Flathead Basin Forest Practices Water Quality and Fisheries Cooperative Program

Final Report

June 1991

About This Report

This is the *Final Report* summarizing ten individual studies conducted for the Flathead Basin Forest Practices/Water Quality and Fisheries Cooperative Program. The Cooperative Program was administered by a Coordinating Team representing the Montana Department of State Lands Forestry Division, the Flathead National Forest, Plum Creek Timber Company, L.P., the Montana Department of Fish, Wildlife and Parks, the Montana Department of Health and Environmental Sciences' Water Quality Bureau, the University of Montana, and the Flathead Basin Commission.

The Cooperative Program's specific objectives were (1) to document, evaluate, and monitor whether forest practices affect water quality and fisheries within the Flathead Basin, and (2) if detrimental impacts exist, to establish a process to utilize this information to develop criteria and administrative procedures for protecting water quality and fisheries.

The ten individual studies included the evaluation of: (1) specific practices at the site level, (2) accumulation of practices at the watershed level, (3) general stream conditions, (4) water quality variables relative to levels of management activity in small watersheds, (5) fish habitat and abundance relative to stream variables influenced by forest practices at the watershed level, (6) long-term changes in large-stream dynamics related to historical records of natural and man-related disturbances, and (7) changes in lake sediments relative to historical records of natural and man-related disturbances.

Contributors

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June 1991

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Abstract of the Final Report of the Flathead Basin Forest Practices Water Quality and Fisheries Cooperative Program

The Flathead Basin Forest Practices/Water Quality and Fisheries Cooperative Program was initiated in 1988. It's goal was to evaluate the effects of forest practices on water quality and fisheries in the Flathead Basin.

The Cooperative Program was administered by a Coordinating Team representing the Montana Department of State Lands Forestry Division, the Flathead National Forest, Plum Creek Timber Company, L.P., the Montana Department of Fish, Wildlife and Parks, the Montana Department of Health and Environmental Sciences' Water Quality Bureau, the University of Montana, and the Flathead Basin Commission.

The Cooperative Program's specific objectives were (1) to document, evaluate, and monitor whether forest practices affect water quality and fisheries within the Flathead Basin, and (2) if detrimental impacts exist, to establish a process to utilize this information to develop criteria and administrative procedures for protecting water quality and fisheries.

Eight study leaders developed ten individual studies (modules). They conducted these studies during 1989 and 1990. They held a coordination workshop early in 1989 to develop linkages among the studies and to obtain external review from three watershed and fisheries scientists from Idaho and Washington. A set of study watersheds was selected at this workshop to help integrate as many of the field studies as possible.

The ten individual studies included the evaluation of: (1) specific practices at the site level, (2) accumulation of practices at the watershed level, (3) general stream conditions, (4) water quality variables relative to levels of management activity in small watersheds, (5) fish habitat and abundance relative to stream variables influenced by forest practices at the watershed level, (6) long-term changes in large-stream dynamics related to historical records of natural and man-related disturbances, and (7) changes in lake sediments relative to historical records of natural and man-related disturbances.

Each of the individual studies were documented in "stand-alone" reports available through the Flathead Basin Commission (723 Fifth Avenue East, Kalispell, Montana 59901). The study leaders summarized their reports for inclusion in this *Final Report*.. Then the study leaders individually drafted conclusions and recommendations as a basis for discussion and interaction.

The study team leaders held workshops during the spring of 1991 to review results and to develop a consensus set of summary conclusions and summary recommendations for consideration by the cooperating land management organizations. The land management organizations then developed a formal response to the recommendations for inclusion in this *Final Report*. Following final editing and printing, this *Final Report* will be presented at a summer workshop for public information and response.

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INTRODUCTION

Introduction

Over the past few decades, the make-up of the economy of the Flathead Basin has steadily changed. Once almost dominated by timber processing and agriculture, the area has experienced steady growth in recreation and tourism, retirement population, and more diversified manufacturing. People have been attracted by the Basin's considerable amenity values, uncrowded landscapes, a relatively mild temperate climate, and a clean environment. As populations have grown, the concern to keep Flathead Basin waters pristine has also increased, and forest management activities have come under more intensive public scrutiny. Many people have challenged logging and road construction activities as a perceived threat to water quality and fishery habitat.

The concern over what may happen to state forested watersheds has been expressed through the passage of House Joint Resolution 49 by the Montana Legislature in 1987, appeals of national forest plans, and increased public scrutiny of timber management programs of State-owned and privately-owned lands. Timber managers and purchasers are in turn affected by the uncertainty, as planned operations are delayed and adverse economic impacts result.

In response to these concerns the principal forest land managers in the Flathead River Basin (Flathead National Forest, Plum Creek Timber Company, L.P., and Montana Department of State Lands) proposed a cooperative effort to learn how forest practices are affecting water quality and fisheries within the Basin.

Cooperative Study Program

The Flathead Basin Forest Practices/Water Quality and Fisheries Cooperative Program represents a concerted and coordinated effort by state, federal, and private interests to work together to learn how forest practices are affecting water quality and fisheries, and to develop methods to utilize the findings in the management of Flathead Basin forests.

The Cooperative Program was administered by a Coordinating Team representing the Montana Department of State Lands Forestry Division, the Flathead National Forest, Plum Creek Timber Company, L.P., the Montana Department of Fish, Wildlife and Parks, the Montana Department of Health and Environmental Sciences' Water Quality Bureau, the University of Montana, and the Flathead Basin Commission. A representative of the Environmental Quality Council served as a liaison to the Cooperative.

The Flathead Basin Commission was the nominal sponsor of the effort, providing logistical and staff support and serving as an "umbrella" organization under which the Cooperative Program operated. Each specific research project was under the direction of a scientific study leader, while resource specialists from various organizations provided technical assistance as needed. Citizen participation in the Cooperative Program was coordinated through the Flathead Basin Commission, with both formal and informal opportunities for the interested public to review and comment on the research design and findings. A formal Memorandum of Understanding was signed by all the cooperating members in August of 1988. (See Appendix A.)

Purpose and Specific Objectives

Purpose:

To improve the management of Flathead area forested watersheds through the development and application of state-of-the-art information to prevent or mitigate the potential adverse effects of specific forest practices on water quality and fisheries.

Specific Objectives:

- To document, evaluate, and monitor whether forest practices affect water quality and fisheries within the Flathead Basin; and,
- If detrimental impacts exist, to establish a process to utilize this information to develop criteria and administrative procedures for protecting water quality and fisheries.

Nature of Project Results

The initial product of the research, monitoring, and analysis was a series of reports and scientific publications that define how certain forest practices affect water quality and fisheries. The second and most important product of the Cooperative Program will be the use of the research results in the management of Montana forests.

This cooperative program included a variety of modules. Some studies were conducted to obtain a better understanding of the overall interactions among forest practices, water quality, and fisheries. Other studies were direct approaches to evaluate and provide new information on management practices. A variety of research methods were used, including historical analysis of existing data, collection of new field data, field audits of management practices by teams of experts, formal summaries of expert opinion, field assessment of environmental conditions, experimental work, and evaluation of models. Workshops were held during the program in an attempt to communicate and explore all possible opportunities to link studies together where possible and appropriate.

The studies were conducted in cooperation with the land managers and resource management agencies. However, every attempt was made to have the researchers maintain independence of analysis and interpretation of results. The organization of reports illustrates this process. The complete individual module reports stand alone as scientific documentation of findings of the individual studies. This report provides a summary of module results with the addition of specific conclusions.

The administrative structure of the Cooperative Program itself was conducive to translating the results of the research into on-the-ground management. The participants included the major land managers and natural resource agencies in the upper Flathead Basin. These participants worked cooperatively throughout the study. The public has also been informed and involved in the Cooperative Program through the Flathead Basin Commission. The consequence of this structure was a shared "ownership" of the research results by all parties, and thus a substantial momentum toward understanding and improving forest management practices based on the research results.

Funding

The Coordinating Team worked closely with the Flathead Basin Commission to coordinate the logistics of funding. All participants in the Cooperative Program provided financial, technical, and in-kind contributions.

Each study component was funded separately and from a variety of sources. The Cooperative Program approach facilitated funding assistance. Some study proposals incorporated ongoing projects already funded through McIntire-Stennis Research Program funds and the Montana Riparian Association. A grant request was also received from the Renewable Resource Development program administered by the Department of Natural Resource and Conservation for partial support of the program.

Implementation

The scientist study leaders implemented the individual projects following thorough development of a study plan, peer review, approval of the project by the Coordinating Team, and allocation of research funds. Each scientist study leader conducted independent research according to the study plan. The Coordinating Team reviewed annual work plans, offered suggestions, encouraged scientific team efforts, and facilitated appropriate technical assistance from resource specialists working with the various organizations involved in timber management and oversight in the Flathead Basin.

During the first year of the program, the module study leaders and technical resource specialists conducted a coordination workshop. A team of scientists provided a formal review of the individual cooperative program and offered suggestions for improvements. The participants identified linkages among modules and new modules were developed to provide missing information.

Structure of the Program

The funding agencies agreed on nine separate "study modules."

(A) ***An Analysis of the Effect of Timber Harvest on Streamflow Quantity and Regime: An Examination of Historical Records.*** This study by the Flathead Lake Biological Station statistically examined the relationships between water flow, weather, logging, and fire data for the basin dating back to the turn of the century. The final study report discusses the implications of past fires and timber harvests on stream flow in the Swan River and the North and Middle Forks of the Flathead River.

(B) ***Evaluation of Historical Sediment Deposition Related to Land Use through Analysis of Lake Sediments.*** To evaluate the impact of land use activities, floods, and fires on sediment deposition in several lakes in the Flathead Basin over the last 150 years. The first lake (Whitefish Lake) is located in a watershed that has had extensive logging activity during the past century. The second lake (Swan Lake) is located in an area that has had a number of natural and human-related disturbance activities. The third lake (Lake McDonald) is located in an area with no logging — although a major road was constructed during the middle part of this century.

(C) ***The Effect of Timber Management on Stream Water Quality.*** This was an in-stream study to measure any specific changes in aquatic ecology (biological, chemical, and physical characteristics) due to forestry practices and to describe the implications of those changes. The streams evaluated included "control" streams in undeveloped watersheds and test streams in watersheds from which timber has been harvested. The Flathead Lake Biological Station conducted this study.

(D) ***Fisheries Habitat and Fish Populations.*** This study, conducted by the Montana Department of Fish, Wildlife and Parks, examined cutthroat and bull trout habitat and how changes in stream-bottom sediment conditions are important to populations of these species.

(E) ***Application of the Montana Nonpoint Source Stream Reach Assessment in the Flathead Basin.*** This module evaluated impairment to beneficial uses in the Flathead Basin and evaluated the accuracy of the assessment procedure by comparing its results with the results of quantitative studies performed by other Cooperative Program members. The Montana Department of Health and Environmental Sciences completed this assessment.

(F) ***Assessments of Best Management Practices.*** The University of Montana School of Forestry conducted this interdisciplinary team review of completed timber sales. The review evaluated the success of implementing forestry Best Management Practices (BMPs) for preventing soil erosion and protecting water quality. They examined fifty-three field locations on a mix of land ownership (federal, state, and private) within the Flathead Basin.

(G) ***Management Guidelines for Riparian Forests.*** This study module developed management guidelines or "recommended management practices" that are specifically tailored to the wetland vegetation types found along stream courses in the Flathead Basin. It also determined field procedures for consistent field identification of Streamside Management Zones and a soil erosion risk matrix.

(H) ***Application of the Sequoia Method for Determining Cumulative Watershed Effects in the Flathead Basin.*** This study assessed possible cumulative effects in a watershed due to timber harvesting and road building activities. The University of Montana School of Forestry conducted this study.

(I) ***A Forest Management Nonpoint Source Risk Assessment Geographic Information Systems Application.*** This module developed a computer geographic display capability for a watershed risk assessment model based on a variety of practices with risk assessment for specific slopes and soils. This methodology will be used to help evaluate future management strategies for individual watersheds. The University of Montana School of Forestry conducted this study.

In addition, the study participants decided that they needed a module to determine direct linkages between timber harvest activities and the presently used modeling and monitoring methods.

(J) ***Linear Correlation/Regression Analysis of Forestry Models, Risk Assessment, and Water Quality and Fisheries Data.*** Those working on this module provided the current modeling and monitoring data for testing relationships with data from other modules in the study, evaluated correlations of variables currently available from the

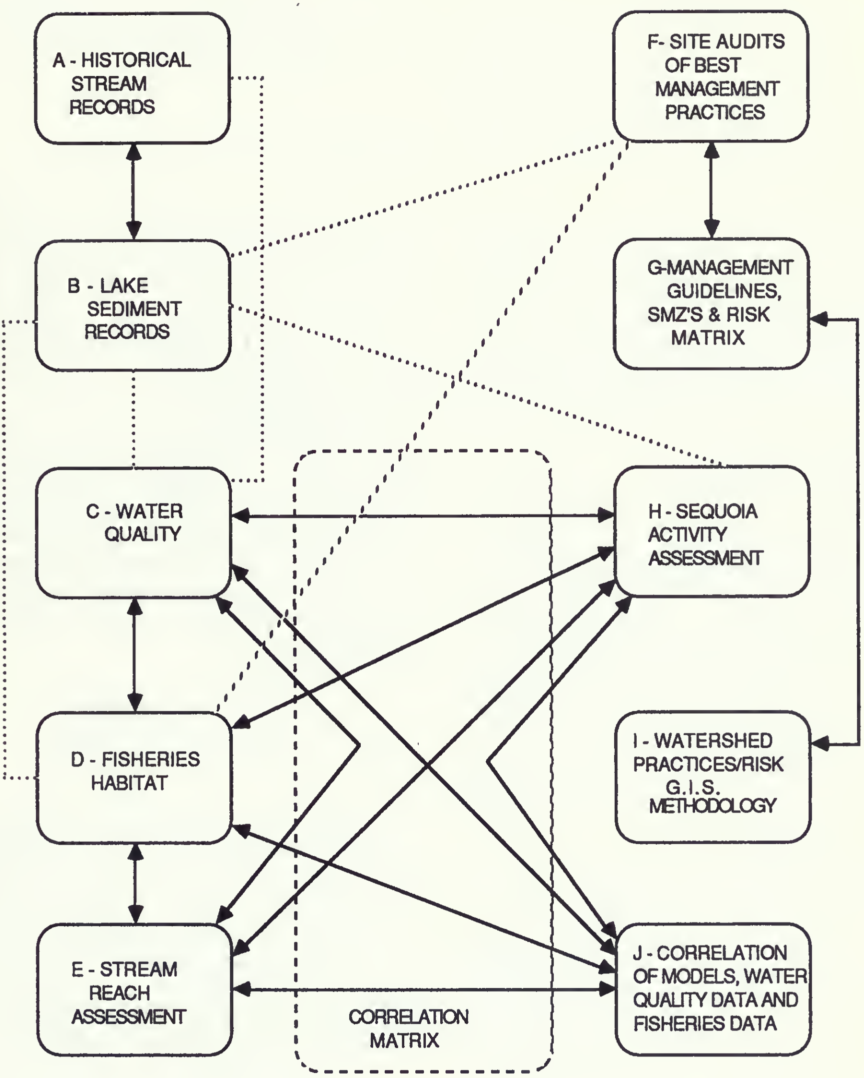

Figure 1- Direct(⟷) and reference(······) linkages among study modules.

Flathead National Forest database, conducted correlation analyses for all selected variables, and jointly interpreted the results of the correlation analyses. The Flathead National Forest led this effort with the cooperation of several study leaders.

Although the Flathead Basin Forest Practices/Water Quality and Fisheries Study Cooperative reports were designed as individual, independent modules, the study team made several efforts to develop coordination as the program progressed. Figure 1 demonstrates linkages of the modules.

Cooperative Program results will be reported in several ways.

(1) The nine official study reports (Modules A through I) have been printed for distribution to interested parties.
(2) The study leaders have worked together to develop this summary report to synthesize individual study results and recommendations into a consolidated document for public distribution.
(3) Land owners have prepared a written response to the recommendations (which is incorporated in this *Final Report*).
(4) The study results and management recommendations will be presented to the public in a workshop hosted by the Flathead Basin Commission. This will include a discussion by the study leaders of their results and recommendations as well as an interactive panel discussion between the three principal land managers and the public.
(5) A videotape has been prepared for public television and organizational viewing. The video details the Cooperative's goals, the study modules, the study results, and the management recommendations.

Information about This Report

This report is organized into eight major sections: (1) Introduction, (2) Summaries of Individual Study Module Reports, (3) General Discussion, (4) Summary of Conclusions, (5) Summary of Recommendations, (6) Response of Major Forest Land Managers to the "Summary of Recommendations," (7) References, and (8) Appendixes

When reading the summaries of individual study module reports, be aware that the researchers used many different kinds of scientific data analyses. For those studies involving statistical analysis, the term "significant" means that the data show a relationship that can be stated with a degree of confidence. A probability level is usually shown in parentheses or with asterisks. For example:

* = 90% level of confidence
** = 95% level of confidence
*** = 99% level of confidence.

For regression or correlation analyses, the probability value is commonly used to indicate that a relationship exists between the variables (for example, $p < 0.01$ means at the 99 percent level, $p < 0.05$ means at the 95 percent level, and $p < 0.10$ means at the 90 percent level). Often the r or r^2 value is also included as a measure of variation of points about the regression line.

In any statistical test, the sample size is important in determining "statistical significance." Furthermore, statistical interpretations relate to a population. Therefore use caution when evaluating a specific site or population.

Summaries of Individual Study Module Reports

This section of the *Final Report* summarizes studies published by the Flathead Basin Commission (723 Fifth Avenue East, Kalispell, Montana 59901).

FLATHEAD BASIN FOREST PRACTICES

WATER QUALITY AND FISHERIES COOPERATIVE PROGRAM

STUDY MODULE A:

AN ANALYSIS OF THE EFFECT OF TIMBER HARVEST ON STREAMFLOW QUANTITY AND REGIME: AN EXAMINATION OF HISTORICAL RECORDS

BY F. RICHARD HAUER

This section of the *Final Report* summarizes a study of the same name published by the Flathead Basin Commission (723 Fifth Avenue East, Kalispell, Montana 59901).

An Analysis of the Effect of Timber Harvest on Streamflow Quantity and Regime: An Examination of Historical Records

By F. Richard Hauer[1]

Introduction

The purpose of this module was to determine the effect, if any, of timber management practices on streamflow quantity or regime. The analyses were based on Flathead Basin historical records of:

(1) streamflow (United States Geological Survey)
(2) precipitation, temperature, and snow pack (National Weather Service),
(3) timber harvest quantity, location, and type (Flathead National Forest, Department of State Lands, and Plum Creek Timber Co.), and
(4) historical fire records (Flathead National Forest and Glacier National Park).

I analyzed streamflow quantity and regime from 22 gauging sites located throughout the Flathead Basin for changes that may be attributed to timber harvest. These analyses were conducted in light of natural interannual variabilities of climate, past fire history, and current logging practices. I focused the study on determining possible changes in four components of annual streamflow:

(1) discharge response to specific rainfall events that are distinct and separate from the influence of water stored as snow pack,
(2) spring runoff quantity or regime (for example, height, breadth, and timing),
(3) annual discharge to annual precipitation relationships, and
(4) the relationship of annual maximum and minimum discharge.

This report does not attempt to detail every analysis that was conducted. Many of the comparative statistics that were run, particularly on untransformed data (that is, data which did not account for interannual variability in temperature, precipitation, or snow pack), were insignificant due to high interannual variability Furthermore, some of the databases, particularly streamflow on very small creeks, spanned relatively short time periods (typically three years), which did not permit long term comparative analyses.

Results

Results of the analyses revealed that:

(1) There was no significant correlative relationship between recorded rainfall events during the summer and fall (that is, not affected by snow pack) and increased river discharge during the

[1]Dr. F. Richard Hauer is a Research Associate Professor with the Flathead Lake Biological Station in Polson, Montana.

same time period. This was attributed to insufficient weather recording stations rather than to an uncorrelated relationship. Mountain precipitation is currently unmeasured outside of accumulated snow pack during winter. Thus high precipitation events are underestimated by valley precipitation recordings.

(2) When the climatic factors that drive spring runoff are accounted for by comparing years of similar temperature regimes and the data are transformed based on available snow pack, the accumulated volume of the spring runoff of Flathead Basin Rivers occurs earlier in the runoff period in years since timber management compared to years prior to such management. Simply stated, spring runoff waters are coming into the Flathead Rivers earlier in the year today than prior to extensive timber harvests.

(3) Comparison of long term trends of annual maximum and minimum discharge relationships (Qmax:Qmin) suggest that the Middle Fork of the Flathead River, which has experienced relatively little logging, is becoming increasingly stable in its Qmax:Qmin relationship while the North Fork, which has had significantly more timber harvest, is becoming increasingly variable in its Qmax:Qmin relationship. In other words, the North Fork is trending toward a discharge pattern of higher maximum flows compressed over a shorter time period while the Middle Fork is tending toward a discharge pattern in which peak flows are lower and the higher discharge of spring runoff extends over a longer time period. This is particularly important in light of the decrease in fires in both drainages, which presumably would result in a longer runoff period. Thus, the Middle Fork, which had similar area to that of the North Fork involved in forest fires prior to the advent of broad scale fire prevention (that is, since the 1930s), has been progressing to increased discharge stability, while the North Fork has decreased in discharge stability since the advent of extensive logging.

Conclusions

The analyses conducted within the auspices of this study provide some insight into the effects of timber harvest on streamflow. However, they were limited by the lack of long-term data collection among the smaller watersheds. All of the long-term databases of streamflow in the Flathead Basin are restricted to the major streams and rivers (for example, North Fork, Middle Fork, Swan River, etc.). This is a particularly important consideration since it is the lower order watersheds that are likely to respond most dramatically and quickly to alteration of the landscape.

Nonetheless, important conclusions can be drawn from this study.

(1) The North Fork and Middle Fork drainages experienced several large fires between 1880 and 1930. Subsequently, fire suppression efforts have greatly reduced forest fire frequency and size.

(2) The North Fork and Swan River drainages have experienced a substantial quantity of timber harvest in comparison to that of the Middle Fork drainage. Most of this timber harvest has occurred since 1950.

(3) The accumulation of spring runoff waters has occurred earlier in the North

Fork and Swan River drainages during the past two decades compared to pre-1950 runoff patterns and when compared to trends that have occurred in the Middle Fork during the same time periods and the same comparison years.

(4) The maximum discharge of the spring runoff has demonstrated a general trend toward increasing in the North Fork and decreasing in the Middle Fork.

Study Module B:

Evaluation of Historical Sediment Deposition Related to Land Use through Analysis of Lake Sediments

By Craig N. Spencer

This section of the *Final Report* summarizes a study of the same name published by the Flathead Basin Commission (723 Fifth Avenue East, Kalispell, Montana 59901).

Evaluation of Historical Sediment Deposition Related to Land Use Through Analysis of Lake Sediments

By Craig N. Spencer[1]

Introduction

One of the biggest environmental concerns with regard to timber harvest is the potential for enhanced erosion and transport of sediment to surface waters. Increased sediment loadings are considered undesirable as they may degrade gravel spawning habitat used by stream fish (see Weaver and Fraley, Module D). Furthermore, since sediments represent a major source of water-borne nutrients (Mortimer 1941; Perry and Stanford 1982) increased erosion and sediment transport may accelerate the eutrophication process in surface waters, especially in lakes and reservoirs.

Current debate over the impact of logging activities on water quality in the Flathead Basin is hampered by a scarcity of quantitative data on conditions prior to the commencement of timber harvest. Early logging activities began 50 or more years ago in many parts of the Basin. However, most water quality monitoring efforts in the Basin were initiated only within the last 10 to 20 years or less. Without pre-logging water quality data, it is difficult to assess the impact of harvest activity on water quality in the Flathead Basin.

Previous studies in other areas have documented increased sediment loadings to surface waters resulting from timber harvest activities (Likens et al. 1970, Lowe et al. 1986). Nevertheless, it may not be appropriate to extrapolate findings from other areas to the Flathead Basin. A number of streams in the Basin are flanked by steep, naturally occurring, unstable stream banks composed of sand, silt and clay. The presence of these erosive deposits may result in naturally elevated sedimentation rates in the Basin. Thus it is possible that erosion of sediments associated with logging activities in the Flathead Basin may be minor in comparison to natural sediment loadings.

The vast majority of suspended stream sediments carried into large deep lakes are deposited within the quiescent lake environment. Significant changes in surface erosion and sediment transport within the catchment of a lake should be reflected in changes in the sediment character and the rate of sediment accumulation in the lake (Berglund 1986). Thus, undisturbed sediments deposited on the bottom of lakes contain a record of the past history of sedimentation from their respective catchments. Modern paleolimnological techniques are available which allow estimation of past sedimentation rates through detailed analysis of the "paleo" record preserved in the lake sediments (Berglund 1986). A record of past changes is most evident in sediments deposited in the deep-water (profundal) region of the lake. This environment is much more stable than near-shore, shallow lake, or stream environments; deep lake sediments may remain largely undisturbed

[1]Dr. Craig N. Spencer is a Research Assistant Professor with the University of Montana, Flathead Lake Biological Station in Polson, Montana.

for thousands of years.

One of the more notable paleolimnological studies, by Hutchinson and others (1970), documented increased sedimentation rates in a lake in Italy (Lago di Monterosi) over 2000 years ago, coinciding with construction of the Roman Road, the Via Cassia, in about 171 B.C. Numerous studies report changes in sedimentation rates in other lakes which correlate with various land disturbance activities including timber harvest, plowing of fields, and road building (Davis 1975, Batterbee and others 1985, see reviews in Berglund, 1986). Although there have been previous paleolimnological studies in the Flathead Basin (Moore et al. 1982), none have quantified recent sedimentation rates.

The present research was initiated to study the historical record of sediment deposition over the last 100-150 years in three lakes in the Flathead Basin. Whitefish Lake and Swan Lake are located in watersheds that have a history of land disturbance activity (primarily road building and timber harvest) throughout much of this century. Lake McDonald is located in Glacier National Park, and its watershed has not been logged. However, a road was constructed from the bottom to the top of the catchment during the middle part of this century.

Methods

Sediment cores were collected from the deep central basin of each lake using a freeze-coring technique modified from Shapiro (1958). Sampling locations were located on flat areas of the lake bottom away from steeper regions which may be subject to underwater landslides or slumps which would distort the sediment record. The sediments deposited in the deep central regions of the study lakes consist of fine sediments composed largely of silt and clay sized particles. The cores were sectioned in horizontal slices (approximately 1 cm thick), and the date of deposition was estimated for each section. Dates were established using a naturally occurring radioisotope (^{210}Pb) which decays at a known rate (half life=23 years). By measuring the activity of ^{210}Pb in each section, it was possible to establish a time line of sediment deposition dates along the length of each core (Appleby and Oldfield 1983). In undisturbed sediments, this technique has been shown to be useful in dating sediments deposited up to 150 years ago.

An independent technique was used for an alternate estimate of the location of the year 1963, along the sediment core. Atmospheric testing of atomic weapons peaked in 1963, and previous studies have documented a peak in ^{137}Cs activity in sediments deposited in 1963, due to global fallout of the radioactive decay particles (Pennington and others 1973). Comparison of dates indicated close agreement between the two dating methods in the study cores.

Once chronological ages were determined, sediment accumulation rates (mg dry wt/cm^2/yr) were estimated. These rates were calculated by multiplying the width of the core section (cm) by the dry weight density of the section (mg/cm^3) and dividing by the length of time (years) spanned by the section. These rates represent mean sedimentation values which occurred over the time span of each 1 cm thick section of sediment.

One core from each lake was chosen for detailed analysis. Ideally, several cores would have been analyzed from each lake; however, the available budget was not sufficient for multiple core analysis. Although only one core was analyzed in detail from each lake, the selected cores appeared to be representative of whole-lake conditions in Whitefish and Lake McDonald. For example, distinct patterns of horizontal banding noted in a particular lake core also were visible in the same relative location in other cores collected from the same lake. Since no banding was observed in cores collected from Swan Lake, visual cross-comparisons between cores was not possible.

It is important to note that the present analyses were not designed for quantitative establishment of whole-lake sediment budgets over the last 150 years. Thus the study results should not be used to estimate the total sediment loading to the study lakes over the period of record. Such analyses would require analyses of a number of cores collected from various parts of each lake. Rather, the present analysis simply utilized the stable deep-lake sediments as a continuous monitor of relative changes in deposition of fine sediment from the watershed to the lake environment. Thus, the absolute sedimentation rates are of less interest that the relative change in these rates over time.

Results and Discussion

Whitefish Lake

The Whitefish Lake catchment has been subject to a number of land disturbance activities (both man-induced and natural) which may have influenced the sedimentation rate in this lake. I assembled a history of major land disturbance activities in the catchment, including natural and human-related activities. These various activities will be chronologically compared with the lake sedimentation rates for evaluation of potential causal relationships.

Natural Disturbances

There were four years in which fires burned 500 acres or more in the watershed during the period of record. The greatest acreage burned in 1910, when 5562 acres burned, representing 6.7% of the total watershed area.

Data collected in this study do not show evidence of large changes in lake sedimentation following any of these fires (Figure B–1). The sedimentation rate did increase during the time interval of the 1910 fire, and some of this increase may have been attributed to fire. However, human land activities (described later) also occurred in the basin at this time; thus specific fire effects are difficult to discern. Moreover, no obvious ash layer was visible in the lake core around 1910. The mean sedimentation rates shown in Figure B–1 were in the midst of decade-long periods of decline during the time period of two other fires (1919, 1937). Sedimentation rates increased slightly during the period of the 1926 fires; however, extensive human disturbance of the watershed commencing in the late 1920s complicates determination of actual cause and effect. Nevertheless, a thin layer of black ash is clearly visible in the sediment core at a depth corresponding to the time period around 1926. (See photo in complete report.) This distinct ash layer undoubtedly resulted from transport of ash from the 1926 fires into the lake (either from the air or via streams). One of the 1926 fires, called the Hellroaring Fire, burned down to the shore of Whitefish Lake, and extended up into the Whitefish Range into the area that subsequently became the Big Mountain Ski Resort. Nonetheless, changes in the sediment record resulting from the 1926 fire appear short-lived, and of small magnitude, compared to other disturbance events described later.

Flooding is another natural disturbance activity which may influence lake sedimentation rates. It is well known that over the course of a given year, the of majority sediments carried by Rocky Mountain streams are transported during spring run-off. Thus during

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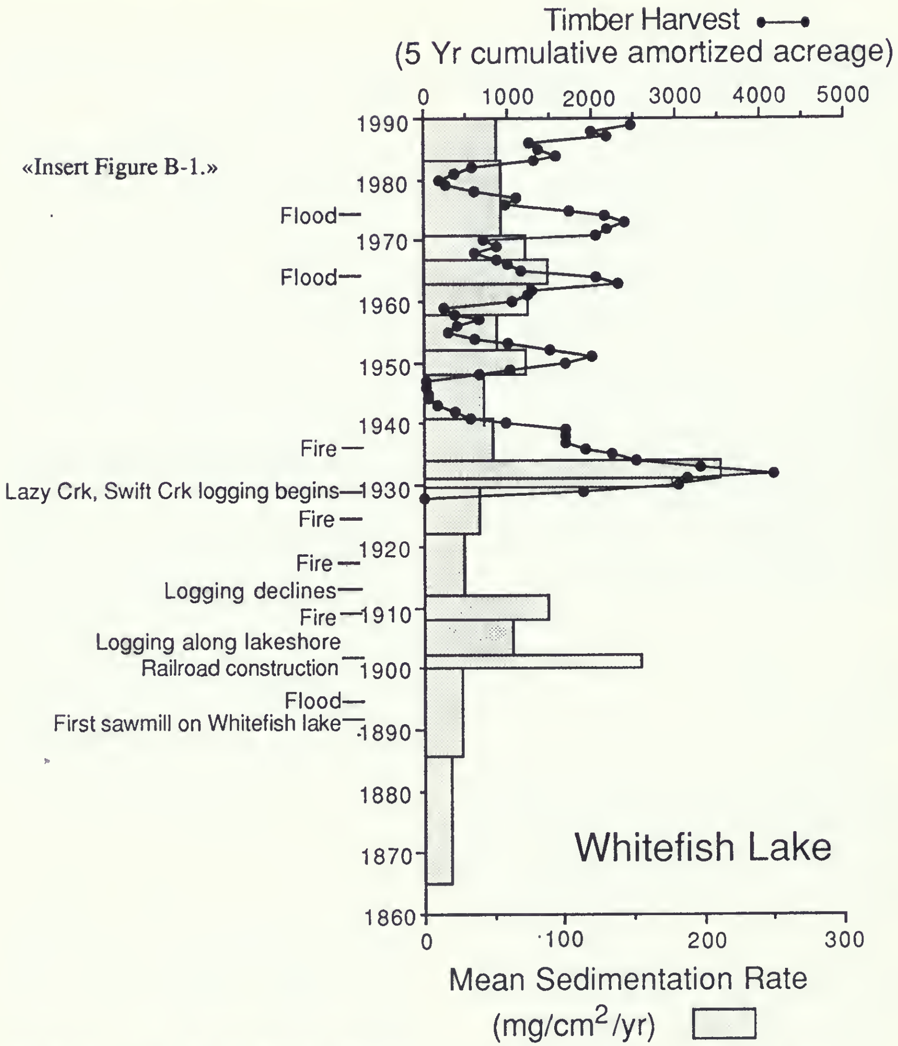

Figure B-1. Mean sediment accumulation rates in Whitefish Lake over the last 125 years, and timber harvest activity over the time period (since 1929) when harvest records could be assembled. This latter activity is expressed as a 5 year cumulative acreage, with previous 4 years acreages amortized using the Flathead National Forest new road sediment delivery coefficients.

unusually large spring flood events, one might expect to observe increased sedimentation rates in the study lakes. Three major spring floods have been observed in the Flathead Basin during the period of record. These occurred in 1894, 1964 and 1974. The largest of the three occurred in 1894, when severe spring floods produced the highest flood waters ever recorded in the Flathead Basin. Whitefish Lake was raised to its highest recorded level, 9.5 feet above the low water mark (Schafer and Engelter, 1973). The sedimentation rate estimated for the core section spanning 1894, was 26 mg/cm²/yr compared to 20 mg/cm²/yr during the previous period. For a flood of such magnitude, this increase in sedimentation rate was relatively small in comparison to subsequent changes. Furthermore, the 1894 flood was not the only land disturbance event in the watershed. Early land clearing and timber harvest activities commenced in the catchment in the late 1880s and early 1890s. The first sawmill on on the Whitefish River, just below the lake, was built in 1891. Nevertheless, in 1894, the vast majority of land in the Whitefish Lake watershed remained undisturbed by human activities. Thus it appears that major floods in undisturbed watersheds have a relatively small impact on deposition of fine sediments in lakes in comparison to extensive human disturbance activities (discussed later).

More detailed analysis of the lake sediment record over shorter time increments (<1 year) would likely reveal increased sediment deposition for a short time following major flood events such as 1894. However, such increases were not sufficient to elevate the mean sedimentation rates over the longer intervals measured in this study. Shorter water retention time in lakes during flood events may lessen their impact on lake sedimentation rates. Nevertheless, the majority of sediments entering Whitefish Lake are deposited in the lake, even during spring run-off events (Golnar 1985).

The 1964 flood was the next most intense flood event recorded in the valley. The sedimentation rate in Whitefish Lake reached levels up to 88 mg/cm²/yr during this time period; however, there were significant timber harvest activities (described later) occurring in the basin over the same time interval (Figure B–1). Thus it is difficult to isolate the effects of the flood. The smallest of the three floods occurred in 1974. As with the 1964 flood, it is difficult to determine the effect of this flood on lake sedimentation rates. The sedimentation rate was well above background levels during this period; however, significant timber harvest activities occurred during this time period as well.

The 1964 and 1974 floods washed out numerous culverts and several bridges in the Swift Creek drainage. Observations by local foresters (T. Vars, D. Klehm) indicate that widespread surface erosion did not appear to have taken place in the Whitefish Lake watershed during these floods. Nevertheless, the floodwaters were reported very muddy and carried high levels of suspended sediment. These foresters speculated that increased sediment loads associated with these floods likely came from transport of sediment previously deposited in the stream channels, together with erosion of unconsolidated banks which are prominent along Swift Creek. More detailed discussion of these floods will follow in subsequent coverage of human disturbance activities.

Another natural disturbance event which may have influenced the sedimentation rate in Whitefish Lake was the 1980 eruption of Mt. St. Helens. This eruption produced a fallout of volcanic ash across western Montana. There is no visible ash layer in the study cores, and lake sedimentation rates did not appear to increase during this time period. Nevertheless, it is possible that the most recent sedimentation rates would have been lower in the absence of volcanic ash deposition.

Human Disturbances

1865-1929. Distinct correlations between natural disturbance events and changes in fine sediment deposition in Whitefish Lake are difficult to make. By contrast, correlations between human activities in the basin and lake sedimentation are more readily apparent. Prior to the arrival of the earliest Europeans settlers in the late 1880s, the Whitefish Lake watershed was heavily forested and virtually undisturbed by human activity. Human activities in the watershed apparently were limited to an occasional small Indian fishing encampment near the outlet of Whitefish Lake (Trippett 1956, Schafer and Engelter 1973). Mean sedimentation rates in Whitefish Lake during this pre-settlement period were the lowest recorded over the 125 year period of record. Between 1865 and 1886, the estimated mean sedimentation rate was approximately 20 mg/cm^2/yr (See Figure B–1).

Due to the low sedimentation rate during the pre-settlement period, the mean sedimentation rate shown in Figure B–1 spans a relatively long time interval (21 years). Annual sedimentation rates likely varied within this long interval. However, I have no evidence to suspect that large changes occurred during the period from 1865-1886. In the first place, the mean sedimentation rate from 1865-1886 was comparable to the subsequent rate from estimated between 1886 and 1900. Second, if some unknown, natural disturbance event occurred and resulted in large short-term changes in the seemingly stable, pre-settlement sedimentation rate then one would expect to see changes reflected in the visual character of the sediment core. No distinct visual changes were evident in the core over the 30 year pre-settlement period.

The sedimentation rate increased slightly during the period from 1886 -1900, concurrent with the 1894 flood and early logging activity around Whitefish Lake. The earliest European settlers arrived in the watershed in the late 1880s (Schafer and Engelter 1973). These early residents were primarily trappers and lumbermen. A sawmill was constructed at the outlet of Whitefish Lake in 1891. Small logging operations were concentrated at the southeast end of the lake. Trees were cut, and pulled to the lake with horses whereupon they were floated down the lake, or pulled on sleds across the ice to the sawmill. This early logging activity around the lake may have contributed to the slight increase in sedimentation rate recorded between 1886 and 1900. The 1894 flood also may have contributed to this increase.

The sedimentation rate increased dramatically in the early 1900s, reaching a rate of 155 mg/cm^2/yr, representing a 7-8 fold increase over background levels. This increased sedimentation rate coincides with increased human activities in the basin including construction of a railroad line for the Great Northern Railroad along the entire 7 mile southern shoreline of the lake. The terrain along the south lakeshore is steep in places, thus considerable earth moving, and road bed leveling occurred along the lakeshore. Rail preparations along the lake also included blasting through bedrock, excavation of a tunnel near the head of the lake, and construction of a trestle and filling of Beaver Bay on the lake's southwest shore. Most of the construction occurred over a several year period prior to the official opening of the railroad in 1904.

There is little doubt that substantial amounts of sediment were dumped and/or washed into Whitefish Lake during construction of the rail line. This activity likely contributed to the sedimentation increase measured in the lake core during this period. In addition, early logging activity around the lake during this time period also may have contributed to increased sediment deposition in the lake. Unfortunately, I have found no comprehensive early logging records which allow estimation of land areas or timber volumes involved in the Whitefish Lake basin.

The lake sedimentation rate declined following construction of the railroad. Nevertheless, the deposition rate from 1902 to 1908 was 62 mg/cm²/yr, which is 3 times higher than background levels. Following completion of the railroad along the lakeshore, timber harvest was the primary human land disturbance activity in the Whitefish Lake watershed. Logging demand was fueled by the need for railroad ties as well as building materials for the new town of Whitefish (then called Stumptown), established in 1904. The Whitefish townsite, established in 1904, was located along the Whitefish River below the lake outlet. Thus clearance of land for the townsite did not likely contribute additional sediments to Whitefish Lake. A small sluice dam was operated at the outlet of Whitefish Lake for 10-15 years during this period, and lake level fluctuations associated with this dam may have increased shoreline erosion around the lake in the early 1900s.

During the early 1900s, logging activity in the watershed was limited to the immediately vicinity of Whitefish Lake and the adjacent railroad line. Little logging apparently occurred in upstream drainages since Swift Creek and other tributaries to Whitefish Lake were not suitable for carrying logs. Logging above Whitefish Lake in those days consisted of selective cutting of the larger trees in the immediate vicinity of Whitefish Lake, which were pulled to the lake using horses, and then floated (or skidded across the ice) to the sawmills (Schaffer and Engelter 1973). By 1904-1905, there were several sawmills in the area including the one on Whitefish Lake near the outlet, one downstream on the Whitefish River, and several others farther downstream on the Stillwater and Flathead Rivers. Logging camps sprung up around Whitefish Lake, and along the Whitefish River below the Lake.

The lake sedimentation rate increased to 88 mg/cm²/yr from 1908 and 1912. In addition to human land disturbance described above, the 1910 fires may have contributed to this increase.

The sedimentation rate declined to 29 mg/cm²/yr from 1912 to 1922. This decrease correlates with a decline in land disturbance activity in the watershed. Desirable timber around the lake apparently was depleted by earlier logging activities, and logging efforts shifted to other areas of the Flathead Basin.

<u>1929-Present</u>. There was a large increase in sedimentation in Whitefish Lake for a short time period in the early 1930s (Figure B–1). Sedimentation levels increased 10-fold over background, reaching levels up to 212 mg/cm²/yr. This large peak corresponds with extensive logging activities which commenced in 1929 in the Lazy Creek and Lower Swift Creek drainages above the head of Whitefish Lake. Most of this acreage was located on private lands owned by the Glacier Park Timber Company (which was subsequently incorporated into the Burlington Northern Company and then split off into Plum Creek Timber Company).

A railroad spur was constructed from the head of Whitefish Lake up the Lazy Creek drainage during this time period. Trees were cut, pulled to the rail line using horses, and transported to the mills via railcar. The Lazy Creek railspur was operated for three years, and then removed in 1932 (D. Klehm, pers. comm.). Thereafter, logs were hauled out of the Lazy and Swift Creek drainages by truck. Logging roads and skid trails were constructed throughout the areas being logged. During this period, there apparently was little concern about water quality impacts, and few, if any, regulations existed. Stream crossings were unrestricted, culverts were used infrequently, and "corduroy" roads were constructed across wet areas simply by clearing the trees and then placing timbers, side by side, across the wetlands, creating a road bed. These and other timber-related activities, including construction of the railspur, likely were major causes of enhanced erosion and sediment transport to surface waters.

The situation likely was compounded by large stream flows in the catchment during the spring of 1932 and 1933 (Schaffer and Engelter 1973). Comparatively low sedimentation rates following the large flood of 1894 suggest minimal increases in sediment deposition in the lake from an undisturbed watershed. However, high stream flows in the early 1930s likely accelerated the erosion and transport of sediment from areas disturbed by various logging-related activities in the watershed.

The correlation between logging activities and increased sedimentation in the early 1930s is striking and leaves little doubt concerning a cause and effect relationship between these two events. Thereafter, lake sedimentation rates declined in the mid to late 1930s in concert with declines in timber harvest activity .

During the mid-1930s the Civilian Conservation Corps (CCC) completed a road in the Whitefish Lake watershed which extended around the east side of the lake and up through the Swift Creek drainage. This road was used extensively for log hauling and appears to be the only other significant human-related land disturbance activity which may have affected sedimentation during the 1930s. However, the amount of land disturbance caused by the CCC road was small in comparison to area impacted by the network of roads, skid trails, and railspur used in the timber harvest efforts. The 1937 fire also may have contributed to sedimentation during this period. However the impact of this fire is believed small, due to the limited aerial extent of the fire (750 acres), and the fact that it left no visible ash layer in the lake sediments (unlike the ash layer corresponding to the 1926 fire).

During the 1940s there was little timber harvest or road building activity in the catchment. Concurrent with the decline in timber harvest and associated activity, sedimentation rates in the lake declined to 42.5 mg/cm^2/yr. A road was built in the Whitefish Lake watershed up to the Big Mountain ski resort in 1947. Although there has been considerable development at the ski area, the vast majority of this activity is located in the Haskill Creek drainage, which is outside the Whitefish Lake Basin.

Logging and associated road building activity in the Whitefish Lake watershed commenced again in earnest in 1948, primarily on the Stillwater State Forest in the Swift Creek drainage. Harvest activities peaked around 1950, declined again, and then increased through the mid-1960s. This pattern of logging activity was correlated with similar changes in lake sedimentation (see Figure B-1). Lake sedimentation rates peaked at 72 mg/cm^2/yr around 1950, declined to 52 mg/cm^2/yr in the mid 1950s, and then increased over a ten year period, peaking at 87.8 mg/cm^2/yr in the mid-1960s.

During the two decade period from the late 1940s through the 1960s, timber harvest and accompanying road and skid trail construction occurred across large parts of the watershed on Stillwater State Forest Lands, and beginning in the early 1960s on Burlington Northern lands. During the first part of this time period, activities were concentrated on the gently sloping valley bottoms. However, by the 1960s harvest and associated road building activities had moved up into steeper, more erosive areas. This twenty year period of timber harvest and associated activity appears correlated with sediment deposition in Whitefish Lake.

