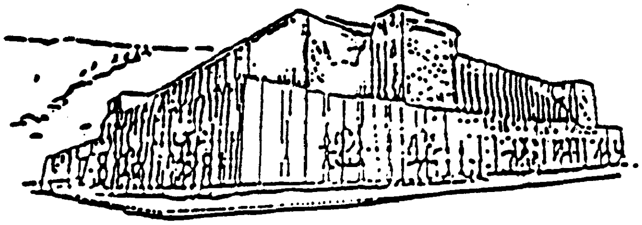
2000

South Fork Tenderfoot Creek: Watershed analysis

Steven E. Kem
The University of Montana

Recommended Citation

Kem, Steven E., "South Fork Tenderfoot Creek: Watershed analysis" (2000). *Graduate Student Theses, Dissertations, & Professional Papers*. 4739.
https://scholarworks.umt.edu/etd/4739



South Fork Tenderfoot Creek:

Watershed Analysis

by

Steven E. Kem

B.A. The University of Illinois 1989

presented in partial fulfillment of the requirements

for the degree of Master of Science

The University of Montana

2000

Approved by:

Chairperson

Dean, Graduate School

November 17, 2000

Date

Kem, Steven E., M.S., Oct. 2000 Forestry

South Fork Tenderfoot Creek: Watershed Analysis

Director: Donald F. Potts DFP

Landowners in Montana face complex challenges in managing their properties with a multitude of often-conflicting management goals. The Bair Ranch Foundation owns and manages 8,220 acres of forest and rangelands in the Tenderfoot Creek watershed 35 miles Northwest of White Sulphur Springs, MT in the Little Belt Range. The Foundation was rechartered in 1997 as a non-profit organization focused on conservation research and education, with a main long-term goal of managing the ranch property formerly owned by the Bair family to improve understanding and application of Ecosystem Management concepts. Land ownership in the South Fork watershed is checkerboard with the United States Forest Service and the Bair Foundation as principal landowners, and Montana Department of Natural Resources and Conservation (DNRC) and the Zehntner family owning the remainder.

With the management goals of maintaining a watershed that is ecologically healthy, economically productive, and a useful arena for conservation education and research, the Bair Ranch Foundation sought to conduct a watershed analysis in the South Fork watershed to 1) determine possible cumulative watershed effects from past management activities (primarily timber harvest and cattle grazing) 2) provide a baseline for future natural resource research to be conducted in the Tenderfoot watershed and 3) provide information to aid in informed land management and restoration planning . The Bair Ranch Foundation lands in the South Fork of Tenderfoot Creek watershed provide an excellent opportunity to foster the unification of conservation and resource management education.

Preface and Acknowledgments

I would like to first thank my committee members, Dr. Don Potts, Dr. Vicki Watson and Dr. Bob Pfister for their support, encouragement and guidance throughout the graduate school process. An appreciative thank you to the Bair Ranch Foundation, whose financial support was instrumental in developing and completing this project. To the families in the White Sulphur Springs area that shared the Bair Cabin with me last summer, thank you for your generosity. I am also grateful for field assistance provided by Daniel Covington, Stephanie Mulica, and Craig Bailes, as well as technical help from Mike Sweet and the staff of the Riparian and Wetlands Research Project (RWRP). Staff at the Tenderfoot Creek Experimental Forest, the USFS Lewis and Clark Supervisor's Office, and Kings' Hill Ranger District provided invaluable assistance and data. I greatly appreciate the support of friends in the music, boating and conservation communities...You have made the journey a full one. Finally, to Gretchen and Jacob, for their wisdom and ability to teach me about the important things in life.

Table of Contents

Page

Introduction

Literature Review

Methods

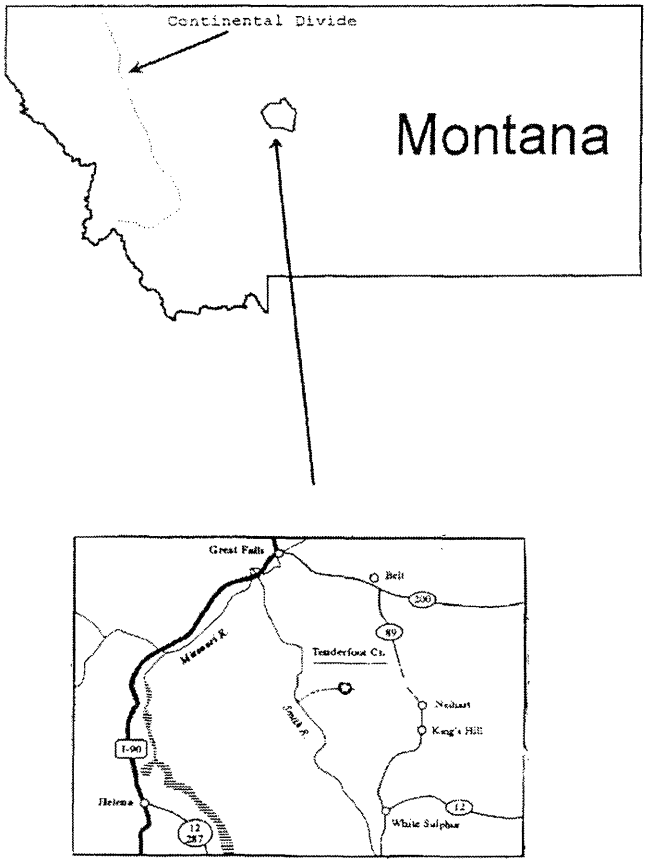
Watershed Characterization – Results and Discussion

Field-based Assessment - Results and Discussion

Tables and Figures

List of Maps

Study Area – Tenderfoot Creek Watershed – South Fork Tributary



Purpose of the Study

This study was designed to serve as a watershed analysis/ baseline assessment to assist landowners and managers in the South Fork of Tenderfoot Creek (Bair Ranch Foundation, USFS, and Zehntner) in making informed, ecology-based land management decisions. The underlying goal of the study centers on the idea that given the overall condition of the watershed, future land management and possible restoration efforts would evolve as part of a combined effort to protect the many aquatic resources of the South Fork and ultimately Smith River watersheds. From an ecological standpoint, one of the main priorities in future land management decisions in the South Fork will be restoration and protection of the habitat of the 97% genetically pure westslope cutthroat trout population, a species of special concern in Montana.

Literature Review

Cumulative Effects – Watershed Analysis

The U.S. Congress in 1969 formally recognized the concept of cumulative environmental effects (Cobourn 1989). A cumulative effect has been defined by many organizations, but can be understood generally as impacts on the environment that result from incremental impacts of land uses when combined with other past, present and reasonably foreseeable future uses of the land (Reid

1998). As a result of activities such as channelization, road construction, livestock grazing, mining and water diversion, most streams and riparian zones in the western U.S. have been greatly altered since Euro-American settlement (Kauffman et al. 1997).

Starting with the concept that a watershed is a unified ecological unit, a cumulative *watershed* effect is a specific type of cumulative effect shaped by processes that involve the generation or transport of water (Figure 1 from Kauffman et al. 1997)

. ***Figure 1*** - Components of Riparian and Stream Ecosystem Function

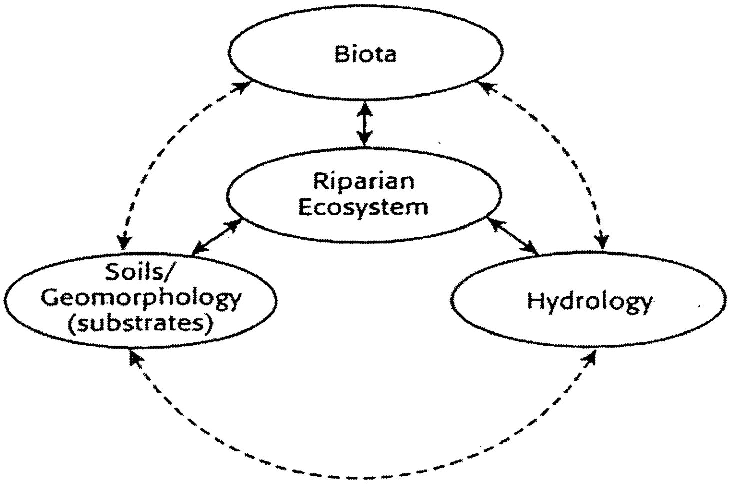


Figure 1 illustrates the linkages of the biotic, hydrologic, and geomorphic components combined to shape the unique structure and function of riparian and stream ecosystems. Each arrow represents an infinite number of biological and physical processes and interrelationships among these ecosystem features. Because of these inextricable linkages, human or natural actions that alter any one component or process will have feed-forward influences that can affect all other components of the ecosystem.

Cumulative watershed effects *analysis* provides a method for analyzing the erosion hazards, hydrologic effects and biotic responses to the combined effects of these different land uses (Montgomery et al. 1995). While Congress required that cumulative impacts be evaluated as part of the National Environmental Policy Act (NEPA) in the early 70/s, little progress in actual application of cumulative effects concepts occurred through the 70's and 80's. Eventually, courts in the Western U.S. began upholding lawsuits by environmental groups stating that cumulative watershed effects were not adequately addressed in forest management plans.

The importance of understanding cumulative effects in designing far-sighted, sustainable land-use and conservation strategies cannot be overstated. While many dismiss the term as a buzzword or hazy concept that derives its teeth solely from legal necessity, a thorough understanding of cumulative effects provides a conceptual framework for approaching land use planning. Reid (1998) suggests addressing the following basic questions in developing an understanding of cumulative watershed effects for possible restoration projects: a) what areas are important for fish, and why? b) where has habitat been impaired? c) what aspects of habitat have changed? d) what caused those changes? e)what is the relative importance of the various habitat changes to fish? f) what is the present trend of changes in the system? G) what changes are reversible? H) what is the expected effectiveness of potential remedies? I) what are the effects of those remedies on other land uses and ecosystem components? and J) what are the relative costs of the potential remedies over the long term? These questions provide a framework for cumulative effects analysis that provides the underlying conceptual framework for the South Fork watershed analysis and management recommendations.

Restoration

Restoration has been defined as the process of returning a river or watershed to a state in which it can function "ecologically in a self-sustaining way, more nearly resembling its former function prior to human induced disturbance." (Bisson et. al. 1992) The National Research Council (NRC) argued that "restoring altered, damaged, or destroyed lakes, rivers, and wetlands is a high-priority task" (NRC 1992).

Restoration and habitat management in the past have been hurt by a lack of focus on ecological context and a lack of knowledge of the processes involved in the degradation of aquatic resources (Frissell 1998). By focusing initially on strategic issues in study design, planning and evaluation, researchers and ultimately managers can *avoid a)* wasting precious resources, *b*) misunderstanding and misrepresenting success or failure of projects *c*) underestimating the possible risk of cumulative, synergistic effects from multiple land use activities and *d*) increasing the risk of ecosystem scale environmental crises (Frissell 1998).

Frissell (1998) suggests asking the following questions in order to develop an "ecologically sound, guiding strategy for restoration." *a)* What processes are causing habitat loss? *b)* How can these processes be reversed? *c*) Are structures even feasible? Or are other kinds of treatments necessary *d*) should effort be concentrated in certain localities, or dispersed across the watershed? e) which species will benefit from a given action, and will the benefits be long term? f) what is the risk that unwanted side effects could accrue from a particular set of treatments?"

Too often in past aquatic restoration projects, the focus has been on small-scale, in-channel structures that ignore the underlying cause of degradation and do not allow enough time for natural recovery (Kauffman et al.1997, Stanford et al. 1996). Numerous examples of costly, structure-based projects that have experienced structural failure or unwanted physical or biological consequences suggest the benefits of carefully planned projects that utilize natural recovery in the plan (Frissell 1998). Here too the questions of scale and underlying strategy are prominent. Fixing the symptoms of habitat decline in the most heavily disturbed reaches of the most degraded streams will not reverse or even halt the negative effects of the underlying, watershed-scale causes of decline. Simply placing physical structures in a highly degraded reach or introducing an extirpated species back into its former habitat is not a viable restoration effort because the underlying processes and function of the ecosystem are not taken into consideration. In the wake of technological solutions to declining salmonid populations (hatcheries, ladders, instream structures) it has become clear that the natural processes affecting fishery declines are interrelated and complex and that successful restoration depends on moving the emphasis to the restoration of ecological processes and function.

Ultimately, the goal of any ecologically-based restoration project should aim at restoring the "natural ecosystem processes" which will through time allow for the recovery of the structure and function of the ecosystem. The Natural Research Council suggested that "restoration is different from habitat creation, reclamation, and rehabilitation-it is a holistic process not achieved through the isolated manipulation of individual elements" (NRC 1992).

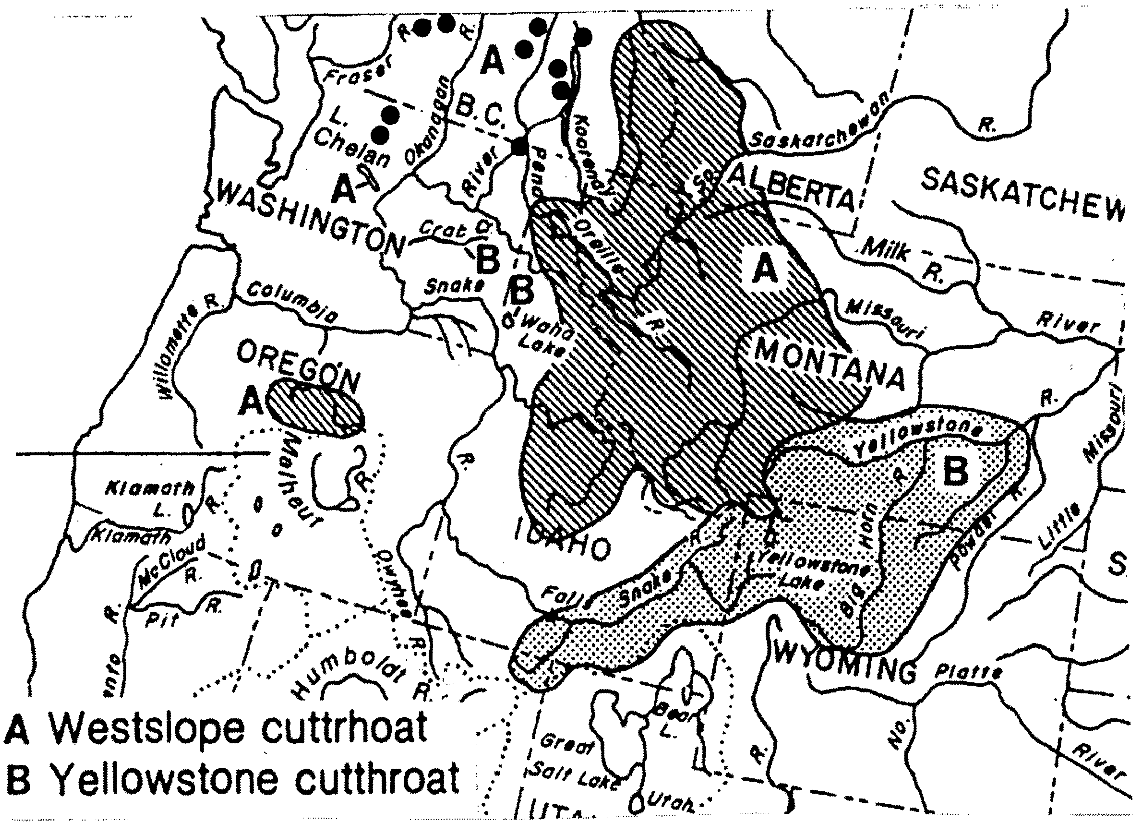
They continue on to recommend in the planning stages that riparian zones be separated into those with predictably rapid, slow or little chance of recovery. Initial restoration plans should target those areas capable of rapid recovery to increase the probability of successful restoration and keep costs down. Once you have determined which sites will be restored first, the underlying causes of degradation must be minimized or halted completely (Kaufmann et al. 1997, Frisell 1998, Kondolf and Micheli 1995).

Westslope Cutthroat Trout - Basic Biology and Habitat Range

The WCT (*Oncorhynchus clarki lewisi*) has developed three distinct lifestyle strategies over its range: adfluvial, which migrate between lakes and streams; fluvial that migrate between small tributaries and rivers, and nonmigratory residents of tributaries (Behnke 1992). The South Fork Tenderfoot Creek population is nonmigratory. Spawning occurs from March to July when water temperatures are at or near 10 degrees Celsius (Behnke 1992, Shepard et al. 1997). While other subspecies of cutthroat trout demonstrate piscivory as an adaptive feeding trait, westslope are specialized as invertebrate feeders (Behnke 1992).

By the time of the Lewis and Clark expedition, WCT had evolved to become the most widely distributed native trout in the inland Northwest. Its historic range West of the continental Divide included all major drainages of the Columbia River basin (Behnke 1992, Leary et al. 1991). They were originally the most abundant salmonid in the upper Kootenai river drainage and the entire Clark Fork drainage of Montana and Idaho down to the current Washington/Idaho border. They are also native to the Salmon and Clearwater drainages of the Snake River drainage in Idaho where they are believed to have moved over from the Clark Fork system (Behnke 1992).

MAP 1. Historic Range of Westslope Cutthroat Trout



East of the continental divide the known historical range includes the upper South Saskatchewan river basin south of the Bow River, as well as the upper Missouri basin east to approximately 60 km below Great Falls near Ft. Benton, MT (as well as the headwaters of the Judith, Milk, and Marias rivers downstream of Ft.

Benton). Evidence also suggests the existence of WCT populations in some headwaters in the Missouri basin in northwestern Wyoming and southern Alberta (Leary et al. 1991, Behnke 1992).

The current limited range of WCT compared to its once vast historical range is striking. In the upper Missouri River Basin by the late 1980's, WCT populations existed in approximately 80 streams compared to its historical range of approximately 3600 streams (American Wildlands et al. 1997). The remaining populations are located primarily in isolated, headwater areas and high elevation/low order streams where exotic species have been unable to hybridize and human impacts are minimized (Shepard et al. 1997). Major causes for WCT decline include habitat loss due to effects of road building and logging, mining, grazing, water diversion for agriculture, as well as competition, predation and hybridization from introduced species (Shepard et al. 1997).

While estimates on the amount of range decline vary, recent figures for the state of Montana using the Montana River Information System suggest that 100% genetically pure populations occupy 1% of their historic range in the Upper Missouri (600 out of 57,365 possible stream miles with approximately 2500 miles untested) (MT FWP 1999). While the sizable loss of habitat presents a daunting barrier to long term WCT survival, these figures tend to underestimate the severity of habitat decline because they utilize total stream miles in the computation without taking into account stream volume. Because WCT have been isolated in high elevation, low order streams with relatively little volume, the habitat area available to them has been reduced to an even greater extent than that suggested by stream mile calculations (Behnke 1992).

A joint USFS/BLM study on extinction risk for WCT in the upper Missouri Basin suggests that 71% of the 144 remaining populations with genetic purity levels greater than 90% have a very high risk of extinction within 100 years (Shepard et al. 97). 18% of the populations received a high risk rating, while 10% were deemed at a moderate risk for extinction. The estimation was calculated using a Bayesian viability assessment procedure based on a subjective evaluation of population survival and reproductive rates as affected by environmental conditions. None of the existing populations received a low risk of extinction rating (Shepard et al. 1997).

The Tenderfoot Creek watershed received a rating of very high probability of extinction within 100 years. The risk of extinction to remaining WCT populations is extremely high because they are predominately isolated in higher elevation reaches where stochastic events (massive debris flow and scour, flooding, droughts, ice-over, stand-replacing fire) might wipe out a population with no possibility of recolonization from adjacent streams. The impact of existing and future land use activities, while not absolutely clear, contributes substantially to low persistence probabilities for remaining populations. Among the management risk factors correlated with impacts on WCT population parameters (spawning habitat available, fry survival etc.), grazing and the existence of nonnative species demonstrate the highest and most consistent impacts (Shepard et al. 1997). The relative impacts of timber harvest and roads were not clearly determined in the study. Reduced analysis of integrated risk factors suggested that cumulative effects and catastrophic risk are also important factors in determining survival probability. A more recent study by Shepard suggests that regression models that include temperature and location, mining impacts, pool habitat proportion and stream order best explain WCT densities (Shepard et al. 1998).

