

Guidelines for Managing Cattle Grazing in Riparian Areas to Protect Water Quality: Review of Research and Best Management Practices Policy

by

**Jeffrey C. Mosley,
Philip S. Cook,
Amber J. Griffis,
and
Jay O'Laughlin**

*Internet Edition
Published December 1999*

[This edition is published in Portable Document Format (PDF). The content is identical to the original 1997 edition; however, some formatting changes occurred in conversion from its original format to PDF.]

Idaho Forest, Wildlife and Range Policy Analysis Group
Jay O'Laughlin, Director

Idaho Forest, Wildlife and Range Experiment Station
Charles R. Hatch, Director

- ! The Idaho Forest, Wildlife and Range Policy Analysis Group was established by the Idaho Legislature in 1989 to provide objective analysis of the impacts of natural resource proposals (see Idaho Code § 38-714).
- ! The Policy Analysis Group is administered through the University of Idaho's College of Forestry, Wildlife and Range Sciences, Charles R. Hatch, Dean.

Advisory Committee

Bruce Bowler, Attorney Environmental interests Boise, Idaho	Mark Brinkmeyer, President Riley Creek Lumber Laclede, Idaho	Tom Geary, President Idaho Farm Bureau Burley, Idaho
Stan Hamilton, Director Idaho Dept. of Lands Boise, Idaho	Jack Lavin, Coordinator Idaho Recreation Initiative Boise, Idaho	Steve Mealey, Director Idaho Dept. of Fish and Game Boise, Idaho
Mike Medberry Idaho Conservation League Boise, Idaho	Barbara Opdahl, Outfitter Idaho Travel Council Pierce, Idaho	Dave Rittenhouse, Supervisor Boise National Forest Boise, Idaho
<u>Representing U of I Faculty</u> David L. Adams, Professor Department of Forest Resources		

Policy Analysis Group Reports

- No. 1 Idaho's endowment lands: a matter of sacred trust. *J. O'Laughlin* (March 1990).
- No. 2. BLM riparian policy in Idaho: analysis of public comment on a proposed policy statement.
K.L. Johnson, C. Mosley, J.C. Mosley, and J. O'Laughlin (June 1990).
- No. 3. Idaho Department of Fish and Game's land acquisition and land management program.
C. Wise and J. O'Laughlin (October 1990).
- No. 4. Wolf recovery in central Idaho: alternative strategies and impacts.
C. Wise, J.J. Yeo, D. Goble, J.M. Peek, and J. O'Laughlin (February 1991).
- No. 5. State agency roles in Idaho water quality policy. *A.C. Turner and J. O'Laughlin* (February 1991).
- No. 6. Silver Valley resource analysis for pulp and paper mill feasibility.
J.G. MacCracken and J. O'Laughlin, editors (October 1991).
- No. 7. A national park in Idaho? Proposals and possibilities.
J.G. MacCracken and J.O'Laughlin (June 1992).
- No. 8. Design of forest riparian buffer strips for the protection of water quality: analysis of scientific literature.
G.H. Belt, J. O'Laughlin, and T. Merrill (June 1992).
- No. 9. Analysis of methods for determining minimum instream flows for recreation.
T. Merrill and J. O'Laughlin (March 1993).
- No. 10. Idaho roadless areas and wilderness proposals.
J.G. MacCracken, J. O'Laughlin, and T. Merrill (July 1993).
- No. 11. Forest health conditions in Idaho. *J. O'Laughlin, J.G. MacCracken, D.L. Adams, S.C. Bunting, K.A. Blatner, and C.E. Keegan, III* (December 1993).
- No. 12. Grizzly bear recovery in Idaho. *J.G. MacCracken, D. Goble, and J. O'Laughlin* (November 1994).
- No. 13. Endangered Species Act at the crossroads: new directions from Idaho case studies.
J. O'Laughlin, P.S. Cook (October 1995).
- No. 14. Idaho water quality policy for nonpoint source pollution: a manual for decision-makers. *J. O'Laughlin* (December 1996).

Guidelines for Managing Cattle Grazing in Riparian Areas to Protect Water Quality: Review of Research and Best Management Practices Policy

by

Jeffrey C. Mosley,¹
Philip S. Cook,²
Amber J. Griffis,³
and
Jay O'Laughlin⁴

*Internet Edition
Published December 1999*

[This edition is published in Portable Document Format (PDF). The content is identical to the original 1997 edition; however, some formatting changes occurred in conversion from its original format to PDF.]

¹Dr. Mosley is Associate Professor and Extension Range Management Specialist, Department of Animal and Range Sciences, Montana State University, Bozeman, and was formerly Associate Professor, Department of Range Resources, University of Idaho, Moscow.

²Mr. Cook is Research Associate, Idaho Forest, Wildlife and Range Policy Analysis Group, University of Idaho, Moscow.

³Ms. Griffis was a part-time Research Assistant, Idaho Forest, Wildlife and Range Policy Analysis Group, University of Idaho, Moscow.

⁴Dr. O'Laughlin is Director, Idaho Forest, Wildlife and Range Policy Analysis Group, and Professor, Department of Forest Resources, University of Idaho, Moscow.

ABOUT THE POLICY ANALYSIS GROUP

Role and Mission. The Idaho Legislature created the Policy Analysis Group (or "PAG") in 1989 as a way for the University of Idaho to respond quickly to requests for information and analysis about current natural resource issues. The PAG's formal mission is to provide timely, scientific and objective data and analysis, and analytical and information services, on resource and land use questions of general interest to the people of Idaho.

Advisory Committee. A standing Advisory Committee (see inside cover) has specific functions assigned by the PAG's enabling legislation. The committee's main charge is to review current issues and suggest topics for analysis. Based on those suggestions, the dean of the College of Forestry, Wildlife and Range Sciences works closely with the PAG director to design analysis projects. The Advisory Committee has a responsibility to suggest the appropriate focus of the analysis. This is done iteratively, until an outline for the project is mutually agreed upon by the committee and the PAG. The outline is usually organized as a series of focus questions, and the PAG's analytical tasks are to develop replies to the questions. The PAG uses the resources of the university and other public and private organizations as needed. When the PAG becomes active on a project, the committee receives periodic oral progress reports. This process defines the scope of PAG report content and provides freedom for the PAG to conduct unbiased analysis.

Technical Review. Peer review of PAG work is absolutely essential for ensuring not only technical accuracy but also impartiality and fairness. Reviewers (see **Acknowledgments**) are selected separately for each project by the dean and PAG director, sometimes upon recommendation of the Advisory Committee, to ensure that a wide range of expertise is reflected in the design and execution of PAG reports, and that no point of view is favored. Report review criteria used by the National Research Council of the National Academy of Sciences are the guidelines furnished to PAG reviewers.

PAG Reports. This is the fifteenth report in the PAG publication series. The other fourteen reports are listed on the inside cover. The PAG is required by law to report the findings of all its work, whether tentative or conclusive, and make them freely available. PAG reports are primarily policy education documents, as one would expect from a state university program funded by legislative appropriation. The PAG identifies and analyzes scientific and institutional problems associated with natural resource policy issues. In keeping with the PAG's mandate, several alternative policy options are developed and analyzed. As an operational policy the PAG does not recommend an alternative.

Idaho Forest, Wildlife and Range Policy Analysis Group
University of Idaho
Moscow, ID 83844-1134

voice: 208-885-5776

FAX: 208-885-6226

e-mail: pag@uidaho.edu

WWW: <http://www.uidaho.edu/cfwr/pag>

ACKNOWLEDGMENTS—TECHNICAL REVIEW

The following individuals provided technical review of this report. Their efforts are gratefully acknowledged.

Dr. Kirk Lohman
Assistant Professor
Dept. of Fish and Wildlife
Resources
University of Idaho

Dr. Kendall Johnson
Professor and Head
Dept. of Range Resources
University of Idaho

Dr. Clayton Marlow
Associate Dean of Agriculture
Montana State University
Bozeman, MT

Jim Cornwell
USDA Natural Resources
Conservation Service
Boise, ID

Biff Burleigh
Idaho Soil Conservation
Commission
Boise, ID

David Blew
Idaho Soil Conservation
Commission
Boise, ID

Jon Marvel
Idaho Watersheds Project
Hailey, ID

Chapter 1 also was reviewed by:

Dr. Warren P. Clary
Project Leader
Riparian-Stream Ecology and
Management Research
Work Unit
Intermountain Research Station
Boise, ID

Dr. Paul Hook
Assistant Professor
Dept. of Animal and Range
Sciences
Montana State University
Bozeman, MT

ACKNOWLEDGMENTS—TECHNICAL ADVISORY COMMITTEE

The efforts of the Technical Advisory Committee are gratefully acknowledged. These four individuals provided guidance on the design of the plan for this study, and provided technical review of the report.

Dr. Robert Mahler
Professor
Cooperative Extension Service
University of Idaho

Dr. Terry Tindall
Extension Soils Specialist
Twin Falls Research and
Extension Center
University of Idaho

Dr. Richard Battaglia
Professor and Head
Dept. of Animal and Veterinary
Sciences
University of Idaho

Ervin Cowley
USDI Bureau of Land
Management
Boise, ID

TABLE OF CONTENTS

About the PAG	i
Acknowledgments	ii
Table of Contents	iii
Lists of Tables, Figures, and Sidebars	v
Executive Summary	1
Focus Questions and Short Replies	1
(1) What are appropriate management strategies for cattle grazing in riparian areas?	1
(2) What are Best Management Practices?	3
(3) How is cattle grazing in riparian areas addressed in Idaho water quality policy?	4
Introduction	6
Objectives	7
Chapter 1. What are appropriate management strategies for cattle grazing in riparian areas?	9
Timing and frequency of grazing	9
Effects of grazing timing and frequency on nutrient loading to surface water	10
Effects of grazing timing and frequency on sediment and streambanks	11
Effects of grazing timing and frequency on fish	11
Effects of grazing timing and frequency on vegetation	11
Effects of grazing timing and frequency on cattle behavior	12
Intensity of grazing	13
Effects of grazing intensity on nutrient loading to surface water	13
Effects of grazing intensity on fecal bacteria loading to surface water	13
Effects of grazing intensity on sediment and streambanks	15
Effects of grazing intensity on fish	17
Effects of grazing intensity on riparian graminoids	17
Effects of grazing intensity on riparian forbs	19
Effects of grazing intensity on riparian shrubs and trees	19
Grazing distribution	20
Fertilization as a method of controlling livestock grazing distribution	20
Supplemental feeding practices for better livestock distribution	20
Additional management strategies for livestock distribution	21
Grazing systems	22
Buffer strips	23
Chapter 2. What are best management practices?	25
How are BMPs established and implemented?	25
What are BMPs for cattle grazing in riparian areas?	26
Effectiveness of BMPs	35
Monitoring and modifying BMPs	38
BMPs on federal and state lands	39

Chapter 3. How is cattle grazing in riparian areas addressed in Idaho water quality policy?	40
The federal Clean Water Act	40
Idaho water quality policy	40
Water quality standards: designated beneficial uses and criteria	41
Idaho’s water quality	41
Idaho Agricultural Pollution Abatement Plan	43
Idaho Stream Channel Protection Act	43
Federal agency roles	43
U.S. Environmental Protection Agency (EPA)	43
U.S. Forest Service (USFS)	43
Bureau of Land Management (BLM)	44
USDA Natural Resources Conservation Service (NRCS)	44
State agency roles	44
Idaho Division of Environmental Quality (IDEQ)	44
Idaho Department of Water Resources (IDWR)	44
Idaho Soil Conservation Commission (ISCC)	45
Idaho Department of Lands (IDL)	45
Idaho Department of Fish and Game (IDFG)	45
Other public water quality organizations	45
Soil Conservation Districts (SCDs)	45
Basin Advisory Groups (BAGs)	45
Watershed Advisory Groups (WAGs)	46
Additional policies affecting riparian area grazing	46
Endangered Species Act (ESA)	46
PACFISH	46
INFISH	46
Interior Columbia Basin Ecosystem Management Project	47
Appendix: Proper Grazing Use, Riparian Areas BMP Component Practice	48
References Cited	51
Glossary	64
Case Examples	28
Case 1. Sawmill Creek Riparian Project	28
Case 2. Clover Creek Allotment Plan	32

LIST OF TABLES

Table 2.1. Cost-sharing programs for agriculture and livestock grazing BMP implementation in Idaho 26
Table 2.2. BMP component practices for livestock grazing lands and riparian wetlands 36
Table 3.1. Water quality impaired waters within the Interior Columbia Basin Ecosystem Management Project (ICBEMP) assessment area, 1996 42
Table 3.2. Water quality-limited waters in Idaho affected by sediment, by basin, 1996 42
Table 3.3. Anadromous fish habitat on federal lands in Idaho 47

LIST OF FIGURES

Figure 2.1. Example of the development of a riparian/wetland BMP using component practices . . . 27
Figure 2.2. Feedback loop process for nonpoint source control 38

LIST OF SIDEBARS

Sidebar 1. What are riparian areas? 6
Sidebar 2. Why are riparian areas important? 7

EXECUTIVE SUMMARY

Riparian areas* are lands adjacent to water bodies. Consequently, these lands are more moist and more productive than contiguous floodplains or uplands. Riparian areas provide a wealth of products and values including clean water, fish and wildlife habitat, recreational opportunities, and scenic beauty. These lands are also valuable sites for timber production, cropland agriculture, and livestock grazing. Appropriate management of riparian areas is thus a vital environmental and economic issue.

