned/Removed (skid trail)	19	1	0.05
Existing Skid Trail (ford)	8	4	0.50
New Skid Trail (ford)	2	0	0
Existing Humboldt	7	17	2.43
New Humboldt	1	0	0
Existing Bridge	11	0	0
Existing Rolling Dip	2	1	0.5
Other	2	3	1.50
Totals	**491**	**482**	**0.98**

* A two-sample T test comparing the number of problem points at existing versus new culverted crossings revealed that the means of these groups are significantly different at alpha < 0.01.

As with the other hillslope monitoring area categories, when a problem point was discovered, the field team rated the implementation and effectiveness of applicable Forest Practice Rule(s) associated with that problem (Table 28). Problems at crossings were associated with poor implementation of 24 Rule requirements, with 15 being cited as responsible for 95 percent of the problem points. All of the problem points were caused by either minor or major departures from specific Rule requirements. Overall, approximately 51 percent of the implementation ratings at the crossing problem points were recorded as minor Rule departures, while 49 percent were rated as major departures.

An overall effectiveness rating for each of the potential problem types listed in Table 26 was also completed for each crossing. A complete summary of watercourse crossing effectiveness questions is displayed in Table A-2 in the Appendix. Significant scour at the outlet of culvert crossings was found 33 percent of the time, with some degree of plugging occurring 24 percent of the time. Some level of diversion potential was noted for about 27 percent of the culverted crossings. Approximately 11 percent of the fill slopes at crossings had some amount of slope failure present. The road surface drainage cutoff structure above the crossing allowed all or some of the water running down the road to reach the crossing at about 23 percent of the sample sites. For abandoned or removed crossings, approximately 82 percent had channels established close to natural grade and orientation, with about 18 percent having minor or major differences.

Sediment delivery to watercourses is assumed to be 100 percent at crossings since these structures are built directly in and adjacent to the channels. Therefore, the evaluation of sediment delivery from the various types of problems associated with crossings was not conducted.

Table 28. Problem point implementation ratings that account for 95 percent of all the Forest Practice Rule requirements rated at watercourse crossings.

Forest Practice Rule	Description of Rules Rated for Implementation at Problem Points	Number of Times FPR Cited	Meets/ Exceeds Rule (%)	Minor Departure (%)	Major Departure (%)
923.2(h)	size, number, and location of structures minimizes erosion	126	0	43.7	56.3
923.2(o)	no discharge on fill unless energy dissipators installed	118	0	39.8	60.2
923.4(n)	crossing/approaches maintained to avoid diversion	71	0	77.5	22.5
923.2(h)	size, number, and location of structures sufficient to carry runoff	68	0	44.1	55.9
923.2(d) Coast	fills across channels built to minimize erosion	67	0	29.9	70.1
923.3(e)	crossing/fills built to prevent diversion	58	0	51.7	48.3
923.4(d)	crossing open to unrestricted passage of water	55	0	69.1	30.9
923.4(c)	waterbreaks maintained to divert into cover	43	0	74.4	25.6
923.8	abandonment—minimizes concentration of runoff	16	0	56.3	43.8
923.2(h)	size, number, and location of structures-maintains natural drainage pattern	15	0	73.3	26.7
923.8(d)	abandonment--pulling/shaping of fills appropriate	11	0	27.3	72.7
923.3(d)(2)	removed crossings--cut bank sloped back to prevent slumping and to minimize erosion	10	0	40.0	60.0
923.8(c)	abandonment--grading of road for dispersal	9	0	55.6	44.4
923.8(b)	abandonment--stabilization of exposed cuts/fills	9	0	55.6	44.4
923.3(d)(1)	removed crossings--fills excavated to reform channel	7	0	71.4	28.6

Watercourse Protection Zones (WLPZs, ELZs, EEZs)

From 1996 through 2001, 683 randomly located watercourse and lake protection zone (WLPZ) transects, equipment limitation zone (ELZ) transects, and equipment exclusion zone (EEZ) transects were evaluated, covering a total of approximately 510,800 feet or 96.8 miles for all three categories. The distribution of transects for each watercourse class is displayed in Figure 17. Approximately 17 percent of the WLPZs were associated with Class I watercourses (21.5 miles), 56 percent with Class IIs (64.4 miles), 27 percent with Class IIIs (10.4 miles), and less than one percent with Class IV waters (0.5 miles). Class III watercourses were not sampled as part of the Hillslope Monitoring Program from 1996 through 1999, but were included in 2000 and 2001.[20] For about 36 percent of the watercourse protection zone transects, the slope distance from the channel bank to the nearest road was greater than 150 feet; 18 percent had a distance of 100 to 150 feet; 25 percent had a distance of 50 to 100 feet, and 21 percent had a distance of less than 50 feet. The type of yarding upslope from the transect was classified as tractor 69 percent of the time, cable 22 percent, cable/tractor 6 percent, helicopter 2 percent, and tractor/helicopter less than 1 percent. Roads were located in 75 WLPZs, one equipment limitation zone (ELZ), and one equipment exclusion zone (EEZ).[21]

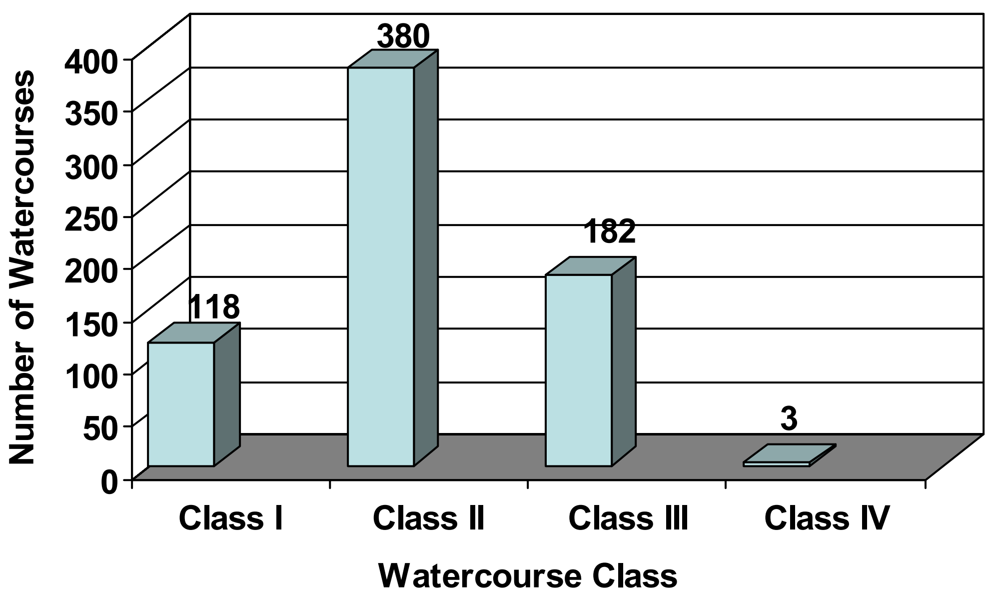

Figure 17. Distribution of watercourse classes evaluated from 1996 to 2001.

[20] Twelve Class III watercourses with WLPZs were evaluated in 1999 and 2 Class III watercourses with WLPZs were evaluated in 1997.

[21] WLPZs are not required for Class III watercourses. ELZs have been required for Class IIIs since January 1, 1998 (see 14 CCR 916.4(c)(1)). EEZs are often specified for these types of watercourses as well. ELZs allow heavy equipment in the zone only where explained in the THP and approved by the Director; EEZs are zones where heavy equipment is totally excluded.

As part of the WLPZ , ELZ, and EEZ transects, the field team rated the implementation and effectiveness of applicable Forest Practice Rules as they were encountered and as part of a subsequent overall evaluation following completion of the transect. A total of 56 questions were developed from 34 Rule sections and answered in the overall evaluation. When considering all the Forest Practice Rules related to watercourse protection zones, the implementation rate where the Rules were met or exceeded was **98.4** percent. The five Rule requirements with at least 30 observations and five percent or more major and minor departures are shown in Table 29. Three of these Rules relate to the requirement for the RPF to evaluate riparian areas for sensitive conditions, including the use of existing roads within the standard WLPZ and unstable and erodible watercourse banks. These factors are to be identified in the THP and considered when proposing WLPZ widths and protection measures. The other two Rules in Table 29 require that WLPZ widths must be at least equal to that specified in Table 1 (14 CCR 916.5 [936.5, 956.5]) in the Forest Practice Rules.

Very few erosion features associated with the current plan were found on the watercourse protection zone transects (Table 30). A total of 37 erosion features were recorded, with mass failures accounting for almost 50 percent. Most of the mass failures documented in the watercourse protection zones, however, were judged to either predate the current THP (127 features), were created after the THP but were not affected by the THP (17 features), or it was impossible to determine the feature date (17 features). The frequency of the erosion features associated with the current plan per mile of watercourse protection zone transect monitored is displayed in Table 31. Total erosion volumes for mass failures, sloughing, and gullying were approximately 2,900, 50, and 100 cubic yards, respectively. As was the case for the road and skid trail transects, these volume estimates are based on the dimensions of the voids remaining

Table 29. Watercourse protection zone (WLPZ, ELZ, and EEZ) related Forest Practice Rule requirements with more than five percent total departures based on at least 30 observations for the overall transect evaluation where implementation could be rated (note that some of the Rule sections are separated into components and the table is ordered by the percentage of total departures).

Forest Practice Rule	Description	Total Number	% Total Departure	% Minor Departure	% Major Departure
916.2(a)(4)	sensitive conditions--existing roads in WLPZ—appropriate mitigation measure(s) applied	133	9.0	4.5	4.5
916.4(a)	sensitive conditions--existing roads in WLPZ—identified in the THP	132	7.6	3.8	3.8
916.4(a)	sensitive conditions--erodible banks—identified in the THP	316	6.0	5.4	0.6
916.4(b)(3)	width of WLPZ conforms to Table 1 in the FPRs	593	5.6	4.7	0.8
916.4(b)	WLPZ widths as wide as specified in Table 1 in the FPRs	597	5.5	4.5	1.0

Table 30. Watercourse protection zone (WLPZ, ELZ, EEZ) transect erosion features associated with the current THP or NTMP NTO.

Erosion Feature	Number of Features 1996-1998	Number of Features 1999-2001	Total Number of Features 1996-2001
Cutbank/sidecast Sloughing	1	3	4
Mass Failure	13	5	18
Gullying	4	2	6
Rilling	5	4	9
Totals	23	14	37

on the hillslopes, not the amount of sediment delivered to watercourse channels. Also, similarly to what was reported for the road and skid transects, the number of erosion features for the various types of erosion were generally lower in the period 1999 through 2001 than from 1996 to 1998 (Table 30). Possible reasons for this difference are provided in the Discussion and Conclusions section of this report.

The percentage of watercourse protection zone transects that had one or more erosion features associated with the current plan of a given erosion type is shown in Table 32. Approximately 1.3 percent of the transects had at least one rill recorded, about 0.7 percent had one or more gullies, 2.0 percent had at least one mass failure, and 0.6 percent had sloughing present. These percentages are much lower than were found on roads and skid trails (see Tables 8 and 16).

When an erosion feature or other problem was found along the watercourse protection zone transects, implementation of the applicable Forest Practice Rule(s) was also rated for that problem point. A total of 27 Rule requirements were rated for implementation at watercourse protection zone problem sites. Of these, 20 Rules were associated with over 95 percent of the problem points (Table 33). When considering all the ratings

Table 31. Frequency of various types of erosion features associated with the current plan for the watercourse protection zone transects monitored.

Erosion Type	Class I (# features/mile)	Class II (# features/mile)	Class III (# features/mile)
Cutbank/Sidecast Sloughing	0	0.05	0.1
Mass Failure	0.4	0.2	0.2
Gullying	0.1	0.05	0.1
Rilling	0.1	0.1	0.1
Totals	0.6	0.4	0.5

Table 32. Percent of watercourse protection zone transects (all watercourse classes combined) with one or more erosion features associated with the current plan for selected types of erosion features.

Erosion Feature	Percent of Transects with One or More Features
Sloughing	0.6
Mass Failures	2.0
Gullying	0.7
Rilling	1.3

assigned at problem points encountered, about seven percent were associated with situations where the Rule requirements were found to have been met or exceeded and roughly 93 percent of the problem points were associated with minor or major departures from Rule requirements. The most commonly cited Rules rated for implementation at problem points were: 1) an inappropriate WLPZ width, 2) trees were not felled away from the watercourse channel, and 3) heavy equipment was not excluded from the watercourse protection zone and the approved THP did not permit this activity.

Canopy cover was measured with the spherical densiometer from 1996 through 1998 (Figure 18) and the sighting tube from 1999 through 2001. Mean total canopy cover measurements are displayed in Table 34. In all cases, average post-harvest values were above 70 percent. Average canopy values were also determined for each of the three CDF Forest Practice Districts for the sighting tube data (Figure 19). Mean values were highest in the Coast Forest Practice District (approximately 80 percent for both Class I and IIs) and lower in the interior districts. Lower values inland are probably related to warmer, drier conditions and the presence of slower growing tree species. In all cases, mean total canopy levels exceeded the Forest Practice Rule requirements in place for Class II watercourses. This is likely true for Class I watercourses as well, but overstory and understory canopy were not differentiated in this project as described by the Rules.[22]

Surface (or ground) cover was evaluated at 100 foot intervals along the watercourse protection zone transects for Class I, II, and III watercourses (Table 35). In all cases, surface cover exceeded the post-harvest Rule standard of 75 percent. Surface cover was generally similar for the three different Forest Practice Districts. Southern District Class I surface cover was slightly lower than that found in the other two districts. In the Coast Forest Practice District, high precipitation and summer fog near the ocean promote an environment that is quickly covered with surface vegetation. In the drier

[22] Since pre-harvest canopy measurements were not made at the THP and NTMP project sites, it is not possible to state what the change in canopy was due to timber harvesting activities associated with the current plan.

inland districts, bare soil is common in some locations even prior to logging. For all three districts, Class II and III surface cover means were higher than that for Class I watercourses.

Table 33. Problem point implementation ratings that account for over 95 percent of all the Forest Practice Rule requirements rated along watercourse protection zone segments.