Protection and Restoration of WCT

Debate remains over the level of protection, or restoration scheme that will best foster improvement in the range and quality of cutthroat populations and available habitat. The Montana westslope cutthroat trout, "Salmo sp.," was listed as an endangered species in the U.S. Department of the Interiors redbook on endangered species between 1966 and 1973. The lack of specific distinction stemmed from misidentification with the Yellowstone cutthroat trout (*Oncorhynchus clarki* *bouvieri*). Due to classification confusion the westslope was taken off the original endangered species list in 1973.

A petition to list the westslope as threatened throughout its range under the Endangered Species Act was filed in June 1997 by six regional non-profit environmental organizations and Bud Lilly, a world-famous fly-fishing guide and conservationist. They recommend listing based on a collection of studies and agency reports suggesting that remaining WCT populations remain threatened by human induced impacts that threaten the long-term viability of the species (American Wildlands et al. 1997).

At present, the Montana Department of Fish, Wildlife and Parks lists the WCT as a species of special concern. Guidelines for the long-term protection of the species are presented in the WCT Conservation Agreement published in May 1999 with the cooperation of all relevant state and federal agencies (MT FWP 1999). Details of the agreement were developed by the WCT Technical Committee directed by Brad Shepard of the Montana Department of Fish, Wildlife and Parks. The overall goal of the agreement is "to insure the long-term, self-sustaining persistence of the subspecies within each of the five major river drainages they historically inhabited in Montana, and to maintain the genetic diversity and life history strategies represented by the remaining local populations" (MT FWP 1999). The agreement also states that the protections afforded to pure populations will be provided to slightly introgressed populations (less than 10%) until the agencies detail the role of these habitats and populations in restoration efforts. (Objective 2) Further genetic testing in the highest reaches of the South Fork could potentially demonstrate that genetically pure WCT exist in the watershed.

Protection also includes measures to expand small, isolated populations where possible and the maintenance or development of high quality habitats to avoid local extinction due to small population size or stochastic occurrence. The agreement includes the possibility of using existing genetic stocks to restore a population in other locations. If a pure population is lost, it must be replaced by rehabilitating an introgressed population to make it pure or by establishing a new, pure population. The agreement ultimately seeks to drastically reduce or halt threats to the viability of WCT, then restore and expand a sufficient number of viable populations to ensure the long-term survival of WCT in Montana. The ultimate success or failure of the agreement depends to a great extent on the cooperation of public land managers and users, as well as voluntary collaboration with private landowners.

Again, the most effective methodology for WCT restoration remains to be seen. The current conservation agreement is a positive step yet implementation of the plan is far from concrete and will take decades. Clear, positive results are at least decades away. Arguments for the most stringent protection under the Endangered Species Act are convincing, but can be offset by possible public backlash to federal authority. Listing could also tie-up federal agency time and budgets on ESA involvement that could be spent on active restoration field work (Enk 2000).

Ecological Function of Riparian Areas

The physical structure of waterways is made up of the mixture of pools, riffles, falls, instream cover and bank stabilization provided by fallen trees, rootwads, gravel and boulders. Much of the physical character of the stream develops from plants, trees and other vegetation in the riparian zone. Referred to as large woody debris, the logs and branches that naturally fall into the stream create substrate characteristics and flow velocities that are beneficial for salmonid production and serve as an energy source for other aquatic organisms (Budd et al. 1987, Beschta 1994, Naiman 1992).

The extreme importance of riparian zones in maintaining water quality, and influencing aquatic and wildlife habitat is as clear as the highly degraded state of much of the countries' riparian environments (Kaufmann et al. 1997). A great deal of research has gone into the many factors involved in classifying, protecting and restoring riparian ecological conditions in the United States. In an effort to halt riparian degradation and begin the process of restoration, government agencies at the federal, state and local level have adopted riparian management policies, regulations and assessment procedures that range greatly in the level of protection and effectiveness. Some common themes from research in riparian conservation are that effective riparian protection plans need to be site specific and are often complex, requiring conscientious planning by natural resource managers, land owners and local officials.

The importance of comprehensive riparian ecosystem protection and restoration through farsighted land management cannot be overstated. To adequately protect and/or restore riparian resources, it is essential to understand the normal functions of a healthy riparian system. These functions include regulating water temperature, sediment filtering, streambank building, storing water, aquifer recharge, providing fish and wildlife habitat, and dissipating stream energy (Naiman 1992, Hansen et al. 1995, Wissmar and Beschta 1998, Elmore 1992).

Ideally, for restoration purposes, land managers would be able to use pristine riparian zones as a reference guide to monitor the effectiveness of their recovery actions. They could measure vegetation and wildlife densities, determine average stream flows and model their restoration efforts on the characteristics of the reference stream. Unfortunately, examples of pristine streams and uncompromised riparian areas are rare.

Importance of Riparian Function - The health of riparian vegetation is a major determinant of the overall health of riparian ecosystems (Naiman 1992, Hansen et al. 1995). Healthy riparian vegetation serves as a bank stabilizer, lessening erosion during high flow periods, and also reduces damage to streambanks from grazing animals, ice flows and log debris (Beschta 1994). High levels of suspended sediments due to increase erosion can cause significant harm to aquatic organisms (contaminating salmonid spawning beds) and gradually alters the soil, drainage and vegetation characteristics of the riparian zone. The roots of riparian vegetation stabilize streambanks in such a way that overhanging banks are created, providing cover for aquatic organisms (Hansen et al. 1995). Nutrient filtering in riparian zones have also been shown to be effective in reducing levels of agricultural nonpoint-source pollution (Elmore 1992).

Although riparian ecosystems make up a small portion of overall land area in the Western U.S. (approximately 1- 2%), they are far and away the most productive wildlife habitats, benefiting the greatest number of species (Ames 1977, Patton 1977). Population densities of upland bird species in areas adjacent to riparian zones are directly influenced by the quality of riparian or wetland areas nearby (Carothers 1977).

Regarding aquatic wildlife, riparian vegetation can provide up to 90% of the organic matter needed to support stream communities (Naiman 1992, Hansen et al. 1995). Fish populations have also been found to decrease significantly downstream from riparian alterations through the effects of temperature increase, siltation, debris barriers, introduction of chemicals and increases in flow fluctuations (Budd et al. 1987).

Human Settlement-History

"The creek and country were named from long ago, that place where horses traveled "tenderfooted". They bruised their feet crossing on the path of stones, broke their hooves and wore them off to hurts that made them lame… The creek runs soft and deep, then falls and races wide and pools again to spread across the rocks and wash away the silence of an empty land." The preceding passage was taken from "Tenderfoot", an unpublished chronicle of homestead life by Carolyn Mongar Woirhaye, daughter of the original homesteaders in the South Fork Tenderfoot drainage who first arrived in May 1886. Early trappers, prospectors and big game hunters traveled through the area but did not set up permanent residence. Their impacts on watershed health were significant as the decimation of beaver, deer and elk populations was widespread (Woirhaye –unpub.). Before the first trappers and prospectors arrived in the Little Belts, plains Indians considered the area sacred ground where different tribes could gather peacefully to take advantage of the restorative powers provided by the hot springs. Crow to the South and Blackfeet in the North used the Smith River valley as a travel route and hunting ground as evidenced by the remains of buffalo jumps (Rademacher 2000). While small bands may have lived in the Tenderfoot region year round, little evidence exists of significant impacts to the watershed.

The Mongars, along with two other families that arrived soon after, raised cattle and sheep in the South Fork from 1886 until 1918, surviving harsh winters that left the road into the drainage covered by snow sometimes until early July. The hardships they endured during the long winters are impressive. During the spring of 1916, especially harsh storms decimated the Mongars sheep herd with only 90 sheep surviving out of the original 1700. While difficult to gauge in hindsight, the impacts of sheep and cattle on riparian areas and channel morphology starting with the original homesteaders has clearly been significant.

Following the flu epidemic in fall 1918, and with memories of floods, blizzards and fires, the Mongars and Chambers decided that it was time to move from the Tenderfoot. During my field time in the South Fork, I had the privilege of meeting

George Mongar, grandson of the original homesteaders, who brought his family to camp at the site of the original homestead for the summer.

Howard Zehntner bought property and has leased state lands in the South Fork since the late 1950's. Together with sons Lee and Steve, the Zehntner's run a cattle ranching operation in the Main and South Fork drainage, enduring the same harsh winter conditions faced by the Mongars a hundred years earlier.

Methods

Watershed Characterization

Land managers in state and federal agencies throughout the West eventually developed a wide range of standardized cumulative effects procedures in the 1980's, but the majority of those methods lacked technical credibility and often were limited in the type of cumulative effect they addressed. Some examples of standard methods include use of index values, mechanistic models, and checklists for specialist input (Reid 1998).

More recent methodologies of watershed analysis have been created that provide contextual information necessary for cumulative effects assessment, as well as a more complete characterization of the watershed. Many have developed into an integral component of land management plans. (USDA Forest Service 1993, Reid

1998, Bisson et al. 1992). This watershed analysis was based on portions of three of the more prominent methodologies in use today. These include the method used by the state of Washington (WFPB 1993), the USFS and BLM method developed for use on federal lands (McCammon et al. 1998), and a watershed analysis checklist for watershed management developed by Satterlund and Adams (1992).

Ad Hoc Study Design

Based on the intent and the goals of the study as well as time and resource constraints, the watershed analysis developed into an *ad hoc* evaluation with analysis procedures taken from a variety of sources. The initial step involved researching and collecting available data for the South Fork and surrounding watersheds. This included gathering land use history and available maps on forest and grazing practices in the South Fork Tenderfoot drainage from the USFS – Lewis and Clark National Forest and the Bair Ranch Foundation. These maps included cattle grazing allotments, ownership, landtype associations, land use history, as well as recent and proposed timber harvests. The next step involved collecting all available pre-existing data on stream assessments and fishery surveys from the Lewis and Clark Forest Service Supervisor's Office in Great Falls. It was also necessary to gather available GIS layers and hydrologic data for the Tenderfoot Creek Experimental Forest from the Rocky Mountain Research Station in Bozeman, Montana.

The procedures brought together for the study were chosen based on whether they helped answer questions related to future land management in the watershed as well as whether they were achievable in the context of one field season with limited resources. For this reason a combination of field-based procedures and office-based methods of watershed characterization were used. Because the study involves a combination of methodologies, some information is given to explain why the particular aspects of watershed function are included in the study as well as explaining the procedural specifics.

Erosion - Fine Sediment Evaluation

This procedure first attempts to predict expected levels of fine sediments in streams based on landtype associations which correlate parent material type and weathering to the landform. By separating stream segments based on landtype associations, the goal is to compare existing levels of fine sediment with the habitat requirements of WCT.

With the given time and resource constraints, the best methodology for determining the current level of fines as a gauge of watershed health included combining elements of the Idaho Cumulative Effects Procedure with sediment size determination procedures used in the University of Montana Riparian and Wetlands Research Program (RWRP) assessment (RWRP 1999, IDL 1994). The stream network in the drainage was separated into stream segments or "polygons" based on land type associations, channel confinement classes based on the ratio of floodplain width to bankfull width (entrenchment ratio), gradient classes based on field measurement and obvious land management borders. Percentages of fine sediments < 6.35 mm in selected reaches were estimated at 5-7 random sites within the selected reach and averaged. Percentage of fine sediments were then compared with levels estimated to negatively effect spawning habitat, i.e. > 20%.

Water Quality – Nutrient Assessment

Several forms of nitrogen were sampled for the study. Dissolved nitrogen forms included nitrite (NO2) plus nitrate (NO3) and ammonia (NH4). Because nitrite is unstable in most streams, the nitrite plus nitrate is primarily nitrate. The forms of phosphorous measured include orthophosphorous and total phosphorous. Orthophosphorous is more readily available for uptake by aquatic vegetation than is total phosphorous (USGS 1995, 1999).

Latitude and longitude of the five sampling sites were specified using USGS 71/2-minute maps. After the four collection sessions spread from late August to early

October, samples were packed in ice and transported to the Montana Department of Health and Human Services Environmental Lab in Helena, MT. The Environmental Lab analyzed the samples according to EPA quality-assurance procedures. Concentrations were reported in mg/L.

Riparian Ecological Condition

The importance of riparian function was detailed previously in the literature review section. The University of Montana Riparian and Wetland Research Project (RWRP) Lotic Health Assessment was utilized on the South Fork and perennial tributaries of the watershed to characterized the ecological condition of riparian zones (RWRP 1999). The RWRP methodology focuses on characteristics of streamside vegetation and channel health as a means of determining human impacts and overall ecological condition. The RWRP assessment procedure was utilized because it provides the necessary data for a qualitative analysis with which to make future management and restoration recommendations. An example of the procedure is provided in Appendix A.

Assessment Methodology

Vegetation and Physical characteristics included in the riparian assessment include:

-Canopy Coverage and age class estimates of trees, shrubs, forbs and graminoids
-Canopy cover of invasive weeds and undesireable herbaceous species

-Browse utilization levels of trees and shrubs
-Amount of fine material present to hold water and act as a rooting medium
-Percentage of polygon with human caused exposed soil surface
-Percentage of streambank with active lateral cutting
-Percentage of streambank structurally altered by human activity
-Percentage of streambank with deep binding root mass
-Level of channel incisement
-Revised Pfankuch Rating – Channel assessment procedure developed in the USFS Northern Region to measure and evaluate the resistance of mountain stream channels to the detachment of bed and bank materials, and to provide information about the capacity of streams to adjust and recover from changes in flow and/or sediment production.
-Rosgen Stream Type- Designed as an aide in designing river restoration programs, the Rosgen system utilizes physical attributes, including entrenchment ratio, width to depth ratio, sinuosity, slope and dominant bed material as a means to universally classify stream channels.

The RWRP procedure relies on ocular estimates for canopy coverages, channel and bank substrate size classification and physical characteristics such as "percentage of streambank structurally altered by human impacts". To assure as high a level of accuracy as possible and avoid individual sampling bias, the estimates were discussed and agreed upon by two or more field observers with experience in canopy cover estimation. Physical site characteristics including width-depth ratios, average riparian width, entrenchment ratio, slope and sinuosity were averaged from 4-6 measured sites spread throughout each polygon.

Stream Temperature Assessment

The original goal in this section of the evaluation was to evaluate the degree of canopy closure provided by riparian vegetation relative to what is necessary to maintain the desired stream temperature based on existing fishery requirements. Based on maximum peak summer temperature limits for westslope cutthroat trout, the goal was to evaluate the current condition of canopy closure through field measurements and compare target shade values with existing conditions. The next step involved monitoring stream temperature periodically throughout the field season to correlate estimates from canopy closure percentages. Comparing pre and post timber-removal aerial photos, no change in canopy density in riparian zones is evident in the watershed, eliminating the usefulness of the correlation procedure. Instead, stream temperature measurements were taken at water quality sample sites periodically throughout the field season. Thermographs would have been ideal but were not available. Data on water temperature extremes from the Tenderfoot Experimental Forest suggest that seasonal high water temperatures for the watershed occur sometime in mid August, so monitoring focused around that time period. Water temperature data from past fisheries and hydrologic assessments completed during the past four years by the Forest Service were also included in the range of water temperatures evident in the watershed.

Canopy Cover Removal Impact Assessment

The primary goal of this procedure is to measure the probability of channel impacts from increased peak flows resulting from canopy removal. Given the lack of historical hydrologic data for the South Fork, an ad hoc methodology was developed. The first step involved determining a channel stability rating based on the revised Pfankuch procedure (Pfankuch 1978).

Using the conversion of Stability Rating to reach condition by stream type, each of the 25 polygons in the watershed is given a stability score based on the Pfankuch channel stability rating system, with an adjustment to account for differing value ranges for each stream type (Rosgen 1996). The Pfankuch rating system has been widely used in the Northwest as a means of qualitatively indexing how resistant stream channels and banks are to the forces exerted by increased flows as well as presenting an idea of how the stream will adjust and recover to alterations in the timing and intensity of flows (Pfankuch 1978). Ratings greater than the mean values for that stream type suggest the initial stages or existence of channel instability. These include a heightened potential for increased erosion with increases in streamflow magnitude and duration. Values lower than the averages suggest that while instability does not currently exist, the system has the potential for instability with increased channel disturbance.

Using aerial photographs to determine the canopy removal index (i.e. percentage canopy removal from timber harvest) combined with the channel stability index (CSI) based on the revised Pfankuch rating, the risk of adverse hydrologic impacts was estimated based on the Idaho State Cumulative Effects Assessment Procedure

(IDL 1994). Hydrologists on the Assessment Development team developed the risk ratings based on best professional estimates. Given the previous information regarding variability between basins and lack of specific research quantifying the relationship between canopy cover removal and increased streamflows, the Idaho estimation of hydrologic risk is a best guess measure to identify potential problem areas. An analysis of historical channel change is definitely an important aspect of developing alternative management strategies. While the scope of this study did not allow for permanent cross-section measurement sites to gauge channel alteration, future hydrologic research in the watershed would benefit from the development of a long-term channel morphology database.

Color copies of aerial photos of the South Fork Watershed were obtained from the Supervisor's Office of the Lewis and Clark National Forest for the years 1989,1990 and 1994 (scale = 1:15,840) to determine pre-harvest canopy cover estimates for the three sections where canopy cover was removed between 1996-1998 (sections 3,5 and 31 see map 5). These photos were enlarged 200% to match the scale of the post harvest digital photos at 1:7920. Estimates were determined by dividing each section into 10-acre parcels, then occularly estimating canopy density for each parcel by comparing with a reference crown coverage scale used by the USFS Intermountain Forest and Range Experiment Station. Post-logging canopy cover levels for the entire watershed were determined using the same method using digital aerial photos from flights in the Fall and Winter of 1998/99 by Andersen Engineering Company in Dillon, MT (rectified using obvious landmarks- scale 1: 7920). These flights were completed after a moratorium on logging was enacted pending future land management and land swap decisions.

Road System BMP and Density Assessment

The next step involved working with the Montana BMP Audit Procedure Group to thoroughly examine the road and skid trail system in the watershed. The eastern region Best Management Practice (BMP) team surveyed two stands adjacent to streams on Bair property on October 8th, 1999. With training experience gained with the Eastern Montana BMP team and training in Road Obliteration Survey techniques with the USFS, all roads in the watershed were evaluated using the Idaho Sediment Delivery and Erosion Source Evaluation procedure. This procedure was designed to determine how much surface erosion is occurring in the watershed as a result of roads, skid trails, and mass failures, and what amount of eroded sediments is actually delivered to the stream channel. The criteria included examination of:

a) erosion from unstabilized cut and fill slopes

Roads

b) location, construction and maintenance of ditches

c) maintenance and drainage availability on road surfaces

d) observed level of actual sediment delivery from roads

Skid Trails

e) level of rutting and erosion on skid trails

f) skid trail proximity to riparian zones

Mass Failure

g) Relative frequency and size of slumps

h) Failure proximity to streams

Road Density – Road density was determined using post logging aerial photos at a scale of 1: 7290. Road distance was calculated by measuring the length of roads in the section and then using the section line as a 1-mile reference. Area was determined by measuring section perimeter lengths and multiplying. Section 31 is actually 1.28 sq. miles in area.

Watershed Characterization – Results and Discussion

Physiography

The South Fork Tenderfoot Creek watershed lies in the west-central region of the Little Belt Mountains, approximately 35 miles Northwest of White Sulphur Springs, Montana. The South Fork flows east to west for the first half of its length then turns sharply to the northwest, where it reaches the confluence with the Main

Tenderfoot, a westerly flowing stream whose headwaters originate approximately 10 miles upstream. The Main Tenderfoot feeds into the Smith River approximately 9 stream miles downstream from the confluence. The watershed covers approximately 7,250 acres or 11.34 square miles. UTM coordinates for the approximate center of the watershed are 0490350E, 5196916N in zone 12. Lands in the watershed include all or portions of T13N R4W Sect. 1,12; T13N R5W Sect. 3-10; T14N R4W Sect. 25,36; and T14N R5W Sect. 28-33.

The Rimrock Ridge provides the watershed delineation on the southern edge, with private landownership bordering. The northern and western watershed boundaries are adjacent to a portion of the Lewis and Clark National Forest that was proposed as the possible Tenderfoot/Deep Creek wilderness area by Congressman Pat Williams due to its remote location. The eastern boundary marks the boundary between Post and Mongar Creek, with adjacent lands in checkerboard ownership pattern split by the Bair Foundation and USFS.

