INTERIM REPORT TO THE
CALIFORNIA STATE BOARD OF FORESTRY
AND FIRE PROTECTION

HILLSLOPE MONITORING PROGRAM:

MONITORING RESULTS FROM 1996 THROUGH 1998

PREPARED BY THE
MONITORING STUDY GROUP OF THE
CALIFORNIA STATE BOARD OF FORESTRY
AND FIRE PROTECTION

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EXECUTIVE SUMMARY

The Monitoring Study Group was created by the California State Board of Forestry and Fire Protection to determine how effective the Forest Practice Rules are in protecting water quality. The California Department of Forestry and Fire Protection (CDF) implemented hillslope monitoring in 1996 on 50 randomly selected Timber Harvesting Plans (THPs) in Humboldt and Mendocino Counties to provide information on forest practices within the range of coho salmon. The program expanded in 1997 and 1998, with 50 randomly selected THPs evaluated each year throughout the state. Field work on all 150 THPs was conducted by private contractors who were Registered Professional Foresters with significant amounts of experience developing THPs and using the Forest Practice Rules. An earth scientist was required to be part of the contractor's field team for the state-wide work.

THPs selected for hillslope monitoring had to: 1) have been accepted for filing under the revised Forest Practice Rules after October 1991, 2) have been through at least one but not more than four winters since logging was completed, 3) have been logged with crawler tractors and/or cable yarding systems, and 4) contain at least 500 continuous feet of a Class I or II watercourse. A randomly selected pool of THPs was generated and permission for access was requested. Access was granted by large industrial landowners for all but one THP, but roughly one-third of the small-nonindustrial landowners failed to grant access. About 65% of the sampled THPs were on large industrial timberlands, and 35% had non-industrial timberland owners or other types of ownership (state, small companies, etc.). The Coast Forest Practice District contained 66% of the THPs, while the Northern and Southern Districts had 22 and 12%, respectively. Only THPs were evaluated (no Emergencies, Exemptions, or Non-industrial Timber Management Plans were included).

Evaluation of individual THPs occurred at five sample areas that past studies indicated were the greatest risk to water quality—roads, skid trails, landings, watercourse crossings, and watercourse and lake protection zones (WLPZs). Comprehensive forms were developed for recording site information, implementation data, and effectiveness data for each of these five sample areas. In total, 190 Forest Practice Rule requirements that could be determined by field review were evaluated. The data in this report are only for the standard Rules (not alternatives or in-lieu practices). Class III protection, impacts from winter operations, and restorable uses of water (three areas referred to in CDF's 1995 survey report on watercourse protection as having concern for proper implementation and effectiveness) have not been addressed by this project except where intersected by erosion features that also involve one of the previously described sample areas.

All five sample areas were evaluated twice within each THP if possible. Roads, skid trails and WLPZs were sampled using transects that were 1000 feet in length when available (in all cases they were at least 500 feet long). Landings and watercourse crossings were evaluated as individual features without transects. All sample areas were randomly located within the THP. Large erosion events were inventoried when they were encountered on a THP. Implementation of the Forest Practice Rules applicable to a given sample site was rated as either exceeding the Rule requirements, meeting the requirements, minor departure from requirements, or major departure from requirements (with other categories for not applicable, etc.). Major departures were assigned when sediment was delivered to watercourses, or when there was a substantial departure from Rule requirements. In contrast, minor departures were assigned for slight Rule departures when there was no evidence that sediment was delivered to watercourses.

Results to date have been developed from frequency counts. As this program continues, additional analyses may be performed to determine if there are significant differences between Rule applications and site or operator factors. It is also important to note that the results apply only to implementation and effectiveness on hillslope locations—and are not directly linked to current instream conditions.

Roads and their associated crossings were found to have the greatest potential for sediment delivery to watercourses. Twenty-two road Rule requirements had either minor or major departures for implementation more often than 5% of the time (based on a sample of at least 30 observations where implementation could be rated). Similarly, 14 Rule requirements for crossings had minor or major departures that exceeded the 5% level. Most of the road Rule implementation departures fell within the minor departure category, while a larger proportion of the crossing Rule implementation ratings were for major departures. Results to date indicate that greater attention should be focused on improvement of crossing design, construction, and maintenance due to the high levels of departures from Rule requirements and the close proximity of crossings to channels. For roads, better implementation of Rules related to drainage structure design, construction, and maintenance is needed. Mass failures associated with current timber operations were mostly related to roads and produced the highest sediment delivery to watercourse channels when compared to other erosion processes. The majority of the road related mass failures were associated with fill slope problems—indicating that proper road construction techniques are critical for protecting water quality.

Watercourse and lake protection zones generally met Forest Practice Rule requirements for width, canopy, and ground cover. Very few erosion features associated with current THPs were recorded within WLPZs. Six rule requirements for WLPZs had either minor or major departures for implementation more often than 5% of the time, but the vast majority of the departures were in the minor category.

Landings had few erosion features associated with current operations and generally did not deliver significant amounts of sediment to watercourses. Four landing Rule requirements had either minor or major departures for implementation more often than 5% of the time, and most ratings were within the minor category. Impacts from skid trails were also relatively minor compared to those produced by roads and crossings. Frequency of erosion problem points on skid trails was much lower than that documented on road transects. Only three skid trail Rule requirements had either minor or major departures for implementation that exceeded 5% of the observations. The majority of the departures fell within the minor category.

Several general observations regarding the Hillslope Monitoring Program and the preliminary results that have been produced were made by the Monitoring Study Group. These observations include the need to: (1) develop training programs for Registered Professional Foresters, Licensed Timber Operators, and equipment operators about the Forest Practice Rules that were found to have the poorest implementation, (2) continue monitoring in order to test infrequently encountered Forest Practice Rules and infrequent natural events, (3) continue monitoring to provide a sufficient sample size to evaluate non-standard (i.e., in-lieu and alternative) practices, (4) evaluate current quality assurance/quality control (QA/QC) information and determine what additional work needs to be completed, and (5) complete a more in-depth analysis of the existing hillslope monitoring data set.

In summary, the Forest Practice Rules and individual THP requirements (i.e., site-specific mitigation measures developed through recommendations of interagency Review Teams) were generally found to be sufficient to prevent hillslope erosion features. The Hillslope Monitoring Program results, however, do not allow us to draw conclusions about whether the existing Rules are providing properly functioning habitat for aquatic species because evaluating the biological significance of the current Rules was not part of this project. For all five sample areas, erosion problem points were almost always associated with improperly implemented Forest Practice Rules. In other words, nearly all of the erosion problems resulted from non-compliance. These conclusions are similar to those reached in the "208 Team" report (SWRCB 1987), where it was reported that the standard practices in the Rules generally appeared to provide adequate water quality protection when they were properly implemented, and poor Rule implementation was the most common cause of observed water quality impacts.

ACKNOWLEDGEMENTS

The Monitoring Study Group would like to acknowledge and thank several individuals and companies for their assistance with the Hillslope Monitoring Program. Roger Poff of R.J. Poff and Associates and Cliff Kennedy and Joe Hiss of High Country Forestry displayed great personal interest in the program, worked hard to make the program succeed, helped improve the monitoring protocols, and entered data in the database. All three have provided assistance in developing database queries and have reviewed drafts of this report. Dr. Don Warner, Calif. State Univ., Sacramento, developed the Hillslope Monitoring database and the queries run on the data sets. Don has displayed a high degree of technical competence, as well as patience in dealing with a very large and complex database. In 1996, Gary Rynearson, Jim Hawkins and Lou Tirado of Natural Resources Management Corporation collected the field data in Humboldt County. Chris Hipkin assisted R.J. Poff and Associates with the 1996 field data collection in Mendocino County. Tom Schott and Curtis Ihle representing the Mendocino and Humboldt County Resource Conservation Districts respectively, played significant roles in making the 1996 monitoring projects in their counties successful.

Simpson Timber Company, Georgia-Pacific Corporation, Pacific Lumber Company, Sierra Pacific Industries, Stimson Timber Company, Mendocino Redwood Company, Louisiana Pacific Corporation, William M. Beaty and Associates, Eel River Sawmills, Fruit Growers Supply Company, Soper-Wheeler Company, Gualala Redwoods Company, Wetsel-Oviatt Lumber Company, Barnum Timber Company, and Roseburg Resources Company provided access onto their timberlands, as well as assistance in locating Timber Harvesting Plans. We also thank all the small non-industrial timberland owners who granted access to their parcels.

Chuck Abshear, Norm Cook and Janice Stein queried CDF RBASE databases for a pool of Timber Harvesting Plans from 1996 through 1998 in Santa Rosa, Fresno, and Redding, respectively. Scott Gregory, Student Assistant, entered the 1996 data in the database and completed numerous tasks to make the program run smoothly. Mavis Hotchkiss developed the CDF contracts that allowed the monitoring work to proceed. CDF Forest Practice Program staff members Pete Cafferata and John Munn were responsible for compiling and summarizing information and were the primary authors of the report.

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INTRODUCTION

Difficult questions are increasingly being asked by agency scientists, legislators, and the public about the impacts of current forestry operations on critical downstream beneficial uses of water. Unfortunately, in many cases there has been insufficient scientifically valid data available to answer the types of questions that have been asked. The listing and potential listing of numerous fish and wildlife species under the federal Endangered Species Act (ESA) and the listing of numerous watersheds as impaired waterbodies under Section 303(d) of the Clean Water Act have heightened the need for valid data on impacts to these resources from current timber operations. As a result, monitoring the impacts of forestry practices on water quality and anadromous fish habitat has received a greater degree of emphasis in the 1990's (MacDonald et al. 1991, MacDonald and Smart 1993, Wissmar 1993, Dissmeyer 1994).

In California, the State Board of Forestry and Fire Protection (BOF) and the California Department of Forestry and Fire Protection (CDF) have jointly worked throughout the 1990's to develop and implement a long-term monitoring program which could provide information to decision makers and the public regarding the effectiveness of the current Forest Practice Rules in protecting water quality. The BOF formed the Monitoring Study Group (MSG) in 1989 to develop this long-term program. The long-term monitoring program includes both instream and hillslope components.

The Hillslope Monitoring Program has received the most emphasis to date. Specific objectives of this program include: (1) determining if the Forest Practice Rules (FPRs) affecting water quality are properly implemented—implementation monitoring, and (2) determining if the FPRs affecting water quality are effective in meeting their intent when properly implemented—effectiveness monitoring. These two types of monitoring are necessary for differentiating between water quality problems created by non-compliance with a FPR, versus problems with the forest practice. The goal is to provide information on where, when, and in what situations problems occur under proper implementation (Tuttle 1995).

This report summarizes the results that have been obtained from data collected on 150 Timber Harvesting Plans (THPs) that were evaluated from 1996 through 1998 as part of the Hillslope Monitoring Program. **These are to be considered interim results, as this program is an on-going project that will continue to collect field data. Additionally, only frequency count data is presented--without statistical tests.** As more data are collected and sample sizes become larger, detailed statistical analysis will be performed on the hillslope monitoring data sets.

Other projects have been undertaken in California that provide information regarding impacts from timber operations conducted under the modern (i.e., after 1974) Forest Practice Rules. Readers of this report are encouraged to review results from research projects such as the Caspar Creek watershed studies (Ziemer 1998, Lewis et al. 1998), and the Critical Sites Erosion Study (Durgin et al. 1989, Lewis and Rice 1989, Rice and Lewis 1990).

BACKGROUND INFORMATION

Monitoring forestry practices in California has historically related to protection of water quality. Much less emphasis has been placed on monitoring impacts of logging on terrestrial wildlife species by CDF and the BOF, since the California Department of Fish and Game has had the lead for that type of monitoring. The relationship between monitoring and water quality grew out of CDF and the BOF's desire to have the Forest Practice Rules and Review Process certified as Best Management Practices by the U.S. Environmental Protection Agency (EPA), beginning as early as 1977.

After the passage in 1983 of the modern watercourse protection rules specifying protection based on the beneficial uses of water present, the Forest Practice Rules and Review Process were conditionally certified as meeting Best Management Practices standards for Section 208 of the Clean Water Act by the State Water Resources Control Board (SWRCB). The Water Board required that a monitoring and assessment program be implemented for this certification. Due to lack of sufficient funding for a comprehensive four-year program, a one-year qualitative assessment of forest practices was undertaken in 1986 by a team of four resource professionals (Johnson 1993). The "208 Report" (SWRCB 1987) resulted from this review of 100 Timber Harvesting Plans completed over the entire state. The team found that the Rules generally were effective when properly implemented on terrain that was not overly sensitive. They recommended several changes to the Forest Practice Rules based on their observations.

In 1988, CDF, the Board of Forestry (BOF), and the SWRCB entered into a Management Agency Agreement (MAA) that required the BOF to improve forest practice regulations for better protection of water quality, largely based on the "208 Report". At this point, the SWRCB approved certification. EPA, however, withheld certification until the conditions of the MAA were satisfied, one of which was to develop a long-term monitoring program to determine the effectiveness of the Forest Practice Rules and Review Process in protecting water quality. The BOF formed an interagency task force, later known as the Monitoring Study Group, to develop the long-term monitoring program.

The MSG, working with the consulting firm William Kier Associates, held public outreach meetings throughout the state in 1990 to capture what the public felt was important in a monitoring program. The two biggest concerns expressed by members of the public were the protection of cold water fish habitat and domestic water supplies. They also stated that the monitoring program being developed should be able to detect changes in these beneficial uses resulting from timber operations (CDF 1991). The MSG used the information collected by Kier to write a detailed report for the BOF (BOF 1993). This document stressed the need for both implementation and effectiveness monitoring, as well as the value of a pilot project to develop appropriate techniques for both instream and hillslope monitoring. The Pilot Monitoring Program was completed during 1993 and 1994, and reports documenting the work were written in 1995. The Department of Fish and Game conducted the instream pilot work and documented training and quality control needs for several instream monitoring parameters, as well as the range in variability encountered (Rae 1995).

For the hillslope component of the pilot program, Dr. Andrea Tuttle and CDF modified previously developed U.S. Forest Service hillslope monitoring forms (USFS 1992) 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, 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, logging operations, and watercourse and lake protection zones). 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).

The 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 was then pared down to 190 Rule requirements that are implemented during the conduct of a Timber Harvesting Plan and can be evaluated by subsequent field review. Cumulative watershed effects Rules and Rules related to the THP Review process were not included because they could not be evaluated using an on-the-ground inspection of the THP area. Many of the Rules were broken down into separate components to specify the multiple requirements for field evaluations.

The Division of Mines and Geology assisted with the hillslope pilot program and provided detailed geomorphic mapping for two of the watersheds used for the pilot work (Spittler 1995). Pilot Monitoring Program Manager Gaylon Lee of the SWRCB wrote a summary document and recommendations for the long-term program (Lee 1997).

Due to the fact that hillslope monitoring 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), CDF and BOF chose to place more emphasis on hillslope monitoring for the Long-Term Monitoring Program. A pilot cooperative instream monitoring project is currently in progress in the Garcia River watershed, located in southern Mendocino County (Euphrat et al. 1998).

THP SAMPLE SELECTION

The CDF/BOF long-term monitoring program was officially launched in 1996, with the collection of hillslope monitoring data on 25 randomly selected THPs in both Humboldt and Mendocino Counties. The initial phase of the hillslope monitoring program was conducted on the North Coast with the goal of collecting information from watersheds with coho salmon habitat due to the recent listing of that species. Contracts were developed with the Resource Conservation Districts in each county, who in turn hired Registered Professional Foresters (RPFs) to collect the detailed field data on THPs that had over-wintered for a period of 1 to 4 years. Natural Resources Management Corporation was the contractor hired by the Humboldt County RCD, while R.J. Poff and Associates was hired by the Mendocino County RCD (Figure 1). Stratified random sampling was utilized to select the THPs for the work completed in 1996. Based on erodibility ratings developed for a study completed by CDMG (McKittrick 1994), approximately 50% of the THPs were included in the areas designated as high overall erosion hazard, 35% were included in the moderate category, and 15% were included in the low erosion hazard rating.[1]

The second phase of the hillslope monitoring program—the statewide sample of THPs—was begun in 1997. CDF directly hired a contractor to collect field data on 50 randomly selected plans statewide in both 1997 and 1998. The contractor for these contracts was R.J. Poff and Associates. An RPF and an earth scientist (professional soil scientist, registered geologist or certified erosion and sediment control specialist) were required to participate in the field work. THPs were randomly selected from a state-wide pool and no longer stratified based on the CDMG erodible watershed categories utilized in 1996.

THPs were included in the random selection for 1996 through 1998 if they met the following criteria:

1. The THP had been filed and completed under the Forest Practice Rules adapted by the BOF after October 1991 (when the most recent WLPZ rules were implemented).

2. The plans selected had been through at least one but not more than four winters since logging was completed. The CDF Completion Report for the entire THP must have been signed by a CDF Forest Practice Inspector, and the date used to determine the 1-4 over-wintering periods was the date

[1] This project rated large (e.g., 50,000 ac) 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.

supplied by the RPF that indicated when all the logging was completed on the THP.

3. The THP primarily involved wildlands (e.g., it is not a campground or golf course). Also, the THP was not a road-right-of-way-only plan.

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

5. The THP had at least 500 continuous feet of a Class I or II watercourse present.

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

7. The THP was not previously sampled.

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). A randomized list was produced to provide a preliminary set of THPs to evaluate. Individual THP files were reviewed at each of the three locations to determine when the logging was completed, watercourses present, yarding system(s), size, and wildland classification. THPs eliminated from the preliminary list were replaced with the next acceptable THP meeting the above criteria, keeping the original percentages for each CDF Forest Practice District (i.e., Coast, Northern and Southern) established in the original random sort.[2] Statewide sampling, therefore, is very similar to the distribution of THPs CDF receives at each of its three Forest Practice District offices.

Permission for THP access was requested by letter with follow-up telephone calls for those where a response was not received. Where permission was not granted, the next THP on the list was used. Permission for large industrial owners was received for all but one THP. In contrast, approximately 30% 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 (Table 1).

[2] 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.