Forest Practice Rule	Description of Rules Rated for Implementation at Problem Points	Number of Times FPR Cited	Meets/ Exceeds Rule (%)	Minor Departure (%)	Major Departure (%)
916.4(b)(3)	width of WLPZ conforms to Table 1	43	0	62.8	37.2
916.4(b)	WLPZ widths as wide as specified in Table 1	42	0	59.5	40.5
916.3(e)	trees in WLPZ felled away from channel	25	4	60.0	36.0
916.4(d)	heavy equipment excluded from the zone unless explained and approved	13	0	46.2	53.8
916.5(e)"I"	Class II--50% of total canopy left in WLPZ	11	0	45.5	54.5
916.3(c)	roads, landings outside of WLPZs	10	0	30.0	70.0
916.5(b)	beneficial uses consistent with WLPZ classes	9	0	33.3	66.7
916.2(a)(4)	sensitive conditions--unstable banks--mitigation measure(s) applied	8	0	100.0	0.0
916.4(b)	THP provides for upslope stability	8	25	62.5	12.5
916.5(a)(3)	side slope classes used to determine WLPZ width and protective measures	7	0	71.4	28.6
916.4(b)	THP provides for protection of water temperature	7	28.6	42.9	28.6
916.2(a)(4)	sensitive conditions--existing roads in WLPZ-- mitigation measure(s) applied	6	0	16.7	83.3
916.3(g)	Class I/II--2 living conifers per acre 16 in. or greater DBH, 50 ft tall retained within 50 feet of the watercourse	6	16.7	66.7	16.7
916.4(a)	sensitive conditions--existing roads in WLPZ identified in the THP	6	0	33.3	66.7
916.4(b)	THP provides for channel stabilization	6	33.3	33.3	33.3
916.4(b)	THP provides for filtration of organic material	4	50	50.0	0.0
916.5(e)"G"	Class I--50% overstory and 50% understory retained	3	0	100.0	0.0
916.4(a)	sensitive conditions--erodible banks identified in the THP	3	0	100.0	0.0
916.4(b)(4)	WLPZ width segregated by slope class	3	0	100.0	0.0
916.4(c)(3)	Class III--soil removed or stabilized	3	0	66.7	33.3

Table 34. Mean WLPZ total canopy cover measurements.

Year/Location	Class I Canopy Cover (%)	Class II Canopy Cover (%)
1996—North Coast Spherical Densiometer	79	77
1997 to 1998—Statewide Spherical Densiometer	74	75
1999 to 2001—Statewide Sighting Tube	73	75

Figure 18. Measuring canopy cover with the spherical densiometer in western Mendocino County in 1996.

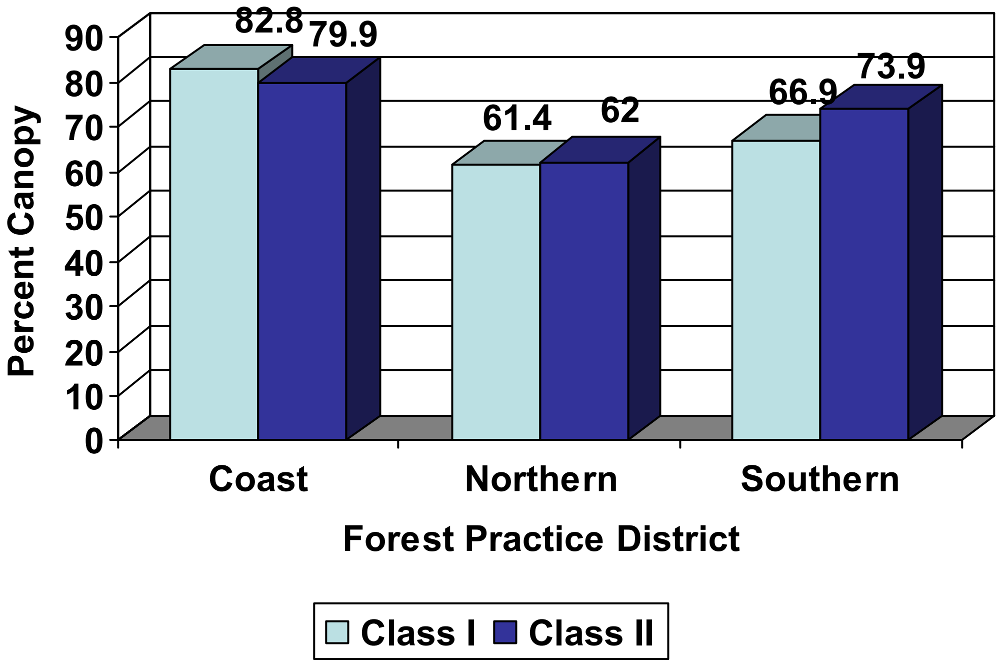

Figure 19. Total canopy cover percentages for Class I and II watercourses from 1999 through 2001 by Forest Practice District (data measured with a sighting tube).

Table 35. Mean surface cover values for the three CDF Forest Practice Districts.

CDF Forest Practice District	Class I Surface Cover (%)	Class II Surface Cover (%)	Class III Surface Cover (%)
Coast	82.5	97.1	98.3
Northern	81.9	95.3	93.0
Southern	76.2	95.4	97.6

Mean watercourse protection zone widths were estimated or measured as part of the transect effectiveness evaluation process. Mean widths for Forest Practice Rule side slope categories are shown in Table 36. It was often difficult for the field team to determine the upper extent of the WLPZ—particularly where selective silvicultural systems were used above the WLPZ. Flagging used to denote the WLPZ was often gone or difficult to locate following several overwintering periods, resulting in the estimation of WLPZ widths in some cases. It is also unknown exactly how many of the WLPZs sampled utilized the allowable reduction granted for cable yarding systems (50 foot reduction for Class I and 25 foot reduction for Class II watercoures). Thirty percent of the WLPZ transects had cable or helicopter yarding upslope of the transect (this includes areas that were listed as both cable and tractor). As reported above (Table 29), WLPZ width problems were only cited on about six percent of the transects, and major departures for the overall evaluation were only recorded for one percent of the transects.

The percentage of inventoried watercourse protection zone erosion features related to current operations that had dry season evidence of sediment reaching the high or low flow channel of a watercourse is shown in Figure 20. The percentages of sediment delivering features for sloughing, mass failures, gullying, and rilling features are 66.7, 64.3, 83.3, and 88.9 percent, respectively. No sediment was transported to the channel for 33.3 percent of the sloughing features, 35.7 percent of the mass failures, 16.7 percent of the gullies, and 11.1 percent of the rills. Of the rills that delivered sediment to watercourses, 12.5 percent delivered to Class III watercourses. For gullies that delivered sediment, 20 percent input sediment to Class III watercourses. Sediment delivery data was not reported for 0 percent of the rilling features, 0 percent of the gullies, 22.2 percent of the mass failures, and 25 percent of the sloughing events. The proportions of erosion features delivering sediment in watercourse protection zones are considerably higher than that reported from similar types of erosion features found on the road and skid trail transects (Figures 9 and 10), due to the close proximity of these features to the channel.

Table 36. Mean WLPZ width estimates.

Watercourse Class	Side Slope Gradient Category (%)	Mean WLPZ Width (feet)	Standard Forest Practice Rule Width (feet)
I	<30	79	75
	30 to 50	96	100
	≥50	119	150[23]
II	<30	53	50
	30 to 50	72	75
	≥50	90	100[12]

[23] 50 foot and 25 foot reductions in WLPZ width are allowed with cable yarding for Class I and II watercourses, respectively (see Table 1, 14 CCR 916.5 [936.5, 956.5]).

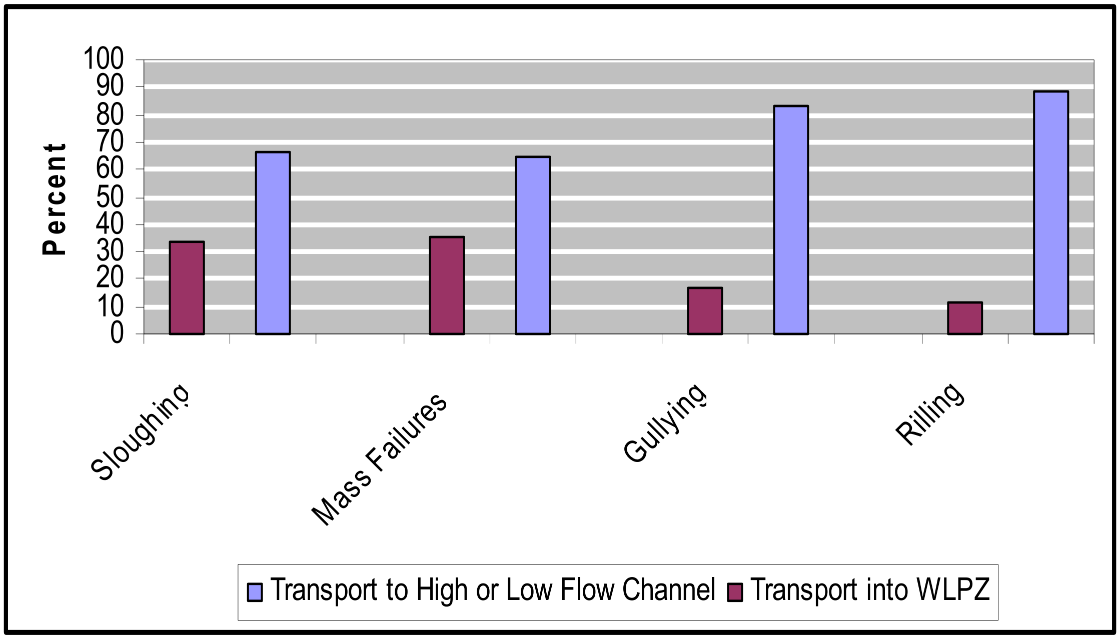

Figure 20. Percent of erosion features with dry season evidence of delivered sediment to the high or low flow channel of a watercourse from watercourse protection zone transect features associated with the current THP or NTMP project.

Large Erosion Events

While the sampling approach for roads, skid trails, landings, watercourse crossings, and watercourse protection zones utilized a very detailed evaluation for a small portion of a THP or NTMP Project, the inventory of large erosion events and associated site and management factors covered a significant portion of the THP or NTMP Project area as a whole. This more extensive approach was used in an attempt to determine the impacts of large erosion events, which may be responsible for a majority of hillslope erosion while occurring on a very limited portion of the landscape that a randomized sample approach is likely to miss. This is particularly important where mass wasting is the dominant erosional process (Rice and Lewis 1991, Lewis and Rice 1989, Lee 1997).

Erosion sites with: 1) 100 cubic yards or more on hillslopes, and 2) 10 cubic yards or more at failed watercourse crossings, were documented wherever they were found. Large erosion events were identified primarily when traveling within the THP, either by foot or in a vehicle, as part of the evaluations for randomly located road segments, skid trail segments, landings, crossings, and watercourse protection zones. Additional large erosion events were identified from THP maps. Recorded information included the size and type of erosional feature, site conditions, and specific timber operations. Where specific Forest Practice Rules could be connected to a feature, they were recorded as well. These types of evaluations were completed only for the statewide hillslope monitoring work (1997 through 2001).[24]

In-unit mass wasting was not included in this inventory because surveys of logging unit(s) were not required in the other components of the Hillslope Monitoring Program. Therefore, the impacts of the Forest Practice Rules on in-unit mass wasting, other than those large erosion events primarily triggered by the roads, skid trails, watercourse crossings, and landings evaluated within the plan, were largely undetermined (Stillwater Sciences 2002).[25]

A total of 50 large erosion events were located on the 250 THPs and NTMP projects included in this portion of the Hillslope Monitoring Program. These events were found on 37 THPs, or 15 percent, with nine plans having multiple features. Of the 50 total

---

[24] The 1996 large erosion event monitoring in Humboldt and Mendocino Counties was considered a pilot project to further refine how the data would be collected. The initial procedure used in 1996 is described in Tuttle (1995). The process was modified significantly based on information provided by the Hillslope Monitoring Program contractors who completed the field work in Mendocino and Humboldt Counties during 1996.

[25] Additional information on this subject can be found for Humboldt County watersheds in PWA (1998a, 1998b) and Marshall (2002), Mendocino County in Cafferata and Spittler (1998), and Northern California in general as part of the Critical Sites Erosion Study (Durgin et al. 1989, Lewis and Rice 1989, Rice and Lewis 1991). Also, the California Geological Survey has preliminary data on frequency of mass wasting events in clearcut units and adjacent uncut units in Jackson Demonstration State Forest, located near Fort Bragg, California (contact Mr. Thomas Spittler, CGS, Santa Rosa, CA). Information on mass wasting related to forestry operations in Oregon is available in Robison et al. (1999).

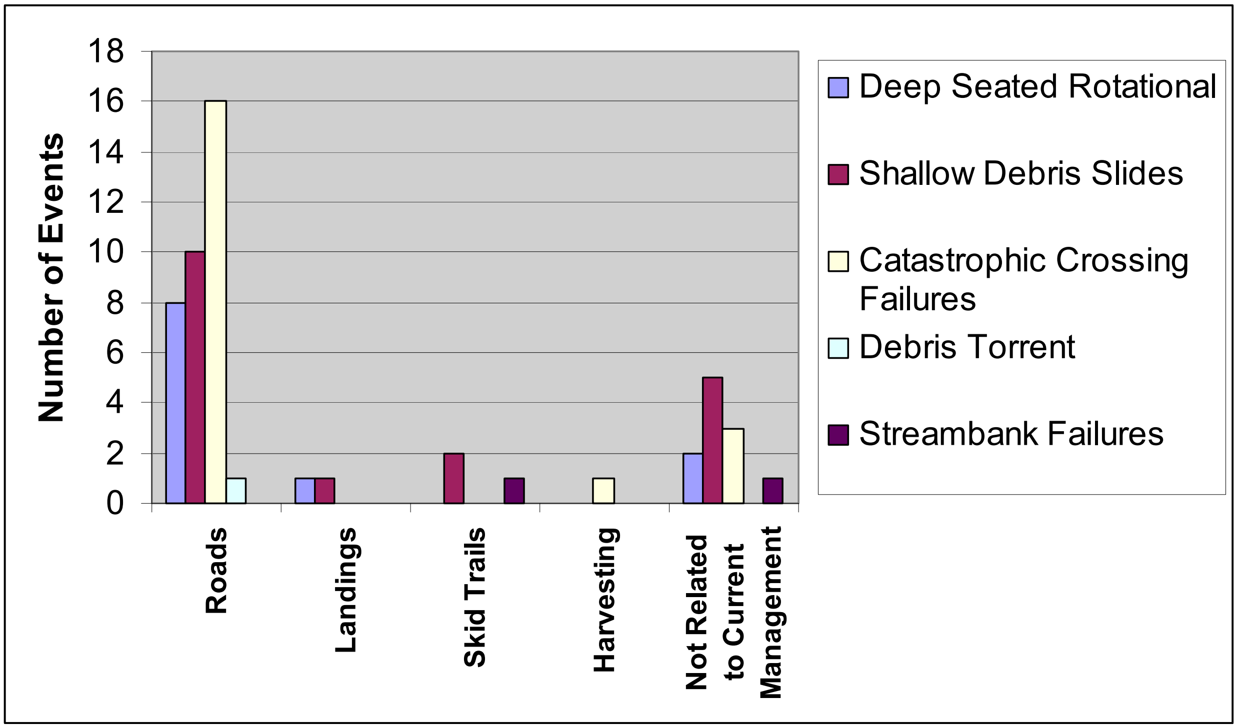

Figure 21. Primary causes of large erosion events and type of feature (note that multiple causes were assigned in some instances).

features, 39 were classified as being related to current timber management activities (Figure 21).