The South Fork watershed ranges in elevation above mean sea level from 4650 feet at the confluence with the main Tenderfoot to 7195 feet at the top of Rimrock Ridge. Hypsometric analysis by digital planimeter gave a mean watershed elevation of 5904 feet. The South Fork Tenderfoot Creek flows 4.6 miles from its headwaters to the Main Tenderfoot. Average elevation decrease over the entire course of the creek is 439.5 ft/mile.

Slope

The Arcview Spatial Analyst feature was utilized to characterize slope in the watershed. Each 30x30-meter grid was assigned a slope class from which a percentage of the total watershed area in each class was determined. The breakdown of slope classes in the South Fork is as follows:

Slope	% of Watershed
0-15%	61.6
16-30%	24.8
31-45%	3.9
46-77%	0.7

Geology

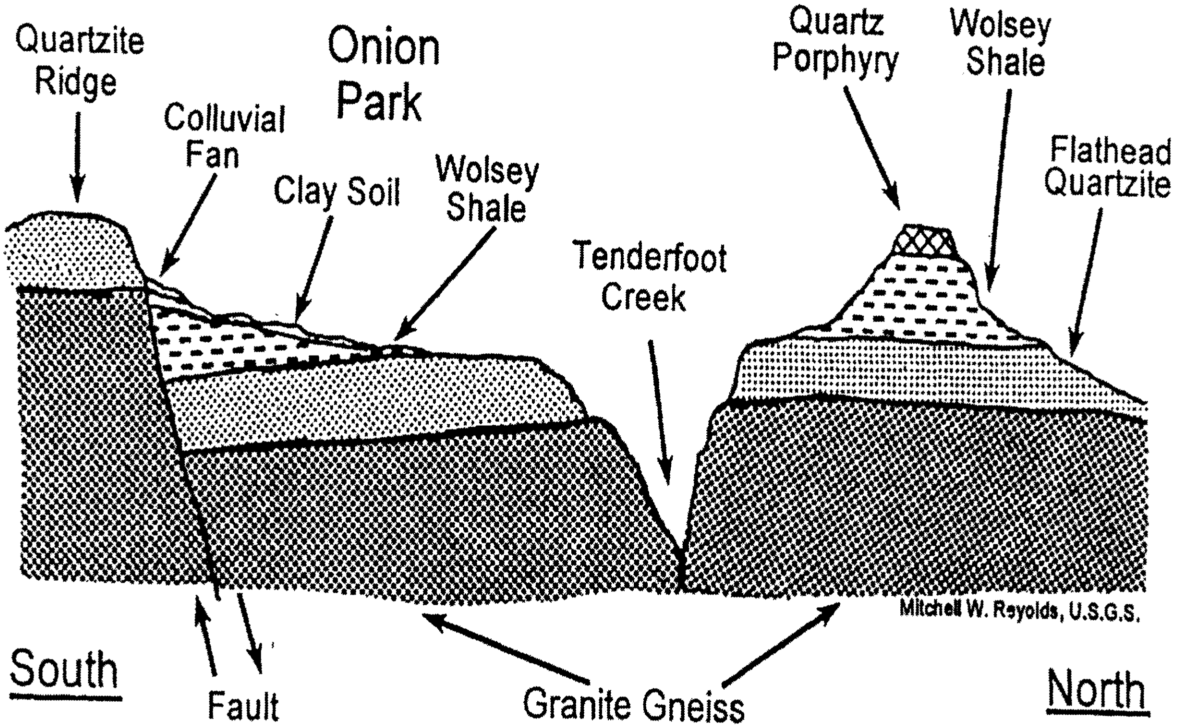
While geologic maps specific to the South Fork have not been developed, detailed maps of adjacent areas, including the TCEF and Sheep Creek areas give a picture of the geologic structure of the area (see map 3 from Farnes 1995). While the geologic units have experienced uplifting and faulting, the area has maintained a simple geologic structure. Moving from oldest to youngest geologic units, the basement rock of the Little Belt Range is made up of Early Proterozoic gneiss, part of the continental crust with the original rock at approximately 2.4 billion years old (Farnes et al. 1995).

The next geologic unit of Cambrian Flathead Sandstone lies on top of early-pronounced faulting, uplift and erosion of the crystalline crust dated to between 600 and 800 million years before present. The Flathead Sandstone is a fine to coarse-grained sandstone cemented with quartz and ranges in thickness from approximately 275 to 450 feet thick. It is generally firmly cemented, highly resistant to weathering and forms ledges or steep slopes. Along with the Wolsey shale strata, the Sandstone layer is practically flat with a dip of 1 to 2 degrees in some areas (Farnes et al. 1995, McClernan 1969).

Clay soil and silty clay soil, with depths ranging from 0 to 2 meters developed on top of the Middle Cambrian Wolsey Shale strata (approx. 560 million years old) in open meadow areas. Up to 400 feet of Wolsey exists on the northern edge of the Main Tenderfoot, where it weathers to form clay-rich soils and gentle slopes with low permeability, but high erodibility. During spring runoff and other wet periods, low-lying areas are saturated and seeps develop along the margins of colluvial and alluvial sediments in thin aprons on the Wolsey Shale. Trilobite fossils were discovered within the Wolsey strata as well (Farnes et al. 1995).

The most recent strata in the Tenderfoot Creek region are made up of igneous intrusive sills from the Eocene, approximately 50 million years old. Horizontal quartz porphyrytic intrusions 3 to 15 meters thick cut into the older Cambrian and Proterozoic strata. Fractures and pore spaces in the coarse-grained quartz porphyry capture, hold and transmit groundwater to Tenderfoot Creek and allow for the growth of coniferous vegetation. Tertiary rocks less than 47 million years old do not exist in the central region of the Little Belt Range (Farnes et al. 1995).

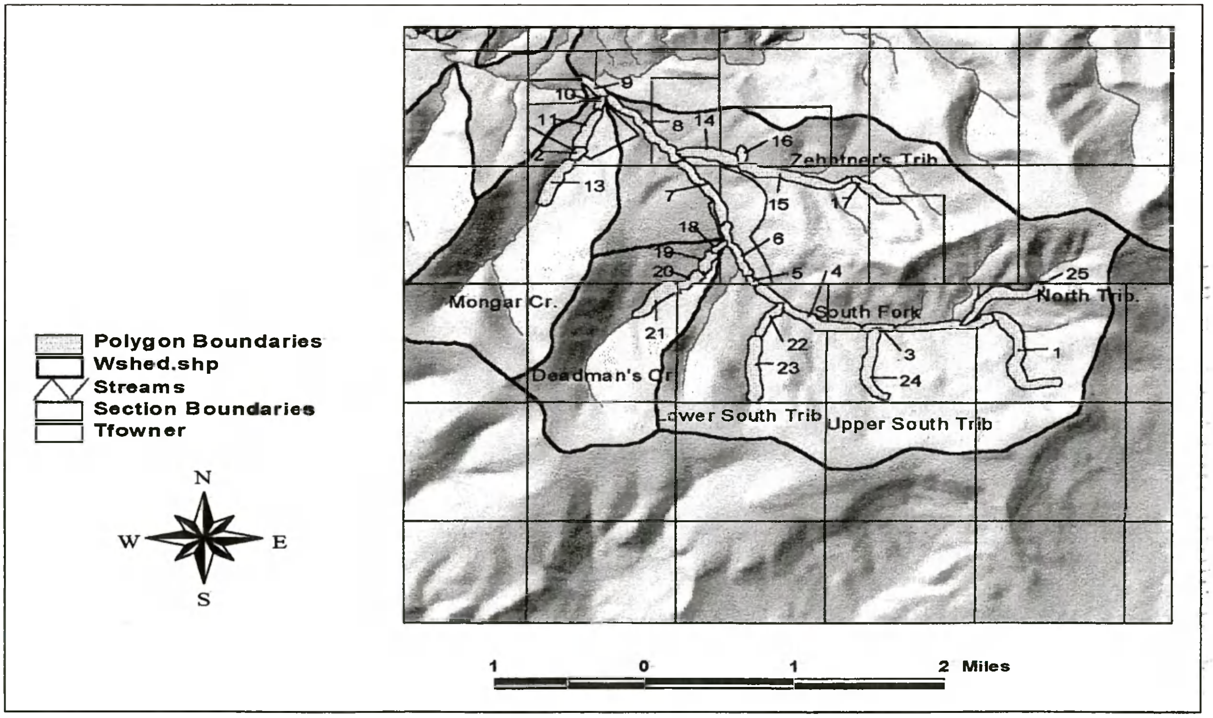
MAP 2 Geology of the Tenderfoot Creek Watershed



Landtypes

Detailed soil surveys by the NRCS have not been completed in the Little Belt Range. The available soil classification comes from landtype surveys made by the Lewis and Clark National Forest. The classification system relies heavily on stereoscopic photo interpretation of landform properties, with field observations that crossed representative areas of all the landtypes identified. Soils are classified at the family level of the soil taxonomy and representative soil profiles are characterized using standard soil survey procedures. Riparian areas of the South Fork and its tributaries were broken up into 25 polygons based on vegetation type, distinct management changes and obviously recognized landmarks for future assessments (see Map 3).

Map 3 – Pologyon delineation



Ten polygons, primarily on Deadman's Creek and the upper tributaries are classified as type 42, with strongly developed forest soils underlain by grayish-brown silty clay loam topsoils 4 to 15 inches thick. The subsoil is characterized as a red to gray silty clay containing 10% to 35% shale chips or gravel. The soils are approximately 20 to 40 inches deep, moderately well drained and have slightly acidic topsoils with moderately alkaline subsoils. This landtype has a Type III limitation for road maintenance due to possible road cutbank mass failures, meaning the limitation is difficult and costly to overcome (Holdorf 1981).

Six polygons, primarily along the South Fork are classified as type 200, with soils forming in texturally layered alluvial deposits along the floodplain. Soils strata are deep, well or moderately well drained and often calcareous. The water table in this landtype is deep and fluctuates, providing subirrigation to riparian vegetation. Logging activity is basically prohibited in these areas that correspond to the SMZ or streamside management zone regulations. Road building on main channels has historically occurred at a high level due to the relatively flat slope of these areas (Holdorf 1981).

Five polygons, primarily along Mongar Creek and Zehntner's Tributary have the type 59 association, with weakly to moderately developed grassland soils developing mostly in weathered shales. Topsoils are dark brown loam 5 to 15 inches thick with brown clay loam subsoils with 10 to 35 percent shale chips and cobble. Soils are 20 to 40 inches deep, well drained and neutral to moderately alkaline. The underlying shale bedrock greatly reduces water movement and vegetation root development. A severe erosion hazard for stock trails or roads limits this type. Road density in this landtype is very low <1.0 mile/sq. mile.

Climate

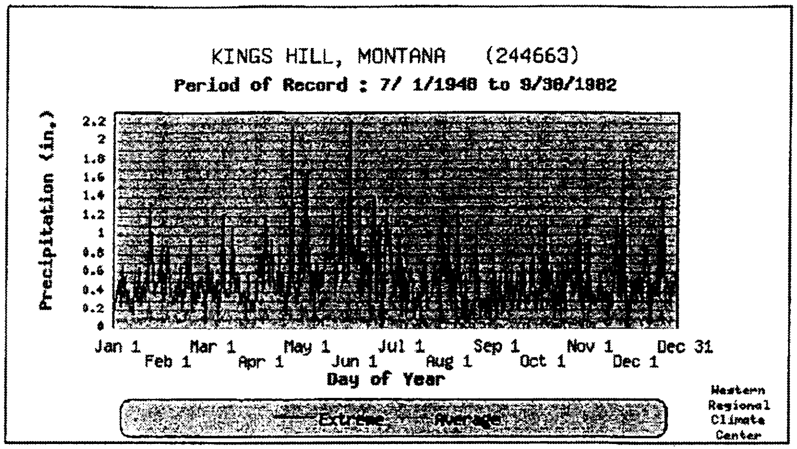
The dominant climatic patterns of a region determine yearly precipitation levels and thereby determine groundwater and stream system dynamics. The climate of the Little Belts is basically Continental with strong Pacific Maritime influence along the Continental Divide (Holdorf 1981).

Temperature- Average daily temperature and precipitation levels for the closest Western Region Climate Center data site at Kings Hill Pass are given in Figure 2 (following page).

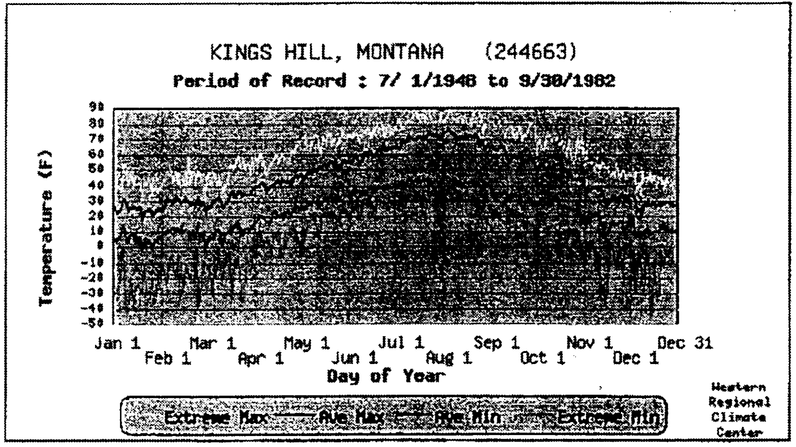
Figure 2. Daily precipitation and temperature averages for Kings Hill, MT

KINGS HILL, MONTANA

POR - Daily Precipitation Average and Extreme



POR - Daily Temperature Averages and Extremes



Freezing temperatures and snow have occurred in every month of the year, with growing seasons ranging from 30 to 75 days (Holdorf 1981). Strong polar frontal systems dominate the winter climate of the region with temperature inversions causing lower elevations to maintain temperatures up to 10 to 20 degrees Fahrenheit colder than higher elevations (Farnes 1995).

Precipitation-Average annual mean precipitation for the South Fork watershed for the 1961-1990 base period was 61.2 cm (24.1 inches) (Farnes 1995). Precipitation levels are governed by winter snowfall and to a lesser extent by the brief "rainy" season in late spring and early summer. 60% of the annual precipitation falls during March through June, with overland flow and erosion primarily associated with spring snowmelt (Holdorf 1981). Rainfall intensity-duration frequency curves for Helena and Miles City are presented in Appendix B. Frequency curves for the S. Fork should approximate those of the surrounding area.

Evaporation- Potential evapotranspiration in the South Fork was estimated using Linacre's method (1977) and available temperature data from the nearby Tenderfoot Creek Experimental Forest (Farnes et al. 1995). Mean minimum temperature data was substituted for the mean monthly dewpoint temperature, which was not available. Results using Linacre's method are presented in Figure 3 assuming an environmental lapse rate of –5 degrees F for every 1000 feet of elevation gain. The mean watershed elevation (5904 ft.) derived from hypsometric analysis was converted to meters and used in the calculations. Fahrenheit temperatures were converted to Celsius equivalents. The approximate latitude of the center region of the watershed is 47 degrees North.

$700(Ta+0.006z)/100-L + 15(Ta-Td)$ where Ta = mean daily temp. (C)
Td = mean minimum temp. (C)
z = elevation (m) L = latitude

Figure 3 - Potential ET in South Fork using Linacre's Method

Month	**Daily ET (mm)**	**Monthly ET (mm)**
Oct	2.38	73.78
Nov	1.14	34.2
Dec	1.45	44.95
Jan	1.08	33.48
Feb	1.53	42.84
Mar	2.01	62.31
Apr	3.63	108.9
May	6.84	212.04
Jun	7.62	228.6
Jul	7.35	227.85
Aug	5.32	164.92
Sep	3.63	108.9
Mean Yearly Potential ET		1342.77

Land Use and Cover Conditions

Before logging activity began in 1996, land use in the South Fork watershed was focused primarily on livestock grazing, with impacts concentrated primarily in lowland areas and in riparian zones in the upland areas. Small-scale agriculture in the form of forage production on state and Zehntner lands has also occurred. Recreation impacts have historically been focused on the Main Tenderfoot, with minimal impacts in the South Fork drainage.

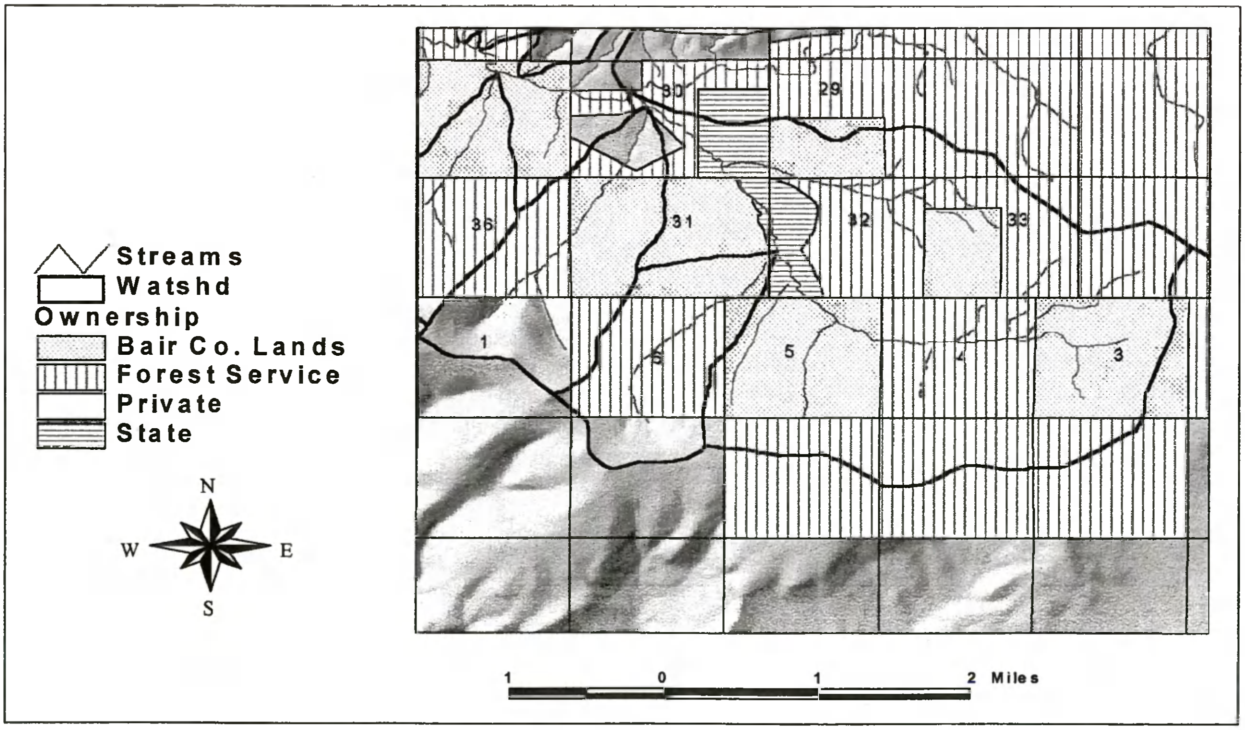
Distribution of land cover classes based on Wildlife Spatial Analysis Lab coverages is presented in Figure 4.

Figure 4 - Distribution of land cover classes

Land Use	**Acres**
Altered Herbaceous	6.005
Broadleaf Riparian	5.285
Conifer Riparian	5.371
Douglas-fir	1593.666
Douglas-fir/Lodgepole Pine	143.125
Graminoid and Forb Riparian	11.291
Lodgepole Pine	2452.338
Low/Moderate Cover Grasslands	572.226
Mixed Broadleaf Forest	191.928
Mixed Mesic Forest	65.907
Mixed Mesic Shrubs	374.970
Mixed Subalpine Forest	1050.569
Mixed Whitebark Pine Forest	68.458
Mixed Xeric Forest	286.830
Moderate/High Cover Grasslands	38.540
Montane Parklands and Subalpine Me	76.444
Ponderosa Pine	212.010
Rock	12.527
Sagebrush	17.682
Shrub Riparian	12.011
TOTAL ACRES	7197.183

Ownership – Map 4 displays ownership in the South Fork watershed. The area is in checkerboard pattern ownership with approximate percentages of the watershed owned as follows; USFS – 52% Bair Ranch Foundation – 34% Private (Non-Bair) – 9% and State – 5%. The proposed land exchange between the USFS and Bair Ranch Foundation would consolidate all lands in the watershed south of the South Fork in Bair ownership. The approximate ownership percentages given the exchange would be; USFS – 30%, Bair – 56%, with Private and State remaining the same. Given specific regulations, including minimal grazing impacts, no timber removal or road building, the proposed Conservation Easement for the main tributary and riparian areas of the South Fork would aid in long-term habitat protection for the WCT population.