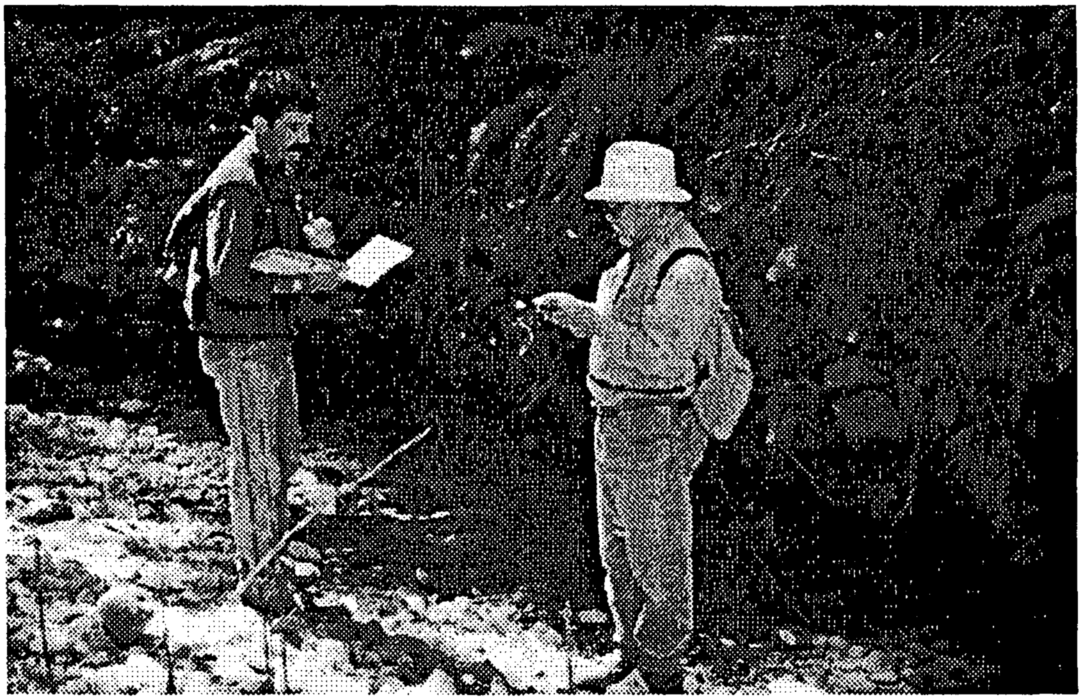

Figure 1. Cliff Kennedy and Roger Poff collecting field data in Mendocino County in 1996.

The THPs sampled from 1996 through 1998 are displayed by Forest Practice District in Table 2 (due to the exclusive sampling in the Coast Forest Practice District in 1996, the sample is disproportionately high for that District). Table 3 displays the distribution of THPs by county.

Table 1. Distribution of THPs by landowner category.

Landowner Category	THPs Selected	THPs Reviewed	Percent Selected	Percent Reviewed
Large industrial timberland owners	76	98	51	65
Small nonindustrial owners/others[3]	74	52	49	35

[3] Other types of landowners include small companies, State Forests, city properties, and water company properties.

Table 2. Distribution of THPs by Forest Practice District.

Forest Practice District	THPs	Percent
Coast	99	66
Northern	33	22
Southern	18	12

Table 3. Distribution of THPs evaluated from 1996 through 1998 by county.

County	North Coast 1996	Statewide 1997-1998	Total Number of THPs
Coast Forest Practice District			
Del Norte		6	6
Humboldt	25	17	42
Mendocino	25	21	46
Trinity		1	1
Sonoma		1	1
Santa Cruz		2	2
Santa Clara		1	1
Northern Forest Practice District			
Shasta		8	8
Butte		4	4
Lassen		2	2
Placer		2	2
Nevada		2	2
Modoc		2	2
Siskiyou		6	6
Trinity		4	4
Glen		1	1
Sierra		1	1
Yuba		1	1
Southern Forest Practice District			
Tuolumne		5	5
Amador		6	6
Calaveras		2	2
El Dorado		3	3
Fresno		2	2
Totals	50	100	150

METHODS

GENERAL INFORMAITON

There are five sample areas to be evaluated within each THP: landings, roads, logging operations (skid trails), watercourse and lake protection zones (WLPZs), and watercourse crossings. All five sample areas are evaluated twice within each selected THP if possible. Additionally, large erosion events are inventoried where they are encountered on the THP.

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

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

- Filling out "Site Information" sheets for each sample site. These are the top sheets in each packet. Much of this information can be obtained from the THP.

- Lay out road segment grid as described under "Site Selection" below.

SITE SELECTION

Selection of specific sample areas begins with marking approximate 500 foot road segments on all roads on the THP map. Each of these segments is assigned a number. Then a random number table or generator is used to identify one of the segments. From this point, a coin is flipped to determine a direction of travel until a landing is encountered. This randomly selected landing is used for the landing sample. Where more than one road enters or exits the landing, coin flips are used to identify a road transect that begins where the selected road leaves the landing. Coin flips are also used to determine the direction of travel to the first available skid trail transect. Watercourse crossing sites are selected as either the first crossing encountered during the road transect or, if no crossing is encountered, the first crossing along a road selected by coin flip. Finally, the closest approach of a Class I or Class II watercourse is used as the starting point for the WLPZ transect, and direction of travel along the WLPZ is determined by a coin flip. Either GPS readings or topographic maps may be used to record site locations with UTM coordinates.

FIELD ACTIVITIES COMMON TO ALL SAMPLE AREAS

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

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

At "problem" sites (such as cut bank failures, gullies, excessive grades, and rule violations), the problem type, erosion and sediment delivery site are recorded and a rule implementation evaluation is conducted. Any rills, gullies, or mass failures that are encountered as part of the transect and site inspections are followed to determine whether sediment from these erosional features reached a WLPZ or stream channel. The presence of rills, gullies or deposited sediment at the edge of the high flow or low flow channel is sufficient to class the sediment as having entered that portion of the stream.

After the field review has been completed, an evaluation of all the Rules is conducted based upon the overall frequency of problem sites and rule violations along the transect as a whole. Implementation of the Forest Practice Rules applicable to a given subject area is rated as either exceeding the requirements of the Forest Practice Rules or THP requirements, meeting the requirements, minor departure from requirements, major departure from requirements, not applicable, cannot determine (evidence is masked), or cannot evaluate (supply reason).

Major departures were assigned when sediment was delivered to watercourses, or when there was a substantial departure from Rule requirements (e.g., no or few waterbars installed for 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).[4]

[4] Minor and major departures from Rule/THP requirements 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 transect starting point is located using procedures described under Site Selection. Roads or skid trails that were not used as part of the THP being evaluated are not included. The starting point for the road or skid trail transect is the point at which it narrows to its "normal width" and is outside of the influence of operations on the landing. Where a road forks, the transect follows the road that is of the same general type of construction and level of use. Where a skid trail forks, the branch that continues in the same basic direction (up-hill or down-hill) as the transect to that point is followed. If there are no clear differences, a coin flip is used to determine direction. The direction that was chosen is described in the comments section to provide a record for follow-up inspections or re-measurement.

At the start of a transect, a measurement string is tied to a secure object, the string box counter is set to zero, and the location of the starting point is described in the comments for future reference. The road or trail is walked in the pre-determined transect direction for a distance of 1000 feet or to the end, whichever occurs first.[5]

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

The minimum skid trail transect length is 500 feet. If needed, this distance can be made up of several segments. Skid trails are randomly selected from those entering the landing if possible. If a skid trail is not available at this location, the nearest trail that brought logs to the measured road segment is used. Skid trail transects are no shorter than the length of trail requiring two waterbars. If the total skid trail distance is less than 300 feet, the transect is continued from the most recently passed trail intersection. Where there has been no intersection, the transect is continued from the landing without resetting the string box counter, and the transect is continued in this fashion up to a maximum of 1000 feet. If there is less than 500 feet of skid trail, the available trail length is sampled and an explanatory comment is included. If there are no skid trials, this is noted at the start of one of the logging operations forms.

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[5] 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 under sampled due to this problem.

Data Recording

The general procedure for linear transects is to record the starting and ending distance to each feature as it is encountered. On roads, for example, the beginning and ending point of all features (e.g., inside ditches, cut banks, location of waterbreaks, cross drains, etc.) are recorded, regardless of whether or not they present a water quality problem. Consecutive numbers are assigned to each feature, which, in combination with the THP and transect numbers, becomes a unique database identifier for that feature. Then codes are entered to indicate the type of feature and any associated drainage problems, erosion causes, and sediment production, plus information about road or trail gradient, sideslope steepness, and dimensions of erosion features.

LANDING METHODS

Site Identification

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

Landing Surface

The entire landing surface is inspected for rills and gullies. Gullies are defined as being 6" or greater in depth and of any length. The total length of all gullies and their average width and depth is recorded on the data forms. Sample points for rills were located along a single transect that bisects 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 1997-1998. To be counted, rills had to be a least one inch deep and 10 feet long. Both rills and gullies are inspected to determine whether they continue for more than 20 ft. past the toe of the landing fill slope, and gullies are followed to determine if sediment has been delivered to the nearest WLPZ and channel.

Cut Slopes (if present)

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

Fill Slopes (if present)

The toe of the fill slope is inspected for evidence of slope failures, rilling and gullying. Rills or gullies that are not caused by drainage from the landing surface are traced to determine whether they extend to a downslope channel. All slope failures are evaluated to determine the total amount of material moved and whether the material moved reaches a stream channel.

WATERCOURSE CROSSING METHODS

Site Identification

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

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

Fill Slopes

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

Road Surface

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

Culverts

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

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

The crossing is examined to determine the type and condition of armoring and whether downcutting or scouring at the outlet is occurring. Crossing approaches are evaluated to determine if they have 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 are examined to determine whether the restored channel configuration is 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 are assessed to determine if they are sloped back from the channel and stabilized to prevent slumping and minimize erosion. The crossing is 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.

WLPZ TRANSECT METHODS

Transects

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

For Class I waters, two 1000 foot long transects are sampled parallel to the stream within the WLPZ. One of these is a "mid-zone" transect located between the watercourse bank and the up-slope boundary of the WLPZ. The other is 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 is used.

Data Recording

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

Parameters estimated in the mid-zone transect include groundcover at every 100 feet, canopy cover at every 200 feet, WLPZ width at every 200 feet (concurrent with canopy measurement) and whenever there is a change in sideslope class, and sediment to the channel wherever it occurs. Measurements in the Class I watercourse streambank transect include canopy cover at 200 foot intervals, disturbance to streambanks wherever it occurs, and other stream related features. In addition, rule implementation is evaluated continuously along both transects, and any rule requirements or discrepancies are noted as a feature and are included in the implementation evaluation.

The general procedure for recording WLPZ transect data and the use of codes is similar in format to the methods used for roads and skid trails, but with features that are specific to WLPZ conditions and rule requirements. As with roads, the starting and ending distance to each feature is recorded along with a unique identification number and information about feature type, erosion causes, dimensions of erosion features, and sediment deposition.

Groundcover is estimated in an area with a diameter of approximately one foot located directly in front of the observer's boot toe, where adequate cover is 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." To date, canopy cover has been measured using a spherical densiometer (Figure 2). However, future measurements will be made using sighting tube transects with randomly located starting points to reduce the potential for bias resulting from overstory conditions in areas adjoining the measurement site (Robards et al. 1999) (Figure 3).

Features do not need to intersect the transect line to be included. This is necessary because dense vegetation and other obstructions in WLPZs make a straight line transect impractical to accomplish, so the location of the transect line will be biased by access within the WLPZ, and some extensive WLPZ features may not intersect the transect, as would be the case with a road running parallel to, but not on, the transect. In cases of steep terrain and limited visibility, identifying features at a distance from the transect line is benefited by the assistance of a second person who is not limited by the string box and can move about within the WLPZ.

The WLPZ measurements begin at one end of the mid-zone transect and include a continuous record of the beginning and end points of features encountered along the transect for a distance of 1000 feet. The streamside transect begins at a point perpendicular to the end of the mid-zone transect and proceeds in the opposite direction toward the starting point of the mid-zone transect.

LARGE EROSION EVENT EVALUATION METHODS

Erosion events with voids larger than 100 cubic yards are assessed whenever they are encountered on the THP. For watercourse crossings that have failed, a large erosion event is defined as greater than 10 cubic yards. These sites may be identified during the standard site evaluations, while traveling within the THP, or as a result of information provided by landowners or managers. Information collected includes the location, size, and type of feature, and an evaluation of the causal connections between the feature and specific timber operations, along with any applicable Forest Practice Rules.

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

DATABASE DEVELOPMENT

The Hillslope Monitoring 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, and flexible enough to accommodate monitoring form changes. A preliminary set of queries has been developed that is the basis for the results presented in this report. Future queries and sorts will provide more information on Forest Practice Rule implementation and effectiveness. As an example, queries are planned to provide information about how geologic type affects the frequency of erosion events on road transects.

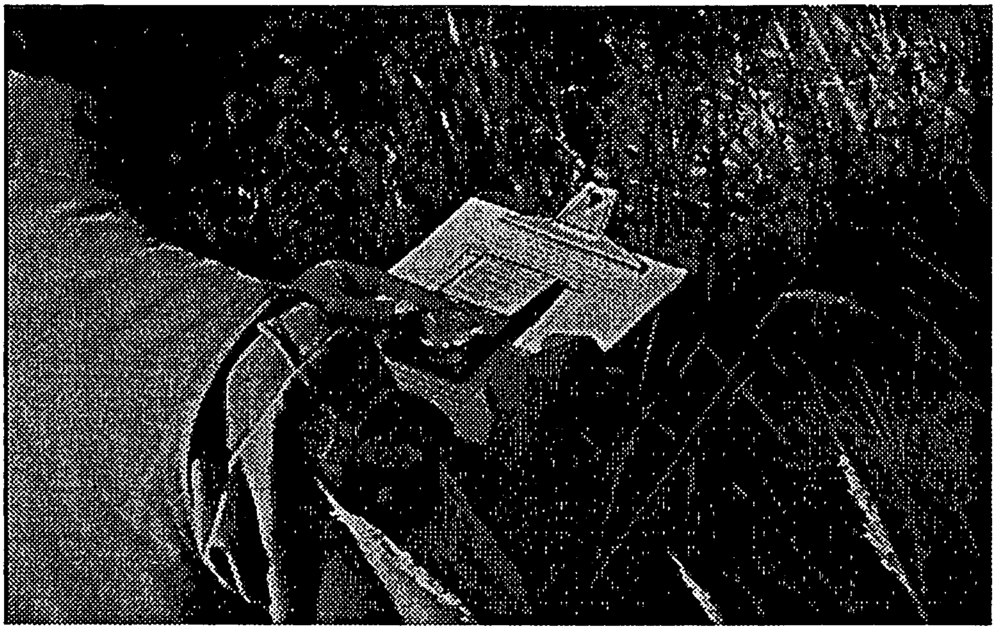

Figure 2. Concave spherical densiometer with the Strickler (1959) modification.

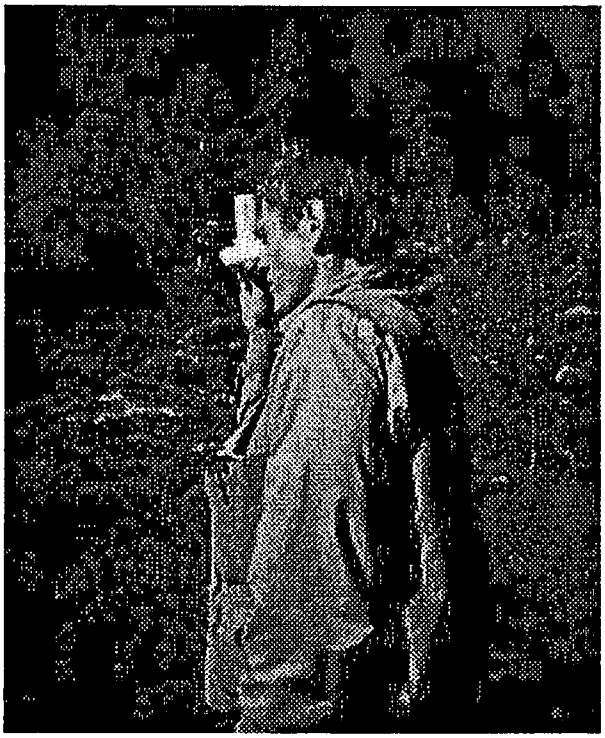

Figure 3. Sighting tube use for unbiased estimate of canopy cover.

RESULTS

The results of the hillslope monitoring conducted to date are summarized by major category: roads, logging operations, landings, watercourse crossings, watercourse and lake protection zones, and large erosion events. The data that are presented are frequency counts; detailed statistical tests have not been run to date. Statistical tests that involve categorical data, such as the implementation data, will require large sample sizes which generally are not available at this time (Lewis and Baldwin 1997). Future reports on the Hillslope Monitoring data will include the results of statistical tests when sample sizes are appropriate.

ROADS

From 1996 through 1998, 292 randomly located road transects were evaluated, for a total of 279,150 feet (52.87 mi.). Approximately 81% of the road transects were classified as seasonal, 12% as permanent, 5% as temporary, and 2% as a combination of road types. About 29% of the road length reviewed had been surfaced with rock.

Upon completing the evaluation of the randomly located 1000 foot road transect, the field team rated the overall implementation of specific Forest Practice Rules that relate to roads and water quality (Table A-1). A total of 59 questions were answered in the field based on 46 Forest Practice Rules, since some Rules were broken down into separate components. Most of the Forest Practice Rules evaluated on road transects had high percentages (i.e., greater than 90%) of cases where implementation ratings either met or exceeded the standard Rule. For Forest Practice Rules where the sample size was adequate [6], 22 Rule requirements were found to have combined minor and major departures greater than 5% (Table 4). However, the majority of the implementation ratings that triggered Rules to be displayed in Table 4 were for minor departures from Rule requirements.

The Rules with the highest numbers of departures were related to waterbreak spacing, maintenance, and construction standards; adequate number, size,

[6] For all categories (i.e., roads, skid trails, landings, watercourse crossings, and WLPZs), there had to have been at least 30 observations where field team assigned an implementation rating of exceeded rule requirement, met requirement, minor departure from requirement, or major departure from requirement. Thirty observations represents 10% or more of the implementation ratings in all cases.