Livestock grazing in riparian areas is controversial. Many riparian areas in the United States have been mismanaged and degraded by improper livestock grazing. However, the negative effects of grazing in riparian areas can be minimized or eliminated with proper management. Grazing management is the key to attaining the benefits riparian areas offer livestock while maintaining water quality standards and fully functioning riparian ecosystems.

Water quality in many of Idaho's waters translates directly into conditions that support adequate habitat for fish. Protecting water quality and providing forage for cattle are only two of the many functions of land areas adjacent to water. This report addresses only the water quality protective functions of riparian zones. This is not to say that the many other values of riparian areas are less important than water quality, but these other purposes are not required by the federal Clean Water Act.

The purpose of this report is to provide management guidelines that will help livestock producers meet the goals of the Clean Water Act while grazing cattle in riparian areas. Depending on the current condition of a particular riparian area, this could mean that the producer may have to modify the timing, frequency, and intensity of grazing in order to maintain conditions that will protect water quality. These guidelines are based on a review of research results published in the scientific literature. That review is in Chapter 1 of this report. Best management practices, or BMPs,

are the Clean Water Act's approach to minimizing the adverse impacts of livestock grazing and other land-use activities on water quality. The guidelines in this report may be useful for resource stewardship in riparian areas whether or not a livestock producer is following grazing management strategies that have been officially incorporated into BMPs. Chapter 2 of this report explains the origin and purpose of BMPs, and should be informative not only for producers considering their use but also for officials responsible for designing and overseeing the implementation of BMPs.

In addition, the overall policy context of livestock grazing and water quality in Idaho is addressed in Chapter 3. Two case examples from Idaho (Sawmill Creek and Clover Creek) illustrate the relationship between scientific research and on-the-ground BMP application.

This report attempts to reply to three focus questions about riparian grazing. In short, what management strategies are indicated by research, how are BMPs administered, and how does state policy protect water quality? The full questions and short summaries of the replies are given below.

Focus Questions and Short Replies

Three focus questions were developed by the Policy Analysis Group's Advisory Committee to serve as the outline for this report. Short replies follow, with full replies in each of the three chapters of the report for which the focus questions are chapter titles.

(1) What are appropriate management strategies for cattle grazing in riparian areas?

Cattle grazing in riparian areas affects nutrients, fecal bacteria, sediments, streambanks, and vegetation in the riparian ecosystem, with associated effects on water quality. Appropriate management of grazing involves controlling the timing, frequency, and intensity of cattle use.

*Definitions of this and other technical terms are provided in the **Glossary** at the end of this document.

Riparian grazing plans should be site-specific and based upon the best research and empirical evidence available. Based upon a review of the research literature* the following guidelines are suggested as starting points for developing cattle grazing plans that will protect the functions of riparian areas that affect water quality:

1. To reduce negative impacts of grazing, determine the critical period(s) of a riparian site, and then limit grazing during the critical period(s) to no more often than once every 3 or 4 years. Critical periods and impacts are likely to be either in late spring-early summer, when streambanks are more easily broken down by trampling; or late summer-early fall, when excessive browsing may damage vegetation. Each site has its own critical period that should be individually determined. Important critical period variables are soil moisture, plant species composition, and animal behavior patterns. Sites may be grazed every year if use does not occur during the critical period(s). Extended periods of rest or deferment from grazing may be needed to enable recovery of badly degraded sites.
2. To maintain streambank stability, limit cattle access to surface water when adjacent streambanks and shorelines are overly wet and susceptible to trampling and sloughing. Streambank trampling can often be reduced by capitalizing on the natural foraging behavior of cattle. Cattle generally avoid grazing excessively wet sites or in cold-air pockets. Cattle seek out wind-swept ridges, and they graze on upland forage when it is more palatable than forage in riparian areas.
3. To increase vegetative reproduction, schedule cattle grazing to increase tiller (or sprout) density by periodically removing apical meristems (or growing points) in shoots of desirable plants. More vegetation reduces the transport of nutrients, fecal bacteria, and sediment in overland flow. If new plants need to be established **and** if the desirable plant species do not reproduce vegetatively, these plants should be allowed
4. to reach seed maturity no less often than once every 3 or 4 years.
4. To graze a site more than once per growing season, moisture and temperature conditions should be conducive to plant regrowth. For such sites, allow a recovery period of at least 30 to 60 days, depending on vegetation type, before regrazing within the same growing season. Grazing more often and for shorter periods—that is, 3 weeks or less at a time—is preferable to fewer and longer grazing periods.
5. To control the timing, frequency, and intensity of cattle grazing, managers should consider creating smaller riparian pastures with similar, or homogenous, features. Adjusting timing, frequency, and intensity of grazing in individual pasture units is more important than adopting a formalized grazing system.
6. To protect streambanks, prevent cattle from congregating near surface waters. Fencing, alternative water sources, supplemental feeding, and herding work best. Inappropriate cattle grazing will usually first be evidenced by excessive physical disturbance to streambanks and shorelines.
7. To reduce impacts from cattle urine and feces, locate the edges of features where cattle congregate—such as salt grounds, water developments, and winter feeding grounds—away from surface waters to allow the filtering of runoff from heavy fecal accumulation areas through vegetation before the runoff enters surface waters. Although very little research exists, studies of manure-polluted runoff indicate that distances of at least 12.5 to 20 feet from surface waters may be appropriate depending on vegetative cover, soil type, slope, and runoff.
8. To sustain vegetation which protects water quality, herbaceous utilization levels of less than 65% are usually appropriate. Proper grazing intensity will depend on existing riparian condition, grazing system, and management objectives. Stubble heights will vary by type of vegetation. For example, in

*Citations are omitted here, and provided in Chapter 1 of the report in support of these guidelines.

grazed units or pastures, leave an end-of-the-growing season stubble height of 3 to 4 inches for sedges, tufted hairgrass, and similar species, and 2 inches for Kentucky bluegrass. Large bunchgrasses such as basin wildrye will require 4 to 6 inches. Utilization of riparian shrubs should not exceed 50 to 60% during the growing season. Maintaining at least 50% protective ground cover—plant basal area, mulch, rocks, or gravel—is appropriate.

9. To protect banks and reduce impacts from cattle urine and feces, vegetation buffer strips usually should not be necessary when cattle are grazing in riparian areas unless (1) cattle congregate near surface waters to the point that protective ground cover is less than 50%; (2) trampling damage is causing excessive streambank sloughing; or (3) large amounts of feces and urine are being deposited in or immediately adjacent to surface waters. Where buffer strips are necessary to protect water quality, there is little guidance in the literature as to an effective minimum width. However, from studies of manure-polluted runoff widths of at least 12.5 to 20 feet on each side of the stream appear to be adequate to allow filtering of nutrients and bacteria depending on slope, soil type, vegetative cover, fecal concentration, and runoff levels. Water bodies adjoined by steep terrain may need wider strips.

Again, it should be emphasized that *riparian grazing plans should be site-specific*. These guidelines are principally useful for indicating what the water quality protective functions of riparian areas are, and some basic information that the grazing manager should consider. Given the high degree of variability across the state, neither these nor any other guidelines could serve to indicate what the specific dimensions of an appropriate grazing management plan would be.

(2) What are Best Management Practices?

Idaho's water quality law defines best management practices (BMPs) as "practices, techniques or measures developed, or identified, by the designated agency and identified in the

state water quality management plan which are determined to be a cost-effective and practicable means of preventing or reducing pollutants generated from nonpoint sources to a level compatible with water quality goals" (Idaho Code § 39-3602(2)).

In other words, BMPs are officially approved ways of controlling nonpoint source water pollution, or polluted runoff. BMPs include maintenance and operational procedures as well as structural and non-structural controls. BMPs must be technically and economically feasible and socially acceptable. Idaho law requires the implementation of BMPs for mining and forest practices; however, agricultural and livestock grazing BMP implementation is nonregulatory in nature. There is a back-up regulatory program for ensuring compliance.

For private landowners, a BMP is established and implemented by working with a resource specialist from the local Soil Conservation District or the local office of the USDA Natural Resources Conservation Service, or both. A BMP is actually comprised of one or more "component practices" that have been adopted by the Idaho Soil Conservation Commission and listed in the *Idaho Agricultural Pollution Abatement Plan*. Component practice descriptions provide general guidelines and criteria that are adapted at the local level to fit a specific site. A copy of one of these component practices, *Proper Grazing Use, Riparian Areas* is provided in this report as an Appendix.

Monitoring of BMPs is important at two levels. On-land compliance monitoring of individual BMPs is necessary, and so is periodic instream monitoring of the watershed. Monitoring of individual compliance with BMPs indicates whether BMPs have been properly installed to achieve what they were designed to do on the site. Monitoring at the watershed level shows whether water quality standards are being fully supported, as the federal Clean Water Act requires. If not, then BMPs need to be modified until water quality condition is such that standards are fully supported.

(3) How is cattle grazing in riparian areas addressed in Idaho water quality policy?

Cattle grazing in riparian areas can cause

nonpoint source water pollution, and BMPs are designed to control it. Although they are fundamentally important, BMPs are only one part of the water quality policies that address nonpoint source pollution.

Water quality policy is a complex federal-state-local partnership. Numerous agencies and units at all levels of government are responsible for maintaining water quality and the management of the riparian lands that influence water quality.

Idaho has a two-pronged strategy for protection of water quality. The first provides for stream channel protection, dam safety, instream flows, and classification of rivers as natural or recreational, and is primarily managed by the Idaho Department of Water Resources. The second prong is pollution control and is chiefly administered by the Division of Environmental Quality in the Idaho Department of Health and Welfare.

As a state, Idaho must abide by the provisions of the federal Clean Water Act. In 1995, Idaho revised its state water quality law and planning process in order to comply with the Clean Water Act. The new Idaho law (Idaho Code § 39-3601 et seq.) is complex and has not yet been fully implemented in the state. The law requires the Idaho Division of Environmental Quality to identify areas in Idaho having impaired water quality, to improve water quality in those areas, and to prevent water quality in other areas from becoming impaired.

The *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993) is the state's plan to address nonpoint source pollution from agricultural activities including livestock grazing. The most recent plan focuses on BMP development, implementation, coordination, monitoring, and evaluation. It is a source of information about programs that provide technical assistance, information, and cost-sharing to livestock producers.

Many federal and state agencies have roles in the implementation and enforcement of Idaho's water quality policy. At the federal level, the U.S. Environmental Protection Agency is responsible for ensuring that the state complies with the Clean Water Act. The U.S. Forest Service and the Bureau of Land Management manage more than 60% of Idaho's

land and have agreed to implement grazing policies that abide by state water quality law. The Natural Resources Conservation Service in the U.S. Department of Agriculture has broad responsibilities for agricultural and conservation programs on private lands.

At the state level, the Idaho Division of Environmental Quality has the responsibility for general environmental protection and administration of state water quality standards. These are the keys to water quality policy. The Idaho Department of Water Resources is responsible for development of the State Water Plan, water allocation, and stream flow protection. The Idaho Soil Conservation Commission is the agricultural and grazing nonpoint source pollution management agency at the state level. Soil Conservation Districts are the local management units for agricultural nonpoint source pollution activities within their boundaries. The Idaho Department of Lands is responsible for implementing the Idaho Forest Practices Act, which is designed to protect water quality in forest areas. This law requires BMPs for silvicultural activities in forested areas. The Idaho Department of Lands also is responsible for managing the 2.4 million acres of state school trust or endowment lands and the beds and banks of navigable streams and lakes. The Idaho Department of Fish and Game is responsible for collecting information about water quality violations resulting in the loss of fish and wildlife resources.

Other policies also affect cattle grazing in riparian areas. The federal Endangered Species Act affects cattle grazing because several of the 20 species currently listed under the Act in Idaho depend on riparian and aquatic habitat. The U.S. Fish and Wildlife Service, and, for salmon and steelhead, the National Marine Fisheries Service are responsible for protecting and recovering species listed under the Endangered Species Act. On federal lands in Idaho, the U.S. Forest Service and the Bureau of Land Management have adopted an interim strategy called PACFISH for protecting riparian areas adjacent to salmon and steelhead streams. PACFISH has provisions that affect livestock grazing in riparian zones. The U.S. Forest Service also has adopted a similar interim strategy called INFISH for addressing the needs

of inland native fish, particularly bull trout and including cutthroat trout. Both of these interim policies establish Riparian Habitat Conservation Areas, or buffer zones, where livestock grazing and other activities must be managed so as to protect fisheries. These interim strategies remain in place on federal lands until the Interior Columbia Basin Ecosystem Management Project is completed in late 1998, which through

the Upper Columbia River Basin Environmental Impact Statement (available in draft form for public comment until February 6, 1998) is supposed to replace interim guidelines with standards, or “required actions” that will affect livestock grazing on lands administered by the U.S. Forest Service and Bureau of Land Management.

INTRODUCTION

Riparian areas are lands that are adjacent to water bodies. Consequently, these lands are more moist and productive than contiguous floodplains or uplands (see **Sidebar 1**). Riparian areas provide or promote a wealth of products and values including clean water, fish and wildlife habitat, recreational opportunities, and scenic beauty. These lands are also valuable sites for timber production, cropland agriculture, and livestock grazing (see **Sidebar 2**). For all of these reasons, the proper management of riparian areas is important for the environmental and economic health of the United States.