Map 4 – Ownership in the South Fork watershed



Forest land condition – The South Fork watershed contains several forest cover types (Pfister et al. 1977). Approximately 77% of Bair lands in the watershed are classified as Douglas Fir (Pseudotsuga menziesii) types, while lodgepole pine (Pinus contorta) forest types occupy approximately 15 % of Bair lands in the watershed. Ponderosa pine (Pinus ponderosa) and limber pine (Pinus flexilis) cover types are restricted to small acreages less than 1% of the total. Riparian areas in the drainage are predominantly Picea X (hybrid white and Engelmann spruce) / Red-osier dogwood (Cornus stolonifera) habitat types. While the forest understory in non-logged areas remains more or less undisturbed, skid trails and slash piles have had a significant impact on the soils and vegetation in logged areas. Also, vegetation utilization in riparian areas has remained low in comparison with impacts to stream channel morphology from unrestricted grazing access to the streams.

Range Condition

Grazing information from USFS allotment records at the Kings Hill District Office in White Sulphur Springs detail overall livestock numbers for the South Fork drainage. Over 100 years ago when the Mongar homestead was established as the first permanent residence in the South Fork, the total livestock (sheep and cattle) population of the little Belt range numbered close to 100,000, as compared to 3,000 currently. The late 1890's saw an 80% decrease in sheep population and

60% decrease in cattle numbers across the range. Grazing intensity remained relatively constant from this point until the 1940's when economic changes moved local ranchers to focus primarily on raising cattle and move away from the sheep industry (Bond 2000).

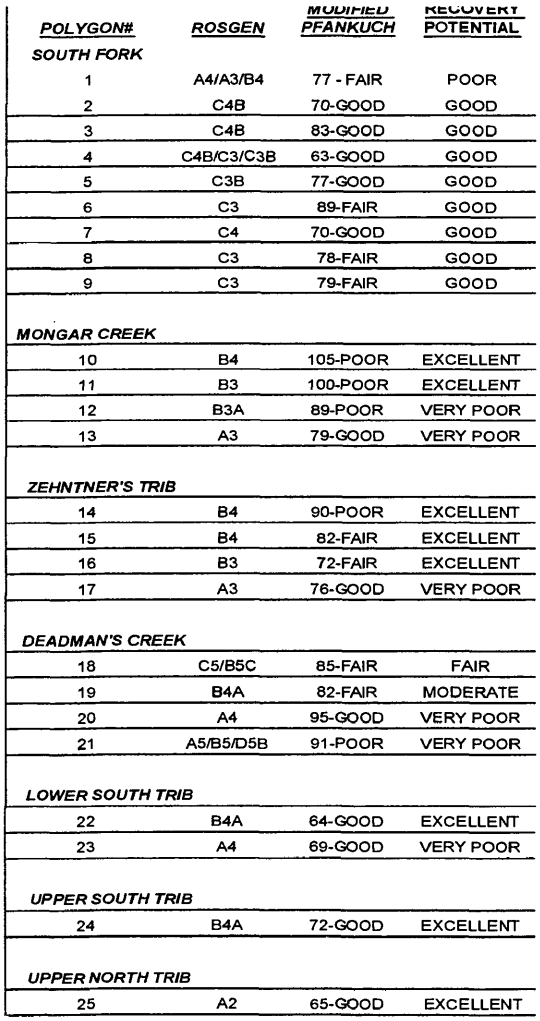
Grazing records dating to the early 30's show that Bair Company lands supported 4 bands of sheep with a total of 900-1200 head from July 1 to approximately Sept 15 until 1969 when the switch to cattle occurred. The current yearly allotment on Bair Ranch Foundation lands is broken up into alternating yearly upper and lower pastures. The allowed allotment of 50 head on USFS lands and 150 head on Bair property are allowed to range freely from July 1 to September 30 (Bond 2000). Typically the cattle are placed as low as possible within the drainage and are collected after having moved up the drainage. Little exists in the form of fencing, alternative water sources, or active management of grazing effects. The streams of the watershed serve as the primary water source and act as primary travel corridors demonstrated by the multitude of trails adjacent to streams.

The Zehntner family has maintained approximately 200-250 head of cattle since moving to the drainage in the late 50's on a combination of state leased and privately held lands.

Watershed Hydrology -Rosgen Stream Classification / Channel Stability

Stream polygons in the South Fork were classified in the field according to the Rosgen classification system (Rosgen 1996). The breakdown of Rosgen classification by polygon can be examined in Figure 5, with polygons delineated in map 3. Polygons were given a channel stability rating using the modified Pfankuch channel evaluation procedure and field observations (Pfankuch 1978).

Figure 5 – Rosgen classification –Channel Stability Rating



POLYGON#	*ROSGEN*	*MODIFIED PFANKUCH*	RECOVERY POTENTIAL
SOUTH FORK			
1	A4/A3/B4	77 - FAIR	POOR
2	C4B	70-GOOD	GOOD
3	C4B	83-GOOD	GOOD
4	C4B/C3/C3B	63-GOOD	GOOD
5	C3B	77-GOOD	GOOD
6	C3	89-FAIR	GOOD
7	C4	70-GOOD	GOOD
8	C3	78-FAIR	GOOD
9	C3	79-FAIR	GOOD
MONGAR CREEK			
10	B4	105-POOR	EXCELLENT
11	B3	100-POOR	EXCELLENT
12	B3A	89-POOR	VERY POOR
13	A3	79-GOOD	VERY POOR
ZEHNTNER'S TRIB			
14	B4	90-POOR	EXCELLENT
15	B4	82-FAIR	EXCELLENT
16	B3	72-FAIR	EXCELLENT
17	A3	76-GOOD	VERY POOR
DEADMAN'S CREEK			
18	C5/B5C	85-FAIR	FAIR
19	B4A	82-FAIR	MODERATE
20	A4	95-GOOD	VERY POOR
21	A5/B5/D5B	91-POOR	VERY POOR
LOWER SOUTH TRIB			
22	B4A	64-GOOD	EXCELLENT
23	A4	69-GOOD	VERY POOR
UPPER SOUTH TRIB			
24	B4A	72-GOOD	EXCELLENT
UPPER NORTH TRIB			
25	A2	65-GOOD	EXCELLENT

Aside from the “good” scores of inherently stable, high gradient A type reaches, existing channel condition in the South Fork drainage is generally fair to poor. Unstable streambanks and increased width to depth ratios from cattle impacts are the dominant factor in low stability ratings.

The hydrologic characteristics of the South Fork watershed were characterized using aerial photos, topographic maps and through field measurements. Minimal pre-existing data was gathered from the USFS, consisting of 1 year’s worth of cross-sectional data and proper functioning condition surveys. Because no streamflow or precipitation data was available specific to the South Fork, “synthetic hydrology” techniques were utilized to determine mean annual flow and create a flow duration curve with the aim of giving a general characterization of the hydrologic character of the basin. Ideally, given more available hydrologic and climatic data, a physical process distributed parameter hydrologic model such as TOPMODEL could provide a more site specific and detailed characterization of the South Fork watershed (Beven et al. 1995)

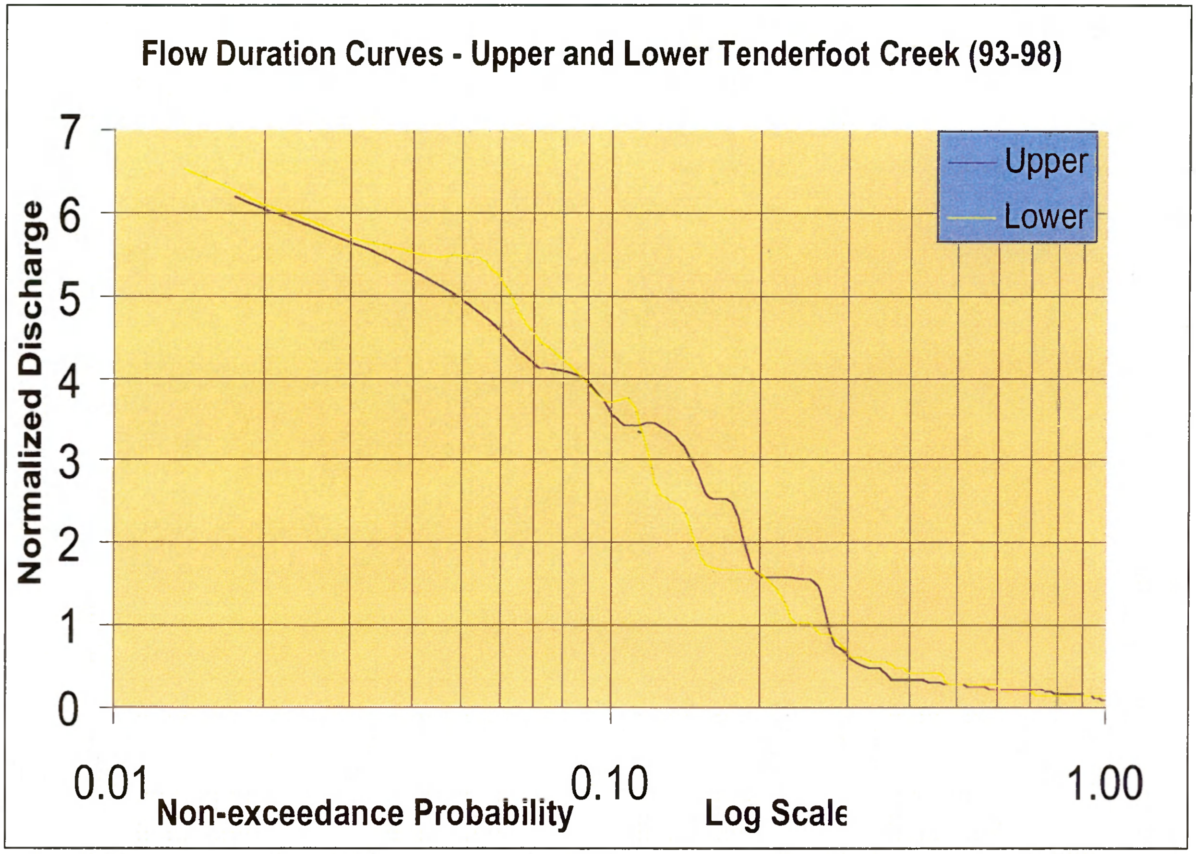
Estimates of peak discharges for the South Fork watershed near the confluence with the Main Tenderfoot were calculated using the methodology developed by Parrett, Hull and Omang (1987). After they determined peak discharges for various recurrence intervals for over 350 gauging stations in the region, they used simple regression analysis to develop regional equations relating peak discharge with channel geometry data. Using the average bankfull width measurement of polygon #9 at the mouth = 6.5 feet, peak discharges are given for the South Fork in Table #3. The figures are based on equations developed for the Southwest Region of Montana. The coefficients of determination for the region ranged between .80 and .90, with 59 gauging sites used in the regression analysis.

Figure 6_- Peak discharge estimates for selected recurrence intervals-South Fork

Q2 = $.189\ W(bf)^{1.76}$ =9 cfs
Q5 = $.722\ W(bf)^{1.82}$ = 22 cfs
Q10 = $1.42\ W(bf)^{1.7}$ = 30 cfs
Q25 = $2.94\ W(bf)^{1.57}$ = 56 cfs
Q50 = $4.64\ W(bf)^{1.49}$ = 75 cfs
Q100 = $7.02\ W(bf)^{1.47}$ = 100 cfs

Daily streamflow data measured at sites from the nearby Tenderfoot Creek Experimental Forest were used to develop a regional flow duration curve as a means for typifying precipitation/hydrologic characteristics of the region. Streamflow measurements were not taken in the South Fork because of obvious difficulty in using data from one field season to characterize temporally variable hydrologic data.

Figure 7. Flow Duration Curves — Upper and Lower Tenderfoot Creek



In general, discharge frequency curves plotted at the same scale can be utilized to compare the hydrologic characteristics of watersheds. Discharge values for the Experimental Forest were normalized by dividing by the Q50 (the discharge exceeded 50% of the time). Typically, a curve with a steep slope throughout suggests a highly variable or flashy stream, while less steep slopes suggest a slower response to rainfall. The slope at the lower end of the flow duration curve demonstrates the effect of storage, in soil or groundwater (Smith and Stopp 1978). Large storage amounts that provide significant baseflow tend to flatten out the lower end of the curve. Watersheds that receive large quantities of snow or remain swampy during wet seasons store water at these times and usually have flatter slopes at the upper end of the curve. Waterways with significant floodplain storage demonstrate the same effect, with a flattened upper section (Smith and Stopp 1978). The curves for Upper and Lower Tenderfoot Creek, with similar climatic and geologic characteristics suggest that the South Fork watershed demonstrates significant baseflow capacity and does not rely to the same extent on direct runoff from snowmelt or surface collection during the rainy season.

Quantitative Morphology

The drainage density of a watershed also provides information on how quickly precipitation and snowmelt moves through the hydrologic system. The higher the drainage density, the more rapid the watershed's response to precipitation and the greater likelihood of flooding given the same amount of precipitation. Factors including soil depth and infiltration capacity, geologic permeability, mean annual flood magnitude, slope, vegetation and land use all have an influence on drainage density. Also the higher the rainfall intensity, the greater the drainage density. Areas of the Badlands in South Dakota have drainage densities approaching 200 miles per square mile (Smith and Stopp 1978). Watershed area and stream mileage were measured by planimeter in English units for the South Fork. Drainage density is a relatively low 1.38 miles/sq. mile, with 16.47 miles of intermittent and perennial streams and an area of 11.34 square miles. This figure suggests that the South Fork responds relatively slowly to precipitation events.

The steepness of a watershed provides the necessary energy for the detachment and transport of material, i.e. erosion and sediment production. The relief ratio, calculated by dividing the difference in elevation between the basin mouth and watershed divide by the maximum length of the basin parallel to the primary channel, suggests an average slope for a watershed. It is correlated with speed of response to precipitation and levels of sediment production. The relief ratio for the South Fork is 439.5 ft/mile or approximately 8 %, suggesting a high gradient system with significant available energy for water transportation.

The Compactness coefficient is the ratio of the perimeter of a watershed to the circumference of a circle with the same area. Kc = .28 (Perimeter length/ Sq. root of Watershed Area). A circular watershed with a ratio close to one is a more efficient and “flashy” or floodprone system. With a compactness coefficient of 1.13, the South Fork drainage tends towards lower times of concentration suggesting flashiness. A visual inspection of the general shape of the watershed confirms the oval, relatively circular shape of the watershed.

Water Use

Surface flow in the South Fork watershed is generated by precipitation runoff, primarily from snowmelt. The South Fork and its tributaries are the primary water source for the minimal water use in the drainage. Aside from livestock use, the Zehntner Ranch diverts a minimal portion of the stream flow near Deadman's Creek to power a small generator for electricity. A table summarizing water rights and permits follows.

Figure 8 - Summary of Water Rights and Uses

Owner	Year	Type	Quantity
State Lands	1900	irrigation	3 cfs
USFS	1905	stock use	4.49 gal./min
Zehntner's	1960	stock use	30 gal/day/AUM

Fishery Health

The most recent fisheries surveys conducted by the USFS in 1997 and 1999 suggest that the WCT population in the South Fork remains healthy and viable with slight genetic introgression, despite declines in habitat quality from various sources. The most recent relative abundance estimate for the main South Fork based on electroshocking studies performed by the USFS during 1997 is approximately 50 fish per 100 meters, with all ages well represented. Density estimates for a second order stream of its size suggest a robust population with medium to high WCT density (Enk 2000). Rainbow Trout and hybridized WCT were found in the South Fork below the falls near the state/USFS boundary in section 30, T14N, R5E. Genetic testing based on allele frequencies at the diagnostic loci completed at the University of Montana Wild Trout and Genetics Laboratory demonstrate that the South Fork WCT population above the falls remains approximately 96% pure. Because only two of 10-12 diagnostic loci had non-WCT genes (Rainbow Trout or Yellowstone CTT), the introgression was most likely caused by a decades old one-time stocking event whose effects are fading out due to back-crossing with native WCT (Enk 2000). The fisheries' biologist for the Lewis and Clark National Forest suggests that the South Fork population is most likely moving towards an increasingly lower level of hybridization with primarily pure fish most abundant. While it may not be used as a restocking population in the statewide restoration scheme, according to the guidelines of the WCT Conservation Agreement, the South Fork population merits the highest level of protection.

While the WCT population in the South Fork remains robust, there are a range of possible threats given land-use history and possible stochastic events. The population remains protected from " natural" hybridization by a set of falls located approximately _ of a mile upstream from the confluence with the Main Tenderfoot in NW1/4, SE1/4, section 30, T14N, R5E on National Forest land.. Current threats to the WCT population in the South Fork include loss of spawning habitat due to increased fine sediment levels (bank erosion, roads etc.) and loss of habitat due to stochastic events such as drought, floods, ice-over and scouring flows (Weaver and Fraley 1993).

Because the South Fork WCT population is isolated in the headwaters of the watershed, recolonization from adjacent populations is not possible. Perhaps the greatest threat to the isolated South Fork population is the cumulative effects of existing land use activities (grazing, timber harvest, and recreation) that can combine to simplify stream systems and reduce habitat availability. Reduced stream habitat complexity remains one of the most widespread cumulative effects of past forest activities, especially in combination with other land use activities, like grazing impacts, that lead to incised, straightened channels (Bisson et al. 1992, Hicks et al. 1991). While our understanding of the complexities involved in alterations to stream habitat and salmonid populations from cumulative impacts has greatly improved, our ability to completely define and understand our effects remains limited (Hicks et al. 1991). Recent studies have also suggested that the cumulative effects of land use activities may not be apparent for up to 70-100 years after the original activities (Reid 1998, NRC 1992).

Field-based Assessment- Results and Discussion

Fine Sediment Evaluation

The desired outcome of this part of the study was to establish whether erosion from various land uses contributes significant sediment to streams. The percentage of fine sediments is an important indicator of fishery habitat health (Heede and Rinne 1990, Weaver and Fraley 1993). Bjornn and Reiser (1991) among other studies, demonstrated that survival and emergence of salmonid embryos begins to decline if the percentage of fine sediments exceeds 20 – 30% (by volume) in spawning riffles.

Weaver and Fraley (1993) conducted a study in a natural stream channel designed to specify quantitative predictors of fish response to a range of sediment levels, with the ultimate aim of suggesting specific standards to protect the westslope species. By simulating the characteristic incubation conditions of natural westslope redds and altering the percentage of fines, they found a significant inverse relationship ($r2 = .072$, $P<. 005$, $N = 17$) between cutthroat fry emergence success and percentage of fines less than 6.35 mm. Specifically, mean fry emergence success was 76, 55, 39,34,26, and 4% respectively in simulated redds with 0, 10,20,30,40 and 50% fines less than 6.35mm present. With increasing percentages of fines, potential spawning sites are covered. When the spaces between gravel sized particles in redds are filled with fines, groundwater-sufacewater exchange is blocked and Dissolved Oxygen (DO) levels decrease. Trout fry have difficulty emerging as a result while the eggs do not receive as much oxygen. Typical threshold levels set by fisheries biologists for optimal spawning habitat for westslope cutthroat trout are 5% fines, with significant alterations in spawning habitat occurring with fines levels above 20% (Behnke 1992).

Because the South Fork WCT population currently remains free from the effects of competition from brook trout, hybridization from rainbow trout and over-utilization by humans, negative effects on spawning habitat from increased fine sediment levels would not significantly impact overall reproduction rates (Enk 2000). The real damage potential of increased fines would come after a significant population crash, when the loss of spawning habitat combined with lower reproductive potential could combine to create difficult conditions for population recovery.

Increased levels of fine sediments in streams typically originate from one or more of several human induced sources. Possible sediment sources in the South Fork include; increased streambank erosion from cattle/wildlife trampling, loss of deep binding root mass due to overgrazing of riparian vegetation, and the building and use of logging roads that cross or are located near streams. Level of road use has been shown to have a dramatic impact on sediment yields from road segments, with a heavily used road segment contributing as much as 130 times as much sediment as an abandoned road (Reid and Dunne 1984). Failure to maintain logging roads long-term can prove damaging to aquatic life as sediment pulses caused by plugged culverts, gully erosion etc. may enter the stream system for decades after construction and logging (USDA Forest Service 1996).