Table 4. Road related Forest Practice Rule requirements with more than 5% departures based on at least 30 observations where implementation could be rated (note that some Rules are broken into component requirements, table is ordered by total departures).[7]

Forest Practice Rule	Description	Minor Departure (%)	Major Departure (%)
914.6(c)	Waterbreak spacing according to standards	20.1	2.7
923.1(f)	Adequate numbers of drainage facilities provided to minimize erosion	16.7	3.1
923.4(c)	Waterbreaks maintained to minimize erosion	16.7	2.7
923.2(h)	Drainage structures of sufficient size, number and location to carry runoff water	13.9	3.2
923.2(h)	Drainage structures of sufficient size, number and location to minimize erosion	14.4	2.5
923.2(b)	Sidecast minimized for slopes>65% for distances >100 feet	16.7	0
914.6(g)	Waterbreaks have an embankment of at least 6 inches	12.1	1.4
923.2(o)	Discharge onto erodible fill prevented	10.4	1.9
914.6(f)	Waterbreaks installed to discharge into cover	12.3	0
923.1(a)	If landing on road >1/4 ac or required substantial excavation-shown on map	7.3	4.8
914.6(g)	Waterbreaks constructed with a depth of at least 6 inches cut into firm roadbed	11.0	0.9
923.2(p)	Waterbreaks installed according to standards in 914.6	9.4	1.0
923.1(d)	For slopes >65% or 50% within 100 ft of WLPZ, soil treated to minimize erosion	8.2	2.0
914.6 (f)	Where waterbreaks don't work--other erosion controls	7.0	0.9
923.4 (j)	Drainage ditches maintained to allow flow of water	7.3	0
923.2 (d) C	Fills constructed with insloping approaches, etc.	6.1	1.2
923.2 (d) N	Breaks in grade above/below throughfill	7.0	0
923.6	Wet spots rocked or otherwise treated	6.7	0
923.1 (a)	Road shown on THP map correctly	5.6	0.3
923.4 (c)	Erosion controls maintained during maintenance period	5.9	0
923.2(l)	Trash racks, etc. installed where appropriate	5.6	0
923.2 (m)	Sidecast extending >20 ft treated to avoid erosion	2.6	2.6

[7]Major departures were assigned when sediment was delivered to watercourses, or when there was a substantial departure from Rule requirements (e.g., no or few waterbars installed for 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).

and the location of drainage structures to minimize erosion; prevention of discharge onto erodible fill; and sidecast limitations on steep slopes. Erosion problem points (i.e., rills, gullies, cutbank or sidecast sloughing, mass failures) were described on the road transects where they were encountered. A total of 727 erosion problem points associated with the sampled THPs were noted. While some road transects had no erosion problem points, the overall average equated to one problem point for every 380 feet of road. The distribution of erosion features associated with current Timber Harvesting Plans are summarized in Table 5. Total erosion volumes from cutbank/sidecast sloughing, mass failures, and gullying were approximately 1990, 3010, and 1050 yds^3, respectively.[8] These estimates are the volumes of voids remaining at hillslope locations, not the amount of sediment delivered to watercourse channels. When a problem point was discovered, implementation of the appropriate Forest Practice Rule(s) was also rated. A total of 41 Rule requirements were rated for implementation at erosion problem points along road transects. Of these, 13 were responsible for approximately 90% of the problem points associated with roads (Table 6).

Table 5. Erosion features found on road transects created by the current THP.

Erosion Feature	Number of Features
Cutbank/sidecast sloughing	80
Mass Failure	18
Gullying	148
Rilling	478
Other Erosion Features	3

From Table 6, it is clear that the vast majority of the problem points noted along the road transects were judged to be due to either minor or major departures from specific Forest Practice Rule requirements. When considering all the implementation ratings assigned at erosion problem points encountered, only 3.1% were associated with situations where the Forest Practice Rule requirements were judged to have been met or exceeded and 96.9% were associated with minor or major departures from the Rule requirements. In other

[8] Note that rilling volumes were not determined. Erosion from rilling is generally a much smaller component when compared to that from mass wasting and gullying. For example, Rice et al. (1979) found that rilling accounted for only 3% of total hillslope erosion following tractor logging in the South Fork Caspar Creek watershed. Other volumes listed are to be considered preliminary data. Only when lengths, depths, and widths were all greater than 1 foot were volumes calculated to make these estimates. Additionally, all the width, depth and length data were rounded to the nearest integer. Efforts are now underway to revise these calculations and use the one-tenth foot values available for width and depth estimates.

Table 6. Forest Practice Rules that account for approximately 90% of all the Rule requirements rated for implementation at erosion problem points along road transects.

Forest Practice Rule	# of Times FPR Cited	Description of Rules Rated for Implementation where Problems Occurred	Exceeds/ Met Rule (%)	Minor (%)	Major (%)
923.1(f)	254	Adequate number of drainage facilities to minimize erosion	4.7	83.9	11.4
923.2(h)	240	Drainage structures of sufficient size, number and location to minimize erosion	7.9	78.3	13.8
923.2(h)	226	Drainage structures of sufficient size, number and location to carry runoff water	0.4	86.7	12.8
914.6(c)	195	Waterbreak spacing according to standards	6.2	80.0	13.8
923.4(c)	134	Waterbreaks maintained to minimize erosion	0	69.4	30.6
914.6(f)	125	Waterbreaks discharge into cover	0	98.4	1.6
923.2(o)	119	Discharge onto erodible fill prevented	0	95.8	4.2
914.6(g)	71	Waterbreaks have embankment of at least 6 inches	0	77.5	22.5
914.6(g)	61	Waterbreaks cut to depth of 6 inches	0	73.8	26.2
923.2(p)	51	Waterbreaks installed according to 914.6	11.8	66.7	21.6
914.6(f)	28	Where waterbreaks are not effective, other erosion controls installed as needed	0	89.3	10.7
923.4(i)	25	Soil stabilization treatments installed on cuts, fills, or sidecast to minimize surface erosion	4.0	88.0	8.0
923.4(j)	19	Drainage ditches maintained to allow free flow of water	15.8	84.2	0

words, nearly all of the problems resulted from non-compliance. For a small percentage of the problem points, even though properly implemented, the Rule(s) still resulted in erosion problems.[9]

Table 7 displays the counts of road drainage structures inventoried with and without problem points. From the total population of waterbreaks evaluated, approximately 10% did not conform to the requirements of the Rules. Rolling dips and culverted cross drains had deficiencies 7% and 5% of the time, respectively. Note that multiple types of Rule requirement violations are possible at each drainage structure with a problem. Therefore the sum of drainage structures with problems will be less than the counts for major and minor Rule departures.

[9] Lewis and Baldwin (1997) suggested in their statistical review of this project that implementation would have to be rated immediately following the completion of logging and prior to stressing storm events to remove observer bias. 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. The percentage of departures for which this is true is unknown. CDF's Modified Completion Report will provide information on implementation following harvesting that may help us address this problem.

Table 7. Counts of drainage structures evaluated along road transects with and without problems.

Drainage Structure Type	Total Number	Count-No Problem	Count—Problem	% with Problems
Waterbreaks	1,055	957	98	9.3
Rolling Dips	271	251	20	7.4
Leadoff Ditch	138	136	2	1.5
Culvert cross drain	137	130	7	5.1
Other drainage structure	38	37	1	2.6

Information recorded during the road transect evaluations allows us to determine the source, cause, and depositional area associated with the erosion features. Table 8 displays the different types of erosion and percentages of features associated with varying types of source areas. Cutbank and sidecast sloughing came predominantly from road cutbanks, with a lesser component from fill slopes. Mass failures were associated mostly with fill slopes, with much smaller components from cutslopes and hillslopes above the road. Gullying was more equally distributed through all the source codes, but the major sources were waterbar outlets, fill slopes, and road surfaces, respectively. Rilling, in contrast, was nearly always associated with the road surface.

Erosion cause codes are displayed in Table 9.[10] Most of the observed cutbank and sidecast sloughing was associated with cut slopes that were judged to be either too steep or too tall. Other frequently cited codes for contributing causes

Table 8. Number (and percentage) of the source location of the recorded erosion features for road transects (note that multiple source codes can be assigned to single erosion features).

Source	Sloughing	Mass Failure	Gullying	Rilling
Cut Slope	38 (70.4)	2 (11.8)	4 (2.7)	5 (1.1)
Fill Slope	9 (16.7)	12 (70.6)	30 (20.0)	15 (3.2)
Road Surface	1 (1.9)	1 (5.9)	24 (16.0)	388 (83.6)
Hillslope Above Road	4 (7.4)	2 (11.8)	6 (4.0)	7 (1.5)
Hillslope Below Road	1 (1.9)	0	0	0
Inside Ditch	0	0	14 (9.3)	6 (1.3)
Rolling Dip Outlet	0	0	10 (6.7)	1 (0.2)
Waterbar Outlet	1 (1.9)	0	54 (36.0)	35 (7.5)
Waterbar Ditch	0	0	4 (2.7)	3 (0.6)
Rolling Dip Ditch	0	0	2 (1.3)	1 (0.2)
Other	0	0	2 (1.3)	2 (0.6)
Total	54 (100)	17 (100)	150 (100)	464 (100)

[10] Note that more than one cause code could be recorded for an erosion event.

were steep side slopes, unstable fill, and highly erodible surface material. Unstable slopes, steep side slopes, and unstable terrain were the most commonly cited cause codes associated with mass failures. More than three-quarters of the observed gullying was coded as being associated with drainage feature problems. Approximately 10% of the time, highly erodible surface material was also listed as a cause of the observed gully. Finally, over 60% of the rilling was associated with drainage feature problems, with highly erodible surface material and steep road gradient being less frequently cited cause codes.

Because drainage feature problems were the most commonly cited cause for gullying and rilling, additional detail for this category is displayed in Table 10. For gullying, spacing of drainage structures (judged to be too wide) was the most frequently cited problem, closely followed by cover (drainage structure did not discharge into vegetation, duff, slash, rocks, etc.). Inappropriate location of the drainage structure was the third most frequently cited drainage problem. The results for rilling are similar to those for gullying. Spacing of drainage structures was cited over 70% of the time when rilling was encountered, with cover being recorded about 8% of the time. Drainage feature problems were often not cited as being associated with mass failures. When they were, shotgun outlets without armoring, plugged culvert inlets, cover, and maintenance were the most frequently cited problems. Similarly, sloughing was usually not associated with drainage feature problems, as illustrated by the fact that the most commonly cited drainage feature problem was the "other" category.

Table 9. Number (and percentage) of recorded erosion cause codes that contributed substantially to development of recorded erosion features on road transects (note that multiple cause codes can be assigned to a single erosion feature).

Cause	Sloughing	Mass Failure	Gullying	Rilling
Drainage feature problem	2 (2.6)	4 (10.8)	124 (76.5)	322 (61.1)
Highly erosive surface	8 (10.5)	3 (8.1)	16 (9.9)	95 (18.0)
Other	4 (5.3)	4 (10.8)	8 (4.9)	12 (2.3)
Steep road gradient	0	0	5 (3.1)	51 (9.7)
Unstable fill	9 (11.8)	10 (27.0)	4 (2.5)	0
Rutting	0	0	3 (1.9)	27 (5.1)
Steep side slopes	11 (14.5)	8 (21.6)	1 (0.6)	15 (2.8)
Unstable terrain	7 (9.2)	6 (16.2)	1 (0.6)	1 (0.2)
Cut slope too long	1 (1.3)	0	0	1 (0.2)
Cut slope too steep	16 (21.1)	1 (2.7)	0	1 (0.2)
Cut slope too tall	18 (23.7)	1 (2.7)	0	2 (0.4)
Total	76 (100)	37 (100)	162 (100)	527 (100)

The location of sediment deposition resulting from these various types of erosion features is of critical concern when addressing protection of beneficial uses of water. Figure 3 displays the sediment deposition categories for the various types of erosion features previously described above. Only 6% of the sloughing features were found to have transported sediment to the channel; another 3% had material transported into the WLPZ. For gullying, about 18% of features had sediment transported into the channel, with another 3% deposited in the WLPZ. Mass wasting resulted in sediment transported into the channel 47% of the time, and material entering the WLPZ an additional 3% of the time. Finally, rilling features had sediment deposited in channels 13% of the time, with an additional 3% deposited in the WLPZ.

Table 10. Number (and percentage) of drainage feature problems associated with erosion features on road transects (note that multiple drainage feature codes can be assigned to a single erosion feature).

Drainage Feature Problem	Sloughing	Mass Failure	Gullying	Rilling
Spacing	1 (10)	0	73 (36.0)	342 (70.5)
Cover	2 (20)	1 (20)	67 (33.0)	39 (8.0)
Location Inappropriate	0	0	26 (12.8)	16 (3.3)
Divert	0	0	10 (4.9)	32 (6.6)
Maintenance	0	1 (20)	7 (3.4)	33 (6.8)
Flow	0	0	7 (3.4)	7 (1.4)
Other	4 (40)	0	5 (2.5)	5 (1.0)
Rolling dip break	0	0	3 (1.5)	4 (0.8)
Shotgun outlet w/out armoring	1 (10)	2 (40)	2 (1.0)	0
Runoff escaped	0	0	2 (1.0)	2 (0.4)
Blocked ditch	2 (20)	0	1 (0.5)	2 (0.4)
Plugged inlet	0	1 (20)	0	0
Height	0	0	0	3 (0.6)
Total	10 (100)	5 (100)	203 (100)	485 (100)

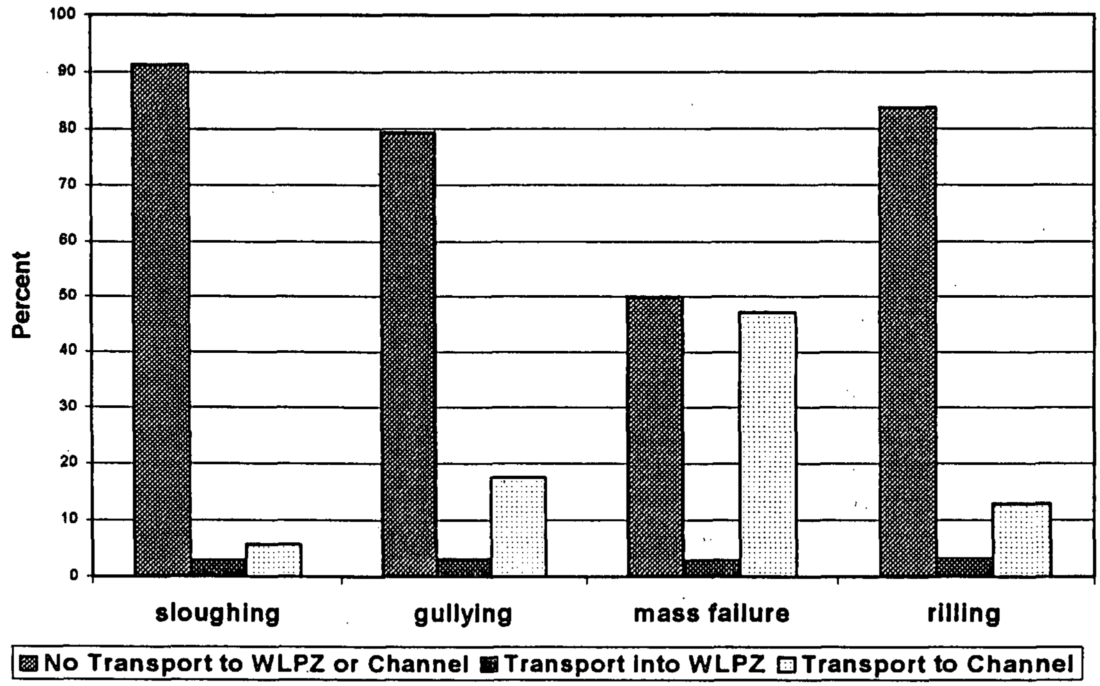

Figure 4. Sediment deposition sites for erosion features produced from current THPs and associated with road transects (percent of the number of occurrences for each feature type).

Logging Operations (Skid Trail Transects)

The logging operations component of the hillslope monitoring program sampled 246 randomly located skid trail transects, for a total of 173,976 feet (32.95 mi.). For THPs that had been yarded exclusively with cable systems, this portion of the field work was omitted. Field procedures and forms are similar for both roads and logging operations—except that implementation ratings are assigned for Forest Practice Rules relating to ground skidding operations and the site information recorded is somewhat different. Therefore, results will be presented in a similar manner.

Overall implementation ratings of the Forest Practice Rules relating to logging operations on skid trail transects are displayed in Table A-2. A total of 26 questions were developed from 22 Forest Practice Rules. Table 11 shows that for Rule requirements with at least 30 observations, three Rules were found to have more than 5% major and minor departures. The highest percentage of departures from Forest Practice Rule requirements were for Rules specifying the installation of other erosion control structures where waterbreaks cannot disperse runoff, waterbreak spacing, and waterbreak maintenance.

Table 11. Skid trail related Forest Practice Rule requirements with more than 5% departures based on at least 30 observations where implementation could be rated (note that table is ordered by total departures).

Forest Practice Rule	Description	Minor Departure (%)	Major Departure (%)
914.6 (f)	Where waterbreaks cannot disperse runoff, other erosion controls installed as needed	19.7	3.9
914.6(c)	Waterbreak spacing equals standards	11.0	4.7
923.4 (c)	Waterbreak maintained to divert runoff water	7.1	0.4

Problem points were described along skid roads where they were observed by the field team. A total of 148 erosion problem points were recorded that could be attributed to the current THP, equating to an average of one problem point for every 1,175 feet of skid trail evaluated. Eight Forest Practice Rule requirements were associated with significant numbers of erosion problem points (Table 12). All of the problem points encountered along skid trails were judged to be due to either minor or major departures from specific Forest Practice Rule requirements. The total count of waterbreaks along skid trail transects was 1,614. Sixty-four of these waterbreaks were inventoried as problem points that did not conform to the requirements of the Rules. This equates to approximately 4% of all waterbreaks.

Erosion features associated with current Timber Harvesting Plans are summarized in Table 13. Gullying, rilling, and mass failures were recorded in roughly the same percentages as were recorded for the road transects--but much less frequently. Total erosion volumes for gullying, mass failure, and cutbank/sideslope sloughing were approximately 200, 1070, and 5 yds^3, respectively.[8] These estimates are the volumes of voids remaining at hillslope locations, not the amount of sediment delivered to watercourse channels.

Table 12. Forest Practice Rules that account for approximately 90% of all the Rules rated for implementation at problem points along skid trail transects.

Forest Practice Rule	# of Times FPR Cited	Description of Rules Rated for Implementation where Problems Occurred	Exceeds/ Met Rule (%)	Minor (%)	Major (%)
914.6(c)	68	Waterbreak spacing equal standards	0	85.3	14.7
914.6(f)	37	Waterbreaks discharge into cover	0	100	0
914.6(f)	29	If waterbreaks inappropriate—other structures installed to minimize erosion	0	89.7	10.3
923.4(c)	28	Waterbreaks maintained to divert runoff	0	100	0
914.6(f)	28	Waterbreaks built for unrestricted discharge at lower end	0	100	0
914.6(g)	23	Waterbreaks installed diagonally	0	100	0
914.6(g)	23	Waterbreaks have embankments 6 in high	0	87.0	13.0
914.6(f)	20	Waterbreaks installed to spread runoff water to minimize erosion	0	90.0	10.0

As with the road evaluations, information recorded along the skid trail transects included the source, cause, and deposition associated with these erosion features. Cutbank and sidecast sloughing originated entirely from cut slopes, while 95% of skid trail rilling was associated with the skid trail surface. Mass failures were mostly from cut and fill slopes. Greater than 70% of the gully erosion was associated with the skid trail surface, of which 20% was related to waterbar outlets.

Table 13. Erosion features created by the current THP found on skid trails.

Erosion Feature	Number of Features
Gullying	35
Mass Failure	6
Cutbank/Sidecast Sloughing	3
Rilling	104

Erosion cause codes are displayed in Table 14. Approximately 60% of the rilling was associated with drainage feature problems, with highly erosive surface material (21%) and steep trail gradients (10%) also being cited frequently. Similarly, 60% of the gullying was caused by drainage feature problems, with steep trail gradient (12%) and highly erosive surface material (12%) also cited. About 40% of the mass failures on skid trails were judged to be caused by unstable terrain, with unstable fill and steep side slopes also mentioned.