As shown in Table 37, nearly all of the shallow debris slide features were found in the Coast Forest Practice District, as were the majority of the deep seated rotational features. Since there were 4.7 and 2.3 times more THPs and NTMP projects in the Coast Forest Practice District when compared to the Southern and Northern Districts (Table 1), respectively, the actual frequency of catastrophic crossing failures is much higher in the inland districts. This can be partly explained by the very large rain-on-snow event which occurred in January 1997, which was at least a 100-year recurrence interval runoff event in many parts of the Sierra Nevada Mountains. Streambank failures related to the current plan and debris torrents were recorded infrequently. As with the numbers of erosion features recorded on road, skid trail, and watercourse protection zone transects, the numbers of large erosion events were considerably lower in period from 1999 through 2001 (15 features) than during the 1997-1998 period (35 features) (Figure 22).

Average volumes for the various types of erosion features related to current management activities in all three Forest Practice Districts were as follows: deep seated rotational failures—19,800 cubic yards, shallow debris slide features—3,500 cubic yards, catastrophic crossing failure features—65 cubic yards, streambank failures—600 cubic yards, and debris torrent features—550 cubic yards.

Table 37. Frequency distribution of large erosion events that were encountered on THPs and NTMP projects evaluated from 1997 through 2001.

Type of Feature	Coast	Northern	Southern	Total
Deep seated rotational	7	3	1	11
Shallow debris slide	14	3	0	17
Debris torrent	1	0	0	1
Streambank Failure	1	0	1	2
Catastrophic crossing failure	6	6	7	19
Totals	29	12	9	50

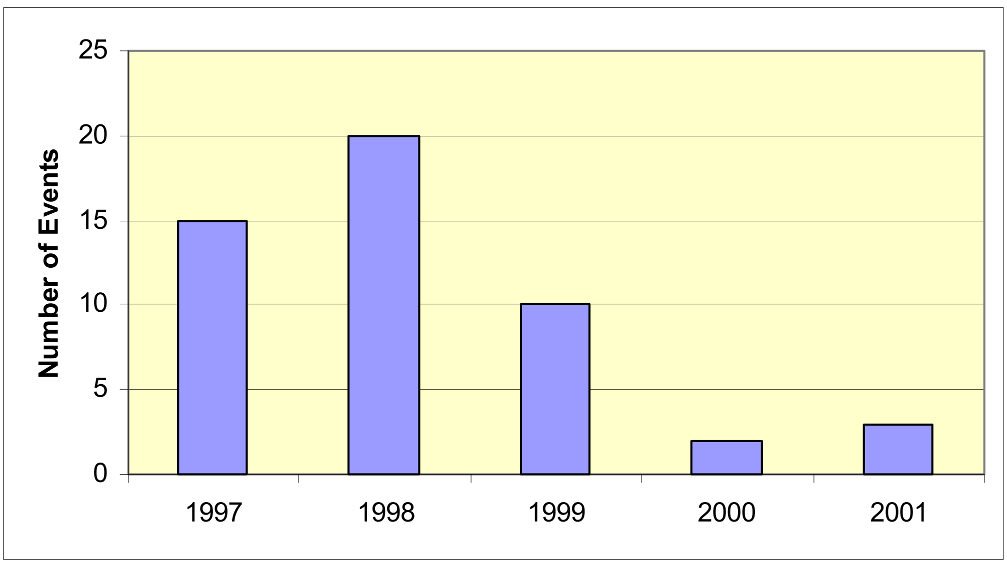

Figure 22. Year data was recorded on the large erosion events inventoried.

Most of the inventoried large erosion events related to management activities in the current plan were associated with roads (35), with smaller numbers of events associated with skid trails (3), landings (2), and harvesting (1). Cause codes and associated features are displayed in Figure 21, while specific cause codes are shown in Table 38 (multiple cause codes were assigned in some instances, so the total is greater than the 39 events). The most frequent causes of management related large erosion events were: cutbanks with slope support removed; subsurface water concentration;

culverts with plugged inlets; fill slopes with overloaded, deep sidecast; and culverts which were judged to be too small.

Table 38. Management related causes of inventoried large erosion events (note that multiple causes were often assigned to a single event).

Type of Feature	Cause of Feature	Count
Roads	Waterbars-discharge onto erodible material	3
	Waterbars-improperly constructed or located	3
	Fill slopes-too steep	3
	Fill slopes-overloaded, deep sidecast	6
	Fill slopes-poorly compacted	4
	Fill slopes-excessive organic material	1
	Culverts too small	5
	Culverts-discharge onto erodible material	2
	Culverts-inlet plugged	8
	Culverts-broken and leaking into the roadbed	1
	Inside ditch-ditch blocked and/or diverted	1
	Inside ditch-other drainage onto road not handled	4
	Cutbanks- too steep	3
	Cutbanks-slope support removed	11
	Subsurface flow alteration	1
	Cross drains-too small	1
	Cross drains-discharge onto erodible material	1
	Cross drains-improperly constructed or located	3
	Subsurface water concentrations-discharge onto erodible material	9
Skid Trails	Waterbars-not properly draining area	2
	Cutbanks-too steep	1
	Cutbanks-slope support removed	2
	Surface water concentration-rilling and gullying	1
	Surface water concentration-discharge on erodible material	2
Landings	Cutbanks-too steep	1
	Cutbanks-slope support removed	1
	Fill slopes-excessive organic material	1
	Waterbars-discharge onto erodible material	1
	Subsurface flow alteration	1
Harvesting	Alteration of natural drainage during yarding	1

Non-Standard Practices and Additional Mitigation Measures

Additional mitigation measures beyond the standard Rule requirements are often added to THPs. These mitigations may be the basis for acceptance and approval of proposed in-lieu or alternative practices and, ultimately, the THP. This summary should be considered an initial, first-phase review of non-standard practices (including in-lieu and alternative practices) and additional mitigation measures, from which future work can be built upon. Further evaluation of the implementation and effectiveness of these types of practices is needed.

A more complete evaluation approach was not developed during the Pilot Monitoring Program (1993-1995) due to the difficulty in addressing the variability of prescriptions developed for site specific problems (Lee 1997), but is needed for future monitoring work. The Hillslope Monitoring Program Interim Report (CSBOF 1999) did not address this topic, so this is the first time that these data have been summarized. It is important to note that site-specific practices and/or additional mitigation measures often did not apply at the randomly selected transects and features, so the totals reported below are a small sample that does not include all of the types of practices that were included in the THPs and NTMP projects. Additionally, the features were not examined to the same degree of rigor as on the randomly located transects evaluated for standard Rule compliance and at large erosion sites, and the narrative evaluations were based on requirements specified in the THP provided to the contractors, some of which may have been modified through amendments that were not reviewed.[26]

A brief summary of the qualitative responses provided for non-standard practice and additional mitigation measure implementation and effectiveness follows for each feature type.

Roads

Of the 568 road transects evaluated in the field, a total of 45 transects had entries in the Hillslope Monitoring Program database for the implementation and effectiveness of non-standard practices or additional mitigation measures. The most commonly approved non-standard practice was the use of roads in WLPZs,[27] followed by roads on steep slopes (greater than 65 percent). Frequently prescribed additional mitigation measures were: 1) seeding and mulching or rocking road surfaces and 2) decreasing the distance between waterbreaks (to high or extreme erosion hazard rating standards). As shown in Table 39, about 15 percent of these sites had existing or potential problems, of which four percent was associated with lack of implementation and nine percent with

[26] The field team was not always supplied with a complete set of the reviewing agencies' Pre-Harvest Inspection reports and Amendments to the THP.

[27] Currently, construction or reconstruction of a road within a WLPZ is an in-lieu practice (14 CCR 916.3(c) [936.3(c), 956.3(c)], except at new crossings approved as part of the Fish and Game Code process. Use of existing roads in WLPZs is addressed in 14 CCR 916.4(a) [936.4(a), 956.4(a)], but is not considered an in-lieu practice.

acceptable implementation. Overall, the specified practices were not fully implemented at about 13 percent of the applicable sites, and approximately 70 percent were judged to be properly implemented and effective. For approximately three percent of the applicable sites, full implementation of the specified measures was lacking but effectiveness was judged to be acceptable.

Skid Trails

Non-standard practices or additional mitigation measures were evaluated at thirty-seven of the 480 skid trail transects completed for this project. The most common practices included: 1) more frequent waterbreak spacing than required by the standard Rules, 2) tractor operations on slopes steeper than permitted by the standard FPRs, and 3) use of existing skid trails in watercourse protection zones. As shown in Table 40, only four of these practices (9 percent) were described as having existing or potential problems, of which three were associated with poor implementation and one with acceptable implementation. The specified practices were not fully implemented on approximately 25 percent of the applicable sites and were judged to be properly implemented and effective about 60 percent of the time.

Landings

A total of 28 landings had entries for non-standard practices or additional mitigation measures, out of a possible 569 features. Nearly all of these were alternatives with approval for use of WLPZ landings, usually in conjunction with additional mitigation measures that generally specified the use of seeding and mulching or rocking. As shown in Table 41, about seven percent of the sites where these practices and measures were applied had existing or potential problems, all of which were associated with acceptable implementation. About four percent of the practices were not fully implemented and almost 90 percent were properly implemented and effective.

Watercourse Crossings

Of the 491 watercourse crossings evaluated, non-standard practices or additional mitigation measures were evaluated at 18 sites as part of the hillslope monitoring process. Common mitigation measures applied at these sites included: mulching and seeding fill slopes or abandoned crossings, and use of rock for inlet or road approaches. As shown in Table 42, three of the practices at these 18 crossings (about 11 percent) had existing or potential problems, of which all were associated with acceptable implementation. Approximately 15 percent of the practices were not fully implemented. Fifty-six percent of the practices evaluated were judged to be properly implemented and effective.

Watercourse Protection Zones (WLPZs, ELZs, and EEZs)

Of the 683 watercourse protection zones transects evaluated in the field, 56 transects had entries in the Hillslope Monitoring Program database for the implementation and effectiveness of non-standard practices or additional mitigation measures. Commonly specified practices and mitigation measures were: 1) use of existing roads within WLPZs, 2) use of existing skid trails in the WLPZ , 3) no-cut WLPZs, 4) additional canopy retention requirements in the WLPZ over the standard Rule, and 5) wider WLPZs than required by the standard Rule. When evaluating the frequent practice of using existing WLPZ roads, the field team often stated that there was no *apparent* sediment delivery to the watercourse channel. It is important to recognize that these inspections were completed in the dry summer and fall months, when observation of possible fine sediment transport during winter storm events was not possible.

Table 43 displays the implementation and effectiveness ratings for the non-standard practices and additional mitigation measures for watercourse protection zones. About eight percent of these practices and measures were applied had existing or potential problems, of which one percent was associated with poor implementation and seven percent with acceptable implementation. Approximately five percent of the practices were not fully implemented. Seventy-four percent of the practices were properly implemented and effective (see the comments about fine sediment transport above).

Table 39. Summary of recorded non-standard practices and additional mitigation measures for roads.

Non-Standard Practice	Count	I/E	I/P	I/UE	UI/E	UI/P	NI/E	NI/P	NI/U
Use of WLPZ road	20	17	2		1				
No harvesting between road and stream	1	1							
Extreme EHR waterbar spacing	2	1					1		
High EHR waterbar spacing with 12 inch waterbars	1	1							
High erosion hazard rating for waterbar spacing	4			1				1	2
Use of reduced waterbar spacing	2	1	1						
Place hay bale at WLPZ waterbar outlets	1	1							
Seed and mulch road surface	4	4							
Straw mulch on road	3	3							
Road rocking	6	6							
Rock crossing approaches	1		1						
Rock Class III crossings	1	1							
Road on >65% slopes	3	3							
Roads on >65% slope and road segment >15% grade	1	1							
Full bench road construction	2	2							
Full bench road construction on unstable slopes<65%	1							1	
Outslope roads	2			1			1		
Endhauling	1	1							
Place fill in safe location	2			1					1
Push excess material to slopes <40%	1	1							
No sidecast	2	2							
No deposition from clearing cutbanks and/or brow log	1								1
Remove overhanging banks	1			1					
Reconstruct roads in wet areas	1	1							
Road moved and new crossing installed	1	1							
Class III off of road/improve drainage through landing	1	1							
Road abandonment	1								1
Remove culvert	1					1			
Winter hauling limited to firm road surface	1		1						
No winter hauling when sediment can reach stream	2		2						
Dip out crossing and mulch	1	1							
Use of excavator	1	1							
Whole tree yarding from road	1			1					
Block road	2	1						1	
Totals	76	52	7	5	1	1	2	3	5
Percent	100	68.4	9.2	6.6	1.3	1.3	2.6	4	6.6

"I/E" = Implemented and Effective/No Problem Observed
"I/P" = Implemented and Problem or Potential Problem Exists
"I/UE" = Implemented and Unknown Effectiveness
"UI/E" = Unknown Implementation and Effective/No Problem Observed
"UI/P" = Unknown Implementation and Problem or Potential Problem Exists
"NI/E" = Not Implemented and Effective/No Problem Observed
"NI/P" = Not Implemented and Problem or Potential Problem Exists
"NI/U" = Not Implemented and Unknown Effectiveness

Table 40. Summary of recorded non-standard practices and additional mitigation measures for skid trails.