Livestock grazing in riparian areas is a controversial issue. Many riparian areas have been degraded by improper livestock grazing. Negative effects include excessive amounts of nutrients and fecal bacteria delivered to surface waters; destabilized streambanks; increased water temperature; changes in stream structure that are detrimental to fish; decreased yield and reproduction of desirable plants; and undesirable changes in plant species composition and vegetative cover. (For informative reviews, see Kauffman and Krueger 1984, Skovlin 1984, Platts 1991, Fleischner 1994, Ohmart 1996, and Belsky et al. 1997). It is important to remember,

however, that the effects of cattle grazing depend entirely upon how the grazing is managed. Well-managed cattle grazing can be compatible with healthy, functioning riparian ecosystems that simultaneously provide a diverse array of other products and values.

From a policy perspective, riparian areas are important for protecting water quality. The federal Clean Water Act requires that the “designated beneficial use” of a water body be maintained (see O’Laughlin 1996). In Idaho, such uses include agricultural water supply, domestic water supply, industrial water supply, cold water biota, warm water biota, salmonid spawning, primary contact recreation, secondary contact recreation, wildlife habitat, and aesthetics (IDEQ 1995). Water quality measurements—and criteria or standards to support designated uses—include such things as temperature, nutrient levels, and sediment loading. Some designated uses require higher levels of water quality than others. Management practices in riparian areas can be especially important for maintaining cold water organisms and spawning and rearing habitat for trout and salmon.

Appropriate grazing management is the key to attaining the benefits riparian areas offer livestock while maintaining water quality

Sidebar 1. What are Riparian Areas?

Riparian areas are lands directly adjacent to creeks, rivers, streams, ponds, or lakes where surface water influences the surrounding vegetation (Chaney et al. 1993a). The riparian zone is the transition between uplands where there is seldom standing water and the stream, river, or lake where free flowing or standing water should be common (Svejcar 1997a). Riparian areas are difficult to define and delineate because of nearly unlimited variation in hydrology, soil, and vegetation types, and because riparian areas are lands transitional between aquatic and terrestrial systems (see Gregory et al. 1991).

The following definition of riparian ecosystem from the American Fisheries Society (1980) has received widespread support (Windell et al. 1986):

Riparian ecosystems are wetland ecosystems which have a high water table because of proximity to an aquatic ecosystem or subsurface water. Riparian ecosystems usually occur as transitional zones, or ecotones, between aquatic and terrestrial (upland) ecosystems, but they have distinct vegetation and soil characteristics. Aridity, topographic relief, and presence of depositional soils most strongly influence the extent of high water tables and associated riparian ecosystems. Riparian ecosystems are most commonly recognized by bottomland, floodplain, and streambank vegetation in the West. Riparian ecosystems are uniquely characterized by the combination of high species diversity, high species densities, and high productivity. Continuous interactions occur between riparian, aquatic, and adjacent terrestrial ecosystems through exchanges of energy, nutrients and species.

Sidebar 2. Why are Riparian Areas Important?

Abundant forage, water, and wildlife habitat attract a greater amount of use of riparian zones than their small land area would indicate. Riparian areas are of prime importance to stream function, water quality and quantity, and fisheries habitat. They are also valuable for livestock grazing, cropland agriculture, and timber production (Hansen et al. 1994).

Riparian vegetation slows flood waters, and riparian areas store water that otherwise might contribute to downstream flooding. Stored water is released more slowly, lessening its destructive effects, and extending the seasonal supply of water (see Ponce and Lindquist 1990). The stored water in riparian areas is often an important source of groundwater recharge.

Riparian areas are important for water quality (Svejcar 1997a). Riparian vegetation filters sediments and can absorb nutrients, chemicals and other pollutants that might otherwise be released into surface waters or aquifers (Lowrance et al. 1985).

Riparian vegetation decreases erosion and stabilizes streambanks by binding streambank soil. Vegetation further decreases erosion by providing roughness at the interface between the streambank and the water. Water velocity, and thus the energy available for transport of sediment, is decreased. Streambank building may occur during high streamflow periods as sediments are deposited. Deposits of fine fertile soils on many floodplains are due to the filtering effect of riparian vegetation. Within the active channel, vegetation debris, such as logs, create pools and reduce stream gradient.

Riparian areas provide habitat for numerous wildlife species and are critical in the life cycle of many of them (Chaney et al. 1993a, 1993b; Knopf and Samson 1994). Riparian areas are well-defined habitat zones within drier surrounding areas and provide a large diversity of breeding and forage sites (Kauffman and Krueger 1984). They create a large, significant proportion of edge as compared to upland zones, and as ecotones, contain and support many organisms associated with adjacent aquatic and terrestrial upland habitats (Connin 1991). They also serve as important travel corridors for wildlife (Hansen et al. 1994).

Riparian vegetation provides canopy that affects water temperature by providing solar insulation (Li et al. 1994). Streamside vegetation also controls the food chain of the aquatic ecosystem. If it is removed, organic detritus (or food source) needed to provide food for aquatic organisms is removed, and habitat for terrestrial insects that are a portion of the diets of many fish species is reduced (May and Davis 1982).

Riparian areas provide water, forage, and loafing sites for domestic livestock. These productive, often narrow strips of vegetation attract domestic livestock, particularly cattle, because of the shade, relatively gentle topography, drinking water, and vegetation that may remain palatable long after upland forage begins to cure.

Riparian ecosystems provide many options for humans (Svejcar 1997b). They furnish scenic resting areas and shade for recreationists and provide opportunities for hunters, fishermen, birdwatchers, and others.

standards and fully functioning riparian ecosystems.

Objectives

One objective of this report is to provide useful research-based guidelines for riparian area management that are consistent with the national goal of protecting water quality. It is therefore

necessary to summarize what research has to say about managing cattle grazing in riparian areas. Chapter 1 contains this information. Although many types of livestock and wild ungulates graze within riparian areas, cattle are the most common livestock in Idaho, and most research studies have investigated cattle. Therefore, this report focuses on cattle.

Although many livestock managers have implemented, or will implement, grazing

strategies that maintain the health of riparian ecosystems, many managers may be asked to implement more formal requirements for grazing management called “best management practices,” or BMPs. BMPs are site-specific practices that have been approved by the state to control nonpoint source water pollution, which includes the effects of livestock grazing.

A second objective of this report is to provide an overview of BMPs. What are BMPs, how are they created, and who is responsible for their development and implementation? Chapter 2 replies to these questions. The overall policy context of livestock grazing and water quality in Idaho is addressed in Chapter 3.

CHAPTER 1. WHAT ARE APPROPRIATE MANAGEMENT STRATEGIES FOR CATTLE GRAZING IN RIPARIAN AREAS?

The impact of cattle grazing on riparian ecosystems depends entirely upon how the grazing is managed. The important variables are the timing, frequency, and intensity of grazing. It is important to note that there cannot be one simple recipe for success (Elmore and Kauffman 1994, Briggs 1996). Each situation is unique and requires its own creative, locally tailored solutions. The only way to know for certain whether a management strategy is suitable for a particular site at a specific point in time is first to make an educated guess, then implement the strategy, and then monitor its effectiveness and adjust the practice as needed. This is the essence of an adaptive management strategy (see Walters 1986, Lee 1993).

Riparian grazing plans should be site-specific and based upon the best available research and empirical evidence. The review of the research literature in this chapter summarizes the existing scientific knowledge about management practices for cattle grazing in riparian ecosystems and supports the guidelines presented in the Executive Summary.

Only limited research information is available to offer much practical guidance. Although the literature is replete with studies comparing the effects of cattle grazing to the effects of no grazing (see reviews by Meehan and Platts 1978, Kauffman and Krueger 1984, Skovlin 1984, Platts 1991, Ohmart 1996), most of these studies do not provide much insight for management guidelines because they did not report sufficient details about site conditions and how grazing was managed. These are important lapses in research methods because riparian ecosystems and cattle grazing practices are extremely variable. Some of the more influential riparian site condition variables include hydrogeology, soil moisture, soil permeability, plant phenology, weather conditions, plant palatability, plant regrowth potential, and plant species composition. Important cattle grazing management variables include stocking rates, stock densities, the age and physiological condition of cattle, grazing season, and cattle

behavior. All of this variability highlights the underlying principle concerning cattle grazing in riparian areas: cookbook recipes of management prescriptions are likely to fail.

Because of these reasons, a more complete description of the purpose of this chapter is to provide land managers with the best available information to help them make their educated guesses about appropriate management practices for cattle grazing in riparian areas. Research findings about controlling the timing, frequency, and intensity of grazing are presented, as are findings about grazing distribution, grazing systems, and buffer strips. These management topics are discussed with respect to grazing's effects upon nutrients, fecal bacteria, sediments, streambanks, fisheries, and vegetation within riparian ecosystems.

It should be noted that some reviewers felt that this material should be organized differently, with the effects being major headings. We used management topics as the major headings to make the analysis more useful to grazing managers.

Timing and Frequency of Grazing

The effects of cattle grazing on riparian ecosystems depend largely upon when the grazing occurs. This is because biological and physical processes such as plant nutrient uptake, plant growth, infiltration, runoff, and streambank stability are all affected by the season of year and weather conditions. For example, plants are more likely to be harmed by defoliation if grazing occurs late in the growing season when an insufficient number of growing-degree days remain for plants to regrow and replenish their organic reserves.

Frequency of grazing refers to how often a plant is grazed. If given an opportunity to regrow and replenish its organic reserves, a plant can be grazed several times during one growing season. Riparian vegetation is especially resilient to recurring defoliation because moisture is usually available to fuel plant growth. Consequently, well-managed moderate grazing can usually occur more than once per grazing season. Sheeter and Svjekar (1997), however, urged caution when making assumptions about regrowth. They measured

very little regrowth when clipping occurred after mid-July. Their study site was a grass-sedge riparian community in the mountains of northeastern Oregon.

The timing of grazing can greatly influence the sustainable grazing capacity of a riparian area. Elmore (1989) described one example in central Oregon where season-long grazing was replaced with spring grazing. This change enabled the stream channel and riparian vegetation to make significant improvement while also allowing a four-fold increase in grazing capacity.

Moderate grazing can usually be sustained in successive years without rest or deferment as long as grazing does not occur during certain critical periods. Each site tends to have its own critical period, or time within a year, when it is particularly vulnerable to grazing damage. Some sites may have more than one critical period. Common examples of critical periods include late spring-early summer periods due to high streambank soil moisture, or late fall due to heavy shrub utilization. A subjective analysis of 34 grazing systems in southwestern Montana led Myers (1989) to recommend that fall-season grazing be limited to about 1 year in 4. Claire and Storch (1983) reported that a rotational grazing system with 1 full year of rest out of every 3 was sufficient to achieve desired streamside management objectives. Minimum 30 to 60-day recovery periods between defoliations are generally appropriate depending on the type of vegetation and provided that moisture and temperature conditions are conducive to plant regrowth (Myers 1989, Allen and Marlow 1994).

It is important to note that riparian areas in degraded condition cannot withstand grazing as frequently as healthy riparian areas. Extended periods of rest or deferment from grazing may be needed to achieve recovery or at least jump-start the process (see Kauffman et al. 1997). The length of this recovery period will vary from site to site.

Effects of Grazing Timing and Frequency on Nutrient Loading to Surface Water. The two nutrients of primary concern for water quality are nitrogen (N) and phosphorus (P). These two are especially significant because one or the

other is the limiting nutrient in most streams, lakes, and reservoirs. It has often been assumed that P is the more common limiting nutrient, but an increasing number of studies has identified N as the limiting element, particularly in the western and midwestern U.S. (Marcus et al. 1978, Grimm and Fisher 1986, Lohman and Priscu 1992). Both N and P are essential nutrients for flora and fauna, but excessive amounts of either N or P in water bodies can over-stimulate aquatic plant growth, accelerate eutrophication of lakes, and deplete oxygen levels (Goldman and Horne 1983).

Timing of grazing in relation to precipitation and runoff events can affect nutrient transport from riparian sites to water bodies. Nutrients in cattle urine and feces, especially nutrients that are not adsorbed to sediment particles, are more likely to be transported in overland flow when soil moisture is high or when soils are frozen. Transport decreases drastically with lower initial soil moisture (Heathman et al. 1985). High soil moisture prior to rainfall can also accelerate movement of water into the soil and groundwater. This does not affect groundwater content of total P or ortho-P, but can increase N levels in groundwater (Tennyson et al. 1975).

About 20 to 50% of the forage-N consumed by cattle will be removed from the site either through retention in body tissue or lost to the atmosphere via ammonia (NH_3) volatilization from urine and feces (Dean et al. 1975, Woodmansee 1978, Schimel et al. 1986). Of the N initially excreted in urine, 60 to 80% will be volatilized (Watson and Lapins 1964, 1969). Only negligible amounts of urinary-N will be removed from the soil surface via leaching (Watson and Lapins 1969). About 80% of fecal-N will volatilize if feces remain on the soil surface, but only 5 to 15% if buried by dung (or coprophagous) beetles before the feces dry (Gillard 1967). Senft et al. (1987) found that yearling heifers retained 16% of the forage-N ingested during the growing season, but N retention was negligible when grazing occurred in the dormant season. Nutrient assimilation is also greater when grazing cattle are gaining weight. Shewmaker (1997) estimated that summer cattle grazing removed 0.02 to 0.04 lbs. P per head per day from riparian pastures in central Idaho.