The most frequently cited drainage feature problems for rilling were spacing of waterbreaks (68%), incomplete diversion of water by waterbreaks (12%), and inappropriate location (11%). For gullying, spacing was recorded 58% of the time, with inappropriate location (16%) and lack of discharge into cover (11%) cited frequently as well.

Table 14. Number (and percentage) of erosion cause codes that contributed substantially to development of recorded erosion features on skid trail transects (note that multiple cause codes can be assigned to a single erosion feature).

Cause	Sloughing	Gullying	Mass Failure	Rilling
Drainage feature problem	0	25 (59.5)	0	64 (60.4)
Highly erosive surface material	1 (33.3)	5 (11.9)	1 (8.3)	22 (20.8)
Steep trail gradient	0	5 (11.9)	0	11 (10.4)
Steep side slopes	1 (33.3)	2 (4.8)	2 (16.7)	2 (1.9)
Other	0	2 (4.8)	1 (8.3)	5 (4.7)
Unstable fill	0	2 (4.8)	3 (25)	1 (0.9)
Organic matter in fill	0	1 (2.4)	0	0
Cut slope too steep	1 (33.3)	0	0	0
Unstable terrain	0	0	5 (41.7)	0
Rutting	0	0	0	1 (0.9)
Total	3 (100)	42 (100)	12 (100)	106 (100)

Figure 4 shows the frequency of sediment deposition sites for rilling and gullying. Sloughing and mass failures are not included because of the small number of occurrences. Approximately 4% of the rills deposited sediment into watercourses; another 4% deposited material into the WLPZ.[11] For gullying, 26% deposited material into channels, with another 5% depositing material into the WLPZ.

[11] Euphrat (1992) documented little transport of sediment to watercourse channels from skid trails in the Mokelumne River watershed.

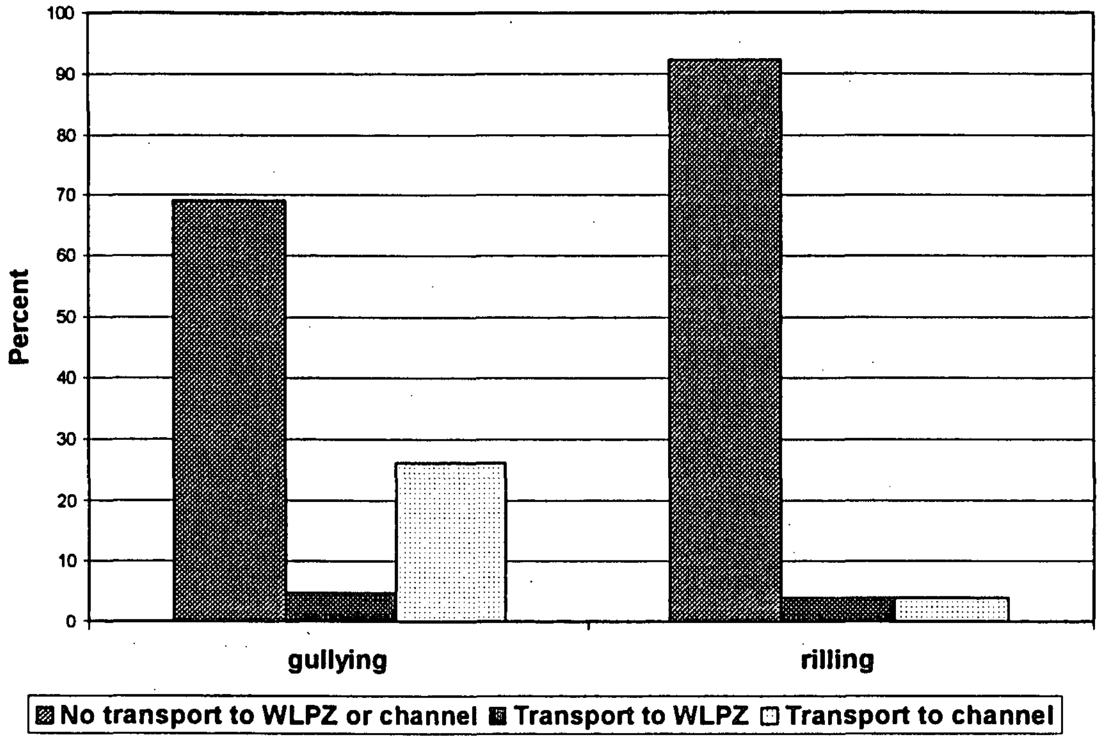

Figure 5. Sediment deposition sites for rilling and gullying produced from current THPs and associated with skid trail transects.

Landings

A total of 291 landings were evaluated as part of the Hillslope Monitoring Program from 1996 through 1998. Approximately 53% of the landings were more than 300 feet from the nearest watercourse receiving drainage off the landing, and 85% were more than 100 feet away. About 87% were constructed on slopes less than 45%, and 48% were built on slopes less than 30%. The landings evaluated were constructed on the "nose of a ridge", above a break in slope, or on a ridge top 84% of the time.

Overall implementation ratings of the Forest Practice Rules relating to landings are displayed in Table A-3. A total of 23 questions were developed from 20 Forest Practice Rules. Table 15 shows that for Rule requirements with at least 30 observations, four were found to have more than 5% major and minor departures. The Rule with the highest percentage of total departure was 923.1(a), which requires the RPF to map landings greater than one-quarter acre in size, or those requiring substantial excavation. About 10% of the landings were judged to have either minor or major departure from the Forest Practice Rule requiring adequate numbers of drainage facilities. Rules requiring treatment of fill material when it has access to a watercourse and rocking of wet areas had smaller percentages of departures from stated requirements.

Table 15. Landing related Forest Practice Rule requirements with more than 5% departures based on at least 30 observations where implementation could be rated (note that table is ordered by total departures).

Forest Practice Rule	Description	Minor Departure (%)	Major Departure (%)
923.1(a)	Landings>1/4ac or substantial excavation--shown on THP map	11.0	5.9
923.1(f)	Adequate #s of drainage structures	9.0	1.5
923.5(f)(2,4)	Fill extending 20ft with access to watercourse—treated	8.5	0
923.6	Wet spots rocked or treated	6.5	0

Problem points were described for specific components of landings where they were observed by the field team. A total of 36 problem points were recorded, equating to an average of approximately one problem point for every eight landings evaluated. While seven Forest Practice Rules were cited as being poorly implemented causing these problem points, only 923.1(f) which requires adequate drainage structures, was cited frequently (Table 16). All of the problem points encountered at landings were judged to be due to either minor or major departures from specific Forest Practice Rule requirements.

Table 16. Forest Practice Rules that account for approximately 90% of all the Rule requirements rated for implementation at problem points for landings).

Forest Practice Rule	# of Times FPR Cited	Description of Rules Rated for Implementation where Problems Occurred	Exceeds/ Met Rule (%)	Minor (%)	Major (%)
923.1(f)	24	Adequate #s of drainage structures	0	79.2	20.8
923.5(f)(3)	6	Sloped/ditched to prevent erosion	0	83.3	16.7
923.8	3	Abandonment-minimize concentration of runoff	0	100	0
923.5(f)(2)	2	Ditches associated with the landing clear of obstructions	0	100	0

The problem points associated with the landings evaluated are displayed in Table 17. The majority of the problems were associated with either fill slopes or surface drainage features. Presence of significant erosion features (rills or gullies) below the edge of the landing surface associated with drainage structure outlets were the most frequently cited type of problem encountered. Significant amounts of sediment transport were cited as problem points on only four occasions.

Table 17. Distribution of problem points noted at landings.

Type of Problem	Cut Slopes	Fill Slopes	Surface	Below Edge of Landing
Mass Failures	1	3		
Gullies		6		
Rilling	1	3	4	
Rilling/Gullying				14
Sediment Transport		1	3	

The complete summary of the landing effectiveness questions is displayed in Table A-4. Rills or gullies resulting from concentrated flow at drainage structure outlets were present about 28% of the time, and erosion features extending beyond 20 feet below the edge of the landing were found slightly more than 5% of the time.

The location of sediment deposition originating from landing surfaces and fill slopes was also evaluated (Figure 5). For fill slopes, 2% of the time material entered channels, with another 3% reaching the WLPZ. Similarly for surface drainage, 1.5% reached channels, with another 5% reaching the WLPZ.

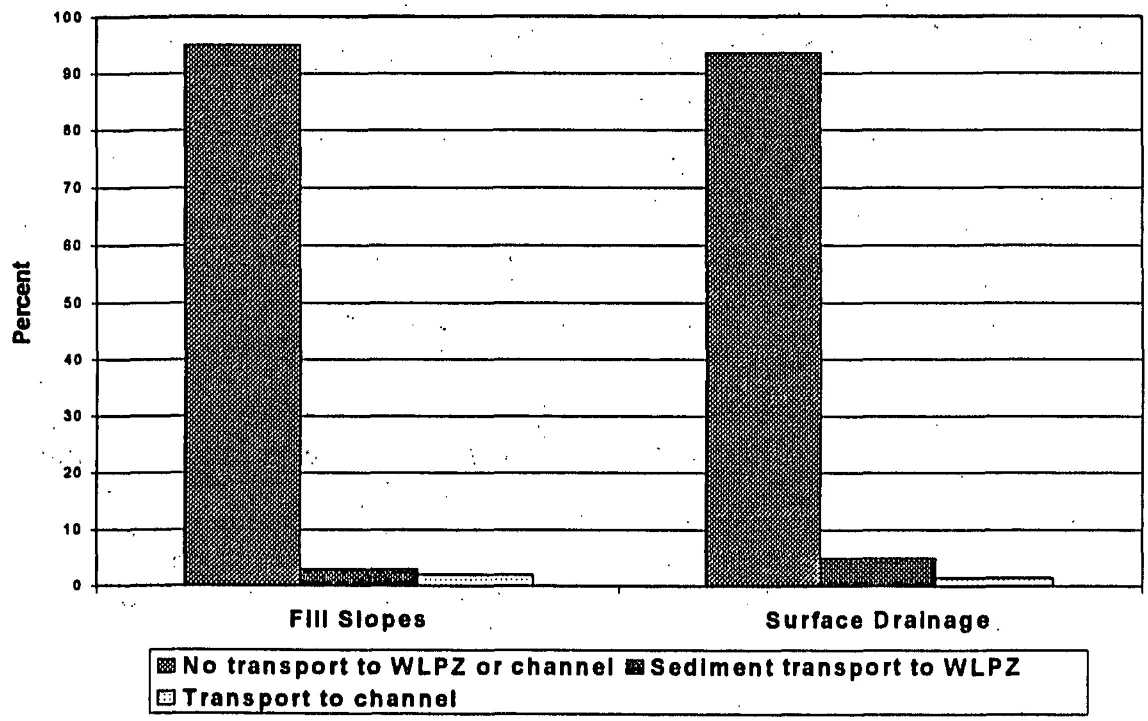

Figure 6. Sediment deposition sites associated with landing fill slopes and surface drainage.

Watercourse Crossings

A total of 263 watercourse crossings were evaluated from 1996 through 1998. Approximately 73% were crossings with culverts, while 16.5% were fords, 2.5% were structural crossings, and 8% were other types of crossings. Seventy percent of the crossings were associated with seasonal roads, 19% with permanent roads, 5% with temporary roads, and 6% with skid trails. Eighty-five percent of the crossings were existing when evaluated, 8% were abandoned, and 7% were removed for the winter period. Fifty percent of the crossings were in Class III watercourses, 45% in Class II drainages, 4% in Class I's, and less than 1% in Class IV watercourses.

Overall implementation ratings of the Forest Practice Rules relating to crossings are displayed in Table A-5. A total of 27 questions were rated for implementation and were developed from 24 Forest Practice Rules. Table 18 shows that for Rule requirements with at least 30 observations, 14 were found to have more than 5% major and minor departures. The Rule with the highest percentage of total departure is 923.2(o), which prevents discharge onto erodible fill material unless energy dissipators are used. Numerous rules requiring proper channel configuration following crossing removal or abandonment also had high departures from stated requirements. The Rules requiring crossings to avoid diversion potential, fills built to minimize erosion, crossings open to unrestricted passage of water, and trash racks in place where appropriate also were cited as having substantial departure percentages.

Problem points were described for specific components of crossings where encountered. A total of 254 problem points were recorded, equating to nearly one problem point for every crossing evaluated. Thirty-seven percent of the watercourse crossings had problem points assigned, indicating that deficient crossings generally had more than one problem point. Poor implementation of 22 Forest Practice Rules were cited as being responsible for these problem points, with 14 Rule requirements being cited the majority of the time (Table 19). All of the problem points were judged to be due to either minor or major departures from requirements of specific Forest Practice Rules. Approximately 64% of the Rule implementation ratings for watercourse crossing problem points were judged to be minor departures, while 36% were rated as major departures from Rule requirements.[12]

[12] Minor and major departures from Rule requirements for crossings relate to the severity of the problem discovered and less on sediment delivery (since sediment delivery at crossings is assumed to be 100%). For example, a culvert with 10% blockage would equate to a minor departure for 923.4(d), while a culvert with 50% blockage would be rated as a major departure.

Table 18. Watercourse crossing related Forest Practice Rule requirements with more than 5% departures based on at least 30 observations where implementation could be rated (note that some Rules are broken into component requirements, table is ordered by total departures).

Forest Practice Rule	Description	Minor Departure (%)	Major Departure (%)
923.2(o)	No discharge on fill unless energy dissipators are used	13.5	7.1
923.3(d)(1)	Removed-fills excavated to reform channel	16.1	3.2
923.8	Abandonment—minimized concentration of runoff water	12.9	6.5
923.2(d)	Fills across channels built to minimize erosion	10.8	6.7
923.4(1)	Trash racks installed where lots of LWD	12.8	5.1
923.8(d)	Abandonment—pulling/shaping of fills	6.7	10.0
923.4(n)	Crossing/approaches maintained to avoid diversion	14.1	2.4
923.3(d)(2)	Removed-cut bank sloped back to prevent slumping	9.7	6.5
923.3(e)	Crossings/fills built to prevent diversion	10.7	3.4
923.4(c)	Waterbreaks maintained to divert into cover	12.9	0.8
923.4(d)	Crossing open to unrestricted flow of water	9.7	3.4
923.4(d)	Trash racks installed where needed at inlets	6.7	6.7
923.2(h)	Drainage structures of sufficient size, #, and location to carry runoff water	6.5	5.8
923.4	Trash racks in place as specified in THP	6.1	0

The problem points associated with crossings are displayed in Table 20. Fill slope gullies, culvert plugging, and diversion accounted for 15, 14, and 11% of the problem points, respectively. Fill slope failures (7%), fill slope rilling (7%), and fill slope vegetative cover (6%) accounted for smaller percentages of problem points.

The complete summary of the crossing effectiveness questions is displayed in Table A-6. Significant scour at the outlet of crossings was found 35% of the time, with some degree of plugging occurring 22% of the time. Diversion potential was noted for about 17% of the culverted crossings. Almost 40% of the fill slopes at crossings had some amount of slope failure present. Road surface drainage towards the crossing had either slight or significant sediment delivery 36% of the time. For abandoned or removed crossings, approximately 80% had channels established close to natural grade and orientation, with about 20% having minor or major differences. Sediment delivery to watercourses can generally be assumed to be 100% at crossings since these structures are built directly in channels.

Table 19. Forest Practice Rules that account for approximately 90% of all the Rule requirements rated for implementation at problem points for watercourse crossings.

Forest Practice Rule	# of Times FPR Cited	Description of Rules Rated for Implementation where Problems Occurred	Exceeds/ Met Rule (%)	% Minor Departure	% Major Departure
923.2(o)	36	No discharge on fill without energy dissipators	0	58.3	41.7
923.4(n)	32	Crossing/approaches maintained to avoid diversion potential	0	84.4	15.6
923.2(h)	31	Structures of sufficient size, #, locations to minimize erosion	0	51.6	48.4
923.3(e)	27	Crossing/fill built to prevent diversion	0	66.7	33.3
923.4(d)	27	Crossing open to unrestricted passage of water	0	66.7	33.3
923.2(d)	24	Fills across channels built to minimize erosion	0	50.0	50.0
923.4(c)	12	Waterbreaks maintained to divert water into cover	0	91.7	8.3
923.2(h)	10	Size, #, location of structures sufficient to carry runoff water	0	30	70
923.8	7	Abandonment-minimizes concentration of runoff, erosion	0	57.1	42.9
923.8(b)	7	Abandonment-adequate stabilization of exposed soil on cuts, fills, sidecast	0	57.1	42.9
923.4(1)	6	Trash rack installed where LWD	0	83.3	16.7
923.8(d)	6	Abandonment-pulling/shaping fills	0	50	50
923.3(d)(2)	6	Removed-excavated material sloped back and stabilized to prevent erosion	0	66.7	33.3
923.2(h)	6	Size, #, location of structures sufficient to maintain drainage pattern	0	83.3	16.7

Table 20. Distribution of problem points noted at watercourse crossings.

Drainage Type	Problem Type	Count
Culvert	Plugging	36
	Diversion	29
	Scour at outlet	13
	Gradient	12
	Scour at inlet	4
	Piping	3
	Crushed	2
	Corrosion	1
Fill Slopes	Gullies	38
	Slope failures	18
	Rilling	17
	Vegetative cover	16
	Cracks	4
Road Surface Draining to Crossings	Rutting	7
	Inside Ditch	5
	Rilling	5
	Ponding	4
	Gullies	2
Non-Culvert Crossing	Armoring	7
	Scour at outlet	3
Removed/Abandoned Crossing	Road Approach-grading	10
	Grading/Shaping	7
	Channel bank gullies	4
	Configuration	5
	Channel bank slope failure	1
	Bank stabilization	1

Watercourse and Lake Protection Zones (WLPZs)

The Hillslope Monitoring Program sampled 274 watercourse and lake protection zone (WLPZ) transects, with a total of 244,940 feet (46.39 mi) of transects evaluated.[13] Approximately 76% of the transects were along Class II watercourses, 23% next to Class I watercourses, and 1% beside Class III watercourses with WLPZs. For about 43% of the transects, the slope distance from the channel bank to the nearest road was greater than 150 feet; 17% had a distance of 50-100 feet, 15% had a distance of 100-150 feet, 14% had a distance of 0-20 feet, and 11% had a distance of 20-50 feet.