Non-Standard Practice	Count	I/E	I/P	I/UE	UI/E	UI/P	NI/E	NI/P	NI/U
Use of WLPZ skid trail	4	2	1	1					
Use of WLPZ road for heavy equipment	1	1							
More frequent waterbar spacing than standard rule	2	1						1	
Waterbreak spacing at extreme EHR	7	4					1		2
Waterbreak spacing at high EHR	9	4					2	2	1
High EHR waterbar spacing with 12 inch waterbars	2			2					
Seed and mulch removed skid trail crossing	2	1		1					
Mulch approaches ot removed skid trail crossing	1	1							
Seed and mulch skid trails in WLPZ	2	1					1		
Seed and mulch skid trails on slopes >40%	1						1		
Seed and slash skid trails	1	1							
Slash and mulch skid trails	1	1							
Chip and slash skid trails	1	1							
Use of existing skid trails on slopes >65%	4	4							
Use of tractors in cable area	1	1							
Use of existing skid trails without watercourse crossings	2	2							
Skid trail crossing of Class II watercourse	1			1					
Tractor yarding during dry conditiong in winter period	1	1							
Tractor crossing of Class IV watercourse	1			1					
Totals	44	26	1	6	0	0	5	3	3
Percent	100	59.1	2.3	13.6	0	0	11.4	6.8	6.8

"I/E" = Implemented and Effective/No Problem Observed
"I/P" = Implemented and Problem or Potential Problem Exists
"I/UE" = Implemented and Unknown Effectiveness
"UI/E" = Unknown Implementation and Effective/No Problem Observed
"UI/P" = Unknown Implementation and Problem or Potential Problem Exists
"NI/E" = Not Implemented and Effective/No Problem Observed
"NI/P" = Not Implemented and Problem or Potential Problem Exists
"NI/U" = Not Implemented and Unknown Effectiveness

Table 41. Summary of recorded non-standard practices and additional mitigation measures for landings.

Non-Standard Practice	Count	I/E	I/P	I/UE	UI/E	UI/P	NI/E	NI/P	NI/U
Use of WLPZ landing	17	15	2						
Use of ELZ landing	1	1							
Rock landing surface	4	4							
Seed and mulch landing surface	4	4							
Slash and mulch landing surface	2	2							
Inslope landing, mulch, install brow log	1	1							
Drain to avoid discharge on fillslope	1								1
Install ditch for drainage	1						1		
Outslope landing	2	2							
Seed and mulch, install brow log, hay bale	1	1							
Seed landing	2	2							
Mulch landing	3	3							
Install brow log on landing surface	2	1	1						
Landing >1/4 ac for helicopter yarding	1	1							
Helicopter landing in WLPZ	1	1							
Relocate landing away from Class III watercourse 50 feet	1	1							
Rechannel watercourse	1	1							
Totals	45	40	3	0	0	0	1	0	1
Percent	100	88.9	6.7	0	0	0	2.2	0	2.2

"I/E" = Implemented and Effective/No Problem Observed
"I/P" = Implemented and Problem or Potential Problem Exists
"I/UE" = Implemented and Unknown Effectiveness
"UI/E" = Unknown Implementation and Effective/No Problem Observed
"UI/P" = Unknown Implementation and Problem or Potential Problem Exists
"NI/E" = Not Implemented and Effective/No Problem Observed
"NI/P" = Not Implemented and Problem or Potential Problem Exists
"NI/U" = Not Implemented and Unknown Effectiveness

Table 42. Summary of recorded non-standard practices and additional mitigation measures for watercourse crossings.

Non-Standard Practice	Count	I/E	I/P	I/UE	UI/E	UI/P	NI/E	NI/P	NI/U
Rock road at crossing	4	2		1					1
Install 3/4 inch rock	1		1						
Rock Class III watercourse crossing	1	1							
Rock armor inlet of crossing	2	2							
Seed and mulch fill slopes at watercourse crossing	1		1						
Seed and mulch banks of removed crossing	1						1		
Straw mulch removed watercourse crossing	1	1							
Mulch 20 feet on either side of the crossing	1	1							
Seed and mulch road surface approaches to crossing	1	1							
Straw mulch new or reconstructed crossing	1			1					
Hydromulch fill slopes	2			2					
Use of existing watercourse crossing	2	2							
Install trash rack	1						1		
Install standpipe	2	2							
Remove 36 inch pipe, rock armor for slope stabilization	1	1							
Use of gravel ford crossing	1			1					
Install concrete sacks to stabilize downstream fill slope	1	1							
Install brow logs, berm logs	1						1		
Rechannel Class III watercourse along road	1	1							
Block road	1		1						
Totals	27	15	3	5	0	0	3	0	1
Percent	100	55.6	11.1	18.5	0	0	11.1	0	3.7

"I/E" = Implemented and Effective/No Problem Observed
"I/P" = Implemented and Problem or Potential Problem Exists
"I/UE" = Implemented and Unknown Effectiveness
"UI/E" = Unknown Implementation and Effective/No Problem Observed
"UI/P" = Unknown Implementation and Problem or Potential Problem Exists
"NI/E" = Not Implemented and Effective/No Problem Observed
"NI/P" = Not Implemented and Problem or Potential Problem Exists
"NI/U" = Not Implemented and Unknown Effectiveness

Table 43. Summary of recorded non-standard practices and additional mitigation measures for watercourse protection zones (WLPZs, ELZs, and EEZs). [see the previous tables for the definitions of the abbreviations used below]

Non-Standard Practice	Count	I/E	I/P	I/UE	UI/E	UI/P	NI/E	NI/P	NI/U
Use of existing WLPZ road for hauling	19	18		1					
Use of existing road and landing in WLPZ	1			1					
Reconstruction of road in WLPZ	1	1							
Use of existing WLPZ road for skidding logs	1	1							
Use of existing WLPZ skid trail	2	2							
Extreme EHR waterbreak spacing	1	1							
Seed and mulch existing WLPZ road	2	1							1
Slash pack skid trails	1	1							
Seed and mulch removed skid trail crossing	1	1							
Rocked road in WLPZ	3	3							
Rocked cross drains on WLPZ road	1	1							
No sidecast in WLPZ from existing road	1	1							
No harvesting in WLPZ	5	3		1					1
No harvesting in WLPZ except at cable corridors	1			1					
Equipment exclusion zone (EEZ) established	1	1							
EEZ 10 feet for Class III watercourse	1	1							
No equipment in WLPZ between road and stream	1	1							
No harvesting in WLPZ between road and stream	1	1							
Reduction in WLPZ width from 150 ft to 115 ft	1	1							
WLPZ width increased to 200 ft	2	2							
WLPZ width increased to 150 ft	1			1					
WLPZ width increased to 100 ft	1	1							
WLPZ width 150 ft; no variable zone based on slope	1							1	
Class II WLPZ 75 ft regardless of slope	1	1							
WLPZ width wider than standard Rule requirement	3	2		1					
WLPZ width--maximum distance possible in Rules	1	1							
75% retention of overstory vegetation	1	1							
70% overstory and 50% understory retention	1			1					
70% overstory retention	4		3	1					
70% total canopy retention	3	1	2						
50% canopy retention in ELZ for Class III watercourse	2			2					
Retain 5 largest trees in WLPZ	1	1							
Retain 5 trees/acre >32 inches DBH	1	1							
Very limited harvesting in WLPZ	2	2							
Removal of debris jams in channel	2	2							
Remove slash from WLPZ	1								1
Allow tree falling to occur across watercourse	2	1		1					
Exception to Rule requiring 2 conifers >16 in w/in 50 ft	1	1							
Totals	76	56	5	11	0	0	0	1	3
Percent	100	73.7	6.6	14.5	0	0	0	1.3	3.9

Discussion and Conclusions

Project Limitations

The Hillslope Monitoring Program has primarily reviewed Timber Harvesting Plans, with a very limited evaluation of Nonindustrial Timber Management Plans. Exemptions, Emergency Notices, and Conversions have not been monitored. The THP "Review Process" and the degree to which this process contributes to water quality problems has not been considered (Lee 1997). Also, since winter documentation of fine sediment delivery to streams was not possible with this program, the percentages of sediment delivery to watercourse channels from erosion features found on roads, landings, and skid trails are likely to underestimate total sediment delivery. Analysis completed on the data set to date has primarily been composed of frequency counts and has been limited by time and access to database analysts. Additional data analysis will be conducted in the future.

Key points regarding what has been learned are summarized and discussed below.

<u>Implementation rates of the Forest Practice Rules related to water quality are high, and individual practices required by the Forest Practice Rules are effective in preventing hillslope erosion features when properly implemented</u>.

Table 44 shows that overall ratings of the FPRs for each monitoring subject area are high—over 90% for all but watercourse crossings. This result is similar to what has been reported for other western states. For example average implementation rates for BMPs have been reported as 96 percent, 94 percent, and 92 percent in Oregon, Montana, and Idaho, respectively (Ice et al. 2002). In California, implementation of applicable Rules at problem points was nearly always (98% overall) found to be less than that required by the FPRs (Table 45). Therefore, problem points were almost always caused by non-compliance with the FPRs. These results are consistent with findings reported in earlier studies conducted in California (Dodge et al. 1976, CSWRCB 1987). The above conclusion refers to "individual practices," since the THP Review and inspection process was not evaluated as part of the Hillslope Monitoring Program.

Table 44. Summary of acceptable (i.e., meets or exceeds requirements) Forest Practice Rule implementation ratings for transects (roads, skid trails, watercourse protection zones) and features (landings and watercourse crossings) as a whole.

Hillslope Monitoring Program Sample Area	% Acceptable Implementation
Road Transects	**93.2**
Skid Trail Transects	**95.1**
Landings	**93.5**
Watercourse Crossings	**86.3**
Watercourse Protection Zones (WLPZ, ELZ, EEZ)	**98.4**
Total	**94.5**

Table 45. Summary of Forest Practice Rule implementation ratings at problem points for individual Hillslope Monitoring Program evaluation areas.

Hillslope Monitoring Program Sample Area	Percent Acceptable Implementation	Percent Major or Minor Departure from Requirements
Road Transects	**2**	**98**
Skid Trail Transects	**0**	**100**
Landings	**0**	**100**
Watercourse Crossings	**0**	**100**
Watercourse Protection Zones	**7**	**93**
Total	**2**	**98**

Watercourse crossing problems remain frequent, with nearly half the crossings evaluated having at least one problem point.

Large numbers of problem points were found at crossings. Reasons for this include:

- crossings are sometimes built incorrectly,
- many types of crossings have a relatively short expected life,
- culverts are sized with planned failure if a discharge event exceeds a selected recurrence interval (often 50 or 100 years),
- culverted crossings are often not built to properly accommodate large wood and sediment,
- maintenance of crossings—particularly culverts—is often difficult due to remote locations, lack of staff, and road passage problems in winter months,
- abandonment principles are subjective, difficult to apply in the field, and require considerable experience for proper implementation,
- upgrading old crossings can be very expensive, and
- shared use agreements on roads with crossings can complicate the responsibility and timing of improvement work.

The most frequent types of crossing problems encountered during the hillslope monitoring work were culvert plugging, diversion potential, fill slope gullies, scour at the outlet of the culvert, ineffective road surface cutoff waterbreaks, and fill slope mass failures. These problems are primarily related to the design, construction, and maintenance of crossings. Replacing and upgrading numerous crossings along a road segment can be a large, difficult, and expensive task for a landowner. Inventorying for the worst crossings with the most potential for adverse impacts to water quality and developing a plan to complete the work may be a realistic solution (see Flanagan et al. 1998). Gucinski et al. (2001) list several techniques for decreasing the negative hydrologic effects of roads, several of which relate to crossings.

Proper crossing abandonment requires considerable expertise and experience. Guidelines for accomplishing this work are provided in Weaver and Hagans (1994). Long-term sediment savings can be provided by removing crossings that will eventually fail (Madej 2001), but a small short-term flush of sediment is likely to occur during the first winter following heavy equipment work. Weaver (2001) estimated that this will often be on the order of 5 to 10 cubic yards per crossing.[28] Monitoring of crossing removal work in the Caspar Creek watershed found that an average of approximately 10 cubic yards was eroded from abandoned crossings during the first winter (excluding the one crossing in the South Fork that was retaining old splash dam deposits—see the Summary of Related Studies section earlier in this report for additional details).

Roads with drainage structure problems are the main cause of sediment delivery to stream channels.

About half the road transects evaluated by the Hillslope Monitoring Program field crews had one or more rills, approximately 25 percent had at least one gully, and four percent had a mass failure associated with the current plan. Forest Practice Rules related to these features were nearly always found to be out of compliance, usually due to drainage feature problems. Specifically, these problems were most often related to having: 1) inadequate size, number, and location of drainage structures to carry runoff water and minimize erosion, and 2) inadequate waterbreak spacing and waterbreak discharge into cover. About six percent of all evaluated drainage structures had problem points assigned to them. Gullies delivered sediment to channels about 24.5 percent of the time and rills about 12.6 percent of the time.

The monitoring results reported here are consistent with those described by MacDonald and Coe (2001—see the Related Studies section of this report). For their sites in the Central Sierra Nevada Mountains, they found that 16 percent of the segments and 20 percent of the road length had gullies or sediment plumes that were within 10 meters (32.8 feet) of a stream channel. In this study, contributing surface area multiplied by slope (A*S) was the best predictor of road surface erosion, and decreasing A*S by improving and maintaining road drainage was recommended to reduce erosion on native surfaced roads. In other words, proper spacing of rolling dips, waterbreaks, and where necessary, culvert cross drains, is a key component to reducing road surface erosion. Numerous publications have described techniques to reduce road surface erosion (see for example Burroughs and King 1989).