The 1964 flood occurred during the latter part of this trend. The sedimentation rate did not increase dramatically following this flood, the second largest on record. Rather, the sedimentation rate continued an increasing trend which was initiated in the 1950s. Although the 1964 flood likely contributed to increased erosion and sediment transport in the basin, the impact of this flood on lake sedimentation appears small in comparison to previous land disturbance activities.

From 1967-1971, the sedimentation rate declined to 72.6 mg/cm^2/yr, concurrent with a decline in logging activity in the late 1960s. From 1971 to 1983, the lake sedimentation rate was reduced to 54.7 mg/cm^2/yr. Although timber harvest was elevated at the beginning of this period, harvest declined to low levels during the latter part of this period. The 1974 flood also occurred during this period. Foresters report that the 1964 and 1974 floods did not cause extensive erosion and gullying throughout the Whitefish Lake watershed. Rather, these floods resulted in considerable erosion and channel destabilization in the main stream courses and floodplains. Although the flood of 1894 suggests that flooding of undisturbed watersheds may not result in greatly increased sedimentation rates compared to human disturbance activities, it is unclear whether the same may be said for floods occurring in watersheds disturbed by timber harvest. For example, it is possible that the floods of 1964 and 1974 flushed out sediments from the larger streams which had accumulated there as a result of past activities.

Between 1983 and 1990, the mean sedimentation rate was 52.2 mg/cm^2/yr. Timber harvest activities increased during this period; however, as in the 1970s, this increased harvest was not accompanied by comparable increases in sedimentation as in previous years. In addition to timber harvest activities, two other factors may have contributed to changes in lake sedimentation in recent years. First, the 1980 eruption of Mt. St. Helens produced a fallout of volcanic ash across western Montana. There is no visible ash layer in the study cores, and lake sedimentation rates did not appear to increase during this time period. Nevertheless, sediments were deposited in the basin as a result of this eruption. Second, recent increases in lakeshore housing and other developments along Whitefish Lake may have contributed sediments to the lake. Considerable areas of the shoreline still remain undeveloped. Although lake sedimentation rates did not increase during recent years, it is possible that observed sedimentation rates would have been lower in the absence of volcanic ash deposition and lakeshore development.

There are several factors which may explain the reduced sedimentation rate in Whitefish Lake during the 1970s and 1980s. First, this time period coincides with significant efforts on the part of government resource management agencies and the timber industry to attempt to reduce the impact of timber harvest activities on erosion and sediment transport to surface waters. A combination of mandatory and voluntary standards were adopted in an attempt to reduce the sedimentation risk. These efforts focused on minimizing erosion associated with road construction, stream crossings, and restricting harvest activities on the most sensitive lands. The sedimentation data provide evidence that these more recent logging practices may have reduced the rate of sediment transport to Whitefish Lake, in comparison to previous timber harvest activities in the basin.

Although the recent reduction in lake sedimentation may support the effectiveness of newer logging practices in reducing sediment transport, this observation must be tempered by several important observations. First, the recent sedimentation rates are still well above background sedimentation rates estimated for the period prior to human settlement. Second, the 1980s have been characterized by a series of relatively mild run-off years. It is possible that subsequent flood events could dislodge sediments deposited in the flood plain and/or pools in the stream channel during the 1980s, and carry them into the lake. If this occurs, then lake sedimentation rates would increase, as these sediments, eroded during recent years, were finally transported into the lake.

Another factor may have contributed to the reduced lake sedimentation rate observed since the early 1970s. Recent timber harvest in the Whitefish Lake watershed has been concentrated on bottom lands where the erosion potential is reduced compared to the steeper, more erosive lands in the upper regions of the watershed which were logged during the 1960s. In fact, a significant portion of the land logged in the 1980s lies on Plum Creek Timber Company lands in the Lazy Creek drainage, and represents harvest of timber regrown since the area was first logged in the 1930s. Reduced sedimentation also may be due to the fact that new road construction, a major source of sediments, was reduced somewhat in the 1980s due to availability of pre-existing roads in the drainage. Nevertheless, a portion of the recent logging activity lies on previously unlogged, steeper terrain (located on Stryker Ridge).

It is clear that recent logging efforts concentrated in the lower portion of the Basin have had less impact on sedimentation in Whitefish Lake, compared to the original roading, logging, and rail spur construction on many of the same areas in the early 1930s which produced a 10-fold increase in lake sedimentation. However, it is not clear from these data whether the recent logging practices including Best Management Practices (BMPs) have reduced sediment loadings in comparison to activities in the 1950s and 1960s. There is some evidence to suggest this; however before drawing definitive conclusions one must sort out the relative importance of improved practices together with other potential causal factors such as use of pre-existing roads, a series of comparatively mild run-off years, and other factors which may affect sedimentation such as lakeshore housing development and the eruption of Mt. St. Helens. Furthermore, it is not clear if BMPs have been utilized for a long enough period to see any effect on lake sedimentation.

Swan Lake

The history of the Swan Lake Basin over the last 120 years includes a number of natural and human-related disturbance activities. There were large floods in 1894 and 1964. As in the other lakes, neither of these floods appeared to be accompanied by large changes in lake sedimentation. However definitive conclusions about the 1894 flood are speculative in Swan Lake since this flood occurred within the oldest dated core section. There were no large fires in the Swan Basin during the period of record. Relatively small fires did occur in 1910, 1919, 1936 and 1963. The largest of these occurred in 1919 when several thousand acres burned, representing less than 1% of the Swan Lake drainage area. There were no visible ash layers in the sediment cores. Further discussion of natural disturbances is incorporated in the following chronological discussion of changes in the Swan Lake Basin.

The lowest sedimentation rate measured in Swan Lake over the 120 year period of record occurred from 1874 and 1899, prior to human disturbance activities in the basin (Figure B–2). The mean sedimentation rate during this period was 16 mg/cm^2/yr. During the first two decades of the 1900s, the sedimentation rate increased slightly to 19 mg/cm^2/yr. There are a number of factors which may have contributed to this increase. First, the dating precision for these early dates is less certain than for more recent dates. Thus, this small increase in lake sedimentation may not be significant. Nevertheless, there were a number of land disturbance activities in the basin in the early 1900s which could have contributed to an increase in lake sedimentation.

A few small homesteads began to appear in the basin in the early 1900s. Cattle were brought into in the upper part of the basin near Condon around 1910; however, early cattle ranching efforts were abandoned in 1912 (Art Whitney personnel communication). Wildfires in 1910 fire burned a small portion of the basin above Condon. A road was built along the north shore of Swan Lake in 1916-1917. In addition, fires in 1919 burned several thousand acres near the head of Swan Lake. Finally, early logging activity commenced near the head of Swan Lake in 1914. During the late teens and early 1920s, logging activities intensified. A 3 mile-long railroad spur was built from the head of Swan Lake up to S. Lost Creek. Logs were cut and then pulled by horses down to South and North Lost Creeks. In addition, a sluice dam was built on South Lost Creek during this period (Art Whitney personnel communication). Water was released by blasting out the dam during spring run-off and large numbers of logs were swept downstream into the Swan River and subsequently into Swan Lake.

The mean lake sedimentation rate increased to 33.4 mg/cm²/yr for the period between 1920 and 1933. This increase represents a doubling over background levels during pre-settlement years. There are a number of factors which may have contributed to this increase. Timber harvest activities including log drives and rail operation continued near the head of Swan Lake through the early 1920s. Log drives on S. Lost Creek and the Swan River likely caused considerable stream-bank erosion. The fires of 1919 and construction of a road along Swan Lake also likely increased sediment transport to the lake. Given the present information, it is not possible to estimate the relative importance of these various factors in contributing to increased lake sedimentation. The actual causes likely involve a combination of factors.

Some of the early land disturbance activities such as rail-line construction and early log drives appear to have preceded the lake sedimentation increase by several years or more. Delays in lake sedimentation could have been caused by the nature of the Swan River above Swan Lake. The Swan River passes through a broad meandering delta area which extends for several miles above the lake. This appears to be an area of sediment deposition. As such, this area could buffer, dampen, or delay transport of sediments from the river into the lake.

The lake sedimentation rate declined to 27 mg/cm²/yr from the mid-1930s to the mid-1940s. This decline corresponds with a decline in land disturbance activity in the basin. From the mid-1920s to 1940, there was virtually no timber harvest or road construction in the Swan Lake basin. Fires burned a relatively small portion of the upper basin in 1936.

The mean sedimentation rate increased to 37 mg/cm²/yr for the time period between 1946 and 1957. This increase corresponds with construction of the Swan Highway as well as a resumption of timber harvest activities. Work on the new highway began in the late 1940s and included relocation of portions of the old road closer to Swan Lake. In particular, this work included bank excavation and filling along the lakeshore just north of the Swan Lake campground. By 1956, the road extended past the head of the lake, up to Goat Creek, some 15 miles above Swan Lake. The road reached the head of the drainage in the late 1950s.

In addition, substantial logging and associated road building activity commenced again in

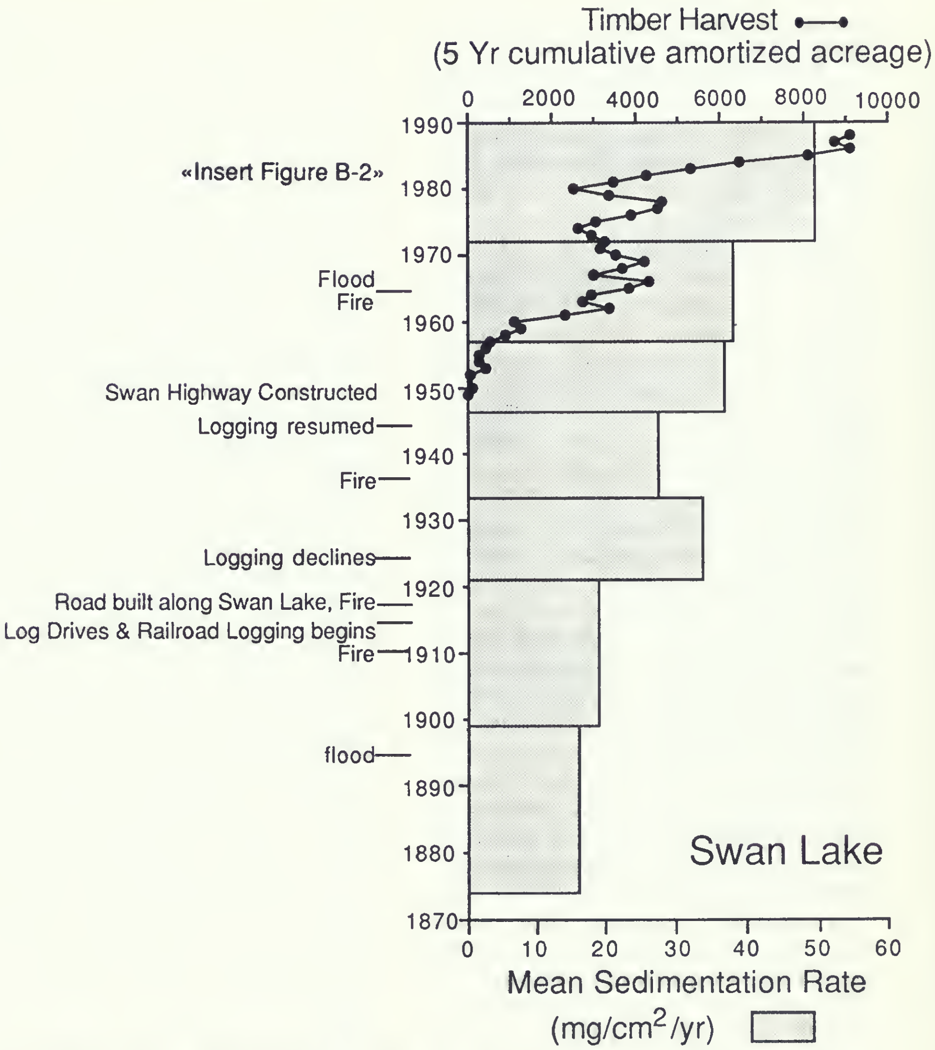

Figure B-2. Mean sediment accumulation rates in Swan Lake over the last 125 years, and timber harvest activity over the time period (since 1948) when harvest records could be assembled. This latter activity is expressed as a 5 year cumulative acreage, with previous 4 years acreages amortized using the Flathead National Forest new road sediment delivery coefficients.

the Swan Lake drainage in the 1940s. Although I was unable to obtain accurate timber harvest estimates for the 1940s, the level of harvest was comparable to the 1950s (Art Whitney, personal communication). Logging roads and skid trails were built in the lower portion of the basin during this period.

Timber harvest and associated road building activities accelerated during the 1960s and lake sedimentation rates remained elevated during this period, reaching a mean rate of 38 mg/cm²/yr from 1957 to 1972 (Figure B–2). The 1964 flood also occurred during this time interval, and these flood waters may have accelerated sediment transport to the lake. However, as in the other two study lakes, this large flood did not appear to be correlated with a large increase in lake sedimentation. A small fire in 1963 burned less than 1000 acres in the upper portion of the Lost Creek basin and also may have contributed to lake sedimentation.

The lake sedimentation rate increased again to 49.5 mg/cm²/yr from 1972 to 1990. This sedimentation rate was the highest recorded over the 120 year period of record, some threefold higher than background rates estimated for the late 1800s. This recent sedimentation increase is correlated with a large increase in logging activity and associated road building in the Swan Basin (Figure B–2). During the 1980s, timber harvest activities doubled over the levels attained during the 1960s and 1970s. During this period, timber harvest and associated road building expanded on bottom lands as well as on the flanks of the Mission and Swan mountain ranges that enclose the Swan Valley. Results from Module H (Potts 1991) indicated that a few areas in the Swan River drainage had an unusually high concentration of timber harvest activities. Much of this increased harvest occurred on private lands owned by Plum Creek Timber Company. Timber harvest on State and Federal lands declined slightly during this same time period.

Although timber harvest and related road building represent the largest human land disturbance activity in the basin in recent years, there has been an increase in construction of lakeshore cabins and homes around Swan Lake. This activity also may have contributed to increased lake sedimentation. Nevertheless, large areas of lake shoreline remain undeveloped.

Comparisons between Swan Lake and Whitefish Lake yield additional insight into the impact of lakeshore development on lake sedimentation rates. The lakeshore area around Whitefish Lake also has experienced home and recreational development. Recent development around Whitefish Lake may even exceed that around Swan Lake. However, in contrast to Swan Lake, recent sedimentation rates in Whitefish Lake do not appear to have increased. Thus it is unlikely that lakeshore development is responsible for the recent large increase in sedimentation in Swan Lake. Rather, the contrasting lake sedimentation responses appear more closely related to differences in recent timber harvest and road building activities in the two basins. As described earlier, recent timber harvest activities in the Swan Basin far exceed past acreages subject to harvest in the Basin. By contrast, recent timber harvest acreages in the Whitefish Basin fall within the level of activity reached several times over the last 60 years.

As in Whitefish Lake, the lack of large flushing flows in recent years may have resulted in substantial accumulation of sediments in the river system. This could be more of a factor in Swan Lake than Whitefish Lake, given the low gradient depositional area in the river immediately above Swan Lake. If so, then subsequent flushing flows could carry large quantities of previously eroded material into the lake.

Lake McDonald

As in the other study lakes, the lowest sedimentation rate in Lake McDonald was recorded at the beginning of the period of record. Between 1880 and 1910, the sedimentation rate was 7 $mg/cm^2/yr$ (Figure B–3). The sedimentation rate increased to 10 $mg/cm^2/yr$ between 1910 and 1935, and then increased substantially to 29 $mg/cm^2/yr$ over the period between 1935 and 1945. These increases follow construction of a two lane highway, called the Going to the Sun Road, which passes through a large part of the Lake McDonald watershed. This major road runs along the south shoreline of Lake McDonald for much of its 9 mile length, and continues up the drainage along McDonald Creek for 11 miles, closely bordering the creek in numerous locations. The road then switches back up the along steep .exposed terrain within the Lake McDonald catchment leading up to Logan Pass on the Continental Divide. Roadbed preparation included construction of numerous embankments along steep areas, blasting tunnels through bedrock, and considerable earth moving activities, all of which undoubtedly contributed sediments to surface waters.

Although the initial road was completed in the early 1930s, the sedimentation rate in Lake McDonald did not peak until the late 1930s. This apparent lag in lake sedimentation may have resulted from a delay in transport of sediments from the upper portion of the watershed down into the lake. Such delays could be due to the long distance between road building activities on the erosive slopes near the continental divide and Lake McDonald. In addition, the heavily forested streams in the McDonald Creek Basin, may have higher sediment retention rates compared to logged watersheds. Natural downfall in the stream bed serve as stream sediment traps. Furthermore, unlogged watersheds may have smaller maximum stream flows compared to logged watersheds, which could result in reduced sediment flushing capacity in undeveloped watersheds (see Hauer, module A). Thus there are a number of factors which may have contributed to the apparent delay in sediment deposition in Lake McDonald.

The sedimentation rate declined rapidly in the 1960s. Revegetation and stabilization of the original road cuts likely reduced sediment delivery to surface waters along the road. This reduction also may have been partially due to stabilization of the road surface by paving in the 1950s. It is possible that periodic regrading of the road together with road dust stirred up by cars along this heavily travelled road may have contributed to elevated sedimentation levels in Lake McDonald. After the road was paved, the potential contribution of road dust to lake sedimentation would have been greatly reduced.

The mean sedimentation rate for the 29 year period from 1961 to the present declined to 14 $mg/cm^2/yr$. This rate is roughly twice the rate estimated for the late 1800s. Reasons for the continued existence of sedimentation levels above background are speculative. The 1980 eruption of Mt. St. Helens left no visible band of sediments in the core. However, it is possible that this eruption caused increased sediment deposition in Lake McDonald. Thus, it is possible that in absence of this eruption, the most recent sedimentation rate may have been closer to levels measured in the late 1800s. In addition, there have been limited human activities in the basin which could have contributed to recent sedimentation rates. These activities include ongoing maintenance on the Going to the Sun road, as well as limited construction projects around the lake. However, future plans call for significant "improvement" along much of the Going to the Sun road.

Although the Going to the Sun Road represents the largest human land disturbance activity in the Basin, there has been some other

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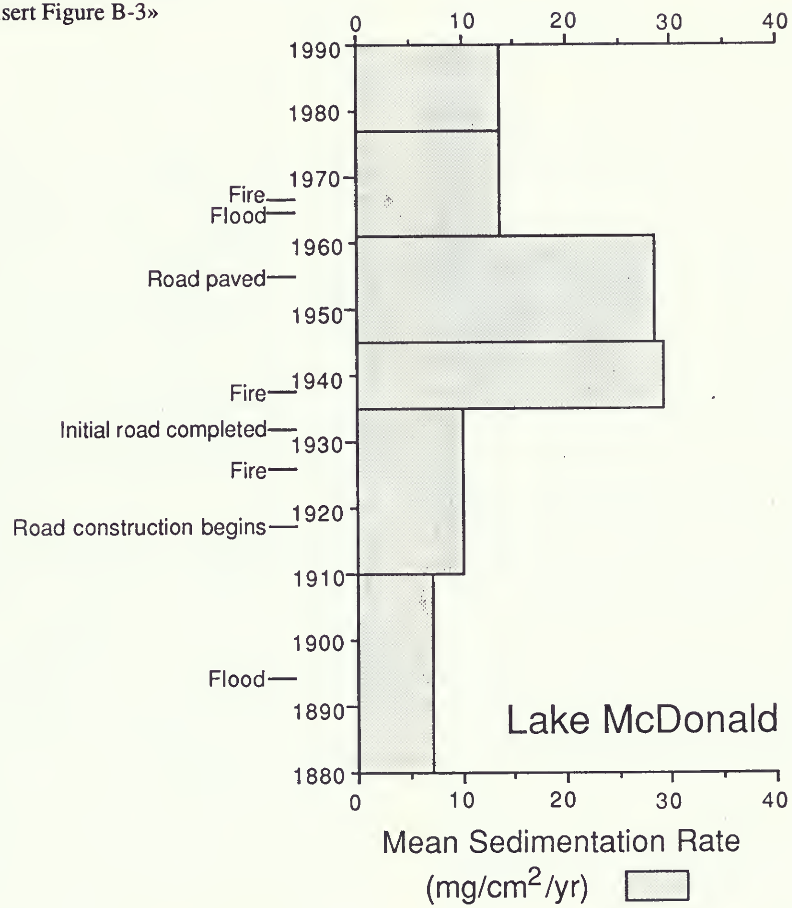

Figure B-3. Mean sediment accumulation rates in Lake McDonald over the last 135 years.

limited development around the lake. This includes construction of several lodges along the lakeshore as well as small lakeshore cabins limited to the extreme east and west ends of the lake. Much of this activity occurred in the early part of this century, and does not appear to have noticeably influenced mean lake sedimentation rates shown in Figure B–3.

Natural disturbance events did not appear to be closely correlated with major changes in sedimentation rate in Lake McDonald. As in the other study lakes, there were no large fires in the basin during the period of record. One of the larger fires in the watershed occurred in 1967, when approximately 5% of the watershed burned. In addition, the 1964 flood occurred during this interval. Sedimentation rates during the time interval following the flood and fire remained well below those achieved during the 1940s and 1950s. Sedimentation rates may have increased for a short time after these events, however any such increases were dampened out by subsequent sedimentation rates. Smaller fires in 1926, 1937 may have contributed to increased sedimentation in Lake McDonald; however, the impact of these natural disturbances are likely masked by the road building activities.

None of the McDonald Basin fires or floods left visible bands in the sediment core during the 110 year period of this study. However, a thick black band is visible in the Lake McDonald core at a depth of 18-19 cm, which is below the oldest strata dated in this study (see complete report for details and photograph). This band may correspond to extensive fires which burned during the year 1735. Several large fires burned portions of the Lake McDonald Basin that year, including much of the steep landscape leading down to the shoreline of Lake McDonald (Barrett 1988). Sedimentation rates must have increased dramatically in Lake McDonald following this large fire, given the appearance of this thick (1 cm) ash layer in the lake sediments. Unfortunately, I was unable to estimate the actual sedimentation rate during this period since current sediment dating techniques are not available for close estimation of dates over 150 years old.

Management Implications

This study shows that past land disturbance activities are correlated with increased sediment deposition rates in all three study lakes. Sedimentation rates increased 3 to 10 fold over background levels, corresponding with logging, road building, and/or railline construction in the watersheds. Results of the BMP audits revealed that the greatest number of BMP deviations were related to road drainage and road maintenance(Potts, Module F). Lake sediment analyses suggest that over time, the sediment contribution from roads (such as the Going to the Sun Highway) is greatly reduced. Recent sedimentation rates in Whitefish Lake provide equivocal evidence for reduced sedimentation rates using newer forest practices. However, sedimentation rates in Swan Lake reached their highest estimated level within the last 15-20 years concurrent with a doubling of timber harvest activities in the basin in the last 10 years. Results from Potts (Module H) indicate that a few areas in the Swan drainage had an unusually high concentration of harvest activities. Water quality violations resulting from recent timber harvest activities also have occurred in the Swan Basin.Therefore, if recent forest practices employed in the 1970s and 1980s do indeed reduce sediment delivery compared to older practices, then any such improvement appears to have been offset by the recent large expansion of harvest activities, at least in the Swan Lake Basin. In addition, sediments resulting from past activities may still be in transit in the river systems above Swan and

Whitefish Lakes.

Since increased sedimentation may have negative impacts on both stream and lake environments the large increases in sediment loadings documented in this study represent an important environmental concern regarding both past and projected activities. Hauer and Blum (Module C) reported that increased timber harvest activities were correlated with increased suspended sediments, nutrients, and algal growth in streams. These results are consistent with studies of timber harvest in other areas (Likens et al. 1970, Lowe et al. 1986). Weaver and Fraley (Module D) showed that increased levels of fine sediments in fish spawning areas in streams may substantially reduce the spawning success and viability of bull trout and westslope cutthroat trout. These species are native to the Flathead Basin and have been designated sensitive species by the U.S. Fish and Wildlife Service and species of special concern by the state of Montana.

Unfortunately there are no comparable techniques available for quantifying historical changes in the sediment composition in important salmonid spawning and rearing areas of streams. However, since the majority of lake sediments transported to lakes enter via streams, past large increases in erosion, transport, and subsequent deposition of fine sediments in the lake environment would likely have been accompanied by increased deposition of sediments in portions of the stream channels. Thus I expect that past increases in sedimentation documented in this study had negative impacts on stream ecosystems in these watersheds. The fact that estimated sedimentation rates in Swan Lake reached their highest levels within the last 15-20 years raises concerns about the potential negative impact of increased sedimentation in important bull trout and Westslope cutthroat trout streams above Swan lake, and the effect of future land disturbance activities on these streams.

Another concern regarding increased sedimentation in surface waters is undesirable stimulation of algal productivity and lake eutrophication. Sediments represent a major source of nutrients to surface waters (Mortimer 1941; Perry and Stanford 1982). Data from the Flathead Basin show a close correlation between suspended sediment concentrations in streams and stream nutrient (phosphorus and nitrogen) concentrations (Spencer and Hauer 1991, Ellis and Stanford 1988, Stanford and Ellis 1988, Stewart 1983, Golnar 1985). Detailed nutrient budget analyses from Whitefish and Flathead Lakes indicate that 60-70% of the annual phosphorus and nitrogen loadings come from stream inputs, with the bulk of this input associated with turbid spring run-off and unrelated to point source inputs (Stanford and Ellis 1988, Stewart 1983, Golnar 1985).

Lakes serve not only as sediment traps, but also nutrient traps. Golnar (1985) estimated that 74% of the phosphorus entering Whitefish Lake was retained in the lake. While some nutrients may become permanently buried in the lake sediments, a portion of the nitrogen and phosphorus pool entering the lake environment remains in the water column. In studies on Flathead Lake, Dodds, Priscu, and Ellis (1991) showed that phosphorus and nitrogen could be recycled in the water column in a matter of hours or less. Thus, past increases in nutrient loadings are still likely affecting the lake ecosystems.

Phosphorus and nitrogen availability have been shown to be the primary factors limiting algal production in lakes in the Flathead Basin (Dodds and others 1989, Spencer and Ellis 1990). Stanford and Potter (1976) and Perry and Stanford (1982) hypothesized that stream sediments in the Flathead Basin, upon entering the lake environment, may settle out and strip phosphorus and algae from the lake water column. However Stewart (1983) disproved this hypothesis and concluded that algal production in Flathead Lake appeared to be stimulated by sediment additions. Furthermore, controlled bioassay experiments demonstrate that addition of sediments from a variety of locations in the Flathead Basin stimulate algal growth (Perry and Stanford 1982, Ellis and Stanford 1988). Although the bioavailability of phosphorus contained in turbid spring run-off in the basin may be only 6% (Ellis and Stanford 1988), this still represents the largest single nutrient source to Flathead Lake (Stanford and Ellis 1988). Thus, enhanced erosion and sediment transport, as documented in this study, have undoubtedly contributed to lake eutrophication, an undesirable process resulting from stimulation of algal growth, reduced water clarity, oxygen depletion and other related problems (Wetzel 1988).

At present, Whitefish Lake is in a transitional state between oligotrophy and mesotrophy (Golnar 1985). Late-summer hypolimnetic oxygen depletion already is occurring in the lake. Golnar (1985) concluded that Whitefish Lake lies near a critical threshold of "excessive" phosphorus loading, as determined from the nutrient loading model of Vollenweider and Kerekes (1980). Other lakes in the Flathead Basin are threatened by increased nutrient loadings. Flathead Lake also is undergoing eutrophication as evidenced by increased algal production (Stanford and Ellis 1988). As with Whitefish Lake, scientists have described Flathead Lake as being on a threshold, such that increased nutrient loadings seriously threaten water quality in the lake (Bahls 1986, Stanford and Ellis 1988). Other lakes in the Flathead Basin including Ashley Lake and Lake Mary Ronan develop summer hypolimnetic oxygen depletion and are also at risk from increased nutrient loadings.

During 1990, dissolved oxygen levels in Swan Lake declined to 0.5 mg/L near the bottom of the south basin (see data in the complete report). This appears to be the lowest dissolved oxygen measurement recorded in any of the large lakes in the Flathead Basin which are noted for their high water quality. There are smaller seepage-type lakes in the basin (for example, Echo, Loon, and Foy's Lakes) which have more severe dissolved oxygen depletion, together with algal blooms and reduced water quality which characterize these more productive lakes. Two limnological studies of Swan lake conducted in the mid-1970s also reported dissolved oxygen depletion in Swan Lake but not nearly to the extent of the 1990. Unfortunately, the measurements made in the 1970s were taken from shallower depths than in 1990. Although the 0.5 mg/L measurment made in 1990 is significantly lower than any previously recorded level, there is insufficient data to say with any certaintly that DO concentrations have declined significantly since the 1970s. Nevertheless, reduction of hypolimnetic oxygen levels to near anaerobic conditions in Swan Lake (regardless of the past history) is surprising and alarming, especially given the short water residence time in the lake.

The existing data documenting substantial oxygen depletion in Swan Lake have led to the lake being described as an impaired lake (Loren Bahls, Montana Water Quality Bureau, personal communication). Reduced oxygen concentrations undoubtedly exclude trout and other aquatic organisms from portions of the lake in late summer and fall. Evidence from numerous scientific studies indicate that if oxygen concentrations decline just a little bit more in Swan Lake, than one can expect a rapid increase in available phosphorus in Swan Lake (Mortimer 1941, Wetzel 1988). This would be caused by the release of sediment-bound phosphorus into the lake water when oxygen concentrations decline to 0 mg/L at the sediment-water interface. If this happens, the eutrophication process would accelerate rapidly, leading to a deleterious cycle of further oxygen depletion, which in turn stimulates more widespread release of sediment-bound phosphorus into the lake water. Such changes would likely lead to serious declines in water quality, including nuisance algal blooms, poor water clarity, and degradation of fisheries habitat. This negative scenario of events has been documented in numerous lakes in other parts of the country, frequently fueled by increased human activities and development in the lake basin.

The USEPA (1976) estimated that 99.7% of the total phosphorus load to Swan Lake was from non-point sources. Unfortunately, there is insufficient data available at present to allow compilation of a comprehensive nutrient budget for Swan Lake in 1990, or to fully explain the cause of the dissolved oxygen depletion in the lake. There may be other important sources of nutrients and/or organic loadings to the lake that also have contributed to current water quality conditions (e.g. shoreline homes, upstream development, and natural sources). However, regardless of the actual cause, the reduced oxygen levels in Swan Lake raises serious concerns about any future increases in nutrient loadings to the lake.

Available data provide evidence that increased sediment loadings have negatively impacted stream and lake resources in the Flathead Basin. Symptoms of aquatic resource degradation include elevated fine sediment levels in key bull trout and westslope cutthroat trout spawning streams (see Weaver and Fraley, Module D) and increased sediment loadings to lakes. The cause-and-effect relationship between increased fine sediment loading (from whatever source) and spawning habitat degradation is well understood. However, given the limited data available on nutrient budgets from the study lakes, it is more difficult to assign a direct causal relationship between increased sediment loadings and lake water quality. Nevertheless, there is no question that sediments represent a significant source of nutrients to lakes in the Flathead Basin. Increased nutrient loadings to lakes typically lead to increased productivity, and given sufficient productivity, water quality problems such as periodic oxygen depletion and algal blooms.

The present study provides evidence for a link between past human land disturbance activities (primarily related to timber harvest and road building) and increased fine sediment (and nutrient) loadings to lakes. These data provide evidence from the Flathead Basin that human disturbance activities increase fine sediment deposition to a greater extent than natural disturbance events. Similar conclusions have been drawn from studies in other regions (Hutchinson and others 1970, Davis 1975, Batterbee and others 1985, see reviews in Berglund, 1986).

Considerable efforts are presently being made to reduce the input of nutrients to lakes in the Flathead Basin, in an attempt to maintain the high water quality which characterizes many of its lakes. Examples of nutrient control measures being employed include a ban on the sale of phosphate detergents in 1985 and nearly $20 million dollars towards construction and/or expansion of wastewater treatments plants and collection facilities for phosphorus removal. New, or upgraded treatment plants, are either in place or under construction for all major communities upstream from Flathead Lake. Similar efforts should be directed at other controllable nutrient sources in the basin such as timber harvest and related road building and road maintenance.

Conclusions

(1) Lake coring analyses indicated that past human land disturbance activities were correlated with increased fine sediment deposition up to 10-fold in Whitefish Lake, 4 to 5-fold in Lake McDonald, and 3-fold in Swan Lake.

(2) Lake McDonald

(a) Initial road construction and upgrading of the Going to the Sun Road from Lake McDonald to the continental divide at Logan Pass during the 1930s and 1940s were followed by substantial increases in sediment deposition in Lake McDonald.

(b) After the road was paved in the early 1950s the sediment deposition rate in Lake McDonald declined substantially; however, sedimentation rates still remain above background levels.

(3) Whitefish Lake

(a) Large increases in sediment deposition occurred during the early part of this century (1900-1910) and were attributed to railroad construction along the lakeshore, logging activity around the lake, and the 1910 fires.

(b) The largest sedimentation increases occurred in the early 1930s when substantial logging and associated road and railline construction were concentrated in the Lazy Creek drainage and Lower Swift Creek, near the head of Whitefish Lake.

(c) Sedimentation rates also were elevated near 1950 and again in the 1960s. These increases were largely attributed to substantial logging and associated road building activity, which extended to upper portions of the Whitefish Lake drainage.

(d) Recent logging activities in the Whitefish watershed appear to have had less impact on lake sedimentation that past activities. Possible explanations for reduced sediment impacts include use of pre-existing roads, logging on less-erodible lands, improved logging and road building practices, and a series of comparatively mild run-off years.

(4) Swan Lake

(a) Sedimentation rates increased during the 1920s following a number of land disturbance activities including road construction, fires, and timber harvest activities that included sluice dams, log drives, and rail line construction.

(b) Sedimentation rates increased again in the 1950s in concert with a resumption of timber harvest and road building activities.

(c) From the early 1970s up to the present, the lake sedimentation rate reached its highest level. This increase occurred as timber harvest intensified, more than doubling the previous maximum harvest level in the basin.

(5) Results from the three study lakes suggest that roads represent the greatest disturbance activity resulting in increased fine sediment transport and deposition in the downstream lakes. Once constructed, the sediment contribution appears to decline.

(6) Changes in deposition of fine sediments directly attributed to natural stream banks, floods, fires, and other natural erosion processes during the past 150 years were much smaller that changes attributed to human disturbance activities in these two watersheds. Previous speculation that erosion of naturally unstable stream banks and other natural sources may mask sediment inputs attributed to human activities appear unfounded with respect to fine sediment deposition in Whitefish Lake, Swan Lake, and Lake McDonald.

STUDY MODULE C:

THE EFFECT OF TIMBER MANAGEMENT ON STREAM WATER QUALITY

BY F. RICHARD HAUER AND CHRISTOPHER O. BLUM

This section of the *Final Report* summarizes a study of the same name published by the Flathead Basin Commission (723 Fifth Avenue East, Kalispell, Montana 59901).

The Effect of Timber Management on Stream Water Quality

By F. Richard Hauer[1] and Christopher O. Blum[2]

Introduction

The primary purpose of this study was to determine if past forest management practices (logging and related roads) have affected stream-water quality. Based on this primary purpose, we established the following goals:

(1) to evaluate techniques that would be useful in examining the effects of forest management practices on stream water quality,
(2) to implement studies using those techniques to evaluate water quality and the conditions of streams affected by forest practices, and
(3) to establish a baseline from which a longer monitoring plan might be developed.

We defined stream-water quality as including physical, chemical, and biological variables of stream ecosystems, but did not include issues specifically associated with fisheries management. We founded the hypotheses of this study on the concern that timber harvest and associated activities may result in increased sediment and nutrient loading to streams. These physical and chemical factors may, in turn, affect the basic structure and function of the stream food web through increased stream-algae production and changes in stream invertebrates.

Specific study objectives were to examine streams in watersheds with different levels of timber harvest and to determine if there have been measurable changes in:

(a) sediment transport or nutrient concentrations,
(b) the accumulation of attached algae expressed as surface density of Chlorophyll α and ash-free-dry-mass, and
(c) the structure and function of the stream invertebrate community.

We chose 12 stream sites for study based on differing levels of timber management, stream size, and basin characteristics. Three study stream sites had no timber harvest or road building in the basin, five study sites were identified as having low to moderate activity in the drainage above the site, and four sites were distinguished as having a high level of timber harvest and roads in the watershed. Ideally, a study designed to answer the question, "Do current forest management practices affect stream water quality?" would entail a water sampling frequency of 15 to 20 times per year and seasonal sampling for algal growth and invertebrates over a 3 to 5 year period. However, we were limited in this study by both time and financial resources. Nonetheless, we found

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distinct, quantifiable, and statistically significant differences between streams associated with differing levels of timber management activity for several of the water quality parameters.

Sediment Transport and Nutrient Concentrations

We compared sediment transport, nutrient concentrations, and various physical variables between watershed sites and upstream/downstream study sites. We selected four sampling dates to represent time periods of distinctly different stream discharge dynamics — three during the spring runoff period (that is, rising limb of runoff, peak runoff, falling limb of runoff) and stable stream discharge (that is, autumn low flow). Total suspended sediment, both organic and inorganic combined, was studied because of the broad effect of sediment on all stream biota (for example, microbial growth, attached algae growth, invertebrate communities, fish reproduction). Dissolved and particulate forms of nitrogen ($NO_{2/3}$; NH_3; total persulfate nitrogen —TPN) and phosphorus (soluble reactive phosphorus — SRP; total phosphorus — TP) were analyzed because of their importance to algal production and their well-documented effects on eutrophication of downstream lakes.

We found that all study sites had low concentrations of suspended particulates during base flow conditions and, not surprisingly, that maximum suspended materials occurred during June, the peak in spring runoff in 1990. However, results also indicated that total suspended sediment (TSS) was closely associated with stream gradient; and, that among paired streams, higher annual maximum concentrations of total suspended sediment was found among streams associated with moderate to high levels of timber management compared to streams from no to low activity watersheds. (See Table C–1.)

We also compared annual mean nutrient values paired as no to low activity watershed sites with moderate to high activity watershed sites. Results of these comparisons revealed that statistically there was a very high significant difference ($p < 0.001$; Low Activity < High Activity) among all forms of nutrient variables combined and a significant difference ($p < 0.1$; Low Activity < High Activity) among TPN and TP concentrations. (See Table C–1.)

Differences were particularly distinct for maximum concentrations of total phosphorus and total persulfate nitrogen. (See Figure C–1.) In this cross-watershed comparison, total phosphorus (TP) and total persulfate nitrogen (TPN) concentrations were progressively higher between respective no to low activity, moderate activity and high activity paired watersheds.

Stream Algae

We monitored attached algal growth and biomass in each of the study streams by placing artificial substrates in riffle habitats. Artificial substrates consisted of pre-leached, non-glazed clay tiles held above the stream bed by a solid frame to minimize invertebrate colonization and grazing. We removed three substrate samples from each stream after 2, 4, and 8 weeks of incubation and algal colonization. We analyzed the collected algae from each substrate for Chlorophyll α concentrations and ash-free-dry-mass. Analyses of these data revealed a general pattern of increased algal growth associated with higher levels of watershed management activity. (See Figure C–2.) Stream sites within no to low activity watersheds had very low algal production. Sites located within streams of moderate watershed activity had

Table C-1. Wilcoxon's signed-rank comparison of mean total suspended solids (TSS), three forms of nitrogen (NH_3, $NO_{2/3}$, and total persulfate nitrogen — TPN), and two forms of phosphorus (soluble reactive phosphorus — SRP and total phosphorus — TP) between no to low activity watershed sites paired to moderate to high activity watershed sites.

Nutrient Variable	Summary Statistic Low Activity < High Activity	Level of Significance
TSS	$p = 0.043$	*
All nutrient variables combined	$p = 0.0053$	***
NH_3	$p = 0.715$	ns
$NO_{2/3}$	$p = 0.465$	ns
TPN	$p = 0.068$	*
SRP	$p = 0.273$	ns
TP	$p = 0.068$	*

ns = not significant
* = significant ($p < 0.10$)
** = highly significant ($p < 0.05$
*** = very highly significant ($p < 0.01$)

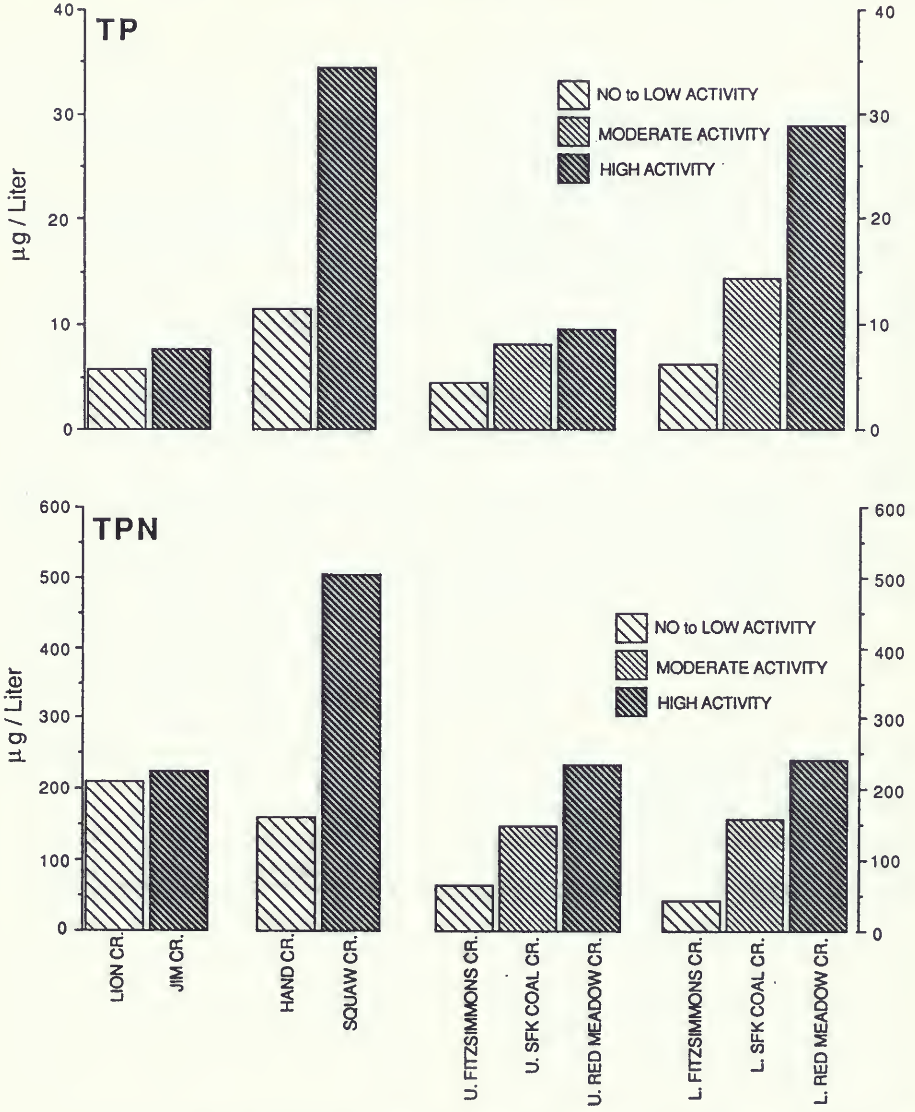

Figure C-1. Annual maximum total phosphorus (TP) and total persulfate nitrogen (TPN) at each of ten paired watershed sites. Site pairs appear as directly comparable sites with different levels of timber management activity in the watershed.

comparatively moderate levels of algal density; while the highest Chlorophyll α concentrations were measured within streams in high timber management activity watersheds. An analysis of variance (ANOVA) of maximum Chlorophyll α data, in which sites falling into the three different activity levels were collectively compared, revealed that algal production was significantly less ($p < 0.05$) among no to low activity sites when compared to sites representing high timber management activity watersheds. Moderate activity sites were not statistically significantly different from either high or low activity sites, although the general trend of increased algal density above that observed for low activity watersheds is readily apparent. (See Figure C–2.) This trend was not significant concerning algae mass accumulations because of the high variance between similar activity sites; however, mean values of ash-free-dry-mass were generally much higher at high activity stream sites.

Based on this study, which involved a range of stream types and sizes with a mix of open and closed canopy sites among streams with differing levels of upstream timber harvest, increased timber harvest results in increased stream algae production even in streams that are well canopied. These results are consistent with the pattern of increased nutrient concentrations among streams flowing from high activity basins. Thus, these data are mutually supportive from an ecological perspective.

Zoobenthos

We collected benthic samples during autumn to determine quantitatively and qualitatively the possible effects of timber management on benthic invertebrates. We were limited to a single sampling period because of time and financial constraints. However, autumn is characterized among Flathead Basin zoobenthic species as having high biodiversity and broad trophic function. Thus, some of the differences between sites should be observable during this period.

We identified a total of 67 taxa from the 12 study sites. Most taxa were identified to the species level of organization, particularly the mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*) and caddisflies (*Trichoptera*). Our analysis of taxa frequency revealed high variability between sites that reflect the multitude of factors affecting zoobenthic species distributions and abundance (for example, stream type, stream size, habitat, substrate, source of food, stream velocity, competition, predation). Measures of taxa richness and Simpson's index of equitability (Figure C–3) at each study site were highly variable. No specific pattern of either reduced richness or taxon dominance could be attributed to any of the measured physical or nutrient variables, or specifically increased algal production. This was documented by no significant relationships being apparent employing non-parametric tests of taxon abundance among paired comparative streams.

This does not mean that timber management has no effect on stream zoobenthos or that zoobenthic organisms are a poor indicator of change in stream ecosystems, but rather that within the constraints of this study, no statistically significant patterns associated with the level of timber management activity could be determined.