Following the completion of WLPZ transect(s), the field team rated the overall implementation of specific Forest Practice Rules related to WLPZs (Table A-7). A total of 55 questions were developed from 34 Forest Practice Rules. Table 21 shows that for Rule requirements with at least 30 observations, six were found to have more than 5% major and minor departures. Three of these Rules deal with the requirement for the RPF to evaluate riparian areas for sensitive conditions—including unstable and erodible watercourse banks and use of existing roads within the standard WLPZ. These factors are to be identified in the THP and considered when proposing WLPZ widths and protection measures. Two Rules cited require that WLPZ widths be at least equal to that specified in Table 1 in the Forest Practice Rules. The remaining Rule requires accidental depositions of soil to be removed from watercourses.

Very few erosion features caused by current Timber Harvesting Plans were noted when completing the WLPZ transects (Table 22). Most of the erosion features noted were judged to either predate the current THP, were created after the THP but were not affected by the THP, or it was impossible to determine the feature date. Only one of the mass failures was associated with problems with Rule implementation. The remaining features were natural streambank or inner gorge failures not related to logging operations. Total erosion volumes for mass failures and gullying were 2,050 and 65 yd^3, respectively.

[13] Class III watercourses were not evaluated from 1996 through 1998, but a pilot project for evaluating protection of Class III watercourses is expected to be implemented during the summer of 1999.

Table 21. WLPZ related Forest Practice Rule requirements with more than 5% departures based on at least 30 observations where implementation could be rated (note that some Rules are broken into component requirements, table is ordered by total departures).

Forest Practice Rule	Description	Minor Departure (%)	Major Departure (%)
916.4(a)	Sensitive conditions—erodible banks—identified in THP	9.0	1.8
916.2(a)(4)	Sensitive conditions—existing roads in WLPZ—appropriate mitigation measure applied	7.0	2.8
916.4(a)	Sensitive conditions—existing roads in WLPZ—identified in THP	5.7	2.9
916.4(b)(3)	Width of WLPZ conforms to Table 1 in FPRs	6.4	0.8
916.4(b)	WLPZ widths as wide as specified in Table 1	5.6	0.8
916.3(b)	Accidental depositions of soil removed from watercourses	5.9	0

Table 22. Erosion features associated with the current THP and recorded during WLPZ transect evaluations.

Erosion Feature	Count
Cutbank or sidecast sloughing	1
Mass Failure	13
Gullying	4
Rilling	5

Mean WLPZ widths and side slope gradients were estimated for the transects evaluated. Mean widths for side slope categories are displayed in Table 23. 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 commonly is very difficult to locate following several overwintering periods. Therefore, the WLPZ widths must be regarded as rough estimates. It is also unknown at this time how many of these WLPZs utilized the allowable reduction granted for using cable yarding systems above the WLPZ (50 ft reduction for Class I and 25 ft reduction for Class II watercoures). Thirty percent of the WLPZ transects had only cable or helicopter yarding upslope of the transect.

Ground cover was evaluated at 100 foot intervals along the WLPZ transects. Mean ground cover was estimated to be 87 percent. It should be noted that ground cover varied greatly for different Forest Practice Districts. In the Coast District, higher moisture levels create more leaf fall and forb cover—resulting in very high ground cover, while in the drier inland districts, bare soil is common in WLPZs even without logging disturbances. Canopy cover was estimated with the spherical densiometer (1996 without modification, 1997-98 with the Strickler (1959) modification to reduce bias). Mean canopy was found to be above 70% in all cases (Table 24).[14] Canopy estimates are for total canopy in all cases (not overstory or understory, as is specified for Class I watercourses).

Table 23. Mean WLPZ width estimates.

Watercourse Class	Side Slope Gradient Category (%)	Mean WLPZ Width (ft)	Standard Forest Practice Rule (ft)
I	<30	80	75
	30-50	100	100
	>=50	115	100-150[15]
II	<30	55	50
	30-50	75	75
	>=50	90	75-100

Table 24. Mean WLPZ canopy estimates.

Watercourse Class	Year/Location	Canopy (%)
I	1996 (North Coast)	79
I	1997-1998 (statewide)	74
II	1996 (North Coast)	77
II	1997-1998 (statewide)	75

[14] Robards et al. (1999) have reported that the spherical densiometer produces a biased estimate of canopy and recommend the use of the sighting tube to reduce bias. In a field test conducted on Jackson Demonstration State Forest, the range of densiometer estimates was reported to be from 20% low to 10% high compared to actual canopy closure. In 1999, the Hillslope Monitoring Program will use the sighting tube for estimating canopy cover.

[15] 50 foot and 25 foot reductions in WLPZ width are allowed with cable yarding for Class I and II watercourses, respectively.

Large Erosion Events

Large erosion events were identified when traveling within the THP; as part of the evaluations for randomly located road segments, skid trail segments, landings, crossings, and WLPZs; or from information provided by landowners. The type, size, location, and cause of the large erosion event were described. This work was completed only for the statewide survey completed in 1997-1998 (not for the 1996 work in Mendocino and Humboldt Counties). For the 100 THPs included for this evaluation, a total of 35 large events were documented. Of these, 27 were related to current timber management activities (Table 25). Nearly all the shallow debris slides described were found in the Coast Forest Practice District, as were half of the deep seated rotational failures. Six of the ten catastrophic crossing failures were from the Southern Forest Practice District, largely due to the very large rain-on-snow event which occurred in January 1997 (100-yr+ in many Sierran watersheds). Large erosion events were located on 24 of the 100 THPs, with seven THPs having multiple large erosion events.

Mean erosion volumes for the various types of features related to current management activities are as follows: deep seated rotational (3,600 yd^3), shallow debris slide (3,700 yd^3), catastrophic crossing failure (200 yd^3), and streambank failure (600 yd^3). Most of the large erosion events were related to roads (24), with smaller numbers associated with landings (2) and skid trails (3). Eight of the features were judged to be unrelated to current management activities.[16] General cause code and associated feature type are displayed in Figure 6. Specific causes associated with the large erosion events are displayed in Table 26. The most frequent causes associated with large erosion events were: cutbanks with slope support removed; culverts with the inlet plugged; fill slopes with overloaded, deep sidecast; fill slopes with poorly compacted material; and surface water concentration.

[16] Note that multiple causes were assigned in some instances, so the total is greater than the total number of large erosion events.

Table 25. Frequency distribution of large erosion events related to current management activities that were encountered on THPs evaluated from 1997-1998.

Type	Coast	Northern	Southern	Total
Deep seated rotational	3	2	1	6
Shallow debris slide	9	1	0	10
Catastrophic crossing failure	1	3	6	10
Streambank failure	0	0	1	1
Total	**13**	**6**	**8**	**27**

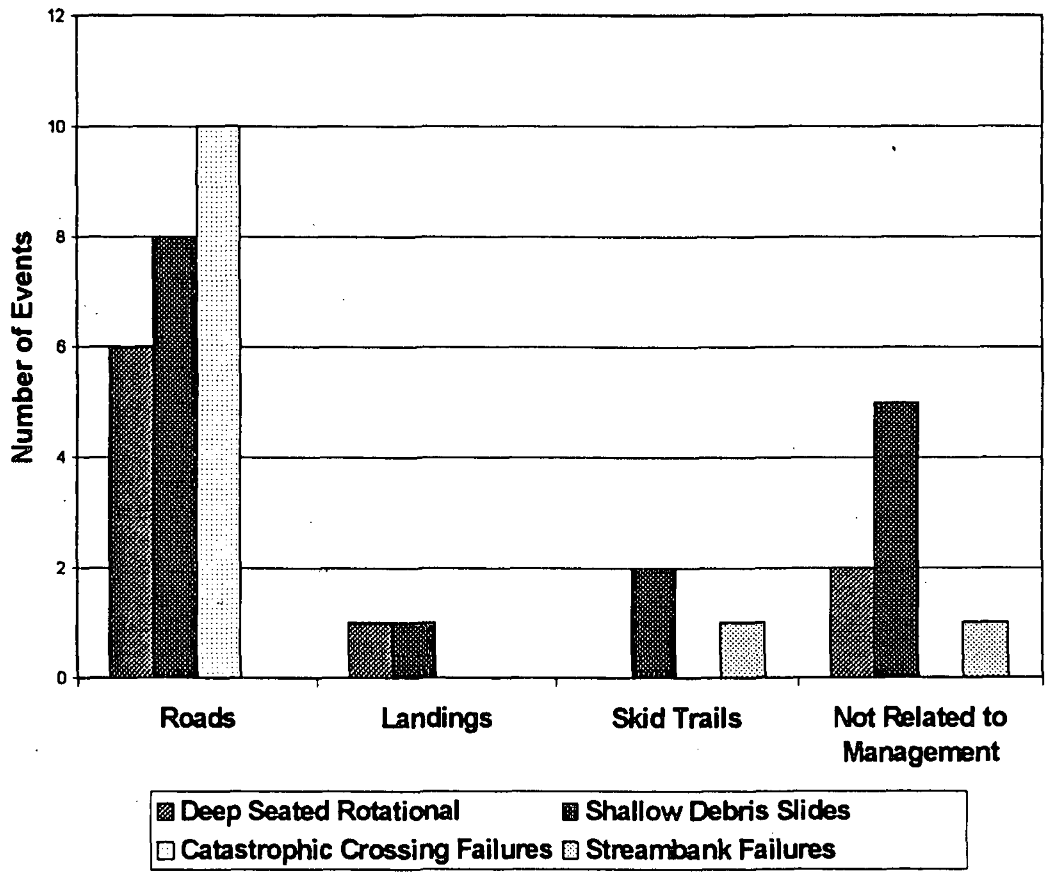

Figure 7. Causes of large erosion events and type of feature.

Table 26. Specific management related causes associated with large erosion events.

Type	Cause of Feature	Count
Roads		
	Waterbars-discharge onto erodible material	1
	Waterbars-improperly constructed or located	2
	Fill slopes-too steep	2
	Fill slopes-overloaded, deep sidecast	4
	Fill slopes-poorly compacted	4
	Fill slopes-excessive organic material	1
	Surface water concentration	4
	Culverts too small	2
	Culverts-discharge onto erodible material	1
	Culverts-inlet plugged	4
	Inside ditch-ditch blocked and/or diverted	1
	Inside ditch-other drainage onto road no handled	2
	Cutbanks- too steep	1
	Cutbanks-slope support removed	7
	Subsurface flow alteration	1
Skid Trails		
	Waterbars-not properly draining area	1
	Cutbanks-too steep	1
	Cutbanks-slope support removed	2
	Surface water concentration-rilling and gullying	1
	Surface water concentration-discharge on erodible material	1
Landings		
	Cutbanks-too steep	1
	Cutbanks-slope support removed	1
	Fill slopes-excessive organic material	1

DISCUSSION AND CONCLUSIONS

The data that has been collected to date as part of the Hillslope Monitoring Program point toward several preliminary conclusions. This is an on-going program, and additional information and more detailed queries will be available for future reports. Therefore, it is still too early to arrive at final conclusions. Further, this work has evaluated the implementation and effectiveness of selected **standard** Forest Practice Rules that can be evaluated in the field (not alternative or in-lieu practices). It also did not evaluate the THP "review process" or the degree to which this process contributes to observed water quality problems (Lee 1997). Finally, it is important to note that only THPs have been evaluated, not Exemptions, Emergency Notices, Conversions, or Non-industrial Timber Management Plans (NTMPs).

The following preliminary conclusions are based on data collected to date for the implementation and effectiveness of standard Forest Practice Rules related to water quality that could be evaluated in the field at selected sites (i.e., roads, landings, skid trails, crossings and WLPZs) on 150 THPs:

1. **Erosion problem points noted for roads, skid trails, landings, crossings, and WLPZs were almost always associated with improperly implemented Forest Practice Rules.**

The data collected to date suggests that the vast majority of erosion problem points were caused by minor or major departures from specific Forest Practice Rule requirements. Nearly all the problem points were judged to result from non-compliance. For example on the road transects, only about three percent of the implementation ratings assigned at erosion features were for situations where the Rule requirements were judged to have been met or exceeded.

The Forest Practice Rules and individual THP requirements (i.e., site-specific mitigation measures developed through recommendations of interagency Review Teams) were generally found to be sufficient to prevent hillslope erosion features when properly implemented on the ground by Licensed Timber Operators (LTOs).[17] To improve implementation, new training programs for LTOs and their employees should be encouraged, and these programs should include a field component.

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[17] Rice and Datzman (1981) previously reported that operator performance may equal site characteristics as a source of variation in logging related erosion.

2. **Roads and their associated crossings were found to have the greatest potential for delivery of sediment to watercourses. Implementation of Forest Practice Rules that specify drainage structure design, construction and maintenance need improvement.**

More than 80% of the road transects evaluated from 1996 through 1998 were seasonal roads, and less than 30% of the sampled road mileage was surfaced with rock. Overall, 36 Rule requirements for roads and crossings were found to have more than 5% minor and major departures, considerably more than that found for landings, skid trails and WLPZs. The Forest Practice Rules with the highest departures from stated road requirements were related to waterbreak spacing, maintenance, and construction standards; adequate number, size, and location of drainage structures; prevention of discharge onto erodible fill; and sidecast limitations on steep slopes. Erosion problem points were noted, on average, approximately every 400 feet. Rilling was common, but had low sediment delivery to channels; mass failures were noted much less frequently but had high sediment delivery. Rilling and gullying were primarily caused by drainage feature problems, while mass failures were most commonly associated with unstable fill material.

In most types of terranes, earlier studies have reported that roads produce 75-95% of the erosion related to timber operations (Rice 1989). Based on the data collected to date as part of this program, these estimates still seem reasonable in the late 1990's.[18] The data suggests that there is considerable room for improvement in road design and construction—particularly regarding fill slopes, cutslopes, and crossings (see No. 4 below). As documented by Lewis and Rice (1989) as part of the Critical Sites Erosion Study, site factors overwhelm management impacts in most terranes. Therefore, *where* roads are built will remain critical for reducing the likelihood of producing significant sediment input to channels.

3. **Mass failures related to current timber operations are most closely associated with roads and produce the highest sediment delivery to watercourse channels when compared to other erosional processes.**

Data from 100 THPs shows that about one-quarter of the plans had large erosion features. More than 80% of the large erosion events that were documented as part of the statewide survey were associated with roads and crossings. Estimates from the randomly located road transects revealed that about 50% of the mass failures delivered material to stream channels—much higher than the

[18] Exceptions include landscapes that are highly unstable and have significant components of erosion resulting from inner gorge landsliding, such as have been found in portions of southern Humboldt County (PWA 1998).

average sediment delivery associated with sloughing, rilling, and gullying. The majority of the mass failures were associated with fill slopes, with cutbank and culvert problems also commonly noted. The data from both the large erosion event record and the randomly located road transects suggests that RPFs must locate and design, and LTOs must construct, drain, and maintain roads in a manner that will reduce the frequency of mass failure events.

4. Numerous problems were noted at watercourse crossings. Implementation of Forest Practice Rules that specify design, construction, and maintenance of crossings require considerable improvement.

Conclusions about watercourse crossings are based on a sample with 95% of the crossings in Class II or III watercourses. Very few Class I crossings were reviewed, because the random selection of crossings was tied to road transects and roads that were commonly located high on hillslopes. Only 15% of the crossings evaluated had been removed or abandoned, so the sample sizes for these types of crossings is still relatively small. The data collected to date shows that problem points at watercourse crossings are a major source of sediment delivered to watercourses. Because crossings are adjacent to and within channels, eroded material has direct access to the watercourses. Approximately 40% of the crossings had one or more problems, while more than 60% had none, indicating that they were functioning properly. Common problems included fill slope gullies, plugging, scour at the outlet, and high diversion potential. Although not readily derived from the database, the field crew members observed that where a well designed and constructed crossing was encountered in a THP being reviewed, the other crossings in the plan were usually also well constructed. These data indicate that more attention is needed with the design, construction, and review of crossings. Recent research has provided RPFs and Licensed Timber Operators new information on how to build better crossings (Flanagan et al. 1998).

5. Watercourse and lake protection zones (WLPZs) have been found to generally meet Forest Practice Rule requirements for width, canopy, and ground cover. Additionally, very few erosion features associated with current THPs were recorded in WLPZs.

Approximately three-quarters of the WLPZs evaluated to date have been on Class II watercourses, which are much more common than the generally larger Class I waters. The data collected in WLPZs indicates that minimum canopy requirements following harvesting on Class I and II watercourses are being exceeded, since an average of greater than 70% canopy cover following harvesting has been measured using the spherical densiometer. Similarly, mean ground cover requirements in WLPZs following logging was estimated to exceed 85%. Required WLPZ widths generally met Rule requirements, with major departures from Rule requirements noted only about 1% of the time. Erosion events originating from current THPs and encountered on mid-zone or streambank WLPZ transects were found to be rare. The implementation data suggests that RPFs should do a better job of taking existing roads and erodible, unstable stream banks into account when designing WLPZs and specifying protection measures.

6. Landings did not have substantial numbers of erosion events associated with current operations and erosion events on landings generally did not transport sediment to watercourses.

More than half of the randomly selected landings were greater than 300 feet from the nearest watercourse (I, II, III, or IV), almost 90% were built on slopes less than 45%, and more than 80% were built on a ridge or above the break in slope. These factors indicate why landings generally did not create significant water quality problems and why very few erosion events transported sediment from landings, with the exception of landings located very near watercourses (generally old landings built for previous entries). Drainage structures associated with landings were cited as needing improvement about 10% of the time, but most of the Rule requirement implementation ratings were for minor departures, indicating that direct adverse impacts to water quality were infrequent.

7. Skid trail segments had a lower frequency of erosion features related to current operations when compared to road segments. Overall, skid trails are having much less impact to water quality than roads.

The frequency of erosion problems noted on skid trail transects was fairly low when compared to problems documented on roads. For example, problem points assigned to waterbreaks that did not conform to the Rule requirements on skid trails occurred at about half the rate as on road transects (i.e., 4% vs. 9%). The overall average was one erosion problem point assigned for every 1,175 feet of skid trail evaluated, verses one problem every 380 feet for roads. Rills were noted fairly frequently on skid trails but had very low delivery to watercourse channels. Gullies were noted with about one-third the frequency of rills, but had a higher percentage of sediment delivery to watercourse channels. Spacing of waterbreaks was the most commonly cited drainage feature problem associated with skid trail rilling and gullying.