Hillslope monitoring results in Oregon are also consistent with data collected in California. Robben and Dent (2002) report that non-compliance with road related BMPs, especially drainage and maintenance requirements, was the largest source of sediment delivery to stream channels in their BMP compliance monitoring project. They also state that because the surveys were performed in the dry season, they likely underestimated the number of sediment delivery sources and total eroded volume. Skaugset and Allen (1998) stated that relief of road drainage at stream crossings was the most common source of sediment delivery in western Oregon. This study found that 25 percent of the surveyed road length delivered sediment directly to a stream channel. Additionally, Luce and Black (1999) found that sediment production was related to road surfaces, unvegetated ditches, and cutslope lengths draining to stream channels.

[28] This estimate was made based on field work conducted in Humboldt County.

Watercourse protection zones provide for adequate retention of post-harvest canopy and surface cover, and for prevention of harvesting related erosion.

Class I watercourses made up approximately 17 percent of the evaluated watercourses, 56 percent were Class IIs, and 27 percent were Class IIIs. Statewide, mean post-harvest total canopy cover exceeded 70 percent, regardless of instrument used for measurement. Mean total canopy exceeded Forest Practice Rule requirements in all three Forest Practice Districts, and was approximately 80 percent in the Coast Forest Practice District for both Class I and II watercourses. Surface cover exceeded 75 percent for all watercourse types in all three Forest Practice Districts. Required WLPZ widths generally met Rule requirements, with major departures from Rule requirements recorded only about one percent of the time. Additionally, the frequency of erosion events related to current timber operations in watercourse protection zones was very low for Class I, II, and III watercourses.

These results are consistent with the Modified Completion Report Monitoring program data collected by CDF Forest Practice Inspectors discussed earlier in the Related Studies section (Brandow 2002). Canopy measurements were remarkably similar for Class I and II watercourses in all three Forest Practice Districts. Similarly, erosion features related to the current operations in Class I and II WLPZs have been very rare.

With the federal listing of coho salmon as a threatened species in 1997 for the Southern Oregon/Northern California Coasts Coho ESU, it has been a common practice in the Coast Forest Practice District to either have 70 percent post-harvest canopy in Class I watercourses (CDF 1997) or prescribe no-harvest zones.[29] Greatly reduced harvesting within WLPZs has also been a common practice for interior area THPs in recent years. However, total canopy cover in the interior area is lower than on the Coast, which is probably due to past harvesting, slower conifer growth rates, and drier growing conditions for understory vegetation.

The monitoring work described in this report does not allow conclusions to be made regarding instream channel conditions for fish habitat (CSBOF 1999), and evaluating the biological significance of the Rules was not part of this program. For example, no relationship between post-harvest canopy levels and acceptable water temperatures for coldwater fish species can be determined from the data collected in this study. This type of monitoring has been and is currently being conducted in numerous locations throughout the state (see for example Lewis et al. 2000 and James 2001). Instream sediment production from timber operations conducted under the modern Forest Practice Rules, and impacts to macroinvertebrate communities and anadromous fish are available from the Caspar Creek watershed study (see Lewis et al. 2001, Rice et al. 2002, Bottorff and Knight 1996, Nakamoto 1998, and the summary provided in the

[29] The July 2000 Threatened and Impaired Watersheds Rule Package approved by the BOF requires at least 85 percent overstory canopy post-harvest for the first 75 feet for planning watersheds with listed or candidate anadromous salmonid species, but THPs accepted by CDF after July 1, 2000 (when the Rule package went into effect) have not been included in the plans evaluated by the Hillslope Monitoring Program to date.

Related Studies section of this report). Additionally, research is underway by Drs. Mary Ann Madej (USGS) and Peggy Wilzbach (HSU) on the relative importance of size-specific, inorganic vs. organic components of the suspended load of streams and the influence of these components on stream health, as reflected in the efficiency of growth of juvenile salmonids and their invertebrate food base. This work is being conducted in the Caspar Creek and Redwood Creek watersheds of California. Data on large wood loading and recruitment in second-growth redwood/Douglas-fir watersheds found in the Coast Forest Practice District is available in Benda et al. (2002).

Landings and skid trails are not producing substantial impacts to water quality.

Erosion problems on landing surfaces, cut slopes, and fill slopes were relatively rare. Only about 11 percent of the landings evaluated were assigned problem points and the largest category of these occurrences was related to rills or gullies that formed from concentrated runoff below the outlet of a landing surface drainage structure. Dry season evidence of sediment delivery from landing surface drainage and fill slope erosion features to watercourse channels was recorded only seven and six times, respectively, from 569 landings.

Rill and gully erosion features on skid trails were found to deliver sediment to watercourse channels 3.8 percent and 13 percent of the time, respectively. Nearly all of these erosion problems were related to improper implementation of FPRs specifying installation of drainage structures. Low rates of sediment delivery from skid trails with properly installed and functioning drainage structures are not surprising, since earlier work in California has shown that skid trails used under the current Forest Practice Rules have not had a large impact on water quality. For example, Euphrat (1992) studied sediment transport related to timber harvesting in the Mokelumne River watershed in the central Sierra Nevada Mountains. The data he collected on numerous skid trails revealed that sediment was not transported to watercourses, and the data implied that relatively little material flowed off other well drained skid trail segments. Additionally, data collected by MacDonald and Coe (2001) in the central Sierra Nevada Mountains has shown that most harvest units (primarily tractor logged with skid trails) and landings produced relatively little sediment. Recently, Benda (2002) reported no erosion off well drained skid trails at the Southern Exposure research site in the Antelope Creek watershed in Tehama County.

The frequency of erosion events has decreased substantially in the last three years of the program.

The numbers of rills, gullies, mass failures and cutbank/sidecast sloughing features found on road, skid trail, and watercourse protection zone transects and the number of large erosion events decreased for the period from 1999 through 2001 when compared to 1996 through 1998. The primary reason for this decrease is probably reduced storm size, intensity, and frequency after the winter of 1997/1998. The January 1997 storm produced a 100-year discharge event in many Sierra Nevada Mountain watersheds, and was also a very significant event in the Coast Forest Practice District. For example, in southern Humboldt County in the Bull Creek basin, the January 1997 event is the flood of record, surpassing even the legendary December 1964 flood. The following winter of 1997/1998 (water year 1998) was a strong El Niño winter, with large, nearly continuous storm events. This hydrologic year produced the winter of record for total precipitation in the Caspar Creek watershed and produced numerous legacy road related landslide features in the South Fork basin (Cafferata and Spittler 1998). Maximum annual instantaneous peak discharge values for three free flowing stream systems located throughout Northern and Central California are displayed in Figure 23 and show much higher values in water years 1995, 1996, and 1997, when compared to those that occurred in 1998 through 2001. Therefore, it is possible to conclude that the Hillslope Monitoring Program study period has included large stressing storm events that have tested the Forest Practice Rules related to water quality—particularly in the first three years of the project.

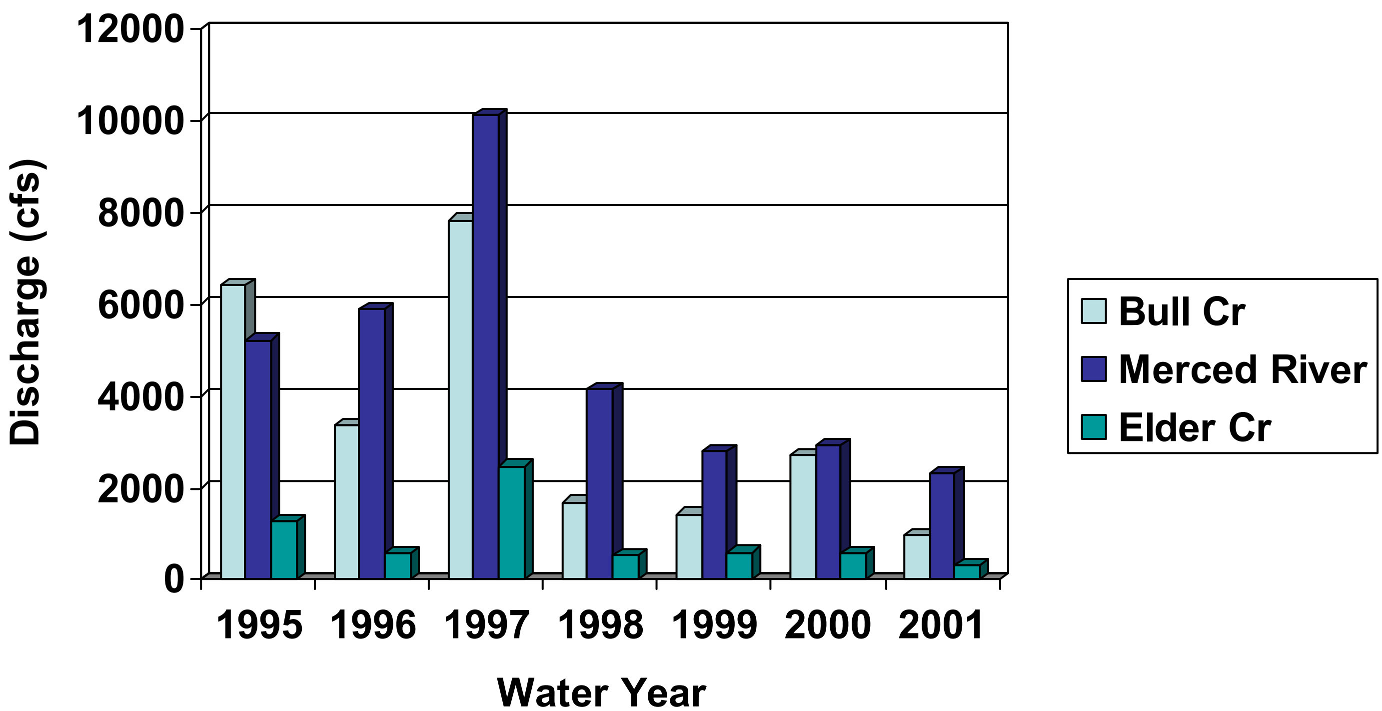

Figure 23. Stream gauging station maximum annual instantaneous peak discharge data for three free flowing river systems. The Merced River at Happy Isles is located in Yosemite National Park in the central Sierra Nevada Mountains, Bull Creek is located in southern Humboldt County, and Elder Creek is located in western Mendocino County.

The connection between storm size and intensity and the frequency of erosion features is supported by the results that Coe and MacDonald (2002), who noted large interannual variability in sediment production rates over three years of monitoring at their central Sierra Nevada sites, and attributed these differences to the magnitude and type of the precipitation. For example, sediment production for the 1999-2000 winter was 3 to 11 times higher than the sediment production rates for the 2000-2001 winter.

Additional reasons for reduced erosion feature frequency for the second three year period include increased familiarity with field methods and a change in the THP selection process. The lead contractor for the project, Mr. Roger Poff, has stated that rilling on road and skid trail transects may have been overestimated during the first two years (1996 and 1997) of the project, primarily because of the complexity of the data recording process and the learning curve required to successfully complete adequate data collection. Rills were not usually measured to determine if they met the stated criteria for this type of feature and were probably tallied too frequently (R.J. Poff, personal communication). Also, there were more small non-industrial landowner THPs and NTMP projects, with generally smaller plan size for the period from 2000 to 2001, which probably reduced the opportunity for finding the various types of erosion features.

The Hillslope Monitoring Program results to date are similar to data collected on CDF violations for THPs related to water quality.

Water quality violations of the Rules are identified and corrected, where possible, as part of the normal CDF Forest Practice Inspection process. Information from CDF's Forest Practice Program Database shows that 975 violations were issued on the 4,749 THPs open from 1998 through 2000.[30] These violations can be separated into three basic groups: harvesting practices and erosion control (347), watercourse and lake protection (308), and logging roads and landings (320). The FPRs with the highest number of violations generally involved waterbreak requirements, timber operations in the winter period, proper removal of temporary crossings, roads and landings located outside of WLPZs, removal of debris from very small watercourses, WLPZ trees felled away from the watercourse, removal of accidental depositions in watercourses, crossings open to unrestricted passage of water, size/number/location of drainage structures adequate to minimize erosion, and crossing removal adequate to prevent erosion. This type of information complements the data from the Hillslope Monitoring Program and CDF's Modified Completion Report monitoring work. Together, these three independent data sources allow cross-checking and corroboration of the results of each type of monitoring (Ice et al. 2002).

[30] This data analysis was completed by Mr. Clay Brandow, CDF, Sacramento.

Several reasons exist for why THPs with approved Work Completion Reports can have relatively high percentages of total departures from Forest Practice Rule requirements.

The deviations from the FPRs reported in the 1999 Interim Report (CSBOF 1999) for THPs with approved Work Completion Reports has prompted criticism of the adequacy of the CDF's inspection and enforcement program (see for example, Stillwater Sciences 2002). Reasons for these post-inspection Rule problems include:

- CDF Forest Practice Inspectors focus on the whole THP to identify threats to water quality and often will not find minor departures. Most of the Rule departures associated with problem points in the six years of hillslope monitoring have been minor departures with little or no direct impact to water quality. Of all the total number of departures for the problem point sites, 76.5 percent have been minor and 23.5 percent major departures. The category with the highest percentage of major departures is watercourse crossings, with approximately 49 percent major departures at identified problem points.

- CDF inspectors must balance the time necessary to enforce the repairing of a single or small problem against forgone inspections on other plans where there may be significant numbers of problems or a significant consequence from a problem.

- Some FPRs are qualitative in nature, and a minor deviation identified in the Hillslope Monitoring Program when an erosion feature is found would not necessarily trigger a rule violation by CDF during an inspection before the erosion occurred. A common example of this type of Rule is 14 CCR 923.2(h) [943.2(h), 963.2(h)], which requires drainage structures of sufficient size, number and location to minimize erosion.

- In the Hillslope Monitoring Program, major departures are assigned for sediment delivery with or without a significant departure from Rule requirements.

Several steps have been taken to improve implementation of the FPRs related to water quality since 1999. These include implementation of the Modified Completion Report monitoring process by CDF Forest Practice Inspectors in 2000 (see discussion on this program in the Related Studies section of this report), BOF passage of a rule requiring RPF supervision of active logging operations in 2000,[31] and information dissemination/ training related to monitoring results provided to CDF Foresters and RPFs in California.

[31] This Rule was passed by the BOF in 2000 and went into effect on January 1, 2001. See 14 CCR 1035.1, Registered Professional Forester Responsibility.

Preliminary results on the use of non-standard practices and additional mitigation measures indicate the need for more thorough inspection and a more focused study design to adequately examine the implementation and effectiveness of these practices.