Summary

(1) An experimental design of stream sites was chosen for study of the effects of timber management activity on the water quality of Flathead Basin streams. Stream sites were chosen to represent a broad cross-section of stream and wa-

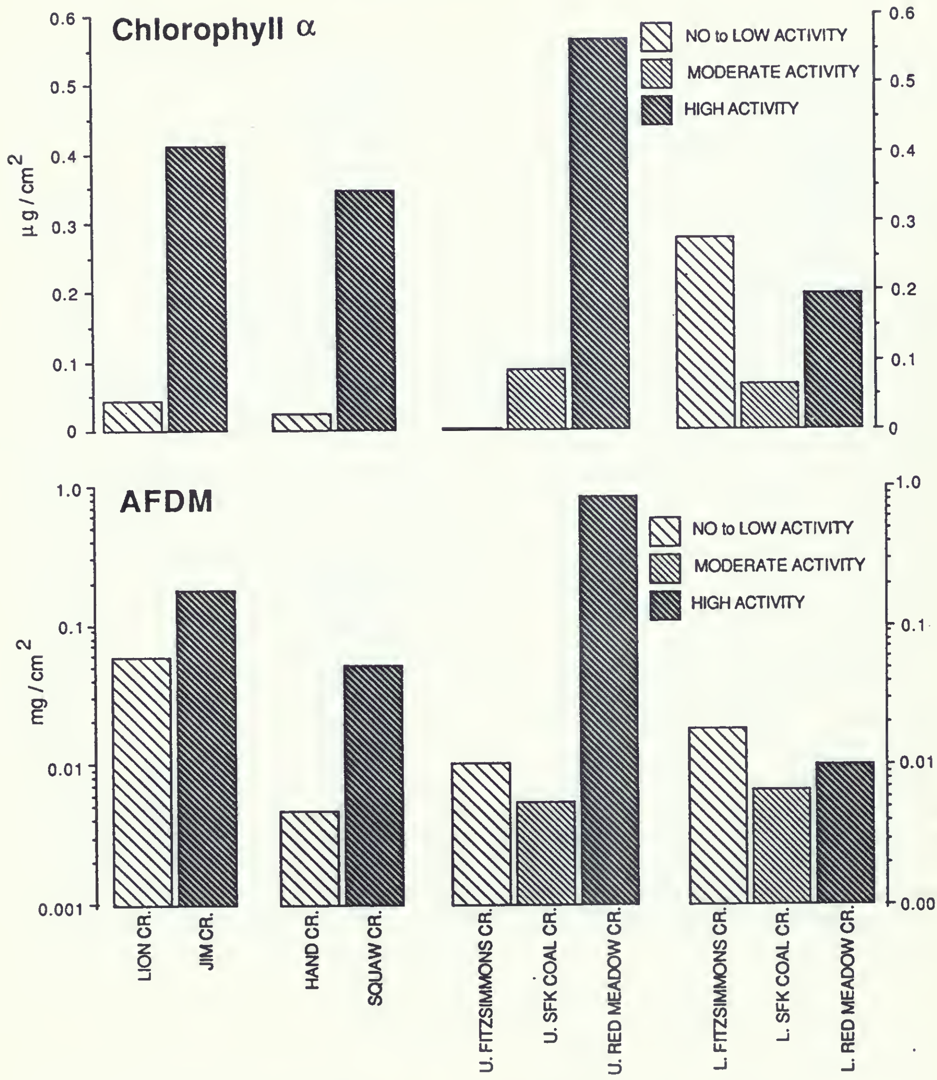

Figure C- 2. Summer maximum Chlorophyll a and ash-free-dry-mass (AFDM) at each of ten paired watershed sites. Site pairs appear as directly comparable sites with different levels of timber management activity in the watershed.

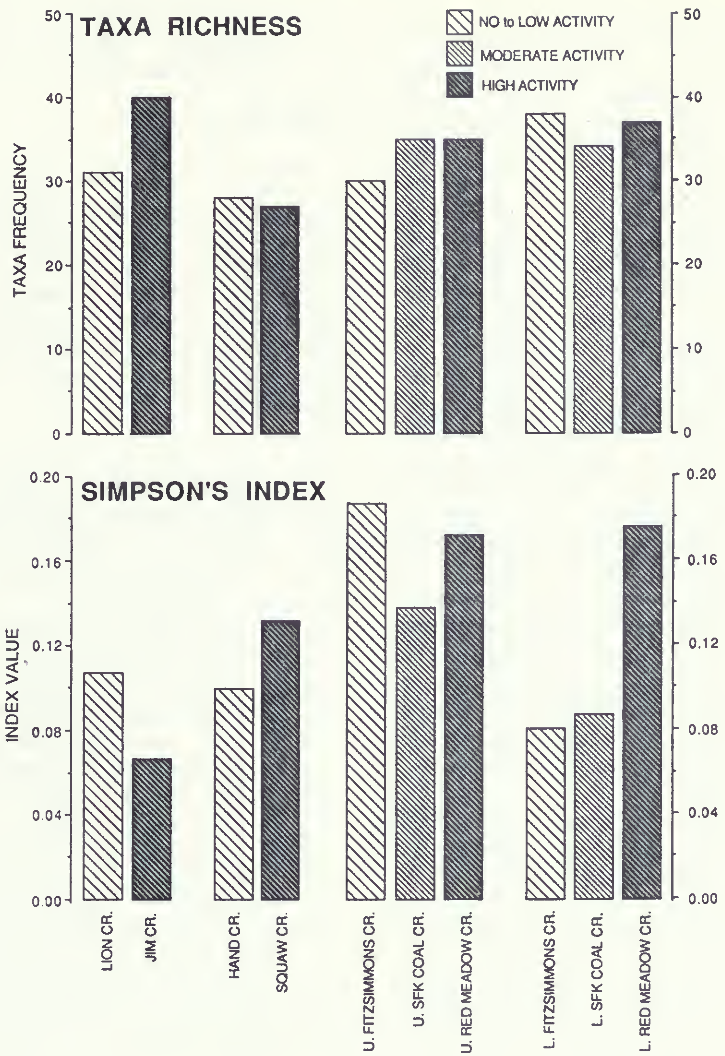

Figure C-3. Autumn taxa richness and Simpson's index of riffle habitat macroinvertebrates at each of ten paired watershed sites. Site pairs appear as directly comparable sites with different levels of timber management activity in the watershed.

tershed types; from very small streams to large creeks, from no to high timber harvest activities in the watershed, and from widely different geologies (Swan drainage, North Fork drainage, Upper Stillwater drainage, Upper Tally Lake drainage).

(2) Concentration of sediment in transport was closely associated with the slope of the watershed and the gradient of the stream at the sample site. However, comparison of annual maximum suspended sediment concentration between paired-stream study sites revealed that moderate and high activity watersheds had a general pattern of significantly higher suspended sediment concentration ($p < 0.05$) than their respective no to low activity watershed site.

(3) Nutrient concentrations, particularly N and P fractions of Total Phosphorus (TP) and Total Persulfate Nitrogen (TPN), were significantly higher ($p < 0.1$) among stream sites within high activity watersheds compared to streams from no or low activity watersheds.

(4) Attached algae growth was measured at each sample site using artificial substrates for colonization of algae. The density of Chlorophyll α on substrates incubated in streams with high timber management activities in the watershed was significantly higher ($p < 0.05$) than in streams from no or low activity in the watershed.

(5) No significant differences in invertebrate trophic relationships, taxa richness, or taxa equitability were observed between streams of differing watershed timber management activity; however, there was a general trend toward increased species richness associated with harvest activity.

Conclusions

Because the conclusions drawn from this research are best expressed holistically as they relate to the other empirical studies, most conclusions and recommendations of this study appear in the "Summary of Conclusions" and "Summary of Recommendations" sections at the end of this document. However, the following points should be made here in the context of the cooperative studies:

(1) Timber management activity has a quantifiable effect on stream water quality in several important areas:
   (a) increased maximum suspended sediment concentration during spring runoff,
   (b) increased mean annual concentration of algal growth nutrients (nitrogen and phosphorus), and
   (c) increased maximum algal density on the stream bottom.

   These factors not only profoundly affect the ecology of the stream, but also that of downstream lakes.

(2) Future monitoring of timber management effects on streams should concentrate on measurement of suspended sediment, nutrient concentrations (TP, SRP, TPN, $NO_{2/3}$, NH_3), and attached algal growth (Chlorophyll α density).

(3) Monitoring of macroinvertebrates will be most useful when used to define the most severe of impacts that result in catastrophic degradation of the stream biota. General baseline data of invertebrates is therefore needed among streams at risk.

Study Module D:

Fisheries Habitat and Fish Populations

By Thomas Weaver and John Fraley

This section of the *Final Report* summarizes a study of the same name published by the Flathead Basin Commission (723 Fifth Avenue East, Kalispell, Montana 59901).

FISHERIES HABITAT AND FISH POPULATIONS

By Thomas Weaver[1] and John Fraley[2]

INTRODUCTION

The fisheries study module focused on fisheries habitat and fish populations. Westslope cutthroat trout and bull trout are native to the Flathead system. Montana recognizes these fish as "Species of Special Concern," and affords them special protection. Sediment originating from road building and other land management activities can reduce embryo survival and emergence of both species and decrease the available space in the streambed used for rearing by bull trout. Spawning/incubation by both species and rearing by bull trout are the life stages most sensitive to sediment effects. Sediment deposition can also affect rainbow and brook trout, as well as other fish species, by covering spawning gravel, filling in pools, and altering food habits. However, these other fish species are not good indicators of sediment effects on rearing due to specific behavioral differences.

The objectives of this study were to (1) evaluate the relationship between sediments and westslope cutthroat and bull trout emergence success, (2) determine capabilities of several methods of measuring fish habitat quality, (3) examine cause and effects relationships between forest practices and fish habitat and populations, and (4) recommend methods for a monitoring program for fish habitat and populations in the basin, relative to forest management.

In this study module, we concentrated on 29 tributaries. (See Table D–1 and Figure D–1.) These tributaries were located in the following drainages: Swan, Stillwater/Whitefish, North Fork, Middle Fork, and South Fork of the Flathead River. These tributaries were chosen by the study team to be representative of the variety of geography, habitat, land ownership and fisheries conditions in the basin. We selected specific variables to indicate quality of spawning habitat (McNeil coring and Whitlock-Vibert box sampling), rearing habitat (substrate scoring), juvenile population levels (electrofishing estimates) and spawner use (redd counts). A complete description of the study design, methods, and findings is available in the Final Module Report.

RESULTS AND DISCUSSION

EMBRYO INCUBATION STUDIES

Researchers examined emergence success and quality (length and weight) of westslope cutthroat trout fry in relation to varying levels of fine substrate materials in a natural stream environment. We simulated natural incubation conditions in a stream (Chapman 1988) by constructing cells with particle sizes, egg pockets, and egg planting depths characteristic of natural westslope cutthroat trout redds. A significant negative relationship ($p < 0.005$) ex-

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[2]John Fraley was a Fish and Wildlife Program Officer with the Montana Department of Fish, Widlife and Parks in Kalispell, Montana.

Table D-1: List of study streams showing activities scheduled for each stream included as part of the Flathead Basin Commission Cooperative Forest Practice, Water Quality, and Fisheries Study.

Area/Drainage: Stream	Fish Monitoring Activity				
Stillwater					
Fitzsimmons Creek	MN	WV	SS	–	P
Chepat Creek	MN	WV	SS	–	P
Swan River					
Elk Creek	(MN)	(WV)	(SS)	(RC)	(P)
Goat Creek	(MN)	WV	SS	(RC)	(P)
Squeezer Creek	(MN)	WV	SS	(RC)	P
Jim Creek	(MN)	WV	SS	RC	P
Lion Creek	(MN)	WV	SS	(RC)	(P)
Piper Creek	MN	WV	SS	RC	P
Island Unit					
Freeland Creek	MN	WV	SS	RC	P
Tally Lake					
Fish Creek	(MN)	WV	SS	RC	P
Hand Creek	(MN)	WV	SS	–	P
Swift Creek	MN	WV	SS	RC	P
Sheppard Creek	MN	WV	SS	–	P
Squaw Tributary	MN	–	SS	–	P
North Fork					
Big Creek	MN	WV	SS	RC	(P)
Coal Creek DH	(MN)	WV	(SS)	(RC)	(P)
NF Coal Creek	(MN)	(WV)	(SS)	(RC)	(P)
SF Coal Creek	(MN)	(WV)	(SS)	(RC)	(P)
Cyclone Creek	MN	WV	SS	RC	P
Red Meadow Creek	(MN)	WV	SS	–	(P)
Whale Creek	(MN)	WV	SS	(RC)	(P)
Trail Creek	(MN)	WV	SS	(RC)	P
Middle Fork					
Granite Creek	(MN)	WV	SS	(RC)	–
Challenge Creek	(MN)	WV	SS	(RC)	(P)
Ole Creek	–	–	SS	(RC)	(P)
Morrison Creek	(MN)	WV	(SS)	(RC)	(P)
South Fork					
Hungry Horse Creek (2)	(MN)	WV	(SS)	(RC)	(P)
Margaret Creek	(MN)	WV	(SS)	(RC)	(P)
Tiger Creek	(MN)	WV	(SS)	(RC)	(P)
Emery Creek	(MN)	WV	(SS)	(RC)	(P)

Fish Monitoring Activity Codes:

( ) Denotes Montana Department of Fish, Wildlife and Parks (MDFWP) and/or Flathead National Forest (FNF) work supported by other funding.

__ Denotes MDFWP work contracted by FNF.

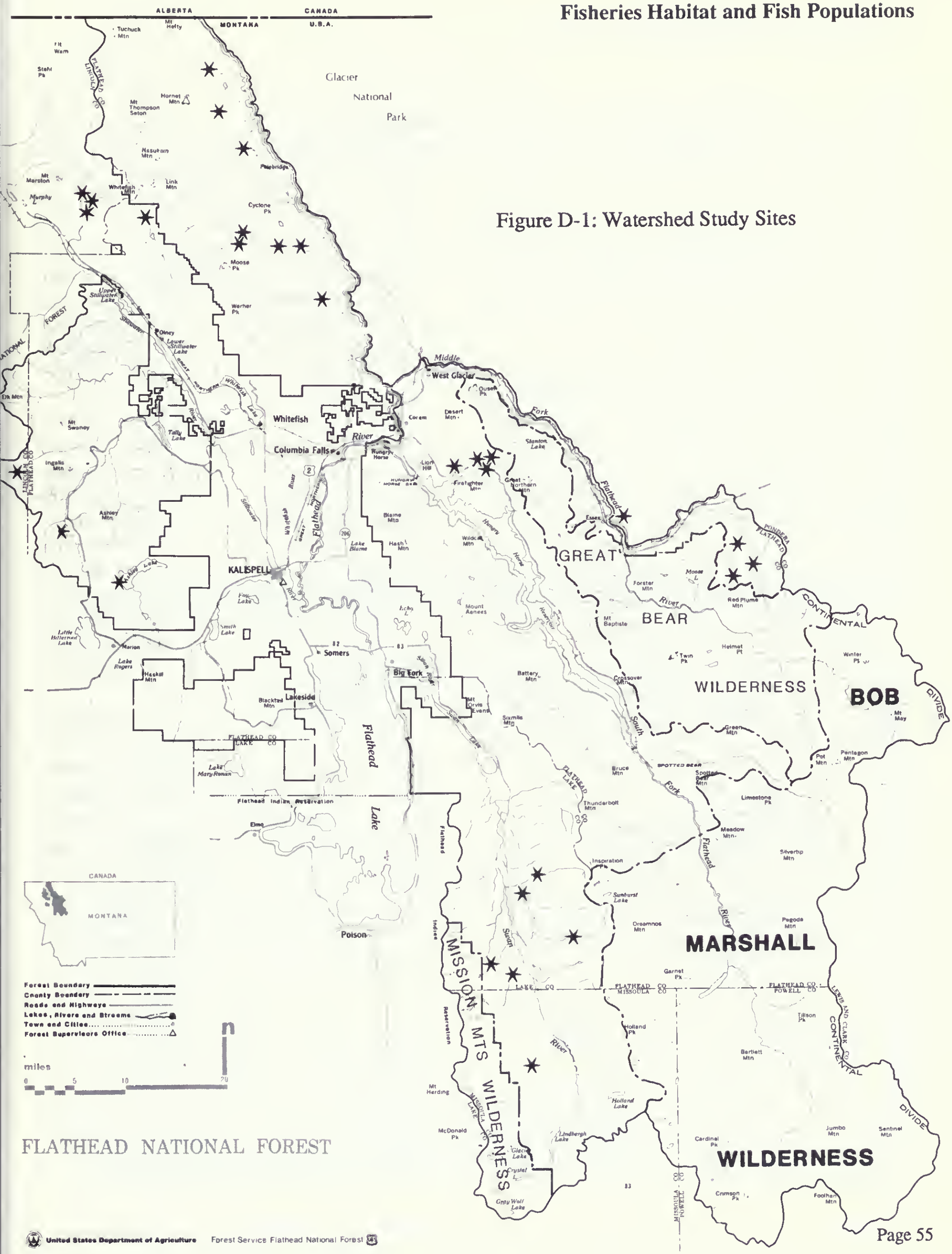
MN McNeil gravel core samples (12 cores at each site; 4 cores on each of 3 transects).

SS Substrate scores (15 transects in a 150 m stream section).

RC Redd counts (total number of spawning sites in a stream section).

P Fish population estimates (electrofishing estimates for a 150 m stream section)

Figure D-1: Watershed Study Sites



isted between fry emergence success and the percentage of substrate materials less than 6.35 mm in diameter. (See Figure D–2.) Mean fry emergence success was 76, 55, 39, 34, 26, and 4 percent, respectively, in cells containing 0, 10, 20, 30, 40, and 50 percent materials less than 6.35 mm. We measured no distinct trend in emergence timing, and no significant differences in length or weight of fry emerging from the six gravel mixtures.

Biologists also examined emergence success of bull trout fry in relation to varying levels of fine substrate materials in a natural stream environment. We simulated natural incubation conditions in a stream (Chapman 1988) by constructing cells with particle sizes, egg pockets, and egg planting depths characteristic of natural bull trout redds. We found a significant negative relationship ($p < 0.005$) between fry emergence success and the percentage of substrate materials less than 6.35 mm in diameter. (See Figure D–3.) Mean adjusted fry emergence success was 79, 64, 44, 39, 26, and 4 percent respectively, in cells containing 0, 10, 20, 30, 40, and 50 percent materials less than 6.35 mm. A major portion of the observed mortality resulted from fry entombment in the heavier sediment levels.

Results from these studies showed an embryo mortality of about two-thirds when 35 percent of the gravel comprising the incubation environment is smaller than 6.35 mm. At 40 percent smaller than 6.35 mm, approximately three-quarters of the embryos deposited did not emerge successfully.

Freeze Coring in Spawning Sites

Project personnel collected frozen core samples from migratory westslope cutthroat trout redds in Hungry Horse Creek. This work was recommended to verify the locations and structure of egg pockets in natural spawning sites (Chapman 1988). This sampling confirmed the setup used for the incubation studies. We found an egg deposition depth of greater than 10.0 cm but less than 20.0 cm. We observed an undisturbed layer of large angular particles (mostly greater than 50.8 mm and some greater than 76.1 mm) in the frozen samples beginning around 17.8 cm below the surface and extending downward. It is likely that these particles prevented deeper excavation by the fish and formed the "floor" of the redds.

In all samples, less fine material (percent less than 6.35 mm) was present in the 10.0 cm depth band containing the eggs than in the one immediately above it. Likewise the geometric mean (Platts and others 1979) and Fredle index (Lotspeich and Everest 1981), two other measures of particle size, were greater in the egg pocket strata. A comparison of the mean values for egg pocket depth bands and the 10.0 cm strata above it showed significant differences for both the geometric mean particle size and the Fredle index ($p < 0.05$).

It is possible that the female fish cleaned the substrate in the egg bearing strata in the process of spawning (Chapman 1988). Although embryos may incubate in egg pockets having greater geometric mean particle size and less fine sediment, emerging fry must still migrate up through the material covering the egg pocket to successfully reach the stream. Entombment by this material resulted in the majority of the mortality observed during the incubation studies.

Field crews collected frozen core samples from bull trout redds in Lion Creek. We found no eggs in these samples, but other interesting observations were made. Researchers have reported that some fish spawning in higher levels of fine sediment may build larger redds, but deposit eggs at a shallower depth (Everest and others 1987). Our work supported these findings although our sample size was small.

Figure D-2: Relationship between numbers of westslope cutthroat trout fry successfully emerging from replicates of six gravel mixtures and the percentage of material smaller than 6.35 mm in each mixture

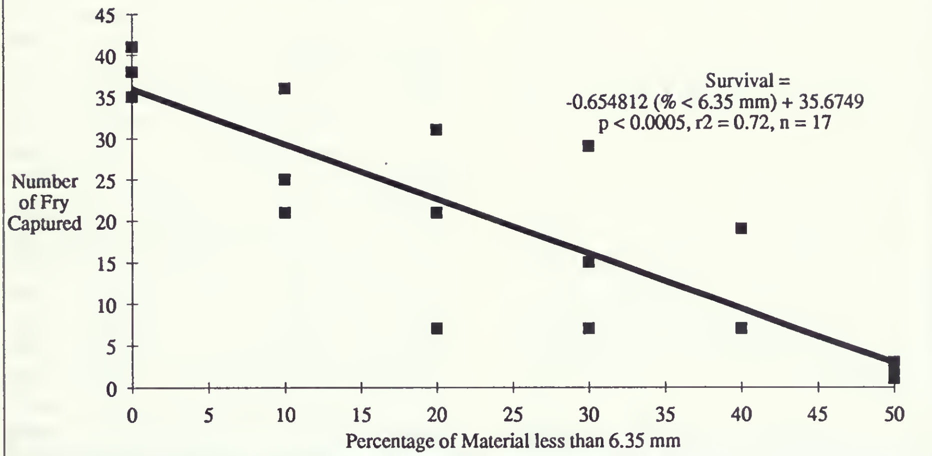
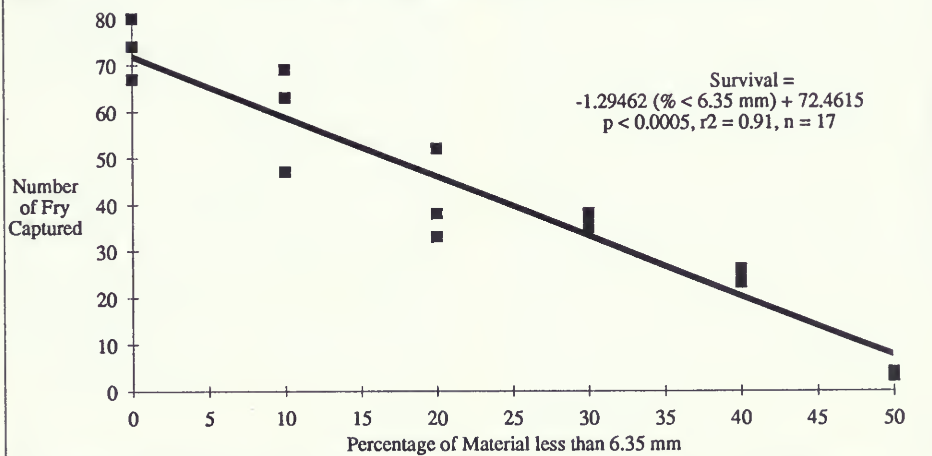


Figure D-3: Relationship between number of bull trout fry successfully emerging from replicates of six gravel mixtures and the percentage of material smaller than 6.35 mm in each mixture



Bull trout redds are much larger than the cutthroat trout redds we sampled. The greater area of disturbed gravel makes it more difficult to obtain egg pocket samples. We feel this effort should continue to further refine embryo survival modeling. Data from even a small number of bull trout egg pockets would help our predictive ability.

Streambed Coring

The size range of streambed material is indicative of spawning and incubation habitat quality. Most research shows negative relationships between fine sediment and embryo survival to emergence (Chapman 1988). We used a McNeil Corer (McNeil and Ahnell 1964) to collect streambed samples which were dried and sieve analyzed to determine the particle size composition. As the percentage of fine material increased, habitat quality decreased.

Median percentages (12 per site) of streambed material less than 6.35 mm ranged from 24.8 percent in Chepat Creek to 50.3 percent in Jim Creek. The values at our 29 sampling sites averaged 36.3 percent. The maximum variability observed within individual streams was about 20 percentage units. To obtain an indication of natural sediment levels, we averaged the McNeil core sampling results for the nine watersheds where the Sequoia index (Potts and McInerney 1990) was 0.00, indicating no disturbance. This calculation resulted in an average value of 31.7 percent. Of these nine watersheds, we know of significant natural sediment sources with high levels of channel storage above the study areas at two sites — Elk Creek and Lion Creek. The Sequoia Model does not consider natural sediment sources or other natural phenomena which may alter streambed conditions. Eliminating these two sites from calculations of the average condition in "undisturbed" watershed results in a value of 29.8 percent.

Researchers have collected McNeil core samples in selected spawning areas annually during the past ten years. This period of record gives an idea of how spawning area gravel composition changes from year to year. The average annual change in the median percentage ($n = 12$) of material smaller than 6.35 mm in samples from Big, Coal, and Whale Creeks has been 4.8 percentage units; changes ranged from 0.1 to 10.7 percentage units. These drainages are mainly roaded timber lands. The average annual change in the Trail Creek samples during this same ten year period was 2.1 percentage units (range = 0.2 to 5.2). The Trail Creek spawning area is not subject to the ground-disturbing activities in the drainage above, which are occurring in Big, Coal, and Whale Creeks. The average annual change observed in "undisturbed watersheds" (Sequoia index = 0.0) where we have completed five annual samplings is 3.0 percentage units (range = 0.4 to 5.5).

We believe McNeil core sampling is reflective of streambed conditions in the specific sampling sites. Once one year of information exists, annual sampling provides an adequate monitoring tool for detecting changes in streambed composition. However, more cost efficient methods would allow us to increase the level of this activity basin-wide.

Whitlock-Vibert Boxes

As an attempt to validate a more cost efficient method of monitoring streambed composition, field crews planted a total of 380 Whitlock-Vibert (W-V) boxes during the study. Other researchers have reported good results in substituting these slotted, plastic boxes for McNeil core sampling (Reiser and others 1987, Wesche and others 1989). We recovered 182, for a recovery rate of 48 percent. Other researchers reported a 58 percent recovery rate for boxes in a similar field test (Reiser and others 1987).

Most of our box loss occurred during a November, 1989, precipitation event. We noted substantial movement of streambed material at this time. We lost all W-V boxes planted in several South Fork and Middle Fork Flathead tributaries. Some box displacement and loss occurred in the North Fork Flathead and Swan River drainages as well. In all, we lost well over 100 W-V boxes during this event.

Of the 182 boxes recovered, we analyzed 109 in the laboratory for fine sediment accumulation and density. The overall linear regression of submerged weight of a W-V box against the percentage of material less than 4.75 in the associated McNeil core sample showed a significant positive relationship ($p < 0.05$), although considerable scatter existed ($r = 0.48$). When we compared the mean percentage less than 4.75 mm in the W-V boxes (12 per site) with the mean from McNeil coring (12 per site) at each study area, we observed significant differences ($p < 0.05$) in eight of the 12 comparisons. We expected the mean percentages from the boxes to be in closer agreement with the coring data.

Based on these findings, we question whether W-V boxes are suitable for monitoring streambed conditions at this time. However, we believe the potential advantages of this technique over presently used methods warrant greater effort at developing a W-V box program for the Flathead Drainage. Questions relating to box planting, box loss, timing of box planting, and best marble size will require more evaluation. A change in box design to use perforations 6.35 mm in diameter would yield more usable results and might eliminate questions about the maximum particle size which could enter the boxes.

Streambed Substrate Scoring

Rearing fish, particularly juvenile bull trout, often occupy open spaces between or under streambed materials. Substrate score (Crouse and others 1981) is an index indicating the habitat's potential for rearing and overwintering fish. Silt-free streams with large rocks and lots of hiding space would get a high substrate score. As the streambed becomes more imbedded with silt and sand, the substrate score would become less. Scores above 11.0 generally indicate good rearing habitat quality. Other researchers have specified 9.0 as the minimum critical standard (Shepard and others 1984).

Substrate scores ranged from 8.8 in Freeland Creek to 13.2 in Piper Creek. Based on the above values, Jim and Freeland creeks are at or below the minimum recommended level. Squeezer, Lion, and Coal Creeks scored between 9.0 and 10.0. Sixty-two percent of the scores basin-wide were 11.0 or higher.

Linear regression of juvenile bull trout densities (number of trout per 100 m^2) against substrate score showed a significant positive relationship ($r = 0.54$, $p = 0.05$; $n = 15$). (See Figure D–4.) Densities of other trout species in our study streams did not correlate with this index. This is probably due to behavioral differences. These species are not strongly associated with the streambed at the time our estimates were made.

During winter, long portions of stream channel are completely ice- and snow-covered. Field crews have also observed extensive areas of anchor ice. In other areas, upwelling ground water keeps certain sections open, even during extreme conditions. These open areas may support the majority of the winter rearing in the streams where they occur. It is likely that if we could obtain estimates of juvenile fish densities during this winter period instead of late summer, a stronger relationship would result.

Figure D-4: Relationship between transformed substrate scores and juvenile bull trout densities (number of trout less than 75 mm per 100 m2) for 15 tributary reaches in the Flathead River Basin during 1989

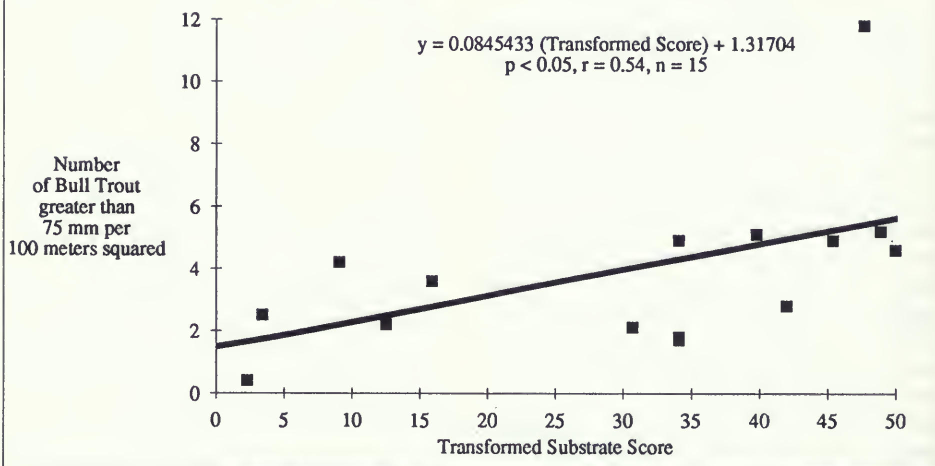


Table D-2: Summary of 1989 rainbow trout spawning site inventories.

Creek		Redd Numbers 1989
Fish	(Ashley Lake)	27
Freeland	(Lake Mary Ronan)	200
Hillburn	(Lake Mary Ronan)	19

Spawning Site Counts

We completed rainbow trout spawning site inventories on Freeland and Fish Creek drainages. (See Table D–2.) The number of spawners using these two streams during spring of 1989 appeared similar to observations made during past years.

We completed westslope cutthroat trout spawning site inventories on all proposed streams. (See Table D–3.) In the South Fork drainage, redd numbers in Hungry Horse Reservoir tributaries were up during 1989. Our index stream in the Middle Fork drainage contained fewer redds in 1989 than observed during 1982 surveys when we documented 24 redds. Since we had made no previous counts in Cyclone Creek in the North Fork drainage, comparisons with existing data are not possible.

We conducted bull trout spawning site inventories in established monitoring areas basinwide. (See Table D–4.) We identified 244 and 158 bull trout redds in North and Middle Fork Flathead tributaries, respectively. They were approximately nine percent above the ten-year average figure. (See Figure D–5.) We counted 371 redds in the Swan River tributary monitoring areas during 1989. This was approximately 57 percent above the seven-year average. (See Figure D–6.) Our numbers do not represent the total annual spawning run. We estimate our annual counts represent about 35 percent of the annual Flathead Lake spawning escapement and about 75 percent of the Swan Lake run.

Table D-3: Summary of westslope cutthroat trout spawning site inventories from 1986-1987

		Redd Numbers			
Drainage	Creek	1986	1987	1988	1989
South Fork:	Hungry Horse	93	28	123	118
	Margaret	18	10	37	43
	Tiger	10	7	46	61
	Emery	88	74	108	129
Middle Fork:	Challenge	- -	- -	- -	19
North Fork:	Cyclone	- -	- -	- -	31

Table D-4: Summary of annual bull trout spawning site inventories between 1979 and 1989.

Drainage/ Stream	Redd Numbers 1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
North Fork:											
Big	10	20	18	41	22	9	9	12	22	19	24
Coal	38	34	23	60	71	53	40	13	48	52	50
Whale	35	45	98	211	141	133	94	90	143	136	199
Trail	34[a]	31[a]	78	94	56	32	25	69	64	62	51
Total	117	130	217	406	290	227	168[b]	184	277	269	324
Middle Fork:											
Morrison	25[a]	75	32[a]	86	67	38	99	52	49	50	63
Granite	14	34	14[a]	24	31	47	24	37	34	32	31
Lodgepole	32	14	18	23	23	23	20	42	21	19	43
Ole	–	19	19	51	35	26	30	36	45	59	21
Total	71	142	83	184	156	134	173[b]	167	149	160	158
Flathead Drainage Total	188	272	300	590	446	361	341	351	426	429	482
Swan:											
Elk	–	–	–	56	91	93	19	53	162	201	186
Goat	–	–	–	33	39	31	40	56	31	46	34
Squeezer	–	–	–	41	57	83	24	55	64	9[b]	67
Lion	–	–	–	63	49	88	26	46	33	65	84
Total	–	–	–	193	236	295	109	210	290	321	371

[a]Counts may be underestimated due to incomplete survey.
[b]High flows may have obliterated some of the redds.

Figure D-5: Summary of annual bull trout redd counts in the North and Middle Forks of the Flathead River Drainage from 1979 through 1989.

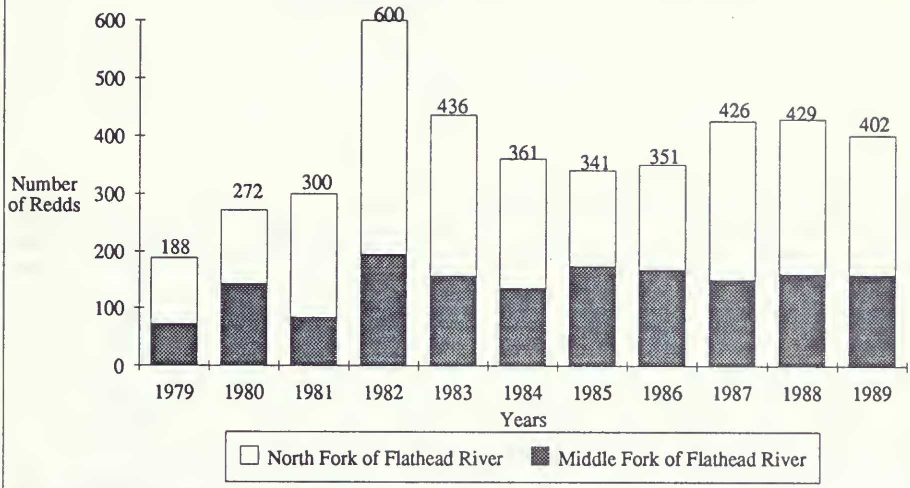
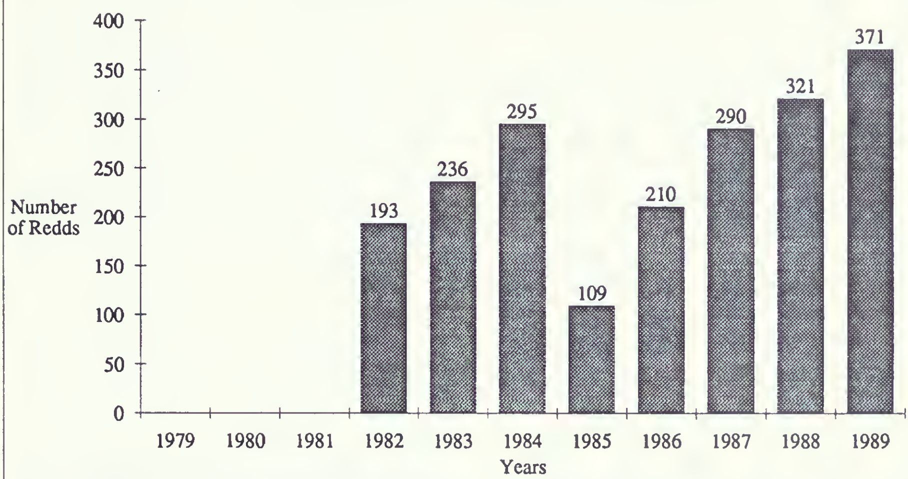


Figure D-6: Summary of annual bull trout redd counts in the Swan River Drainage from 1982 through 1989.



Population Estimation

Mean total fish density for the 28 electrofishing areas was 13.1 trout *greater than or equal to* 75 mm per 100 m^2 of stream surface area. Densities ranged from 2.1 in Jim Creek to 75.8 in Freeland Creek. (See Table D–5.) Tributary streams to large lakes which support rearing populations of rainbow trout (Freeland and Fish Creeks) and westslope cutthroat trout (Hungry Horse, Tiger, Margaret, and Emery creeks) had the highest densities. Eastern brook trout populations in Sheppard and Hand Creek were also present at high densities. (See Table D–5.)

Juvenile bull trout are much more substrate oriented than these other trout species. Because of their close association with the streambed, bull trout are better indicators of the influence of fine sediment. We compared juvenile bull trout densities with substrate scores and found a significant positive relationship ($r = 0.54$; $p = 0.05$; $n = 15$) existed. (See Figure D–3.) Previous work showed a similar but somewhat stronger relationship for Swan River tributaries supporting juvenile bull trout (Shepard and others 1984).

We observed a mean juvenile bull trout density of 3.8 fish *greater than or equal to* 75 mm per 100 m^2. Densities ranged from 0.4 in Jim Creek to 11.8 in Morrison Creek. (See Table D–5.) Swan River tributaries supported juvenile bull trout at an average density of 2.7 fish *greater than or equal to* 75 mm/100 m^2 while the North and Middle Forks averaged 4.6 fish/100 m^2. Eastern brook trout are present in the Swan River tributaries but not in the North and Middle Fork sections.

Information on juvenile bull trout densities and streambed conditions in winter rearing areas may show stronger relationships than we obtained using late summer electrofishing. It is possible that winter rearing habitat may control juvenile bull trout densities in our study streams. Any ground-disturbing activities proposed above these critical rearing areas should be carefully planned and monitored. In general, these findings support the use of bull trout as an indicator species for future monitoring efforts.

Linkage between Risk Assessment and Fisheries

To demonstrate the linkage between land management activities and fisheries we used simple linear regression analysis. We used arcsine transformations on the output from the Sequoia index and H_2OY model. This is a standard procedure used when data are percentages and the values are limited in range and close to zero. We evaluated the McNeil coring data and the substrate scores as percent differences.

$$X = \frac{\text{observed value - minimum value}}{\text{minimum value}} (100)$$

This was necessary to expand the range of the data.

Results showed significant relationships ($p < 0.05$) between McNeil coring results and output from both Sequoia and H_2OY models. The correlation with the Sequoia index was slightly stronger than with the H_2OY model. (See Figures D–7 and D–8.) Comparisons of substrate scores with output from both the risk assessment index and H_2OY model also show significant relationships ($p < 0.05$). In this case the correlation with Sequoia was slightly weaker than with H_2OY results. (See Figures D–9 and D–10.)

Although these relationships are significant, considerable scatter exists. There are several reasons which may explain a portion of this scatter. First, to keep this analysis as simple as possible we elected to use linear regression techniques. By including more variables in a multiple regression analysis it is likely we could

Table D-5: Comparison of total fish density, juvenile bull trout density, and juvenile cutthroat trout density (for those ≥ 75 mm/100 m^2) calculated from electrofishing estimates at 28 sites around the Flathead Basin during 1989.

Stream	Area of Section	Total Fish Density # ≥ 75 mm/100 m^2	Juvenile Bull Trout # ≥ 75 mm/100 m^2	Juvenile Cutthroat Trout # ≥ 75 mm/100 m^2
Big	1695	5	4.9	
Challenge	705	19.6		19.4
Chepat	540	13.9		13
Coal DH	1410	7.4	4.2	
Elk	1605	3	2.8	
Emery	810	11.2		11.2
Fish	375	16.5		
Fitzsimmons	645	9.1		4.5
Freeland	360	75.8		
Goat	930	6.6	3.6	
Hand	735	12.4		
Hungry Horse	810	14.3		14.3
Jim	1155	2.1	0.4	
Lion	1710	3	2.2	
Margaret	465	25.6		25.6
Morrison	1095	11.8	11.8	
North Coal	900	10.6	5.1	5.7
Ole	810	5.5	4.9	
Piper	795	14.3	4.6	3.4
Red Meadow	1170	7.2	1.7	5.5
Sheppard	795	15.6		1.4
South Coal	810	9	1.8	7.3
Squaw Trib.	345	5.2		
Squeezer	960	9.9	2.5	
Swift	1245	4.4		4.2
Tiger	555	41.4		41.4
Trail	915	5.5	5.2	
Whale	1545	2.4	2.1	

Figure D-7: Relationship between the arcsine transformations of Sequoia model output and transformed McNeil core results for 28 watersheds in the Flathead River Basin during 1989

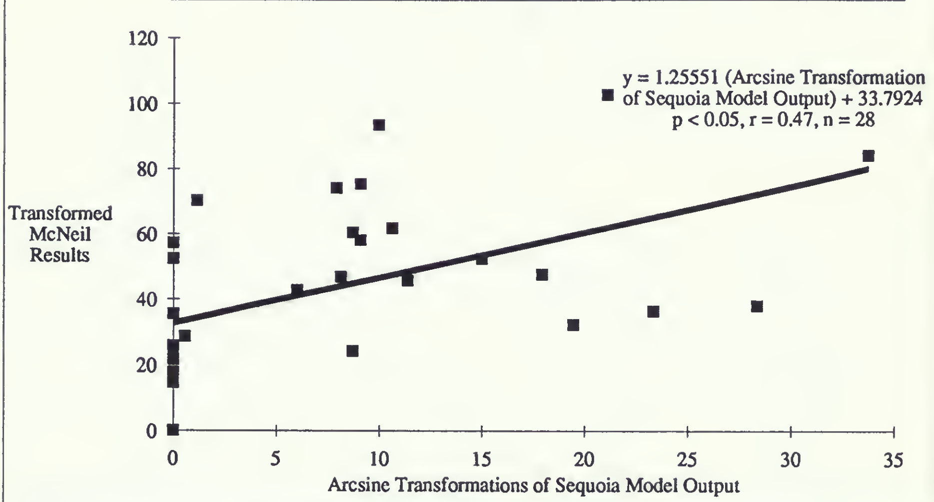


Figure D-8: Relationship between the arcsine transformations of H2OY model output and transformed McNeil core results for 28 watersheds in the Flathead River Basin during 1989

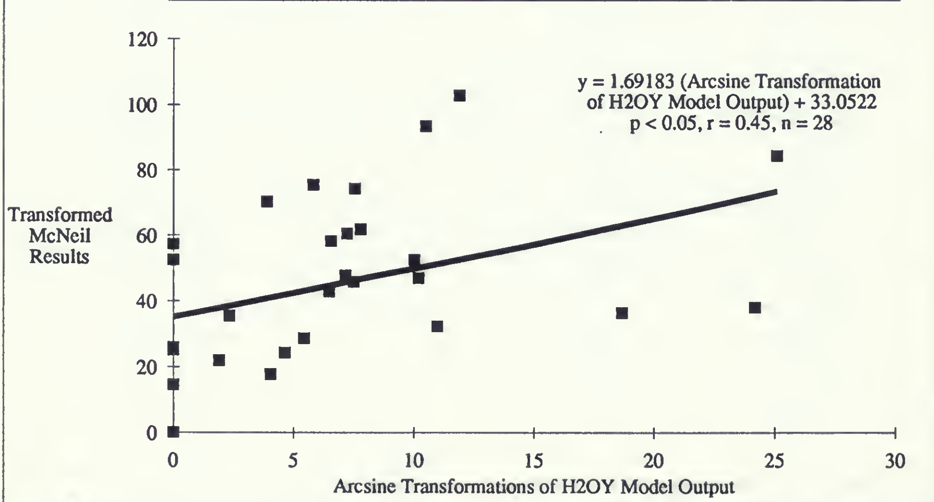


Figure D-9: Relationship between the arcsine transformations of Sequoia model output and transformed substrate scores for 28 watersheds in the Flathead River Basin during 1989

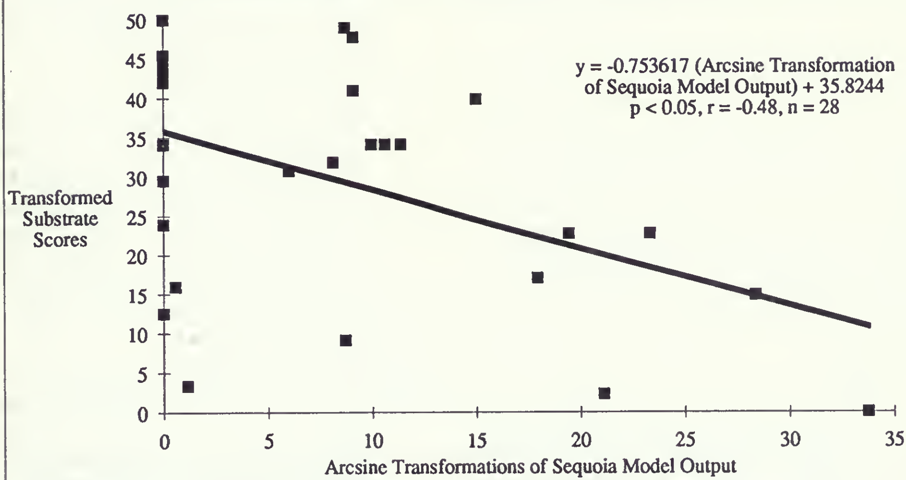
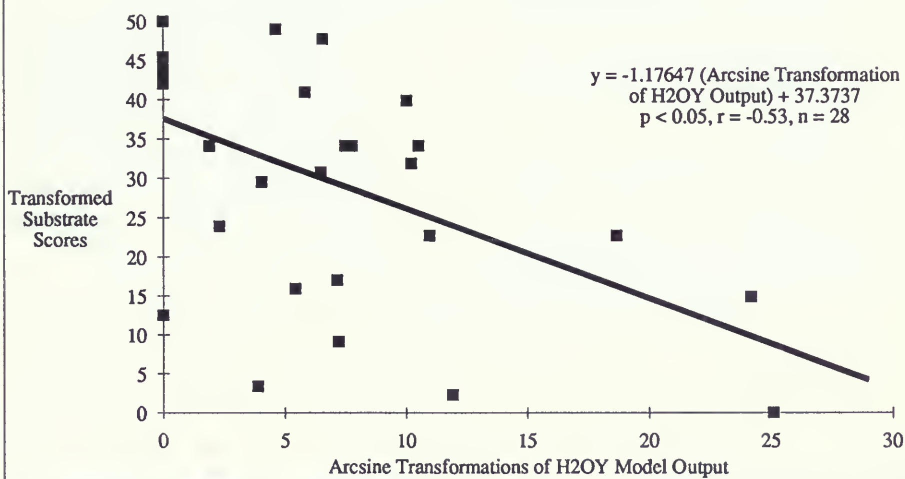


Figure D-10: Relationship between the arcsine transformations of H2OY model output and transformed substrate scores for 28 watersheds in the Flathead River Basin during 1989



tion between independent variables could cloud the assessment of cause and effect. The Sequoia index assumes a ten year recovery period. It does not take into account older problems still having a major influence on the percentage of fines in spawning gravel in several watersheds. Sequoia does not consider catastrophic events such as fires or floods. The channel morphology and percentage of fine material in several of our spawning areas are still showing effects of the 1964 flood. By eliminating the watersheds where assumptions dealing with recovery rates and natural events are not reflective, the fit improved ($r = 0.65$; $n = 21$).