8. **Recent timber operations cannot be linked to current instream channel conditions based on results from the Hillslope Monitoring Program.**

This program has evaluated Forest Practice Rule effectiveness on hillslopes—not in the stream channels. This type of monitoring can provide a rapid feedback loop to managers for improving hillslope practices. It does not, however, address current instream channel conditions which are often the result of land use impacts that took place decades ago. Instream measurements can be difficult to relate to individual forest practices (Murphy 1995). In addition, results presented in this interim report do not allow us to draw conclusions about whether the existing Rules are providing properly functioning habitat for aquatic species because evaluating the biological significance of the current Rules is not part of this project. For example, hillslope monitoring in WLPZs does not allow us to draw conclusions regarding whether canopy levels resulted in acceptable water temperatures for anadromous fish, or whether the observed timber operations retained an adequate number of mature trees for large woody debris recruitment that is needed to create complex habitats for anadromous fish species. Also, the adequacy of the Rules in addressing cumulative watershed effects are not covered by this program.[19]

GENERAL OBSERVATIONS

The findings of this interim report mirror those of the "208 Team" (SWRCB 1987), where it was reported that: (1) the standard Rules generally appeared to provide adequate water quality protection when they were properly implemented, and (2) poor Rule implementation was the most common cause of observed water quality impacts. More than 95% of the Forest Practice Rules associated with erosion problem points encountered from 1996 through 1998 were rated as having either minor or major departures from Rule requirements. This indicates that the Rules are generally effective in preventing erosion events when properly implemented. In a nation-wide survey on monitoring, Brown and Binkley (1994) reported that forest practices can protect water quality if prescriptions are carefully developed and implemented.

The Forest Practice Rules listed in Table 27 have been identified as having the highest percentages of total departures from Rule requirements and should be made known to RPFs, LTOs and their employees, and to CDF Forest Practice Inspectors. They need to be made aware of which Rules are not being

[19] The adequacy of the Forest Practice Rules addressing cumulative watershed effects is currently being reviewed by several scientific and agency task forces, with final reports expected during the summer of 1999.

implemented well in the field, and these groups should be targeted for intense training efforts.

Much remains to be learned about Forest Practice Rule implementation and effectiveness. Many of the Forest Practice Rules have not been adequately tested to date because the situations in which they apply are very limited. The continued long-term collection of hillslope data will enable the performance of these Rules to be adequately reviewed. Similarly, many situations have yet to be fully studied as part of the Hillslope Monitoring Program. For example, protection of Class III watercourses has yet to be addressed. Class III protection was noted as one of three areas of Rule requirements where concerns were expressed over both implementation and effectiveness by resource professionals in a survey of watercourse and lake protection zone protection measures (CDF 1995).[20] Similarly, impacts to hillslopes that have been cable yarded have not been included in the program (other than documenting large erosion events where encountered). The evaluation of non-standard practices (in-lieu and alternative practices) will also require considerably more work before conclusions can be made whether these practices provide the same level of protection as the standard Rules.[21]

The Hillslope Monitoring Program can be improved in several areas. Only a small amount of quality assurance/quality (QA/QC) control work has been completed to date to test the repeatability of the data reported.[22] CDF conducted very limited QA/QC work for canopy measurements in 1996 and found that the canopy measurements reported by the contractors was approximately 7% higher than that estimated internally. Transects established on 10 THPs from the 1997 THPs have been remeasured but that data has yet to be compared to the original data.- Recent CDF staff additions will allow improved QA/QC work in the future. In addition, CDF has yet to implement a program to resample a certain percentage of THPs to monitor impacts from strong stressing storms. This work would be particularly important on those THPs which had not been tested by large storm events during the overwintering periods prior to the first THP

[20] The other two areas were winter operations and restorable uses of water.

[21] The SWRCB (1987) report stated that the use of non-standard practices frequently resulted in less protection than would have been provided by standard practices.

[22] Even though little work has been completed to test repeatability, the data presented in this report was collected with a high degree of consistency, since R.J. Poff and Associates evaluated 125 out of 150 THPs.

evaluation.[23] There are plans to begin this type of expanded hillslope monitoring program in the near future.

Table 27. Forest Practice Rule requirements with at least 10% total departures based on at least 30 observations where implementation could be rated (note this table was developed from Tables 4, 11, 15, 18, and 21).

Location	Rule No.	Description
Roads/ skid trails	914.6(c)	Waterbreak spacing equals standards
Roads/ landings	923.1(f)	Adequate numbers of drainage facilities
Roads	923.2(b)	Sidecast minimized for slopes > 65% for distances > 100 ft
Roads	923.1(d)	For slopes >65% or 50% within 100 ft of WLPZ, soil treated to minimize erosion
Roads/ crossings	923.2(h)	Drainage structures of sufficient size, number and location to minimize erosion, carry runoff water
Roads/ crossings	923.2(o)	No discharge onto erodible fill unless energy dissipators are used
Roads	914.6(g)	Waterbreaks have an embankment of at least 6 inches
Roads/ crossings	923.4(c)	Waterbreaks maintained to divert into cover
Roads	923.2(h)	Drainage structures of sufficient size, number and location to minimize erosion
Roads	914.6(f)	Waterbreaks installed to discharge into cover
Roads/ landings	923.1(a)	If landing on road >1/4 ac or required substantial excavation, --shown on THP map
Roads	914.6(g)	Waterbreaks constructed with a depth of at least 6 inches cut into firm roadbed
Roads	923.2(p)	Waterbreaks installed according to standards in 914.6
Skid trails	914.6(f)	Where waterbreaks cannot disperse runoff, other erosion controls installed as needed
WLPZ	916.4(a)	Sensitive conditions—erodible banks identified in THP
Crossings	923.3(d)(1)	Removed fills excavated to reform channel
Crossings	923.8	Abandonment—minimizes concentration of runoff water
Crossings	923.2(d)	Fills across channels built to minimize erosion
Crossings	923.4(1)	Trash racks installed where abundant LWD
Crossings	923.8(d)	Abandonment-pulling/shaping of fills
Crossings	923.4(n)	Crossings/approaches maintained to avoid diversion
Crossings	923.3(d)(2)	Removed crossings-cut bank sloped back to prevent slumping
Crossings	923.4(d)	Crossing open to unrestricted passage of water
Crossings	923.4(d)	Trash racks installed where needed at inlets
Crossings	923.3(e)	Crossings/fills built to prevent diversion

[23] Lewis and Baldwin (1997) suggest that stressing storm events need to be defined and effectiveness should only be evaluated after stressing events have occurred. Some measure of the magnitude of the stressing events should be included in the analysis.

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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 (CFPR 895.1).

Beneficial uses of water - According to the Porter-Cologne Water Quality Control Act, the 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 the following: 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, and estimated from 1996 through1998 for this project with a spherical densiometer. 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 (CFPR 895.1).

Cutbank/sidecast sloughing - Shallow surficial sliding associated with either the cutbank of fill material of a forest road, with smaller dimensions than would be associated with mass failures.

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

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

Large erosion event - For hillslope mass failures, these events are 100 cubic yards for a void left on a hillslope; for catastrophic crossing failures, these events are defined as at least 10 cubic yards.

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

Minor/major departure – Major departures were assigned when sediment was delivered to watercourses, or when there was a substantial departure from Rule requirements (e.g., no or few waterbars installed for 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 (CFPR 895.1).

Problem point - In Hillslope Monitoring Program, the occurrence of: (a) rilling, gullying, mass failures, or cutbank/sidecast sloughing found along landings, roads, skid trails, watercourse crossings, or WLPZs and (b) canopy reduction, streambank erosion, or ground cover reduction in a WLPZ. Problem points also include Forest Practice Rule violations (e.g., waterbreak improperly constructed) (Lee 1997).

Process - The process by which the Rules/BMPs are administered and implemented, including: (a) the process elements for THP preparation, information content, review and approval by RPFs, Review Team agencies, and CDF decision-makers, and (b) the process elements for timber operation conduct, inspection, and completion by LTOs 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).

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 (CFPR 895.1).

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 (CFPR 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 (CFPR 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 therefrom. Waterbreaks are synonymous with waterbars (CFPR 895.1).

Appendix[24]

[24] For Tables A-1, A-2, A-3, A-5, and A-7, the columns are defined as follows: (1) Forest Practice Rule number, (2) brief description of Forest Practice Rule, (3) total number of times the Rule was rated for implementation following evaluation of the entire transect/feature, (4) total number of times implementation rating was either exceeded Rule requirements, met Rule requirements, minor departure from Rule requirements, or major departure from Rule requirements, (5) number of implementation ratings for both exceeded Rule requirements and met Rule requirements divided by column no. 4 and multiplied by 100, (6) number of implementation ratings for minor departure of Rule requirements divided by column no. 4 and multiplied by 100, and (7) number of implementation ratings for major departure of Rule requirements divided by column no. 4 and multiplied by 100.

Table A-1. Roads—implementation ratings for transects as a whole.

Rule No.	Description	Number of Observations	Number of Observations (1-4)	% Meets or Exceeds FPR	% Minor Departure	% Major Departure
923(d)	Road located to avoid bottoms of steep canyons	287	255	98.8	1.2	0
923(d)	Road located to avoid marshes/wet areas	289	209	98.1	1.9	0
923(d)	Road located to avoid unstable areas	289	180	96.1	3.9	0
923(d)	Road located to avoid watercourses	288	268	98.5	1.1	0.4
923.4(i)	Soil stabilization on cuts, fills, sidecast	287	185	95.7	3.8	0.5
923.6	Wet spots rocked or otherwise treated	288	134	93.3	6.7	0.0
923.1(a)	if landing on road >1/4ac, shown on THP map	288	124	87.9	7.3	4.8
1038(b)(5)	Permitted activities-new road construction/reconstr.	288	2	100.0	0.0	0.0
923.4(j)	Drainage ditches maintained to allow flow of water	288	192	92.7	7.3	0.0
914.6(f)	Waterbreaks built to discharge into cover	289	228	87.7	12.3	0.0
914.6(f)	Waterbreaks built to spread water to min. erosion	288	226	97.8	2.2	0.0
914.6(g)	Waterbreaks constructed diagonally	288	220	98.2	1.8	0.0
914.6(g)	Waterbreaks cut to depths of at least 6 inches	288	218	88.1	11.0	0.9
914.6(g)	Waterbreaks have embankment of at least 6 inches	287	215	86.5	12.1	1.4
923(c)	Road planned to fit topography, minimize disturbance	288	287	98.6	1.4	0.0
923(e)	Road located to minimize number of crossings	288	283	99.3	0.7	0.0
923(f)	Road located on benches/flatter slopes, stable soils	288	286	96.2	3.8	0.0
923(g)	Excavation or placement of fills on unstable soils	288	195	97.9	2.1	0.0
923.1(a)	Road shown on THP map correctly	288	286	94.1	5.6	0.3
923.1(a)	if road reconstructed--failures shown on THP map	289	81	96.3	3.7	0.0
923.1(e)	if new, grade> 15% or 20% less than 500 ft	288	77	100.0	0.0	0.0
923.1(f)	Adequate #s of drainage structures to min. erosion	292	288	80.2	16.7	3.1
923.1(g)	Road width appropriated for yarding system used	288	282	99.6	0.4	0.0
923.2(d)C	Fills constructed with insloping approaches, etc	288	82	92.7	6.1	1.2
923.2(d)N	Breaks in grade above/below throughfill	288	100	93.0	7.0	0.0
923.2(g)	Excess material stabilized so as avoid impact	288	263	98.5	0.8	0.8
923.2(h)	Size, #, location of structures okay to carry runoff water	288	281	82.9	13.9	3.2

923.2(h)	Size, #, location of structures sufficient to min. erosion	290	285	83.2	14.4	2.5
923.2(l)	Trees with >25% roots exposed by construction cut	288	269	98.9	0.7	0.4
923.2(m)	Sidecast extending>20 ft treated to avoid erosion	288	76	94.7	2.6	2.6
923.2(o)	Discharge onto erodible fill prevented	289	259	87.6	10.4	1.9
923.2(v)	Construction in WLPZ limited to crossings	288	106	100.0	0.0	0.0
923.4(c)	Waterbreaks maintained to minimize erosion	291	221	80.5	16.7	2.7
923.4(c)	Erosion controls maintained during maintenance period	288	102	94.1	5.9	0.0
923.4(f)	drainage structures removed if not sized for 50-yr flow	288	111	98.2	1.8	0.0
923.4(m)	inlet/outlet structures/add. Structures been maintained	289	202	95.5	4.5	0.0
923.8(a)	abandoned roads-blockage of road completed	288	4	50.0	50.0	0.0
923.8(b)	abandoned roads-stabilization of exposed soil	288	4	100.0	0.0	0.0
923.8(d)	abandoned roads-pulling or shaping of fills/sidecast	288	3	66.7	33.3	0.0
923.8(e)	removed crossing-fills excavated to form appropriate channel	288	4	75.0	25.0	0.0
923.8(e)	removed crossing-excavated material sloped back	288	4	100.0	0.0	0.0
923.8(e)	if removal of crossing not feasible, diversion pot. Handled	287	2	100.0	0.0	0.0
1038(b)(2)	permitted activities-new tractor roads on slopes>40%	288	1	100.0	0.0	0.0
914.6(c)	waterbreak spacing according to standards in 914.6(c)	288	224	77.2	20.1	2.7
914.6(f)	waterbreaks built to provide unrestricted discharge	288	226	98.7	0.9	0.4
914.6(f)	where waterbreaks don't work--other erosion controls	287	115	92.2	7.0	0.9
923.1(d)	slopes >65%, 50% within 100 ft of WLPZ-treat soil	288	49	89.8	8.2	2.0
923.1(g)(3)	insloped roads-adequate number of ditch drains	288	141	95.7	4.3	0.0
923.2(b)	sidecast minimized for slopes >65% distance >100 ft	289	30	83.3	16.7	0.0
923.2(h)	size, #, location of structures-natural drainage pattern	289	272	98.5	1.5	0.0
923.2(l)	trash racks, etc installed where appropriate	289	71	94.4	5.6	0.0
923.2(k)	road without overhanging banks	288	270	99.3	0.7	0.0
923.2(u)	slash placed to avoid discharge to Class I/II	288	223	100.0	0.0	0.0
923.4(e)	roadside berms removed or breached	288	248	98.0	2.0	0.0
923.4(g)	temporary roads blocked before winter period	288	17	64.7	29.4	5.9
923.8(c)	abandonment-shaping to allow dispersal of water	288	4	100.0	0.0	0.0

923.8	abandonment-allows permanent drainage	288	4	75.0	25.0	0.0
923.8	abandonment-minimizes concentration of runoff	287	4	50.0	50.0	0.0
923.2(p)	waterbars installed according to 914.6	287	191	89.5	9.4	1.0

Table A-2. Skid Trails--implementation ratings for transects as a whole.

Rule No.	Description	Number of Observations	Number of Observations (1-4)	% Meets or Exceeds FPR	% Minor Departure	% Major Departure
1038(b)(9)	permitted acts--cutting in WLPZ	240	2	100.0	0.0	0.0
1038(b)(4)	permitted acts--ops on slides, etc.	240	2	100.0	0.0	0.0
1038(b)(6)	permitted acts--ops in WLPZs	240	2	50.0	0.0	50.0
1038, 1038.1	permitted acts--ops comply with FPRs	240	2	100.0	0.0	0.0
914.1(a)	trees felled away from watercourses	243	188	99.5	0.5	0.0
914.2(f)(1)	tractor ops avoided slopes >65%	240	133	100.0	0.0	0.0
914.2(f)(2)	ops avoided slopes>50% above I/II	240	97	99.0	1.0	0.0
914.2(f)(3)	ops avoided slopes>50% high, extreme	241	55	100.0	0.0	0.0
914.3 Coast	ops avoided cable yarding areas	240	34	97.1	2.9	0.0
914.6(f)	waterbreaks allow discharge into cover	240	229	97.8	1.7	0.4
914.6(f)	waterbreaks spread water to min erosion	240	229	96.9	2.2	0.9
914.6(f)	if waterbreaks don't work, other structures	240	76	76.3	19.7	3.9
914.6(g)	waterbars placed diagonally	240	229	98.3	1.3	0.4
1038(b)(1)	permitted acts--ops on slopes>50%	240	3	100.0	0.0	0.0
1038(b)(2)	permitted acts--new trails >40%	239	3	100.0	0.0	0.0
914.2(c)	tractor roads minimized-#, width	240	237	96.2	3.4	0.4
914.2(d)	tractor ops avoided unstable soils	240	160	99.4	0.6	0.0
914.2(e)	slash/debris placed to avoid class I or II	240	215	99.5	0.5	0.0
914.6(c)	waterbreak spacing = standards	241	236	84.3	11.0	4.7
914.6(c)	waterbreaks--100 ft intervals cable roads	241	127	95.3	2.4	2.4
914.6(e)	waterbreaks for natural channels	239	108	95.4	1.9	2.8
914.6(f)	waterbreaks -unrestricted discharge	240	229	97.8	1.7	0.4
914.6(g)	waterbreaks cut to minimum depth 6 in.	240	228	97.8	2.2	0.0
914.6(g)	waterbreaks have embankment of 6 in	239	227	96.9	2.6	0.4
914.7(c)(3)	appropriate ops for winter period	240	3	100.0	0.0	0.0
923.4(c)	waterbreaks maintained to divert water	240	225	92.4	7.1	0.4

Table A-3. Landings--implementation ratings for landings as a whole.

Rule No.	Description	Number of Observations	Number of Observations (1-4)	% Meets or Exceeds FPR	% Minor Departure	% Major Departure
923(g)	Minimize cut/fill on unstable areas	290	206	98.1	1.5	0.5
923.1(a)	>1/4ac, substantial excavation-shown on THP map	291	118	83.1	11.0	5.9
923.1(d)	Slopes>65% or 50% within 100ft-treat	288	14	92.9	7.1	0.0
923.1(f)	Adequate #s of drainage structures	288	267	89.5	9.0	1.5
923.5(a)	New--slopes>65%, sidecast minimized	288	4	75.0	25.0	0.0
923.5(f)(2,4)	Fill extending 20ft with access--treated	289	47	91.5	8.5	0.0
923.5(f)(5)	Fill removed—channel refomed correctly	288	3	100.0	0.0	0.0
923.6	Wet spots been rocked/treated	288	46	93.5	6.5	0.0
923.8(a)	Abandonment--blocked to vehicles	287	5	100.0	0.0	0.0
923.8(b)	Abandonment--stabilization of cuts/fills	287	5	100.0	0.0	0.0
923.8(e)	Abandonment--proper channel formed	287	2	100.0	0.0	0.0
923.8(e)	Abandonment--cut banks sloped back	287	2	100.0	0.0	0.0
923.8(e)	Where fill removal infeasible-overflow channel	287	1	100.0	0.0	0.0
923.8	Abandonment-min. concentration of runoff	288	5	60.0	40.0	0.0
923.5(d)	Min. size consistent with yarding system	289	288	95.5	4.5	0.0
923.5(f)(1)	Slopes>65% or 50% within 100ft-treat edge	288	13	92.3	7.7	0.0
923.5(f)(2)	Ditches clear of obstructions	287	172	95.3	4.7	0.0
923.5(f)(3)	Sloped/ditched to prevent erosion	288	271	95.6	4.1	0.4
923.5(f)(5)	Sidecast/fill across watercourse pulled	288	2	100.0	0.0	0.0
923.5(f)(5)	Fill removed—cut banks sloped back	288	3	66.7	33.3	0.0
923.8(c)	Abandonment--grading for water dispersal	287	5	60.0	40.0	0.0
923.8(d)	Abandonment--fill pulled to prevent discharge	287	4	75.0	25.0	0.0
923.8	Abandonment--maintenance free drainage	288	5	100.0	0.0	0.0

Table A-4. Landings--effectiveness ratings.