The determination of whether proposed non-standard practices (i.e., alternatives, in-lieus, exceptions, etc., collectively referred to as non-standard practices) and additional mitigation measures are appropriate for a given site is a major component of the Timber Harvesting Plan Review Process, so there is clearly a need for monitoring the adequacy of these practices. However, the focus of the Hillslope Monitoring Program has been on evaluating the adequacy of standard Forest Practice Rules, so results from the limited data collected on non-standard practices should be considered as preliminary.

The data collected to date show that existing or potential problems were found on approximately 15 percent of road transects, 7 percent of landings, 11 percent of crossings, 9 percent of skid trail transects, and 8 percent of watercourse protection zone transects where non-standard practices and additional mitigation measures were prescribed. Improper implementation of these practices was 13 percent on roads, 25 percent on skid trails, 4 percent on landings, 15 percent at crossings, and 5 percent for watercourse protection zones. These results are consistent with the findings for the standard Forest Practice Rules for watercourse protection zone transects, with both standard and non-standard Rules having high overall implementation ratings and few problems. Additionally, these preliminary results suggest that better implementation of non-standard practices could be achieved with more thorough inspection by RPFs and CDF Forest Practice Inspectors.

The California Forest Practice Rule requirements with the lowest overall implementation related to water quality have been identified and education efforts related to these Rules are required.

To focus on areas where improvement in Rule design or implementation would provide the greatest benefits to water quality, Table 46 summarizes the 20 Forest Practice Rule requirements with four percent or more major departures (the table shows 24 Rule requirements, but one Rule was cited for both roads and landings[32], and three Rules were cited for both roads and crossings). The need for improved implementation of these Rule requirements, in particular, should be made known to RPFs, LTOs, and CDF Forest Practice Inspectors. Seven rule requirements relate to roads, one to skid trails, two to landings, 13 to watercourse crossings, and one to watercourse protection zones.

[32] Note that 14 CCR 923.1(a) is a THP mapping requirement and does not directly cause an adverse impact water quality.

Table 46. Forest Practice Rule requirements with at least four percent major departures based on at least 30 observations where implementation could be rated (note this table was developed from Tables 6, 14, 22, 25, and 29).

Location	Rule No.	Description of Rule	Major Departure %
Roads	914.6(f)	where waterbreaks do not work--other erosion controls installed	4.2
Roads	923.1(f)	adequate numbers of drainage structures to minimize erosion	4.8
Roads	923.2(h)	size, number, and location of structures sufficient to carry runoff water	5.3
Roads	923.1(a)	landing on road greater than ¼ acre or requiring substantial excavation--shown on THP map	11.5
Roads	923.2(h)	size, number, and location of structures sufficient to minimize erosion	4.1
Roads	923.2(d) Coast	fills constructed with insloping approaches, berms, rock armoring, etc., to minimize erosion	4.7
Roads	923.2(m)	sidecast extending greater than 20 feet with access to a watercourse protected by a WLPZ treated to reduce erosion	7.4
Skid Trails	914.6(c)	waterbreak spacing equals standards	5.6
Landings	923.1(a)	landings greater than ¼ acre or requiring substantial excavation--shown on THP map	10.9
Landings	923.5(f)(4)	sidecast or fill extending greater than 20 feet with access to watercourse—treated to reduce erosion	4.3
Crossings	923.2(o)	no discharge on fill unless suitable energy dissipators are used	12.6
Crossings	923.2(h)	size, number, and location of structures minimizes erosion	11.2
Crossings	923.2(d) Coast	fills across channels built with insloping approaches, berms, rock armoring, etc., to minimize erosion	9.8
Crossings	923.4(n)	crossing/approaches maintained to avoid diversion	4.0
Crossings	923.8	abandonment—minimize concentration of runoff	4.6
Crossings	923.3(e)	crossing/fills built to prevent diversion	5.5
Crossings	923.4(d)	crossing open to unrestricted passage of water	4.0
Crossings	923.8(d)	abandonment--pulling/shaping of fills	9.8
Crossings	923.8(c)	abandonment--grading of road for dispersal of water flow	4.8
Crossings	923.3(d)(2)	removed--cut bank sloped back to prevent slumping and to minimize soil erosion	6.3
Crossings	923.8(b)	abandonment--stabilization of exposed cuts/fills	4.8
Crossings	923.2(h)	size, number, location of structures sufficient to carry runoff	7.1
Crossings	923.8(e)	abandonment--fills excavated to reform channel	5.1
WLPZs	916.2(a)(4)	sensitive conditions--existing roads in WLPZ—appropriate mitigation measure(s) applied	4.5

Recommendations

Based on the results compiled from six years of Hillslope Monitoring Program data, we recommend the following items:

TRAINING

1. Develop robust training programs based on monitoring results for LTOs, RPFs, CDF Forest Practice Inspectors, and members of other reviewing agencies. Training program agendas will be tailored to the needs of the various targeted audiences.

2. Require more thorough and consistent inspection of watercourse crossings by CDF Forest Practice Inspectors and other reviewing agencies based on the above training programs.

3. Inform CDF Forest Practice Inspectors on monitoring results at the annual CDF Forest Practice enforcement training course in Fort Bragg. Note that while the course is offered annually, each Inspector attends the class every four years. Additionally, inform CDF Forest Practice Inspectors of monitoring results and needed improvements at annual forester meetings.

4. Develop a Licensed Timber Operator (LTO) implementation guidance document for installation of watercourse crossings and road drainage structures. This effort should be coordinated with the other reviewing agencies, particularly the California Department of Fish and Game. The goal is to produce a relatively simple document that quickly and simply illustrates the most important principles for successful crossing and drainage structure design and installation. For example, some of the concepts to include for crossings would be proper: gradient, alignment, diversion potential, pipe length, armoring, etc.

5. Raise awareness of key hillslope monitoring findings to forest landowners, the public, Licensed Timber Operators, RPFs, and other interested parties. This is to be accomplished through updates provided to the BOF's Licensing News, the CLFA Update, CDF Mass Mailings to RPFs, and other regularly produced newsletters.

6. Work with the California Licensed Foresters Association (CLFA), Associated California Loggers (ACL), Forest Landowners of California (FLOC), the California Forestry Association (CFA), and other forestry related trade associations to develop workshops that address key issues identified through hillslope monitoring. For example, a CLFA workshop on watercourse crossings is scheduled for March, 2003.

ROAD MANAGEMENT PLAN

7. Upgrade those watercourse crossings with problems, including old, existing structures, with a voluntary, cooperative Road Management Plan, including an agreed to schedule to complete upgrading work.

MODIFICATIONS FOR THE HILLSLOPE MONITORING PROGRAM

8. Revise the Hillslope Monitoring Program to adequately examine: 1) additional mitigation measures applied to THPs, and 2) non-standard practices applied to THPs (including in-lieu and alternative practices).

9. Revise the Hillslope Monitoring Program to: 1) address the changes in the Forest Practice Rules since the BOF passed the Threatened and Impaired Watersheds Rule Package in July 2000, and 2) reduce emphasis on semi-qualitative assessments by conducting more rigorous and scientifically defensible tests of individual practice effectiveness (e.g., pre and post-harvest, overstory/understory, conifer/hardwood canopy data; detailed information on watercourse crossings built as part of the current plan under the Threatened and Impaired Watersheds Rule Package, allowing for passage of wood and sediment as well as 100-year flood flows; and detailed information on newly constructed road drainage structures, including contributing surface area, slope, surfacing, grading, erosion problems, sediment delivery, etc.).

WORK NEEDED TO COMPLEMENT THE HILLSLOPE MONITORING PROGRAM

10. Continue to support the implementation and funding of instream monitoring projects that have a peer-reviewed study design, including pre-project data collection, to answer questions about Forest Practice Rule effectiveness and compliance with Regional Water Quality Control Board Basin Plan standards.

Literature Cited

Benda, L.E. 2002. Southern Exposure Study: wood recruitment and erosion studies. Power Point presentation to the California State Board of Forestry and Fire Protection, November 2002 Meeting, Sacramento, CA.

Benda, L.E., P. Bigelow, T.M. Worsley. 2002. Recruitment of wood to streams in old-growth and second-growth redwood forests, Northern California, U.S.A. Can. J. For. Res. 32: 1460-1477. In press.

Bottorff, R.L. and A.W. Knight. 1996. The effects of clearcut logging on stream biology of the North Fork of Caspar Creek, Jackson Demonstration State Forest, Fort Bragg, CA -- 1986 to 1994. Unpubl. Final Rept. prepared for the California Department of Forestry and Fire Protection, Contract No. 8CA63802. May 1996. Sacramento, CA. 177 p. http://www.rsl.psw.fs.fed.us/projects/water/caspubs.html

Brandow, C. 2002. Modified Completion Report Monitoring Update—Power Point Presentation prepared for the California State Board of Forestry and Fire Protection's Monitoring Study Group meeting held at the CDF Mendocino Unit Headquarters—Howard Forest, located near Willits, CA, September 17, 2002.

Burroughs, E.R. and J.G. King. 1989. Reduction of soil erosion on forest roads. Gen. Tech. Rep. INT-264. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 21 p.

Cafferata, P.H. and T.E. Spittler. 1998. Logging impacts of the 1970's vs. the 1990's in the Caspar Creek watershed. In: Ziemer, R.R., technical coordinator. Proceedings of the conference on coastal watersheds: the Caspar Creek story, 1998 May 6; Ukiah, CA. General Tech. Rep. PSW GTR-168. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. P. 103-115. http://www.rsl.psw.fs.fed.us/projects/water/caspubs.html

California Department of Forestry and Fire Protection (CDF). 1997. Coho salmon (*Oncorhynchus kisutch*) considerations for timber harvests under the California Forest Practice Rules. CDF Mass Mailing to all RPFs dated April 29, 1997. Sacramento, CA. 49 p.

California State Board of Forestry (CSBOF). 1993. Assessing the effectiveness of California's Forest Practice Rules in protecting water quality: recommendations for a pilot monitoring project and longer term assessment program. Prepared by the Monitoring Study Group (MSG) with assistance from William M. Kier Associates. Sacramento, CA. 55 p.

California State Board of Forestry and Fire Protection (CSBOF). 1999. Hillslope monitoring program: monitoring results from 1996 through 1998. Interim Monitoring Study Group Report prepared for the California State Board of Forestry and Fire Protection. Sacramento, CA. 70 p. http://www.fire.ca.gov/bof/board/msg_supportedreports.html

California State Board of Forestry and Fire Protection (CSBOF). 2000. Monitoring Study Group Strategic Plan. Sacramento, CA. 24 p. http://www.fire.ca.gov/bof/board/msg_strplan.html

California State Water Resources Control Board (CSWRCB). 1987. Final report of the Forest Practice Rules assessment team to the State Water Resources Control Board (the "208 Report"). Sacramento, CA. 200 p.

Coe, D. and L.H. MacDonald. 2001. Sediment production and delivery from forest roads in the Central Sierra Nevada, California. Eos Trans. American Geophysical Union, 82(47), Fall Meeting Suppl., Abstract H51F-03. http://www.agu.org/meetings/waisfm01.html

Coe, D. and L.H. MacDonald. 2002. Magnitude and interannual variability of sediment production from forest roads in the Sierra Nevada, California. Poster Session Abstract, Sierra Nevada Science Symposium 2002, October 7-10, 2002, Lake Tahoe, CA. http://danr.ucop.edu/wrc/snssweb/post_aquatic.html

Dodge, M., L.T. Burcham, S. Goldhaber, B. McCulley, and C. Springer. 1976. An investigation of soil characteristics and erosion rates on California forest lands. Final Report, Department of Conservation, Division of Forestry. Sacramento, CA. 105 p.

Durgin, P.B., R.R. Johnston, and A.M. Parsons. 1989. Critical sites erosion study. Tech. Rep. Vol. I: Causes of erosion on private timberlands in Northern California: Observations of the Interdisciplinary Team. Cooperative Investigation by CDF and USDA Forest Service Pacific Southwest Forest and Range Experiment Station. Arcata, CA. 50 p.

Euphrat, F.D. 1992. Cumulative impact assessment and mitigation for the Middle Fork of the Mokelumne River, Calaveras County, California. Unpublished Ph.D. dissertation, University of California, Berkeley. 107 p.

Euphrat, F., K.M. Kull, M. O'Connor, and T. Gaman. 1998. Watershed assessment and cooperative instream monitoring plan for the Garcia River, Mendocino County, California. Final Report submitted to the Mendocino Co. Resource Conservation District and the California Department of Forestry and Fire Protection. Sacramento, CA. 112 p.

Flanagan, S.A., M.J. Furniss, T.S. Ledwith, S.Thiesen, M. Love, K.Moore, and J. Ory. 1998. Methods for inventory and environmental risk assessment of road drainage crossings. USDA Forest Service. Technology and Development Program. 9877--1809—SDTDC. 45 p. http://www.stream.fs.fed.us/water-road/w-r-pdf/handbook.pdf

Gucinski, H., M.J. Furniss, R.R. Ziemer, and M.H. Brookes, editors. 2001. Forest roads: a synthesis of scientific information. USDA Forest Service General Technical Report PNW-509. Portland, Oregon: Pacific Northwest Research Station, Forest Service, U.S. Department of Agriculture. 103 p. http://www.fs.fed.us/pnw/pubs/gtr509.pdf

Ice, G., L. Dent, J. Robben, P. Cafferata, J. Light, B. Sugden, and T. Cundy. 2002. Programs assessing implementation and effectiveness of state forest practice rules and BMPs in the west. Paper prepared for the Forestry Best Management Practice Research Symposium, April 15-17, 2002, Atlanta, GA. Journal of Water, Air and Soil Pollution Focus. In press. 24 p.

James, C. 2001. Background information on research conducted at Southern Exposure research site. Document produced for the State Board of Forestry and Fire Protection for the October 2001 meeting. Sierra Pacific Industries, Redding, CA. 15 p.

Johnson, R. D. 1993. What does it all mean? Environmental Monitoring and Assessment 26: 307-312.