Conclusions

(1) Results indicated a direct linkage between ground-disturbing activity (Sequoia and H_2OY) and a measurable fisheries habitat parameter (percentage of material less than 6.35 mm) which is linked to embryo survival by westslope cutthroat and bull trout.

(2) Findings also illustrated a direct linkage between ground-disturbing activity (Sequoia and H_2OY) and an index of fisheries habitat (substrate score) which is linked to juvenile bull trout rearing potential.

(3) Spawning area gravel composition in the nine watersheds with no development averaged 31.7 percent material smaller than 6.35 mm. This size class comprised an average of 39.0 percent in the 17 watersheds where disturbed area exceeded one percent of the drainage. Forest management activities have had a quantifiable effect on streambed composition and fish populations in the Flathead Basin.

(4) Monitoring streambed composition in known westslope cutthroat and bull trout spawning areas can provide fisheries information useful in making land management decisions. Once an initial sampling is complete, McNeil coring is an adequate tool for quantifying streambed particle size composition in spawning areas. We can detect changes in gravel composition.

(5) Monitoring streambed substrate score in known bull trout rearing areas can provide fisheries information useful in making land management decisions. Substrate scores are not adequate indicators of rearing potential for fish species other than bull trout. Behavioral differences between the trout species present in our study area makes use of a single index impossible.

(6) A significant relationship exists between substrate samples collected using modified Whitlock-Vibert boxes and McNeil core samples taken at the box planting sites. However, more work is required before the W-V box technique can replace McNeil coring in our streambed substrate monitoring program.

Study Module E:

Application of the Montana Nonpoint Source Stream Reach Assessment in the Flathead Basin

By Steve Tralles

This section of the *Final Report* summarizes a study of the same name published by the Flathead Basin Commission (723 Fifth Avenue East, Kalispell, Montana 59901).

Application of the Montana Nonpoint Source Stream Reach Assessment in the Flathead Basin

By Steve Tralles[1]

Introduction

Nonpoint source pollution is the major cause of aquatic degradation in Montana (Montana Water Quality Bureau 1990). Nonpoint source pollution originates from diffuse runoff primarily during extreme rains or snowmelt and is generally caused by land management activity.

In order of significance, the following land management activities are the major causes of nonpoint source pollution in Montana: agriculture, stream modification, mining, and forest practices (Montana Water Quality Bureau 1990).

Forest practices only impair approximately 13 percent of Montana's streams. However, those streams are usually located in areas with the highest aquatic resource value. Streams in the Flathead Basin are no exception.

The Flathead Basin exhibits some of Montana's highest water quality and supports a variety of aquatic life, including westslope cutthroat and bull trout (both species of special concern). In the Flathead Basin, siltation is the leading cause of stream pollution and forest practices are the leading causes of nonpoint source pollution (Flathead Basin Commission 1990).

Montana has developed a nonpoint source pollution management plan to identify and resolve nonpoint source pollution problems. The Montana Department of Health and Environmental Sciences/Water Quality Bureau has designed a nonpoint source pollution stream reach assessment procedure. We use it as an initial screening method to identify and prioritize moderate and severe nonpoint source pollution problems across the state.

In conducting the stream reach assessment, surveyors walk the stream and visually evaluate stream conditions. They note perceived impairment to beneficial uses caused by nonpoint source pollution and by natural or hydrologic influences. Impairment is the degree to which a stream or stream reach will support designated beneficial uses. For the purpose of this study, the primary beneficial use is fisheries. The surveyors also evaluate land management activities and application of best management practices.

Since agency resources (people and money) are limited, the assessment procedure is relatively quick and easy — designed primarily to identify the most significant problems. Consequently, the assessment procedure is subjective and nonquantitative.

Goals of the nonpoint source pollution stream reach assessment study were (1) to evaluate impairment to beneficial uses in the Flathead Basin and (2) to evaluate the accuracy of the assessment procedure by comparing its results with the results of quantitative studies performed by other Cooperative Program members.

[1]Steve Tralles is an Environmental Specialist with the Water Quality Bureau of the Montana Department of Health and Environmental Sciences in Helena, Montana.

Methods

One surveyor conducted all assessments on 30 streams containing 95 reaches. (See Figure E–1.) We selected the streams to correspond to sample sites or drainages used by the other Cooperative Program studies. The surveyor assigned stream reaches and defined them by their relative homogeneity of factors (such as valley bottom shape, gradient, channel substrate, vegetation, and land use).

Using information collected at one or more relatively accessible observation points within each reach, the surveyor completed one assessment form per stream reach. The form assesses reaches using 16 separate categories and subcategories. (See Figure E–2 and Appendix F.) The first eight assessment categories best describe conditions in the Flathead Basin. Therefore we present impairment ratings based on those eight categories only.

We essentially rate the categories on a scale of good-to-bad relative to stream conditions. Surveyors assign scaled numerical values to each category. The overall impairment rating for a given ***reach*** is based on a straight percentage derived from the sum of individual category ratings divided by the total rating possible for the categories that were rated. The impairment value for a ***stream*** is derived from an average of impairment ratings for all reaches on that stream. We defined and then calibrated impairment values by assessing several streams of known impairment (severe and none).

The assessment form also provides space for narrative elaboration pertaining to individual assessment categories and best management practices. The narrative information summarized specific management activities that the surveyor observed to be contributing to stream impairment or had a high potential for causing future problems.

To evaluate the accuracy of this procedure, we compared the assessment results to the results of other Cooperative Program studies. We compared the overall impairment value, averaged by drainage, to a relative activity level derived by Sequoia (cumulative runoff acreage — Module H) or H_2OY (predicted water yield increase based in part on clearcut equivalent — Module J).

We compared assessed stream reaches to corresponding reaches that had Region 1, Channel Stability Rating (CSR — Module J) and fish habitat data (Module D). We established an impairment value based on four categories from the assessment form to compare the stream reach assessment data against the Channel Stability Ratings. The four categories were bank stability, substrate composition, channel stability, and channel modifiers. We selected these categories because of direct applicability to parameters on the Channel Stability Rating.

The assessment category of Substrate Composition evaluates stream substrate relative to sediment influence on fish spawning and rearing habitat. For corresponding reaches, we compared substrate composition to stream substrate score and percentage of fine materials (less than 6.35 mm) as reported by the fisheries study (Module D).

We ranked all reported values and applied nonparametric statistical analysis. The Kendall Rank-Order Correlation (tau) test was used for analysis. A z test statistic applied to the tau value, was significant at the 0.05 level when greater than $\pm$ 1.96.

Results

We conducted assessments on 30 streams containing 95 reaches. Table E–1 lists streams by order of impairment. Of the 30 ***streams*** assessed, 47 percent were rated as having minor, moderate, or severe impairment. (See Figure E–3.) Of the 95 ***stream reaches*** as-

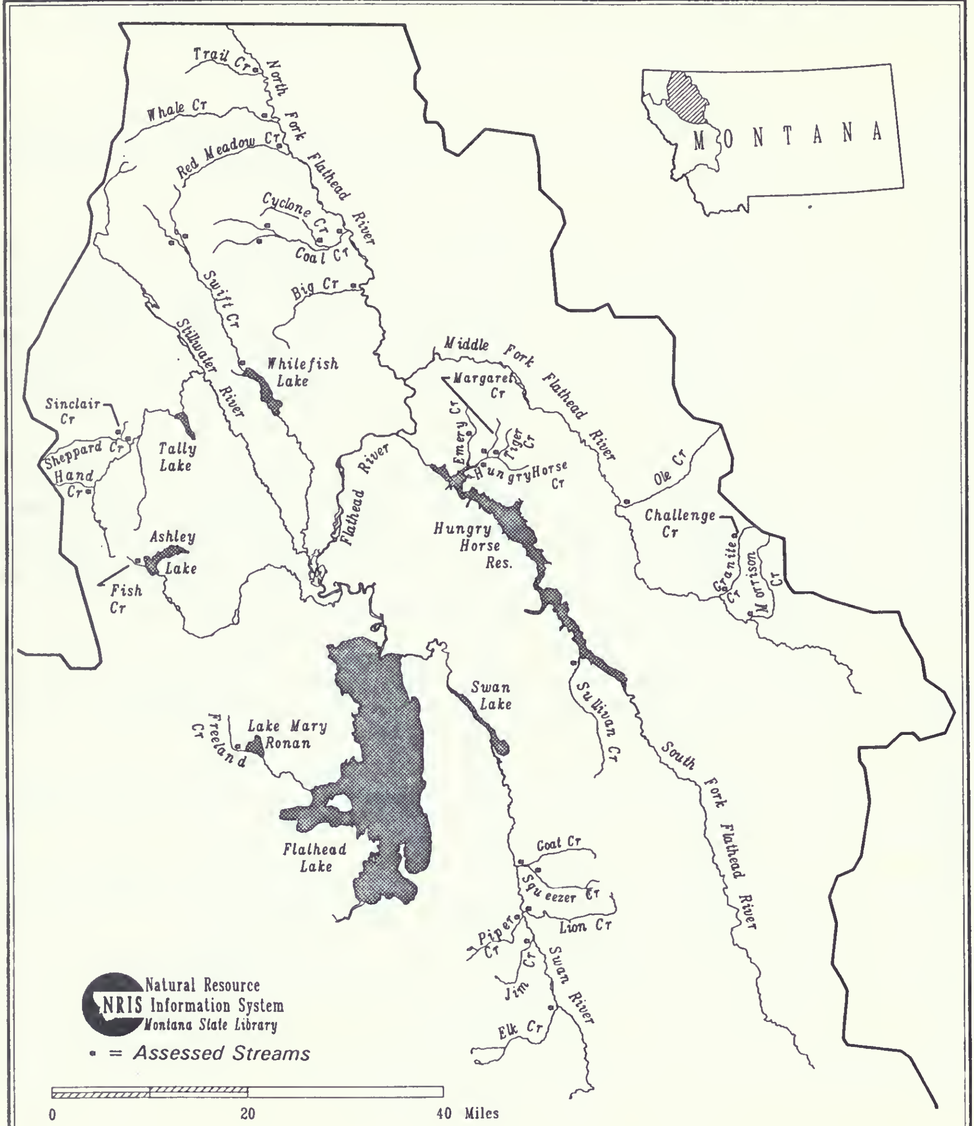


Figure E-1: Map: Completed NSPS Stream Reach Assessments
Upper Flathead River Basin

Figure E-2: Nonpoint Source Stream Reach Assessment Overview

INTRODUCTION: NONPOINT SOURCE (NPS) POLLUTION IS HIGHLY DIFFUSE IN NATURE, UNLIKE POINT SOURCE POLLUTION WHICH CAN BE ATTRIBUTED TO A SINGLE POINT. NPS POLLUTION DISCHARGES OCCUR OVER DISPERSED PATHWAYS AND ARE GENERALLY ASSOCIATED WITH PRECIPITATION AND RUNOFF. NPS POLLUTION IS RELATED TO HUMAN LAND USES WHICH ARE CONTROLLABLE. BEST MANAGEMENT PRACTICES (BMP'S) ARE METHODS INCORPORATED WITH LAND USES THAT AVOID OR MINIMIZE IMPACTS TO WATER RESOURCES CAUSED BY NPS POLLUTION.

PURPOSE: THIS ASSESSMENT PROCEDURE IS DESIGNED FOR STATEWIDE USE TO PROVIDE AN INITIAL, STANDARDIZED METHOD TO IDENTIFY NONPOINT SOURCES, APPRAISE BMP APPLICATION AND EFFECTIVENESS AND ASSESS STREAM IMPAIRMENTS THAT HAVE RESULTED FROM NONPOINT SOURCE (NPS) POLLUTION. HYDROLOGIC FACTORS THAT CONTRIBUTE TO IMPAIRMENT OF THE STREAM WILL ALSO BE ASSESSED. THE WATER QUALITY BUREAU (WQB) WILL ASSIGN NUMERICAL RATINGS TO EACH ASSESSMENT PARAMETER WHICH WILL CATEGORIZE STREAMS RELATIVE TO DEGREE OF IMPAIRMENT. STREAMS CATEGORIZED AS SEVERELY IMPAIRED WILL RECEIVE EMPHASIS FOR FUTURE NPS POLLUTION MANAGEMENT. INFORMATION FROM THE ASSESSMENTS AND THE SUBSEQUENT RATINGS WILL PROVIDE A UNIFORM DATA BASE FOR EACH STREAM AND STREAM REACH. THIS DATA BASE WILL BE STORED IN THE MONTANA REACH TRACKING SYSTEM DEVELOPED BY THE WQB. INFORMATION IN THE REACH TRACKING SYSTEM WILL BE AVAILABLE TO INTERESTED INDIVIDUALS.

INSTRUCTIONS: THE ASSESSMENT PROCEDURE WILL BE LIMITED TO SECOND, THIRD AND FOURTH ORDER STREAMS[1]. THE DISTANCE OF EACH STREAM REACH ACTUALLY OBSERVED IS DEPENDENT ON FACTORS SUCH AS TIME OR ACCESSIBILITY. OBVIOUSLY THE BEST ASSESSMENT WOULD INVOLVE WALKING THE ENTIRE STREAM. REALISTICALLY THIS WILL NOT BE POSSIBLE IN MOST SITUATIONS AND IS NOT NECESSARY. AS A GENERAL GUIDE THE SURVEYOR SHOULD CHOOSE THE MOST ACCESSIBLE OBSERVATION POINTS THAT ALLOW ADEQUATE IDENTIFICATION OF IMPAIRMENTS THAT MAY BE OCCURRING IN A REACH. EXAMPLES WOULD BE AT THE STREAM MOUTH, ABOVE AND BELOW HUMAN ACTIVITIES AND BELOW TRIBUTARIES. THE SURVEYOR SHOULD WALK AT LEAST 100' OF THE STREAM AT EACH OBSERVATION POINT OR ENOUGH DISTANCE TO GET A REPRESENTATIVE PICTURE OF THE SITUATION AT THAT POINT. IF POSSIBLE, TRY TO INCORPORATE A RIFFLE, RUN AND POOL AT EACH OBSERVATION POINT.

EACH STREAM WILL CONSIST OF ONE OR MORE REACHES. ONE ASSESSMENT FORM WILL BE COMPLETED FOR EACH REACH. STREAM REACHES WILL BE DETERMINED BY THE SURVEYOR. EACH REACH SHOULD EXHIBIT FAIRLY HOMOGENOUS CONDITIONS. AS A GENERAL RULE REACH BREAKS OCCUR WHERE OBVIOUS CHANGES IN STREAM CONDITION ARE DETECTED. THE SURVEYOR SHOULD BE AWARE OF CHANGES SUCH AS LAND PRACTICES, FLOW, GRADIENT, VEGETATION, VALLEY TOPOGRAPHY AND SUBSTRATE.

CONSIDER THE ENTIRE REACH WHEN RATING PARAMETERS. AVOID CONCENTRATING ON SPECIFIC FEATURES UNLESS THEY ARE A MAJOR PROBLEM. PLEASE RATE ALL PARAMETERS ON THE FORM AND CHOOSE THE DESCRIPTION THAT IS MOST APPLICABLE. DO NOT LEAVE ANY RATING PARAMETERS BLANK. IN CASES WHERE RATING FACTORS DO NOT APPLY RECORD AS N/A; OR IF A PARAMETER RATING IS UNKNOWN RECORD AS SUCH.

TOPOGRAPHIC MAPS AT A MINIMUM AND AERIAL PHOTOS (IF POSSIBLE) SHOULD BE CONSULTED PRIOR TO THE ASSESSMENT TO PICK OUT PROMINENT FEATURES IN THE WATERSHED AND TO SELECT OBSERVATION POINTS. MAPS WITH IDENTIFICATION OF OBSERVATION POINTS, REACH BREAKS, AND ANY IMPORTANT FEATURES SHOULD BE TURNED IN WITH ASSESSMENT FORMS.

ANY OUTSTANDING FEATURES OBSERVED I.E. GROSS SEDIMENT SOURCES, FISH BARRIERS, POINT SOURCE DISCHARGES, ETC. SHOULD BE PHOTOGRAPHED (IF POSSIBLE) AND LABELED ON THE MAP TO BE TURNED IN WITH THE ASSESSMENT FORM.

EQUIPMENT: AT MINIMUM YOU WILL NEED FIELD FORMS AND MAPS TO DO ASSESSMENTS. IT IS SUGGESTED THAT THE SURVEYOR INCLUDE A THERMOMETER IF IRRIGATION RETURNS ARE EXPECTED TO BE ENCOUNTERED, AND A CAMERA TO PHOTOGRAPH ANY NOTABLE FEATURES ALONG THE STREAM.

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[1] FOR DEFINITION OF STREAM ORDER SEE PAGE 1 OF ASSESSMENT FORM UNDER GENERAL INFORMATION.

Table E-1: Streams Ordered by Impairment Value

STREAM NAME	RATING	IMPAIRMENT
SINCLAIR	41.5%	SEVERE
OLE	60.0%	MODERATE
W. FK. SWIFT	63.0%	MODERATE
E. FK. SWIFT	66.0%	MODERATE
SWIFT	66.0%	MODERATE
GRANITE	71.0%	MINOR
CHALLENGE	71.0%	MINOR
FISH	74.0%	MINOR
MORRISON	75.0%	MINOR
GOAT	76.0%	MINOR
SHEPPARD	77.0%	MINOR
ELK	77.0%	MINOR
RED MEADOW	78.0%	MINOR
LION	79.0%	MINOR
WHALE	81.0%	NONE, BUT THREATENED
SULLIVAN	81.0%	NONE, BUT THREATENED
S. FK. COAL	81.0%	NONE, BUT THREATENED
PIPER	82.0%	NONE, BUT THREATENED
SQUEEZER	86.0%	NONE, BUT THREATENED
JIM	86.0%	NONE, BUT THREATENED
COAL	87.0%	NONE
EMERY	87.0%	NONE
HUNGRY HORSE	89.0%	NONE
N. FK. COAL	90.0%	NONE
CYCLONE	91.0%	NONE
HAND	91.0%	NONE
BIG	91.0%	NONE
MARGARET	92.0%	NONE
TRAIL	93.0%	NONE
TIGER	94.0%	NONE

Impairment Values
87 - 100% = Non-impaired
80 - 86% = Non-impaired, but Threatened
71 - 79% = Minor Impairment
55 - 70% = Moderate Impairment
0 - 54% = Severe Impairment

sessed, 46 percent were rated as impaired. (See Figure E–4.)

In comparing the individual assessment categories, "Land Use" contributed to impairment on 72 percent of the assessed reaches. "Land Use" is a measure of potential risk. It is based primarily on the distance from the stream that management activity has occurred. Channel stability and substrate composition contributed to impairment on approximately 30 percent of the assessed reaches. Figure E–5 summarizes the percentage of reaches where specific assessment categories contributed to impairment.

The character and extent of management on identified stream reaches varied considerably throughout the Flathead Basin. Of the 95 assessed reaches, 75 were managed to some extent and 20 were unmanaged or "pristine." Timber harvest and the presence of roads accounted for the majority of management activities. However livestock grazing occurred on several reaches.

Of the "managed" stream reaches assessed, 48 percent were impaired to some extent, and 52 percent were unimpaired. Of the unimpaired reaches, 33 percent were rated as threatened. (See Figure E–6.)

While conducting assessments, the surveyor identified several management activities as either contributing to stream impairment or having a good potential to cause problems. The surveyor attributed observed sedimentation to timber harvest, roads, and livestock. The primary problems were inadequate streamside management zones for logging units, poor road surface maintenance, and bank trampling by livestock. Table E–2 summarizes this information.

Of the 20 unmanaged stream reaches assessed, 40 percent were impaired and 60 percent were unimpaired. (See Figure E–7.) The

Figure E-3: Impairment Values by Percentage of Total Streams (30)

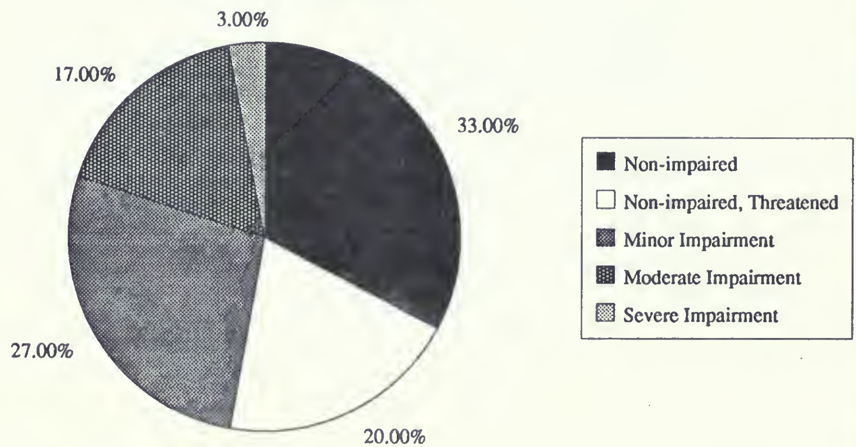

Figure E-4: Impairment Values by Percentage of Total Reaches (95)

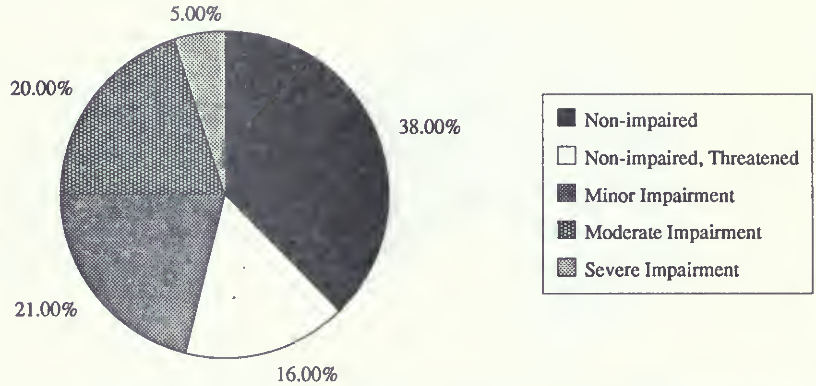

Figure E-5: Assessment Categories Rated as Impaired by Percentage of Total Reaches (95)

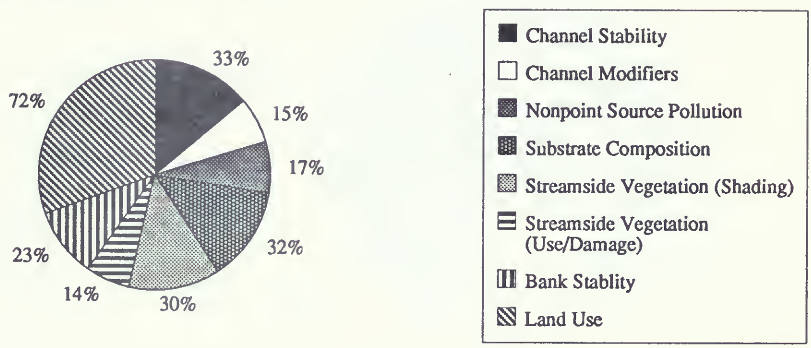

Figure E-6: Impairment Values by Percentage of Managed Reaches (75)

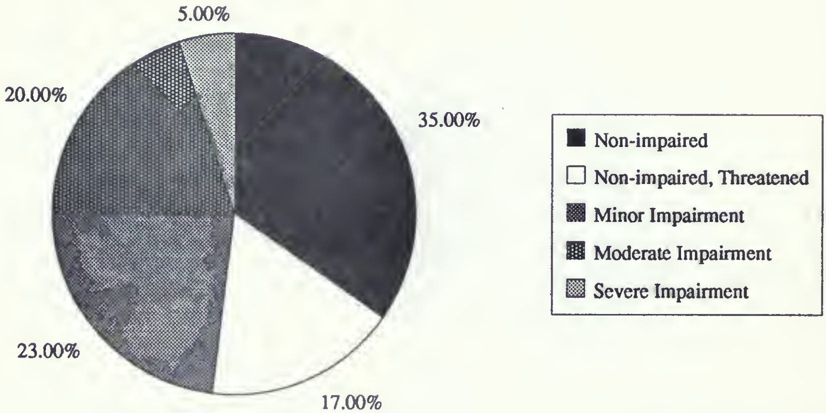

Figure E-7: Impairment Values by Percentage of Unmanaged Reaches (20)

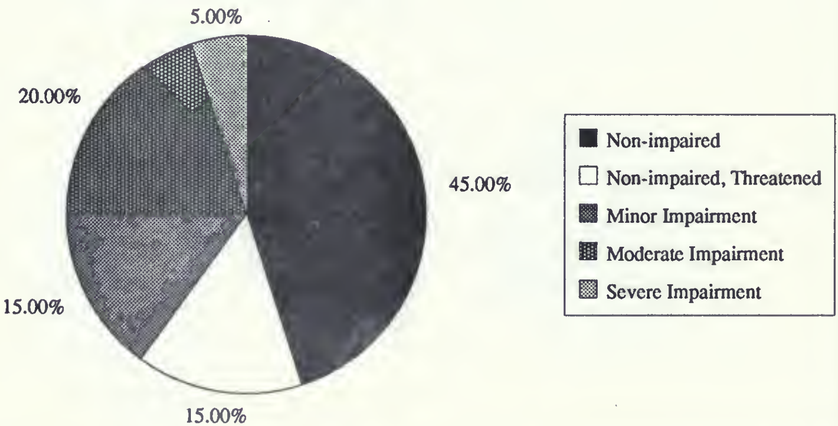

Table E-2: Summary of Management Activities as Actual or Potential Sources of Stream Problems*

Timber Harvest	
Inadequate Streamside Management Zone (SMZ)	32%
Excessive Blowdown	9%
Excessive Stream Opening	3%
Slash in Channel	20%
Equipment in Channel	9%
Skid Trail Erosion	5%
Water Yield	1%
Attributable Sediment to Channel	5%
Roads	
Crossings	5%
Inadequate SMZ	5%
Culvert Maintenance	3%
Surface Maintenance	9%
Poor Road Closure	1%
Road Headcut	1%
Attributable Sediment	17%
Livestock	
Bank Trampling	8%
Attributable Sediment	8%
Miscellaneous Litter	5%
Fireline Erosion	1%

* Percentages based on the number of reaches (out of 75 managed reaches) where the surveyor could tie an activity directly to a stream problem or was confident that the activity would be a problem in the near future.

impaired reaches were primarily affected by natural erosion and bank or channel instability.

Comparison of impairment ratings, by stream, to activity values derived from Sequoia (Module H) and H_2OY (Module J) revealed a non-significant correlation.

We compared modified impairment ratings using a combination of Bank Stability, Substrate Composition, Channel Stability, and Channel Modifiers to the R1 Channel Stability Survey (CSR — Module J) results. Comparisons were made on eight corresponding stream reaches. Correlation between these methods was significant, but negative ($z = -2.23$). High CSR values correspond to poor channel stability. High assessment values indicate low impairment.

For corresponding reaches, we compared the Substrate Composition category from the assessment procedure to the percentage of fine materials (less than 6.35 mm) and substrate scores obtained by the fisheries study. (See Module D.) Again, the correlation was not significant.

Discussion

Given that the assessment procedure is subjective and nonquantitative, we expect less accuracy or resolution in identifying subtle nonpoint source pollution impairment. The impaired streams assessed in the Flathead Basin are more likely to have subtle (rather than major) impairment. Our assessment results did not correlate well with activity levels or with quantitative fisheries habitat evaluations that indicated impairment to spawning or rearing habitat.

Of the "pristine" non-managed reaches assessed, 30 percent were rated as impaired. Two of these streams (Granite and Morrison Creeks), have management activity in the upper reaches. The impaired, non-managed reaches were located downstream and generally exhibited very poor channel stability. These problems may or may not have been influenced by upstream management activity. The assessment procedure is meant to identify natural or hydrologic as well as nonpoint source pollution influences on stream condition. Admittedly, it is difficult to do this. However some reaches that have no management activity may be naturally impaired. They may exhibit channel instability or occur in erosive geology. Such reaches may not fully support beneficial uses.

One could argue that natural conditions should not be considered as "impairment." Water pollution laws certainly do not apply to natural impairment. However, it is important to recognize that natural conditions may impair fisheries habitats. Although it is unlikely that natural impairment can or ever will be addressed, resource managers should consider such natural "impairment" when evaluating future land management activities.

Ideally, the impairment rating of the assessment procedure should be tied to beneficial uses. Our comparisons of assessment results and fisheries habitat data generally yielded poor correlations. This indicated that the assessment resolution or accuracy may not be suitable in areas of subtle impairment (such as in the Flathead Basin). This is not surprising since the method was designed to assess the most severe problems in the state.

Conclusions

The surveyor observed tree blowdown due to inadequate streamside management zones, sediment from poor road maintenance, logging slash in the stream channel, and bank trampling by livestock as the primary causes of stream problems related to management practices. Although these activities negatively influenced stream conditions, they where not always conclusively tied to impairment of beneficial uses.

In areas of relatively subtle nonpoint source pollution impairment and/or erosive geology (as in many of the Flathead Basin study streams), the assessment procedure did not adequately separate natural factors from management influences.

Eight out of 16 initial assessment categories were generally not applicable to the study streams. Of the eight assessment categories used to determine impairment values for this study, most were potentially influenced by, but not directly tied to, management activity.

The assessment results generally revealed less impairment than the results of the quantitative fisheries habitat studies. This indicates that the assessment procedure either does not identify or underestimated impairment to beneficial uses.

STUDY MODULE F:

ASSESSMENTS OF BEST MANAGEMENT PRACTICES

BY DON POTTS

This section of the *Final Report* summarizes the study called
On-Site Assessment of Best Management Practices
as an Indicator of Cumulative Watershed Effects in the Flathead Basin
published by the Flathead Basin Commission
(723 Fifth Avenue East, Kalispell, Montana 59901).

ASSESSMENTS OF BEST MANAGEMENT PRACTICES

By Don Potts[1]

This report discusses a forest practice monitoring tool which involves on-site assessments of Best Management Practices (BMPs).The BMP assessment was intended to measure the level of application and practice effectiveness in preventing soil erosion and protecting water quality in the Flathead Basin.

The BMP assessment had two objectives: (1) The results would document the level of application and the skill in implementing the State's voluntary Best Management Practices.This included an examination of their effectiveness in controlling nonpoint source pollution, and (2) A comparison would be made between these results and those of the 1988 Montana Legislature's Environmental Quality Council (EQC) statewide BMP assessment.

This report includes a thorough examination of the methodology of BMP assessment.The various aspects of setting up the study and conducting the field work are discussed.This information summarizes to document procedures and sheds light on possible alternatives and suggestions for future studies.

In order to provide a basis for comparison with the work of the EQC, similar site selection criteria were utilized in this study.A stratified random sample of 52 timber sales were selected from four land ownership groups: Flathead National Forest — 22 sales; Plum Creek Timber Company — 19 sales; Montana Department of State Lands — six sales; and Non-Industrial Private — five sales. All timber sales were harvested between January 1986 and December 1988.Each sale was evaluated on up to 39 separate practices.These practices corresponded to the *Best Management Practices for Forestry* (December 1988 revision) developed by the Environmental Quality Council's BMP Technical Committee. Ratings were carried out by three teams, each composed of five members representing industry, state and federal agencies, and environmental groups.Each team member had technical expertise in some aspect of forest or watershed management.

The Flathead Basin timber sale audits revealed that 90 percent of all management practices were adequately applied; 7 percent of the practices were rated "minor" departures; and 3 percent were rated as "major" departures. Generally there was a close correlation between the failure to adequately apply a BMP and the resulting impact which was observed.Major BMP departures produced major resource impacts.

In eight of the 52 sales (15 percent), audit teams identified at least one practice as having "major detrimental impacts on soil and water resources." Impacts were considered "extensive and long term" in two of these sales.The "major" impacts observed on the other six sales were considered to impart short term effects.

In 31 of the 52 sales (59 percent), audit teams identified at least one practice as having "minor detrimental impacts on soil and water resources." Minor impacts were all considered to be of short duration. Figures F–1 and F–2 show the distribution of major and minor im-

[1]Dr. Don Potts is a Professor with University of Montana's School of Forestry in Missoula, Montana.

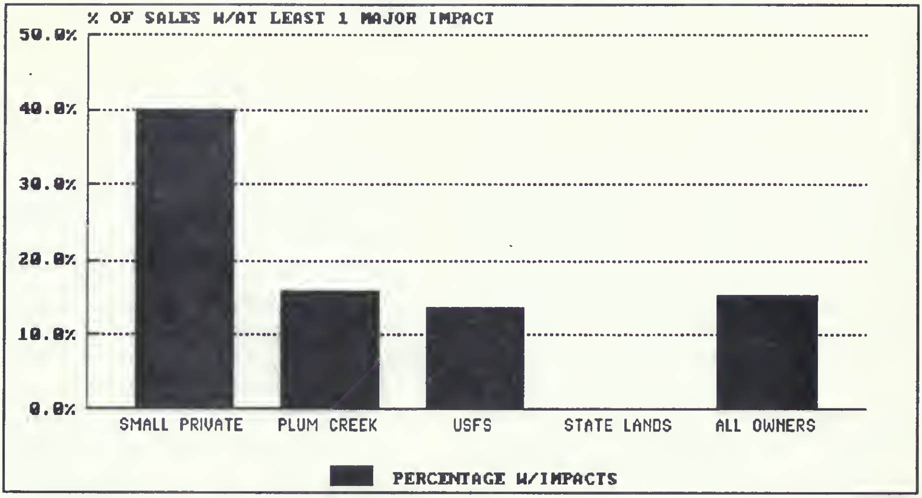

Figure F-1: Percentage of timber sales with at least one major impact

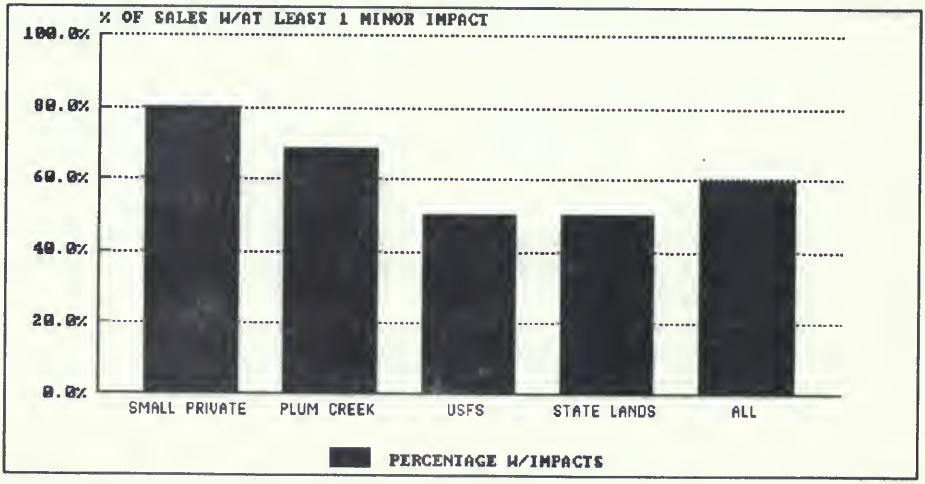

Figure F-2: Percentage of timber sales with at least one minor impact pacts by ownership.

The impacts have been summarized by the major categories of BMPs identified on the audit form.The "Timber Harvest" category, which represents 11 of the 39 practices audited, contributed the greatest number of potential impacts to water quality — more than 30 percent of all impacts, both "major" and "minor," came from this one category alone.Most of these deficiencies were associated with practices in the Streamside Management Zones (SMZs) and with the location and drainage of skid trails.

The "Road Drainage" category involved five of the 39 practices audited, but accounted for more than 20 percent of all "major" and "minor" impacts observed. Figure F–3 shows the percentage of impacts as they were distributed by BMP category and by ownership.

The Montana Department of State Lands' timber sales were the only ones on which major impacts were not observed.Major impacts were most often found on the Private Non-Industrial sales, and 40 percent of their sales had at least one major impact.The Flathead National Forest and Plum Creek Timber Co. rated very similarly with approximately 14 percent and 16 percent of their sales, respectively, registering at least one major impact.

This assessment included the same set of BMPs that were audited in the 1988 EQC field study, as well as additional or amended practices added to the audit form as a result of adopted changes in the BMPs resulting from the House Joint Resolution 49 report (1987 Legislature). Most of those changes involved improvements of practices associated with streamside management zones, including minimum SMZ width criteria.This practice was evaluated

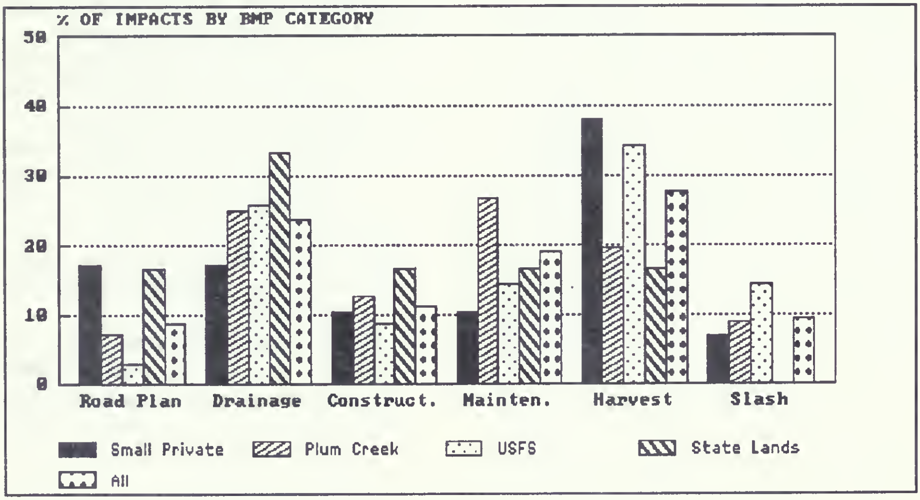

Figure F-3: Percentage of impacts by BMP category to determine its present level of application in the Flathead Basin, but was not included in the comparative analysis with the EQC results.

Overall, the ratings indicate that BMPs are being applied and are effective in a relatively high percentage of timber harvesting operations in the Flathead Basin. Care must be exercised in interpreting results based solely upon the percentage of the practices rated as "adequately applied." Extensive erosion was observed on a number of sales and it resulted from only a few inadequately applied practices.Every practice evaluated did not have the same potential to protect water quality from nonpoint source pollution.

Comparison of these results with those from the EQC study indicate that BMPs are better applied and are generally more effective in the Flathead Basin than they are statewide.

However, there is clearly room for improvement. It was found that one "major" (either short- or long-term) impact to water quality is occurring for every two timber sales conducted in the Flathead.It was also found that almost two "minor" (short-term) impacts per timber sale were occurring.

The damage to a watershed resulting from a single timber sale with major practice departures and impacts is generally easy to recognize. However, minor impacts should not be underestimated and are a concern from a cumulative effects perspective.The primary benefit from an assessment process like a BMP audit is to reduce the potential risk of cumulative watershed effects.Discovering and controlling minor practice departures and impacts from various timber sales across mixed ownerships, may decrease the potential for basin-wide effects.

The highest scores (best BMP implementation) awarded were frequently on sites where harvest boundaries were adjacent to perennial streams that had clearly defined banks and channels and easily recognized beneficial uses, for example, trout habitat.

Often the lowest scores given were on sites that would not have been expected to produce potential water quality problems. This illustrates the need for a program of continued education to aid in interpretation and selection of correct practices under a variety of site conditions.

Timber sales on which departures and impacts were more frequently observed were characterized by the following:

(1) Non-industrial private ownership. This ownership class registered the poorest performance in BMP application and effectiveness. Furthermore, the group was the least cooperative participant in the study,frequently denying us access to their lands.
(2) Large management areas, where uniform practices were applied and not tailored to micro-site conditions
(3) Higher-elevation headwaters drainages with poorly defined stream channels
(4) Wet or moist sites with either shallow water tables and/or high stream drainage densities.
(5) Older sales where planning of transportation systems and sale layout predated the recognition of statewide BMPs.
(6) Sales which did not physically mark or delineate streamside management zones.
(7) Inadequate road drainage features on active system roads as well inadequate drainage on roads that have been closed.
(8) Sales which lacked a routine maintenance schedule for ditches, culverts, and road surfaces.
(9) Sales which were conducted on highly erodible soils, where the increased risk of sediment production requires an

adjustment in the frequency and standards of erosion prevention.

Other Findings

(1) No formalized process to conduct BMP assessments exists, although assessments are periodically conducted on the Department of State Lands by their hydrologist and soil scientist.
(2) Refinements in the BMP audit process are needed to remove the subjective nature of the process and to tailor the rating scales to better account for nonpoint source pollution and sediment delivery.
(3) Efforts at educating loggers, equipment operators, and sale administrators have been initiated by the Montana Logging Association and Plum Creek Timber Company's Kalispell management unit. A comprehensive cooperative program of education, either through instructional tapes or training sessions is needed. The goal of the education effort would be to reach a targeted number of operators, administrators and sale planners throughout the Basin.
(4) BMP assessments, by themselves, are unsuited for quantification of any cumulative watershed impact, but do address this problem through the fundamental assumption that if BMPs are properly applied and effective, then cumulative watershed effects may be minimized.

Summary

This study provided the first opportunity for many Flathead Basin resource professionals from both timber industry and land management agencies to participate in BMP assessment.The feedback we received from many participants indicates that much of the value of this effort was in education. The active participation in the field reviews and the interest of many individuals in the Flathead Basin is important to the continued success of such efforts.Only with support and encouragement from the upper levels of management will programs such as this nonpoint source monitoring project work.

The State of Montana has committed itself to the BMP field audit process in the future.The problem with the state-wide effort is that it can not concentrate in specific areas.The Flathead Basin could only have two or three timber sales evaluated in any year.The Flathead Basin deserves a more thorough evaluation than that, and again, the process has great value in education. The more often that equipment operators and sale administrators are exposed to the audit process, the better BMP application and effectiveness will become.The Flathead Basin should continue the audits annually and involve as many people and interest groups in the process as possible.

Flathead Basin Forest Practices

Water Quality and Fisheries Cooperative Program

Study Module G:

Management Guidelines for Riparian Forests

By Robert Pfister and Kim Sherwood

This section of the *Final Report* summarizes a study of the same name published by the Flathead Basin Commission (723 Fifth Avenue East, Kalispell, Montana 59901).

Management Guidelines for Riparian Forests

By Robert Pfister[1] and Kim Sherwood[2]

Background

This general study was initiated in 1987 by the Montana Riparian Association and the McIntire-Stennis Cooperative Research Program to develop improved management guidelines for riparian/wetland forests of Montana. Experienced professionals from several disciplines were invited to join a Management Guidelines Working Group in 1988.

Three linkages to other current studies were established during 1988 which redirected some aspects of this study:

(1) State Environmental Quality Council (EQC)/Best Management Practices (BMPs) to meet 319 Water Quality Regulations.
(2) Watershed risk assessment (Potts and Lull).
(3) BMP Site Audit study (Potts and Ehinger).