Effects of Grazing Timing and Frequency on Sediment and Streambanks. Siekert et al. (1985) found no effects from cattle grazing on an ephemeral channel with low soil moisture. But if grazing occurs when soils are wet, trampling effects on runoff and streambank stability are aggravated (Tromble et al. 1974; Warren et al. 1986a, 1986b; Marlow et al. 1987). For example, Bohn and Buckhouse (1985a) documented that infiltration in a mountain meadow was unaffected by moderate grazing in September (2.1 ac/AUM), but grazing in October (1.9 ac/AUM) decreased infiltration compared to the ungrazed control. The authors attributed this reduction to October precipitation that increased soil moisture and made soils more vulnerable to compaction from trampling. On a site in southwestern Montana, Marlow et al. (1987) observed that soil moisture levels in late June or early July were not great enough to preclude cattle from utilizing streambanks, but the soil moisture levels were sufficient to render streambanks more susceptible to deformation by trampling. Deformed banks were then more easily eroded. These authors recommended deferring grazing until mid to late summer to allow streambank soil moisture levels to decline. Livestock in their study did not alter streambanks when soil moisture totaled between 12 to 18%.

Summer cattle grazing in Ohio caused little surface runoff or soil erosion, but feeding hay to cattle every winter in the same pasture greatly increased runoff and erosion (Owens et al. 1997). Winter feeding areas should be rotated to prevent one area from being heavily impacted.

Effects of Grazing Timing and Frequency on Fish. Cattle grazing can affect fisheries by changing streamside vegetation which may lead to changes in cover, stream channel size and shape, water temperature, nutrient and bacterial content of water, and abundance and types of food. In addition, cattle excretion and trampling in streams affects water quality and thus fish habitat. Literature examining these changes is reviewed in other sections of this chapter.

No studies were located that examined different timings and frequencies of cattle grazing and their effects on fish. Most studies

document the effects of grazing intensity on fish and are reviewed in that section of this chapter.

Effects of Grazing Timing and Frequency on Vegetation. Grazing in riparian areas can be timed to remove apical dominance in grass tillers, which causes more grass shoots to grow (Volland 1978, Dahl 1995). If these new tillers are allowed to establish, the grass stand thickens. More dense stands of grass reduce soil erosion, reduce the velocity of overland flow, increase water retention time within riparian zones, and increase settlement of nutrients, fecal bacteria, and sediment (Parsons 1965, Reed et al. 1984). This reduces P loading because in surface runoff from grazed areas, most P losses are particulate P rather than soluble inorganic P (Sharpley 1981, Lee et al. 1989, Reuter et al. 1992). Losses of soluble nutrients that remain in runoff are controlled by infiltration that is influenced by vegetation. Similarly, physical entrapment and chemical adsorption in soil and vegetation are also the primary mechanisms for capturing fecal bacteria in riparian zones (Gerba et al. 1975).

In a northeastern Colorado floodplain dominated by mature plains cottonwood (*Populus sargentii*) trees, late-autumn (October-November) cattle grazing at a moderate stocking rate (1.2 ac/AUM) reduced yield by willows (*Salix* spp.), but prairie cordgrass (*Spartina pectinata*) yield was greater on grazed rather than ungrazed plots (Sedgwick and Knopf 1991). Cattle grazing in summer vs. winter was compared in north-central Colorado. After 75 to 100 years of cattle grazing, the floristic composition of willow communities did not differ (Cannon and Knopf 1984). However, willows in the summer-grazed pasture were larger and notched (i.e., lower branches were missing), more widely spaced, contained a greater proportion of dead branches, and tended to be located closer to the streambanks (Knopf and Cannon 1982).

Green and Kauffman (1995) found that moderate to heavy fall grazing (48 to 70% utilization) increased plant species richness in dry and moist montane meadows in northeastern Oregon; the increases appeared to be due to disturbance created by livestock that facilitated establishment of weedy species.

Effects of Grazing Timing and Frequency on Cattle Behavior. Cattle browsing of riparian shrubs increases with decreased palatability and availability of herbaceous vegetation (Roath and Krueger 1982a). As long as the herbaceous component is succulent and plentiful in the riparian zone, cattle will not utilize shrubs much, even late in the growing season (Kauffman et al. 1983). But cattle shift their diet selection to riparian shrubs if the herbaceous component has been largely consumed or has reached seasonal maturity (Myers 1989, Kovalchik and Elmore 1992). Accordingly, cattle consume more riparian browse in a dry year than they will in a wetter year (Roath and Krueger 1982a). If livestock do begin to browse willows, livestock tend to browse the tips of each willow leader once before returning to browse any of them a second time. Grette (1990) observed that about 4 to 5 inches of leader are commonly removed each time.

Some evidence indicates that increased browsing of willows in late summer may be related to a change in the chemical makeup of willows. Hastings (1993) observed that increased cattle browsing of planeleaf willow (*Salix planifolia*) coincided with decreased concentrations of ampelopsin in its foliage. Ampelopsin is a flavonoid, a specific plant metabolite that is believed to be unpalatable to browsing animals.

In mountain meadows shrub utilization by livestock is usually slight as long as an herbaceous stubble height of 4 inches or greater remains. A definite shift in preference typically occurs when the herbaceous vegetation is utilized beyond this level, and the shift is increasingly apparent when stubble height is reduced below 2 inches (Kauffman et al. 1983). These research results are supported by extensive field observations by Kovalchik and Elmore (1992), who reported that cattle begin consuming the current annual growth of willows when riparian herbaceous vegetation is grazed to a 4 to 6-inch stubble height (45% utilization). Browsing of willows is amplified when herbaceous stubble height reaches 2 to 4 inches (65% utilization), and livestock consume all the willow they can when less than 2 inches of herbaceous stubble height remains (85% utilization). Hall and Bryant (1995)

recommended that cattle use should be closely monitored when stubble height for the most palatable herbaceous species approaches 3 inches. At stubble heights below 3 inches cattle browsing of shrubs can quickly become excessive. Cattle behavior sometimes becomes visibly more unsettled when their diets shift from herbs to browse, and astute observers can use this behavioral cue to indicate when cattle may need to be relocated.

Cattle may disperse out of a riparian zone before the herbaceous stubble height is reduced below 4 inches. In southwestern New Mexico, Goodman et al. (1989) reported that cattle selection for riparian habitat was highest in July to September, but virtually no cattle use occurred in the riparian areas during the dormant season. This resulted from a relative lack of green vegetation in the riparian zones during the dormant season compared to upland sites where evergreen shrubs provided available browse. Cattle often leave valley and canyon bottoms late in the season when cold air accumulates in the riparian zone, and when late-summer or early-fall rains improve the palatability of the forage on adjacent slopes (Bryant 1982, Roath and Krueger 1982a, Gillen et al. 1984, Platts and Raleigh 1984). Conversely, cold-air drainage in flat, broad valleys is not prohibitive and late in the season cattle are often drawn to a riparian area because it contains the only remaining succulent vegetation (Platts and Raleigh 1984). Understanding site-specific animal behavior is critically important for developing a riparian grazing plan.

Allowing cattle to graze an area early in the season may limit utilization of riparian plant communities if surface soil moisture is sufficiently great (Platts and Nelson 1985a, Clary and Booth 1993). In central Idaho, Clary and Booth (1993) reported that even as stocking rates increased from light (about 26% relative utilization and 4 to 5-inch herbaceous stubble height) to moderate (37 to 50% relative utilization and 3 to 4-inch herbaceous stubble height), cattle concentrated most of their additional use on the adjacent drier meadow where the vegetation was equally lush early in the growing season. In mountainous rangeland in northeastern Oregon, Gillen et al. (1985) found that during early season grazing (early

June to early August) cattle spent less total time in riparian meadows and occupied these meadows less frequently than when grazed all season long. Marlow and Pogacnik (1986) similarly reported that cattle on a southwestern Montana study area spent more time feeding on upland sites during late June and early July, and more time in the riparian zone from late August through September. Streeter et al. (1974) found that cattle in western Colorado preferred to graze dry meadow sites dominated by grasses rather than wet sites dominated by sedges throughout the entire study period (June 6 to November 8).

Intensity of Grazing

A growing body of research suggests that grazing intensity is the most important variable affecting response of upland range to cattle grazing (Van Poolen and Lacey 1979, Gammon 1984, Pieper and Heitschmidt 1988, Bryant et al. 1989, Dahl et al. 1992). This appears true in riparian ecosystems as well. Even when the timing and frequency of grazing are optimal, the plant-soil-water resource will deteriorate if cattle are allowed to excessively graze within riparian ecosystems.

Intensity of grazing has not been consistently measured across studies. Stocking rates, percent utilization of plants, or stubble heights have all been used to describe grazing intensity. Each measurement has its purpose, benefits, and shortcomings (see Heady 1975, Vallentine 1990). Some researchers caution against recommendations that call for a uniform level of utilization or stubble height to maintain riparian values because they feel these blanket recommendations ignore the inherent complexity of riparian ecosystems (Green and Kauffman 1995).

Effects of Grazing Intensity on Nutrient Loading to Surface Water. The effects of grazing intensity on surface water chemistry are varied, but moderate grazing intensities generally do not increase nutrient concentrations in surface runoff or stream water. Summer cattle grazing in Ohio on fertilized pasture (Chichester et al. 1979) and unfertilized pasture (Owens et al. 1983) caused very little change in surface

runoff chemistry (N, P, K, Ca, Mg, Na, S, Cl, C, or salts) compared with ungrazed pastures. Stocking rates were about 0.3 ac/AUM and 0.6 ac/AUM on the fertilized and unfertilized pasture, respectively. Effects of grazing on nutrient runoff were conflicting in studies of fertilized pasture in Nebraska. Concentrations of $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, soluble P, total P, Cl, total organic C, and chemical oxygen demand in runoff were increased by cattle grazing in one study (Schepers and Francis 1982). But in another study at the same location, the chemical quality of runoff from the grazed pasture was better than from the ungrazed pasture, cultivated cropland, or urban areas (Doran et al. 1981). The authors suggested that hydrological differences between the areas, the amount of vegetational cover, and wildlife activity may have contributed to differences. The stocking rate in both studies was about 0.3 ac/AUM.

Moderate grazing along a mountain meadow stream in central Colorado did not result in significant changes in suspended solids, $\text{NO}_3\text{-N}$, $\text{NH}_4\text{-N}$, or orthophosphates in streamwater (Johnson et al. 1978, Gary et al. 1983). Tiedemann et al. (1989) found no relation between intensity of grazing and levels of measured chemical constituents ($\text{NO}_3\text{-N}$, PO_4 , Ca, Mg, K, Na, or pH) in streamflow in a study of several watersheds in eastern Oregon. On a pinyon-juniper site that had been chained, burned, and planted to crested wheatgrass (*Agropyron cristatum*), Buckhouse and Gifford (1976a) found that cattle grazing at 55% utilization (4.9 ac/AUM) did not affect $\text{NO}_3\text{-N}$, Na, Ca, P, or K in surface runoff.

Effects of Grazing Intensity on Fecal Bacteria Loading to Surface Water. The contributions of fecal bacteria from cattle grazing to surface runoff and streamwater can be significant. For example, on improved smooth bromegrass (*Bromus inermis*) pasture in south-central Nebraska, fecal coliform counts in runoff increased 5- to 10-fold over ungrazed areas (Doran and Linn 1979, Doran et al. 1981). Cattle stocking rate was about 0.3 ac/AUM. In a high elevation meadow in Colorado, moderate cattle grazing increased fecal coliform and fecal streptococci counts in streamwater 1.6 to 12.5 times and 1.8 to 3.5 times, respectively,

compared to levels without cattle present (Gary et al. 1983). Tiedemann et al. (1987) found fecal coliform concentrations were nearly 6 times greater with cattle present than when they were absent. In southwest Idaho, Stephenson and Street (1978) found fecal coliform counts were directly related to the presence of cattle on summer range with moderate to heavy utilization.

Despite the magnitude of increases over background levels, fecal coliform counts in the presence of cattle grazing do not always violate water quality standards. Many states have adopted a primary contact recreation standard for fecal coliform of no more than 200 counts/100 ml. Some studies, such as Johnson et al. (1978) and Gary et al. (1983), found fecal coliform levels within the standard while other studies, such as Hanks et al. (1981), Sherer et al. (1988) and Tiedemann et al. (1988), found levels that violate the standard. The intensity of grazing affects whether coliform levels violate the standard. For example, Tiedemann et al. (1987) found that stocking rates of 19.0 and 20.3 ac/AUM did not lead to a violation of the standard while a stocking rate of 6.9 ac/AUM did. Although most coliforms themselves are benign, higher fecal coliform counts indicate an increased potential for the presence of pathogens, such as *Salmonella* (Bohn and Buckhouse 1985b, Tiedemann et al. 1987).

Fecal coliform can survive in feces for at least 18 weeks (Buckhouse and Gifford 1976b) so counts may remain elevated long after cattle are removed (Stephenson and Street 1978, Bohn and Buckhouse 1985b, Tiedemann et al. 1988). Fecal coliform counts in streams increase dramatically in response to storms and runoff events (Bohn and Buckhouse 1985b); however, few studies have examined the movement of fecal coliform from feces deposition sites on land to adjacent surface waters. Buckhouse and Gifford (1976b) found very few fecal coliforms appearing in runoff water more than 3.3 feet from the deposition site on dry, chained and seeded, pinyon-juniper range in southeastern Utah. They concluded that feces deposited in streambeds and gullies of dry, ephemeral watersheds with similar soils, slopes, and precipitation posed little danger of contaminating surface waters. Hanks et al. (1981) suggested

that bacteria accumulate in manure, on the soil surface, and at shallow depths during dry periods and then is flushed into ephemeral channels during high intensity-short duration thunderstorms and other runoff events. Fecal coliform survival in aquatic environments is affected by turbidity, conductivity, pH, predators, antibiosis, organic matter, algal toxins, dissolved nutrients, toxic metals, and temperature (Tiedemann et al. 1988, Sherer et al. 1992).