Knopp, C. 1993. Testing indices of cold water fish habitat. Unpublished Final Report submitted to the North Coast Regional Water Quality Control Board and the California Department of Forestry under Interagency Agreement No. 8CA16983. Sacramento, CA. 56 p. http://www.fire.ca.gov/bof/board/msg_supportedreports.html

Koehler, R.D., K.I. Kelson, and G. Mathews. 2001. Sediment storage and transport in the South Fork Noyo River watershed, Jackson Demonstration State Forest. Final Report submitted to the California Department of Forestry and Fire Protection, Sacramento, CA. Report Prepared by William Lettis and Associates, Walnut Creek, CA. 29 p. plus figures and tables.

Lee, G. 1997. Pilot monitoring program summary and recommendations for the long-term monitoring program. Final Report submitted to the California Department of Forestry. CDF Interagency Agreement No. 8CA27982. Sacramento, CA. 69 p. http://www.fire.ca.gov/bof/board/msg_supportedreports.html

Lemmon, P.E. 1956. A spherical densiometer for estimating forest overstory density. Forest Science 2(1): 314-320.

Lewis, J. 1998. Evaluating the impacts of logging activities on erosion and sediment transport in the Caspar Creek watersheds. In: Ziemer, R.R., technical coordinator. Proceedings of the conference on coastal watersheds: the Caspar Creek story, 1998 May 6; Ukiah, CA. General Tech. Rep. PSW GTR-168. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. P. 55-69. http://www.rsl.psw.fs.fed.us/projects/water/caspubs.html

Lewis, J. 2002. Hydrologic data for the Caspar Creek watershed study—Power Point Presentation prepared for the Annual Caspar Creek Watershed Study Meeting, Fort Bragg, CA, May 9, 2002. USDA Forest Service, Pacific Southwest Research Station, Arcata, CA.

Lewis, T.E., D.W. Lamphear, D.R. McCanne, A.S. Webb, J.P. Krieter, and W.D. Conroy. 2000. Regional assessment of stream temperatures across northern California and their relationship to various landscape-level and site-specific attributes. Forest Science Project, Humboldt State University Foundation, Arcata, CA. 400 p.

Lewis, J. and J. Baldwin. 1997. Statistical package for improved analysis of hillslope monitoring data collected as part of the Board of Forestry's long-term monitoring program. Unpublished Final Report submitted to the California Department of Forestry and Fire Protection under Agreement No. 8CA95056. Sacramento, CA. 50 p. http://www.fire.ca.gov/bof/board/msg_supportedreports.html

Lewis, J., S.R. Mori, E.T. Keppeler, and R.R. Ziemer. 2001. Impacts of logging on storm peak flows, flow volumes and suspended sediment loads in Caspar Creek, California. In: M.S. Wigmosta and S.J. Burges (eds.) Land Use and Watersheds: Human Influence on Hydrology and Geomorphology in Urban and Forest Areas. Water Science and Application Volume 2, American Geophysical Union, Washington, D.C. P. 85-125. http://www.rsl.psw.fs.fed.us/projects/water/caspubs.html

Lewis, J. and R. Rice. 1989. Critical sites erosion study. Tech. Rep. Vol. II: Site conditions related to erosion on private timberlands in Northern California: Final Report. Cooperative Investigation by the California Department of Forestry and the USDA Forest Service Pacific Southwest Forest and Range Experiment Station, Arcata, CA. 95 p.

Lisle, T.E. 1993. The fraction of pool volume filled with fine sediment in northern California: relation to basin geology and sediment yield. Final Report submitted to the California Department of Forestry. Sacramento, CA. 9 p.

Lisle, T. E., and S. Hilton. 1999. Fine bed material in pools of natural gravel bed channels. Water Resources Research 35(4):1291-1304. http://www.fire.ca.gov/bof/pdfs/Lisle99WR35_4.pdf

Luce, C.H. and T.A. Black. 1999. Sediment production from forest roads in western Oregon. Water Resources Research 35(8): 2561-2570.

Maahs, M. and T.J. Barber. 2001. The Garcia River instream monitoring project. Final Report submitted to the California Department of Forestry and Fire Protection. Mendocino Resource Conservation District, Ukiah, CA. 96 p. http://www.fire.ca.gov/bof/pdfs/Garcia_River_Instream.pdf

MacDonald, L.H. and D. Coe. 2001. Sediment Production and Delivery from Forest Roads in the Central Sierra Nevada, California. Progress Report dated January 2001 submitted to the USDA Forest Service, Pacific Southwest Region, Vallejo, CA. 17 p.

Madej, M.A. 2001. Erosion and sediment delivery following removal of forest roads. Earth Surface Processes and Landforms 26: 175-190.

Marshall, G. 2002. Rapid review of engineering geologic conditions for specific Timber Harvesting Plans in the Elk River watershed. California Division of Mines and Geology Memorandum submitted to Mr. Ross Johnson, Deputy Director for Resource Management, California Department of Forestry and Fire Protection. Memorandum dated January 11, 2002. 32 p.

McKittrick, M.A.. 1994. Erosion potential in private forested watersheds of northern California: a GIS model. Unpublished final report prepared for the California Department of Forestry and Fire Protection under interagency agreement 8CA17097. Sacramento, CA. 70 p. http://www.fire.ca.gov/bof/board/msg_supportedreports.html

Nakamoto, R. 1998. Effects of timber harvest on aquatic vertebrates and habitat in the North Fork Caspar Creek. In: Ziemer, Robert R., technical coordinator. Proceedings of the conference on coastal watersheds: the Caspar Creek story, 1998 May 6; Ukiah, CA. General Tech. Rep. PSW GTR-168. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. P. 87-95. http://www.rsl.psw.fs.fed.us/projects/water/caspubs.html

Pacific Watershed Associates (PWA). 1998a. Sediment source investigation and sediment reduction plan for the Bear Creek watershed, Humboldt County, California. Unpublished Report prepared for the Pacific Lumber Company. Arcata, CA. 42 p. plus appendices and maps.

Pacific Watershed Associates (PWA). 1998b. Sediment source investigation and sediment reduction plan for the North Fork Elk River watershed, Humboldt County, California. Unpublished Report prepared for the Pacific Lumber Company. Arcata, CA. 50 p. plus appendices and maps.

Poff, R.J. and C. Kennedy. 1999. Pilot study of Class III watercourses for the hillslope monitoring Program. Final report submitted to the California Department of Forestry and Fire Protection. Sacramento, CA. 6 p.

Rae, S.P. 1995. Board of Forestry pilot monitoring program: instream component. Unpubl. Rept. submitted to the California Department of Forestry under Interagency Agreement No. 8CA28103. Sacramento, CA. Volume One. 49. p. Volume Two - data tables and training materials.

Reid, L.M. and M.J. Furniss. 1999. On the use of regional channel-based indicators for monitoring. Unpublished draft paper. USDA Forest Service Pacific Northwest Research Station, Corvallis, OR.

Rice, R.M. and P.A. Datzman. 1981. Erosion associated with cable and tractor logging in northwestern California. In: Erosion and Sediment Transport in Pacific Rim Steeplands. IAHS Publ. 132. Christchurch, New Zealand. P. 362-374. http://www.rsl.psw.fs.fed.us/projects/water/IAHS132rice.pdf

Rice, R.M. and J. Lewis. 1991. Estimating erosion risks associated with logging and forest roads in northwestern California . Water Resources Bulletin 27(5): 809-818. http://www.rsl.psw.fs.fed.us/projects/water/RiceLewis91.pdf

Rice, R.M., F.B. Tilley, and P.A. Datzman. 1979. A watershed's response to logging and roads: South Fork of Caspar Creek, California, 1967-1976. USDA Forest Service Research Paper PSW-146. Berkeley, California: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. 12 p. http://www.rsl.psw.fs.fed.us/projects/water/caspubs.html

Rice, R.M., R.R. Ziemer, and J. Lewis. In press. Evaluating forest management effects on erosion, sediment, and runoff: Caspar Creek and northwestern California. Chapter in: Lessons from the Grandmasters of Watershed Management. Society of American Foresters monograph. Bethesda, Maryland: Society of American Foresters. 18 p. http://www.rsl.psw.fs.fed.us/projects/water/caspubs.html

Robards, T.A, M.W. Berbach, P.H. Cafferata, and B.E. Valentine. 2000. A comparison of techniques for measuring canopy in watercourse and lake protection zones. Calif. Forestry Note No. 115. California Department of Forestry and Fire Protection, Sacramento, CA. 15 p.

Robben, J. and L. Dent. 2002. Oregon Department of Forestry Best Management Practices Compliance Monitoring Project: Final Report. Oregon Department of Forestry Forest Practices Monitoring Program, Technical Report 15. Salem, OR. 68 p.

Robison, E.G., K.A. Mills, J. Paul, L. Dent, and A. Skaugset. 1999. Storm impacts and landslides of 1996: Final Report. Oregon Department of Forestry. Forest Practices Technical Report No. 4. Salem, OR. 145 p.

Skaugset, A. and M.M. Allen. 1998. Forest road sediment and drainage monitoring project. Report for private and state lands in western Oregon. Oregon Department of Forestry, Salem, OR. 20 p.

Spittler, T.E. 1995. Geologic input for the hillslope component for the pilot monitoring program. Unpublished Final Report submitted to the California Department of Forestry under Interagency Agreement No. 8CA38400. Sacramento, CA. 18 p. http://www.fire.ca.gov/bof/board/msg_supportedreports.html

Staab, B. 2002. USDA Forest Service water quality management program. Power Point Presentation prepared for the Central Valley Regional Water Quality Control Board Silvicultural Waivers Workshop, September 5, 2002, Redding, CA. USDA Forest Service, Pacific Southwest Region, Vallejo, CA.

Stillwater Sciences. 2002. Review of the Hillslope Monitoring Program report addressing the effectiveness of Forest Practice Rules in preventing sediment input to streams. Unpublished report presented to the State Water Resources Control Board hearing on SB 390, waivers for waste discharge requirements, July 17, 2002, Sacramento, CA. 5 p.

Strickler, G.S. 1959. Use of the densiometer to estimate density of forest canopy on permanent sample plots. USDA Forest Service Research Note PNW 180. Portland, Oregon: Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. 5 p.

Tuttle, A.E. 1995. Board of Forestry pilot monitoring program: hillslope component. Unpubl. Rept. submitted to the California Department of Forestry and the State Board of Forestry under Contract No. 9CA38120. Sacramento, CA. 29 p. Appendix A and B - Hillslope Monitoring Instructions and Forms. http://www.fire.ca.gov/bof/board/msg_supportedreports.html

U.S. Forest Service (USFS). 1992. Investigating water quality in the Pacific Southwest Region: best management practices evaluation program - user's guide. Region 5. San Francisco, CA 158 p.

Weaver, W.E. 2001. Testimony to the State Water Resources Control Board regarding monitoring requirements for Timber Harvesting Plan 1-97-520 HUM, Pacific Lumber Company, June 25-26, 2001. Sacramento, CA.

Weaver, W.E. and D.K. Hagans. 1994. Handbook for forest and ranch roads. Final Report prepared for the Mendocino Resource Conservation District, Ukiah, CA. 161 p.

Ziemer, R.R., technical coordinator. 1998. Proceedings of the conference on coastal watersheds: the Caspar Creek story. 1998 May 6; Ukiah, CA. General Tech. Rep. PSW GTR-168. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 149 p. http://www.rsl.psw.fs.fed.us/projects/water/caspubs.html

Glossary

Abandonment – Leaving a logging road reasonably impassable to standard production four wheel-drive highway vehicles, and leaving a logging road and landings, in a condition which provides for long-term functioning of erosion controls with little or no continuing maintenance (14 CCR 895.1).

Alternative practice – Prescriptions for the protection of watercourses and lakes that may be developed by the RPF or proposed by the Director of CDF on a site-specific basis provided that several conditions are complied with and the alternative prescriptions will achieve compliance with the standards set forth in 14 CCR 916.3 (936.3, 956.3) and 916.4(b) [(936.4(b), 956.4(b)]. 14 CCR 916.6 (936.6, 956.6). More general alternative practices are permitted under 14 CCR 897(e).

Beneficial uses of water – As described in the Porter-Cologne Water Quality Control Act, beneficial uses of water include, but are not limited to: domestic, municipal, agricultural, and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish and wildlife, and other aquatic resources or preserves. In Water Quality Control Plans, the beneficial uses designated for a given body of water typically include: domestic, municipal, agricultural, and industrial supply; industrial process; water contact recreation and non-water contact recreation; hydropower generation; navigation; groundwater recharge; fish spawning, rearing, and migration; aquatic habitat for warm-water species; aquatic habitat for coldwater species; and aquatic habitat for rare, threatened, and/or endangered species (Lee 1997).

Best management practice (BMP) - A practice or set of practices that is the most effective means of preventing or reducing the generation of nonpoint source pollution from a particular type of land use (e.g., silviculture) that is feasible, given environmental, economic, institutional, and technical constraints. Application of BMPs is intended to achieve compliance with applicable water quality requirements (Lee 1997).

Canopy - the foliage, branches, and trunks of vegetation that blocks a view of the sky along a vertical projection. In the Hillslope Monitoring Program, this was estimated from 1996 through1998 with a spherical densiometer and from 1999 through 2001 with a sighting tube. The Forest Practice Rules define canopy as “the more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody species” (14 CCR 895.1).

Cutbank/sidecast sloughing – Shallow, surficial sliding associated with either the cutbank or fill material along a forest road or skid trail, with smaller dimensions than would be associated with mass failures.

Feature - Any constructed component of a landing, road, skid trail, or watercourse crossing (e.g., cut bank, fill slope, inside ditch, cross drain, water break).

Exception – A non-standard practice for limitations on tractor operations (14 CCR 914.2(f)(3), 934.2(f)(3), 954.2(f)(3)).

Gully - Erosion channels deeper than 6 inches (no limitation on length or width). Gully dimensions were estimated.

In-lieu practice – These practices apply to Rule sections for watercourse protection where provision is made for site specific practices to be proposed by the RPF, approved by the Director and included in the THP in lieu of a stated Rule. The RPF must reference the standard Rule, explain and describe each proposed practice, how it differs from the standard practice, indicate the specific locations where it will be applied, and explain and justify how the protection provided by the proposed practice is at least equal to the protection provided by the standard Rule (14 CCR 916.1, 936.1, 956.1).

Large erosion event - These events were defined for the Hillslope Monitoring Program as 100 cubic yards for a mass failure void left on a hillslope, or at least 10 cubic yards for catastrophic crossing failures.