Revised Objectives — July 1989

Based on discussions with the Working Group, developments in other studies, and the Flathead Basin Cooperative Program, the objectives of this study were revised to:

(1) Review and revise management information for forest riparian/wetland habitat types by:
    (a) Field review by Flathead Basin BMP audit teams,
    (b) Incorporate field review comments with current revision of classification and management information by Boggs and others, and
    (c) Review of management information in Boggs and others (1990) by the Management Guidelines Working Group members.
(2) Develop criteria for consistent and effective designation of Streamside Management Zones by:
    (a) field review of proposed criteria by Flathead Basin BMP audit teams,
    (b) review of criteria by Management Guidelines Working Group members.
(3) Develop an expert opinion consensus of relative soil erosion risks of various forestry practices in relation to a soil/slope classification.

Objectives (1a) and (2a) are directly related to the Flathead Basin Cooperative Study and were conducted in conjunction with the Flathead Basin BMP audits. Objective (3) provided an essential tool for conduct of the Geographic Information System Watershed Risk Assessment study.

[1]Dr. Robert Pfister is a Research Professor with the University of Montana's School of Forestry in Missoula, Montana.

[2]Kim Sherwood was a Research Assistant with the University of Montana's School of Forestry in Missoula, Montana.

Field Procedures — Flathead Basin Audit Sites

With the approval of Don Potts and Bill Ehinger, we assigned Kim Sherwood to accompany the BMP audit teams in order to obtain suggestions for revision of management information on as many sites as possible. On each site, the habitat types were identified by Kim Sherwood who then read the pertinent published management implications (Pfister and others 1977) to the BMP audit team. The team then provided feedback on the existing information relative to observations in that unit. The results were then summarized by habitat types and later incorporated into the new riparian and wetland classification for northwest Montana (Boggs and others 1990).

A second addition to the field audit procedures was to ask the BMP audit team if proposed criteria for determining width of the Streamside Management Zone would have been appropriate for the site. The proposed criteria were (1) 25 foot minimum, (2) include adjacent wetland, and (3) use a soil/slope formula.

Results — Management Information for Habitat Types

Previously defined forest habitat types (Pfister and others 1977) in the Streamside Management Zone (SMZ) were recorded for 48 BMP audit sites. Table G–1 presents a summary of types observed on more than two sites.

Nine habitat types were observed where management information was discussed by the audit teams on at least two sites. Summaries of individual comments were made for each habitat type. These were provided to the classification team for incorporation with all other sources of information in the management information sections of the new wetland/riparian classification of northwestern Montana (Boggs and others 1990). For four of the types, the Flathead management information was simply added to previous information. (An example of the ABLA/OPHO habitat type revision is shown in Appendix D.) However, most of the CLUN types were revised in the new classification to split off the wet end of the types; comments were incorporated into the new management information sections of the new types. One type (ABLA/LUHI,MEFE) illustrated the difficulty of getting to a wetland condition by using the 1977 key. The wetland sites within the upper subalpine would likely key to the new ABILAS/STRAMP *Abies lasiocarpa/Streptopus amplexifolius* habitat type in Boggs and others (1990). For most of the types, the suggested changes were for added information rather than extensive changes. Discussions also revealed that some organizations use the existing habitat type management information much less than others.

Those types previously listed as wetlands (ABLA/CACA, ABLA/OPHO, PICEA/EQAR, and THPL/OPHO) were confirmed to be obvious wetlands by the field observations in all areas. (See Table G–1.) The other types in Table G–1 with the word "variable" indicated were observed to include both wetland and nonwetland conditions within them. Two interpretations are made for this observation. First, these types may need revision to more clearly separate them for wetland characteristics; most of this has been accomplished in the new classification in Boggs and others (1990). The second interpretation is that transitional types in bottomland situations often are found in a mosaic pattern with wetland pockets or stringers reflecting microsites of slightly lower elevations. This cannot be handled by revising the taxonomic classification. Rather, it requires the field person to determine the pattern of types present within a management unit and design the activities to protect the aquatic resources.

Table G-1. Habitat types observed on two or more of the BMP audit sites.

HABITAT TYPE ABBREVIATION	PHASE ABBREV.	WETLAND?	OBSERVED	DISCUSSED	MGMT. O.K.	REVISION NEEDED
ABGR/CLUN	ARNU	No	3	2	2	0
ABGR/CLUN	CLUN	No	2	1	1	0
ABLA/CACA	—	Yes	3	2	0	2
ABLA/CLUN	ARNU	Variable	13	7	5	2
ABLA/CLUN	CLUN	Variable	5	3	2	1
ABLA/LUHI	MEFE	Variable	2	2	0	2
ABLA/OPHO	—	Yes	6	4	0	4
PICEA/CLUN	CLUN	Variable	9	4	2	2
PICEA/EQAR	—	Yes	8	3	2	1
THPL/CLUN	ARNU	Variable	6	4	4	0
THPL/OPHO	—	Yes	3	2	1	1

Management information for individual sites is based on type-specific habitats (Boggs and others 1990). This leaves concerns over other more general situations. These include headwaters management priorities, windthrow problems, stream protection, and regeneration practices.

Results — Management Information for Special Concerns

Watershed concerns in headwaters areas must be a top priority (for example, ABLA/CACA, and other wetlands within ABLA/LUHI, MEFE types). The higher precipitation and snowpack of upper elevation headwaters require special attention to protect water quality. Although the streams may be very small, or intermittent, they require at least the same amount of protection regarding sediment production and transport as larger streams. For basins with a high density of small streams this may require treatment of entire units with the same care exercised in wetlands along streams at lower elevations.

Windthrow is an obvious problem in most wetlands and along streams. Some of the timber sales audited were actually set up to salvage previous blowdown. Blowdown (actual or potential) was specifically identified as a concern on 13 of the 48 sites. Large trees on wetland sites usually have shallow root systems and the soil has little holding strength when water tables are high. An undisturbed stand of large trees along the stream adjacent to cutting units is very susceptible to blowdown, creating unusually high amounts of woody debris in the stream and increased soil erosion potential and streambank damage from upturned root systems. Abrupt edges in stand structures should be avoided. Windthrow risk can be reduced by several techniques, considered in combination with other objectives. Clearcutting removes the potential of windthrow from the immediate site and transfers the problem to adjacent stands. Where clearcutting is used to meet other objectives, a treatment of adjacent stands (or salvage of expected blowdown) should be planned. Light partial cutting (removing less than 30 percent of the basal area) has been suggested for wetland sites. This can be accomplished with single tree or group selection harvesting, depending on the species composition and structure of the stands. One suggestion was to select trees for removal that were the most susceptible to windthrow. Another suggestion was to use partial cutting, leaving windfirm trees on adjacent upland sites, to buffer the effects of wind on trees in the Streamside Management Zone. Local experience is especially valuable for interpreting windthrow risks. General prescriptions for Streamside Management Zones are not the answer. Rather, we recommend that windthrow risks and appropriate management of those risks be addressed specifically in a silvicultural prescription prior to harvesting activities.

Woody debris has been recognized as an essential component of stream structure in several kinds of streams. Potts and Anderson (1990) report on the importance of natural and logging woody debris in small stream channels. Some organizations are developing fairly rigid criteria for the leaving of trees along the stream for future woody debris recruitment. However, the potential of post-treatment blowdown may negate the objective. The suggestion of selective harvesting of the high windthrow risk trees and leaving trees of various sizes that are more windfirm should be considered (as above). Again, we caution against generalized prescriptions. Rather, we recommend that woody debris recruitment be addressed specifically in a silvicultural prescription prior to harvesting activities. Work is also needed to define desired kinds, amounts, and timing of woody debris for different kinds of streams. Furthermore, the prescription for a specific site must be done in conjunction with knowledge of conditions upstream and downstream. Potts and Anderson (1990) recommend a pre-disturbance appraisal to help define specific prescriptions.

Site preparation and successful regeneration are a major concern in streamside areas. Competition from grasses and shrubs often precludes conifer regeneration unless site preparation and regeneration are carefully planned. Hand scalping and planting is usually suggested for SMZs, but this may not be adequate site preparation to ensure regeneration success because of the heavy competition on wetland sites. Equipment usage is generally precluded in the current Best Management Practices. This may lead to general development of non-regenerated conditions which may not meet the desired future condition. Many examples of non-stocked areas in wetlands exist due to inadequate site preparation and/or grazing. A window of opportunity for site preparation may be needed to ensure tree regeneration and to mimic natural plant community succession. For mechanical or burning practices, this may be only a few weeks in late summer when the water tables are at the lowest level. If water tables rise following timber harvesting (as has been observed in several wetland sites), then site preparation may need to be delayed a few years until regrowth is sufficient to lower the water table again. With the present lack of predictability, monitoring may be the most efficient process to adjust timing of site-preparation and regeneration treatments to ensure meeting objectives.

Results — Streamside Management Zones

Adjacent Wetlands

Four habitat types (Pfister and others 1977) had been previously proposed as "wetland" and several other types or phases as "transitional." As discussed previously (see Table G–1), the BMP audits confirmed this categorization. However, classification revision during 1989 and 1990 has provided an expanded list of "wetland" types for northwestern Montana (Boggs and others 1990). Field identification of the following "wetland" habitat types (h.t.) and community types (c.t.) should meet the intent and definitions of the Best Management Practices for including adjacent wetlands within the Streamside Management Zone:

- *Abies lasiocarpa/Calamagrostis canadensis* h.t (Subalpine fir/Bluejoint)
- *Abies lasiocarpa/Oplopanax horridum* h.t. (Subalpine fir/Devil's club)
- *Abies lasiocarpa/Streptopus amplexifolius*, h.t., Ligusticum canbyii phase (Subalpine fir/Twisted stalk h.t., Canby's licorice-root phase)
- *Picea/Calamagrostis canadensis* c.t. (Spruce/Bluejoint)
- *Picea/Cornus stolonifera* h.t. (Spruce/Red-Osier dogwood)
- *Picea/Equisetum arvense* h.t. (Spruce/Horsetail)
- *Picea/Lysichticum americanum* h.t. (Spruce/Skunk cabbage)
- *Thuja plicata/Oplopanax horridum* h.t. (Western red cedar/Devils club)
- *Thuja plicata/Athyrium filix-femina* h.t. (Western red cedar/Lady fern)

Several other forest types are included in the riparian site classification, but are interpreted as being "transitional" between "wetland" and "upland" conditions (for example, *Abies lasiocarpa/Ledum glandulosum* h.t.) At this time we have insufficient data to recommend requiring inclusion within the SMZ. However, examination of local soil and water table situations may suggest including part or all of some transitional types within the Streamside Management Zone.

Slopes and Erodible Soils

The following expanded width guidelines for SMZs were proposed in June, 1989:

> "Calculate SMZ for each side of stream from bank or average high water mark based on the following formula: SMZ (one side) = % slope X 100 X erodibility factor."

See Table G-2 for a description of the soilerodibility classes and SMZ widths.

To estimate soil erodibility classes, we started with the standard used in the Forest Service's Northern Region and Intermountain Region (R1-R4) Sediment Yield Model. Soil erodibility based on parent materials (Cline and others 1981) is shown in Table G-3.

These proposed guides were then reviewed in conjunction with the Flathead Basin BMP audits on 48 sites in 1989. On each site, the field audit teams were asked to evaluate the proposed slope/soil erodibility formula. The field teams encountered numerous problems in application of the proposed criteria. (See Table G-4.)

Most problems centered on trying to use a simplistic formula that did not include natural topographic breaks. There were also some questions raised on how the origin of the distance formula should be established when adjacent wetlands were present. Based on this feedback, we developed a set of illustrations representing a range of field situations. We also developed a decision tree to help field personnel determine the order in which to apply the recommended criteria in a consistent fashion. This decision tree is illustrated in Figure G–1.

The decision tree (Figure G–1) has been reviewed by the Management Guidelines Working Group and field tested on a current Kootenai National Forest mapping project. Careful use of the process will allow practical use of natural topographic features and consideration of adjacent wetlands to meet the minimum standards

Table G-2: Streamside Management Zone widths for various soil and slope classes

Soil Erodibility Class	Slope (%) 10	20	30	40
	SMZ Width (feet)			
LOW (% Slope X 100 X 2)	50*	50*	60	80
MEDIUM (% Slope X 100 X 3)	50*	60	90	120
HIGH (% Slope X 100 X 4)	50*	80	120	160

*Based on 50 foot minimum

Table G-3: Soil erodibility based on parent material type (Cline and others 1981)

Categories	Geologic Erosion Factor
Highly Erodible	
Acid Igneous (Granitics)	1.00
Alluvium	1.05
Moderately Erodible	
Schist	.75
Soft Sediments	.66
Hard Sediments	.52
Slightly Erodible	
Basic Igneous	.42
Metamorphics (Belt Series)	.39
Serpentine	.35

Table G-4: Evaluation of proposed guides (Table G-3) on 48 sites

	Number of Sites
Formula application worked well	20
Topographic breaks worked better than formula	20
Minimum of 25 feet judged inadequate	8
Adjacent wetlands was controlling criteria	5
Dry Draws — SMZ not critical	3

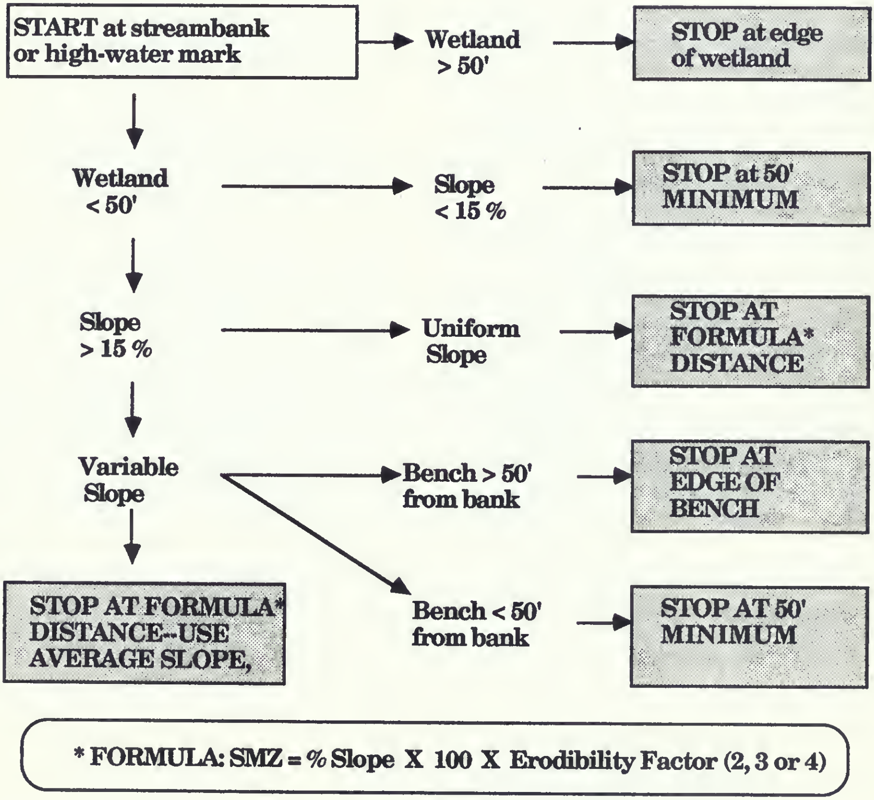

Figure G-1: Field guide for locating the edges of the SMZ of the current Best Management Practices (Montana Environmental Quality Council 1989).

Variability of field conditions will still require professional judgement in delineating the SMZ. Wetlands often occur as pockets or stringers reflecting microsites in bottomlands. Wetlands may also extend up adjacent slopes reflecting unstable conditions. Microtopography also changes within management units. The decision tree process allows for varying the SMZ within the unit to provide stream protection. This needs to be balanced with other management considerations as long as the minimums at any one point along the stream are not violated.

The user should remember that the above criteria are to meet minimum standards and that the current BMPs allow considerable flexibility in management practices within the Streamside Management Zones. In order to ensure protecting water quality, the Audit Teams and the Management Guidelines Working Group made several suggestions that should be considered in any specific operation:

(1) If the existing stand has little woody debris and little undergrowth vegetation to trap and filter sediments, the SMZ should be expanded appropriately to provide an effective filter or use other mitigating measures.

(2) Large trees in or near wetlands are especially susceptible to windthrow. Potential windthrow should be anticipated and planned for to minimize soil disturbance and bank damage caused by uprooted trees. This may mean removal of some high risk streambank trees and/or minimizing edge effects of certain harvesting practices.

(3) Trees should be marked and reserved along those stream segments where woody debris recruitment is needed for stream protection. The selection of reserve trees must be integrated with stream type, existing woody debris, desired woody debris, windthrow risk, silvicultural prescription, harvesting practice, and projected stand development.

(4) A sediment filter buffer may be needed *adjacent to certain wetlands* where routed sediments from roads or skid trails have a potential of being deposited in the adjacent wetlands.

(5) Headwater basin sites may have a pattern of many small streams where it is difficult to define SMZs for each tiny intermittent stream. However, these sites are critical in terms of watershed management. In many situations, it may be most practical to simply treat entire cutting units as a Streamside Management Zone.

One of the first steps to ensure protection of water quality is to recognize and delineate the SMZ and make sure every person involved in a forestry operation knows where the boundaries are. The next step is to make sure the SMZ is not violated inadvertently during logging, slash disposal, or site preparation. It does little good to develop a sound prescription and conduct careful logging if the operator piling slash or the people conducting prescribed burning do not use the same care.

Estimating soil erodibility potential has been done in different ways and the Management Guidelines Working Group considered alternatives such as soil texture. Current studies are underway to obtain better estimators, but are not yet available for routine application. Until better estimates are available, we decided to stay with the original estimators. When better estimates become available (or local expertise is well documented) they can simply be substi-

MONTANA "RISK" MATRIX (3/91)

TYPE		CLEARCUT				PARTIAL CUT				SITE PREP			ROADS	
SLOPE	SOIL EROD.	TRACKED EQUIP.	RUBBER SKID	PARTIAL SUSP.	FULL SUSP.	TRACKED EQUIP.	RUBBER SKID	PARTIAL SUSP.	FULL SUSP.	MACHINE PILE/SCAR	BRDCAST BURN	OTHER	PERM.	TEMP.
0-5%	H	2	2	2	1	2**	2**	1	1	2	1	1	2**	3
	M	2	1	1	1**	2	1**	1	1	2**	1	1	1	1
	L	1	1	1	1	1	1	1	1	1	1	1	1	1
5-20%	H	4	3	2	1	4*	3	2	1	4	2	1	3	4
	M	3	2	1	1	3*	2	1	1	3	2	1	2	3
	L	2	2	1	1	2*	2*	1	1	2	1	1	2	2
20-40%	H	5	5	4*	2	5*	5*	3**	1	5	3**	1	4	5
	M	4*	4	3	1	3	3	2	1	4	3	1	3	4*
	L	3*	2	2	1	2	2	2	1	3	2	1	3*	3
> 40%	H	5	5	4	2	5	5	4	2	5	4	1	5	5
	M	5	5	4	2*	5	5	3	1	5	4	1	5	5
	L	4	4	3	1	4	4	2	1	4	3*	1	4	4

(* Indicates Mean Value Used, ** Final Group Consensus Adjustment for Internal Consistency)

Figure G-2: Montana "Risk" Matrix (3/91) tuted to place soils in one of the three classes.

The practical guidelines for delineating Streamside Management Zones are based on current knowledge. As additional knowledge is gained from current studies and experience, SMZ criteria and BMPs should both be modified to provide a proper balance between protection of water quality and efficiently meeting objectives of the landowners.

A 25-foot minimum SMZ was originally recommended by the Environmental Quality Council's Best Management Practices committee. The Montana Riparian Association Management Guidelines Working Group discussed the minimum at their final meeting in March, 1991. After weighing the minor advantages and disadvantages of 25 feet vs. 50 feet, they agreed to recommend a 50 foot minimum as a reasonable compromise in the context of current BMPs within the Streamside Management Zone.

Results – Soil Erodibility Matrix Risk Assessment

The results of a group expert opinion consensus process (Delphi approach) to develop the soil/slope risk assessment matrix are summarized as Chapter One of Lull's Masters thesis (Lull 1990). The round two matrix was also used as an aid in conducting the 1990 state-wide BMP field audits (Schultz 1990). The Working Group revised the matrix to obtain internal consistency at their meeting on March 6, 1991. This revised matrix is shown in Figure G–2.

The Management Guidelines Working Group considered several alternatives to the parent material classes of Cline and others (1981) for estimating soil erodibility. Fairly close agreement was reached on soil texture in the round two Delphi questionnaire. However, current research by Ed Burroughs (USDA-Forest Service-Intermountain Station, Moscow, ID) suggests that the amount and shape of coarse fragments may be equally important. Also, USDA-Northern Region Hydrologists are currently working on revised information on soil erodibility for input into improved sediment models. The Working Group decided (August 6, 1990) to defer further work on soil erodibility and wait for the results of the current efforts. When better estimates of soil erodibility become available they can be substituted to place soils in one of our three classes. We think it is important to keep the methods for estimating soil erodibility consistent for risk assessment, streamside management zone formulas, and sediment models.

Conclusions

(1) Habitat type-specific management information has now been provided in a 1990 draft publication (Boggs and others 1990). This information is far more suitable than previous generalities and better suited to aid field people in making site-specific evaluations.

(2) Criteria have now been developed and evaluated for consistent field delineation of Streamside Management Zones to meet the intent of the Best Management Practices. Additional suggestions are provided for special situations where the general formula should be adjusted to provide additional protection.

(3) A forest practices risk matrix in relation to slope and soil erodibility is now available to evaluate relative risks. It can be applied for watershed level risk assessment of proposed alternative practices and for several other applications and interpretations. Acknowledgment of relative risk is the first step in prescribing activities and possible mitigation.

Acknowledgments

The following professionals have actively provided input and review for the development of these field guides as well as several related topics. They have all been working together as a Management Guidelines Working Group within the Montana Riparian Association:

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Dan Svoboda	

Study Module H:

Application of the Sequoia Method for Determining Cumulative Watershed Effects in the Flathead Basin

By Don Potts

This section of the *Final Report* summarizes a study of the same name published by the Flathead Basin Commission (723 Fifth Avenue East, Kalispell, Montana 59901).

Application of the Sequoia Method for Determining Cumulative Watershed Effects in the Flathead Basin

By Don Potts[1]

A cumulative watershed effects risk assessment procedure has been applied to the entire Swan River watershed and to 30 smaller Flathead Basin watersheds. The Swan and the 30 smaller watersheds were selected for study by the Flathead Basin Water Quality and Fisheries Cooperative because of their high fisheries values and growing concerns over possible impacts from forest management practices.

The risk assessment model, Sequoia, was developed by the hydrology, soil science and forest management staff on the Sequoia National Forest in 1980. It is basically an accounting system for areal disturbance. The various forest management activities are assigned a Runoff Coefficient that varies with the degree of site compaction and soil exposure. The coefficients range from a high of 1.0 for permanent harvest system roads to a low of 0.1 for cable system partial cuts and low intensity fires (ten percent soil exposure). (See Table H–1.) The Runoff Coefficient times the area disturbed is called the Cumulative Runoff Acreage (CRA, or in other Region 5 methods, the Equivalent Road Acreage). Various assumptions are made about the actual areas disturbed by roads, trails, skid systems, and landings. (See Table H–2.) The procedure assumes that disturbance from all timber harvest-related activities recovers within ten years except for roads, trails, recreation, and administrative sites which never recover.

The basic premise of Sequoia is that soil compaction and soil exposure effectively increase the drainage efficiency of a watershed, thus increasing the magnitude of peak flows, which in turn may cause destabilization of channels and deterioration of fisheries and water quality. Based on research conducted in Oregon and California, the procedure recommends a Threshold of Concern (TOC) for watersheds with "average sensitivity" when the Cumulative Runoff Acreage reaches 12 percent of the watershed.

The Swan River watershed was partitioned into 54 analysis units ranging in size from roughly 1,400 to 23,000 acres. (See Figure H–1.) Many of the analysis units, particularly those at higher elevations, have boundaries corresponding to actual watershed boundaries. All forest management activities during the past decade and all existing road information in each of the units was obtained from the land owners. Sequoia estimates of areal disturbance ranged from a high of nearly 40 percent to a low of zero. Thirteen of the analysis units had disturbance greater than Sequoia's 12 percent threshold of concern. Nearly 11 percent of the Swan River watershed received some sort of harvest treatment during the 1980s. This involved over 750 miles of temporary or permanent roads totalling a Cumulative Runoff Acre-

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Table H-1. Runoff Coefficients and Recovery Rates

ACTIVITY	YEARS 0	1	2	3	4	5	6	7	8	9	10
Tractor Clearcut	.4	.4	.35	.2	.1	.1	.1	.1	.1	.1	.1
Cable Clearcut	.2	.2	.2	.15	.1	.1	.1	.1	.1	.1	.1
Tractor Partial	.2	.2	.15	.1	.1	.1	.1	.1	.1	.1	.1
Cable Partial	.1	.1	.1	.1	0	-	-	-	-	-	-
Site Prep Mech.	.7	.7	.6	.5	.3	.2	.1	.1	.1	.1	.1
Mechan. Release	.5	.4	.4	.3	.25	.15	.1	.1	0	-	-
Aband. Roads	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
Perm. skid sys.	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
Burns 10% soil	.1	.1	.1	0	-	-	-	-	-	-	-
Burns 80% soil	.4	.4	.35	.3	.2	.1	0	-	-	-	-
ORV Trails	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
System Roads	1	1	1	1	1	1	1	1	1	1	1

Table H-2. Extent of Activities — Equivalent Acres

Activity	Equivalent Acres
Tractor Clearcut	Harvested Acres
Cable Clearcut	Harvested Acres
Tractor Partial-cut	Harvested Acres
Cable Partial-cut	Harvested Acres
Mechanical Site Prep.	Treated Acres
Mechanical Release	Treated Acres
Abandoned Roads	Miles x 2 Acres
Rec. & Admin. Sites	Acres of Sites
Perm. Skid System/landings	Harvested Acres x 27%
Burns	Acres Burned
ORV Trails	Miles x 1.5 Acres
System Roads	Miles x 3.5 Acres

age of about eight percent of the watershed in 1989.

Sequoia was similarly applied to the 30 smaller watersheds located within the Flathead Basin. Cumulative Runoff Acreages in these critical fisheries ranged from 0 percent in Elk Creek and Lion Creek to over 30 percent in Freeland Creek. In addition to Freeland Creek, Cumulative Runoff Acreages in Jim Creek, Fish Creek and Sheppard Creek were above Sequoia's 12 percent threshold of concern. The Squaw Creek tributary and Hand Creek are approaching the threshold. (See Table H–3.)

The Flathead National Forest and the Montana Department of State Lands currently use similar water yield models (H_2OY), based on the Equivalent Clearcut Area (ECA) concept. Rather than measuring compaction and soil exposure in anticipation of changes in peak discharges, the ECA models measure canopy removal in anticipation of changes in average annual water yield. In the Flathead Basin, it is assumed that channels with "normal" stability can withstand an increase of ten percent in annual water yield. The ECA and the CRA model predictions should be correlated — you can't remove canopy without soil compaction and exposure. Nevertheless, the models measure different impacts and have different underlying assumptions.

The ECA model was applied to the same 30 critical fisheries watersheds as Sequoia, and in the same rank order Freeland, Fish and Sheppard Creeks were judged to be above the threshold of concern. The ECA model did not, however, find Jim Creek, the Squaw Creek tributary or Hand Creek to be at or near the threshold. Hopefully, these results, when compared and

Figure H-1A: Swan Watershed Analysis Units — North

Figure H-1B: Swan Watershed Analysis Units — South

Table H-3. Comparison of model results

	WATERSHED	SEQUOIA (% DIST)	H_2OY (% INCR)
1A	ELKCREEK	0.00	0.00
1B	ELKCREEK	0.00	0.00
2	GOATCREEK	0.01	0.90
3	SQUEEZER	0.04	0.46
4	LION	0.00	0.00
5A	JIM	12.20	4.49
5B	JIM	13.00	4.26
6	PIPER	0.00	0.00
7	FREELAND	30.90	22.00
8	FISH	22.60	16.78
9	HAND	9.50	1.55
10	UPPER EF SWIFT	>0.00	NA
11	SHEPPARD	15.70	10.24
12A	UPPERBIG	1.20	2.93
12B	LOWERBIG	3.00	3.32
13	LOWERCOAL	2.30	1.58
14	COALCREEKNF	6.70	3.03
15	COALCREEKSF	3.90	1.70
17	REDMEADOW	3.40	1.83
18	WHALE	1.20	1.27
19	TRAIL	2.30	0.65
20	GRANITE	1.90	1.72
21	CHALLENGE	2.50	1.03
23	MORRISON	2.50	1.30
24A	HUNGRYHORSE	>0.00	0.60
24B	HUNGRYHORSE	>0.00	0.50
25	MARGARET	>0.00	1.64
26	TIGER	>0.00	0.11
27	EMERY	2.00	3.14
29	SQUAWTRIB	11.10	3.62

correlated with the other Cooperative studies, will allow us to gain understanding of cumulative watershed effects in the Flathead Basin.

Summary

The Sequoia Method for cumulative watershed effects risk assessment was chosen for use in the Flathead Basin for a number of reasons. The procedure is representative of the official U.S. Forest Service Region 5 (California) procedures. This model or others similar in application and data requirements are currently used by the National Forests in Region 5.

Sequoia is computationally straight-forward. The most difficult obstacle is obtaining all of the information on harvesting, site-preparation, and roads from the various land-owners in mixed ownership watersheds. All of the data required by Sequoia are routinely maintained by landowners.

Finally, since Sequoia is an accounting system for areal disturbances, it is actually compatible with our growing Geographic Information Systems capabilities. All of the information required by Sequoia is found on the Flathead National Forest Geographic Information System (GIS).

Just as Region 5 has made the CRA methods official analysis tools, the Montana Cumulative Watershed Effects Cooperative has made a model much like H_2OY the new "official" model for Region 1. The understanding in the cooperative is that members will work with the new model to resolve its shortcomings. Nevertheless, many of the ECA logic flaws will never be worked out. The most critical of these is that increases in average annual flow are related to channel forming processes. Again, Sequoia is an accounting system that does measure things we know to be related to peak flows and channel forming processes. We have begun working on a computer version of Sequoia for use with microcomputers. When it becomes available, the model will be in a form easily usable by all land managers in the Flathead Basin.

Study Module I:

A Forest Management Nonpoint Source Risk Assessment Geographic Information Systems Application

By Don Potts

This section of the *Final Report* summarizes a study called *Development of a Geographic Information Systems Application for Assessment of Nonpoint Source Pollution Risk on Managed Forest Lands* published by the Flathead Basin Commission (723 Fifth Avenue East, Kalispell, Montana 59901).

A Forest Management Nonpoint Source Risk Assessment Geographic Information Systems Application

By Don Potts[1]

Introduction

The assessment of nonpoint source pollution and cumulative watershed effects resulting from forest management is proving to be a difficult task. Application of Best Management Practices (BMPs) does not provide an assessment of condition, monitoring can be prohibitively expensive, and our quantitative modeling skills are in their infancy. An alternative approach, watershed risk analysis, may, however, provide resource managers with a powerful tool to assist in land-use decision making. In addition, Geographic Information Systems (GIS) allow the correlation of land cover and topographic information such as terrain configuration and drainage networks, thus making GIS useful in assessing the potential effects of land-use activities on water resources (Walsh 1985).

We have developed a methodology to assist forest managers in assessing nonpoint source pollution and cumulative watershed effects by combining watershed risk assessment with GIS. The information required by the procedure is available in the Flathead National Forest GIS. Making a map with GIS is easy, but including appropriate landscape attributes is difficult. The key is the construction of a nonpoint source pollution risk matrix. The results of such an application are presented on a heavily impacted, mixed-ownership watershed.

Risk Matrix Construction

Leopold and others (1971) were among the first to propose the use of an environmental matrix to evaluate potential environmental impact. The matrix provides a comparatively simple system intended to be a guide in the impact assessment process. This approach was adopted by Rickert and others (1978) to evaluate erosion potential for the Oregon 208 nonpoint source assessment project and by Brown III and others (1979) as a guide for land-use planning.

The "risk" matrices developed in these studies assessed the relative impacts of various land-use activities on different combinations of slope and substrate erodibility. Forest management practices were among the land-use activities considered, but Brown III and others suggested that matrices should be developed regionally to reflect local conditions, practices, and socioeconomic considerations.

Therefore, we contacted a large group of soil and water specialists and silviculturists, representing land management agencies and the forest products industry in Montana, to build the Montana erosion-impact matrix. We quickly learned that it was not going to be as easy as we thought. There was considerable

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disagreement over the relative risk values, on a simple scale of 1 to 5, to be used in the body of the matrix as well as the basic combinations of slope and erodibility that would produce different potential impacts.

We convened the group of experts four times and, through the Nominal Group Technique, arrived at the consensus matrix appearing in Figure I-1. The horizontal axis is composed of 4 principal forest management practices: (1) clearcutting, (2) partial cutting, (3) site preparation, and (4) road construction. Each principal practice is further split into specific methods, treatments, or designs.

The group decided that four slope classes on the vertical axis were sufficient and distinctly different in inherent erosion risk, and that three basic soil erodibility classes were also adequate. These classes were based primarily on the geologic erosion factors described in the R1-R4 Sediment Yield Prediction Procedure (USDA Forest Service 1981). Everyone agreed that alluvial and granitic soils were highly erodible, those formed from Belt Series metamorphics had low erodibility, and that most other substrates fell into the moderate erodibility class.

Howard Creek

The Howard Creek watershed, totalling 5015 hectares, is located approximately 32 kilometers southwest of Missoula, Montana. Elevation in the watershed ranges from 1190 to 1770 meters. Average annual precipitation at mean elevation is about 100 cm, and roughly 60 percent of that falls as snow. The forest cover is primarily Douglas-fir mixed with sub-alpine fir at the higher elevations and Ponderosa pine at the lower elevations and south aspects. The main stem of Howard Creek is oriented east-west while the three sub-basins, Tepee Creek, North Fork of Howard Creek, and Krystal Creek, are oriented north-south. (See Figure I–2.) This map, and the following maps were prepared using PAMAP (1989) GIS software and information hand-digitized at a scale of 1:24000.

The Lolo National Forest Land Systems Inventory maps the primary geologic groups found in Howard Creek as metasedimentary and undifferentiated materials. (See Figure I–3.)

Metasedimentary parent materials are derived from Belt Super Group quartzite, argillite, and siltite. Rock fragment hardness is variable depending upon the degree of rock weathering. Weathering is dependent on associated faults, preponderance of argillites, and calcium carbonate content. These materials were classified as either L-low or M-moderate erodibility for the erosion-impact matrix.

Undifferentiated geology is composed of materials derived from Belt Super Group metasedimentary rocks or weakly weathered granitic rocks. Materials include alluvium on terraces and flood plains; shallow soils on flood scoured foot slopes and stream breaklands, strongly frost churned broadly convex ridges, and glacial outwash on plains. These are classified as "H" — highly erodible in the Montana erosion-impact matrix.

Like much of western Montana, the watershed has a "checkerboard" pattern of land ownership. Champion Timberlands owns 34 percent of the watershed, Plum Creek Timber owns 23 percent of the watershed, and the remaining 42 percent is managed by the Lolo National Forest. Ownership was mapped by the GIS and is shown in Figure I–4. Timber harvest-related activities between 1981 and 1986 impacted 17 percent of the watershed. The location of these activities is shown in Figure I–5. In a report to the Lolo Forest Supervisor (Munther and others 1987), cumulative watershed effects in Howard Creek were estimated to have produced a sediment load increase of 50 percent and water yield

MONTANA "RISK" MATRIX (3/91)

TYPE		CLEARCUT				PARTIAL CUT				SITE PREP			ROADS	
SLOPE	SOIL ERÓD.	TRACKED EQUIP.	RUBBER SKID	PARTIAL SUSP.	FULL SUSP.	TRACKED EQUIP.	RUBBER SKID	PARTIAL SUSP.	FULL SUSP.	MACHINE PILE/SCAR	BRDCAST BURN	OTHER	PERM.	TEMP.
0-5%	H	2	2	2	1	2**	2**	1	1	2	1	1	2**	3
	M	2	1	1	1**	2	1**	1	1	2**	1	1	1	1
	L	1	1	1	1	1	1	1	1	1	1	1	1	1
5-20%	H	4	3	2	1	4*	3	2	1	4	2	1	3	4
	M	3	2	1	1	3*	2	1	1	3	2	1	2	3
	L	2	2	1	1	2*	2*	1	1	2	1	1	2	2
20-40%	H	5	5	4*	2	5*	5*	3**	1	5	3**	1	4	5
	M	4*	4	3	1	3	3	2	1	4	3	1	3	4*
	L	3*	2	2	1	2	2	2	1	3	2	1	3*	3
> 40%	H	5	5	4	2	5	5	4	2	5	4	1	5	5
	M	5	5	4	2*	5	5	3	1	5	4	1	5	5
	L	4	4	3	1	4	4	2	1	4	3*	1	4	4

(* Indicates Mean Value Used, ** Final Group Consensus Adjustment for Internal Consistency)

Figure I-1: Montana "Risk" Matrix (3/91)

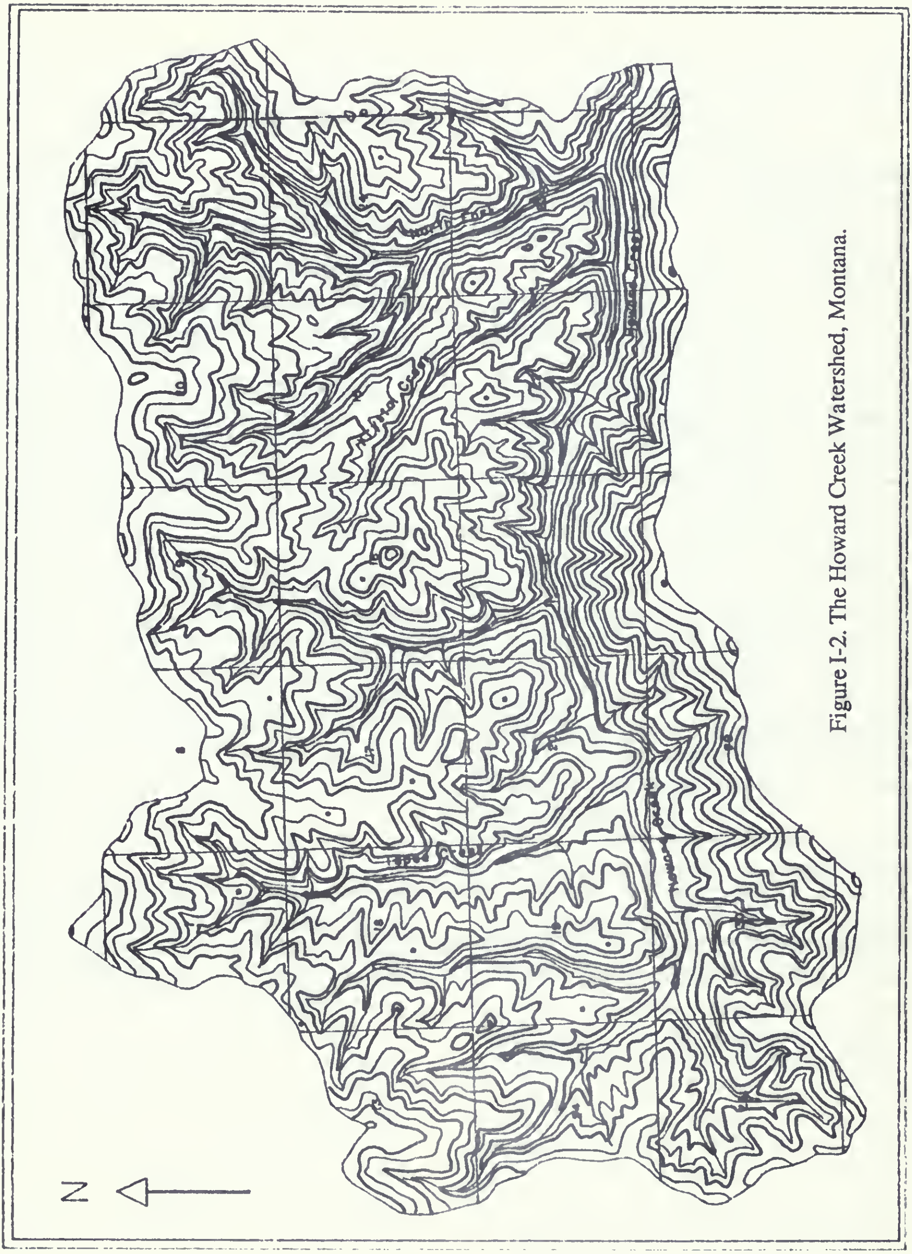

Figure I-2. The Howard Creek Watershed, Montana.

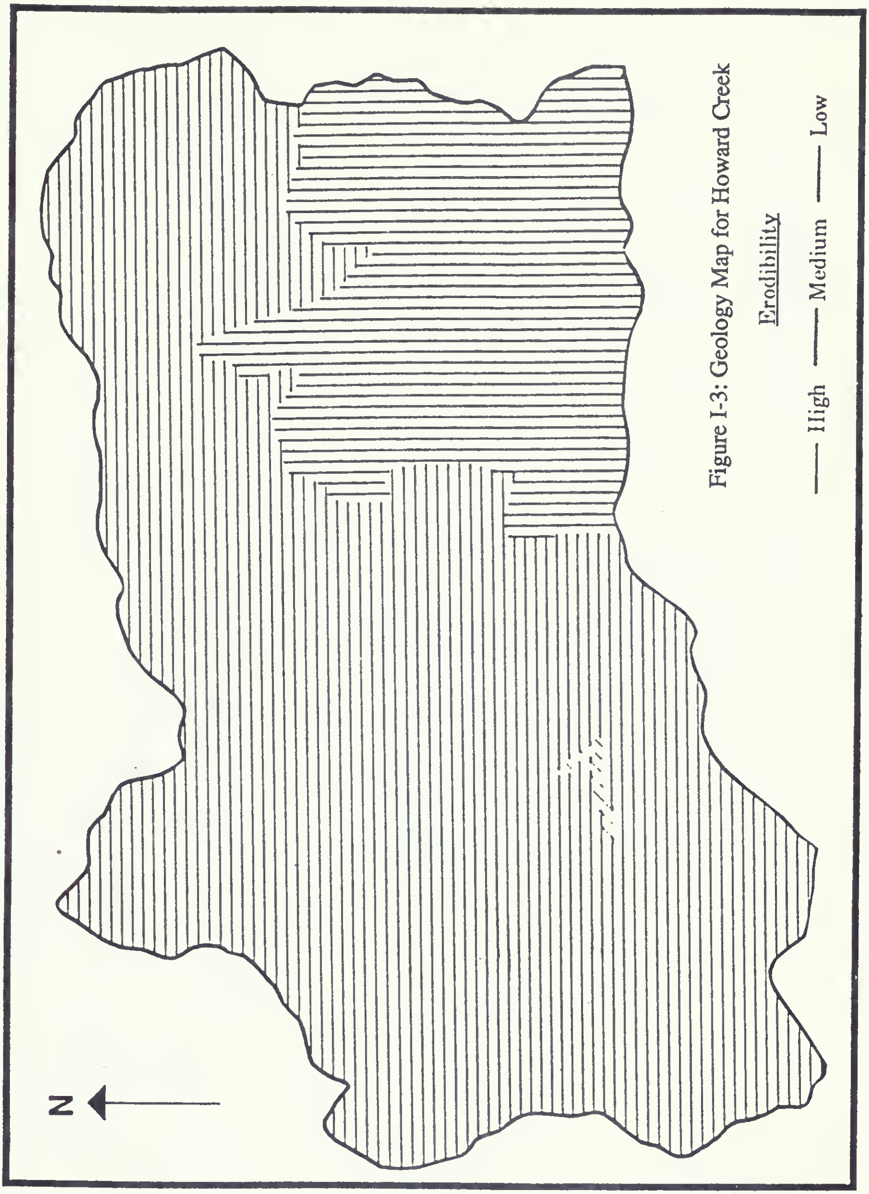

Figure I-3: Geology Map for Howard Creek

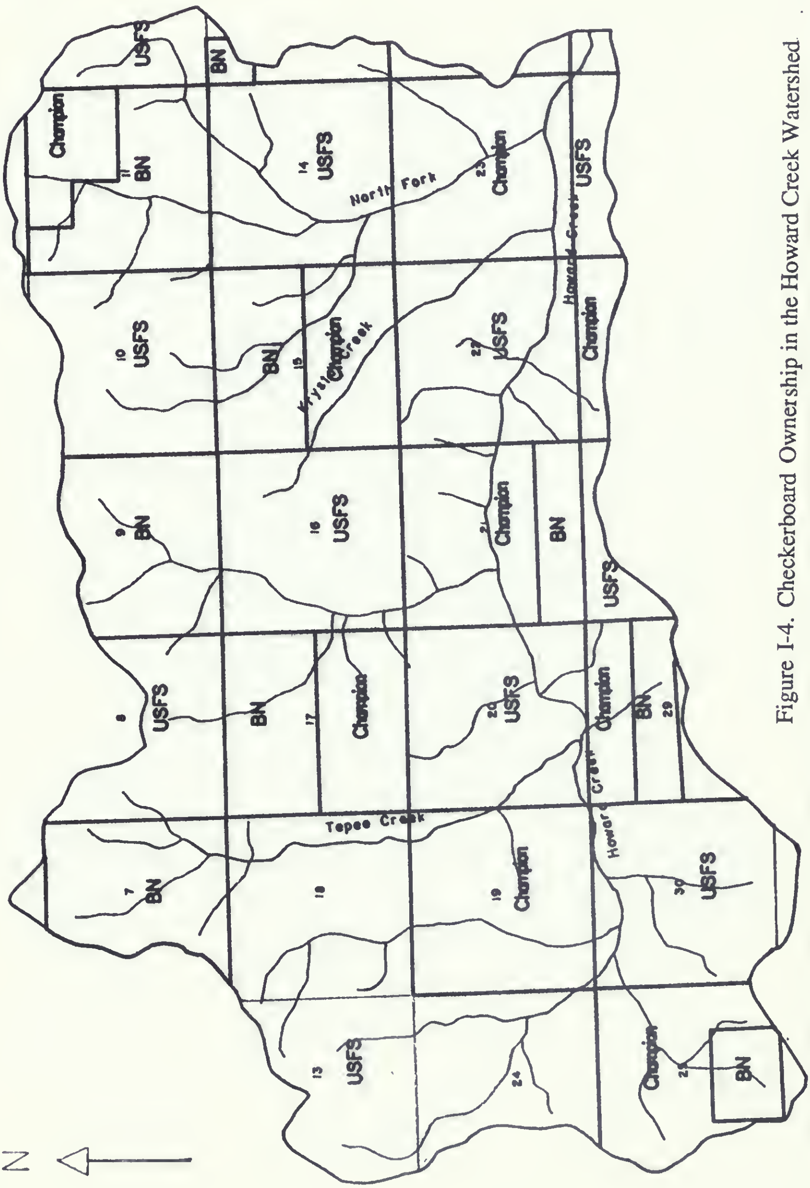

Figure I-4. Checkerboard Ownership in the Howard Creek Watershed.