The length of time cattle spend in the stream plays a significant role in fecal contamination. Johnson et al. (1978) observed cattle spending less than 1% of the day in the stream, but Gary et al. (1983) estimated cattle spent 5% of the day in or adjacent to the stream, and 6.7 to 10.5% of defecations were deposited directly in the stream. They concluded that the potential for cattle to contribute large amounts of manure to the stream appeared to be great (Gary et al. 1983). The amount of time cattle have access to a stream may influence bacterial concentration more than stocking rate (Tiedemann et al. 1987).

Fecal bacteria collect and proliferate in the bottom sediment of streams (Hendricks and Morrison 1967, Stephenson and Rychert 1982, Sherer et al. 1992). Animal traffic, as well as increased stream turbulence due to runoff, can resuspend sediment-load enteric bacteria (Stephenson and Rychert 1982, Sherer et al. 1988, Sherer et al. 1992). For example, concentrations of fecal bacteria in streamwater along reaches where cattle grazed increased 2.4 to 110 times background levels after disturbing the stream bottom; however, concentrations declined to background levels after only 3 minutes (Sherer et al. 1988). Stephenson and Rychert (1982) suggested that elevated bacterial counts are most commonly the result of resuspension of the stream bottom sediments and organic matter, rather than an influx to the stream.

Cattle grazing appears to have little effect on enteric bacterial concentrations in groundwater because most fecal bacteria are readily filtered by the soil. Studies with *Escherichia coli* have shown that 92 to 97% of the bacteria filter out in the top four-tenths of an inch of soil, and most of the rest filter out in the next 1.6 inches (Gerba et al. 1975). Soil's ability

to filter out micro-organisms depends on its texture and pore space (Ellis and McCalla 1978). Fine-textured soils are more effective filters than coarse-textured soils (Butler et al. 1954).

Effects of Grazing Intensity on Sediment and Streambanks. Higher stocking rates generally cause increased sediment production from a site (Gifford and Hawkins 1978; Warren et al. 1986a, 1986b; Thurow et al. 1988), but some vegetation types are more susceptible than others. Overland erosion problems from cattle grazing are less in coniferous forest and mountain meadow ecosystems with adequate plant cover, but potentially greater in sagebrush steppe, juniper steppe, and salt desert shrub types (Branson et al. 1981, Buckhouse and Gaither 1982).

Overland erosion is not often a problem in riparian ecosystems if abundant vegetative cover and soil organic matter are maintained. Soil organic matter content improves soil structure and increases the cohesion of clay particles (Baver et al. 1972), enhancing infiltration and rendering the soil less erosive. In a subalpine meadow in central Utah, Meeuwig (1965) found no differences in soil organic matter content between moderately grazed plots (2 ac/AUM) and plots that had been excluded from cattle grazing for 6 years.

Infiltration and soil stability are influenced primarily by soil bulk density and the amount of protective ground cover, such as plants, mulch, rocks, or gravel. Infiltration is usually greater with increased amounts of standing vegetation (Dee et al. 1966, Pluhar et al. 1987), but infiltration is more affected by soil bulk density (Meeuwig 1965, Ueckert et al. 1978, Dadkhah and Gifford 1980). Infiltration rates also affect groundwater temperatures, which in turn can greatly modify stream temperatures and fish populations (Hynes 1983, Meisner et al. 1988). Trampling is the most important factor influencing bulk density and infiltration (Dadkhah and Gifford 1980), but trampling effects depend upon soil texture. Soils with greater fractions of silt and clay are more susceptible to compaction than sandy soils (Orr 1960). On Kentucky bluegrass (*Poa pratensis*) riparian meadows, Orr (1960) found that heavy season-long grazing

increased soil bulk density in the 0 to 2-inch stratum, but no effect was found below 4 inches. The amount of standing vegetation and litter has more influence on sediment load than does soil bulk density (Meeuwig 1965, Ueckert et al. 1978, Dadkhah and Gifford 1980, Hofman and Ries 1991). Trampling has minimal effect on sediment production when ground cover is greater than 50% (Dadkhah and Gifford 1980). Dadkhah and Gifford (1980) concluded that adequate watershed protection can be obtained on sites with loam soils and less than 15% slope by maintaining 50% protective ground cover—plant basal area, mulch, rock, and gravel—with grass cover being of prime importance in determining sediment yields.

The height of vegetation also affects sediment entrapment. Short, stout herbaceous stems and leaves may entrap more sediment than taller vegetation, which tends to flatten out and offer less flow resistance (Abt et al. 1994, Clary et al. 1996a). For example, more sediment was deposited in Kentucky bluegrass sod clipped to a stubble height of one-half inch compared to stubble heights of 3 inches or 8 inches (Abt et al. 1994). However, when the depth of flushing flows exceeds plant height, more sediment may be retained by taller vegetation that bends over and covers the soil surface (Abt et al. 1994, Clary et al. 1996a). After 4 cycles of sediment loading and flushing, Clary et al. (1996a) found 8-inch and 12-inch stubble heights of Kentucky bluegrass continued to increase sediment retention; retention did not continue to increase under half-inch and 3-inch stubble heights. However, after 4 cycles of loading and flushing, total sediment retention by Kentucky bluegrass did not differ among half-inch, 3-inch, 8-inch, and 12-inch stubble heights (Clary et al. 1996a). Vegetational stiffness and cross-sectional area also appear to directly correlate to sediment-deposition enhancement and long-term entrapment (Abt et al. 1994, Clary et al. 1996a).

Rumsey (1996) found no difference in sediment deposition among unclipped sites and sites clipped to stubble heights of 1 inch, 3 inches, or 6 inches. Rumsey's sites were in well-vegetated streamside communities dominated by timothy (*Phleum pratense*), spike-rush (*Eleocharis* spp.), and bluegrass (*Poa* spp.).

Finally, in a laboratory rainfall simulation with buffer strips of Kentucky bluegrass, Pearce et al. (1997) found that when buffer strips were 5 inches wide, zero-height stubble was more effective than 4-inch stubble at filtering sediment. When buffers were 10 inches wide there was no significant difference in effectiveness between heights, and when buffer strips were 20 inches wide 4-inch stubble was more effective. The authors suggested that vegetation height alone is not a suitable guideline for estimating sediment filtration and that width of the vegetation buffer is more important than vegetation height in filtering sediment (Pearce et al. 1997).

Sloughing and erosion of streambanks can be a significant source of sediment into a stream. Stable and overhanging streambanks are also important for providing thermal and security cover for fish. The longer cattle have access to a stream reach, the more likely accelerated channel alteration will occur from streambank deterioration (Marlow et al. 1989, Myers and Swanson 1996a). For example, in an analysis of 34 cattle grazing systems in southwestern Montana, Myers (1989) found that the duration of fall grazing averaged 21 days in systems judged successful and 37 days in unsuccessful ones. Systems were judged successful if they maintained riparian areas in good or excellent condition or demonstrated an upward trend in riparian areas in fair condition and had a high rate of woody vegetation response (Myers 1989). In southwestern Montana, stream channels narrowed and deepened when streambank disturbance from cattle did not exceed 30 feet per 100 feet of stream reach (Dallas 1997).

The effects of cattle grazing intensity on streambank stability depend on the soil texture and its geologic parent material (Trimble and Mendel 1995, Myers and Swanson 1995, Myers and Swanson 1996b). Coarse, unconsolidated soils such as those derived from decomposed granite are extremely susceptible to erosion and require vegetation with strong, deep root systems. More cohesive soils with higher clay contents are more resistant to erosion and vegetation is not as important. Vegetation and livestock do not have much impact on bedrock or boulder-lined streams.

Community types dominated by sedges may maintain bank structure and streambank stability under cattle grazing better than those characterized by other graminoids such as Kentucky bluegrass (Platts and Nelson 1989, Kleinfelder et al. 1992). In sedge/grass/willow communities in mountain meadows of central Idaho, Platts (1982) found that streambank alteration was increased over a two-year period by cattle grazing in a three-pasture rest rotation system when streamside utilization ranged from 57 to 78%. These levels of use correspond to stubble heights of less than 3 inches (Clary and Booth 1993). Buckhouse et al. (1981) compared several grazing systems—season long continuous, deferred rotation, rest rotation, August-September, and September-October—and found that regardless of grazing system, a stocking rate of 8 ac/AUM did not accelerate streambank degradation compared to ungrazed areas. Rather than livestock grazing, high runoff and occasional ice floes in winter appeared to be the most significant factors affecting bank cutting on this stream. Hayes (1978) also found that streambank instability tended to be related more to spring discharge than cattle grazing in mountain meadow streams of central Idaho.

Freezing-thawing is another natural destabilizer of streambanks. Bare ground undergoes more freeze-thaw cycles than does ground covered by mulch and the basal area of plants. Bohn (1989) reported that streambanks having just 0.4 to 0.8 inches of mulch and Kentucky bluegrass stubble had 50 to 67% fewer freeze-thaw cycles than did streambanks of bare ground. Sods with dense, deep roots resist freezing-thawing best (Decker and Ronningen 1957).

Effects of Grazing Intensity on Fish. Several studies have compared fish populations in stream reaches grazed and ungrazed by cattle. Most of these studies have compared heavily grazed sites with exclosures and concluded that heavy and very heavy grazing intensities degrade fish habitat and limit the size and vitality of fish populations. Such studies have been conducted in southern Idaho (Keller and Burnham 1982), south-central Montana (Gunderson 1968, Marcuson 1983), northeastern Utah (Duff 1983),

northeastern Colorado (Stuber 1985), and southern Nevada (Taylor et al. 1989).

Knapp and Matthews (1996) concluded that cattle grazing harmed trout populations in the mountains of east-central California. When trout density and biomass were compared on a unit-area basis, 3 of 4 ungrazed reaches had higher trout density and biomass than grazed reaches; one reach showed no difference. However, when trout density and biomass were compared in relation to stream length, only one of 4 ungrazed stream reaches had greater trout density and biomass. In two of the 4 reaches there were no differences between grazed and ungrazed areas, and in one reach the trout density and biomass were greater in the grazed area.

Eleven years of exclusion from heavy streamside cattle grazing in northeastern Utah provided no increase in fish production (Platts and Nelson 1985b). These authors believed that low numbers of trout, the unknown impact of recreational fishing, and limiting factors created by upstream conditions and transported through the ungrazed area may be reasons that the enclosure failed to increase fish populations despite improved habitat conditions.

Rinne (1988) compared macroinvertebrate populations in a heavily grazed and ungrazed stream reach in northern New Mexico. Although differences existed in the macroinvertebrate populations, the absence of pretreatment data led him to conclude that the differences between grazed and ungrazed areas could be as easily attributed to inherent variation between the stream reaches as to exclusion of cattle grazing.

Two studies found no differences in fish populations between ungrazed areas and sites heavily grazed by cattle. Platts (1982) in central Idaho found that two years of streamside cattle grazing at 75 to 78% utilization did not decrease fish production within a mountain meadow stream that had been protected from livestock grazing in the previous 19 years. However, because this result was only based on two years of grazing, Platts (1982) concluded that it was too early to determine whether this level of grazing intensity was compatible with fish. In central Wyoming, Hubert et al. (1985) found that heavy cattle grazing did not decrease fish

production in one stream, but these authors theorized that no differences were observed because the stream habitat had not been highly degraded prior to cattle exclusion, little change in habitat quality had occurred in the 4 years since exclusion of cattle grazing, or fishing pressure was greater inside the enclosure.

No studies were located that examined the effect of light or moderate grazing intensities on fish. Furthermore, only the studies by Platts (1982), Knapp and Matthews (1996), and one site in Hubert et al. (1985) appeared to be conducted on sites where the riparian habitat was not severely degraded immediately prior to exclusion from cattle grazing. Much more scientific investigation is needed into the levels of grazing intensity that are compatible with recovering fish populations and the levels of grazing intensity that are compatible with sustaining already healthy fish populations. Future research must employ more rigorous experimental design in order to eliminate the biases and ambiguities that characterize most studies of the interactions between cattle grazing intensity and fish production (Platts 1991).

Effects of Grazing Intensity on Riparian

Graminoids. Exclusion from livestock grazing may initially increase above ground production of grass on sites that were excessively grazed previously, but the benefits may be short-lived. For example, in a Kentucky bluegrass meadow that had been continually grazed, above ground production increased steadily for 6 years after exclusion from cattle, but then began steadily decreasing; after 11 years of exclusion the ungrazed area had lower production and less root mass than an adjacent area that had been continuously grazed all along (Volland 1978).

Kentucky bluegrass sod tolerates heavy defoliation. Ahlgren (1938) found that the carbohydrate content of Kentucky bluegrass rhizomes was not depleted when the sod was clipped to a 1.5-inch stubble height season-long for 6 years. Similarly, Lamman (1994) reported that Kentucky bluegrass could sustain 63 to 70% utilization under season-long continuous clipping. However, Schwan et al. (1949) compared ungrazed, moderately grazed (57% utilization), and heavily grazed (71% utilization) stands of Kentucky bluegrass in a high-elevation meadow

and found perennial grass production diminished as grazing intensity increased.