The estimated percentage of fine sediments < 6.35 mm in diameter broken down by polygon for the South Fork, Mongar and Deadman's Creek is given in Figure 9. Results for other tributaries are not presented because previous fish sampling studies showed a lack of fish habitat in those tributaries.

Figure 9 - Fine Sediment Estimates in WCT habitat

POLYGON #	% Sediment<6.35 mm
SOUTH FORK	
1	20%
2	15%
3	30%
4	25%
5	20%
6	25%
7	25%
8	25%
MONGAR CREEK	
10	25%

POLYGON#	% Sediment<6.35 mm
11	20%
12	25%
13	15%
DEADMAN'S CREEK	
18	30%
19	30%
20	20%
21	20%

The estimated levels of fine sediments< 6.35 mm in fish bearing portions of the watershed ranges from 15% to 30%, with an average of 22.4%. Equivalent levels in Weaver and Fraley (1993) suggest that fry emergence success with that fine sediment level would be approximately 40%. It should be noted that the fine sediment levels are estimations and are not representative of the entire polygon substrate proportions. Exact levels of available high quality spawning habitat are a possible subject of further study in the watershed. As stated earlier, due to a lack of competition and utilization, decreased fry emergence due to increased sediment levels is currently not a serious threat to the WCT population. Potential impacts from increased fines would be more likely given a population crash from drought, ice over, etc., when the loss of spawning habitat combined with lower reproductive potential could create difficult conditions for population recovery.

Attempting to draw correlations between elevated fine sediment levels and specific land use activities remains problematic. Some stream systems have naturally high levels of fines due to geologic and soil characteristics. It would not be unreasonable to suggest that the high intensity of grazing impacts to the banks and channels in the South Fork have elevated erosion rates and thereby increased levels of fines in the streams. The additional impact of sediment inputs from road surfaces must also be taken into consideration but is difficult to measure without historical sediment data. Provided with pre-logging and road building sediment data, the impacts of the road system could have been characterized quantitatively. The section on sediment inputs provides a qualitative description of sediment inputs to streams from the road system, skid trails and mass failures.

Water Quality-Nutrient Assessment

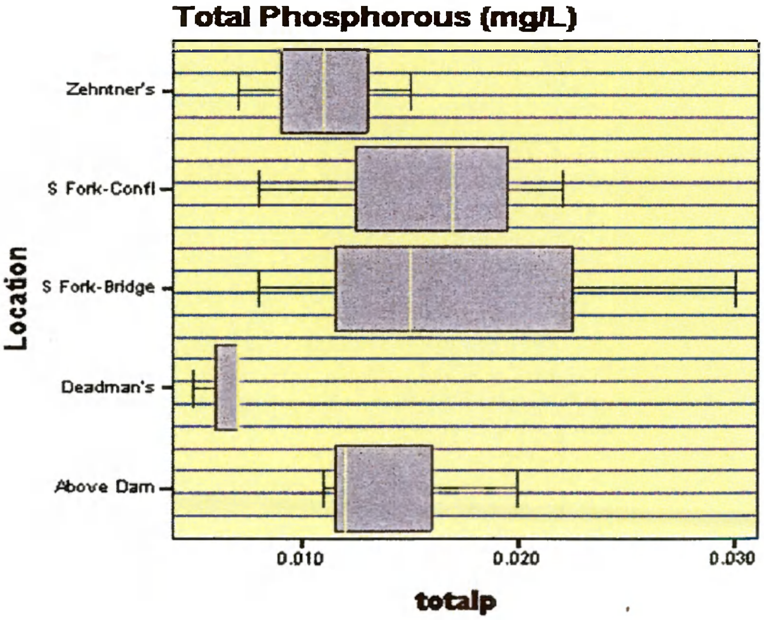
While not an original aspect of the analysis procedure, water quality analysis was added as a possible means of identifying land-use or cumulative impacts. Increased levels of nutrients, especially different forms of nitrogen and phosphorous, can spur growth of existing aquatic vegetation. Excessive plant growth and eventual decay alters the balance of stream systems, causing significant changes in dissolved oxygen (DO) levels with resulting negative impacts on aquatic biota (USGS 1995).

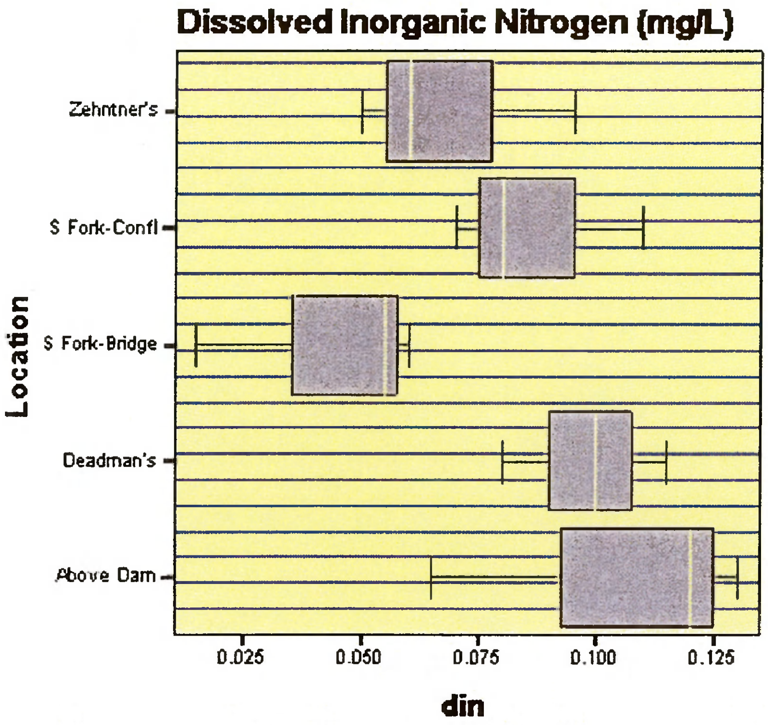
Without historical nutrient data, it is not feasible to make determinations of possible relationships such as increased nitrate levels due to timber extraction or increased phosphorous levels from a specific source. Although the specific impacts of nutrient increases on salmonid and invertebrate populations has not been studied in great detail (Hicks et al. 1991), the opportunity to determine obvious nutrient level oddities or fluctuations between sample sites was deemed to be of value in determining possible abnormalities in watershed function.

The process of developing TMDL (total maximum daily load) levels for essential water quality parameters, as required by the re-authorization of the Clean Water Act in 1987 is still in initial stages in the state of Montana. Nonetheless, the TMDL committee for the Clark Fork River, comprised of dischargers, local governments, conservation groups and consulting scientists, developed a voluntary nutrient reduction plan (VNRP) that suggests instream targets for nutrient levels and likely loading levels required to achieve the intended levels.

The Clark Fork TMDL group decided to focus on total nutrient levels and utilized work by Dodds et al. 1997 to determine acceptable levels of 30 ppb (.03 mg/L) dissolved inorganic nitrogen (DIN) and 39 ppb (.039 mg/L) total P in the middle river and 20ppb (.02 mg/L) in the upper river (Watson et al. 1999). The development of a TMDL for the South Fork Tenderfoot Creek Watershed would ideally involve monitoring of nutrients, sediment levels, and discharge patterns of the South Fork or a reference watershed with similar hydrogeologic, topographic and climatalogical characteristics. Without historical streamflow, nutrient or sediment data in the South Fork to suggest possible TMDL levels, the recommended levels set out by the Clark Fork VNRP group were used as a reference to point out nutrient levels that may warrant further analysis. Box plots of nutrient levels at the 5 sampling sites on the South Fork are presented in Figure 10. (N = 4)

Figure 10 *Box*-plots of Total Phosphorous and Dissolved Inorganic Nitrogen





When compared with the Clark Fork VNRP acceptable levels of 39 ppb (.039 mg/L) total P (based on data from small, shallow streams similar to the South Fork), total phosphorous levels in the South Fork do not demonstrate a significant warning signal that warrants concern at present. While DIN levels in the South Fork are above the suggested levels for the Clark Fork, historical stream surveys and recent field-work have not detailed significant algae blooms in the South Fork that might suggest a problem with nutrient levels in the stream. The nutrient data presented can be used as a baseline level for comparison with future nutrient monitoring. No further water quality analysis is warranted at this juncture, although periodic monitoring should be included in future watershed analysis.

Riparian Ecological Assessment

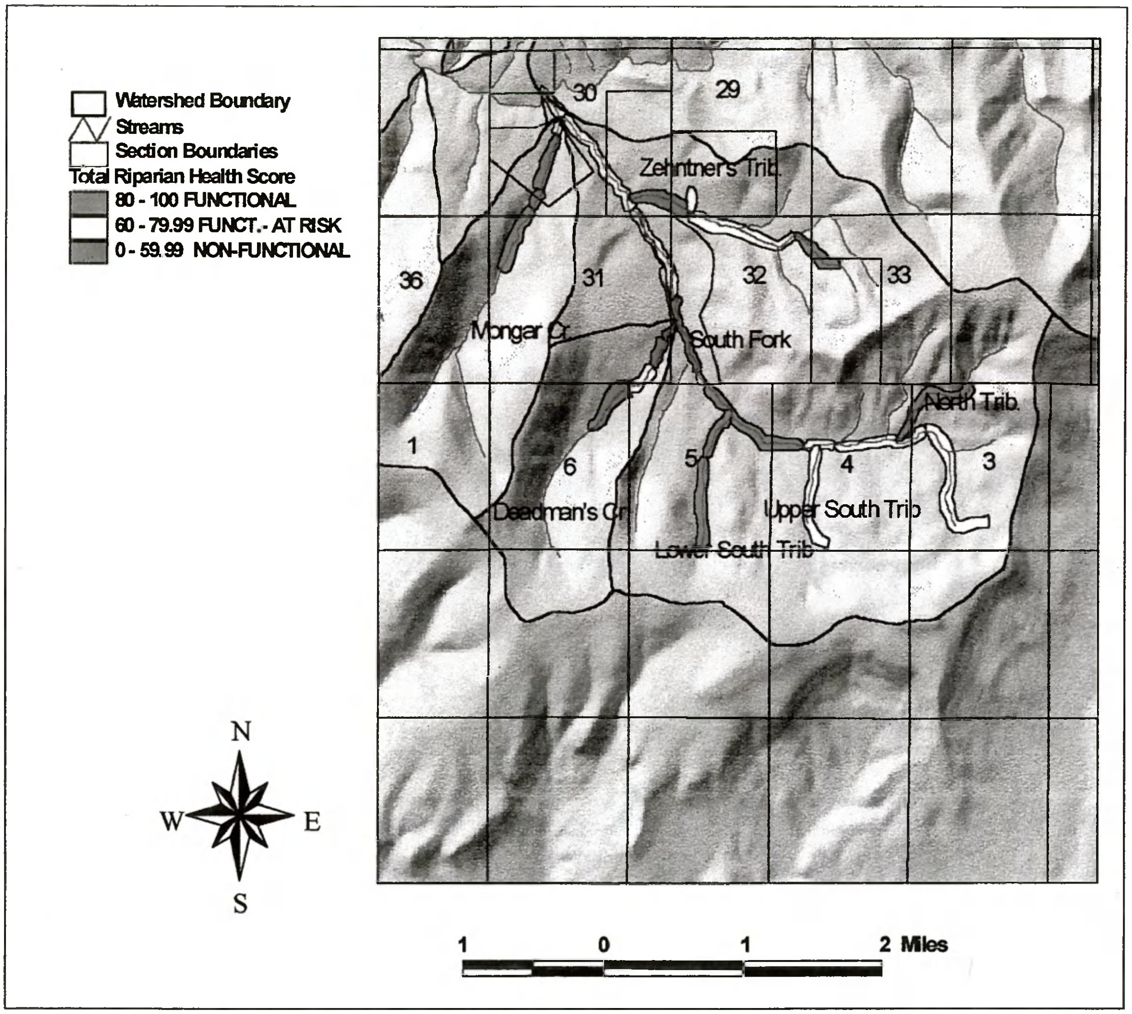
The South Fork and its six perennial tributaries in the watershed were broken down into 25 habitat assessment polygons in an effort to formulate useful management and restoration recommendations to land owners. Polygon length was determined by a combination of obvious physical/ownership boundaries, noticeable changes in riparian vegetation types and obvious changes in stream geomorphology. Upper and lower polygon boundaries, as well as other points of interest were recorded as waypoints using the Garmin GPS 12 handheld unit. Waypoints were then downloaded into an Arcview GIS format for further analysis and display of information. A table of polygon health scores, with problem areas defined, as well as Rosgen classification and restoration potential follows in Figure 11 divided into the mainstem and six tributaries (following page)..

Figure 11. Riparian Health Assessment Scores

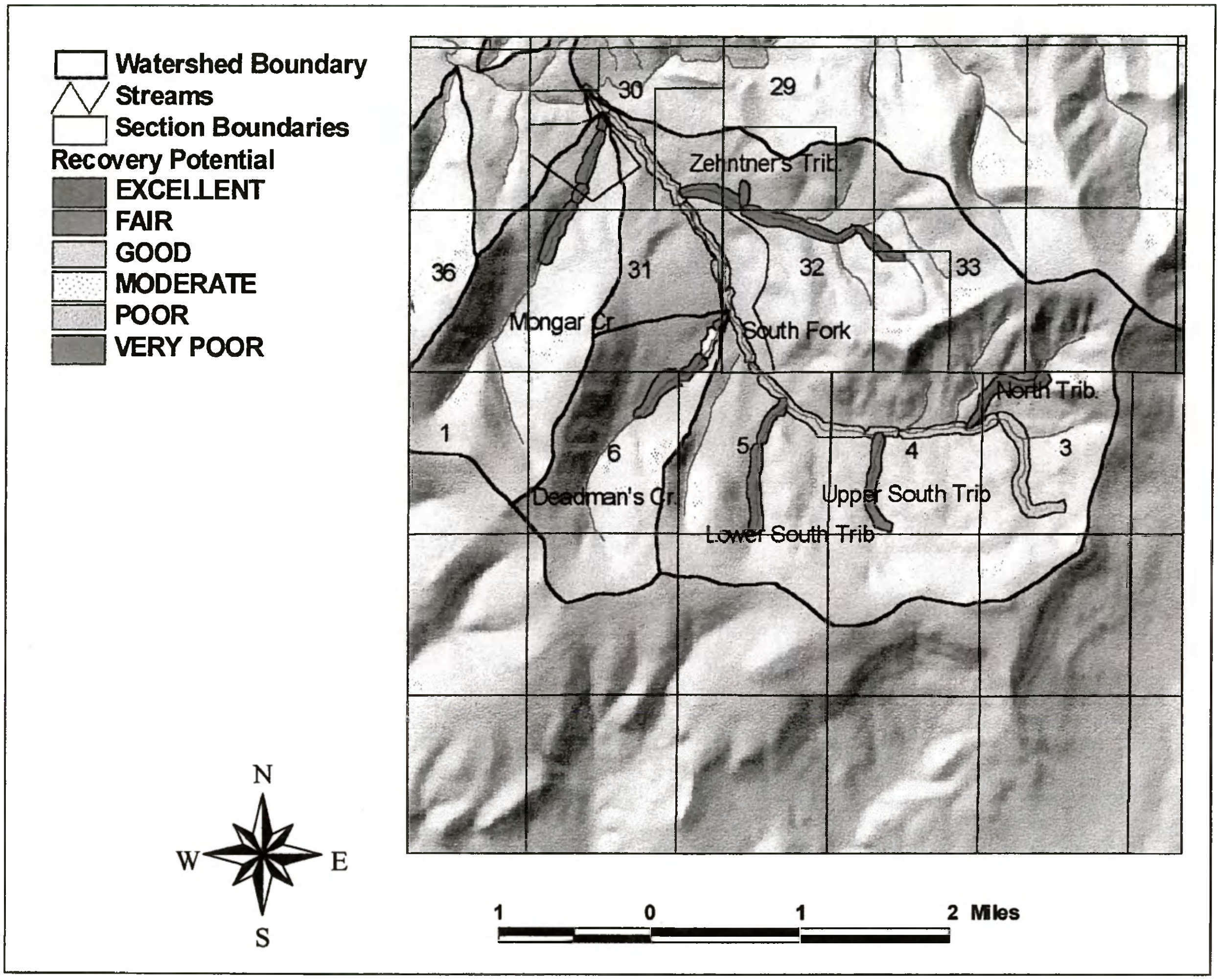
POLYGON#	*VEG.*	*PHYSICAL*	*TOTAL*	*ROSGEN*	*PROBLEM AREAS-COMMENTS*
SOUTH FORK					
1	91.7%	66.7%	Functional-At Risk 69.4%	A4/A3/B4	Bank Shear, Increase w/d ratio, cattle trails, Low DBR (deep binding root mass),2 road xings
2	83.3%	77.7%	Functional-At Risk 77.7%	C4B	Downcutting, Extensive Bank Trampling - Banks Have Good DBRM
3	91.7%	55.5%	Functional-At Risk 63.8%	C4B	Bank Sloughing in steep,sandy gradients, older downcut w/developing floodplain
4	95.8%	72.2%	*Functional 81.9%*	C4B/C3/C3B	early stage invasive weed problem, morebank instability in lower 2/5 with easy cattle access
5	91.7%	55.5%	Functional-At Risk 63.9%	C3B	Numerous cattle crossings, high level of bank trampling, active lateral cutting
6	70.8%	61.1%	**Nonfunctional 59.7%**	C3	stream meanders along fenced pasture, bank trampling on road side. Lower 1/3 entrenced
7	66.7%	55.5%	Functional-At Risk 66.7%	C4	understory heavily grazed,woody veg absent in pasture area, undercut banks, WAYPT 9 - Heavily Impacted site, increased fines below Wpt.9
8	79.2%	66.7%	Functional-At Risk 65.3%	C3	Heavy utilization entire poly-extensive bank trampling, high undesirable herbaceous content
9	95.8%	55.5%	Functional-At Risk 65.3%	C3	Heavy bank trampling-Cattle path across stream at fenceline above confluence w/Main-active lateral cuts
MONGAR CREEK					
10	83.3%	66.7%	Functional-At Risk 66.7%	B4	excessive fine sediments, roadside sediment fence trampled, 3/4 of poly has trampled banks
11	83.3%	44.4%	**Nonfunctional 55.5%**	B3	lower 1/3 heavily impacted by cattle trampling, corral abutts stream lower poly -stream flows in corral-cattle trails on upper 1/3 of poly
12	79.2%	55.5%	**Nonfunctional 59.7%**	B3A	shrub coverage heavily grazed, Picea providing DBRM, some stretches banks held by forbs and graminoids, 2/3 trampled
13	74.1%	83.3%	*Proper Functioning 80.7%*	A3	banks well vegetated - good DBRM -Grazing effects noticeably lessened above fenceline boundary of poly's 3 &4
ZEHNTNER'S TRIB					
14	74.1%	33.3%	**Nonfunctional 52.6%**	B4	banks lacking tree/shrub coverage&regeneration-Low DBRM, channel widening, bank compaction/shearing nearly throughout
15	77.8%	60.0%	Functional-At Risk 68.4%	B4	bank structurally altered for much of poly, high level of exposed ground, logging lower 1/3
16	59.3%	66.7%	Functional-At Risk 63.4%	B3	bank trampling and channel widening for majority of poly, some loss of woodies to utilization,
17	85.2%	83.3%	*Proper Functioning 84.2%*	A3	Lower levels of utilization and bank trampling, heavily forested/dense poly with reduced cattle access
DEADMAN'S CREEK					
18	87.5%	44.4%	**Nonfunctional 56.9%**	C5/B5C	1/3 of poly with active lateral cutting, deeply incised channel-little floodplain development, undercut banks, trampled banks, widened channel - channel splitting, heavy silt deposition
19	83.3%	50.0%	**Nonfunctional 58.3%**	B4A	logging road w/in 8 ft. of channel for lower 1/3, heavily braided channel in high traffic areas, excessive fine sediments, stream widening, 4 headcuts lower poly, logging adjacent to SMZ entire poly
20	77.8%	66.7%	Functional-At Risk 71.9%	A4	lateral cutting, undercut banks, past and current channel incisement, cattle trails & crossings, channel widening in flat areas
21	66.6%	26.7%	**Nonfunctional 45.6%**	A5/B5/D5B	extensive grazing, high level of bare ground, channel braiding in high traffic areas due to trampling and bank shear
LOWER SOUTH TRIB					
22	81.5%	83.3%	*Proper Functioning 82.5%*	B4A	All ages present and reproducing successfully, occassional bank and channel trampling, overall pretty healthy
23	88.9%	93.3%	*Proper Functioning 91.2%*	A4	Minimal bank/channel trampling, minimal utilization, excellent DBRM, very healthy
UPPER SOUTH TRIB					
24	74.10%	66.70%	Functioning-At Risk 70.2%	B4A	Banks, channel heavily degraded due to cattle trampling - multiple trails/crossings, vegetation shows minimal grazing impacts
UPPER NORTH TRIB					
25	96.3%	93.3%	*Proper Functioning 94.7%*	A2	Extremely healthy! Well armored, minimal cattle impacts, trees, shrubs reproducing successfully

A series of maps of polygon location, color- coded health status and restoration potential are presented as maps 5 and 6.