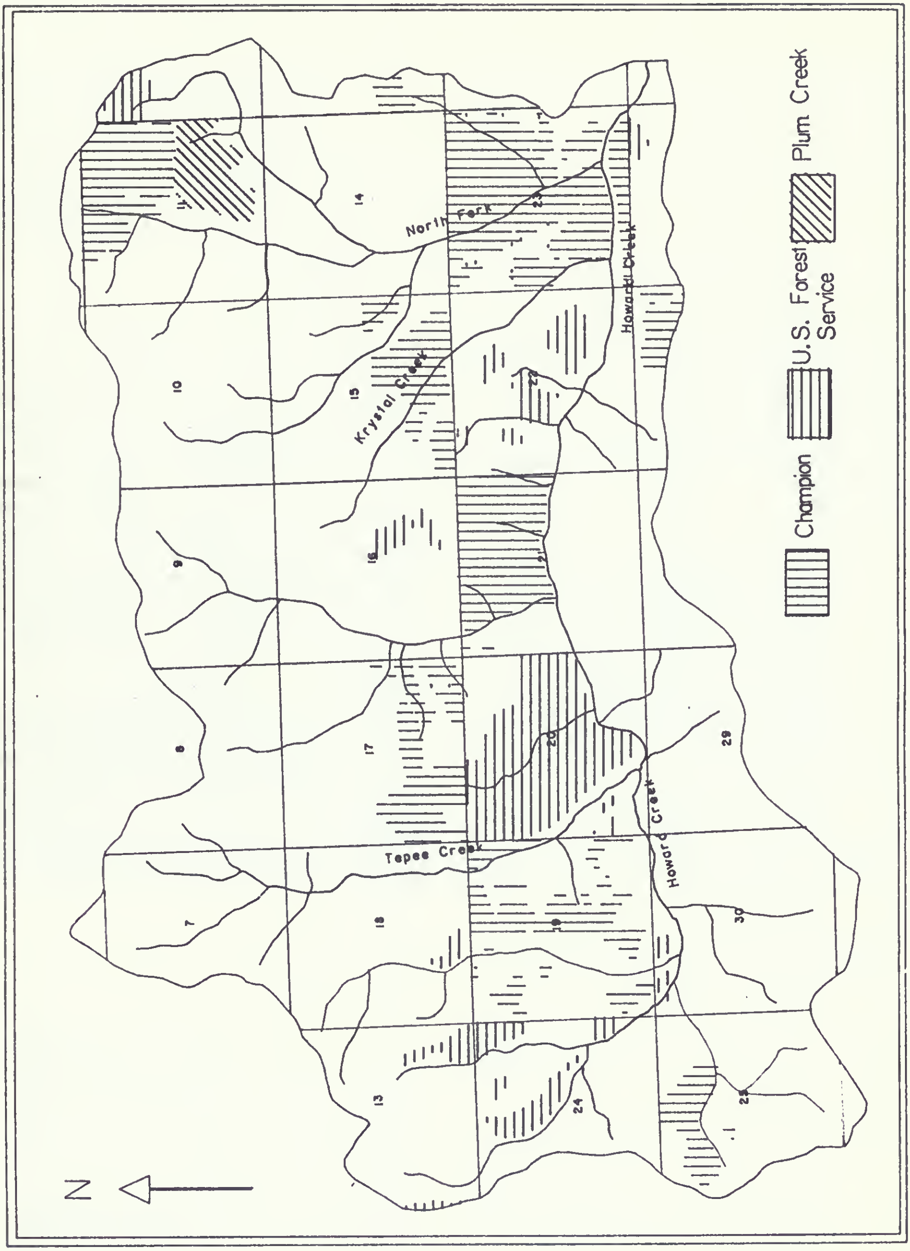

Figure I-5. Timber Harvest Activity in the Howard Creek Watershed.

increase of 8 percent. The Forest Supervisor immediately imposed a 10-year timber harvest moratorium on Forest Service lands. Industry has cooperated, and there has been little activity in the watershed during the past three years.

A Cumulative Effects Risk Index Value

An undisturbed watershed has a zero risk index value. The risk index value for a managed watershed depends on the areal extent of activities, the age of the treatments, and the type of terrain on which they are located. The calculation of a cumulative effects risk index value is straightforward and is outlined in the following eight steps:

Step 1: Determine the year/type/acreage of past (or planned) forest management activities. Permanent road disturbance is calculated at 0.87 ha/km; temporary road disturbance is calculated at.37 ha/km. Digitize this information for use in the GIS if it has not already been done.

Step 2: Determine the erosion classification of the terrain on which the activity has taken (or will take) place. This is generated by the GIS.

Step 3: Determine slope category on which the activity has taken (or will take) place using GIS.

Step 4: Obtain a risk value for each activity from the Erosion-Impact Matrix that has been developed.

Step 5: Determine the areal percentage of the watershed on which the activity took place.

Step 6: Use a recovery coefficient (RC — a value between 1 and 0) to reduce the risk associated with older activities. In this application, we assumed a linear 10-year risk recovery for all activities except roads, which always maintain a RC of 1. Thus, current year activities have a RC of 1, four-year-old activities have a RC of 0.6, and so on.

Step 7: Multiply the risk value times the percentage of the watershed times the RC to obtain the total risk for that activity.

Step 8: Sum all past and planned land-use totals.

Table I–1 contains a summary of disturbance information, by year, for Howard Creek. Harvest, site preparation and road data were obtained directly from the three land owners in the watershed. To avoid double accounting, only the last entry onto a site was counted. Usually this was for site preparation, which was almost always dozer piling of slash. If no site preparation had been completed, then harvesting was the only disturbance counted, and this was almost always partial cutting with tractor skidding.

Note that in 1990, the cumulative risk index value is 0.2284, but if the risk index value had been calculated in 1986, the year the timber harvest moratorium was called, it would have been 0.3998. The differences between the 1990 and 1986 weighted risk columns in Table I–1 are due only to the effect of the recovery coefficients.

Thresholds?

How much disturbance a watershed can tolerate before reaching a level that produces significant environmental damage is both technically and politically difficult to answer. In the Forest Service's Region 5, a watershed's "Threshold for Concern" is typically an areal disturbance (actually, equivalent road acres) of between 10 percent and 20 percent depending

Table I-1. "Risk" Calculations for Howard Creek, Lolo National Forest, Montana.

Year	Activity	Area (ha)	% of Total Area	1990 Weighted Risk	1986 Weighted Risk
1981	Site Prep.	14	0.27	.0004	.0020
1983	Site Prep.	177	3.53	.0342	.0798
1984	Harvest only	36	0.72	.0065	.0130
	Site Prep.	390	7.78	.0650	.1300
1985	Harvest only	92	1.83	.0275	.0495
	Site Prep.	84	1.67	.0160	.0288
1986	Harvest only	6	0.12	.0021	.0035
	Site Prep.	53	1.06	.0247	.0412
Permanent Roads		61.4	1.22	.0360	.0360
Temporary Roads		21.3	0.42	.0160	.0160

Unrecovered Disturbance	18.62%	
1990 Cumulative "Risk"	.2284	
1986 Cumulative "Risk"		.3998

on the watershed's sensitivity (Cobourn 1989). These values are based on research conducted by Harr and others (1975).

If Howard Creek were in Region 5, its combination of slopes and geology would probably classify it as moderately sensitive, and therefore would have a "Threshold for Concern" of 15 percent. Note in Table I–1 that six years of management produced an unrecovered disturbance of nearly 19 percent. The "yellow flag of caution" would not yet have been raised because of recovery and only some percentage of the disturbance was equivalent road acres. The specialists on the Lolo National Forest raised their own "yellow flag of caution" based on monitoring information. Nevertheless, there were some indications of changes in the system, so perhaps a 10 percent to 15 percent disturbance threshold is legitimate.

Similar rationale for assigning a risk index value threshold may be used. A moderate risk for generating cumulative effects has a value of 3 in the Erosion-Impact matrix. If we were to chose a 15 percent areal disturbance limit, and be willing to accept moderate risk, then the risk index target would be 0.45 (0.15 X 3). A ten percent disturbance limit would have a risk index of 0.3. Similarly, acceptance of higher or lower risk could also increase or decrease the target. In either event, the Howard Creek watershed was being stressed, or nearly so, in 1986. Recovery is rapid, however, so deferring activity or selecting low risk options (a combination of sites and methods) would allow the cumulative risk value to fall. Note that by 1990, the cumulative risk index value fell to about 0.23.

Summary

This methodology has not yet been applied to any watersheds in the Flathead Basin. Care was taken, however, to make sure that all information required for the procedure is already available on the Flathead National Forest GIS. We see distinct advantages that this risk assessment procedure offers over other cumulative effects analyses. First, machine processing of data tends to minimize "human errors." Secondly, the technique allows us to weight our assessment of risk by our understanding of both erosion and peak flow generation processes and the inherent impacts associated with various management activities.

We strongly recommend testing the procedure in the Flathead Basin, using the Flathead National Forest's GIS capability and the data sets obtained for the other watershed analyses conducted by the Cooperative, and comparing the results with those of the other techniques.

Study Module J:

Linear Correlation/Regression Analysis of Forestry Models, Risk Assessment, and Water Quality and Fisheries Data

By Dean Sirucek, Elizabeth Hill,
F. Richard Hauer, John Fraley, Thomas Weaver,
Don Potts, and Steve Tralles

Linear Correlation/Regression Analysis of Forestry Models, Risk Assessment, and Water Quality and Fisheries Data

By Dean Sirucek,[1] Elizabeth Hill,[2] F. Richard Hauer,[3] John Fraley,[4] Thomas Weaver,[5] Don Potts,[6] and Steve Tralles[7]

Introduction

An important aspect of the cooperative study was to determine whether there are meaningful, quantitative linkages between the type and intensity of forest management activities within a watershed and measured effects to the stream ecosystem. Some of the nine previous studies were designed to investigate quantitative or qualitative water quality or fisheries habitat monitoring parameters. Other studies applied modeling procedures to test their validity in the Flathead Basin. However none of the studies focused on directly linking computer generated predictions to the measured field parameters. We designed Module J to compare computer model predicted effects of timber harvest directly to actual quantitative and qualitative water quality or fisheries habitat parameters.

Several state-of-the-art watershed computer models are used in modern forestry to predict changes in stream flow volume, regime, and sediment yields from proposed forest management activities. Different watershed models examine various parameters using a number of methods to predict potential changes in the aquatic ecosystem. The Sequoia model (as discussed in Module H), is an index of cumulative disturbed areas. The procedure assumes that disturbance from all timber harvest-related activities recovers within ten years except for roads, trails, recreation, and administrative sites which never recover. The Module H study team developed Sequoia CRA (Cumulative Runoff Acreage) on the 28 fishery watersheds investigated in Module D.

Currently the Flathead National Forest and the Department of State Lands use similar computer models to predict water yield increase. These models are based on an Equivalent Clearcut Area (ECA) concept — that is, an increase in average annual water yield will occur following removal of trees from a site. (As water yield increases, the potential for streambank erosion increases. As the trees grow

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back on the site, the water yield is reduced over time.) The ECA model used on the Flathead National Forest is named H_2OY (Isaacson 1977).

In 1990, the Montana Cumulative Effects Cooperative (which includes the Flathead National Forest, Department of State Lands, and Plum Creek, L.P.) adopted and then updated a watershed computer model for analysis of timber harvest effects in multiple-ownership watersheds. This updated model (named WATSED) combines a sediment yield model (Cline and others 1981) and an ECA water yield predictive model (U.S.D.A. Forest Service Region 1 1972). WATSED predicts the natural levels of water yield and sediment production along with increases due to timber harvest. The WATSED computer model develops predictions for a water yield model based upon an ECA concept. The sediment yield portion of WATSED predicts soil erosion from roads, timber harvest, and fire.

The purpose of this module was to determine the relationships between the quantitative studies and current forest management modeling tools. We applied land use data to the three computer models. Numerical outputs were then applied as independent variables to linear correlation/regression analyses. Results from the water quality and fisheries modules were applied as dependent variables. The goal of this effort was to test the statistical significance of those regressions and to determine whether there is a relationship between what is predicted by the management models and the empirical data collected in the water quality and fisheries studies.

Linear Correlation/Regression Analysis

The quantitative field measurements reviewed included the following: suspended sediment (Flathead National Forest database), total suspended solids (Module C), streambed sediment (Module D — McNeil sediment cores and Whitlock-Vibert box sediment), nutrients (Module C), maximum algae growth (Chlorophyll ſ — Module C), and frequency of bull trout and westslope cutthroat trout redds (Module D). Qualitative procedures were conducted in the stream reaches immediately upstream from the water quality or fishery monitoring sites. These procedures included the following: Region-l stream channel stability rating (Flathead National Forest database, Pfankuch 1978), substrate score (Module D), and Montana Water Quality Bureau's state-wide stream reach assessment procedure (Module E). This represents all available historic and current information collected for each watershed. The ECA model H_2OY was run on the 28 fisheries study watersheds. Model output for H_2OY is water yield increase, which was used for comparison to the water quality and fisheries data. The cumulative watershed effects risk assessment procedure, Sequoia (CRA = Cumulative Runoff Acreage — Module H) was applied to the 28 fisheries study watersheds.

Because WATSED was being updated, it was unavailable for use until late in this cooperative effort. Therefore we did not have time to run data sets on all 28 fishery watersheds. For this reason, we chose from the 28 fishery watersheds, the 10 that had the longest history of water quality and fish habitat monitoring data. There were five variables from WATSED that were used for the correlations: (l) equivalent clearcut acreage—cumulative, (2) water yield increase (WYI)—annual basis, (3) water yield increase—75 percent peak flow duration change, (4) natural sediment yield—annual basis, and (5) sediment yield increase—annual basis.

See Table J-1 for the list of study watersheds and the variables measured. Refer to Figure D-1 for watershed locations.

The Region 1 Channel Stability Ratings (CSR) were conducted on the same ten stream

Table J-1: List of study sites by watershed and the application of water yield increase and/or sediment yield models (H_2OY and WATSED), the Sequoia risk analysis, and the study sites that were investigated in the water quality module (C), the fisheries module (D), and the Montana Water Quality Bureau's qualitative reach assessment module (E).

WATERSHED	H_2OY	WATSED	SEQUOIA	MODULE C	MODULE D	MODULE E
Lion Creek	X	X	X	X	X	X
Chepat Creek	X	X	X	X	X	
Coal Creek	X	X	X		X	X
Challenge Creek	X	X	X		X	X
Upper South Fork Coal Creek	X	X	X	X	X	X
Lower South Fork Coal Creek				X		X
North Coal Creek	X	X	X		X	X
Hand Creek	X	X	X	X	X	X
Squaw Creek	X	X	X	X	X	
Jim Creek	X	X	X	X	X	X
Fish Creek	X	X	X		X	X
Elk Creek	X		X		X	X
Goat Creek	X		X		X	X
Squeezer Creek	X		X		X	X
Piper Creek	X		X		X	X
Freeland Creek	X		X		X	
Sheppard Creek	X		X		X	X
Big Creek	X		X		X	X
Upper Red Meadow Creek	X		X	X	X	
Whale Creek	X		X		X	X
Trail Creek	X		X		X	X
Granite Creek	X		X			X
Morrison Creek	X		X		X	X
Ole Creek	X		X		X	X
Hungry Horse Creek	X		X		X	X
Tiger Creek	X		X		X	X
Margaret Creek	X		X		X	X
Emery Creek	X		X		X	X
Lower Fitzsimmons Creek				X		
East Fork Swift Creek	X		X		X	X
Upper Fitzsimmons Creek	X		X	X	X	
Lower Red Meadow Creek				X		X
Deano Creek				X		

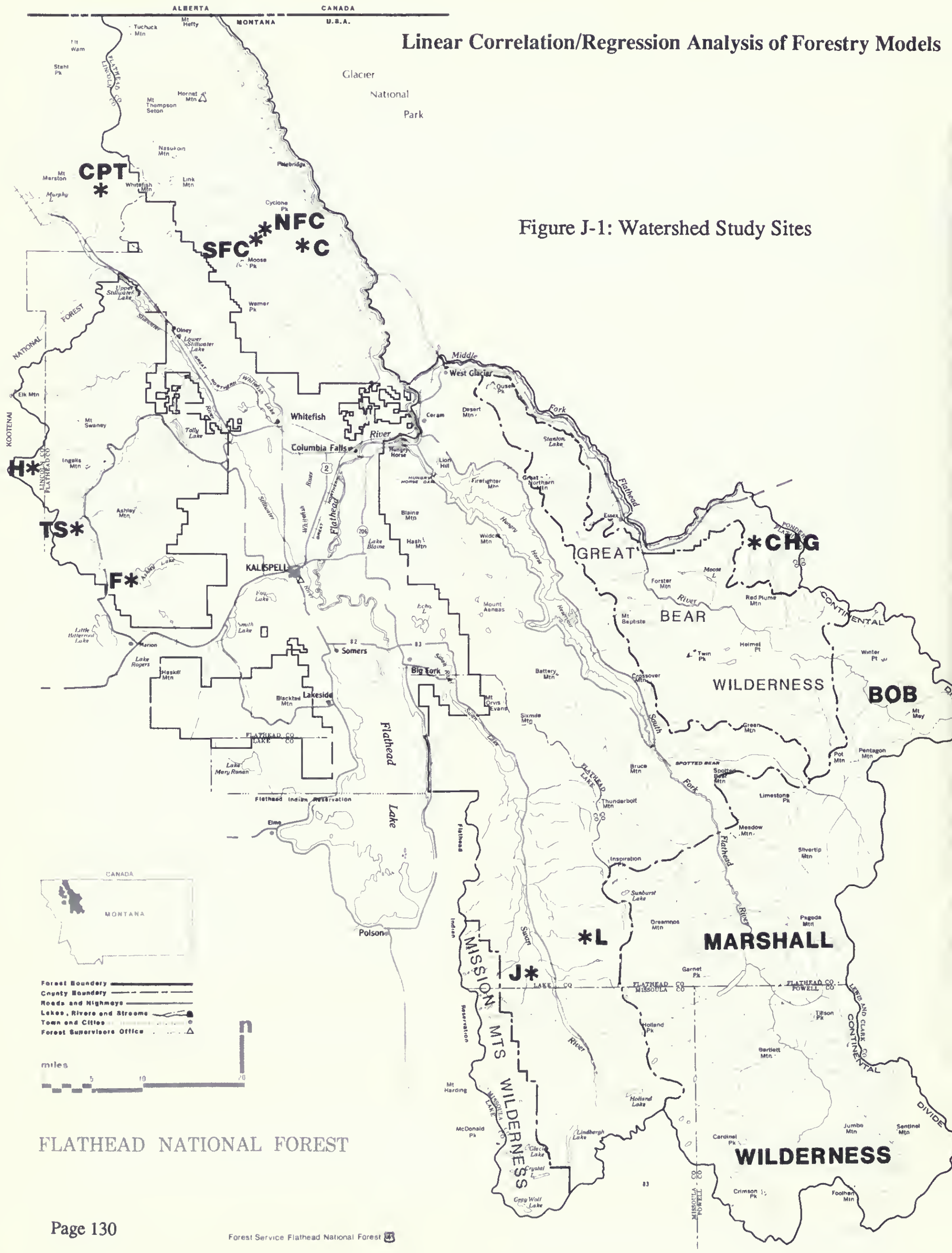


Figure J-1: Watershed Study Sites

Table J-2: Independent and dependent variables applied to the linear correlation/regression analysis. Land use measures, risk assessment value, water yield model output, qualitative reach assessment, and qualitative estimates of substrate score were applied as independent variables. The quantitative in-stream measures were applied as dependent variables.

Independent Variables	Dependent Variables
% of Watershed Harvested	FNF suspended sediment
% of Watershed in Roads	Total Suspended Solids
Sequoia risk procedure	McNeil Core Sediment
H_2OY WYI	Whitlock-Vibert box Sediment
WATSED cumulative acres	Total Nitrogen (persulfate)
WATSED annual WYI	Total Phosphorus
WATSED WYI D75	Algae Growth (Chl a)
WATSED increased sediment	Bull Trout Redds
* Region 1 Channel Stab. Rating	* Region 1 Channel Stab. Rating
* Change in CSR	* Change in CSR
* WQB stream reach assessment	* WQB stream reach assessment
* Substrate Score	* Substrate Score

* The Water Quality Bureau's qualitative stream reach assessment (Module E), the fishery module's substrate score (Module D), and channel stability ratings were examined both as independent and dependent variables.

reaches directly upstream from the WATSED sites. (See Table J–1.) The Channel Stability Rating is a qualitative method of assessing the vulnerability of a stream reach to degradation if increased water flow were added to the stream. Whenever possible, historic CSR values are researched for the same stream reach to see if any major changes occurred over time.

All pair-wise regression analyses were conducted on twelve independent and twelve dependent variables. (See Table J–2 for the variables and Appendix E for the data set.) Model data output in a percentage format was transformed using an arcsine transformation. The regression analyses were performed using StatView II statistical computer program. All significant relationships and accompanying statistics are given in Table J–3. Non-significant relationships were not listed.

Table J-3: Statistically significant regressions of independent and dependent variables; where n = number of cases, p = significance level (only those < 0.1 were considered significant), and r^2 = coefficient of determination.

Figure	Comparison	n	p	r^2
J-2	Sequoia CRA vs. McNeil Core	28	0.02	0.19
J-3	Sequoia CRA vs. Substrate Score	28	0.01	0.23
J-4	Sequoia CRA vs. Maximum algae growth	10	0.08	0.34
J-5	Sequoia CRA vs. Maximum algae growth	10	0.08	0.34
J-6	H2OY WYI vs. McNeil Core	28	0.03	0.16
J-7	H2OY WYI vs. Substrate Score	28	0.004	0.28
J-8	H2OY WYI vs. Total Persulfate Nitrogen	10	0.04	0.43
J-9	H2OY WYI vs. Maximum algae growth	10	0.03	0.49
J-10	WATSED WYI vs. Total Persulfate Nitrogen	6	0.07	0.59
J-11	WATSED 75% Pk Flow Duration vs. Total Persulfate Nitrogen	6	0.08	0.57
J-12	WATSED WYI vs. Maximum algae growth	6	0.05	0.66
J-13	WATSED 75% Pk Flow Duration vs. Maximum algae growth	6	0.002	0.92
J-14	% of Watershed Harvested vs. Total Phosphorus	12	0.015	0.46
J-15	% of Watershed Harvested vs. Total Persulfate Nitrogen	12	0.002	0.63
J-16	% of Watershed Harvested vs. Maximum algae growth	12	0.04	0.36
J-17	H2OY WYI vs. Change in Channel Stability Rating	6	0.003	0.91
J-18	Sequoia CRA vs. Change in Channel Stability Rating	6	0.004	0.90
J-19	WATSED WYI vs. Change in Channel Stability Rating	6	0.012	0.824
J-20	WATSED 75% Pk Flow Duration vs. Change in CSR	6	0.001	0.943
J-21	WATSED Predicted Sediment vs. FNF Suspended Sediment	8	0.0002	0.92

Discussion

We found statistically significant relationships among several paired variables. Sequoia CRA was positively correlated with increased McNeil core measurements (Figure J–2) and substrate score (Figure J–3) at the 28 fisheries study watersheds and with total nitrogen (Figure J–4) and algae growth (Figure J–5) at ten water quality study sites. There was also a statistically significant regression between H_2OY water yield increase and these same four dependent variables. (See Figures J–6 to J–9.) Because of data availability, we were only able to match 6 study sites with the WATSED water yield increase model. WATSED WYI and WATSED 75% peak flow duration were significantly correlated with total nitrogen concentration (Figures J–10 and J–11) and maximum algae densities (Figures J–12 and J–13). No significant relationship was observed between the WATSED WYI or WATSED 75% peak flow duration values and any sediment measurements. We also found that the percent of harvest within a watershed was positively correlated with total nutrient concentrations (total phosphorus and total nitrogen) and with algae growth. (See Figures J–14 to J–16).

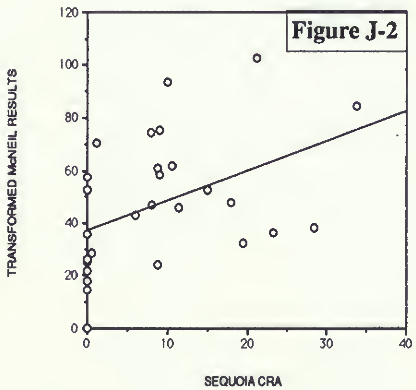
The Montana Water Quality Bureau's stream reach assessment was done on 26 of the study watersheds. We found no statistically significant correlations between the stream reach index and any other independent or dependent variables.

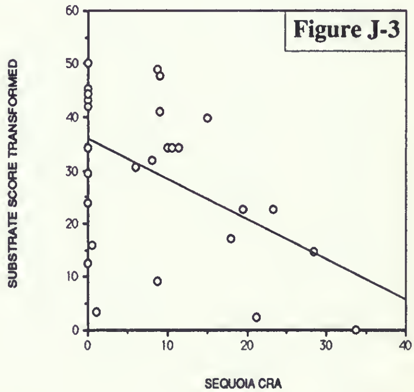
Because Channel Stability Rating and fish habitat measurements have common parameters, it was hypothesized that there would be a correlation between the variables. However, there were no statistically significant correlations between the CSR and any of the three fish habitat measurements.

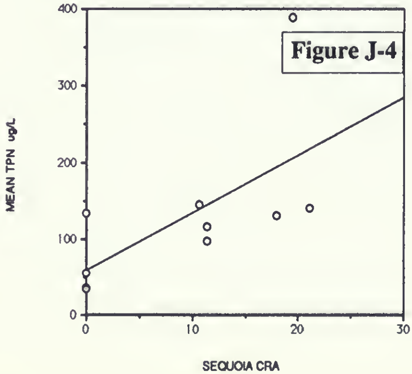
CSR values for those study sites that had historic CSR values were compared to the new CSR values to measure the change over time. This change in CSR was hypothesized to be a result of water yield increase. We did not find any statistically significant relationships between the change in CSR and any of the quantitatively measured dependent variables. However, there were statistically significant relationships between the change in CSR and the water yield models and risk assessment (H_2OY water yield increase, Sequoia CRA, WATSED water yield increase, and WATSED water yield increase—75 percent peak flow duration). (See Figures J–17 to J–20.)

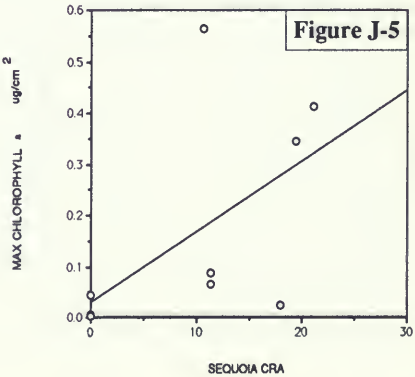
We observed a highly significant relationship between WATSED predicted sediment and the measured sediment yields from the Flathead National Forest water quality monitoring. In order to do the correlation of sampled suspended sediment to WATSED predicted sediment, the predicted natural background values and the management-caused sediment increases were added together. The correlation between the measured suspended sediment values and the predicted values was highly significant with an $r^2 = 0.919$ and $p < 0.001$ — an extremely high level of significance. (See Figure J-21.)

We have the following observations of the relationships that were tested on the sample watersheds. First, we observed a statistically significant relationship between increased timber harvest (as calculated by Sequoia and H_2OY) and increased substrate sediment within known bull trout spawning areas. Although only a fifth of the variation in the substrate sediment values and substrate scores was explained by timber harvest disturbance (Sequoia and H_2OY), the regressions were positively correlated with significance levels better than 95%. However, to use the watershed disturbance models to predict timber harvest impacts to fish habitat would be undesirable because of the high level of variance. Therefore, we recommend that more research effort be put into developing sediment routing relationships (that is, delivery of eroded soil to the stream channel) so that upland activities and changes in streambed materials can be better understood. Second, stream algae growth as measured by Chlorophyll a was significantly correlated to most of the model, risk assessment, or direct measurements of disturbance. However, to date changes in stream algae production have not been used as an index of water quality change or effects on beneficial use. We recommend that more study is needed of algae growth relationships to the stream food web and the potential use of stream algae growth as an indicator of water quality. Third, the hypothesized relationship that channel stability ratings would change over time due to water yield increases was statistically established.









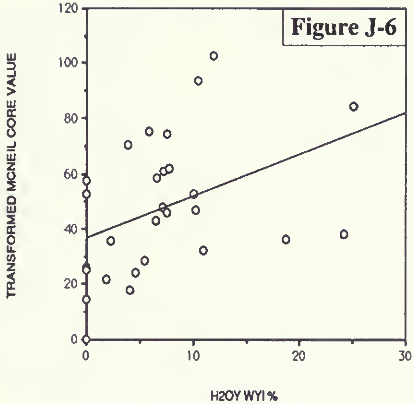


Figure J-6

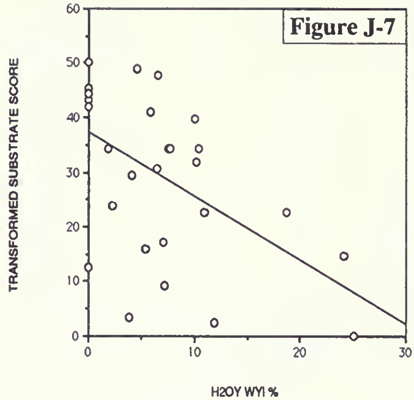


Figure J-7

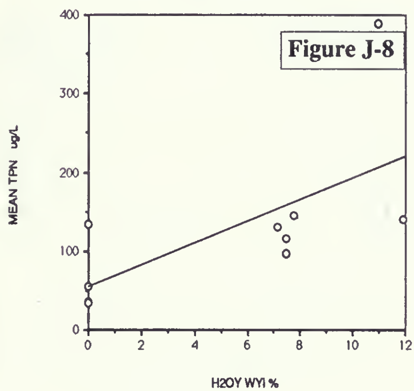


Figure J-8

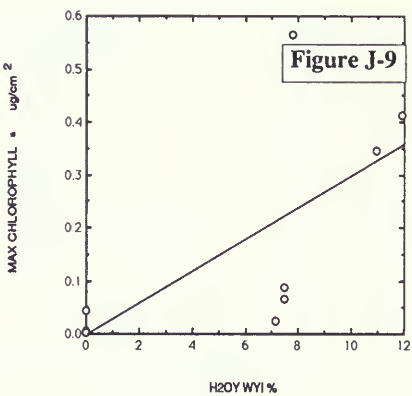


Figure J-9

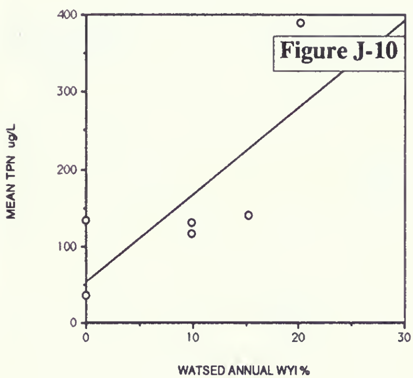


Figure J-10

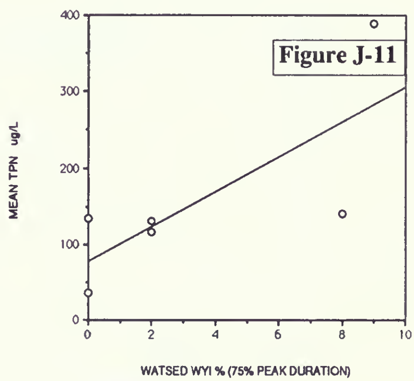


Figure J-11

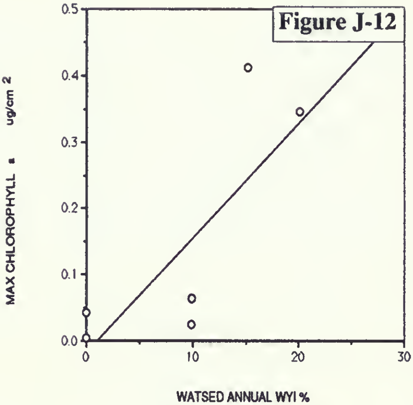
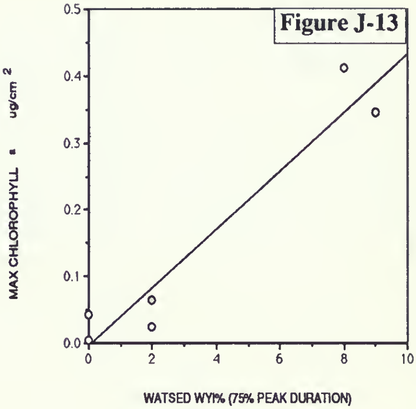


Figure J-12



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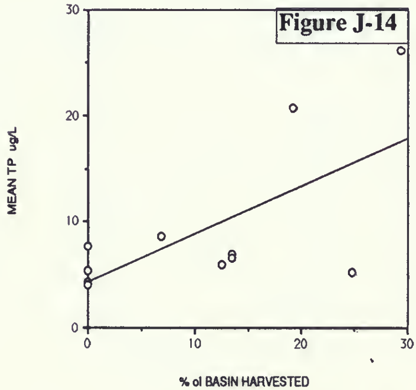

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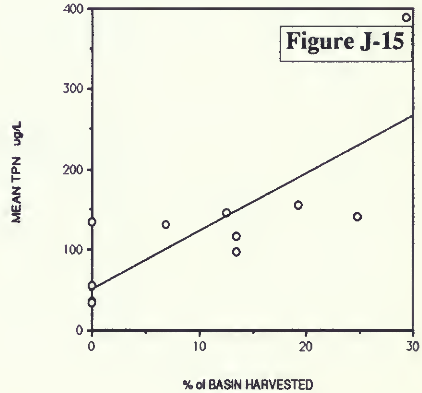

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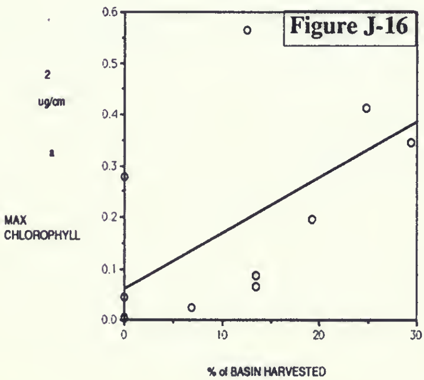

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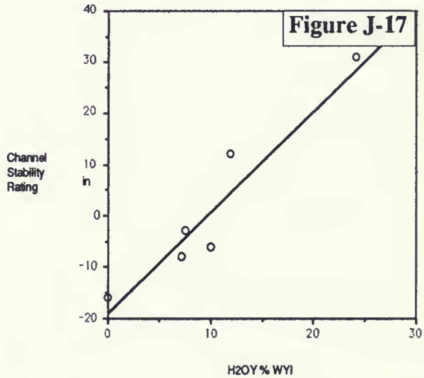

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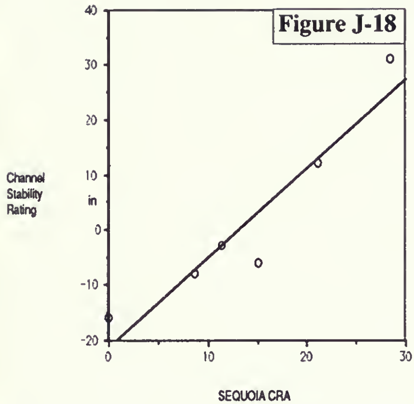

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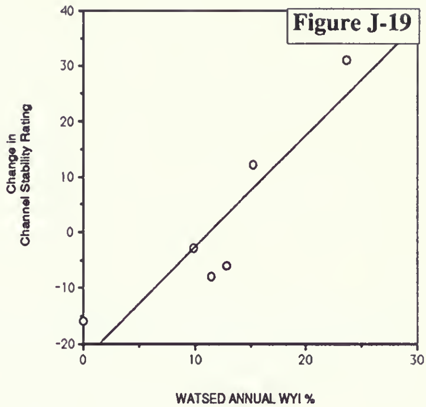

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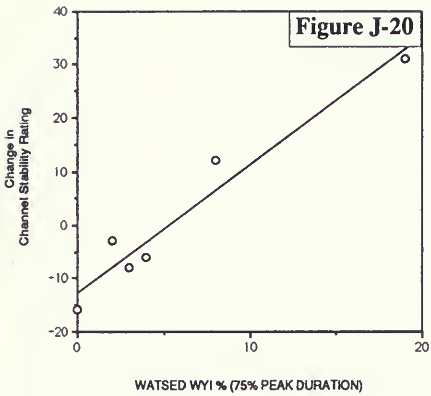

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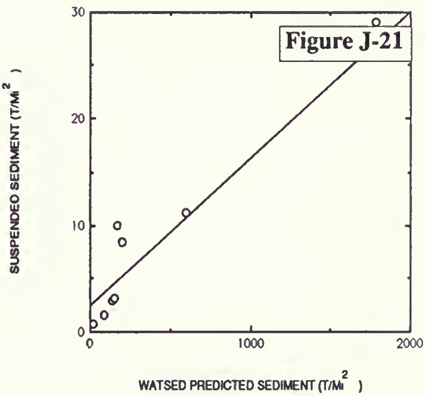

Figure J-21

General Discussion

General Discussion

The "Summary of Conclusions" that follows this section is organized according to the same major headings as used in the body of the report. Within those headings we have either brought forward the specific conclusions from individual modules or combined them where appropriate.

The "Summary of Recommendations" represents a consensus of the study team leaders related to the original objectives of the cooperative program. Total agreement could not be reached on all items. In these cases, we bowed to the lead investigator for that topic. We originally planned to present the recommendations in the same format as the rest of this report, but it didn't work well for making recommendations. Therefore, we organized the recommendations to start at the site where individual practices take place, move to the watershed level of cumulative effects, and then to the general water quality and fisheries concerns.

The land managers who are part of this cooperative were then asked to respond to the "Summary of Recommendations" with the intention that their responses would be published as part of this document.

The recommendations on monitoring are offered as suggestions to be considered also in the Flathead Basin Cooperative Monitoring Plan.

As is true in many studies, by the time the assigned work is completed, it becomes clear that additional questions were raised during the conduct of the study. Several of these are listed as suggested studies.

Some of the issues we addressed may require political decisions and a clear agreement among multiple landowners in the same watershed as to competing objectives and acceptable tradeoffs. Hopefully, we provided useful information to help make difficult decisions regarding the balance between competing and often overlapping socio-economic and socio-environmental concerns.

SUMMARY OF CONCLUSIONS

Summary of Conclusions

The following section represents a consensus of the study team leaders on the conclusions most relevant to the general objectives of the cooperative program. They are arranged in the same general order as the presentation of study modules.

Historical Record, Water Quality, and Fisheries

Changes in stream flow and the transport and deposition of fine sediments over the past 140 years were evaluated by examining two sources of historical records: mean daily discharge at stream gaging sites and sediment accumulation on lake bottoms. These evaluations indicated the following relationships between lake/stream measures and timber harvest, and other land use activities. Source module for each conclusion is identified as:

*A = Module A: An Analysis of the Effect of Timber Harvest on Streamflow Quantity and Regime: An Examination of Historical Records.

*B = Module B: Evaluation of Historical Sediment Deposition Related to Land Use through Analysis of Lake Sediments.

Historical Record

1. Comparison of spring runoff regimes among major river drainages in the Flathead between 1940 and present indicated that drainages having experienced extensive timber harvest also have spring runoff occurring earlier in the year than similar drainages having little timber harvest. (*A)
2. It appears that timber harvest may result in a higher peak in spring discharge during above normal runoff years, but not in major flood years. (*A)
3. Lake coring analyses indicated that past human land disturbance activities increased fine sediment deposition up to 10-fold in Whitefish Lake in the 1930s and 4- to 5-fold in Lake McDonald between 1930 and 1960. (*B)
4. Lake McDonald
   a. Initial road construction and upgrading of the Going to the Sun Road from Lake McDonald to the continental divide at Logan Pass during the 1930s and 1940s were accompanied by substantial increases in sediment deposition in Lake McDonald. (*B)
   b. After the road was paved in the early 1950s the sediment deposition rate in Lake McDonald returned to background levels and has remained at background levels over the last 25 years. (*B)
5. Whitefish Lake
   a. Large increases in sediment deposition occurred during the early part of this century (1900-1910) and were attributed to railroad construction along the lakeshore and logging activity around the lake. (*B)

b. The largest sedimentation increases occurred in the early 1930s when substantial logging and associated road and rail line construction were concentrated in the Lazy Creek drainage and Lower Swift Creek, near the head of Whitefish Lake. (*B)

c. Sedimentation rates also were elevated from the 1950s through the mid-1970s. These increases were attributed to substantial logging and associated road building activity, which extended to upper portions of the Whitefish Lake drainage. (*B)

d. Recent logging activity in the Whitefish watershed was not accompanied by increased sedimentation in Whitefish Lake. Possible explanations for reduced sediment impacts include use of preexisting roads, logging on less-erodible lands, improved logging and road-building practices, and a series of comparatively mild runoff years. (*B)

6. Results from the two study lakes suggest that roads represent the greatest disturbance activity resulting in increased sediment transport and deposition in the downstream lakes. Once road surfaces stabilize (especially when paved), additional delivery of road-related fine sediment was not detected from sediment core analysis in McDonald Lake and road stabilization is probably also responsible for declining sediments in Whitefish lake. (*B)

7. Changes in lake sedimentation directly attributed to floods, fires, and other natural erosion processes during the past 150 years were much smaller than changes attributed to human disturbance activities in the two lake basins. Previous speculation that erosion of naturally unstable stream banks and other natural sources may mask sediment inputs attributed to human activities appear unfounded for the Whitefish Lake and Lake McDonald basins in light of data collected in the present study. (*B)

Water quality and Fisheries

A broad array of streams in the Flathead Basin were evaluated by monitoring various physical, chemical, and biological variables and conducting controlled field experiments. Evaluated stream sites included watersheds with no timber harvest and no roads, no timber harvest with roads, and with timber harvest and roads. Among those watersheds with timber harvest and roads, stream sites were selected to represent different levels of percentage harvest within the basin. Source module for each conclusion is identified as:

*C = Module C: The Effect of Timber Management on Stream Water Quality.

*D = Module D: Fisheries Habitat and Fisheries Populations.

8. Monitoring data collected from this research indicated the following statistically significant relationships ($p < 0.1$, or better) between timber harvest activity (that is, road building, harvest, etc.) and several physical, chemical, or biological measures of stream ecosystem quality.

a. Timber harvest activity was positively correlated with suspended sediment concentrations in streams. (*C)

b. Timber harvest activity was positively correlated with concentrations of nutrients (nitrogen and phosphorus). (*C)

c. Timber harvest activity was positively correlated with the percentage of fine sediment in trout spawning gravels. (*D)

d. Timber harvest activity was positively correlated with gravel imbeddedness in streams. (*D)

9. Field surveys indicated the following statistically significant relationships (correlations analyses; $p < 0.1$, or better).
   a. Timber harvest activity was positively correlated with algal growth in the streams. (*C)
   b. Imbeddedness was negatively correlated with juvenile bull trout densities in streams. (*D)
   c. The mean percentage of fine sediments in spawning areas of undisturbed watershed streams in the Flathead Basin was 31.7% (range 24.8% to 39%) while in watersheds subject to timber harvest the mean percentage of fine material was 39% (range 32.8% to 50.3%). (*D)
10. Experimental studies showed that increases in the amount of fine sediment in spawning gravels caused a significant reduction in embryo survivorship of bull trout and westslope cutthroat trout. When the percentage of fine sediment reached 40%, survivorship of both species was reduced below 30%, and with 50% fine sediments, embryo survivorship was only 4%. (*D)

Stream Reach Assessment

The Water Quality Bureau's statewide nonpoint source stream reach assessments were conducted on 30 study streams containing 95 reaches. The qualitative visual survey results were evaluated by comparison with the results of the other modules. The source module for conclusions is identified as:

*E = Module E: Application of the Montana Nonpoint Source Stream Reach Assessment in the Flathead Basin.