In a riparian meadow in north-central Wyoming, Kentucky bluegrass increased its percentage of the plant community composition under three different summer clipping treatments: clipped biweekly to 1-inch stubble, clipped biweekly to 3-inch stubble, and clipped once in late summer to a 1-inch stubble (Pond 1961). This response occurred under drought conditions. However, clipping to 1-inch stubble reduced the total density and production of native grasses and sedges, comprised mostly of tufted hairgrass (*Deschampsia caespitosa*). Clipping to a 3-inch stubble did not seriously affect the density of the native plants, but did cause a decrease in production on the meadow dominated by sedges, grasses, and forbs, primarily by affecting the sedges.

Redtop (*Agrostis stolonifera*) is also tolerant of grazing. Redtop maintained its yield in an eastern Oregon riparian meadow when clipped to a 0.4-inch stubble height. When clipped to 2 inches or 4 inches redtop produced more yield than unclipped plants (Clary 1995). On riparian sites dominated by timothy in southeastern Wyoming, Rumsey (1996) found no difference in above ground production among sites clipped to heights of 1 inch, 3 inches, or 6 inches. These stubble heights were also compared with unclipped plants and no differences were found in below-ground production. Reid and Pickford (1946) determined that tufted hairgrass in northeastern Oregon can be maintained when grazed to a 3-inch stubble height. This height corresponded to 55% utilization.

In a mountain meadow in Oregon, Dovel (1996) compared three stubble heights (2, 4, and 6 inches) within three different plant communities: bluegrass-clover (*Trifolium* spp.), bluegrass-tufted hairgrass-sedge, and sedge. In all three plant communities, forage yield was greatest when stubble height was 2 inches, and this height did not appear to reduce stand vigor after three successive years of clipping. Plants were clipped three times each summer in June, July, and August, but most of the forage yield was harvested in the June clipping. Temperature and moisture stress later in the summer limited regrowth.

Sedges are generally less tolerant of grazing than Kentucky bluegrass, redtop, or timothy, but more tolerant than tufted hairgrass. Popolizio et al. (1994) reported that percent foliar cover of sedges was not affected by grazing at 65% utilization, and individual sedge species responded differently. Allen and Marlow (1994) reported that moderate cattle utilization of beaked sedge (*Carex rostrata*) resulted in no effect on shoot productivity and an increase in shoot density above ungrazed plants, largely due to rapid growth in July following cattle grazing in June; however, Ratliff and Westfall (1987) found no difference in shoot densities for Nebraska sedge. Nebraska sedge was found to be relatively tolerant to a utilization rate of 64% by Ratliff and Westfall (1987) and 63 to 70% by Lamman (1994). This utilization level corresponds to about a 1.5- to 4.5-inch stubble height (McDougald and Platt 1976).

In subalpine meadows of interior British Columbia, McLean et al. (1963) found that clipping sedges every 60 days to a 2-inch stubble height did not depress forage yields as compared with unclipped plots or those not clipped late in the season. When clipped after the third week of August, sedges were apparently prevented from accumulating as many energy reserves before the plants entered dormancy. Clary (1995) found that clipping high-elevation sedge communities in central Idaho to a 4-inch stubble height did not reduce annual above-ground herbaceous production compared to unclipped control plots, provided that clipping occurred before late August-early September. Defoliation treatments that removed greater than 30% of the annual biomass production reduced the following year's biomass production below that of the control (Clary 1995).

Effects of Grazing Intensity on Riparian

Forbs. Appropriate use levels for riparian forbs have not been widely studied. Popolizio et al. (1994) found no difference in foliar cover of forbs between treatments involving no grazing and 65% utilization. Lamman (1994) reported that forbs in a willow/sedge/Kentucky bluegrass riparian community in northern Colorado were not harmed when the overall herbaceous utilization was 63 to 70% under season-long continuous clipping. Clary (1995) noted an

increase in forb composition when a high-elevation sedge community was defoliated in June to either a 0.4-inch or 2-inch stubble height, and suggested that additional changes may have appeared if the study had been longer, as 3 years is a short period for successional changes.

Effects of Grazing Intensity on Riparian Shrubs and Trees. Heavy browsing harms most shrub and tree species, and can lead to changes in the composition of the riparian vegetative community (Boggs and Weaver 1992). However, some browsing increases the above-ground production of many shrub and tree species including quaking aspen (*Populus tremuloides*) and willow (Julander 1937, Aldous 1952, Wolff 1978, Molvar et al. 1993).

Many riparian shrub species appear to be more tolerant of leaf and twig removal than do shrubs inhabiting drier sites. Many upland shrubs can tolerate utilization levels of 50 to 60%. These species include antelope bitterbrush (*Purshia tridentata*), rubber rabbitbrush (*Chrysothamnus nauseosus*), curleaf mountain mahogany (*Cercocarpus ledifolius*), and cliffrose (*Cowania stansburiana*) (Julander 1937, Hormay 1943, Young and Payne 1948, Garrison 1953). Levels of 60-65% utilization are sustainable for serviceberry (*Amelanchier alnifolia*), Utah honeysuckle (*Lonicera utahensis*), and rose (*Rosa jonesii*) (Young and Payne 1948). Redstem ceanothus (*Ceanothus sanguineus*) and snowbrush ceanothus (*Ceanothus velutinus*) are tolerant of utilization levels less than 50% (Garrison 1953). In a montane riparian community in Colorado, Lamman (1994) reported that planeleaf willow could sustain 58 to 70% utilization. In a non-riparian but nonetheless mesic environment in Minnesota and Pennsylvania, Aldous (1952) reported that willow clipped at 50% or 100% utilization during plant dormancy produced more above-ground biomass than did unclipped controls. Under complete utilization, willow stems grew larger but there were fewer of them (Aldous 1952). Aspen tolerate 65 to 70% utilization, although greater improvement in biomass production will occur with lighter use (Julander 1937). Riparian shrubs are generally more tolerant of browsing because they benefit

from greater water availability to fuel plant growth.

The effect of grazing and browsing on willow reproduction is a concern because willow seeds are short-lived and are not stored in soil seed banks (Brinkman 1974, Densmore and Zasada 1983). Some willow species readily reproduce vegetatively. First-year willow seedlings are reported to be very sensitive to browsing because of their shallow root system. Browsing of first-year shoots often results in the plants being pulled from the ground, or being killed by trampling (Kovalchik and Elmore 1992). Willow and aspen have been shown to reproduce well as long as herbaceous utilization by livestock does not exceed 70 to 75% utilization. For example, when Shaw (1992) compared no cattle grazing with heavy to very heavy continuous season-long grazing (56 to greater than 75% herbaceous utilization), light-moderate spring grazing (20 to 55% herbaceous utilization), and light-moderate fall grazing (20 to 55% herbaceous utilization), there was no difference in the density of Pacific willow (*Salix lasiandra*) seedlings. Seedling density of another species, sandbar willow (*Salix exigua*), decreased under the heavy/very heavy continuous grazing treatment. Willow seedling density increased in the control and other treatments with the greatest rate of increase in the light-moderate spring grazing treatment. This was apparently due to the increased availability of suitable microsites and reduced competition from surrounding vegetation.

Clary et al. (1996b) evaluated sandbar willow, Pacific willow, and narrow-leaved cottonwood (*Populus angustifolia*) under light spring grazing (21% herbaceous utilization, 6-inch stubble height), moderate fall grazing (42% herbaceous utilization, 5-inch stubble height), heavy season-long grazing (70% herbaceous utilization, 2-inch stubble height), and no grazing. For sandbar willow, they found that density was greatest in the spring grazing treatment and least under the season-long treatment. Density in the fall-grazed treatment did not differ from the ungrazed and season-long treatments. For Pacific willow, density did not differ among spring grazing, fall grazing, and no grazing. Pacific willow density was least in the season-long treatment. But when sandbar willow,

Pacific willow, and narrow-leaved cottonwood were considered together, Clary et al. (1996b) found no difference in stem diameter or stem density among spring grazing, fall grazing, season-long grazing, and no grazing.

For aspen, Sampson (1919) stated that it reproduced well under moderate cattle grazing. Grazing was considered moderate when 50 to 70% of the palatable, non-aspen forage (presumably all herbaceous vegetation) was consumed. Clary and Medin (1990) reported that an aspen/willow plot with moderate to heavy herbaceous utilization by cattle and an ungrazed plot both had sufficient numbers of aspen saplings to sustain the stands after the present-day mature trees senesced. Browsing of riparian shrubs and trees should be monitored closely to limit removal of terminal buds from trees and to limit the amount of second year wood removed from trees and shrubs.

Grazing Distribution

To manage the timing, frequency, and intensity of grazing at appropriate levels, a resource manager must be able to control where livestock grazing occurs. This is often the most difficult management challenge in riparian ecosystems because the water, shade, succulent vegetation, and gentle topography typical of many riparian areas makes these sites very attractive to cattle, especially lactating cows with calves. Utilization in riparian areas often can be reduced by using non-lactating cows instead. Several other management practices can also be used to manipulate livestock distribution. These include water developments, fencing, salting and supplementation, predator control, prescribed burning, fertilization, insect control, seedings, trail building, herding, and selective culling (Holechek et al. 1995, Vallentine 1990). Although fencing will obviously exclude cattle from areas, few of these other practices have been evaluated for their effectiveness in influencing cattle occupation of riparian zones.

Fertilization as a Method of Controlling Livestock Grazing Distribution. Green et al. (1958) fertilized adjacent slopes on foothill rangeland in central California with sulfur (S) and reported significant decreases in the amount

of time cattle spent grazing in moist swales during the dry season. Cook and Jefferies (1963) described applying nitrogen fertilizer at the rate of 60 lbs. of N per acre to slopes adjacent to stream valley bottoms in the mountains of northern Utah. This practice increased livestock utilization of slopes. Cook and Jefferies (1963) also increased cattle utilization on slopes by treating the slopes with 2,4-D ([2,4-dichlorophenoxy] acetic acid) herbicide at 2 lbs. acid equivalent per acre. The authors inferred that fertilization and herbicide application helped disperse cattle away from the riparian zones, but no data were presented documenting the effects of the practices on riparian utilization. Livestock were removed from the study area when the most palatable grasses in the bottomlands had reached about 75% utilization. Presumably, this degree of utilization was reached sooner in areas where slopes were not fertilized or treated with herbicides.

Supplemental Feeding Practices for Better Livestock Distribution. Providing supplemental feed may attract livestock away from surface waters. Ares (1953) found that cottonseed meal mixed with salt successfully distributed cattle away from water sources on desert grassland in south central New Mexico. And McDougald et al. (1989) found that cattle utilization of riparian areas was dramatically reduced by moving supplemental feeding sites away from water sources on annual rangeland in central California. Cattle will generally disperse further from supplemental feeding sites if not supplemented too frequently (Melton and Riggs 1964). If possible, protein supplements should not be provided more often than two or three times per week. Energy supplements, however, must be provided daily to prevent reductions in fiber digestion by cattle.

Cook (1967) and Skovlin (1965) used salt as an attractant and reported notable increases in cattle utilization of slopes and forested sites, respectively. Although these authors also inferred decreased cattle use of the riparian zone, neither author presented any data on corresponding utilization levels within the riparian zone. Cattle tend to consume supplemental salt when it is convenient during their normal

foraging pattern, but they are not apt to appreciably alter their behavior pattern to obtain salt (Bryant 1982). Consequently, salt placement is generally incapable of overriding the attraction of water, shade, and palatable forage found in riparian zones (Vallentine 1990). Bryant (1982) and Gillen et al. (1984) reported that salting alone was largely ineffective in reducing cattle usage of riparian zones.

Additional Management Strategies for Livestock Distribution.

Fencing is the most effective way to control grazing distribution, but fencing is not a panacea. A well-placed fence can be invaluable, but a fence situated in the wrong place can exacerbate existing problems and create several new problems as well. Fencing is expensive to build and maintain, may inhibit the movement of some wildlife species, can interfere with human recreation, and may detract from aesthetics. Fencing can also increase nutrient, fecal bacteria, and sediment inputs to surface waters due to cattle trailing along fences and congregating in fence corners that are located near water.

Additional watering sources that complement seeps, springs, streams, lakes, and reservoirs can usually attract livestock away from riparian zones (Smith et al. 1992). Miner et al. (1992) found that an off-stream water source eliminated 94% of the time that cattle spent standing in a stream under winter feeding conditions. The authors speculated that the warmer water in the tank was a contributing factor. After installing one off-stream watering trough, Clawson (1993) documented an 85% decline in stream use by cattle and a 53% decrease in use of an undeveloped spring. Similarly, installation of an off-stream water trough for cattle in Virginia dramatically reduced streambank erosion, nutrient loading, and fecal bacteria loading caused by cattle grazing (Sheffield et al. 1997). However, Gillen et al. (1984) reported that the presence of upland watering sources did not appreciably influence occupation of riparian meadows.

Tiedemann et al. (1987, 1988, 1989) and Higgins et al. (1989a, 1989b) studied the water quality effects of three different grazing distribution strategies: no control of cattle distribution; fencing and water developments to

attain uniform cattle distribution throughout a pasture; and fencing and water developments to attain uniform distribution plus cultural practices (e.g., seeding and fertilization) to improve forage production. No differences were found in storm runoff, streamflow, or stream chemistry (NO_3^- -N, PO_4 , Ca, Mg, K, Na, and pH) amongst streams in ungrazed areas and any of the grazing distribution strategies. Fecal coliform counts, however, were lower within ungrazed streams than in grazed streams. Grazing with fencing and water developments had lower fecal coliform counts than grazing without any effort to control distribution, and the strategy that included cultural practices had the highest fecal coliform counts. But this comparison was confounded by stocking rate. Although the no control strategy and the fencing/water development strategy were grazed at similar stocking rates, the strategy with additional cultural practices was grazed at a stocking rate about three times greater.