Map 5– Riparian Condition Assessment Scores



Map 6 – Restoration Potential based on Stream Type



As demonstrated by the riparian health assessment scores in figure 11 and map 5, the major human-caused impact in the South Fork drainage has clearly been the grazing of domestic livestock. 76% of polygons scored at the Non-Functional or Functional-At Risk level. Of the remaining six polygons with Proper Functioning scores, five are located in steep, upper reaches with very limited cattle access. The level of impact to aquatic resources in the Western United States due to improper livestock use is well established. Estimates as high as 70% of the western United States have been grazed, with most riparian zones having been altered dramatically in the past one hundred years due to improper livestock grazing (Fleischner 1994, Elmore 1992, Adams and Fitch 1998).

Alterations to current grazing strategies will have the greatest positive impact in efforts to restore the streams in the South Fork to a higher level of ecological functioning. In developing new management strategies it is important to consider the "natural stress" of the impacted streams. In other words, streams with naturally high erosion potential cannot withstand a high degree of management stress (Elmore 1992). The disturbance sensitivity level developed by Rosgen based on stream type was utilized to suggest natural stress levels to be taken into account in future grazing strategies. Three out of 25 polygons in the watershed have a "low" or very low sensitivity level. The remaining polygons are split evenly between moderate and very high sensitivity levels. Taken generally, the watershed demonstrates a significant natural stress level, suggesting that continued impacts from intensive grazing would further degrade the stream systems ability to function properly.

Management stress should definitely not be looked at solely in terms of AUM's (animal use months) but in terms of the combined inputs of season of use, duration of use, grazing frequency, and control of distribution (Elmore 1992, MT DNRC 1999).

As stated earlier, the lack of control of livestock distribution provides the greatest impacts to the stream system in the South Fork. Comparing the average vegetation health and average channel health portions of the overall riparian health score, 81.6% to 63.4% supports this observation. The riparian vegetation remains relatively healthy in the "functional" zone, while the physical attributes of the system are barely above the non-functional range. The greatest impacts to stream function clearly are not due to over-utilization of vegetation but to unrestricted cattle access to the stream channel.

Season of use cannot easily be regulated as the allotment season runs the same period (July 1 to Sept. 30) each year, and fenced pastures to allow grazing rotation and rest are not in place. The possibility exists of fencing large portions of the South Fork to limit cattle access to specific watering sites. Such enclosures would also allow a rotational scheme in riparian pastures to spread out impacts to the stream system. Such a project would entail relatively high start-up costs and require constant maintenance of fencing, but has proven extremely effective in minimizing grazing impacts and promoting recovery (Elmore 1992, Adams and Fitch 1998).

A “no change” option in grazing strategy on Bair Ranch Foundation lands will almost certainly continue to move the watershed into a lower state of ecological function. Continued bank trampling and compaction further limits the ability of riparian areas to function as a “sponge”, regulating infiltration and release of groundwater during dry periods. High levels of bank trampling severely alter the natural migration of stream channels within the floodplain and do not allow the system to maintain a more naturally variable state. A continuing increase in fine sediment levels from the erosive effects of bank trampling also further degrades WCT spawning habitat.

Stream Temperature Assessment

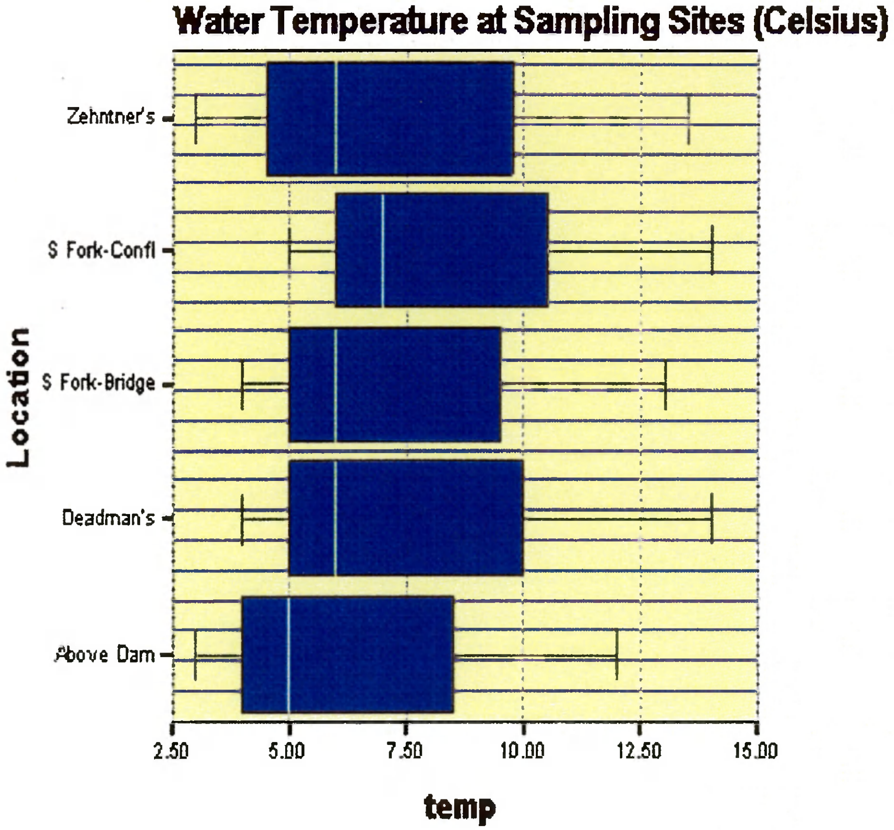
Water temperature is determined mostly by the rate of streamflow, elevation and the amount of shade, but also by undercut embankments, organic debris, depth and velocity (Budd et al. 1987). Water temperatures in salmonid streams fluctuate daily, seasonally, annually and spatially (Bjornn and Reiser 1991). Riparian areas work effectively as reservoirs, storing runoff in soil spaces and wetland areas thereby maintaining stream flow after spring runoff and lowering stream temperature by discharging cooler stored water. Riparian vegetation also creates a microclimate that helps regulate water temperature by providing shade from solar radiation in the summer and acts as insulation to keep streams from freezing over in the winter (Budd et al. 1987). Excessive loss of riparian canopy cover to overgrazing, riparian timber removal or bank erosion increases the amount of solar radiation reaching the stream, thereby altering stream temperature dynamics.

Daily stream temperature fluctuations occur to a much greater extent in smaller, lower volume streams such as the South Fork of Tenderfoot, which can have negative impacts on a wide range of aquatic organisms. Higher water temperatures reduce oxygen solubility, thereby lowering dissolved oxygen levels in streams. Possible effects on salmonid growth and survival include reduced growth efficiency, increased susceptibility to disease, and changes in growth rate and age at smolting. These effects would all tend to reduce a stream's trout population (Hicks et al. 1991).

Studies on temperature effects on WCT suggest that the lower lethal temperature is 0.6 degrees Celsius, with an upper lethal temperature of 22.8 degrees Celcius (Bjornn and Reiser 1991). The Washington State Watershed Assessment Procedure sets a standard of 16 degrees Celcius, while Idaho has a 13 degree Celsius standard during spawning season (WFB 1993; IDL 1994) The state of Montana currently does not have specific standards for maximum stream temperature.

Temperature measurements were taken at the water quality sample sites at four times throughout the field season starting in early August. Data on water temperature extremes from the Tenderfoot Experimental Forest suggest that seasonal high water temperatures occur sometime in mid August. Water temperature data from past fisheries and hydrologic assessments completed during the past four years by the Forest Service were also factored into the range of temperatures. A chart of temperature ranges by site is given in figure 12.

Figure 12 — Stream temperature ranges



Based on available stream temperature data and measurements taken in summer 1999, the highest stream temperature recorded is 14 degrees Celsius, far below the WCT lethal maximum temperature of 22 degrees Celsius, and below the 16 degree C standard for Washington. The temperature data recorded and collected, as well as the lack of change in riparian canopy cover suggest that increased water temperature due to lack of riparian canopy cover is not a current threat to the resident WCT population. Future monitoring should continue to include stream temperature assessments, although with no change in canopy cover in riparian areas, the change in canopy cover methodology is unnecessary.

Canopy Cover Removal Impact Assessment

Stream channels in a pristine state exist in a state of dynamic equilibrium, continually being formed, reformed and maintained by hydrologic and fluvial geomorphologic processes (Leopold et al. 1964). Impacts of forest canopy removal include decreased interception and transpiration and increased snowmelt rates, which can all combine to significantly alter the timing and intensity of streamflow (IDL 1994). The alteration of aquatic biota habitat via alteration of the hydrologic regime was demonstrated in Bisson et al. (1987). The degree of alteration is ultimately determined by the size of the increase in peak flows combined with the susceptibility of the stream channel to the alteration in streamflow. Harvesting timber, grazing and other human-caused impacts that compact soil, remove vegetation or cause an increase in watershed drainage density can increase peak discharges and decrease the recurrence interval of bankfull discharges (the increment of discharge that moves the largest proportion of annual sediment load over a period of water years) (Olsen et al. 1997). Any investigation of hydrologic impacts from land use activities must take into account the fact that hydrologic responses to timber removal and the resulting geomorphologic responses to changes in hydrology vary substantially between basins (Grant and Swanson 1991).

While methods to estimate stream channel stability exist, as well as methods to estimate effects of increased discharge on channel stability, there currently is no widely accepted and applied method for predicting the amount of increased discharge due to forest canopy removal (Olsen et al. 1997; Grant and Swanson 1991; Beschta 1998). This fact is due to the complexity and variability in climatic patterns, parent materials and vegetation distribution between watersheds (IDL 1994). Beschta (1998) outlined necessary research needs related to the effects of forest practices in the Northwest that would aid tremendously in furthering our knowledge of hydrologic relationships and cumulative effects.

As previously mentioned, generalizing the relationship between canopy cover removal and hydrologic/geomorphologic impacts across watersheds is problematic due to the complexity and variability in climatic patterns, parent materials and vegetation distribution between watersheds. The fact that the various methods of timber harvest and inherent regeneration variability differ in resulting levels of soil and vegetation alterations with accompanying changes in runoff patterns adds to the problem of adequately typifying the relationship. While this study focuses on possible cumulative impacts to the aquatic resources of the South Fork, future research into the cumulative impacts of grazing, canopy cover removal, road building, and recreation on the abundant wildlife of the Lower Tenderfoot region should be taken into account in future land management decisions.

Given the difficulty in predicting hydrologic effects due to canopy removal, it is not surprising that the results obtained in this study to characterize hydrologic effects are inconclusive. A summary of total acreage, canopy cover acreage pre and post, along with the formulation of the canopy removal index is provided in Figure 13.

Figure 13._Canopy Cover Pre and Post Logging - Canopy Removal Index

South Fork Total Area – 7250 acres

Canopy Cover Pre – 3787 acres Canopy Cover Post – 3408 acres

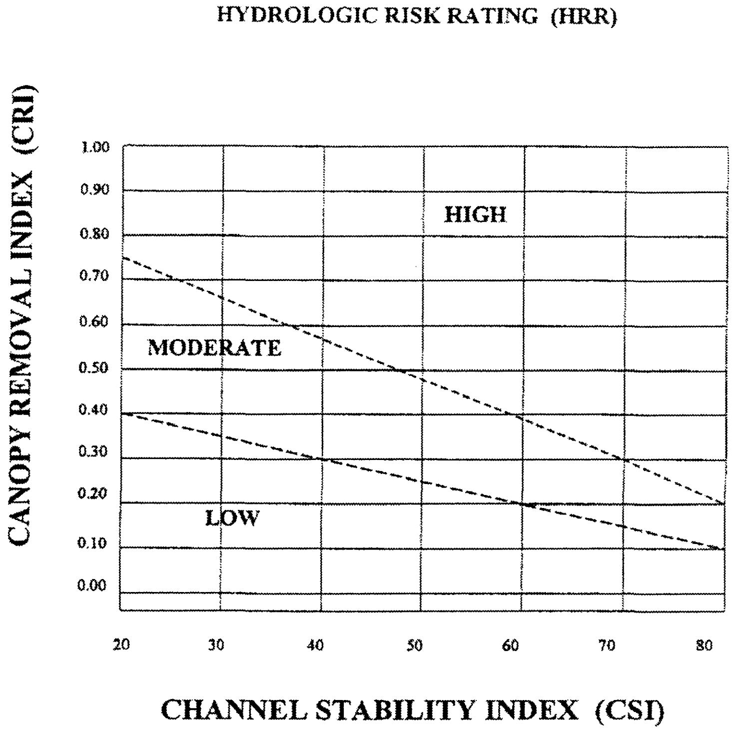
$$\text{CRI} = \frac{\text{(Acres of Forest Canopy Removal/Percentage Natural Canopy Closure)}}{\text{Total Watershed Area (acres)}}$$

CRI = (379)(58.5%)/7250

CRI = .09

With the hydrologic risk rating scale (figure 14) used in the Idaho Cumulative Impact Assessment Procedure, a canopy removal index of .09 corresponds to a low hydrologic risk rating regardless of the Pfankuch channel stability index.

Figure 14. Hydrologic Risk Rating



Several mitigating factors suggest that the low risk rating warrants further investigation. First, the literature on cumulative impacts suggests that the full scale of the combined effects of various land use activities may not be apparent for many decades after the original impacts (Reid 1998; Kauffman et al.1997). At this point, the canopy removal difference is based on impacts to three sections in checkerboard ownership patterns with the USFS not planning any timber removal on its properties in the watershed. The area affected amounts to 1920 acres or 26.5% of the watershed. Looking specifically at hydrologic impacts on sub-watersheds of the South Fork suggests the possibility of increased risk of geomorphic impacts from current and possible future canopy removal. Future timber harvest plans should take into account the already severely degraded channel system in the Mongar Creek sub-watershed. Harvest levels similar to that in section 31 in the surrounding sections, with an already highly taxed stream system from grazing impacts could increase the probability of cumulative effects, in this case continued simplification of the sub-watershed stream system.

With riparian health already classified as non-functional and functional/at risk in the Mongar Creek sub watershed, the risk of future cumulative impacts from continued grazing and timber removal is significant. Future sustainable timber management and road construction on Bair Ranch Foundation lands in the upper South Fork should be monitored closely to avoid possible cumulative effects, given possible implications for further simplification of an already highly impacted stream system that supports a species of special concern. Focusing timber management in sections that drain into the lower South Fork and Main Tenderfoot would lessen the probability of cumulative impacts within the upper

South Fork and concentrate land management impacts on a larger stream system that does not support a WCT population at high risk of possible extinction. Once grazing impacts have been minimized and channels given sufficient recovery time in the South Fork, future analysis may suggest that sustainable logging in the upper South Fork watershed can occur with minimal probability of cumulative effects.

In general, it is difficult to suggest a relationship between current canopy removal levels and channel degradation levels in the drainage. First, the impacts from canopy removal may not be apparent for decades. Also, with a significant portion of the banks in the South Fork disturbed by pugging and hummocking, grazing effects clearly are the dominant cause of loss of ecological/riparian function. The literature on cumulative effects does not suggest recommended limits to canopy cover removal given a specified level of previous geomorphologic disruption. It is important to realize that the management decisions made based on possible cumulative watershed effects are “as much societal value judgments as technical issues” and that “risk is inherent in the forest management enterprise” (Grant and Swanson 1991). The current risk in the South Fork watershed is possible further degradation of an already highly impacted stream system that supports a species of special concern with full protection under the Montana FWP Conservation Agreement.

Road Design and Density

The effects of road densities up to 1.6 mi./sq. mi. on watershed health in most forested regions is practically negligible, while densities approaching 8 mi./sq. mi. combined with other land use effects significantly increase the potential for cumulative effects (Reid and Dunne 1984). Increased road densities introduce greater concentrations of steeper slopes, hardened surfaces that limit infiltration, exposed mineral soils more readily eroded and interception of subsurface flow, all of which concentrate water and increase the drainage efficiency of the watershed. With resulting decreased time of concentration and increased discharge, possible results include increased erosion potential, channel incision with accompanying problems, as well as reducing moisture availability to vegetation (USDA Forest Service 1996, Schnackenberg and MacDonald 1998). It has also been demonstrated that sediment "pulses" from road systems can move into stream networks for decades after road construction and timber removal are completed (USDA Forest Service 1996).

Average scores for the sediment delivery and erosion source evaluation for roads, skid trails and mass wasting are given in Figure 15 for sections 3, 5, and 31 which were impacted by road construction and timber removal during 1996-1998.

Figure 15. Mean Sediment Delivery Scores for Roads, Skid Trails and Mass Wasting

Section	Mean Road Score	Mean Skid Trail Score	Mean Mass Waste Score	Total Score
3	26	4	22	52
5	28	6	28	62
31	34	8	26	68
	Low <31	Low< 7	Low < 28	Low <66
	Moderate 31-50	Moderate 7-10	Moderate 28-45	Moderate 66-105
	High > 50	High >10	High > 45	High >105

Scores from the sediment delivery assessment suggest that the current road network in the South Fork is contributing a relatively "low" level of sediment to the stream system. This qualitative assessment can be attributed to the quality of initial road building, but also to how recently the roads were built. To avoid the potential cumulative effect of increased sediment in streams from roads, regular monitoring and maintenance of stream crossing areas and overall road system health must be part of future land management plans in the watershed. Vegetation levels on cut banks should also be increased to improve binding root mass and decrease erosion potential. The road directly adjacent to Deadman's Creek upstream from the main road crossing should be obliterated and restored to pre-road conditions. Otherwise, road placement in the watershed is generally excellent.

Figure 16 - Road Density by Section

Section 3 – 2.5 mi/sq. mi **Section 5** – 2.75 mi/sq. mi **Section 31** – 4.2 mi/sq. mi

Sediment delivery scores and road density in sections 3 and 5 are low. Additional roading in Section 31, with higher density (4.2 miles/sq. mile) and a moderate sediment delivery score should be minimized to reduce the possibility of cumulative effects.

Figure 17 BMP Audit Summary – from 1998 Forestry BMP Audit Report

Practice	**DNRC**	**Fed.**	**Industry**	**Bair Ranch**
BMP Application	96%	92%	95%	98%
BMP Effectiveness	99%	95%	95%	99%
SMZ Application	96%	96%	94%	100%
SMZ Effectiveness	100%	98%	100%	100%

Figure 17 shows a comparison of average Forestry BMP scores between state, federal, and industry in 1998 with the two units audited in 1999 on Bair Ranch

Foundation lands by the eastern Montana BMP team (Fortunate et al. 1998). The two Bair cutting units were chosen randomly to provide a depiction of the overall level of adherence to the BMP guidelines. The first site was in section 5, adjacent to the South Fork and upstream from Deadman's Gulch. The second site was in section 25, near the main road and adjacent to Post Creek. The Bair Ranch Foundation scores clearly demonstrate overall excellent adherence to the Montana Forestry BMP guidelines. Recommendations made by the BMP team included increasing slash filter/armoring levels on culverts and developing a long -term road maintenance plan to include regular culvert maintenance.

Management and Restoration Recommendations

Looking back at the original questions asked in the study provides a good starting point in approaching possible management and restoration alternatives for the South Fork watershed. Again, the goal of any ecologically-based management and restoration plan should aim at restoring the natural ecosystem processes which will through time allow for the recovery of the structure and function of the ecosystem.