11. Tree blowdown (due to inadequate streamside management zones or prescription), sediment from poor road maintenance, logging slash in the stream channel, and bank trampling by livestock were observed by the surveyor to be the primary causes of stream problems related to management practices. (*E)
12. Quantitative fisheries study results that identified impairment to fish spawning or rearing habitat did not correlate well with impairment values derived from the assessment procedure. The assessments generally identified less impairment than the results from the fisheries study. This indicates that the assessment procedure either does not identify or underestimated impairment to beneficial uses. (*D and *E)

Forest Practices

Forest practices are often viewed as potential threats to water quality and fisheries. Direct measurement of nonpoint source pollution from specific practices is too costly to be used for routine evaluation on all activity areas. Therefore, the standard approach (accepted by the Environmental Protection Agency) for attempting to minimize nonpoint source pollution is to first develop a set of Best Management Practices (BMPs) based on research and experience, that will help protect water quality and beneficial uses. Field audits of BMP application and effectiveness are then used as an indirect evaluation.

The current procedure for evaluation of effectiveness is based on field review by experienced teams. BMPs are general standards and often require site-specific interpretation. Concurrent studies have been underway to develop improved management guidelines for riparian/wetland habitat types as an aid to site-specific interpretations. This section reports the conclusions from those modules that were addressing forest practices at the site-specific level:

*F = Module F: Assessments of Best Management Practices.
*G = Module G: Management Guidelines for Riparian Forests.

13. BMPs are generally better-applied and more effective in the Flathead Basin than in the state in general. However, there is still considerable room for improvement in both application and effectiveness. (*F)
14. Audits revealed that the greatest number of departures were related to road drainage and road maintenance, followed by failure to recognize and modify practices in the SMZ. (*F)
15. A major value of the Audit process is the opportunity for education and improvement of communication. (*F)
16. Application of new "habitat type-specific" management information will be a valuable aid for site-specific evaluation and prescription. (*G)
17. New criteria will provide for consistent field delineation of Streamside Management Zones to meet the intent of the Best Management Practices. (*G)
18. An erosion risk matrix in relation to slope and soil erodibility is now available to estimate erosion hazards of different forest practices. It can be used for watershed-level risk assessment of proposed alternative practices (Module I), for future BMP evaluation (Module F), and for general interpretations. (*G)

Watershed Evaluation

One of the essential links in understanding the relations between forest practices and the aquatic ecosystem is the assessment of cumulative effects. Models to predict cumulative effects are still in the developmental stage. The R1–R4 Sediment Model and the H_2OY Water Yield Model have been the standard prototypes. Two alternative models (Sequoia and GIS Erosion Risk) were evaluated as a part of this program and a very recent model (WATSED) was also partially evaluated. The conclusions in this section are based on the following modules:

*H = Module H: Application of the Sequoia Method for Determining Cumulative Watershed Effects in the Flathead Basin
*I = Module I: A Forest Management Nonpoint Source Risk Assessment Geographic Information Systems Application
*J = Module J: Linear Correlation/Regression Analysis of Forestry Models, Risk Assessment, and Water Quality and Fisheries Data

19. The Sequoia methodology provides a straight-forward, simple accounting system for evaluating watershed disturbance related to water yield and a relative numerical rating. (*H)
20. Application of the Sequoia method in the Swan River Drainage demonstrated that a few analysis areas had an unusually high concentration of activities. (*H)
21. The Sequoia method results generally agreed with estimates of cumulative effects provided by other models. (*H)
22. Watershed erosion risk analysis may provide resource managers with a powerful tool to assist in land-use decision making. In addition, Geographic Information Systems allow the correlation of land cover and topographic information such as terrain configuration and drainage networks, thus making GIS useful in assessing the potential effects of land-use activities on water resources. (*I)
23. There was a statistically significant correlation between the change in Channel Stability Rating (CSR) and H_2OY water yield increase, Sequoia Cumulative Runoff Area (CRA), WATSED water yield increase, and WATSED water yield increase—75 percent peak flow duration. (*J)
24. WATSED equivalent clearcut acreage was positively correlated with suspended sediment. (*J)
25. Three of the 30 watersheds selected for the correlation review were above the thresholds for both Sequoia and H_20Y, while 3 other watersheds with relatively high values for Sequoia had relatively low to moderate values for H_20Y. (*H and *J)
26. The correlation between the measured suspended sediment values and the predicted WATSED sediment values was highly significant. (*J)

SUMMARY OF RECOMMENDATIONS

Summary of Recommendations

The following recommendations have been developed through interaction by the module study leaders. The module summaries and the "Summary of Conclusions" section, presented earlier in this document, were organized in a format that proceeded from analysis of historical records, direct study of water quality and fisheries variables, auditing of adherence to Best Management Practices (BMPs), expert opinion to set riparian management guidelines, and evaluation of watershed risk analysis. This recommendation section is structured in two parts: Part I deals with forestry practices at the site level and evaluation of cumulative effects at the watershed level and Part II deals with general water quality and fisheries concerns.

Part I: Audits of Best Management Practices, Management Guidelines, Watershed Evaluations, and Use of Watershed Models and Inventories

Basis for Recommendations

No federal legislation has had greater significance for management of the environment than the National Environmental Policy Act of 1969 (NEPA). NEPA required federal agencies to evaluate "the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity" and "any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented." These evaluations, as they pertain to forest management, began the practice of Cumulative Watershed Effects (CWE) analysis.

Clearly, the best possible CWE analysis would be the actual measurement of changes in the environment. This is the role of monitoring and field research. Approximately half of the funds expended in this cooperative were devoted to that task. However, monitoring has limitations, among these are cost and time. Forest management takes place in thousands of watersheds of varying size and environmental sensitivity through the Flathead Basin. We simply cannot physically or financially afford to monitor all of these activities. This problem is not unique to the Flathead Basin. Consequently, a great deal of effort has gone toward developing alternative methods (or strategies) for both evaluating and preventing CWEs.

Modeling is one of the alternatives for CWE analysis and has been selected for use by the Flathead National Forest and the Montana Cumulative Watershed Effects Cooperative. Watersheds are very complex and our modeling capabilities are limited. Furthermore we have little faith in model predictions largely because we have not tested our models by monitoring and field research. Again, these problems are not unique to the Flathead Basin. Consequently, other National Forest Regions have also adopted the more qualitative CWE "risk" assessment procedure approach. Recent development of Geographic Information Systems make application of these procedures easier and more comprehensive.

Section 319 of the Clean Water Act, added by amendment in 1987, requires states to establish Best Management Practices (BMPs) for the control of nonpoint sources of pollution (the form of pollution typically generated by forest management activities). BMPs are practices that are targeted to minimize the production of nonpoint source pollution, specifically organic and inorganic sediments, nutrients, and temperature. The State of Montana convened a group of resource specialists to compile Montana's BMPs — thus an expert opinion process. The BMPs have subsequently been approved by the Environmental Protection Agency, and at least for the time being remain voluntary for land managers in Montana (so long as they protect beneficial uses).

Best Management Practices have no value in protecting resources if they are not applied, are improperly applied, or are ineffective. Therefore, nearly every state involved with forest management, including Montana, has developed a process to audit BMPs in the field — another expert opinion "group-decision" process. The audit results generate a qualitative assessment as to whether BMPs have been implemented and evaluate their effectiveness in keeping sediment out of streams.

Nearly every BMP audit finds that the majority of problems result from roads and poor management in the Streamside Management Zone (SMZ). Road BMP criteria were not specifically studied in this cooperative program; however, SMZs were evaluated (Module G). Neither Montana's BMPs nor recent legislation (House Bill 731, Legislative Session 52) consider SMZs as areas of activity exclusion; but rather as areas of special consideration, equipment limitation, and especially careful management.

Riparian areas exhibit tremendous variation in characteristics and susceptibility to damage. There is little published research on management of Montana riparian forests. Consequently, managers have insufficient information or guidelines to help them make site-specific management prescriptions. The current lack of conclusive scientific data thus calls for the use of local experience and expert opinion documented in the form of type-specific management guidelines.

The following recommendations regarding forest practices are primarily from:

- Module E — Application of the Montana Nonpoint Source Stream Reach Assessment in the Flathead Basin,
- Module F — Assessments of Best Management Practices, and
- Module G — Management Guidelines for Riparian Forests.

The following recommendations regarding watersheds are primarily from:

- Module H — Application of the Sequoia Method for Determining Cumulative Watershed Effects in the Flathead Basin,
- Module I — A Forest Management Nonpoint Source Risk Assessment Geographic Information Systems Application, and
- Module J — Linear Correlation/Regression Analysis of Forestry Models, Risk Assessment, and Water Quality and Fisheries Data.

Specific Recommendations

Forest Practices Recommendations

1. Acceptance and use of the State Best Management Practices is the first step toward ensuring that forest practices

will not degrade water quality and fisheries. This will require unqualified commitment of large landowners and continual efforts to educate and encourage private landowners. The education efforts initiated by the Montana Logging Association must be expanded to reach small private landowners. If the "voluntary" system does not work and existing legal procedures are inadequate to ensure prompt action on reported violations, a mandatory system through a forest practices act should be enacted.

2. Land managers should utilize the new riparian habitat type classification and type-specific management information for guidance in site-specific prescriptions.
3. Land managers should adopt the new streamside management zone criteria set by the Montana Riparian Association for consistent delineation and marking of streamside management zones.

Monitoring Forest Practices and/or Further Study Needs

4. Because of the demonstrated value of the audit process, it is recommended that the audits continue on an annual or biennial basis.
5. A cooperative study is needed to address the question of woody debris recruitment for maintaining stream integrity. Consideration needs to be given to inventory techniques for establishing current conditions, establishment of desired future conditions for different sizes and types of streams, appraisal of current streamside forest stand composition and structure, and the effects of different practices on ensuring the desired rate and amount of woody debris recruitment.
6. Because data are lacking on the hydrologic functioning of wetland sites, land managers will never have a comfortable basis for determining and defending reasonable access and practice standards. Therefore, managers and/or cooperative researchers should establish a program and monitor water table depths throughout the season and before and after logging on a set of representative riparian/wetland sites.
7. Qualitative evaluation of SMZ effectiveness relative to width and practices within the SMZ should be continued as part of the standard BMP audit process.

Watershed Evaluation Recommendations

8. We recommend testing the nonpoint source risk matrix assessment procedure in the Flathead Basin. In comparing the results with those of the other techniques, use GIS capabilities and the data sets obtained for the other watershed analyses conducted by the Cooperative.
9. We recommend adding the Sequoia procedure to the package of watershed assessment techniques — especially for application to watersheds that have a high level of activity and may be approaching "threshold" levels of activity concerns.
10. Further study is needed to improve watershed prediction models so that they become more reliable for assessing probable cumulative effects of a range of practices for a range of site conditions.

11. A great opportunity exists for the design of monitoring activities within a framework of cooperative research management to provide definitive results for the calibration models. We recommend that this opportunity not be bypassed.
12. Watershed level analysis and planning to address cumulative effects and scheduling of activities should be standard practice. Cooperative planning and coordination of activities should become a standard practice in all mixed-ownership drainages.
13. The Montana Water Quality Bureau nonpoint source stream reach assessment procedure (Montana Water Quality Bureau 1989) should not be relied upon to identify problem areas relative to the forest practices/water quality and fisheries issue in Flathead Basin.
14. Further analysis and interpretation is recommended for the selected study streams.

PART II: HISTORICAL PERSPECTIVE, WATER QUALITY, AND FISHERIES

BASIS FOR RECOMMENDATIONS

During the initial meetings of this Cooperative, land managers stated that they had seen little or no quantitative evidence that past timber management practices had resulted in significant degradation of water quality and fisheries in the Flathead Basin. We discussed that natural sediment loadings and variability in the Flathead Basin may be so high that increases attributable to timber management activities may be difficult to detect. Land managers stated, "we want to know, one way or the other, if past activities have had an impact on water quality and fisheries in the Flathead Basin." Therefore, one of the primary objectives of this Cooperative was to gather quantitative data to address this question.

Analysis of data collected in the historical record, water quality, and fisheries research modules reveal that timber harvest activities have resulted in: (1) changes in the spring runoff pattern, (2) increased sediment loading in streams and lakes, (3) increased nutrient loading to streams and lakes (since sediments represent a significant source of nutrients), (4) increased attached algae biomass in streams (algal growth responds to increased nutrients), (5) increased percentage of fine sediments in trout spawning gravels, and (6) increased substrate imbeddedness. The largest source of sediments appears to be from new road construction and subsequent existence of unstable roads. (Supporting evidence from the BMP audits in Module F revealed that the greatest number of departures were related to road drainage and road maintenance, followed by failure to recognize and modify practices in the SMZ.)

Increased sediment and nutrient loadings represent significant threats to streams and lakes in the Flathead Basin (as discussed in Modules B, C, and D). Streams may be altered by such increases that affect their food webs and habitats. (See Module C.) Past studies have shown that sediments likely represent the single largest source of phosphorus to most lakes in the Flathead Basin. (See Module B.) Erosion and transport of sediments and nutrients in streams, as a result of land use activities, have undoubtedly contributed to lake eutrophication. This undesirable process results in stimulation of algal growth, reduced water clarity, oxygen depletion, and other problems. At present, important lakes in the Flathead Basin (including Flathead Lake and Whitefish Lake) are on a threshold (for references see Module B), such that further increases in nutrient loading seriously threaten their water quality. Considerable efforts are being made to reduce point-source input of nutrients in the Flathead Basin. This has been done in an attempt to maintain the high water quality that characterizes many lakes in the basin. Such efforts include construction of multi-million dollar advanced wastewater treatment plants in all major communities above Flathead Lake. Similar efforts should be directed at other significant controllable nutrient sources in the basin, including land disturbance activities documented in our studies and elsewhere.

Because of their value as a sport fishery, increasing rarity across their native range, and as indicators of high water quality, both bull trout and westslope cutthroat trout have been designated as sensitive species by the U.S. Forest Service, and "Species of Special Concern" by the State of Montana. Field evidence indicates that juvenile bull trout densities decrease in streams having high substrate imbeddedness. Also, experiments of egg hatching and embryo emergence (one of the most sensitive stages of the salmonid life cycle) of bull trout and westslope cutthroat trout reveal a direct negative relationship between embryo survivorship and the percentage of fine sediment in spawning gravels. Many key spawning streams already are at, or near, the threshold whereby increased levels of fine sediments in spawning gravels will greatly reduce embryo emergence of bull trout and westslope cutthroat trout. Further study may be required to verify these relationships in areas outside the Flathead Basin.

The following recommendations are an integration of the Historical Perspective:

Module A — An Analysis of the Effect of Timber Harvest on Streamflow Quantity and Regime: An Examination of Historical Records and

Module B — Evaluation of Historical Sediment Deposition Related to Land Use through Analysis of Lake Sediments.

and the Water Quality and Fisheries:

Module C — The Effect of Timber Management on Stream Water Quality and

Module D — Fisheries Habitat and Fish Populations.

Specific Recommendations

Historical Perspective, Water Quality, and Fisheries Recommendations

15. Increase efforts toward continued improvement of timber harvest practices, road building, and road maintenance to prevent undesirable increases in erosion, sediment transport, and nutrient loadings to surface waters in the Flathead Basin.
16. At present most timber base lands in the Flathead Basin contain a network of roads, some of which are maintained for use, and others which have been abandoned. Past construction and use of roads appears to be the most significant human disturbance activity associated with timber management that has contributed to sediment delivery to streams and lakes in the Flathead Basin. Therefore we recommend the following:

A. Evaluate the existing road system

and ameliorate those roads and associated cut slopes that are known to contribute sediment or pose a potential threat to contributing sediment to surface waters in the Flathead Basin. Strong consideration should be given to road surfacing and cut-slope stabilization on high risk roads, trunk roads designated for long-term use, and roads in the immediate vicinity of streams.

B. Minimize new road construction and limit construction of new roads to areas of the basin where the risk of increased sediment delivery to surface waters is low. Ensure use of BMPs and mitigation measures with the goal of eliminating undesirable sediment delivery associated with new road construction.

17. Bull trout and westslope cutthroat trout, Species of Special Concern in Montana, are native to the Flathead Basin. Both species are highly valued sport fishes that are very sensitive to degradation of spawning and rearing habitats resulting from increased sediment delivery to streams. Therefore we make the following recommendations:

A. Obtain information on fish species composition in drainages where management activities are planned and current status is unknown.

B. ***Bull Trout:*** Continue monitoring or begin monitoring streams having known bull trout spawning and rearing areas. A listing of these streams is available from the Montana Department of Fish, Wildlife and Parks. (See Appendix G.)

i. ***Threatened Streams.***

When the following stream criteria are met,

- the percentage of fine materials in spawning gravels in any given year is greater than 35% and/or
- the substrate score (measure of imbeddedness) is less than 10,

the stream is considered threatened as a bull trout spawning and/or rearing stream.

If any disturbance activity is planned in the watershed, the land owner should:

a) Take active precautions to minimize new sediment loading to the stream.

b) Steps also should be taken to ameliorate past roading or other human land disturbances that continue to contribute sediments to streams.

ii. ***Impaired Streams.***

When the following stream criteria are met,

- the percentage of fine materials in spawning gravels in any given year is greater than 40% and/or
- the substrate score (measure of imbeddedness) is less than 9,

the stream is considered impaired as a bull trout spawning and/or rearing stream.

If any disturbance activity is planned in the watershed, the land owner should:

a) Take pro-active steps to insure that <u>no additional sediment loading</u> occurs as a result of new land disturbance activity.
b) Stabilize all existing problem roads and/or past activities which are continuing to deliver sediment to streams.

C. ***Westslope Cutthroat Trout:*** Continue or begin monitoring Flathead Basin streams having known areas of concentrated spawning by migratory westslope cutthroat trout. At present, the Montana Department of Fish, Wildlife and Parks has identified eight such streams in the basin. (See list in Appendix G.)

i. ***Threatened Streams.***
When the following stream criterion is met,
- the percentage of fine materials in spawning gravels in any given year is greater than 35%,

the stream is considered threatened as a westslope cutthroat trout spawning stream.
If any disturbance activity is planned in the watershed, the land owner should:
a) Take active precautions to minimize new sediment loading to the stream.
b) Steps also should be taken to ameliorate past roading or other human land disturbances that continue to contribute sediments to streams.

ii. ***Impaired Streams.***
When the following stream criterion is met,
- the percentage of fine materials in spawning gravels in any given year is greater than 40%,

the stream is considered impaired as a westslope cutthroat trout spawning stream.
If any disturbance activity is planned in the watershed, the land owner should:
a) Take pro-active steps to insure that <u>no additional sediment loading</u> occurs as a result of new land disturbance activity.
b) Stabilize all existing problem roads and/or past activities which are continuing to deliver sediment to streams.

D. Streams not supporting bull trout spawning and/or rearing or concentrated westslope cutthroat trout spawning.
i. There is currently insufficient data to establish thresholds for unacceptable percentages of fine material in spawning gravels used by fish species other than bull trout and westslope cutthroat trout. Therefore, we recommend further study of sediment effects on the fish species found in these streams.

18. Ensure strict adherence to BMPs by regular inspection during harvest/site preparation activities followed by monitoring field audits on sales located in watersheds meeting criteria for threatened or impaired bull trout or cutthroat

trout streams.

19. Conduct a two- to three-day symposium/workshop during spring 1992 at the Flathead Lake Biological Station to specifically address innovative means of timber harvest, road building, and other timber transport methods that may be used in the Flathead Basin with the goal of eliminating sediment delivery to surface waters. The product of the workshop should be testable hypotheses that may be used in a series of "Demonstration Projects" accompanied by effective cooperative scientific study and monitoring of sediment routing and delivery, and other key water quality and fisheries parameters. For example, a demonstration project might be to quantitatively test the effectiveness of specific BMPs, road paving, cable logging, etc., by pre- and post-activity monitoring of various water quality and fisheries parameters in adjacent surface waters. Such monitoring would fall under the short-term monitoring effort described below.

Monitoring and Additional Study Needs of Stream Water Quality and Fisheries

In 1985 the Flathead Basin Commission (FBC) adopted a water quality and fisheries *Monitoring Master Plan.* The comments and recommendations for monitoring or further study are made within the context of that *Master Plan*.

We recommend that two types of water quality and fisheries monitoring sites be established — long-term sites and short-term sites. These are summarized briefly here.

Long-term monitoring should have the purpose of establishing baseline conditions and evaluating long-term changes that may be masked over short time periods by interannual variation. These long-term monitoring stations should be representative of the various dominant physical/geological conditions of the land and with various levels and types of management activity. Long-term monitoring should be conducted on a routine, non-intensive basis. Monitoring parameters should consist of stream discharge, routine nutrients, sediments, and other basic water chemistry parameters, as well as fisheries variables. Data from the long-term monitoring stations could also be used for validation of various models used to assist land managers in decision making.

Short-term monitoring should have the purpose of monitoring specific activities. Short-term monitoring stations should change through time with a comparatively short time frame of commitment to any particular site. Short-term monitoring sites should have a multi-year lifetime, beginning two years before the activity, one year during the activity, and two years after the activity. Data from short-term monitoring stations may also be used for model validation, BMP effectiveness monitoring, Demonstration Project evaluation, or evaluation of other proposed forest practice changes designed to reduce impacts on water quality.

With the large amounts of money spent on monitoring, a great opportunity exists to design monitoring efforts so they can be used to test research hypotheses as well as accomplish monitoring goals. These efforts should be developed in concert with the following specific monitoring and study recommendations which were taken from the individual study modules. They are ***not*** listed by order of preference or priority.

20. We recommend that lake basins supporting future, long-term timber harvest and road building activities have a

monitoring program designed to document the impact of these activities on lake water quality. Current water quality monitoring efforts in the Flathead Basin are focused primarily on Flathead Lake and tributary streams. However, there are a number of smaller lake basins in the area which support significant timber harvest activities but have little water quality monitoring information. Lakes in this category which are valued for their water quality and/or fisheries resources include Swan, Whitefish, Ashley, Lake Mary Ronan, and others. **We urge immediate emphasis on Swan Lake** given the recent evidence of oxygen depletion in the lake together with extensive land use activities in the basin. Monitoring efforts should include a combination of in-lake monitoring for documentation of lake conditions as well as upstream monitoring to document various source areas including site specific inputs from new activities in the basin.

Monitoring activities should include establishment of sediment and nutrient budgets for the basin (for nonpoint sources as well as point sources such as septic systems and wastewater effluent), Secchi depth transparency, phytoplankton abundance (chlorophyll α in the lake), as well as dissolved oxygen and temperature profiles. We recommend that serious consideration be given to analysis of additional sediment cores from Swan Lake as well as a sediment core from Bowman Lake which has had no human land disturbance activity. In addition, we recommend development of some simple sediment accumulation monitors (traps) that could be placed at key locations in Swan Lake and other lakes of interest. These collection devices would serve as continuous monitors of sediment delivery into the lake environment. Annual monitoring of sediment accumulation in these traps over a period of years would yield extremely valuable information concerning changes in sediment and nutrient loadings. These data should be integrated with continuous monitoring of sediment in the streams (see Recommendation No. 31).

21. Additional sediment core analysis in Whitefish Lake, focusing on sediments deposited in the last 30 years, would provide a better understanding of the relative importance of the various factors which could explain the recent reduction in lake sedimentation rate. Sediment core sampling increments of one year or less would allow more definitive conclusions to be drawn about BMP effectiveness. In order to evaluate the potential impact of recent mild runoff years on sedimentation rates, it would be useful to collect additional cores from Whitefish Lake following several high runoff years.
22. Expansion of sediment core analyses to other lakes would expand the applicability of conclusions, which at this point come from three lakes in the Flathead Basin. We highly recommend collection of sediment cores from a "control" lake which has had no human disturbance (for example Bowman Lake in Glacier National Park). Other candidate lakes include those found in watersheds supporting past and future logging efforts such as Tally, Ashley, and Flathead Lakes.
23. Lake sediment analyses should be inte-

grated with surface water monitoring and nutrient analysis to provide more in-depth linkages between sediment and nutrient loadings.

24. Develop a basin-wide stream classification system that integrates geomorphology and selected current physical, chemical, and biotic criteria (for example, number of bull trout stream segments, base flow nutrient concentrations).
25. Adjust the FBC *Monitoring Master Plan* to reflect evaluation of cause-and-effect relationships between forest practices such as BMPs and selected water quality variables.
26. Algal growth should be used as a monitoring tool of timber harvest impact and evaluation of BMPs.
27. Macroinvertebrates have been shown elsewhere to be an excellent indicator of stream ecosystem degradation. Although we found no significant relationships in this study between timber harvest and invertebrate community attributes, we believe that this is because the study streams selected for investigation are not sufficiently impaired to result in quantifiable species losses. Therefore, macroinvertebrate studies should be tailored to document severe stream ecosystem damage on a site-by-site basis.
28. Recruitment of woody debris to streams is known to be important to maintaining stream ecosystem character with natural pool-to-riffle ratios, retention of organic matter, retention of sediment, and fish migratory, spawning, and resident fish habitats. However, we do not know the effect of past practices or the possible effect of proposed SMZ management on this important stream attribute. Thus, we recommend that a study be undertaken to determine the frequency distribution and effect of woody debris on the Flathead Basin streams. Additional SMZ research was also recommended in Module G.
29. Continue monitoring fish populations and habitat conditions in Flathead Basin tributaries. Adjust the FBC *Monitoring Master Plan* to reflect continued evaluation of cause-and-effect relationships between forest practices, fish populations, and fish habitat.
30. Use McNeil coring to monitor spawning/incubation habitat in important spawning areas identified in the FBC *Monitoring Master Plan*. However, use caution to ensure that the sediment disturbance caused by the monitoring efforts themselves does not negatively impact spawning areas.
31. Extend efforts to develop a Whitlock-Vibert box sampling program for the Flathead Basin. If this methodology can be validated, it will reduce stream disturbance caused by McNeil coring and provide greater flexibility and expansion of monitoring of the percentage of fine sediment in stream substrates.
32. Continue to monitor substrate scoring in all streams identified as critical rearing habitat for juvenile bull trout.
33. Continue to monitor fish population on streams supporting bull trout. Continue to develop similar estimation/habitat relationships for other species, particularly indices which correlate population densities of westslope cutthroat trout.
34. Expand the fisheries sampling program to a greater number of known high risk watersheds.

Response of Major Forest Land Managers to the "Summary of Recommendations"

Response of Major Forest Land Managers to the "Summary of Recommendations"

By Joel Holtrop,[1] W.J. Parson,[2] and Gary G. Brown[3]

The Flathead National Forest, Montana Department of State Lands, and Plum Creek Timber Company, L.P., are three of the major forest land managers in the Flathead Basin and were the original sponsors of this study. We recognize the importance of maintaining water quality and fisheries and will continue to give these valuable resources the attention they deserve. It is important to recognize that we as professional land managers are charged with the responsibility of managing other resources in addition to water and fisheries — for example, wildlife, timber, recreation, grazing, air quality, minerals, oil and gas, aesthetics, etc. Our challenge is to ensure a balanced management approach for all resources. We agree in concept with the "Summary of Recommendations" and offer the following comments on them.

Forest Practice Recommendations

The managers recognize that the implementation of effective Best Management Practices (BMPs) is required to ensure that the effects of forest practices are minimized. We are all involved in a continuing effort to educate our land managers and all landowners and logging contractors on the benefits associated with the effective use of BMPs.

The Flathead National Forest uses riparian habitat types to design projects associated with riparian areas. The other land managers agree in concept to the use of this classification in future project design. The passage of Montana House Bill 731 will provide mandatory regulations governing the conduct of forest practices within streamside management zones.

Monitoring Forest Practices Recommendations

Internal BMP audits are being conducted on all lands by the respective land managers. We recognize the value of continuing the cooperative interdisciplinary BMP audit program. We agree with the need to develop prescriptions for woody debris recruitment to provide for fish habitat and channel stability. House Bill 731 authorizes the Montana Department of State Lands to establish an interdisciplinary technical committee to assist in the development of rules and guidelines to protect the integrity of streamside management zones. The managers intend to have representatives on the technical committee and assist in the development of appropriate rules and guidelines.

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[2]W.J. Parson is Director of Operations, Rocky Mountain Region of Plum Creek Timber Company, L.P., in Columbia Falls, Montana.

[3]Gary G. Brown is State Forester of the Montana Department of State Lands Forestry Division in Missoula, Montana.

WATERSHED EVALUATION RECOMMENDATIONS

Each of the managers is a member of the Montana Cumulative Watershed Effects Cooperative (MCWEC). The goal of this cooperative is to share information and technology, including the use of WATSED as the primary watershed model in an effort to address the issue of cumulative effects. The studies did not show that the Sequoia model was more accurate than WATSED, and a change to the Sequoia model is not planned.

The MCWEC's members annually provide each other with their plans for roading and timber harvest. Cooperators are then in a position to undertake watershed planning and cumulative effects analysis. The managers encourage continuing close coordination of these complex issues.

WATER QUALITY AND FISHERIES RECOMMENDATIONS

The land managers acknowledge the significance of bull trout and westslope cutthroat trout as "Species of Special Concern" which are sensitive to sedimentation of their habitat. We will cooperate in obtaining more complete information on the distribution of these species and the condition of their habitats. Also, we will continue to support efforts to understand habitat relationships for all fish species which may be affected by forest practices.

The MCWEC provides an excellent forum for the exchange and discussion of fisheries information as it relates to management activities. This process would be greatly strengthened by increased participation from the Montana Department of Fish, Wildlife and Parks. As a starting point, the Department of Fish, Wildlife and Parks should provide a list of bull trout and westslope cutthroat trout streams they consider threatened or impaired.

In recent years, more attention has been focused on eliminating or controlling sediment delivery to streams from management activities. Efforts should continue to improve forest practices to reduce erosion and transport of sediment and nutrients to surface waters. We will emphasize this objective as a crucial step in the protection of water quality and fish habitat.

The land managers will strive to maintain a transportation system which has as little impact on water quality as possible. We recognize that reducing erosion on existing roads is desirable, especially during spring runoff. We will continue to correct problems created by past road construction. Where new road construction occurs, the land managers will take all reasonable and effective measures to reduce erosion and sediment loads. We will continue to maintain existing roads to minimize erosion and employ the most appropriate BMPs available when constructing new roads. We will also continue the Montana Road Management Cooperative, which is providing significant benefits to both wildlife and water quality through road closures.

Most known bull trout spawning areas and some identified westslope cutthroat trout spawning areas in watersheds with timber management allocations are presently being monitored. There are other streams used by fewer bull trout which spawn over a more dispersed area, and many more streams where cutthroat spawning sites are likely to be scattered along considerable stream length. Monitoring all these streams, sites would have to be arbitrarily chosen, especially if spawning areas have not been identified or change annually. Given the reality of limited budgets, monitoring efforts must be focused on streams which could be affected by management activities, plus a sampling of some natural or "control" streams.

We have concerns about using a highlyimpactive sediment sampling technique in smaller streams that have a limited supply of spawning gravel. Continuous monitoring could result in net loss of spawning habitat.

The studies indicate that sediment levels have a critical effect on developing trout. These results provide a basis for assessing habitat conditions and will undoubtedly influence management decisions regarding future road construction and timber harvest. An inherent problem with the use of threshold sediment values is the fact that there is a wide range of natural variability in streams with respect to flows and sediment. In cases where lakes or streams are classified "threatened" or "impaired," increased concern is justified. In these situations, we will comply with the special recommendations to control erosion, protect water quality, and maintain fish habitat.

Difficult questions remain regarding applicability of the recommendations to westslope cutthroat trout streams. Additional monitoring of westslope cutthroat trout spawning areas must be undertaken with caution to avoid habitat degradation. Selecting spawning areas to monitor may be arbitrary in many streams. Random samples of potential spawning gravel do not provide a definitive description of habitat condition or population status for westslope cutthroat trout.

It must be recognized that watersheds are complex and dynamic systems. Most of the variation in aquatic habitat condition was not correlated with upland management activities. Consequently, it should not be assumed that constraints on roading and logging will protect or improve native fisheries in all cases. More effort to develop streamflow and sediment routing relationships is needed so that upland activities and changes in streambed materials can be better understood.

Although we realize that determination of limiting factors for local trout populations was beyond the scope of this study, the issue is an important one. The study results show that sediment alone does not regulate fish abundance in the Flathead Basin. Nevertheless, we accept our responsibility to ensure that forest practices do not degrade fish habitat.

Monitoring and Additional Study Needs

Water quality and fisheries monitoring recommendations have been developed and carried out according to the Flathead Basin Commission Monitoring Master Plan. Land managers agree in concept with the "monitoring and additional study needs." Revisions to the Master Plan should reflect the recommended changes. Water quality and fisheries habitat monitoring are high priority programs. However monitoring must be balanced within budget constraints and within the framework of other management objectives and priorities.

These studies were valuable in providing a focus on the relationships between forest practices, water quality, and fisheries. We appreciate the time and effort that has gone into this comprehensive evaluation and believe it will contribute to the maintenance of high water quality standards in the Flathead Basin.

Joel J. Holtrop — 5/9/91

Joel Holtrop
Supervisor
Flathead National Forest

Date

W. J. Parson — 5/14/91

W.J. Parson
Director of Operations, Rocky Mountain Region
Plum Creek Timber Company, L.P.

Date

Gary G. Brown — 5/14/91

Gary G. Brown
State Forester
Montana Department of State Lands

Date

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APPENDIXES

APPENDIX A:

MEMORANDUM OF UNDERSTANDING

BETWEEN
FLATHEAD BASIN COMMISSION
MONTANA DEPARTMENT OF STATE LANDS
PLUM CREEK TIMBER COMPANY, INC.
FLATHEAD NATIONAL FOREST
MONTANA DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCIES
MONTANA DEPARTMENT OF FISH, WILDLIFE & PARKS
UNIVERSITY OF MONTANA

JULY 1988

This MEMORANDUM OF UNDERSTANDING is made and entered into by and among the Flathead Basin Commission, hereinafter referred to as FBC; Montana Department of State Lands, hereinafter referred to as DSL; Plum Creek Timber Company, Inc., hereinafter referred to as PCTCI; Flathead National Forest, hereinafter referred to as FNF; Montana Department of Health and Environmental Sciences, hereinafter referred to as DHES; Montana Department of Fish, Wildlife & Parks, hereinafter referred to as FWP; and the University of Montana, hereinafter referred to UM.

* * * * *

In the Flathead Basin, one third of the watershed is composed of forested lands which are managed for commercial forest production by FNF, DSL, PCTCI, and other entities. Valuable commodities are produced that substantially contribute to the regional economic base.

Flathead Lake and its tributary streams and rivers host water quality and a fishery of superlative quality which offers a valuable economic and recreational resource.

The effects of certain forestry activities (e.g., logging and associated road construction) may be a potential risk to the aquatic environment. At this time, the cause-and-effect relationship of specific forest practices on water quality and fisheries is not known.

WHEREAS, FBC is a legislatively created body to address the Flathead Basin's aquatic environment, the waters that flow into or out of Flathead Lake, and other resources of the Basin; and

WHEREAS, DSL and FNF are government agencies that manage commercial forest lands within the Flathead Basin; and

WHEREAS, PCTCI is a private enterprise which owns and manages commercial timberlands; and

WHEREAS, DHES is charged with enforcing the laws governing water quality in the state of Montana; and

WHEREAS, FWP is charged with managing the fisheries resource of Montana; and

WHEREAS, UM is an institution of higher education providing teaching, research, and service for the benefit of Montana citizens and resources,

THEREFORE, in consideration of the above, the parties agree to create and participate in the FLATHEAD BASIN FOREST PRACTICES/

WATER QUALITY AND FISHERIES COOPERATIVE PROGRAM, dated July 1988, hereinafter known as the Cooperative Program, as follows:

1. To fulfill the Specific Objectives of the Cooperative Program which are to document, evaluate, and monitor whether forest practices effect water quality and fisheries within the Flathead Basin and to establish a process to utilize this information, if detrimental impacts exist, to develop criteria and administrative procedures for protecting water quality and fisheries.

2. To follow the Purpose of the Cooperative Program which is to improve the management of Flathead area forested watersheds through the development and application of state-of-the-art information to prevent or mitigate the potential adverse effects of forest practices on water quality and fisheries.

3. To work closely and cooperatively as the Coordinating Team of the Cooperative Program to review and approve study elements so that the entire Cooperative Program forms a coherent package of studies and monitoring directed at learning if and how forestry activities affect fisheries and water quality.

4. To work closely as the Coordinating Team with the FBC on the logistics of the studies, funding and public participation.

5. Agree to reach decisions within the Coordinating Team by consensus.

6. The Coordinating Team will serve to review progress, offer suggestions, and facilitate appropriate assistance from resource specialists from the various organizations involved in timber management and oversight in the Flathead Basin.

7. The participants of the Cooperative Program will provide staff support, technical expertise, funding, and/or other in-kind assistance. The FNF, State of Montana, and PCTCI tentatively will make the following funds available to finance administrative studies:

	CY 1988	CY 1989	CY 1990
Flathead National Forest	\$30,000	\$50,000	\$50,000
State of Montana, Renewable Resource Development Grant	-0-	\$25,000[1]	\$25,000[2]
Plum Creek Timber Co, Inc.	\$10,000	\$20,000	\$20,000

[1] applied for
[2] estimated from other state of Montana sources

The indicated funds will be made available and are the maximum amount that each source will contribute in any one calendar year. The funds will not be considered obligated until the necessary procurement documents are completed.[3]

8. Study leaders of individual study modules will prepare annual work plans to be approved by the Coordinating Team but will otherwise operate independently of the Coordinating Team.

9. Progress of study modules will be reviewed by the Coordinating Team through annual work plans and semi-annual progress reports by the Study Leaders to the Coordinating Team.

10. This agreement shall become effective on the date of the last signature and continue for a period of three years from that date.

11. This agreement may be amended at any time with 60 days notice to the other parties. Amendments will require signatory approval by all the parties involved. Termination can be initiated by any one party.

* * * * *

[3] Nothing herein shall be construed as obligating the Forest Service to expend or as involving the United States in any contract or other obligation for the future payment of money in excess of appropriations authorized by law and administratively allocated for this work.

This MEMORANDUM OF UNDERSTANDING is agreed to by:

Executive Director Flathead Basin Commission	8/9/88 Date
State Forester Department of State Lands	8/8/88 Date
Director of Operations Plum Creek Timber Company, Inc.	8/8/88 Date
Supervisor Flathead National Forest	8/8/88 Date
Director Department of Health and Environmental Sciences	8/9/88 Date
Supervisor Region One Department of Fish, Wildlife & Parks	8/29/88 Date
Vice President for Research University of Montana	8/8/88 Date

APPENDIX B:

PARTICIPANTS IN THE FLATHEAD BASIN FOREST PRACTICES/ WATER QUALITY AND FISHERIES PROGRAM

Participants in the Flathead Basin Forest Practices/Water Quality and Fisheries Cooperative Program

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Joel Holtrop, Supervisor, Flathead National Forest, Kalispell, Montana

Glenn Marx, Executive Director, Flathead Basin Commission, Helena, Montana

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APPENDIX C:

ABIES LASIOCARPA/OPLOPANAX HORRIDUM H.T. (SUBALPINE FIR/DEVIL'S CLUB H.T.)

Abies lasiocarpa/Oplopanax horridum h.t. (Subalpine Fir/Devil's Club h.t.)

Abilas/Oplhor (ABLA/OPHO) — Number of stands sampled = 4

Comment — The discussion below represents an expanded description of this habitat type as defined by Pfister and others (1977).

Location and Associated Landforms.

The *Abies lasiocarpa/Oplopanax horridum* (subalpine fir/devil's club) habitat type is an incidental type at mid-elevations. Sampled sites ranged in elevation from 1,200 to 1,500 m (3,900 to 5,000 feet). This habitat type occurs on wet bottoms and sites near streams, springs, or seepage areas where the water table remains near the soil surface all year. Although normally restricted to wet bottoms and sites near streams and springs, the occurrence of seeps in some drainages, such as the Swan and Stillwater effectively expands the acreage of this type considerably. It often forms narrow stringers along streams.

Floristic Characteristics of Late Seral to Climax Stands

Climax stands are codominated by *Abies lasiocarpa* (subalpine fir) and *Picea* (spruce). *Pseudotsuga menziesii* (Douglas fir), *Larix occidentalis* (western larch), and *Pinus monticola* (white pine) are scattered throughout the stands; *Thula plicata* (western red cedar) and *Tsuga heterophylla* (western hemlock) may occur as sporadic accidentals. This habitat type often supports very large old growth trees. The undergrowth is dominated by *Oplopanax horridum* (devil's club), *Taxus brevifolia* (Pacific yew), *Clintonia uniflora* (queen's cup), *Tiarella trifoliata* (trefoil foamflower), *Athyrium filix-femina* (ladyfern), and *Gymnocarpium dryopteris* (oak-fern).

The following table gives the average percent canopy cover and range of indicator species for those species with a 50% or more constancy (e.g.. occurs In at least 50% of the stands sampled) in late seral to climax stands:

Soils

Parent materials were noncalcareous. The soils were non-gravelly loams and the surface soils were acid. Exposed rock and soil were not noted. Duff depths were 7-10 cm (3-4 in). The water table typically remains near the soil surface all year. Soil textures range from fine, poorly drained materials to coarse, well drained soils (Pfister and Sherwood 1989).

Adjacent Communities

Adjacent wetter sites support *Carex* (sedge) communities, and drier sites may include the *Abies lasiocarpa/Calamagrostis canadensis* (subalpine fir/bluejoint reedgrass) habitat type. The *Thuja plicata/Oplopanax horridum* (western red cedar/devil's club) habitat type occupies similar sites, except it Is typically found at warmer, lower elevations.

Species	% Canopy Cover Average	% Canopy Cover Range	Constancy
TREES			
Abies lasiocarpa (subalpine fir)	30	15-45	100%
Larix occidentalis (western larch)	12	0-25	50%
Picea (spruce)	30	0-65	100%
Pinus monticola (western white pine)	2	0-5	50%
Pseudotsuga menziesii (Douglas fir)	12	0-25	50%
SHRUBS			
Acer glabrum (Rocky Mountain maple)	11	0-25	100%
Cornus stolonifera (red-osier dogwood)	1	0-1	50%
Lonicera utahensis (Utah honeysuckle)	1	0-1	75%
Menziesia ferruginea (fool's huckleberry)	10	0-25	50%
Oplopanax horridum (devil's club)	40	15-65	100%
Pachistima myrsinites (mountain boxwood)	1	0-1	50%
Ribes lacustre (swamp currant)	2	0-5	50%
Rubus idaeus (red raspberry)	1	0-1	50%
Rubus parviflorus (thimbleherry)	1	0-1	75%
Symphoricarpos albus (common snowberry)	10	0-25	50%
Taxus brevifolia (Pacific yew)	31	1-65	100%
Vaccinium globulare (globe huckleberry)	1	0-5	75%
GRAMINOIDS			
Bromus vulgaris (Columbia brome)	1	0-5	75%
Carex gravida (heavy sedge)	1	0-1	25%
FORBS			
Actaea rubra (baneberry)	1	1	100%
Adenocaulon bicolor (trail-plant)	3	0-5	50%
Aralia nudicaulis (wild sarsaparilla)	12	0-25	50%
Arnica latifolia (broadleaf amica)	9	0-25	75%
Athyrium filix-femina (ladyfern)	20	1-45	100%
Clintonia uniflora (queen's cup)	7	1-25	100%
Disporum hookeri (hooker fairy-bell)	1	0-1	50%
Galium triflorum (sweetscented bedstraw)	1	0-5	75%
Goodyera oblongifolia (western rattlesnake-plantain)	1	0-1	50%
Gymnocarpium dryopteris (oak-fern)	16	1-25	100%
Hieracium albiflorum (white-flowered hawkweed)	1	0-1	50%
Osmorhiza chilensis (mountain sweet-cicely)	1	0-1	75%

Species	% Canopy Cover Average	Range	Constancy
Pyrola secunda (one-sided wintergreen)	1	0 - 1	50%
Smilacina stellata (starry Solomon-plume)	7	1 - 25	100%
Streptopus amplexifolius (clasping-leaved twisted stalk)	1	0 - 1	50%
Thalictrum occidentale (western meadowrue)	1	1 - 5	100%
Tiarella trifoliata (trefoil foamflower)	16	1 - 25	100%
Trillium ovatum (white trillium)	1	0 - 1	50%
Veratrum viride (green false hellebore)	1	0 - 1	75%
Viola canadensis (Canada Violet)	2	1 - 5	75%
Viola orbiculata (round-leaved violet)	2	1 - 5	100%

Management Information

[In addition to the Information given below, the following information is summarized by species In Appendices 2-8:] 1) forage palatability (cattle, sheep, and horses); 2) wetland status; 3) energy value; 4) protein value; 5) thermal or feeding cover values (elk, mule deer, whitetail deer, upland game birds, waterfowl, small non-game birds, and small mammals); 6) food value or degree of use (elk, mule deer, whitetail deer, antelope, upland game birds, waterfowl, small non-game birds, and small mammals); 7) potential biomass production; 8) erosion control potential; 9) short-term revegetation potential; and 10) long-term revegetation potential.

Livestock — Grazing potential is very low.

Timber — Timber productivity is moderate to high, but sites require careful attention and caution for intensive timber management. High water tables during most of the season may preclude the use of heavy equipment. Heavy equipment operation should be restricted to those times of year when soils are frozen and snow covered.

Proper riparian management needs to be seriously considered for the *Abies lasiocarpa/ Oplopanax horridum* (subalpine fir/devil's club) habitat type. Shallow rooted species, fine textured soils, and high water tables contribute to a high degree of instability, especially following logging of adjacent stands. Logging only one side of a stream, sometimes effective in reducing blowdown, ***does not*** seem to substantially increase the ability of the Streamside Management Zone to remain intact. Heavy partial cutting or harvesting of adjacent stands by even-aged systems will accelerate windthrow of large trees, especially *Picea engelmannii* (Engelmann spruce), in residual stands. Removal of decadent, old growth trees, leaving younger, wind resistant species often leaves the Streamside Management Zone in better condition to withstand winds following logging. However, this may directly conflict with some agency management objectives; if retention of old growth for fish (woody debris recruitment) and wildlife habitat (including nesting and roosting trees) is an objective, prescriptions must be designed to minimize blowdown, or losses to water quality (fisheries habitat) may result (Pfister and Sherwood 1989). If large numbers of uprooted trees lead to water quality degradation, then removal may be appropriate. Silvicultural prescriptions must be clearly defined, objectives should be obtainable, and proposed treatments should be carefully evaluated against their chances for success.