Herding is an effective tool for controlling riparian cattle grazing if it is done diligently. Cattle often must be repeatedly herded to alternative foraging and watering areas that are located in areas unused by livestock or unfamiliar to them. A common thread among successful riparian grazing management systems is the presence of a skillful herder who is committed to maintaining or improving the health of riparian areas (Dallas 1997). In fact, a field survey of 128 stream reaches in Montana found that the only commonalities among successful riparian grazing management programs were the serious commitment and personal involvement of the grazing manager (Ehrhart and Hansen 1997).

Cattle occupation of riparian areas can be influenced by where cattle enter a pasture (Gillen et al. 1985) because they tend to linger in the portion of a pasture first entered. This is especially true if the individual animals are unfamiliar with the pasture. Purposely having cattle enter pastures in successive years through different access points will facilitate better distribution (Roath and Krueger 1982b, Gillen et al. 1985). Cattle that return to a pasture in successive years also tend to distribute themselves more completely across a pasture due to their familiarity with the topography,

available forage, and the location of water and salt (Arnold and Dudzinski 1978, Bryant 1982, Roath and Krueger 1982*b*). When first released into an area at the beginning of the grazing season, livestock should be moved in small groups to selected sites throughout the pasture. Cattle should not be released at a boundary gate and left alone to find areas upon which to congregate, because once a foraging habit is developed it is very difficult to disrupt by herding (Roath and Krueger 1982*b*). Cattle often form subgroups within herds and a subgroup should be dispersed as a unit (Skovlin 1957, 1965; Roath and Krueger 1982*b*). Otherwise, individuals separated from the subgroup will probably return to former territories. The herder should purposely relocate subgroups to alternative grazing sites rather than merely harassing animals to disperse from a preferred site, which can result in cattle returning within hours to their preferred site. Individual animals sometimes do not respond to herding, and these individuals should be selectively culled from a herd (Skovlin 1957, 1965) to facilitate development of a group of animals that readily responds to herding.

Some authors (e.g., Roath and Krueger 1982*b*, Howery et al. 1996) have extended this concept to recommend that selective culling be used to develop a herd of upland-dwelling cattle. This recommendation is based on the hypothesis that certain individuals within a herd prefer or are accustomed to riparian habitats, whereas others prefer or are accustomed to upland habitats. Although a current research study at Montana State University is evaluating the effectiveness of selectively culling cattle that spend too much time in riparian areas (Mosley and Cote 1997), selective culling on this basis should be considered cautiously because its effectiveness is unknown. Some individual herd members do spend disproportionately more time within riparian areas (Roath and Krueger 1982*b*, Howery et al. 1996), but it is likely that in their absence and without diligent herding, the vacated riparian area would simply be reoccupied by other individuals within the herd. This is what occurred in Scotland when Hunter (1960) selectively culled sheep that had occupied the preferred grazing areas within a pasture.

Grazing Systems

The purpose of any grazing system is to help managers attain better control over the timing, frequency, and intensity of grazing. Grazing systems that provide periodic rest or deferment generally keep plants and soils in better condition, but one problem with rotational grazing systems is that topography and fencing limitations sometimes make it difficult to prevent some livestock grazing from occurring during rest or deferment periods. Also, grazing by insects, rodents, and wild ungulates during rest or deferment periods sometimes impedes the recovery that was intended to occur.

Many grazing systems currently in place were designed with upland conditions of primary concern and not specifically for riparian areas. For example, Myers (1989) examined 34 grazing systems in Montana and 25 (74%) showed no improvement in riparian areas over 10-20 years, while most systems showed improvement on the watershed as a whole. Failures in management also occur when a grazing system developed for a certain stream system is applied to another stream/riparian reach with different ecological or management characteristics (Elmore and Kauffman 1994). Grazing systems must be tailored to the characteristics of a particular riparian area.

Use levels tend to be more important than the grazing system (Clary and Webster 1989). Smaller, more homogeneous riparian pastures offer the best opportunity to closely control grazing use (Platts and Nelson 1985*c*), but with one exception formalized grazing systems alone offer little in the way of proven advantages for managing cattle grazing in riparian areas (Marlow 1985, Clary and Webster 1989, Platts 1991, Elmore and Kauffman 1994, Ohmart 1996). The exception is that rest rotation grazing does appear to offer some benefits.

Rotational grazing systems can mitigate impacts to riparian areas by reducing the portion of time the area is occupied by cattle. For example, a three-pasture rotation system by definition will have two-thirds of an area without cattle at any given time during the grazing season.

A deferred-rotation system was evaluated by Gillen et al. (1984). They reported that riparian meadows were highly preferred by cattle, particularly with late-season grazing. In

their study, this occurred because forested sites in the pasture had been logged and alternative forage had matured earlier and become unpalatable by the time cattle entered the deferred pasture. The removal of the tree canopy had accelerated plant growth on the logged areas. Deferred rotation, short duration grazing, season-long continuous grazing, and no grazing were compared by Marlow et al. (1989). They did not detect any differences in streambank stability among these grazing systems during three consecutive drought years in southwestern Montana. This suggests that the interaction or timing between grazing and stream discharge events is the critical factor affecting streambank stability in grazed riparian areas. On the same study area, Davis and Marlow (1990) found that the amount of time cattle spent grazing in a riparian area did not differ among deferred rotation and short duration grazing. However, cattle in the short duration system did spend less time ruminating in the riparian area.

Streambank degradation did not differ among no grazing, season-long continuous grazing, 2-pasture deferred rotation, 4-pasture rest rotation, and heavy late-season grazing where wild ungulates were not allowed access (Buckhouse et al. 1981, Bohn and Buckhouse 1986). Where wild ungulates did have access, grazing differed from no grazing, with season-long continuous and deferred rotation more detrimental than rest rotation. On mountain meadows in northeastern California, rest rotation again showed advantages over season-long continuous grazing by increasing plant basal cover (Ratliff et al. 1972). Myers and Swanson (1996a) documented improved streambank stability when a rest rotation grazing system replaced heavy, season-long grazing. And Bohn and Buckhouse (1985a) found that in mountain meadows rest rotation compared with no grazing did not result in different rates of infiltration and sediment production, but deferred rotation and season-long grazing responded negatively.

Kovalchik and Elmore (1992) subjectively ranked grazing systems for willow-dominated plant communities. They concluded that early-season grazing and winter grazing systems were highly compatible; rotation, rest-rotation, and deferred-rotation grazing systems were

moderately compatible; and spring-fall, deferred, late-season, and season-long grazing were incompatible.

Platts (1991) subjectively rated grazing systems for riparian habitats as related to fisheries needs on a scale of 1 to 10. Continuous season-long use rated lowest (1); deferred-rotation (4) and rest-rotation (5-6) rated moderately; and riparian pasture (8), fencing (9), and complete rest or enclosure (10) rated the highest.

Buffer Strips

Buffer strips are bands of ungrazed vegetation adjacent to surface waters that are designed to remove sediment, nutrients, and fecal bacteria carried by overland flow before such runoff reaches surface waters. Buffer strips remove these materials by slowing the velocity of surface runoff to enhance infiltration, deposition of suspended solids, adsorption to plant and soil surfaces, and absorption of solubles by plants (Lee et al. 1989). For these mechanisms to be effective, overland flow through buffer strips must be slow and shallow (Lee et al. 1989). This is one reason why buffer strips are more effective at filtering runoff from sites with lesser slopes than from steeply-sloped sites (Hamlett and Epp 1994). It is also important to note that sediments and sediment-bound nutrients and bacteria that are trapped during low-to-moderate flow may be flushed out if high overland flow occurs during large storm events or snowmelt runoff (Reuter et al. 1992).

Buffer strips have been studied for their effectiveness as filters of cattle excrement from feedlots and dairies. Buffer strip widths from 12.5 to 20 feet were sufficient to filter nutrients and fecal bacteria from these areas of extremely high cattle concentrations (Doyle et al. 1975, Oksendahl 1997), provided that the rate of overland flow was not excessive (Schellinger and Clausen 1992).

In a laboratory experiment with Kentucky bluegrass sod and dairy manure, Larsen et al. (1994) found that a 2-foot wide buffer strip on a 5% slope reduced fecal coliform in runoff by 83% and a 4.5-foot wide buffer strip by 95%. However, all fecal coliform concentrations

measured 20 and 30 minutes after manure application were in excess of 200 counts/ml.

Review of research literature discovered no study involving a field experiment of livestock grazing and buffer strip dimensions. Based on Doyle et al. (1975) and Oskendahl's (1997) studies of manure-polluted runoff, it appears likely that a buffer strip of at least 12.5 feet on each side of a stream may be adequate to protect water quality from coliform bacteria and effectively filter nutrients. Soil type, slope, vegetative cover, fecal concentration, and runoff

levels all help determine the width of buffer strip that may be needed. Sometimes the sinuosity of the streambank or shoreline dictates that the buffer strip fence is easier to build and maintain when placed greater distances from the edge of the surface water. Water bodies adjoined by steep terrain may need wider strips (Hamlett and Epp 1994). Much more scientific investigation of the relationship between buffer strip width and water quality for cattle grazing is needed.

CHAPTER 2. WHAT ARE BEST MANAGEMENT PRACTICES?

Idaho's water quality law defines a best management practice (BMP) as "practices, techniques or measures developed, or identified, by the designated agency and identified in the state water quality management plan which are determined to be a cost-effective and practicable means of preventing or reducing pollutants generated from nonpoint sources to a level compatible with water quality goals" (Idaho Code § 39-3602(2)). In other words, BMPs are officially approved ways of controlling nonpoint source water pollution. They include maintenance and operational procedures as well as structural and non-structural controls. They must be technically and economically feasible and socially acceptable (IDEQ and ISCC 1993).

In Idaho, the official source of BMPs for agriculture, including cattle grazing, is the *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993). BMPs are recognized in section 319 of the federal Clean Water Act as the primary mechanism to enable achievement of water quality standards when nonpoint sources of pollution are involved. Each state must develop an implementation plan, which may be regulatory or nonregulatory (O'Laughlin 1996). Idaho law requires the implementation of BMPs for mining and forest practices; however, agricultural and livestock grazing BMP implementation takes a nonregulatory approach, which is sometimes described as "voluntary" in nature.

Agricultural and grazing activities are subject to a back-up regulatory program (IDAPA 16.01.02.350, IDEQ and ISCC 1993). If "designated beneficial uses" are impaired or water quality criteria are not met and BMPs are not used, the Idaho Division of Environmental Quality can take enforcement action. However, the agency has agreed to do this only when an imminent and substantial danger to public health and environment exists and the operator refuses to remedy the situation, or when an operation has been demonstrated to be a significant contributor to pollution and the implementation agencies have made every feasible attempt to bring the operation into compliance with voluntary

programs, but the operator refuses to comply (IDEQ and ISCC 1993).

BMPs are not a "one size fits all" approach. A BMP is developed for application to a particular site to address a specific nonpoint source pollution concern based on site-specific data gathered and analyzed by a trained and experienced resource specialist (IDEQ and ISCC 1993). BMPs are designed to meet the landowner's objectives and a site-specific water quality goal. Because of the unique combination of site characteristics, water quality goals, component practices, and decision makers, the selected BMP applied to the site will be unique (IDEQ and ISCC 1993).

How Are BMPs Established and Implemented?

For private landowners, a BMP is established and implemented by working with a resource specialist from either the local Soil Conservation District (SCD) of the State of Idaho or the local unit of the USDA Natural Resources Conservation Service (NRCS), or both. The resource specialist presents to the landowner a number of alternative BMPs that not only meet water quality goals, but also meet the landowner's needs and capabilities (IDEQ and ISCC 1993). Natural resource specialists and engineers from these two agencies provide technical assistance for implementation.

Cost-sharing funds for implementing BMPs are available from a number of sources (Table 2.1). Local offices of SCDs or the NRCS can provide landowners with more information about cost-sharing programs. Cost-share programs require a contract between the farmer or rancher and the SCD, and the contract includes an individual water quality plan. In some watersheds and SCDs, groups of landowners participate in Soil Conservation District Water Quality Projects; however, each landowner still has an individual plan. Each water quality plan is tailored for the individual farm or ranch so as to meet site-specific water quality goals. All water quality plans are required to include "BMPs for all critical areas or pollution sources on the participant's land encompassed in the project area ..." (IDAPA 16.01.144000,02b).

Table 2.1. Cost-Sharing Programs for Agriculture and Livestock Grazing BMP Implementation in Idaho.	
Program	Administrative Agencies
State Agricultural Water Quality Program (SAWQP)	IDEQ, ISCC, SCD
Conservation Operations Program	NRCS
Resource Conservation and Development Program (RC&D)	NRCS
USDA Demonstration and Hydrologic Unit Projects	NRCS, CES, CFSA
Emergency Watershed Protection Program (EWP)	NRCS
Small Watershed and Flood Prevention Program	NRCS
Cooperative River Basin Studies Program (CRBS)	NRCS
Environmental Quality Incentives Program (EQIP)	CFSA, NRCS
Rural Clean Water Program (RCWP)	CFSA, NRCS
Food Security Act of 1985 (FSA)	CFSA, NRCS
Food, Agricultural, Conservation, and Trade Act of 1990 (FACTA)	CFSA, NRCS
Federal Agriculture Improvement and Reform Act of 1996 (FAIRA)	CFSA, NRCS
Clean Water Act Section 319 Demonstration Projects	EPA, IDEQ
Resource Conservation and Rangeland Development Program (RCRDP)	ISCC, SCD
Agencies: CES—U.S. Dept. of Agriculture, Cooperative Extension Service CFSA—U.S. Dept. of Agriculture, Consolidated Farm Service Agency EPA—U.S. Environmental Protection Agency IDEQ—Idaho Division of Environmental Quality NRCS—U.S. Dept. of Agriculture, Natural Resources Conservation Service ISCC—Idaho Soil Conservation Commission SCD—Soil Conservation District(s), State of Idaho	

Source: Adapted from IDEQ and ISCC (1993)

What are BMPs for Cattle Grazing in Riparian Areas?