First, what processes are causing habitat loss, or in this case, habitat degradation? Impacts to riparian areas throughout the drainage are primarily the result of under-regulated or un-regulated grazing. Historical land-use in this remote drainage before logging activity began in 1996 centered first on sheep, then cattle grazing. Historical recreational impacts (fishing and hunting) and the cumulative effects of timber removal impacts during three seasons of logging are relatively minor when compared with the effects of riparian grazing. This conclusion is based on the results of the various parts of this study. As mentioned previously, high levels of bank trampling severely alters the natural migration of stream channels within the floodplain and does not allow the system to maintain a more naturally variable state. Bank trampling and compaction also limits the ability of riparian areas to function as a "sponge", regulating infiltration and release of groundwater during dry periods. Specifically, the low physical component scores of the riparian ecological condition assessment suggest an overall loss of function. Cumulative impacts resulting from the additional impacts of logging and recreation may be more readily detected in the future and should be monitored periodically.

Secondly, what areas are important for fish, and why? With regards to the WCT population in the South Fork, the upper watershed above the barrier falls impacts the primary habitat areas in the main stream channel and should be considered important in maintaining proper function of the aquatic system. Land use impacts should be minimized in riparian areas in the drainage and ideally, a period of rest from grazing would allow the stream channels to begin adjusting to a state of long-term dynamic equilibrium. The period of rest would be determined by the rate of recovery.

A possible alternative to the rest period would be to prescribe a grazing strategy that fits the specifics of the various parts of the stream system. This would require a substantial initial input from the landowners in the drainage for fencing as well more time required for management and monitoring. It should be noted that the South Fork watershed provides an excellent opportunity to demonstrate the effects of various recovery strategies, including rest-rotation grazing, landscape-oriented riparian pastures and/or season of use based strategies (Adams and Fitch 1998). The use of "before and after" pictures from different techniques can be a powerful tool in developing effective grazing management strategies. The landowners in the watershed also have an excellent opportunity to demonstrate the positive benefits of working together to develop comprehensive, watershed-wide management strategies. Given the ability to develop off-stream watering sites, increase range monitoring, and rotate pastures to alter season and intensity of use, total stream channel recovery can be achieved (Elmore 1992). Without active grazing management, the stream system will continue to degrade.

Regarding roads, perhaps the most pressing management concern regarding roads is the cumulative impact of bank and channel trampling immediately upstream of culverts, where cattle “ponds” have developed adjacent to approximately 25% of stream crossings. Future monitoring and management of the road network must deal with partially and fully blocked culverts and solidly reinforce degraded banks at all culvert openings. It should also be noted that the South Fork drainage has remained relatively free from noxious weed infestation. Canada thistle is present in small quantities but could be eradicated manually relatively easily. Recent meetings between the landowners in the South Fork have pinpointed noxious weed prevention as a high-priority land-management goal. Every possible effort should be made by landowners in the South Fork to work together to eradicate current noxious weeds and avoid any further infestation.

Next, where has habitat been impaired and what aspects of habitat have changed? Looking at the overall riparian health score in map 5 the aquatic and riparian system in the South Fork has been impaired in all WCT habitat areas with 76 % of polygons assessed having a non-functional or functional at risk rating. The difference between the mean vegetation health score and the mean physical attribute health score suggests that the impacts of trampling and channel alteration are the most pressing concern. The alterations to channel dynamics have been caused primarily by unregulated grazing strategies.

What is the relative importance of the various habitat changes to fish and what is the present trend of changes in the system? The general simplification of the stream system alters groundwater recharge dynamics, increases fine sediments which affect reproductive success rates and generally limits habitat range for WCT. Again with no competition and little utilization, decreases in stream complexity currently have little apparent negative impacts on the population. Difficulty in restoring the population after a population crash would most likely result given the current level of ecological functioning. With continued grazing impacts and increased levels of other land use activities, the South Fork system will continue to decline.

Finally, what changes are reversible, what is the expected effectiveness of potential remedies, what are the effects of those remedies on other land uses and ecosystem components, and what are the relative costs of the potential remedies over the long term?

Alternative grazing management strategies on Bair and USFS lands include the possibility of a rest period, as well as the development of specific grazing prescriptions. A period of rest (the length determined by monitoring recovery) would most rapidly allow the system to reverse the current trend towards simplification caused by widespread impacts to stream banks and riparian areas.

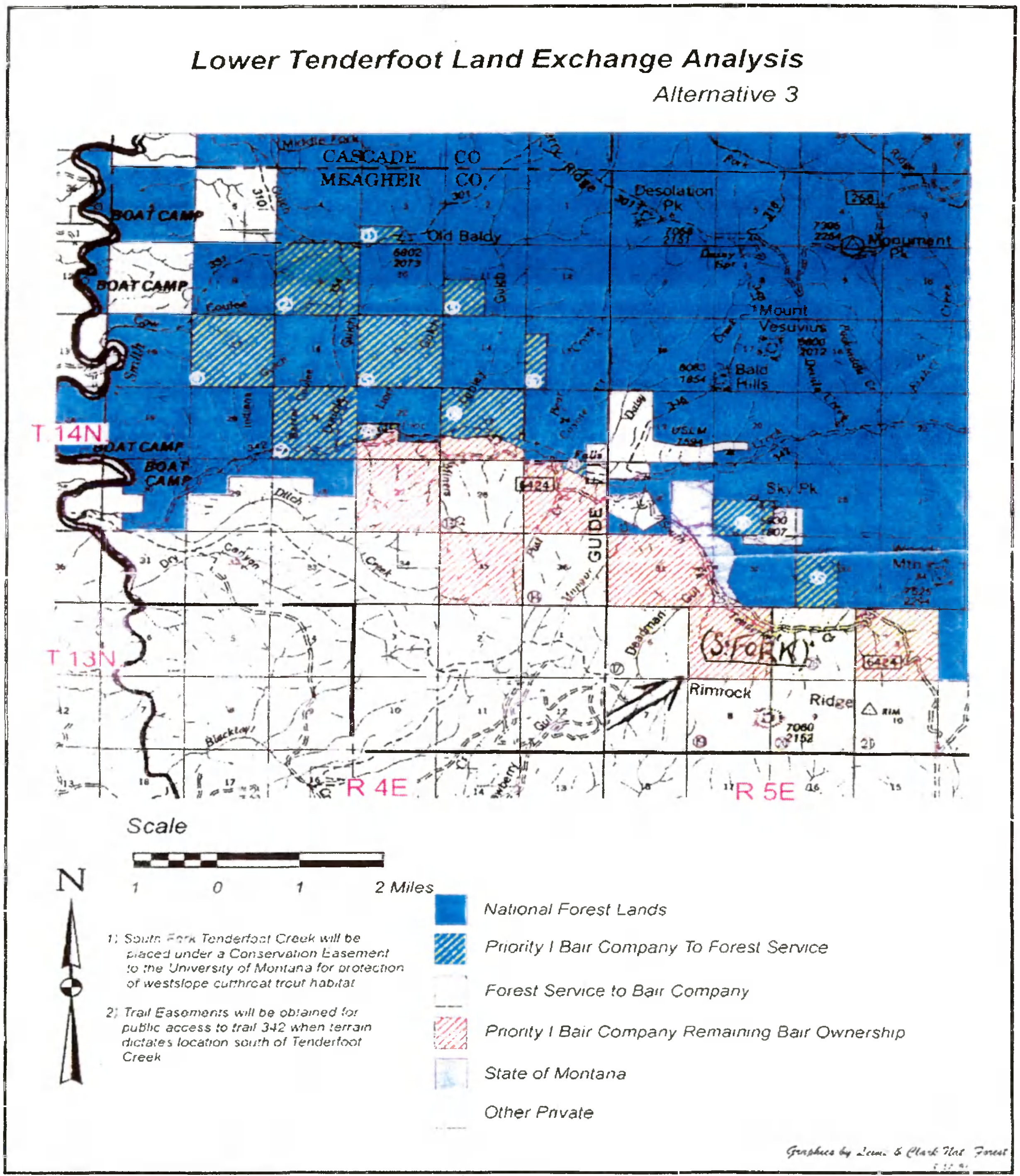
More active forms of restoration such as instream structures designed to increase complexity and provide habitat as well as planting shrubs to stabilize banks are not necessary at this juncture. With or without a period of rest, active grazing management based on specific prescriptions will improve the ecological condition of the stream system. Given more active management, future analysis should demonstrate that without the impacts of unrestricted grazing in riparian areas, the system will move towards a higher level of complexity and better perform its many ecological functions.

Grazing management on the State/Zehntner lands already supports significant infrastructure. Some repairs to fencing, additional fencing, off-stream watering sites and monitoring of riparian pasture usage would greatly aid in system recovery and would not be economically prohibitive. Assistance from state aquatic resources protection funds is available for additional fencing and grazing management requirements. Specifically, the Future Fisheries Improvement Program provides approximately one million dollars from the sale of Montana fishing licenses for projects that restore habitat for native fishes.

Possible Impacts of Proposed Land Swap

A map of one alternative of the proposed land exchange between the Bair Ranch Foundation and USFS is shown below. Because the exchange is still pending, the exact areas involved remain undecided. This alternative is provided as a sketch to look at possible effects of the land swap.

Map7 — One Alternative for Lower Tenderfoot Land Exchange



Lower Tenderfoot Land Exchange Analysis

Alternative 3

1) South Fork Tenderfoot Creek will be placed under a Conservation Easement to the University of Montana for protection of westslope cutthroat trout habitat

2) Trail Easements will be obtained for public access to trail 342 when terrain dictates location south of Tenderfoot Creek

Whether the land exchange will help in restoring diminished ecological function in the South Fork currently depends to a large extent on the land management philosophy of those in charge of handling the Bair Ranch Foundation holdings. Provided the exchange goes through, the Bair Foundation would own all land south of and including the main South Fork. The former Foundation director, Darrell Tunnicliff, sought to consolidate land ownership with the goal to "use Bair Ranch Foundation facilities and support to further education of students and the public in Ecosystem Conservation and Management" (Pfister et al. 1999). Given a similar philosophy behind future management strategies, consolidating ownership in the South Fork would simplify the development of active grazing management to assist in stream system recovery.

Consolidating checkerboard ownership patterns in the region would block off a larger area for the proposed Tenderfoot – Deep Creek wilderness north of the Main Tenderfoot. Resolving the checkerboard pattern will make it a better candidate for being added to the wilderness system. Future impacts from road building by the Bair Ranch Foundation to access their lands north of Tenderfoot Creek would also be avoided if the land exchange were completed. The Bair Ranch Foundation would minimize recreation impacts and possible noxious weed infestation by limiting off-road vehicle access through the South Fork to the adjacent wilderness areas of the Tenderfoot. Finally, the proposed conservation easement for the South Fork, to be overseen by the University of Montana, would be an additional positive step in protecting the long term viability of the WCT population by eliminating potential development and minimizing impacts to the riparian areas of the creek.

Conclusion

Historical precedence strongly suggests that forward thinking land management and maintenance of healthy stream and riparian systems is a valuable investment in the long term health of the landscape and human economy (Kauffman et al. 1997). Based on this watershed analysis, The South Fork stream and riparian system is generally sensitive to disturbance and has been significantly impacted primarily by unrestricted grazing practices. Increased fine sediment levels and simplification of the stream channel morphology present significant potential problems for the long-term survival of the isolated WCT population.

The South Fork watershed remains an area of great natural beauty. With a robust population of WCT and a stream system that can recover to a point of full functioning with cooperative land management improvements, the South Fork watershed presents an excellent opportunity for private and public landowners to work together to protect a “shared investment.”

Literature Cited

Adams, B., and L. Fitch. 1998 Caring for the green zone: Riparian areas and grazing management. Alberta Riparian Habitat Management Project. Alberta, Canada. 41 p.

American Wildlands, Clearwater Biodiversity Project, Idaho Watersheds Project, Montana Environmental Information Center, Pacific River Council, Trout Unlimited Madison-Gallatin Chapter, and B. Lilly. 1997. Petition for a rule to list the westslope cutthroat trout as threatened throughout its range. Submitted to U.S. Fish and Wildlife Service on June 6, 1997. 82 p.

Ames, C.R. 1977. Wildlife conflicts in riparian management: grazing. In: Importance, preservation, and management of riparian habitat. USDA Forest Service General Technical Report RM-43. Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO. pp. 39-51.

Behnke, R.J. 1992. Native Trout of Western North America. American Fisheries Society, Bethesda, MD. 275 p.

Beschta, R.L. 1994. Opportunities and challenges in the restoration of riverine/riparian wetlands. Pages 18-27 in Partnerships and opportunities in wetland restoration. EPA 910/R-94-003. U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Beschta, R.L. 1998. Forest hydrology in the Pacific Northwest: Additional research needs. Journal of the American Water Resources Association, 34:729-741.

Beven, K., R. Lamb, P. Quinn, R. Romanowicz, and J. Freer. 1995. TOPMODEL. In: Computer Models of Watershed Hydrology, edited by V.P. Singh. Water Resources Publications. Highlands Ranch, Colorado. 1130 p.

Bisson, P.A., T.P. Quinn, G.H. Reeves, and S.V. Gregory. 1992. Best management practices, cumulative effects, and long-term trends in fish abundance in pacific northwest river systems. Pages 189-231 in R.J. Naiman, ed. Watershed Management : Balancing Sustainability and Environmental Change. Springer-Verlag, New York, NY, USA.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 in W.R. Meehan, ed. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication 19. Bethesda, MD, USA.

Bond, T., personal communication 2000.

Budd, W.W.; Cohen, P.L.; Saunders, P.R. 1987. Stream corridor management in the Pacific Northwest: I.Determination of stream-corridor widths. Environmental Management 11: 587-597.

Carothers, S.W. 1977. Importance, preservation and management of riparian habitat: an overview In: Importance,preservation, and management of riparian habitat. USDAForest Service General Technical Report RM-43. Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO. pp. 39-51.

Cobourn, J. 1989. Is cumulative watershed effects analysis coming of age? Journal of Soil and Water Conservation. 44(4): 267-70.

Dodds, W.K., V.H. Smith and B. Zander. 1997. Developing nutrient targets to control benthic chlorophyll levels in streams: a case study of the Clark Fork River. Water Research. 31(7):1738-50.

Elmore, W. 1992. Riparian Responses to Grazing Practices. Pages 442-457 in R.J. Naiman (ed.) Watershed Management : Balancing Sustainability and Environmental Change. Springer-Verlag, New York, NY, USA.

Enk, M., personal communication, 2000.

Farnes, P.E., W. W. McCaughey, and K. J. Hansen. 1995. Hydrologic and geologic characterization of tenderfoot creek experimental forest Montana. USDA Forest Service. Intermountain Research Station. Bozeman, MT.

Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology. 8: 629-644.

Fortunate, N.A., P. Heffernan, K. Sanger, and C. Tootell. 1998. Montana Forestry Best Management Practices Monitoring – Final Report. Montana Department of Natural Resources and Conservation, Forestry Division, Missoula, MT. 40 p.

Frissell, C.A. and S.C. Ralph. 1998. Stream and Watershed Restoration. Pages 599-624 in R.J. Naiman and R.E. Bilby eds. River Ecology and Management Springer-Verlag, New York, NY, USA. 705 p.

Frissell, Christopher A. 1997. Ecological Principles. Pages 96 – 115 in J.E. Williams, C.A. Wood and M.P. Dombeck (eds.) Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, MD. 561 p.

Grant, G. and F. Swanson.1991. Cumulative Effects of Forest Practices. Forest Perspectives 1(4): 9-11.

Hansen, P.L., R. D. Pfister, K. Boggs, B. J. Cook, J. Joy and D.K. Hinckley. 1995. Classification and management of Montana's riparian and wetland sites. Montana Forest and Conservation Experiment Station, School of Forestry, The University of Montana, Missoula, MT. 646 p.

Heede, B.H. and J.N. Rinne. 1990. Hydrodynamic and fluvial morphologic processes: Implications for fisheries management and research. North American Journal of Fisheries Management, 3:249-267.

Hicks, B.J., J.D. Hall, P.A. Bisson, and J.R. Sedell. 1991. Responses of salmonids to habitat changes. Pages 483-518 in W.R. Meehan (ed.) Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication 19. Bethesda, MD, USA.

Holdorf, H.D. 1981. Soil Resource Inventory – Lewis and Clark National Forest. Interim In-service Report.

IDL–Idaho Dept. of Lands. 1994. A cumulative watershed effects process for Idaho.

Kauffman, J. B., R.L. Beschta, N. Otting, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. Fisheries 22:12-24.

Kondolf, G.M., and E.R. Micheli. 1995. Evaluating stream restoration projects. Environmental Management, 19:1-15.

Leary, R.F., T. Dotson, D. Genter, B. Hill, G. Holton, J. Huston, K.L. Knudson, S. Rumsey, and G.K. Sage. 1991. Westslope cutthroat trout restoration program: past and present distribution, brood stock program, and conservation genetics committee report. Unpubl. Report, University of Montana Genetics Laboratory, Missoula. 23 pp.

Leopold, L. 1994. A View of the River. Harvard University Press. Cambridge, MA. 298 p.

Linacre, E. 1977. A simple formula for estimating evaporation rates in various climates, using temperature data alone. Agricultural Meteorology. 18 (6): 409-424.

Lull, K.J., J.A. Tindall, and D.F. Potts. 1995 Assessing nonpoint-source pollution risk. Journal of Forestry. 93:35-40.

McCammon B., J. Rector, and K. Gebhardt. 1998. A framework for analyzing the hydrologic condition of watersheds. USDA Forest Service and USDI Bureau of Land Management.

McClernan, H.G. 1969. Geology of the Sheep Creek area, Meagher County, MT. Unpublished Master's Thesis. Montana College of Mineral Science and Technology. 51p.

Montgomery, D.R., G.E. Grant, and K. Sullivan. 1995. Watershed analysis as a Framework for implementing ecosystem management. Water Resources Bulletin 31:369-386.

Montgomery, D.R. and J.M. Buffington. 1997. Channel reach morphology in mountain drainage basins. Geological Society of America Bulletin 109: 596-611.

MT Department of Fish, Wildlife and Parks (FWP). 1999. Memorandum of Understanding and Conservation Agreement for Westslope Cutthroat Trout in Montana. MT FWP. Helena, MT 28 p.

MT Dept of Natural Resources and Conservation. 1999. Best Management Practices for Grazing. MT DNRC. Helena, MT. 28 p.

Naiman, R.J. 1992. Elements of Ecologically Healthy Watersheds. Pages 152-188 in R.J. Naiman (ed.) Watershed management: Balancing sustainability and environmental change. Springer-Verlag, New York, NY, USA.

NRC (National Research Council). 1992. Restoration of aquatic ecosystems: Science, technology, and public policy. National Academy Press, Washington, DC, USA.

Olsen, D.S., A.C. Whitaker, and D.F. Potts. 1997. Assessing stream channel stability thresholds using flow competence estimates at bankfull stage. Journal of the American Water Resources Association, 33:1197-1207.

Parrett, C., and J.A. Hull, 1984. Streamflow characteristics of mountain streams in Western Montana. USGS Open File Report 84-244. 74 p.

Parrett, C., J.A. Hull, and R.J. Omang, 1987. Revised Techniques for estimating peak discharges from channel width in Montana. USGS Water Resource Investigations Report 87-4121. 34p.

Patton D.R. 1977. Riparian research needs. In: Importance,preservation, and Management of riparian habitat. USDA Forest Service General Technical Report RM-43. Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO. pp. 39-51.

Pfankuch, D. 1978. A stream reach inventory and channel classification evaluation (modified 1990 version). Lolo National Forest, Missoula, MT.

Pfister, R.D., B.L. Kovalchik, S.F. Arno, and R.C. Presby. 1977. Forest habitat types of Montana. USDA Forest Service General Technical Report INT-34. Intermountain Forest and Range Experiment Station, Ogden, UT. 175 p.

Rademacher, G. 2000. Personal communication. Meagher County Newspaper.

Reid, Leslie M. and Thomas Dunne. 1984 Sediment Production From Forest Road Surfaces.Water Resources Research. 20:1753-1761.

Reid, Leslie M. Cumulative Watershed Effects and Watershed Analysis. 1998. Pages 476-500 in R.J. Naiman and R.E. Bilby (eds.) River Ecology and Management Springer-Verlag, New York, NY, USA. 705 p.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, CO.

RWRP. 1999. Riparian and Wetland Research Program, field workbook. The University of Montana, Missoula, MT. 200 p.

Satterlund, D. and P.W. Adams. 1992. Wildland Watershed Management 2^{nd} edition. John Wiley and Sons, New York, NY. 436 p.