These sites may need to be regenerated quickly to avoid losses to competing vegetation; recommended species are *Picea engelmannii* (Engelmann spruce), *Larix occidentalis* (western larch), and *Pseudotsuga menziesii* (Douglas fir). While natural regeneration of these sites is known to be a problem, in some parts of the Flathead National Forest, planting of *Larix occidentalis* (western larch) has been successful following clearcutting (Pfister and Sherwood 1989).

Wildlife — Forage productivity for deer and elk is probably low. This habitat type, along with other moist old growth communities, is rare in Montana. Many wildlife species, such as chestnut-backed chickadees and goshawks, are partially to strongly dependent on huge old growth trees for forage, cover, and nesting sites.

Fire — Fires are rare on these sites due to the high water tables.

Soil Management and Rehabilitation Opportunities — Due to the high water tables, any development (road constructions, trails, site development, etc.) has a high potential for problems. Proposed timber management activities, especially road layout, design, and construction, may require consultation with specialists (hydrologists, soil scientists, engineers, etc.) to minimize on-site and off-site impacts. Heavy equipment operation should be restricted to those times of year when soils are frozen and snow covered.

Recreational Uses and Considerations — Old growth stands with large diameter trees have high recreational and aesthetic values, but site development should take into account the difficulty of managing sites with high water tables.

Other Classification Systems

U.S. Fish and wildlife Service Wetland Classification (Cowardin and others 1979) — SYSTEM Palustrine, CLASS Forested Wetland, SUBCLASS Needle-leaved Evergreen, WATER REGIME (NONTIDAL) Seasonally Flooded to Saturated.

Other Studies

Similar habitat types were described by Illingworth and Arlidge (1960) for eastern British Columbia and by Ogilvie (1962) for southwestern Alberta.

Appendix D:

Montana Forest Habitat Types

ADP code[1]	Abbreviation	Habitat types and phases	
		Scientific names	Common names
010	SCREE		
000		PINUS FLEXILIS CLIMAX SERIES	
040	PIFL/AGSP h.t.	Pinus flexilis/Agropyron spicatum h.t.	limber pine/bluebunch wheatgrass
050	PIFL/FEID h.t.	Pinus flexilis/Festuca idahoensis h.t.	limber pine/Idaho fescue
051	-FEID phase	-Festuca idahoensis phase	-Idaho fescue phase
052	-FESC phase	-Festuca scabrella phase	-rough fescue phase
070	PIFL/JUCO h.t.	Pinus flexilis/Juniperus communis h.t.	limber pine/common juniper
100		PINUS PONDEROSA CLIMAX SERIES	
110	PIPO/AND h.t.[2]	Pinus ponderosa/Andropogon spp. h.t.	ponderosa pine/bluestem
130	PIPO/AGSP h.t.	Pinus ponderosa/Agropyron spicatum h.t.	ponderosa pine/bluebunch wheatgrass
140	PIPO/FEID h.t.	Pinus ponderosa/Festuca idahoensis h.t.	ponderosa pine/Idaho fescue
141	-FEID phase	-Festuca idahoensis phase	-Idaho fescue phase
142	-FESC phase	-Festuca scabrella phase	-rough fescue phase
160	PIPO/PUTR h.t.	Pinus ponderosa/Purshia tridentata h.t.	ponderosa pine/bitterbrush
161	-AGSP phase	-Agropyron spicatum phase	-bluebunch wheatgrass phase
162	-FEID phase	-Festuca idahoensis phase	-Idaho fescue phase
170	PIPO/SYAL h.t.	Pinus ponderosa/Symphoricarpos albus h.t.	ponderosa pine/snowberry
171	-SYAL phase	-Symphoricarpos albus phase	-snowberry phase
172	-BERE phase	-Berberis repens phase	-creeping oregon grape phase
180.	PIPO/PRVI h.t.	Pinus ponderosa/Prunus virginiana h.t.	ponderosa pine/chokecherry
181	-PRVI phase	-Prunus virginiana phase	-chokecherry phase
182	-SHCA phase	-Shepherdia canadensis phase	-buffaloberry phase
200		PSEUDOTSUGA MENZIESII CLIMAX SERIES	
210	PSME/AGSP h.t.	Pseudotsuga menziesii/Agropyron spicatum h.t.	Douglas-fir/bluebunch wheatgrass
220	PSME/FEID h.t.	Pseudotsuga menziesii/Festuca idahoensis h.t.	Douglas-fir/Idaho fescue
230	PSME/FESC h.t.	Pseudotsuga menziesii/Festuca scabrella h.t.	Douglas-fir/rough fescue
250	PSME/VACA h.t.	Pseudotsuga menziesii/Vaccinium caespitosum h.t.	Douglas-fir/dwarf huckleberry
260	PSME/PHMA h.t.	Pseudotsuga menziesii/Physocarpus malvaceus h.t.	Douglas-fir/ninebark
261	-PHMA phase	-Physocarpus malvaceus phase	-ninebark phase
262	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
280	PSME/VAGL h.t.	Pseudotsuga menziesii/Vaccinium globulare h.t.	Douglas-fir/blue huckleberry
281	-VAGL phase	-Vaccinium globulare phase	-blue huckleberry phase
282	-ARUV phase	-Arctostaphylos uva-ursi phase	-kinnikinnick phase
283	-XETE phase	-Xerophyllum tenax phase	-beargrass phase
290	PSME/LIBO h.t.	Pseudotsuga menziesii/Linnaea borealis h.t.	Douglas-fir/twinflower
291	-SYAL phase	-Symphoricarpos albus phase	-snowberry phase
292	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
293	-VAGL phase	-Vaccinium globulare phase	-blue huckleberry phase
310	PSME/SYAL h.t.	Pseudotsuga menziesii/Symphoricarpos albus h.t.	Douglas-fir/snowberry
311	-AGSP phase	-Agropyron spicatum phase	-bluebunch wheatgrass phase
312	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
313	-SYAL phase	-Symphoricarpos albus phase	-snowberry phase
320	PSME/CARU h.t.	Pseudotsuga menziesii/Calamagrostis rubescens h.t.	Douglas-fir/pinegrass
321	-AGSP phase	-Agropyron spicatum phase	-bluebunch wheatgrass phase
322	-ARUV phase	-Arctostaphylos uva-ursi phase	-kinnikinnick phase
323	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
324	-PIPO phase	-Pinus ponderosa phase	-ponderosa pine phase
330	PSME/CAGE h.t.	Pseudotsuga menziesii/Carex geyeri h.t.	Douglas-fir/elk sedge
340	PSME/SPBE h.t.	Pseudotsuga menziesii/Spiraea betulifolia h.t.	Douglas-fir/white spiraea
350	PSME/ARUV h.t.	Pseudotsuga menziesii/Arctostaphylos uva-ursi h.t.	Douglas-fir/kinnikinnick
360	PSME/JUCO h.t.	Pseudotsuga menziesii/Juniperus communis h.t.	Douglas-fir/common juniper
370	PSME/ARCO h.t.	Pseudotsuga menziesii/Arnica cordifolia h.t.	Douglas-fir/heartleaf arnica
380	PSME/SYOR h.t.[2]	Pseudotsuga menziesii/Symphoricarpos oreophilus h.t.	Douglas-fir/mountain snowberry
400		PICEA CLIMAX SERIES	
410	PICEA/EQAR h.t.	Picea/Equisetum arvense h.t.	spruce/common horsetail
420	PICEA/CLUN h.t.	Picea/Clintonia uniflora h.t.	spruce/queencup beadlily
421	-VACA phase	-Vaccinium caespitosum phase	-dwarf huckleberry phase
422	-CLUN phase	-Clintonia uniflora phase	-queencup beadlily phase
430	PICEA/PHMA h.t.	Picea/Physocarpus malvaceus h.t.	spruce/ninebark
440	PICEA/GATR h.t.	Picea/Galium triflorum h.t.	spruce/sweetscented bedstraw
450	PICEA/VACA h.t.	Picea/Vaccinium caespitosum h.t.	spruce/dwarf huckleberry
460	PICEA/SEST h.t.	Picea/Senecio streptanthifolius h.t.	spruce/cleft-leaf groundsel
461	-PSME phase	-Pseudotsuga menziesii phase	-Douglas-fir phase
462	-PICEA phase	-Picea phase	-spruce phase
470	PICEA/LIBO h.t.	Picea/Linnaea borealis h.t.	spruce/twinflower
480	PICEA/SMST h.t.	Picea/Smilacina stellata h.t.	spruce/starry Solomon's seal
500		ABIES GRANDIS CLIMAX SERIES	
510	ABGR/XETE h.t.	Abies grandis/Xerophyllum tenax h.t.	grand fir/beargrass
520	ABGR/CLUN h.t.	Abies grandis/Clintonia uniflora h.t.	grand fir/queencup beadlily
521	-CLUN phase	-Clintonia uniflora phase	-queencup beadlily phase
522	-ARNU phase	Aralia nudicaulis phase	-wild sarsaparilla phase
523	-XETE phase	-Xerophyllum tenax phase	-beargrass phase
590	ABGR/LIBO h.t.	Abies grandis/Linnaea borealis h.t.	grand fir/twinflower
591	-LIBO phase	-Linnaea borealis phase	-twinflower phase
592	-XETE phase	-Xerophyllum tenax phase	-beargrass phase

(con.)

ADP code[1]	Abbreviation	Habitat types and phases: Scientific names	Habitat types and phases: Common names
501		THUJA PLICATA CLIMAX SERIES	
530	THPL/CLUN h.t.	Thuja plicata/Clintonia uniflora h.t.	western redcedar/queencup beadlily
531	-CLUN phase	-Clintonia uniflora phase	-queencup beadlily phase
532	-ARNU phase	-Aralia nudicaulis phase	-wild sarsaparilla phase
533	-MEFE phase	-Menziesia ferruginea phase	-menziesia phase
550	THPL/OPHO h.t.	Thuja plicata/Oplopanax horridum h.t.	western redcedar/devil's club
502		TSUGA HETEROPHYLLA CLIMAX SERIES	
570	TSHE/CLUN h.t.	Tsuga heterophylla/Clintonia uniflora h.t.	western hemlock/queencup beadlily
571	-CLUN phase	-Clintonia uniflora phase	-queencup beadlily phase
572	-ARNU phase	-Aralia nudicaulis phase	-wild sarsaparilla phase
600		ABIES LASIOCARPA CLIMAX SERIES	
700		Lower subalpine h.t.s	
610	ABLA/OPHO h.t.	Abies lasiocarpa/Oplopanax horridum h.t.	subalpine fir/devil's club
620	ABLA/CLUN h.t.	Abies lasiocarpa/Clintonia uniflora h.t.	subalpine fir/queencup beadlily
621	-CLUN phase	-Clintonia uniflora phase	-queencup beadlily phase
622	-ARNU phase	-Aralia nudicaulis phase	-wild sarsaparilla phase
623	-VACA phase	-Vaccinium caespitosum phase	-dwarf huckleberry phase
624	-XETE phase	-Xerophyllum tenax phase	-beargrass phase
625	-MEFE phase	-Menziesia ferruginea phase	-menziesia phase
630	ABLA/GATR h.t.	Abies lasiocarpa/Galium triflorum h.t.	subalpine fir/sweetscented bedstraw
640	ABLA/VACA h.t.	Abies lasiocarpa/Vaccinium caespitosum h.t.	subalpine fir/dwarf huckleberry
650	ABLA/CACA h.t.	Abies lasiocarpa/Calamagrostis canadensis h.t.	subalpine fir/bluejoint
651	-CACA phase	-Calamagrostis canadensis phase	-bluejoint phase
653	-GATR phase	-Galium triflorum phase	-sweetscented bedstraw phase
654	-VACA phase	-Vaccinium caespitosum phase	-dwarf huckleberry phase
660	ABLA/LIBO h.t.	Abies lasiocarpa/Linnaea borealis h.t.	subalpine fir/twinflower
661	-LIBO phase	-Linnaea borealis phase	-twinflower phase
662	-XETE phase	-Xerophyllum tenax phase	-beargrass phase
663	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
670	ABLA/MEFE h.t.	Abies lasiocarpa/Menziesia ferruginea h.t.	subalpine fir/menziesia
680	TSME/MEFE h.t.	Tsuga mertensiana/Menziesia ferruginea h.t.	mountain hemlock/menziesia
690	ABLA/XETE h.t.	Abies lasiocarpa/Xerophyllum tenax h.t.	subalpine fir/beargrass
691	-VAGL phase	-Vaccinium globulare phase	-blue huckleberry phase
692	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
710	TSME/XETE h.t.	Tsuga mertensiana/Xerophyllum tenax h.t.	mountain hemlock/beargrass
720	ABLA/VAGL h.t.	Abies lasiocarpa/Vaccinium globulare h.t.	subalpine fir/blue huckleberry
730	ABLA/VASC h.t.	Abies lasiocarpa/Vaccinium scoparium h.t.	subalpine fir/grouse whortleberry
731	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
732	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
733	-THOC phase	-Thalictrum occidentale phase	-western meadowrue phase
740	ABLA/ALSI h.t.	Abies lasiocarpa/Alnus sinuata h.t.	subalpine fir/Sitka alder
750	ABLA/CARU h.t.	Abies lasiocarpa/Calamagrostis rubescens h.t.	subalpine fir/pinegrass
770	ABLA/CLPS h.t.	Abies lasiocarpa/Clematis pseudoalpina h.t.	subalpine fir/virgin's bower
780	ABLA/ARCO h.t.	Abies lasiocarpa/Arnica cordifolia h.t.	subalpine fir/heartleaf arnica
790	ABLA/CAGE h.t.[2]	Abies lasiocarpa/Carex geyeri h.t.	subalpine fir/elk sedge
791	-CAGE phase	-Carex geyeri phase	-elk sedge phase
792	-PSME phase	-Pseudotsuga menziesii phase	-Douglas-fir phase
800		Upper subalpine h.t.s	
810	ABLA/RIMO h.t.[2]	Abies lasiocarpa/Ribes montigenum h.t.	subalpine fir/mountain gooseberry
820	ABLA-PIAL/VASC h.t.	Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium h.t.	subalpine fir-whitebark pine/ grouse whortleberry
830	ABLA/LUHI	Abies lasiocarpa/Luzula hitchcockii h.t.	subalpine fir/smooth wood-rush
831	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
832	-MEFE phase	-Menziesia ferruginea phase	-menziesia phase
840	TSME/LUHI h.t.[2]	Tsuga mertensiana/Luzula hitchcockii h.t.	mountain hemlock/smooth wood-rush
841	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
842	-MEFE phase	-Menziesia ferruginea phase	-menziesia phase
890		Timberline h.t.s	
850	PIAL-ABLA h.t.s	Pinus albicaulis-Abies lasiocarpa h.t.s	whitebark pine-subalpine fir
860	LALY-ABLA h.t.s	Larix lyallii-Abies lasiocarpa h.t.s	alpine larch-subalpine fir
870	PIAL h.t.s	Pinus albicaulis h.t.s	whitebark pine
900		PINUS CONTORTA CLIMAX SERIES	
910	PICO/PUTR h.t.	Pinus contorta/Purshia tridentata h.t.	lodgepole pine/bitterbrush
920	PICO/VACA c.t.	Pinus contorta/Vaccinium caespitosum c.t.	lodgepole pine/dwarf huckleberry
930	PICO/LIBO c.t.	Pinus contorta/Linnaea borealis c.t.	lodgepole pine/twinflower
940	PICO/VASC c.t.	Pinus contorta/Vaccinium scoparium c.t.	lodgepole pine/grouse whortleberry
950	PICO/CARU c.t.	Pinus contorta/Calamagrostis rubescens c.t.	lodgepole pine/pinegrass

Total Number of Habitat Types = 64

Total Number of Habitat Types, Phase, and Pinus contorta Community Type Categories = 105

[1] Automatic data processing codes for National Forest System use.
[2] Minor type in Montana; described in other study areas.

APPENDIX E:

DATA SET FOR MODULE J (LINEAR CORRELATION/REGRESSION ANALYSIS OF FORESTRY MODELS, RISK ASSESSMENT, AND WATER QUALITY AND FISHERIES DATA)

FNL DATA 2/19/91

	WATERSHED	TOT ACRES	TOT RD MI	HARVEST AC	PRNT	TOT FISH	SUBSTR SCORE	MCNEIL	VIBERT	REDD CT	NAT SED WT	H20Y WYI
1	Lion	14349.000	0.000	0.000	0.000	3.000	12.500	57.200	102.600	84.000	9.090	0.000
2	Chpt	1177.000	0.000	0.000	0.000	13.900	43.200	0.000	43.400		10.180	0.000
3	Coal	29268.000	72.500	4926.000	16.800	7.400	9.100	60.500	107.600	50.000	9.580	7.220
4	Chai	4606.000	2.900	244.000	5.300	19.600	40.900	75.400	164.800	19.000	7.480	5.820
5	S Coal	8435.000	22.100	1141.000	13.500	9.000	34.100	45.600		33.000	9.650	7.490
6	N Coal	13339.000	38.900	2646.000	19.000	10.600	39.800	52.400	104.200	29.000	9.370	10.020
7	Hand	550.000	1.800	38.000	6.900	12.400	17.000	47.600	80.100		8.130	7.150
8	Squaw	1075.000	5.600	316.000	29.400	5.200	22.700	32.200			9.890	10.970
9	Jim	8656.000	31.100	2150.000	24.800	2.100	2.300	102.800	119.700	31.000	7.580	11.910
10	Fish	1852.000	13.200	768.000	41.500	16.500	14.800	37.900	76.600	27.000	8.950	24.180
11	Elk						42.000	52.400				0.000
12	Goat						15.900	28.600				5.440
13	Squeezer						3.400	70.200				3.890
14	Piper						50.000	25.000				0.000
15	Freeland						0.000	84.300				25.100
16	Sheppard						22.700	36.300				18.660
17	Big Creek						34.100	93.500				10.500
18	U Red Meadow	10631.000	7.220	1337.000	12.570		34.100	81.700				7.770
19	Whale						30.700	42.700				6.470
20	Trail						48.900	24.200				4.620
21	Granite							74.200				7.540
22	Morrison						47.700	58.100				6.550
23	Ole						45.400					0.000
24	Hungry Horse						29.500	17.700				4.050
25	Tiger						34.100	21.800				1.900
26	Margaret						23.900	35.500				2.320
27	Emery						31.800	46.800				10.210
28	L Fitzsimmons	7353.000	5.200	0.000	0.000							
29	E. Fk. Swift						45.400	14.500				0.000
30	U Fitzsimmons	5087.000	3.000	0.000	0.000		44.300	25.800				0.000
31	L Red Meadow	14518.000	10.700	2786.000	19.190							
32	Deano	1001.000	0.000	0.000	0.000							

FNL DATA 2/19/91

	H2OY TRO	SEQUOIA	NEW CSR	HIST CSR	CSR CHNG	WQB RATE AVG	WQB SITE RCH	MAX CHL A	TP	TPN	WAT SED WYI	WATSED WYI
1	51765.000	0.000	89.000	105.000	-16.000	66.300	82.000	0.043	4.200	133.900	0.000	0.000
2		0.000	99.000					0.005	7.600	35.100	0.000	0.000
3	69460.000	8.720	67.000	75.000	-8.000	62.300	93.000				11.500	12.900
4	5977.000	9.100	102.000			71.000	79.000				5.700	5.700
5	19962.000	11.390	88.000	91.000	-3.000	51.800	85.000	0.075	6.800	98.000	9.900	11.500
6	35198.000	15.000	71.000	77.000	-6.000		82.000				12.900	14.200
7	528.000	17.950	75.000			73.700	81.000	0.023	8.800	130.300	9.900	9.900
8	1032.000	19.460	65.000					0.345	26.200	388.000	20.200	20.300
9	21198.000	21.130	81.000	69.000	12.000	67.500	86.000	0.412	5.200	140.400	15.300	17.500
10	1416.000	28.380	101.000	70.000	31.000	67.000	70.000				23.600	27.300
11		0.000					68.200					
12		0.570				65.100						
13		1.150				70.500						
14		0.000				74.100						
15		33.770										
16		23.340				76.700						
17		9.980				69.900						
18		10.630				56.700		0.564				
19		6.020				83.500						
20		8.720				63.000						
21		7.920				57.800						
22		9.100				66.900						
23		0.000				52.300						
24		0.000				73.800						
25		0.000				70.500						
26		0.000				71.500						
27		8.130				64.300						
28								0.276				
29		0.000				51.500						
30		0.000						0.003				
31								0.196				
32								0.002				

FNL DATA 2/19/91

	WATSED WYI	WATSED SED	WATSED CUM	SAMPL SED	SEQ TRANS	H20Y WYI
1	0.000	205.000	9.000	8.460	0.000	0.000
2	0.000	19.000	0.000		0.000	0.000
3	3.000	1787.000	2732.000	29.060	8.700	10.500
4	2.000	136.000	141.000	2.890	9.100	5.700
5	2.000	170.000	1728.000	10.050	11.400	7.500
6	4.000	596.000	1514.000	11.170	15.000	10.000
7	2.000	23.000	29.000	0.710	18.000	7.000
8	9.000	94.000	263.000	1.620	19.500	10.900
9	8.000	553.000	1409.000		20.500	12.300
10	19.000	155.000	814.000	3.150	28.400	24.200
11						
12						
13						
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APPENDIX F:

NONPOINT SOURCE STREAM REACH ASSESSMENT MONTANA WATER QUALITY BUREAU FIELD REPORT FORM

NONPOINT SOURCE STREAM REACH ASSESSMENT
MONTANA WATER QUALITY BUREAU
FIELD REPORT FORM

GENERAL INFORMATION

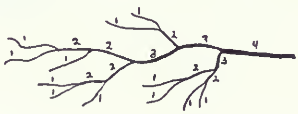
STREAM NAME____________________ RIVER BASIN[1]____________________ COUNTY(S)____________________
ASSESSED BY (NAME)____________________ DEPT./AGENCY/OTHER____________________ DATE ASSESSED____________________
REACH LEGAL DESCRIPTION T./R./S. 1/4SEC. BEGINNING ____________________ END____________________
REACH NUMBER OR LETTER (ASSIGNED BY SURVEYOR) ____________
PLEASE DESCRIBE ANY PROMINENT LANDMARKS THAT MAY DELINEATE REACH BREAKS. ____________________
____

DELINIATE ALL REACH BOUNDARIES AND OBSERVATION POINTS ON MAP/S AND ATTACH TO ASSESSMENT FORMS.

LAST RAINFALL DATE AND AMOUNT OR INTENSITY IF KNOWN____________________ WATER TEMPERATURE ______AT______AM/PM
FLOW STAGE (RELATIVE TO BANK FULL 100%) ___FLOOD,100+% ___HIGH,75% ___MODERATE,50% ___LOW,<25% ___NO WATER
STREAM DESCRIPTION: CHECK THE ITEM IN EACH COLUMN THAT BEST FITS

GRADIENT	VALLEY SHAPE	CHANNEL PATTERN	CHANNEL EROSION	STREAM TYPE
___>3%	___"V" SHAPED	___SINGLE, STRAIGHT	___VERTICAL EROSION DOMINATES	___ MOUNTAIN
___1-3%	___"U" SHAPED	___SINGLE, SINUOUS	___VERTICAL & HORIZONTAL COMMON	___ TRANSITIONAL
___<1%	___ FLAT	___BRAIDED, STRAIGHT	___HORIZONTAL EROSION DOMINATES	___ PRAIRIE
		___BRAIDED, SINUOUS		

FISHERIES: CHECK THE ITEM THAT BEST FITS
___COLD WATER (TROUT SPECIES ONLY) ___WARM/COOL WATER DOMINATED BY SPECIES SUCH AS BASS, CATFISH, SUNFISH, PIKE, WALLEYE.
___COMBINATION OF COLD/COOL/WARM WATER FISHERIES ALL WELL REPRESENTED
STREAM ORDER: ___FIRST ___SECOND ___THIRD ___FORTH
YOU SHOULD USE A TOPO. MAP TO DETERMINE THIS.
TWO OR MORE FIRST ORDER STREAMS BECOME A SECOND ORDER.
TWO OR MORE SECOND ORDER STREAMS BECOME A THIRD ORDER.
TWO OR MORE THIRD ORDER STREAMS BECOME A FOURTH ORDER.
ETC...



FLOW REGIME:
___EPHEMERAL, FLOWS ONLY DURING RAINSTORMS OR PEAK SPRING RUNOFF.
___INTERMITTENT, SEASONAL FLOWS DURING WET WEATHER, SPRING RUNOFF OR FLOWS YEAR ROUND EXCEPT FOR POINTS OF SUBSURFACE FLOW.
___PERENNIAL, FLOWS YEAR ROUND, LITTLE OR NO SUBSURFACE FLOW.

****

ADDITIONAL INFORMATION - COMPLETED BY FIELD PERSONNEL IF KNOWN, OTHERWISE COMPLETED BY WQB.

MT WATER BODY ID #:____________ COUNTY FLAG:____________ STREAM CLASSIFICATION: A, B OR C________ EPA REACH #____________
BENEFICIAL USES: DRINKING WATER___, STOCK WATER___, FISHERIES___, OTHER____________________
IMPAIRMENT SEVERITY: ___MINOR OR NO INTERFERENCE ___THREATENED, NO INTERFERENCE BUT DOWNWARD TREND ___MODERATE, SOME INTERFERENCE BUT USE NOT PRECLUDED ___SEVERE, USE PRECLUDED
WERE WATER SAMPLES OBTAINED? YES, NO. IF YES, WHAT ANALYSES WILL BE PERFORMED? WHAT PRESERVATIVES WERE USED?____________
GIVE RESULTS, IF ANY____
____
____

****

1 RIVER THAT THE STREAM BEING ASSESSED IS A TRIBUTARY TO.

Nonpoint Source Stream Reach Assessment Form

PLEASE CHECK THE MOST APPROPRIATE ANSWER FOR EACH PARAMETER. MAKE SURE TO ELABORATE WHEN ASK OR WHENEVER NECESSARY TO CLARIFY YOUR ANSWER.

GENERAL ASSESSMENT PARAMETERS

1. NATURAL EROSION: (NATEROS) NATURAL EROSION OCCURRING OUTSIDE OF HIGH WATER MARK BUT WITHIN 200' OF THE STREAM. DO NOT BASE THIS RATING ON HUMAN OR STREAM CHANNEL/BANK EROSION. CONSIDER EROSIVE FEATURES SUCH AS LAND SLUMPS/SLIDES, GULLIES/RILLS/SHEETS ETC.
EROSION EVIDENT: ____NONE OR MINOR ____SOME ____MODERATE ____SEVERE [PLEASE ELABORATE]

2. LAND USE: (LAND) HUMAN ACTIVITIES WITHIN THE WATERSHED THAT HAVE THE POTENTIAL TO CREATE NPS POLLUTION.
CHECK ONE OR MORE ITEMS TO DESCRIBE DISTANCE FROM STREAM CHANNEL THAT ACTIVITIES HAVE OCCURRED:
____NO ACTIVITIES HAVE OCCURRED ____GREATER THAN 200' ____50-200' ____LESS THAN 50'

LIST PREDOMINANT ACTIVITIES AND HOW RECENT THE ACTIVITIES ARE (<5, 5-10, >10 YEARS) FOR EACH DISTANCE CATEGORY.
> 200'

50 - 200'

< 50'

3. NONPOINT SOURCE POLLUTION: (NPSP) CONSIDER ONLY THE POLLUTION THAT APPEARS ATTRIBUTABLE TO HUMAN ACTIVITIES. [PLEASE ELABORATE]
POLLUTION EVIDENT: ____NONE ____SOME, THOUGH NOT COMMON ____MODERATE ____SEVERE
(EXAMPLES MIGHT BE SEDIMENT DEPOSITION IN ROAD DITCHES OR BELOW EPHEMERAL, MANURE, IRON PRECIPITATES, TRASH ETC.)

4. BANK STABILITY: (BANKS) CONSIDER ALL OBSERVED STREAM BANK EROSION. [PLEASE ELABORATE]
____ NONE OR MINOR EVIDENCE OF BANK EROSION OR FAILURE (<10% OF TOTAL).
____ MODERATE INSTABILITY, MODERATE AREAS OF BANK EROSION OR BANK FAILURE (10-20% OF TOTAL).
____ SUBSTANTIAL INSTABILITY, FREQUENT AREAS OF BANK EROSION OR FAILURE (21-40% OF TOTAL).
____ UNSTABLE, SEVERE BANK EROSION AND FAILURE (>40% OF TOTAL). EROSION OCCURS ON STRAIGHT SECTIONS AND BENDS.
* AVERAGE SIZE OF ERODED BANKS; HEIGHT ____<1' ____1-3' ____>3' LENGTH ____<5' ____5-20' ____>20'
* ARE BANKS ____VERTICALLY EROSIONAL ____UNDERCUT ____SLUMPS OTHER (DESCRIBE)____________________
* DOES THE EROSION APPEAR TO PRIMARILY BE THE RESULT OF HUMAN ACTIVITY ? ___YES ___NO

5. SUBSTRATE COMPOSITION: (SUBCOMP) CONSIDER ONLY THE TOP (VISIBLE) LAYER OF SUBSTRATE MATERIAL.
RIFFLE = RELATIVELY SHALLOW, FAST MOVING, WITH BROKEN OR TURBULENT SURFACE, RUN = MODERATE FLOW, WATER SURFACE NOT TURBULENT TO THE POINT OF BEING BROKEN; POOL = SLOW FLOW, SMOOTH SURFACE, GENERALLY DEEPER THAN A RUN OR RIFFLE.

	RIFFLE	RUN	POOL
* LIST THE DOMINANT SUBSTRATE MATERIAL FOR EACH FEATURE: FINES <1/4"DIA., GRAVEL 1/4"-3"DIA., COBBLE/RUBBLE 3"-12"DIA., BOULDERS/BEDROCK >12"DIA.	________	________	________
* ESTIMATE PERCENTAGE OF FINE MATERIAL (<1/4") FOR EACH FEATURE:	________	________	________
* INDICATE THE AREA OF THE CHANNEL WHERE THE MAJORITY OF FINE MATERIAL IS DEPOSITED: EDGE, MIDDLE, DOWNSTREAM OF ROCKS/LOGS, THROUGHOUT	________	________	________

* IS SUBSTRATE MATERIAL CEMENTED (SURROUNDED BY TIGHTLY PACKED FINES)? ____ YES, ____ NO.

MISC. NOTES:

STREAM NAME AND COUNTY______________________________ DATE__________ SURVEYOR____________________

GENERAL ASSESSMENT PARAMETERS CONTINUED...

6. CHANNEL STABILITY: (CHANSTAB) CONSIDER SHIFTS IN SUBSTRATE MATERIAL (I.E. SCOURING, DEPOSITION, POOL FILLING).

SCOURING AND DEPOSITION

___ NONE OR MINOR. BARS STABLE AND WELL VEGETATED (<5% AFFECTED BY EITHER PROCESS).
___ SOME SCOUR AT CONSTRICTIONS OR STEEP GRADES, AND/OR POINT BAR ENLARGEMENT BY COURSE GRAVEL. (5-30% AFFECTED).
___ MODERATE SCOUR AND/OR DEPOSITION, POINT BARS ENLARGING BY GRAVEL AND SAND AND SOME NEW BARS FORMING. (31-50% AFFECTED).
___ SEVERE SCOUR AND/OR DEPOSITION OCCURS IN MOST AREAS OF THE STREAM. NEW BAR DEVELOPEMENT BY FINE MATERIAL IS COMMON. (>50% OF THE CHANNEL IS IN THE STATE OF FLUCTUATION)
[NOTE: "NEW" DEPOSITINAL MATERIAL SHOULD BE CLEAN (LIGHTER COLORED), LOOSE AND UNVEGETATED]

POOL DEVELOPMENT

___ POOLS COMMON AND/OR WELL DEVELOPED.
___ MINOR POOL FILLING, MOSTLY BY SILT.
___ POOL SIZE DECREASING DUE TO FILLING.
___ POOLS SEVERELY REDUCED OR LACKING DUE TO FILLING.

CHANNEL CAPACITY

___ CHANNEL CONTAINS PEAK FLOWS PLUS MORE IF NECESSARY (W-D >7)
___ CHANNEL CONTAINS MOST PEEK FLOWS (W-D=8 TO 15)
___ CHANNEL BARELY CONTAINS PEAK FLOWS (W-D=16 TO 25)
___ CHANNEL CAPACITY GENERALLY INADEQUATE FOR PEAK FLOW. OVERBANK FLOWS COMMON (W-D=>25)

7. STREAMSIDE VEGETATION: (STRVEG) CONSIDER VEGETATION ON BOTH BANKS, WITHIN 100' OF ACTIVE (SCOURED) CHANNEL. BRIEFLY DESCRIBE THE STREAMSIDE VEG. COMMUNITY (I.E. DOMINANT SPP., AGE, WIDTH, ETC.)

VEGETATIVE BANK STABILITY: ABILITY OF BANK VEG. TO RESIST EROS. ____GOOD ____FAIR ____POOR

PERCENT BARE GROUND: AMOUNT OF BARE GROUND (EXPOSED MINERAL SOIL) W/IN VEG.ZONE ___<15% ____15-30% ____31-45% ____>45%

AVERAGE WIDTH OF VEGETATIVE ZONE: ____>100' ____76-100' ____51-75' ____25-50' ____<25'
ESTIMATE MINIMUM WIDTH _____' AND MAXIMUM WIDTH _____'

USE AND/OR DAMAGE: CONSIDER NATURAL (I.E. WINDTHROW, DEAD TREES ETC.) OR HUMAN FACTORS (I.E. GRAZING, LOGGING ETC). PLEASE ELABORATE* BY DESCRIBING TYPE OF USE OR DAMAGE OBSERVED.
____NONE OR MINOR ____MODERATE ____SUBSTANTIAL ____SEVERE

STREAM SHADING: CONSIDER HOW MUCH OF THE STREAM IS SHADED BY BANK VEGETATION.
____>75% ____51-75% ____25-50% ____<25%

SEDIMENT FILTERING CAPACITY CONSIDER FACTORS SUCH AS SLOPE AND SEDIMENT SOURCES
____GOOD ____FAIR ____POOR

8. CHANNEL MODIFIERS: (CHANMDF) CONSIDER NATURAL AND ARTIFICIAL MATERIALS AND/OR STRUCTURES (IE.ANY MATERIAL OR STRUCTURE THAT HAS FALLEN IN OR BEEN PLACED IN THE STREAM CHANNEL). EXAMPLES OF MODIFIERS ARE BRIDGES, CULVERTS, DEBRIS JAMS, BEAVER DAMS, CAR BODIES, RIP-RAP ETC... [PLEASE ELABORATE]
____STRUCTURES/MATERIALS STABLE AND IMPROVING STREAM CONDITION (EX. SED. TRAP, FISH HABITAT, BANK STABILITY.) OR OTHERWISE NOT CAUSING FISH PASSAGE OR STABILITY PROBLEMS.
____STRUCTURES/MATERIALS GENERALLY STABLE EXCEPT DURING FLOODS; RELATED STABILITY PROBLEMS MINOR.
____STRUCTURES/MATERIALS HAVE GOOD POTENTIAL TO BE MOVED WITH HIGH TO MODERATE FLOWS. THESE FEATURES MAY RELEASE SEDIMENT INTO THE SYSTEM AND/OR CAUSE BANK OR CHANNEL EROSION.
____STRUCTURES/MATERIALS UNSTABLE AND/OR CAUSING SEVERE BANK OR CHANNEL EROSION.

DESCRIBE THE MATERIALS OR STRUCTURES THAT MAY BE MODIFYING THE CHANNEL.

DESCRIBE ANY POSITIVE CONTRIBUTIONS THAT MODIFIERS ARE MAKING TO THE STREAM (EX. FISH COVER, STABLE SED. TRAPS, BANK STABILIZATION ETC.)

DESCRIBE ANY NEGATIVE CONTRIBUTIONS THAT MODIFIERS ARE MAKING TO THE STREAM (EX.BANK/CHANNEL EROSION, FISH BARRIERS, UNSTABLE SEDIMENT TRAPS, ETC)

IMPAIRMENT INDICATORS
(IF IMPAIRMENTS ARE EVIDENT AND CONCENTRATED IN A SPECIFIC AREA, PLEASE NOTE LOCATIONS ON MAP)

TURBIDITY
CLEAR___ SLIGHTLY OFF COLOR___ CLOUDY___ OPAQUE___ COLOR:_____________

WATER SURFACE OILS
NONE____, SLIGHT____, MODERATE____, SEVERE____
SLICK___, SHEEN___, FLECKS____, OTHER_______________ SOURCE, IF KNOWN ____________________

PRECIPITATES OTHER THAN SEDIMENT ON CHANNEL BOTTOM
NONE____, SLIGHT____, MODERATE____, PROFUSE____ COLOR:__________________

SALINIZATION
___ NONE EVIDENT:
___ SOME: EVIDENCE OF SALINITY IS PRESENT IN THE WATERSHED HOWEVER NO SALT CRUSTS WERE OBSERVED WITHIN 100' OF THE STREAM.
___ MODERATE: SALT CRUSTS PRESENT <100' FROM THE STREAM. MAY BE MINOR EVIDENCE OF SALTS ON THE STREAM BANK. PLANT DIVERSITY AND ABUNDANCE MAY BE REDUCED OR DOMINATED BY SALT TOLERANT SPECIES (I.E. SALTGRASS, RABBIT BRUSH, FOXTAIL BARLEY, W. WHEATGRASS).
___ SEVERE: SALT CRUSTS COMMON WITHIN 100' OF THE STREAM OR ON STREAM BANKS. VEGETATION MAY BE SEVERELY REDUCED DUE TO SALT. SALT DEPOSITS MAY BE EVIDENT ON STREAM ROCKS.

FOREIGN DEBRIS: CONSIDER MATERIALS SUCH AS GARBAGE, MANURE, LOGGING SLASH, ETC. AND POSITION RELATIVE TO STREAM CHANNEL.

LOCATION OF DEBRIS RELATIVE TO DISTANCE FROM CHANNEL	AMOUNT (N = NONE, (P = PRESENT, C= COMMON, E = EXCESSIVE)	POTENTIAL TO REACH CHANNEL (L = LOW, M = MOD., H = HIGH)
___ >200' FROM STREAM CHANNEL.	____________	____________
___ 50-200' OF STREAM CHANNEL.	____________	____________
___ < 50' FROM THE STREAM CHANNEL.	____________	____________
___ MATERIAL PRESENT ON BANKS AND IN THE STREAM CHANNEL.	____________	____________

* DESCRIBE THE MATERIAL OBSERVED.

WATER ODOR
NONE___, SLIGHT___, MODERATE___, STRONG___
SEWAGE___, PETROLEUM___, CHEMICAL___, NATURAL___, OTHER________

DEWATERING: AS A RESULT OF IRRIGATION OR NATURAL FACTORS SUCH AS SUBSURFACE FLOWS.
___ NO APPARENT WATER LOSS (IRRIGATION MAY BE SUPPLEMENTING BASE FLOW)
___ WATER LOSS NOTICEABLE, HOWEVER FLOWS ARE ADEQUATE TO SUPPORT AQUATIC ORGANISMS.
___ FLOW WILL SUPPORT AQUATIC ORGANISMS, THOUGH HABITAT, ESPECIALLY RIFFLES IS DRASTICALLY REDUCED.
___ CHANNEL MAY BE DRY OR FLOW LOW ENOUGH TO PRECLUDE OR SEVERELY IMPAIR AQUATIC ORGANISMS.
* SUSPECTED CAUSES: NATURAL____________________________HUMAN-CAUSED______________________
* WERE IRRIGATION RETURN FLOWS OBSERVED? YES____ NO____ IF YES, RATE TURBIDITY H__ M__ L__
* STREAM TEMPERATURE? ABOVE RETURN_____ BELOW RETURN_____

AQUATIC ORGANISMS
FISHERIES
* WERE FISH OBSERVED? YES____ NO____ IF YES, ____PRESENT, ____COMMON, ____ABUNDANT. SPECIES, IF KNOWN__________________
* DID FISH EXHIBIT ABNORMAL BEHAVIOR? YES____ NO____
* WERE ANY FISH BARRIERS (IMPENETRABLE BLOCKAGES >3' HEIGHT) OBSERVED? YES____ NO____ BE SURE AND LOCATE BARRIERS ON MAP.

AQUATIC PLANT GROWTH
ABSENT____ PRESENT/NOT COMMON____ COMMON____ ABUNDANT____
DOES PLANT GROWTH APPEAR NORMAL GIVEN THE SEASON AND NATURAL STREAM CONDITIONS? YES____ NO____
IS ALGAE FILAMENTOUS? YES_____ NO_____
WHAT COLOR IS THE ALGAE? _______________

PLEASE ANSWER THE FOLLOWING QUESTIONS
- WAS WATER SURFACE FOAM >3" HIGH OBSERVED? YES____ NO____

- HAS CHANNEL BEEN ARTIFICIALLY MODIFIED? CONSIDER ONLY PRACTICES SUCH AS DREDGING, STRAIGHTENING, AND CHANNELIZATION.
YES___ NO___
IF YES, INDICATE THE TYPE OF MODIFICATION__________________ AND APPROXIMATELY HOW RECENT?
<5YRS._____ 5-10YRS._____ >10YRS_____
- HAVE THE MODIFIED PORTIONS OF THE CHANNEL STABILIZED? YES____ NO____.

- WERE POINT SOURCES OBSERVED? YES____ NO____ IF YES, PLEASE DESCRIBE AND RECORD LOCATION ON MAP

STREAM NAME AND COUNTY________________________ DATE__________ SURVEYOR____________________

BEST MANAGEMENT PRACTICES (BMP'S) AND LAND USE CHARACTERISTICS (200' EITHER SIDE OF STREAM)

PLEASE RATE THE FOLLOWING TO THE BEST OF YOUR KNOWLEDGE. GENERALLY CONSIDER BMP'S TO BE ANY MEASURES INCORPORATED WITH LAND USE ACTIVITIES THAT MAY HELP PROTECT WATER RESOURCES FROM NPS POLLUTION.

	EST % OF TOTAL AREA RELATIVE TO DISTANCE FROM STREAM		HAVE BMP'S BEEN APPLIED Y/N*		RATE EFFECTIVENESS OF BMP'S*	
LAND USES	0-50'	50-200'	0-50	50-200'	0-50'	50-200'
NON-IRRIGATED CROP						
IRRIGATED CROP						
GRAZING						
FEEDLOTS						
TIMBER HARVEST						
ROADS (% IS OPTIONAL)						
SURFACE MINING						
SUBSURFACE MINING						
URBAN						
OTHER______________						
OTHER______________						

*APPLICATION OF BMP'S

Y (YES) THE MAJORITY OF EACH PARTICULAR LAND USE IN THE REACH HAS BMP'S APPLIED.

N (NO) THE MAJORITY OF EACH PARTICULAR LAND USE IN THE REACH DOES NOT HAVE BMP'S APPLIED.

* BMP EFFECTIVENESS

1 MORE THAN ADEQUATE PROTECTION

2 ADEQUATE PROTECTION

3 MINOR AND/OR SHORT TERM IMPACTS

4 MAJOR AND/OR LONG TERM IMPACTS

PLEASE ELABORATE:

WHICH BMP'S WERE OBSERVED?

WHAT BMP'S NEED TO BE APPLIED TO IMPROVE THE SITUATION?

WHAT IMPACTS WERE OBSERVED? WHAT IS THE POTENTIAL FOR CORRECTION? G=GOOD, F=FAIR, P=POOR

APPENDIX G:

LIST OF FLATHEAD BASIN STREAMS WITH MAJOR BULL TROUT SPAWNING AND/OR REARING AREAS OR CONCENTRATED USE BY SPAWNING WESTSLOPE CUTTHROAT TROUT

List of Flathead Basin Streams with Major Bull Trout Spawning and/or Rearing Areas or Concentrated Use by Spawning Westslope Cutthroat Trout

The following non-wilderness streams are considered critical spawning and/or rearing habitat for bull trout in the Flathead Basin:

Swan River Drainage:
- Elk Creek*
- Goat Creek*
- Squeezer Creek*
- Lion Creek*
- Piper Creek
- Jim Creek
- Cold Creek
- North Fork Lost Creek
- South Fork Lost Creek

North Fork Flathead River Drainage:
- Big Creek*
- Hallowatt Creek
- Coal Creek*
- South Fork Coal Creek*
- Mathias Creek
- Red Meadow Creek
- Whale Creek*
- Shorty Creek
- Trail Creek*

Middle Fork Flathead River Drainage:
- Bear Creek
- Granite Creek*
- Morrison Creek
- Puzzle Creek

The following non-wilderness streams support areas of concentrated use by spawning westslope cutthroat trout. These streams are considered critical spawning habitat for westslope cutthroat trout:

North Fork Flathead River Drainage:
- Langford Creek
- Cyclone Creek
- Red Meadow Creek
- Moose Creek

Middle Fork Flathead River Drainage:
- Challenge Creek*
- Dodge Creek

South Fork Flathead River Drainage:
- Hungry Horse Creek*
- Tiger Creek*
- Margaret Creek*
- Emery Creek*

The above lists will be subject to change as more information becomes available. Annual updates will be available upon request from the Montana Department of Fish, Wildlife and Parks.

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*These streams are annually monitored by the Montana Department of Fish, Wildlife and Parks as part of the Flathead Basin Commission's Master Monitoring Plan. We recommend continued long term annual sampling in these areas.

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