Mass failure – Downslope movement of soil and subsurface material that occurs when its internal strength is exceeded by the combination of gravitational and other forces. Mass erosion processes include slow moving, deep-seated earthflows and rotational failures, as well as rapid, shallow movements on hillslopes (debris slides) and in downstream channels (debris torrents).

Minor/major departure – Major departures were assigned to problem points when sediment was delivered to watercourses, or when there was a substantial departure from Rule requirements (e.g., no or few waterbreaks installed for an entire transect). Minor departures were assigned for slight Rule departures where there was no evidence that sediment was delivered to watercourses (e.g., WLPZ width slightly less than that specified by the Rule).

Non-standard practice - A practice other than a standard practice, but allowable by the Rules as an alternative practice, in-lieu practice, waiver, exclusion, or exemption (Lee 1997).

Parameter - The variable being studied by sampling, observation, or measurement (Lee 1997).

Permanent road – A road which is planed and constructed to be part of a permanent all-season transportation facility. These roads have a surface which is suitable for the hauling of forest products throughout the entire winter period and have drainage structures, if any, at watercourse crossings which will accommodate the fifty-year flow. Normally they are maintained during the winter period (14 CCR 895.1). After July 1, 2000, watercourse crossings associated with permanent roads have been required to accommodate the estimated 100-year flood flow, including debris and sediment loads.

Problem point - In the Hillslope Monitoring Program the occurrence of: 1) erosion features (rills, gullies, mass failures, or cutbank/sidecast sloughing) found at sample sites or along transects, 2) canopy reduction, streambank erosion, or ground cover reduction in a watercourse protection zone, or 3) Forest Practice Rule violations (e.g., waterbreak improperly constructed) (Lee 1997).

Process - The procedures through which the Rules/BMPs are administered and implemented, including: (a) THP preparation, information content, review and approval by RPFs, Review Team agencies, and CDF decision-makers, and (b) the timber operations completion, oversight, and inspection by LTOs, RPFs, and CDF inspectors (Lee 1997).

Quality assurance - The steps taken to ensure that a product (i.e., monitoring data) meets specified objectives or standards. This can include: specification of the objectives for the program and for data (i.e., precision, accuracy, completeness, representativeness, comparability, and repeatability), minimum personnel qualifications (i.e., education, training, experience), training programs, reference materials (i.e., protocols, instructions, guidelines, forms) for use in the field, laboratory, office, and data management system (Lee 1997).

Quality control - The steps taken to ensure that products which do not meet specified objectives or standards (i.e., data errors and omissions, analytical errors) are detected and either eliminated or corrected (Lee 1997).

Repeatability - The degree of agreement between measurements or values of a monitoring parameter made under the same conditions by different observers (Lee 1997).

Rill - Small surface erosion channels that (1) are greater than 2 inches deep at the upslope end when found singly or greater than 1 inch deep where there are two or more, and (2) are longer than 20 feet if on a road surface or of any length when located on a cut bank, fill slope, cross drain ditch, or cross drain outlet. Dimensions were not recorded.

Rules - Those Rules that are related to protection of the quality and beneficial uses of water and have been certified by the SWRCB as BMPs for protecting the quality and beneficial uses of water to a degree that achieves compliance with applicable water quality requirements (Lee 1997). Forest Practice Rules are included in Title 14 of the California Code of Regulations (14 CCR).

Seasonal road – A road which is planned and constructed as part of a permanent transportation facility where: 1) commercial hauling may be discontinued during the winter period, or 2) the landowner desires continuation of access for fire control, forest management activities, Christmas tree growing, or for occasional or incidental use for harvesting of minor forest products, or similar activities. These roads have a surface adequate for hauling of forest products in the non-winter period; and have drainage structures, if any, at watercourse crossings which will accommodate the fifty-year flood flow. Some maintenance usually is required (14 CCR 895.1). After July 1, 2000, all permanent watercourse crossings have been required to accommodate the estimated 100-year flood flow, including debris and sediment loads.

Standard practice - A practice prescribed or proscribed by the Rules (Lee 1997).

Surface cover – The cover of litter, downed woody material (including slash, living vegetation in contact with the ground, and loose rocks (excluding rock outcrops) that resist erosion by raindrop impact and surface flow (14 CCR 895.1).

Temporary road – A road that is to be used only during the timber operation. These roads have a surface adequate for seasonal logging use and have drainage structures, if any, adequate to carry the anticipated flow of water during the period of use (14 CCR 895.1).

Waterbreak – A ditch, dike, or dip, or a combination thereof, constructed diagonally across logging roads, tractor roads and firebreaks so that water flow is effectively diverted. Waterbreaks are synonymous with waterbars (14 CCR 895.1).

Appendix

Table A-1. Landings--effectiveness ratings.

Evaluation Category	Number of Observations	Description
Surface Rilling and Gullying		
a. Rilling on Landing Surface	430	None
	79	Less than 1 rill/100 ft (0-20%)
	16	Some rilling (less than 1 rill/20 ft of transect)
	0	Greater than 1 rill/20 ft (greater than 20%)
	2	Greater than 20% of landing drained by rills
	41	0-20% of landing drained by rills
b. Gullies on Landing Surface	461	None
	90	Less than 1 gully per 100 ft transect
	3	Some gullying (less than 1 gully per 20 ft of transect)
	0	Gullying that exceeds 1 gully per 20 ft of transect
	11	Gullying present with recorded dimensions
Surface Drainage		
a. Drainage Runoff Structure	270	No evidence of erosion from concentrated flow where drainage leaves landing surface or drainage outlet
	54	Rills or gullies present but do not extend greater than 20 ft below edge of landing or drainage outlet
	24	Presence of rills or gullies which extend greater than 20 ft below edge of landing or drainage outlet
b. Sediment Movement	325	No evidence of transport to WLPZ
	14	Sediment deposition in WLPZ but not to channel
	7	Evidence of sediment transport to, or deposition in channel
Landing Cut Slopes		
a. Rilling	274	No evidence of rills
	15	Rills present but do not extend to drainage structure or ditch
	5	Rills present and extend to drainage structure or ditch
b. Gullies	289	No evidence of gullies
	1	Gullies present but do not extend to drainage structure or ditch
	4	Gullies present and extend to drainage structure or ditch

Evaluation Category	Number of Observations	Description
Landing Cut Slopes		
c. Slope Failures	272	Less than 1 cubic yard of material moved
	18	More than 1 cubic yard moved but it is not transported to drainage structure or ditch
	3	More than 1 cubic yard moved, some material transported to drainage structure or ditch
Landing Fill Slopes		
a. Rilling	332	No evidence of rills
	42	Rills present but do not extend to drainage channels below toe of fill
	2	Rills present and extend to drainage channels below toe of fill
b. Gullies	345	No evidence of gullies
	26	Gullies present, but do not extend to drainage channels below toe of fill
	5	Gullies present and extend greater than a slope length below toe of fill
c. Slope Failures	355	No material moved
	12	Less than 1 cubic yard moved
	8	More than 1 cubic yard moved but does not enter channel
	2	More than 1 cubic yard moved, some material enters channel
d. Sediment Movement	363	No evidence of transport to WLPZ
	8	Sediment deposition in WLPZ but not carried to channel
	6	Evidence of sediment transport to, or deposition in channel

Table A-2. Crossings--effectiveness ratings.

Evaluation Category	Number of Observations	Description
Fill Slopes at Crossings		
a. Vegetative Cover	285	Vigorous dense cover or fillslope of stable material
	101	Less than full cover, but greater than 50% if fillslope has effective cover or is of stable material
	24	Less than 50% of fillslope has effective cover or is of stable material
b. Rilling	332	Rills may be evident, but are infrequent, stable and no evidence of sediment delivery to channel
	46	Few rills present (less than 1 rill per lineal 5 ft) and not enlarging, with little apparent deposition in channel
	32	Numerous rills present (greater than 1 rill per lineal 5 ft), apparently enlarging or with substantial evidence of delivery to channel
c. Gullies	344	None
	14	Gullies present, not enlarging, little apparent deposition in channel
	12	Gullies present and enlarging or threatening integrity of fill
	40	Gully with dimensions provided
d. Cracks	378	None evident
	22	Cracks present, but appear to be stabilized
	7	Cracks present and widening, threatening integrity of fill
e. Slope Failure	302	None
	64	Less than 1 cubic yard (lowest category available in 1996, “none” was not available)
	18	0 to 1 cubic yard of material
	27	Greater than 1 cubic yard of material
Road Surface Draining to Crossings		
a. Rutting	403	No ruts present
	61	Some ruts present, but design drainage not impaired
	13	Rutting impairs road drainage
b. Rilling	433	Little or no evidence of rills
	32	Rills occupy less than 10% of road surface area, or do not leave road surface
	11	Rills occupy greater than 10% of surface and continue off road surface onto crossing or fill
c. Gullies (>6 in deep)	383	None
	8	Gully with dimensions provided

Evaluation Category	Number of Observations	Description
d. Surfacing of Crossing Approach	359	No loss of road surface
	31	Less than 30% of road surface area degraded by surface erosion
	5	Greater than 30% of road surface area degraded by surface erosion
e) Cut-off Waterbar Condition	248	Functional
	49	Allows some water to reach crossing location
	25	Allows all water running down the road to reach crossing location
f) Inside Ditch Condition	107	Open
	19	Some sediment/debris accumulation
	6	Blocked with sediment/debris
g. Ponding	400	No evidence of ponded water
	61	Ponding present, but does not appear to threaten integrity of fill
	12	Ponding present and is causing fill subsidence or otherwise threatening integrity of fill
h. Road Surface Drainage	53	Stable drainage with little or no sediment delivery to stream
(only used in 1996)	22	Slight sediment delivery but configuration is stable or stabilizing
	8	Continuing sediment delivery to stream and configuration is unstable/degrading
Culverts		
a. Scour at Inlet	316	No evidence of scour
	15	Scour evident but extends less than 2 channel widths above inlet and no undercutting of crossing fill
	5	Scour evident that extends more than 2 channel widths above inlet or scour is undercutting crossing fill
b. Scour at Outlet	226	No evidence of scour
	74	Scour evident, but extends less than 2 channel widths below outlet, and no undercutting of crossing fill
	36	Scour evident that extends more than 2 channel widths below outlet, or scour undercuts crossing fill
c. Diversion Potential	243	Crossing configured to minimize fill loss (road doesn't slope downward from crossing in at least one direction)
	62	Crossing has road that slopes downward in at least one direction with drainage structure
	30	If culvert fails, flow will be diverted out of channel and down roadway
d. Plugging	257	No evidence of sediment or debris
	50	Sediment and/or debris is accumulating, less than 30% of inlet or outlet is blocked
	29	Sediment and/or debris is blocking greater than 30% of inlet or outlet

Evaluation Category	Number of Observations	Description
e. Alignment	270	Appropriate
	2	Low angle channel approach
	3	High angle channel approach or discharge is not in channel
f. Degree of Corrosion	222	None to slight (metal discolored but not missing)
	18	Moderate--some corroded metal missing but pipe still competent
	2	Severe--pipe can be punctured with screwdriver or similar tool
g. Crushed Inlet/Outlet	251	None
	23	Pipe deformed but less than 30% of inlet/outlet blocked
	1	Pipe deformed and greater than 30% of inlet/outlet blocked
h. Pipe Length	323	Appropriate
	10	Length causing only minor amount of gullying or fill slope erosion
	2	Length directly related to large gullies or fillslope erosion around pipe
i. Gradient	230	Appropriate--at base of fill and at grade of original streambed
	26	Pipe inlet set slightly too low or slightly too high in fill
	21	Pipe inlet set too high or too low, causing debris accumulation, or water to under cut the culvert
j. Piping	263	No evidence of flow beneath or around culvert
	14	Flow passes beneath or around culvert, or piping erosion evident
Non-Culvert Crossing		
a. Armoring	60	Appropriate
	12	Minor downcutting evident at crossing due to inadequate armoring
	8	Major downcutting evident at crossing due to inadequate armoring
b. Scour at Outlet	59	No evidence of scour
	19	Scour evident, but extends less than 2 channel widths below outlet, and no undercutting of crossing fill
	6	Scour evident that extends more than 2 channel widths below outlet, or scours undercuts crossing fill
c. Diversion	77	Crossing configured to minimize fill loss (road does not slope downward from crossing in at least one direction)
	3	Crossing has road that slopes downward in at least one direction but is unlikely to divert flow down road
	3	Overflow will be diverted down road

Evaluation Category	Number of Observations	Description
<u>Removed or Abandoned</u>		
a. Bank Stabilization	60	Vigorous dense vegetation cover or other stabilization material
	21	Less than full cover, but greater than 50% of channel bank has effective cover or has stable material
	4	Less than 50% of channel bank has effective cover or is composed of stable material
b. Rilling of Banks	79	Rills may be evident but infrequent, stable, with no sediment delivery to channel
	5	Few rills present (less than 1 per lineal 5 ft) and rills not enlarging
	1	Numerous rills present (greater than 1 rill per lineal 5 ft) or apparently enlarging
c. Gullies	80	None evident
	5	Gully with dimensions provided
d. Slope Failures	82	Less than 1 cubic yard of material
	2	Greater than 1 cubic yard of material moved but does not enter stream
	1	Greater than 1 cubic yard of material moved, material enters stream
e. Channel Configuration	69	Wider than natural channel and close to natural watercourse grade and orientation
	12	Minor differences from natural channel in width, grade, or orientation
	3	Narrower than natural channel width, or significant differences from natural channel grade or orientation
f. Excavated Material	77	Sloped to prevent slumping and minimize erosion
	4	Slumps or surface erosion present, but less than 1 cubic yard of material enters channel
	1	Slumps or surface erosion present, greater than 1 cubic yard of material enters channel
g. Grading and Shaping	72	No evidence of erosion or sediment discharge to channel due to failures of cuts, fills or sidecast
	10	Less than 1 cubic yard of material transported to channel due to failures of fills or sidecast
	2	Greater than 1 cubic yard material transported to channel due to failures of fills or sidecast
<u>Road Approaches at Abandoned Crossings</u>		
a. Grading and Shaping	60	No evidence of concentrated water flow to channel from road surface (in excess of designed drainage or erosion of drainage facility)
	9	Less than 1 cubic yard of material transported to channel from eroded surface soil on road approaches
	2	Greater than 1 cubic yard of material transported to channel from eroded surface soil on road approaches