Schnackenburg, E.S., and L.H. MacDonald. 1998. Detecting cumulative effects on headwater streams in the Routt National Forest, Colorado. Journal of the American Water Resources Association. 34:1163-1177.

Shepard, Bradley B., B. Sanborn, L. Ulmer, and D.C. Lee. 1997. Status and Risk of Extinction for Westslope Cutthroat Trout in the Upper Missouri River Basin, Montana. North American Journal of Fisheries Management. 17:1158-1172.

Shepard, B.B., M. Taper, R.G. White and S.C. Ireland. 1998. Influence of abiotic and biotic factors on abundance of stream-resident westslope cutthroat trout in Montana streams. Final Report to USDA, Forest Service, Rocky Mountain Research Station. Boise ID, USA.

Smith, D.I. and P. Stopp. 1978. The River Basin: An Introduction to the Study of Hydrology. Cambridge University Press. Cambridge, U.K. 120 p.

Stanford, J.A., J.V. Ward, W.L. Liss, C.A. Frissell, R.N. Williams, J.A. Lichatowich, and C.C. Coutant. 1996 A general protocol for restoration of regulated rivers. Regulated Rivers: Research and Management. 12:391-413.

USDA Forest Service, 1993. Research and Cumulative Watershed Effects. USDA Forest Service Pacific Southwest Research Station, General Technical Report PSW-GTR 141. 118 p.

USDA Forest Service. 1993. Forest Ecosystem Management: An Ecological, Economic, and Social Assessment. Report of the Forest Ecosystem Management Team.

USDA Forest Service (Moll). 1996. Road Closure and Obliteration in the Forest Service. USDA Forest Service San Dimas Technology and Development Center. 49 p.

USGS. 1999. An Assessment of Stream Habitat and Nutrients in the Elwha River Basin: Implications for Restoration. USGS Water Resources Investigations Report 98-4223. 38p.

USGS. 1995. Nutrients, Suspended Sediment, and Pesticides in Streams in the Red River of the North Basin, Minnesota, North Dakota, and South Dakota, 1993-1995. USGS Water Resources Investigations Report 97-4053.

Vogel, R.M., and N.M. Fennessey. 1995. Flow duration curves II: A review of applications in water resources planning. Water Resources Bulletin, 6:1029-1040.

Washington State Forest Practices Board (WFPB). 1993. Standard Methodology for Conducting Watershed Analysis, Version 2.0.

Watson, V.J., G. Ingman, and B. Anderson. 1999. Scientific Basis of a Nutrient TMDL for a River of the Northern Rockies. In: 1999 Wildland Hydrology Symposium Proceedings, Bozeman, MT.

Weaver, T.M., and J.J. Fraley. 1993. A method to measure emergence success of westslope cutthroat trout fry from varying substrate compositions in a natural stream channel. North American Journal of Fisheries Management 13: 817-822.

Wissmar, R.C. and R.L. Beschta. 1998. Restoration and management of riparian ecosystems: A catchment perspective. Freshwater Biology. 40:571-585.

Woirhaye, C. Tenderfoot. Unpublished Account of Homestead Life.

Appendix A RWRP Assessment Form

RWRP LOTIC INVENTORY FORM

May 15, 1999

ADMINISTRATIVE DATA

A1.

A2.

A3a. BLM State Office: ____________ **A3b.** BLM Field Office: ____________

A3c. BLM District: ____________ **A3d.** BLM Resource Area: ____________

A3e. **A3f.**

A3g: **A3h:**

A4. USFWS Refuge: ____________

A5. Reservation: ____________

A6. NPS Park/NHS: ____________

A7. BOR Project: ____________

A8. USFS National Forest: Lewis and Clark

A9. **A10.** Date field data collected: ____________ **A11.** Observers: ____________

A12.

A13.

LOCATION DATA

B1. State/Province: MT **B2.** County/Municipal District: Meagher

B3. Allotment/Range Unit: ____________

B4. Area name: South Fork Tenderfoot Creek **B5.** Polygon No.: 4

B6. Location: T: 13N R: 4W Sec: 4-5

1/4 Sec: 4/NW 5/NE 1/4 1/4 Sec: 4/SW 5/NE **B7.** Elev. (ft): 5300 ; (m): ____________

B8.

B9a. UTM coordinates of polygon UPPER END: Easting: 0491874 ; Northing: 5196216 ; Zone: 12

B9b. UTM coordinates of polygon LOWER END: Easting: 0490405 ; Northing: 5196756 ; Zone: 12

B9c. UTM coordinates of any other point of interest in the polygon: East: ____________ ; North: ____________ ; Zone: ____________

B9d. GPS Unit #: 5 WPt Upper: 4 WPt Lower: 6 WPt Other: ____________

B9e. Comments: ____________

B10. Quad map(s): ____________

SELECTED SUMMARY DATA

C1. Wetland type: NA **C2.**

C3a. Is the entire polygon an upland? (Yes; No): No If No, **C3b.** Does the polygon consist entirely of functional wetland types? (Yes; No): No **C3c.** **C3d.** Percent of total polygon: 0

C4. Does the polygon contain a defined streambank or channel? (Yes; No): Yes

C5. **C6.**

C7a. Was the Pfankuch rating used? (Yes; No): Yes

C8.

VEGETATION DATA

D1a. Wetland prevalence index:

D1b. Vegetation structural diversity:

Trees

D2a. Are trees present? (Yes; No): Yes

D2b. Tree species by canopy cover class and percent age group

SPECIES	COV	SDLG/DEC	SPLG/DEC	POLE/DEC	MAT/DEC	DEAD	D5. Seedling/Sapling Utilization
Picea X	4	1 / -	2 / -	2 / -	4 / 2	P	None
PSEMEN	P	- /	- /	P / -	8 / P	-	None
POPTRE	P	T / -	P / -	1 / -	8 / P	-	None
		/	/	/	/		
		/	/	/	/		
		/	/	/	/		
		/	/	/	/		
		/	/	/	/		
		/	/	/	/		
		/	/	/	/		
		/	/	/	/		
		/	/	/	/		
		/	/	/	/		
		/	/	/	/		
		/	/	/	/		

Shrubs

D6a. Are shrubs present? (Yes; No): Yes

D6b. Shrub species canopy cover, age/size groups, and utilization

SPECIES	COV	SDLG-SPLG/UTIL	MATURE/UTIL	DEC-DEAD/UTIL	**D6c.** Shrub Growth Form (N,F,U)
SYMALB	P	4 / L	6 / L	0 / 0	N
ALNINC	2	2 / L	7 / N	1 / L	N
SALBEB	2	2 / N	8 / N	0 / 0	N
CORSTO	1	3 / L	6 / M	1 / L	N
SALLUT	1	1 / L	9 / L	0 / 0	N
ROSWOO	P	3 / N	7 / N	0 / 0	N
RIBLAC	P	2 / N	8 / N	0 / 0	N
JUNHOR	P	1 / N	9 / N	0 / 0	N
LINBOR	T	1 / N	9 / N	0 / 0	N
SPIBET	T	T / N	F / L	0 / 0	N

D7. Graminoids

Graminoids present? (Yes; No): Yes

SPECIES	COV
POAPRA	/ P
PHLPRA	/ P
CARROS	/ P

D8. Forbs

Forbs present? (Yes; No): Yes

SPECIES	COV
THAOCC	/ T
FRAVIR	/ T
TAROFF	/ T
STRAMP	/ T
EQUARV	/ P
ARNCOR	/ T

D9. Plant Group by Canopy Cover

Layer	Trees	Shrubs	Graminoids	Forbs
3 (>6.0 ft):	4	P	0	0
2 (>1.5 - 6.0 ft):	1	2	P	T
1 (0 - 1.5 ft):	T	1	P	P

D10. Total canopy cover by lifeform:

Trees: 5 Shrubs: 3

Graminoids: 2 Forbs: 1

D11. Total canopy cover by woody species: 7

D12. Total canopy cover by all plant lifeforms: 9

Weed Data

D13a. Are invasive weeds present ? (Yes; No; NC): Yes

If **Yes, D13b.** The portion of the polygon ***infested*** by each of the following invasive weed species:

Canada Thistle:	P	Leafy Spurge:	
Common Hound's-tongue:		Purple Loosestrife:	
Common Tansy:		Sulphur Cinquefoil:	
Dalmatian Toadflax:		Russian Olive:	
Diffuse Knapweed:		Saltcedar (Tamarisk):	
Spotted Knapweed:		Scotch Thistle:	
Russian Knapweed:		Dyer's Woad:	
Whitetop:		St. John's Wort:	
Others:			
Others:			
Others:			

D13c. What percent of the polygon is ***infested*** by all invasive weeds? ________

D14. Habitat Types and Community Types

Classification Type Name	Phase	Percent of Polygon	Successional Stage or Comments
PICEA/CORSTO		F	

D15a. Are undesirable herbaceous species present? (Yes; No; NC): Yes

If **Yes**, **D15b.** Record the combined canopy cover of all undesirable herbaceous species observed: T

D16. Polygon trend: Improving, Degrading, Static, or Status Unknown? Status Unknown

D17. Explain trend description and give other vegetation comments:

WATER QUALITY DATA (TMDL DATA)

E1.

PHYSICAL SITE DATA

F1. Does the polygon contain a stream bank or channel bottom? (Yes; No; NC): Yes If **No**, go to item **F17a**.

F2a. Is the channel bottom visible? (Yes; No; NC): Yes

If **Yes**, **F2b.** Give the percent of each size (must approx. 100%):

P	>20 inches (Medium Boulders +)	1	0.6 - 2.5 inches (Coarse Gravel)
1	10 - 20 inches (Small Boulders)	1	0.08 inches - 0.6 inches (Fine Gravel)
2	5 - 10 inches (Large Cobbles)	2	0.062 mm - 2 mm (Sand)
2	2.5 - 5 inches (Small Cobbles)	1	<0.062 mm (Silt and Clay)

F3a. Are bank materials present? (Yes; No; NC): Yes

If **Yes**, **F3b.** Give the percent of each size (must approx. 100%):

T	>20 inches (Medium Boulders +)	1	0.6 - 2.5 inches (Coarse Gravel)
P	10 - 20 inches (Small Boulders)	1	0.08 inches - 0.6 inches (Fine Gravel)
P	5 - 10 inches (Large Cobbles)	2	0.062 mm - 2 mm (Sand)
P	2.5 - 5 inches (Small Cobbles)	5	<0.062 mm (Silt and Clay)

F4a. Is there active lateral cutting of stream? (Yes; No; NC): Yes

If **Yes**, **F4b.** How much of the stream length displays active lateral cutting: 2

F5. Percent of the total bank length unstable (0-5%; 6–25%; 26–45%; over 45%; NC): 6-25%

F6a. Is the streambank altered by on-site human activities? (Yes; No; NC): Yes

If **Yes**, **F6b.** Percent of the bank length that has human-caused alterations? 3

F6c. Of this, how much resulted from: (must approx. 100%)

Grazing: F Logging: ____ Railroads: ____ Vegetation Removal: ____

Roads: ____ Mining: ____ Recreation: ____ Other: ____

Explain "other": ____

F7. Percent of the streambanks with deep, binding root mass (0-35%; 36–65%; 66–85%; over 85%; NC): over 85%

F8. Percent of polygon with sufficient fine material to hold water and act as a rooting medium (0-35%; 36–65%; 66–85%; over 85%; NC): over 85%

F9. Rosgen stream types recorded and the percent of the stream length accounted for by each:

Rosgen 1: C4B / 20% Rosgen 2: C3 / 20% Rosgen 3: C3B / 60% Rosgen 4: ____ / ____

F10a. Does the 7.5 min. topo map accurately represent the sinuosity of the stream? (Yes; No; NA; NC): No

If **No**, **F10b.** Determine sinuosity in the field; If **Yes**, determine sinuosity in the office from topo map: 1.2

F11. Average non-vegetated stream channel width: (ft 6 ; (m): ______

F12. Stream gradient (percent): 4

F13a. Active downcutting of the stream? (Yes; No; NC): Yes If **Yes**, **F13b.** Percent of stream actively downcutting: 2

F14a. Headcuts present? (Yes; No; NC): No If **Yes**, **F14b.** No. of headcuts: ______ **F14c.** Average headcut height (ft): ______

F14d. Location of headcut(s): ______

F15a. Is the stream channel braided (has multiple active channels during normal flows)? (Yes; No; NC): Yes

If **Yes**, **F15b.** Percent of the stream channel that is braided: T

F16. Indicate the best description of channel incisement (A; B; C; D):

Uppermost 1/5 of polygon is type B
Remainder is type A

F17a. Is there exposed soil surface (bare ground)? (Yes; No; NC): Y If **No** or **NC**, go to item **F19.**

F17b. Percent of the polygon which is exposed soil surface (bare ground): 1

F17c. Of this, how much is due to Natural Processes: 1 Human-caused disturbance: 9 (must approx. 100%)

F17d. Within ***each*** category (natural & human-caused), how much resulted from the listed processes?

NATURAL PROCESSES *(must approx. 100%)*		**HUMAN-CAUSED PROCESSES** *(must approx. 100%)*	
7 Erosional	______ Type Dependent	F Grazing	______ Construction
3 Depositional	______ Saline/Alkaline	______ Logging	______ Mine tailings
______ Wildlife Use	______ Within Veg. Channel Bottoms	______ Recreation	______ Other
______ Other			

Explain "Other": ______

F18. Non-vegetated ground cover. (**Note:** Bare ground and vascular plant cover recorded above.)
Rocks (>2.5 in.): P Moss: P Litter & duff: T Wood: 1

F19. Are channel point bars revegetating? (Yes; No; NA; NC): Yes

F20a. Are side drainages and hillslopes contributing to degradation of the system? (Yes; No; NA; NC): No

If **Yes**, **F20b.** Human-caused? (Yes; No; NA; NC): ______ Causes: ______

F20c. Natural cause? (Yes; No; NA; NC): ______ Major soil parent material: ______

F21. Is there a nearby source ***on the system*** for large woody debris to enter the stream? (Yes; No; NA; NC): Yes

F22a. Average riparian zone width (ft): 12 ; (m): ______

F22b. Riparian zone width range (ft): 3 to 30 ; (m): ______ to ______

F23. Is the average riparian zone widening? (Yes; No; NA; NC): No

F24. Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting? (Yes; No; NA; NC): Yes

F25a. Livestock-caused pugging and/or hummocks present (Yes; No; NC): Yes

If **Yes**, **F25b.** Percent of polygon affected: 3

F25c. Distribution of hummocks/pugging: Within streambanks: 3 Remainder of polygon: 7 (must approx. 100%)

F26a. Are seeps or springs present? (Yes; No; NC): Yes

If **Yes**, **F26b.** Number of seeps and springs: 3

F26c. How many springs and seeps had hummocks and/or pugging in 25% or more of the wetted area? All

F26d. Location of the springs and seeps: ______

F27a. Is wetland type a pooled channel of an intermittent stream (item C1)? (Yes; No; NC): No

If **Yes**, **F27b.** Percent of the channel length with pooled water: ______

F27c. Is this pooled water expected to remain at the surface through the remainder of the growing season? (Yes; No): ______

F27d. Location of the pools: ______

F28a. Is there evidence of beaver in the polygon? (Yes; No; NC) No

If **Yes**, **F28b.** (Active; Inactive): ______ **F28c.** Describe the type and amounts of beaver activity observed:

F28d. Number of beaver dams and lodges observed: ______

F28e. Level of beaver activity (number of chewed stems). (1-25; 26-100; over 100; NC): ______

F28f. How many beavers were observed? ______

Where? ______

F29. Comments (Summarize unique characteristics or problems not evident from the data collected. Include topics related to any of the optional data. Consider current and historic attributes resulting from human-caused and natural processes.):

As noted earlier, several stream types occur. The upper 1/5 has a smaller substrate and lower gradient than the adjacent 1/5 downstream that is forced into a narrow, canyon-like area with large boulders and significant large woody debris. This section prevents cattle access. The lower 3/5 demonstrates effects of greater access ie. channel trampling. Also smaller substrate and more bank instability.

F30. Detailed description of upper and lower ends of the polygon:

Upper end begins 200 yards below the main road (marker visible from road) Upper limit is marked with a confluence with a small tributary.

Lower limit of polygon is marked by the intersection of the road and creek at the main bridge.

PHOTOGRAPH DATA

G1a. Identification of photos (taken at the ***upstream*** end of polygon): Roll # 1 Photographer: SK

Photo numbers: (upstream): 22 (downstream): 23 (others):

G1b. Location of "other" photos:

G1c. Description of views (up):

(down):

(others):

G2a. Is there an adjacent polygon upstream of this polygon? (Yes; No): Yes

G2b. Is there an adjacent polygon downstream of this polygon? (Yes; No): Yes

G3a. Identification of photos (taken at ***downstream*** end of polygon): Roll # 1 Photographer: SK

Photo numbers: (upstream): 24 (downstream): 25 (others):

G3b. Location of "other" photos:

G3c. Description of views (up):

(down):

(others):

G4. Film and Camera Specifications

Film brand: Film speed (ASA): Lens diameter (mm): Lens focal length (mm):

OPTIONAL DATA

H1. Aspect: NW **H2.** Veg. use by animals (0-25%; 26-50%; 51-75%; 76-100%): 0-25%

H3. Adjacent uplands (Agriculture; Grassland; Shrubland; Forest; or Other): Forest

H4a. Were Category 2 (T & E) plant species observed? (Yes; No): No If **Yes**, **H4b.** Species:

H4c. Location(s):

H5a. Do subsurface water supplies, independent of flowing surface water in the area, appear to influence area vegetation? (An example of this is a hardwood draw with riparian vegetation, but rarely flowing surface water.) (Yes; No): No

If **Yes**, **H5b.** Describe the situation:

H6 Bankfull width/depth ratio: 14 **H7.** Entrenchment ratio (floodprone width/bankfull width) (<1.4; 1.4-2.2; >2.2): 1.4-2.2

H8. Distribution of exposed soil surface (item F17b) (must approx. 100%):

Inside/outside the bank/channel area: Inside: 3 Outside: 7 **H9.** Percent of streambank accessible to livestock: 4

H10a. Has the bank configuration or channel profile been modified by construction? (Yes; No; NC): No

If **Yes**, **H10b.** How much of the bank or channel length is modified? ______

H10c. What part resulted from the various sources: (must approx. 100%)

Dikes ______
Berms ______
Dams ______
Rip-rap ______
Other ______ Explain "Other": ______

Road Construction ______
Water Diversion Structures ______
Vegetation Removal ______
Channelization ______

Railroads ______
Mining ______
Bridges ______
Logging ______

H10d. Location(s): ______

H10e. If human-caused channel modifications are present, are they stable? (Stable; Unstable): ______

H10f. What is the effect of the modifications on the immediate and downstream channel?

______

Waterfowl Data

H11a. Were waterfowl nests or broods observed? (Yes; No): No

If **Yes**, **H11b.** Describe: ______

Fishery Data

H12a. Does the polygon contain a fishery? (Yes; No; Unknown): Yes

If **Yes**, **H12b.** Is it a sport fishery, non-sport fishery, or unknown: unknown

H12c. Fish types present, if known (use common names or descriptions): Westslope cutthroat trout

H12d. How many fish were observed? (0; 1-10; 11-50; >50): 11-50

H12e. If the polygon does not contain a fishery, is there potential for one? (Yes; No; Unknown): ______

Explain: ______

Amphibian and Reptile Data

H13a. Were amphibians observed? (Yes; No): No

If **Yes**, **H13b.** Number observed: Frogs: ______ Toads: ______ Salamanders: ______

H14a. Were reptiles observed? (Yes; No): ______

If **Yes**, **H14b.** Number observed: Snakes: ______ Turtles: ______ Lizards: ______

H15. List amphibian or reptile species and the quantity of each identified in the polygon.

Spp. #1	No.:	Loc.:
Spp. #2	No.:	Loc.:
Spp. #3	No.:	Loc.:
Spp. #4	No.:	Loc.:

Threatened and Endangered Species Data

H16a. Were T & E animal species observed? (Yes; No): No

If **Yes**, **H16b.** What species? Peregrine Falcon: ______ Bald Eagle: ______ Bull Trout: ______

Peregrine Falcon Nest: ______ Bald Eagle Nest: ______

H16c. Other species observed:

Species	Number	Species	Number

H16d. Location in polygon where T & E animals or nests were sighted:

______

Appendix B Intensity –Duration Frequency Curve for Helena, MT

RAINFALL INTENSITY- DURATION-FREQUENCY CURVES