Surface Rilling and Gullying	Effectiveness Category Percent	Effectiveness Category
a. Rilling on Landing Surface	56.1	None
	43.2	<1 rill/100 ft (0-20%)
	0.7	>1 rill/20 ft (>20%)
b. Gullies on Landing Surface	66.2	None
	32.7	< 1 gully per 100 ft transect
	1.1	Some gullying (< 1 gully per 20 ft of transect)
	0	Gullying that exceeds 1 gully per 20 ft of transect
Surface Drainage		
a. Drainage Runoff Structure	72.1	No evidence of erosion from concentrated flow where drainage leaves landing surface
	22.5	Rills or gullies present but do not extend >20 ft below edge of landing
	5.4	Presence of rills or gullies which extend >20 ft below edge of landing
b. Sediment Movement	93.6	No evidence of transport to WLPZ
	4.9	Sediment transport in WLPZ but not to channel
	1.5	Evidence of sediment transport or deposition in channel
Landing Cut Slopes		
a. Rilling	90.7	No evidence of rills
	6.6	Rills present but do not extend to drainage structure or ditch
	2.7	Rills present and extend to drainage structure of ditch

b. Gullies	97.3	No evidence of gullies
	0.5	Gullies present but do not extend to drainage structure or ditch
	2.2	Gullies present and extend to drainage structure or ditch
c. Failures	92.2	Less than 1 cubic yard of material moved
	6.1	More than 1 cubic yard moved but it is not transported to drainage structure or ditch
	1.7	More than 1 cubic yard moved, some material transported to drainage structure or ditch
Landing Fill Slopes		
a. Rilling	86.2	No evidence of rills
	13.4	Rills present but do not extend to drainage channels below toe of fill
	0.4	Rills present and extend to drainage channel below toe of fill
b. Gullies	88.5	No evidence of gullies
	10.6	Gullies present, but do not extend to drainage channels below toe of fill
	0.9	Gullies present and extend greater than a slope length below toe of fill
c. Slope Failures	94	No material moved
	4.6	Less than 1 cubic yard moved
	0.9	More than 1 cubic yard moved but does not enter channel
	0.5	More than 1 cubic yard moved, some material enters channel
d. Sediment Movement	94.9	No evidence of transport
	3.2	Sediment deposition in WLPZ but not carried to channel
	1.9	Evidence of sediment transport to or deposition in channel

Table A-5. Crossings--implementation ratings for crossings as a whole.

Rule No.	Description	Number of Observations	Number of Observations (1-4)	% Meets or Exceeds FPR	% Minor Departure	% Major Departure
923.4(d)	trash racks installed where needed at inlets	249	30	86.7	6.7	6.7
914.8(d)	tractor crossing--cut bank sloped back from channel	249	14	100.0	0.0	0.0
923.3(c)	restricted passage of fish allowed	249	10	60.0	30.0	10.0
923.4(1)	trash racks installed where lots of LWD	249	39	82.1	12.8	5.1
923.4(f)	50-year flood flow requirement	255	187	95.2	3.7	1.1
923.8(c)	abandonment--grading of road for dispersal	249	29	93.1	3.4	3.4
923.8(d)	abandonment--pulling/shaping of fills	249	30	83.3	6.7	10.0
923.8(e)	abandonment--fills excavated to reform channel	249	28	92.9	3.6	3.6
923.8	abandonment—minimize concentration of runoff	249	31	80.6	12.9	6.5
914.8(d)	tractor crossing--fills removed to reform channel	250	14	92.9	7.1	0.0
923.2(d)	fills across channels built to minimize erosion	164	120	82.5	10.8	6.7
923.2(e)	throughfills built in one-foot lifts	165	12	83.3	8.3	8.3
923.2(h)	size, #, location of structures okay to carry runoff	164	155	95.5	1.3	3.2
923.2(h)	size, #, location of structures minimizes erosion	164	155	87.7	6.5	5.8
923.2(h)	size,#,location of structures-nat.drainage pattern	164	155	96.8	2.6	0.6
923.2(o)	no discharge on fill unless energy dissipators	165	155	79.4	13.5	7.1
923.3(d)(1)	removed--are fills excavated to reform channel	249	31	80.6	16.1	3.2
923.3(d)(2)	removed--cut bank sloped back to stop slumping	249	31	83.9	9.7	6.5
923.3(e)	crossing/fills built to prevent diversion	249	206	85.9	10.7	3.4
923.4(c)	waterbreaks maintained to divert into cover	163	132	86.4	12.9	0.8
923.4(d)	crossing open to unrestricted passage of water	249	238	87.0	9.7	3.4
923.4(n)	crossing/approaches maintained to avoid diversion	249	205	83.4	14.1	2.4
923.4	trash racks in place as specified in THP	250	33	93.9	6.1	0.0
923.8(b)	abandonment--stabilization of exposed cuts/fills	249	29	82.8	10.3	6.9
923.8(e)	abandonment--cutbanks sloped back	249	28	92.9	0.0	7.1
923.8(e)	removal not feasible--diversion potential handled	247	9	88.9	0.0	11.1
923.8	abandonment--maintenance free drainage	249	31	96.8	0.0	3.2

Table A-6. Crossings--effectiveness ratings.

Fill Slopes at Crossings	Effectiveness Category Percent	Effectiveness Category
a. Vegetative Cover	68.1	Vigorous dense cover or fill slope of stable material
	23.6	Less than full cover, but >50% if fill slope has effective cover
	8.3	<50% of fill slope has effective cover
b. Rilling	78.6	Rills may be evident, infrequent, stable and no evidence of sediment delivery
	13.5	Few rills present (<1 rill per lineal 5 ft) not enlarging with little apparent deposition
	7.9	Numerous rills present (>1 rill per lineal 5 ft) enlarging or with evidence of delivery to channel
c. Gullies	86.9	None
	7.1	Gullies present, not enlarging, little apparent deposition in channel
	6	Gullies present and enlarging or threatening integrity of fill
d. Cracks	89.2	None evident
	8	Cracks present, but appear to be stabilized
	2.8	Cracks present and widening, threatening integrity of fill
e. Slope Failure	61.4	None
	32.1	Less than 1 cubic yard of material
	2.8	>1 cubic yard of material
	3.7	>1 cubic yard moved and material enters stream
Road Surface Draining to Crossings		
a. Rutting	83.3	No ruts present
	14.3	Some ruts present but design drainage not impaired
	2.4	Rutting impairs road drainage
b. Rilling	89.4	Little or no evidence of rilling
	8.6	Rills occupy <10% of road surface area, or do not leave road surface
	2	Rills occupy >10% of surface and continue off road surface onto crossing or fill
c. Ponding	82.6	No evidence of ponded water
	14.1	Ponding present, but does not appear to threaten integrity of fill
	3.3	Ponding present and is causing fill subsidence or otherwise threatening integrity of fill
d. Road Surface Drainage	63.9	Stable drainage with little or no sediment delivery to stream
	26.5	Slight sediment delivery but configuration is stable or stabilizing
	9.6	Continuing sediment delivery to stream and configuration is unstable/degrading

Culverts		
a. Scour at Inlet	92	No evidence of scour
	5.7	Scour evident but extends less than 2 channel widths above inlet and no undercutting of crossing fill
	2.3	Scour evident that extends more than 2 channel widths above inlet or scour is undercutting crossing fill
b. Scour at Outlet	63.8	No evidence of scour
	23	Scour evident, but extends less than 2 channel widths below outlet, and no undercutting of crossing fill
	13.2	Scour evident that extends more than 2 channel widths below outlet or scour undercuts crossing fill
c. Diversion Potential	83.5	Crossing configured to minimize fill loss (road does not slope downward from crossing in at least one direction)
	11	Crossing has road that slopes downward in at least one direction with drainage structure
	5.5	If culvert fails, flow will be diverted out of channel and down roadway
d. Plugging	78.2	No evidence of sediment, debris
	12.6	Sediment and/or debris is accumulating <30% of inlet or outlet is blocked
	9.2	Sediment and/or debris is blocking >30% of inlet or outlet
e. Piping	97.7	No evidence of flow beneath or around culvert
	2.3	Flow passes beneath or around culvert, or piping erosion evident
Non-Culvert Crossing		
a. Diversion	100	Crossing is configured to minimize fill loss
	0	Overflow will be diverted down roadway
Removed or Abandoned		
a. Bank Stabilization	61	Vigorous dense vegetation cover or other stabilization material
	34.1	Less than full cover, but >50% of channel bank has effective cover or has stable material
	4.9	<50% of channel bank has effective cover or is composed of stable material
b. Rilling of Banks	87.8	Rills may be evident but infrequent, stable, with no sediment delivery to channel
	12.2	Few rills present (<1 per lineal 5 ft) and rills not enlarging
	0	Numerous rills present (>1 rill per lineal 5 ft) or apparently enlarging
c. Gullies	100	None evident
	0	Gullies present but not enlarging
	0	Gullies present and enlarging or threatening integrity of fill
d. Slope Failures	97.6	Less than 1 cubic yard of material
	2.4	>1 cubic yard of material moved, material enters stream
	0	>=1 cubic yard of material moved but does not enter stream

e. Channel Configuration	80.5	Wider than natural channel and close to natural watercourse grade and orientation
	14.6	Minor differences from natural channel in width, grade, or orientation
	4.9	Narrower than natural channel width, or significant differences from natural channel grade or orientation
f. Excavated Material	92.5	Sloped to prevent slumping and minimize erosion
	7.5	Slumps or surface erosion present, but <1 cubic yard of material enters channel
	0	Slumps or surface erosion present, >1 cubic yard of material enters channel
g. Grading and Shaping	80	No evidence of erosion or sediment discharge to channel due to failures of cuts, fills or sidecast
	20	<1 cubic yard of material transported to channel due to failures of fills or sidecast
	0	>1 cubic yard material transported to channel due to failures of fills or sidecast
Road Approaches at Abandoned Crossings		
a. Grading and Shaping	76.5	No evidence of concentrated water flow to channel from road surface
	20.6	<1 cubic yard of material transported to channel from eroded surface soil on road approaches
	2.9	>1 cubic yard of material transported to channel from eroded surface soil on road approaches

Table A-7. WLPZs--implementation ratings for WLPZs as a whole.

Rule No.	Description	Number of Observations	Number of Observations (1-4)	% Meets or Exceeds FPR	% Minor Departure	% Major Departure
916.4(b)	THP provided for filtration of organic material	263	258	100.0	0.0	0.0
916.2(a)(4)	Sensitive conditions--overflow channels	264	84	100.0	0.0	0.0
916.4(b)	THP provided for flow changes by LWD	263	252	100.0	0.0	0.0
916.2(a)(4)	Sensitive conditions--flood prone areas	264	77	100.0	0.0	0.0
916.3(c)	Roads, landings outside of WLPZs	264	224	98.2	1.3	0.4
916.3(e)	Trees in WLPZ felled away from channel	264	238	97.5	2.5	0.0
916.4(a)	Sensitive conditions--erodible banks	264	111	89.2	9.0	1.8
916.4(a)	Sensitive conditions--changeable channels	264	89	98.9	1.1	0.0
916.4(b)(4)	WLPZ width segregated by slope class	264	235	97.4	2.6	0.0
916.4(b)(5)	No reduction in width with unrocked roads in WLPZ	264	3	100.0	0.0	0.0
916.4(b)(6)	75% surface cover retained in WLPZ	264	252	100.0	0.0	0.0
916.4(b)	THP provided for protection for water temp.	262	258	99.2	0.8	0.0
916.4(b)	THP provided for channel stabilization	264	251	98.8	1.2	0.0
916.4(d)	Heavy equip excluded unless explained	264	246	97.2	2.4	0.4
916.4(b)	THP provided for upslope stability	264	258	97.7	2.3	0.0
916.5(a)(3)	Side slope classes used to determine WLPZ	263	254	97.2	2.4	0.4
916.5(e)"D"	Class I-base mark applied below cut line	265	56	100.0	0.0	0.0
916.5(e)"F"	Class IV-when required in THP-trees marked	264	1	100.0	0.0	0.0
916.5(e)"F"	Class III-when required in THP-trees marked	264	3	100.0	0.0	0.0
916.5(e)"H"	Class III-50% of understory vegetation left in WLPZ	264	3	100.0	0.0	0.0
916.5(e)"I"	Class II-50% of total canopy left in WLPZ	264	203	96.6	2.5	1.0
916.5(e)"I"	Class IV-50% of total canopy left in WLPZ	264	3	100.0	0.0	0.0
916.7(b)	Where 800 sq ft exposed--replanting?	263	1	100.0	0.0	0.0
916.7, 916.7(b)	Where 800 sq ft exposed--grass seeding	264	8	100.0	0.0	0.0
916.7	Where 800 sq ft exposed--rip rap	264	1	100.0	0.0	0.0
916.2(a)(4)	Sensitive conditions-debris jam potential	263	98	98.0	2.0	0.0

916.2(a)(4)	Sensitive conditions--unstable banks	264	107	98.1	0.9	0.9
916.2(a)(4)	Sensitive conditions--existing roads in WLPZ	264	71	90.1	7.0	2.8
916.3(d)	*Vegetation by wet areas retained/protected*	*264*	*113*	*100.0*	*0.0*	*0.0*
916.3(d)	Soil within meadows/wet areas protected	264	98	100.0	0.0	0.0
916.3(g)	Class I/II-2 living conifers 16 in DBH, 50 ft tall	264	255	99.2	0.8	0.0
916.3.b	Accidental depositions of soil removed	264	34	94.1	5.9	0.0
916.4(a)	Sensitive conditions--existing roads in WLPZ	267	70	91.4	5.7	2.9
916.4(a)	Sensitive conditions--debris jam potential	264	96	95.8	4.2	0.0
916.4(a)	Sensitive conditions--overflow channels	264	83	100.0	0.0	0.0
916.4(a)	Sensitive conditions-flood prone areas	264	74	100.0	0.0	0.0
916.4(b)(3)	Width of WLPZ conform to Table 1 in FPRs	264	251	92.8	6.4	0.8
916.4(b)(5)	For I/IIs, where WLPZ reduced--still 50 ft wide	264	22	95.5	4.5	0.0
916.4(b)(5)	No WLPZ reduction when unrocked road	264	3	100.0	0.0	0.0
916.4(b)	WLPZ widths as wide as specified in Table 1	264	251	93.6	5.6	0.8
916.4(c)(2)	Class III/IV--measures in Table 1 applied	264	5	100.0	0.0	0.0
916.4(c)(3)	Class III-soil removed or stabilized	264	1	100.0	0.0	0.0
916.4(c)(3)	Temporary crossings removed	264	30	96.7	0.0	3.3
916.4(d)(1)	Class I-location of equipment flagged in WLPZ	264	8	100.0	0.0	0.0
916.5(a)(1)	Location of watercourse used to set WLPZ	271	269	98.5	1.5	0.0
916.5(a)(2)	Restorable beneficial uses used to set WLPZ	265	262	99.6	0.4	0.0
916.5(e)"E"	Class II-base mark below cut line of trees	264	181	98.3	1.1	0.6
916.5(e)"G"	Class I-50% overstory and 50% understory	264	59	100.0	0.0	0.0
916.7(b)	Stabilization 800 sq ft-improve sediment filter	264	10	100.0	0.0	0.0
916.7(b)	Stabilization 800 sq ft-minimize erosion	264	10	100.0	0.0	0.0
916.7(b)	Stabilization 800 sq ft-stabilize banks	264	10	100.0	0.0	0.0
916.7, 916.7(b)	Where 800 sq ft exposed-mulching	264	9	100.0	0.0	0.0
916.7	Stabilization 800 sq ft-prevent soil movement	264	8	100.0	0.0	0.0
916.2(a)(4)	Sensitive conditions--changeable channels	264	87	98.9	1.1	0.0
916.5(b)	Beneficial uses consistent w/WLPZ classes	263	260	98.8	1.2	0.0

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and WY92 had very low production of wild chinook smolts from Prairie Creek. In WY91, it is unknown what percentage of the 7,500 fish migrating past the trap were wild.

Table 8. Number of chinook salmon migrating downstream below May Creek on Prairie Creek from WY90 to WY94. PCFWWRA's trap was located just downstream of channelized section of Prairie Creek (from Farro 1990, 1991, 1992, 1993, 1994 and Anderson 1990, 1991, 1992, 1993, 1994)(1994 reports in preparation)

Outmigrant Chinook Salmon	WY90	WY91	WY92	WY93	WY94
Total hatchbox smolts released in Prairie Creek	33,900	32,226	8,190	62,410	83,000
# hatchbox smolts released above trap	33,900	19,135	1,850	13,380	700
# hatchbox smolts past trap[a]	--	<7,574	< 50[b]	5,420	--
# wild smolts past trap	887	<7,574	< 50	2,835	12,000
# in estuary in late June[c]	6,390	<1,000	48,830[d]	17,990[e]	63,390
# hatchbox smolts in estuary	--	--	--	950	-

96

26,333

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[a] Hatchbox fish were marked only in WY93. They could be differentiated from wild smolts in WY90 in traps based on size. Traps were blown out for several weeks in WY91 and WY93 (so numbers underestimate those years).
[b] In WY92, smolts were missed because 24% of redds and carcasses were below the trap due to low winter flows.
[c] Estuary was open during estimate all years shown. 95% confidence intervals for estimates did not overlap except in WY94, which overlapped with WY93 and WY92.
[d] 1,850 hatchbox fish were released into Prairie Creek after this estimate.
[e] No hatchbox fish were included in this estimate (they showed up in the estuary mostly in July and August).

To compare PCFWWRA's data to RNP's, PCFWWRA 1994 data were re-analyzed using a 1 night/week sampling scheme. If PCFWWRA had sampled only 1 night/week in WY94, they would have captured 439 fish that year. Expanding their trap numbers to account for trapping efficiency (based on mark-recapture tests), about 2,000 fish would have been captured in WY94. Multiplying this estimate by 7 to simulate continuous trapping gives 14,000 fish, which is close to the 12,000 estimate based on continuous trapping. This estimate is much higher than the 1983 or 1984 estimate.

It is possible that PCFWWRA's mark-recapture tests caused some fish mortality (McKeon 1985), which would inflate the population estimates, or that the full-spanning weir missed fish. The pipe trap efficiency (PCFWWRA used the pipe traps most years) was compared to a full-spanning weir without using a marking procedure (Farro 1990). In 1990, a full-spanning weir

MEYER, 1994

Table 9. Densities (fish/m^2) of coho salmon and steelhead trout in Prairie Creek and unaffected tributaries.[a]

	COHO SALMON			STEELHEAD TROUT		
CREEK	1981	1990	1994	1981	1990	1994
Prairie above Brown Creek	0.18	0.01[b]	0.23[b]	0.02	0.02[b]	0.07[b]
Little Lost Man Creek	0.00[b]	0.10[b]	0.43	0.40[b]	0.36[b]	0.30
Streelow Creek[c]	0.04	–	0.40	0.05	–	0.19

SPROWL CREEK — 0.39 0.81 0.83 — .46 .33

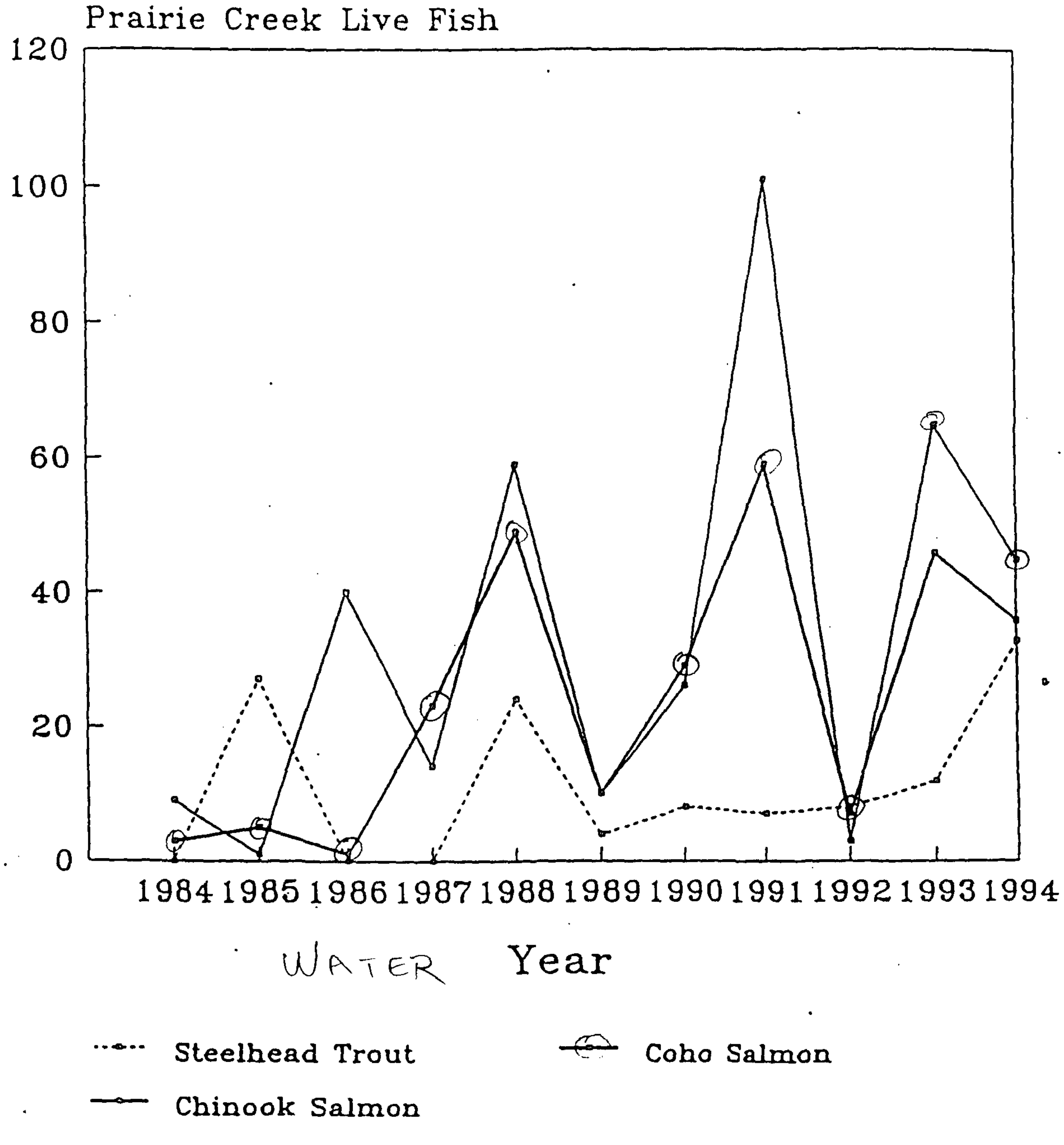
[a] 1994 data are preliminary and unpublished. 1981 data are from (Anderson 1988). 1990 data are from Farro (1990).
[b] The same site was sampled on the creek.
[c] Located just south of Godwood Creek.

Godwood Creek had coho salmon densities between 0.04 m^2 and 0.08 m^2, which was much higher than upper or lower Prairie Creek (0.01 fish/m^2)(Farro 1990). In WY91, a site on Godwood Creek had more or the same numbers of coho than years before the October storm, and a site on May Creek had fewer coho than years before the storm. This shows that another old-growth unaffected stream besides Lost Man Creek did not decrease in numbers following the October storm, but an affected stream did. Interestingly, park staff observed numerous 1+ and 2+ coho salmon when electroshocking in May Creek just this November, 1994. Even lower May Creek may be recovering.

Coho salmon hatchbox releases were 35,645 fish in WY90, 24,880 in WY91, 26,710 in WY92 and 17,430 in WY93 (Farro 1990, 1991, 1992, 1993). Coho salmon were not released in WY94, which probably was a good decision because the year had low flows, good numbers of juveniles in upper Prairie Creek, and likely had improved production over WY90 and WY91 as was found in WY93.

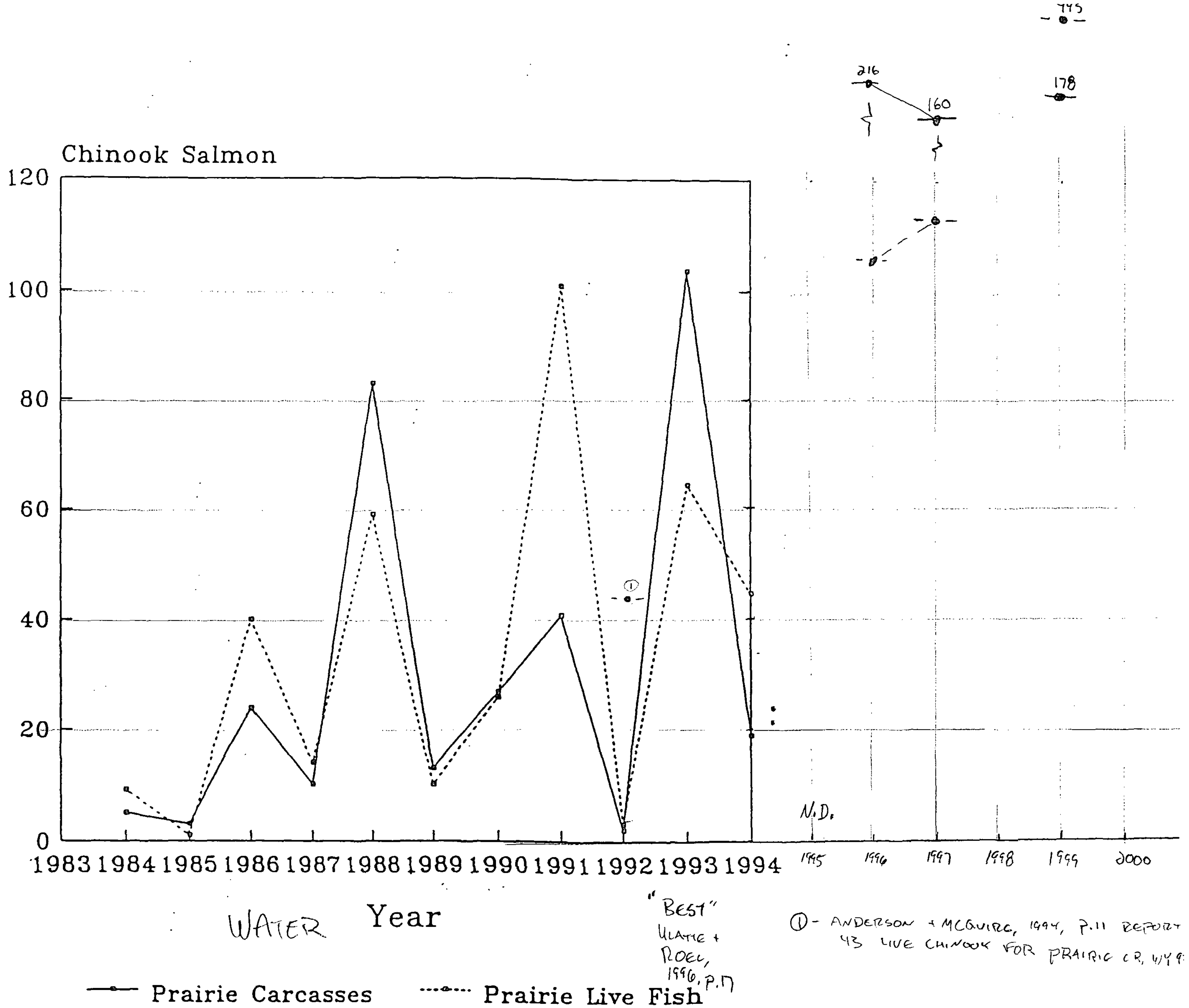
In WY81, WY82, and WY83 of McKeon's (1985) study, less than 2% of the salmon in his Redwood Creek traps were coho salmon. Outside of Prairie Creek and its tributaries, very few tributaries in the Redwood Creek basin contained juvenile coho salmon in 1981 (only Tom McDonald, Coyote, and Karen Creeks)(Anderson 1988). By WY94, Emerald, Copper, and Bridge Creeks also contained coho salmon, but creeks surveyed outside the park still did not (unpublished RNP data). Live or dead (carcasses) coho salmon spawners were not observed in Bridge and Tom McDonald Creek until the early 1990's (Meyer 1990). This indicates coho salmon have been making a recovery in the park, but not in the upper basin. Spawning surveys in Prairie Creek, however, show trends in numbers of live and dead adult coho salmon have not changed from 1987 to 1994. Only the latter two years would have contained many offspring produced after the October storm, and numbers during those years were in the range of variability before the storm (Figure 22). These numbers, particularly in WY93, may have been

Meyer 1994



Standardized to 3 surveys

Figure 23. Number of live steelhead, coho and chinook salmon counted on Prairie Creek during spawning surveys from 1984 to 1994. Numbers were standardized to 3 surveys to facilitate comparisons among years (from Meyer 1994).



Chinook Salmon
120
100
80
60
40
20
0
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994
1995 1996 1997 1998 1999 2000
216
160
178
N.D.
Year
WATER
"BEST" ULATTIE + ROEL, 1996, P.17
① - ANDERSON + MCGUIRE, 1994, P.11 REPORT 43 LIVE CHINOOK FOR PRAIRIE CR,
Prairie Carcasses
Prairie Live Fish

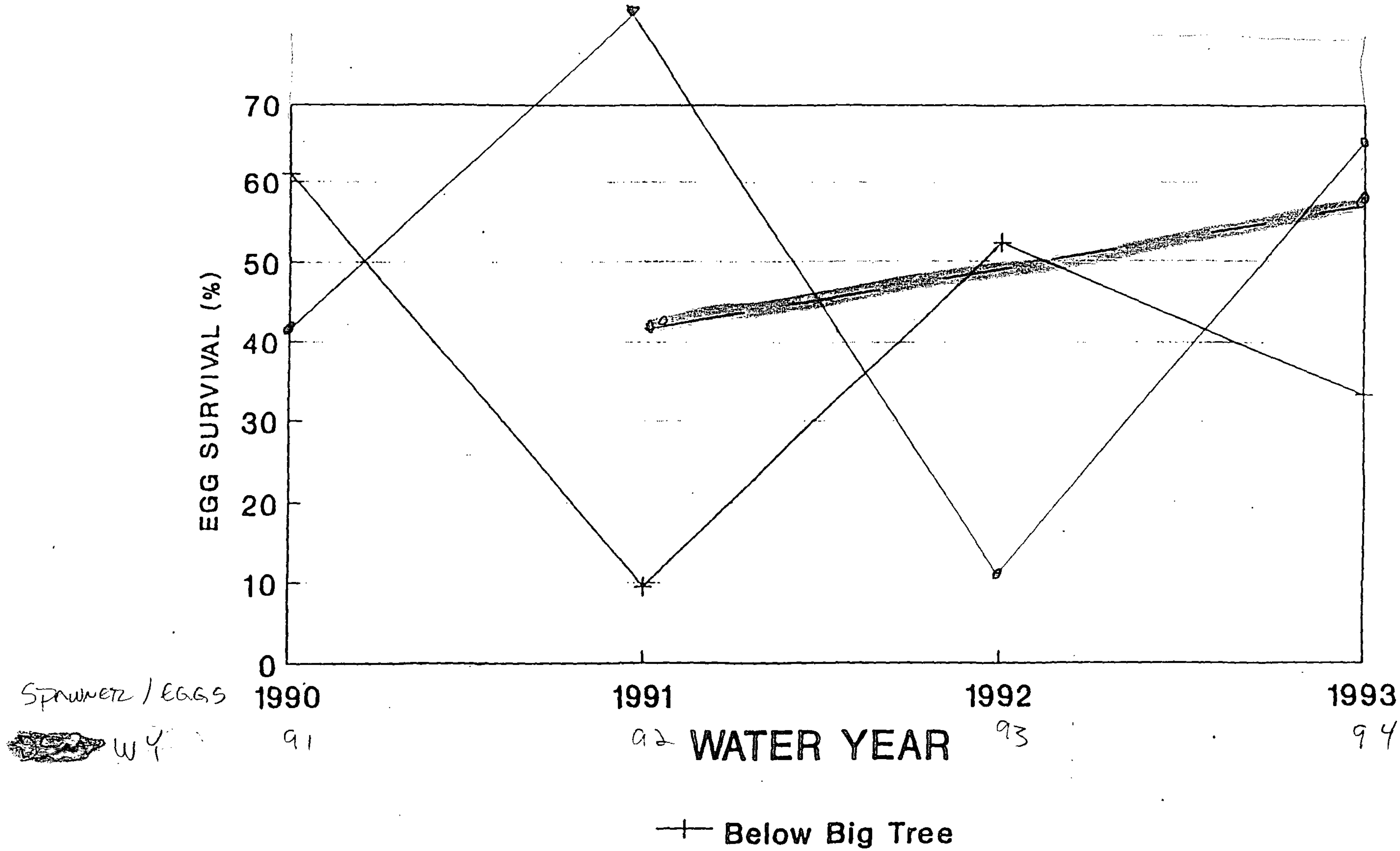
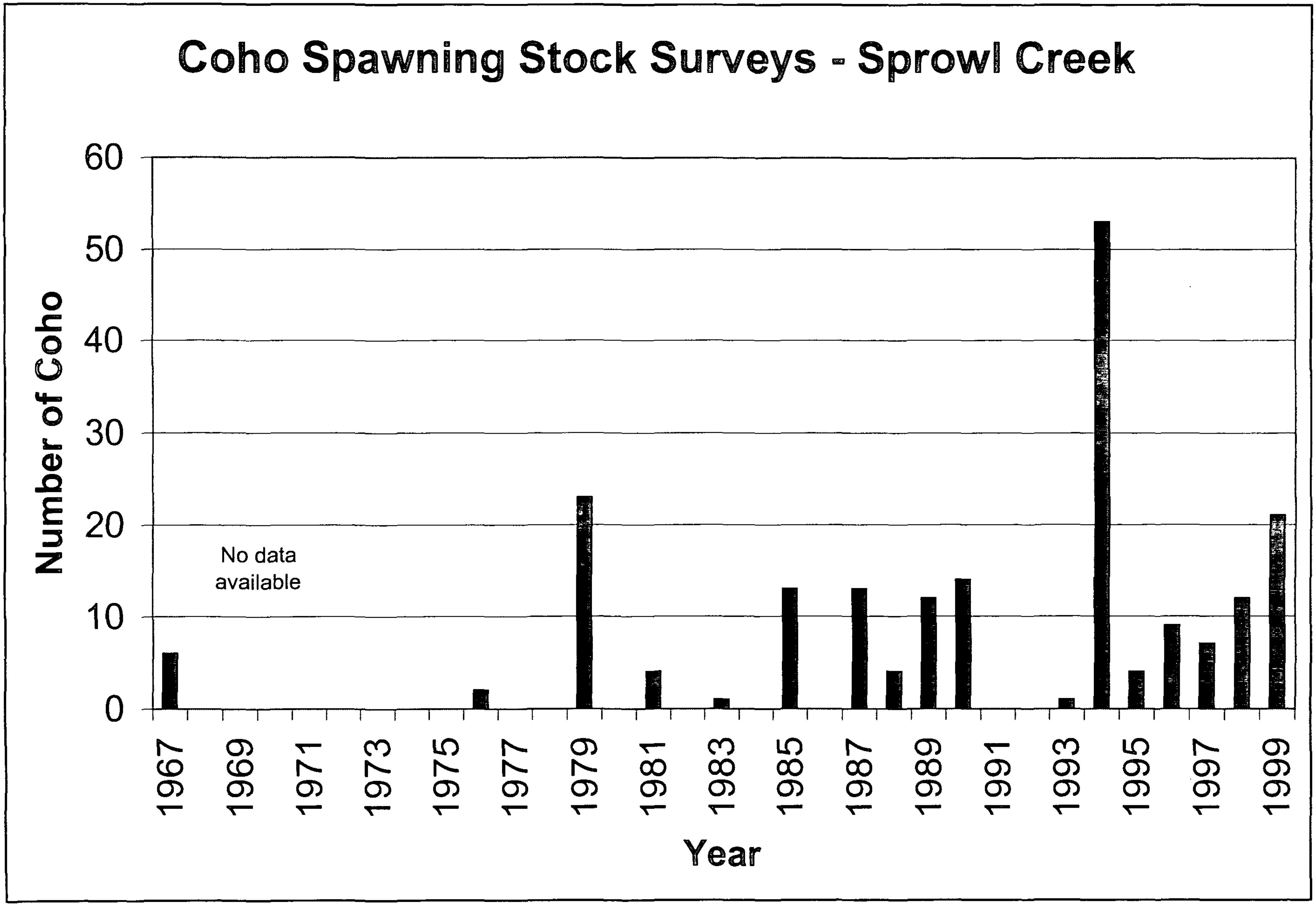


Figure 7. Comparison of egg survival between years on Prairie Creek below Big Tree Creek. All eggs were in place just after fertilization. 1990 eggs were steelhead; 1991 to 1993 eggs were coho salmon.

	90	91	92	93	TOT
SPAWNERS	30	60	8	48	146

x̄ - 36.5

- FR. FIG. 22



Coho Spawning Stock Surveys - Sprowl Creek
Number of Coho
0
10
20
30
40
50
60
No data
available
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
Year

Chinook Spawning Stock Surveys - Sprowl Creek