A BMP is actually comprised of one or more “component practices” that have been adopted by the Idaho Soil Conservation Commission and are listed in the *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993). For example, Figure 2.1 illustrates the development of a riparian/ wetland BMP from component practices for an irrigated pasture. Component

practice descriptions provide general guidelines and criteria that are adapted at the local level to fit a specific site. Therefore, it is impossible to list specific BMPs for cattle grazing in riparian areas. The research results reported in Chapter 1 of this report are intended to help resource specialists, landowners, and local SCDs tailor component practices to achieve a BMP that is appropriate for a specific site.

[Continued on Page 35]

EXAMPLE - B: DEVELOPMENT OF RIPARIAN/WETLAND BMP USING COMPONENT PRACTICES

SITUATION: Beneficial Use Impaired - SALMONID SPAWNING
 Pollutant - SEDIMENT EXCEEDS WATER QUALITY STANDARD
 Source - ERODING STREAMBANK
 Land Use - IRRIGATED PASTURE

PROCEDURE: CONDUCT RESOURCE INVENTORY AND SITE ASSESSMENT,
 EVALUATE DATA TO DEVELOP ALTERNATIVE BMPs

SITE SPECIFIC BMP ALTERNATIVE #1	SITE SPECIFIC BMP ALTERNATIVE #2	SITE SPECIFIC BMP ALTERNATIVE #3
STREAMBANK PROTECTION (i.e. GABION JETTIES) CHANNEL VEGETATION CRITICAL AREA PLANTING PLANNED GRAZING SYSTEM LIVESTOCK EXCLUSION (i.e. DEFERMENT) FENCING PASTURE & HAYLAND MGT.	STREAMBANK PROTECTION (i.e. GABION JETTIES) CRITICAL AREA PLANTING PLANNED GRAZING SYSTEM LIVESTOCK EXCLUSION (i.e. DEFERMENT) FENCING PASTURE & HAYLAND MGT.	STEAMBANK PROTECTION (i.e. RIPRAP)

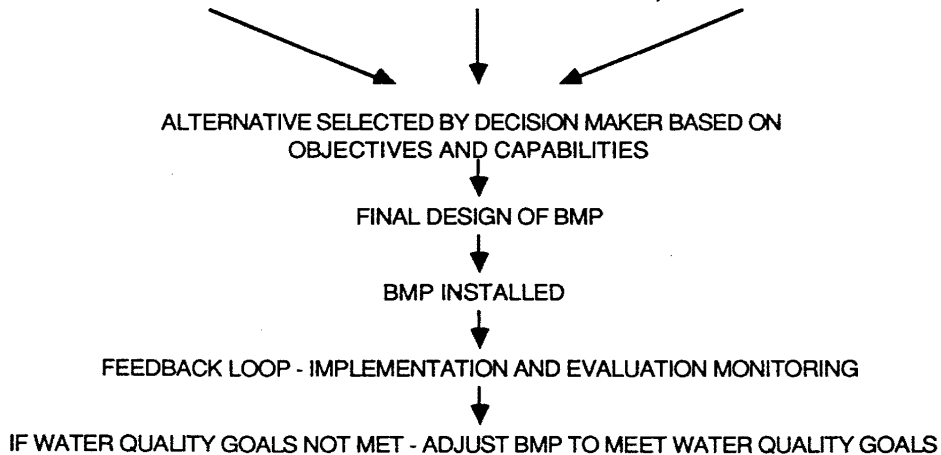
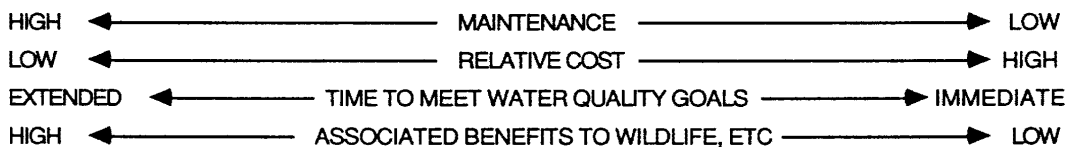


Figure 2.1. Example of the Development of a Riparian/Wetland BMP Using Component Practices

Source: IDEQ and ISCC (1993).

Case Examples

Introduction

It has been said more than a thousand times that a picture is worth a thousand words. When this project was undertaken, one of the Advisory Committee members suggested including several case examples with photographs to illustrate how riparian areas will respond to changes in grazing management. It proved to be difficult to locate such case examples in Idaho. We hope the two included here serve their intended purpose.

Case 1: Sawmill Creek Riparian Project

Approximately 40 miles northwest of Howe, Idaho, the Sawmill Creek riparian project is on a tributary of the Little Lost River. The project encompasses an eight-mile stream segment at the bottom of massive alluvial fans. Elevations range from 6,150 to 6,700 feet, and the area receives an average of 8 to 10 inches of precipitation annually. The combined effects of flooding, channelization, and warm season grazing by livestock eliminated much of the existing riparian vegetation and led to bank instability.

There were seven reasons for undertaking this project: (1) lack of riparian habitat, (2) concern for bull trout populations, (3) cattle damage to riparian vegetation and streambanks, (4) mitigation of fish loss in the flood control project, (5) dewatering of the creek during low flows, (6) erosion and new channels caused by high flows, and (7) channelization (to improve water delivery). During the first 20 years of this project, four objectives were to be achieved:

- ! increase fish populations by 50%,
- ! decrease stream width by 30%,
- ! increase stream depth by 30%, and
- ! increase riparian woody species cover by 75%.

Sawmill Creek is the pilot riparian project for the Idaho Falls District of the Bureau of Land Management (BLM, now part of the Upper Snake River Districts). This project began as a mitigation project for the loss of fish habitat due to construction of the Howe sink trenches. A series of large infiltration galleries, the trenches are designed to “sink” or completely infiltrate the Little Lost River before it reaches the town of Howe, Idaho. The mitigation project was required to offset fishery losses from the construction of the trenches. The Idaho Department of Fish and Game (IDFG), the USDA Natural Resources Conservation Service, and the BLM collaborated to fund the mitigation. The loss of trout populations in Sawmill Creek was mitigated by an \$87,000 habitat improvement project on eight miles of stream.

Approximately eight miles of fence were installed along Sawmill Creek to keep livestock out of the stream and from trampling streambanks. The upper 4.5 miles of fenced riparian area are grazed only in the spring for two successive years and then rested every third year. It is grazed at 200-300 AUMs for two to three weeks in May. The lower 3.5 miles of riparian area were temporarily fenced to totally exclude livestock grazing for 10 years until streambanks improved. Now it is being grazed every third year when the upper riparian area is being rested. In addition, a spring water supply is diverted through 4.5 miles of pipeline to upland watering troughs to provide an alternate source of water for livestock. In the upper fenced 4.5 miles of stream, gaps in the fence provide livestock access to drinking water.

Photograph 1-1.
Upper pasture of
Sawmill Creek in
1986 following
many years of
season-long
grazing.



Vegetative growth and regeneration assessments by BLM are positive. The plan calls for continuing analysis and evaluation of objectives by the project team throughout the project's planned period. It has been indicated that resident populations of bull trout occur in the upper reaches of Sawmill Creek year-round. The creek has taken a significant period of time to recover. Presently, Sawmill Creek is labeled as functioning-at risk because of the fluctuating water temperatures and water flows from year to year. However, as the green belt has increased and the fluctuations in temperature and stream flow have decreased, fish populations have increased as well.

Photograph 1-2.
The same
location as
Photograph 1-1 in
July of 1991 after
a spring-only
grazing system
was implemented
in 1986.



Photograph 1-3.
Another site on the upper pasture of Sawmill Creek in 1988 shows the results of only two years of the spring-only grazing.



On the reach of Sawmill Creek within the project area, rainbow trout, brook trout, and bull trout have been found throughout the summer, although their numbers are not as high as desired. As temperature increases, fish migrate to the upper reaches of the stream. All spawning is occurring in the forested areas of the upper reach.

On the upper fenced portion of the project area, livestock are still allowed to graze spring-only in a short-duration grazing system, which appears to be working very well. Livestock are still excluded from the lower fenced portion of Sawmill Creek.

Photograph 1-4.
The same site as Photograph 1-3 in 1991 after five years of the spring-only grazing.



Photograph 1-5.
Lower pasture of
Sawmill Creek in
1988 with two years
of total livestock
exclusion. Years
1987 and 1988 were
drought years.



Droughts occurred in 1987 and 1988, and lower Sawmill Creek had no flow in 1988. However, droughts equally severe occurred in 1992 and 1994, and the creek maintained late fall base flows due in part to the improved riparian corridor.

Photograph 1-6.
The same location as
Photograph 1-5 in
1991 after five years
of total livestock
exclusion.



Photograph 2-1.

The southern portion of the Clover Creek Allotment in 1959 shows a lack of riparian vegetation adjacent to the streambed. (The road may serve as a location guide for comparison with Photograph 2-2.)



Case 2: Clover Creek Allotment Plan

The 42,560-acre Clover Creek Allotment is located north of Bliss, Idaho. Elevation ranges from 3,200 to 6,600 feet with average annual precipitation of 10 to 16 inches. Riparian vegetation includes aspen, willows, sedges, rushes, a variety of forbs, and meadow grasses.

Many wildlife species use the Clover Creek Allotment. Wintering elk and deer, upland game birds, and resident antelope use the southern area. In the northern area, wildlife species include resident deer, chuckar, Hungarian partridges, and sage grouse. Spring, fall, and winter use is made by deer that migrate south from the Camas Prairie to their winter range northwest of Bliss, Idaho.

Photograph 2-2.

In 1989, 13 years after the deferred-rotation system was implemented, the riparian area shows an increase in woody vegetation.



Photograph 2-3.

Clover Creek in 1950 displays a lack of woody vegetation and unstable streambanks. Bank sloughing is evident by the shrub that has fallen into the streambed. (The ridge line may serve as a location guide for comparison with Photograph 2-4.)



Prior to 1976, the allotment was grazed year-round at high intensity. In 1976 the Clover Creek Allotment Management Plan/Agreement was implemented as a result of the Shoshone Grazing Environmental Impact Statement negotiations. The allotment is divided into two grazing areas by the creek, which flows east to west through the allotment, with a total of 3,378 active cattle AUMs under permit. One of the objectives of the plan was to improve the quality of riparian vegetation. A target utilization level for riparian graminoids (sedges and rushes) of 60 percent was established.

Photograph 2-4.

By 1989, Clover Creek shows an increase in woody vegetation. The plants have helped stabilize the stream channel, which is no longer visible.



Photograph 2-5.

In 1976, Clover Creek exhibits undercut streambanks, heavy siltation, lack of a floodplain, and little woody vegetation. (The shrubs in the upper-left background may serve as a location guide for comparison with Photograph 2-6.)



In the southern area, a three-pasture deferred-rotation system is used where one field each year is deferred from grazing through the growing season (spring use period). The deferred field is alternated among the three fields each year so that once in three years each field is rested from grazing during the growing season. The other fields are alternated between early and late spring grazing during the growing season so that no unit is grazed at the same time of the season in successive years. Half of the forage in the deferred field is used each fall. This becomes the early-spring use field the following spring.

The northern area is managed under a two-pasture deferred system that allows grazing use in one pasture during the late spring/early summer and defers use in the other pasture until fall. The amount of fall use depends largely on the availability of livestock water. Use in the pastures is alternated so that no pasture is grazed at the same time in the season in successive years.

Photograph 2-6:

By 1989, 13 years after implementing the grazing allotment plan, Clover Creek shows an increase in woody vegetation, ground cover, and stabilization of the stream channel.



[Continued from Page 26]

BMP component practices are not specifically categorized into those that apply to cattle grazing in riparian areas; instead, two categories may be applicable: grazing lands and riparian/wetlands. Table 2.2 lists the component practices for these two categories from the 1991 *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993). Not all of these components may be a part of every BMP nor applicable to all riparian grazing areas. In 1993, a component practice entitled *Proper Grazing Use, Riparian Areas* was adopted; a copy of it is located in the Appendix to this report.

Many component practices in the *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993) are based on practices and technical standards in the NRCS *Field Office Technical Guide*. Many NRCS practices are being revised currently. One of the major changes is that a new practice called Prescribed Grazing is being developed that will combine the features of Deferred Grazing, Pasture and Hayland Management, Planned Grazing System, Proper Grazing Use, and Proper Woodland Grazing. However, the NRCS changes must be approved by the Idaho BMP Technical Committee before they can be listed in the Catalog of Component Practices in the *Idaho Agricultural Pollution Abatement Plan*.

Effectiveness of BMPs

The question of effectiveness of BMPs for reducing nonpoint source pollution has two dimensions: effectiveness of individual BMPs on site, and effectiveness of a BMP program over an entire watershed. Neither of these dimensions has been explored extensively in the scientific literature in regards to cattle grazing in riparian areas; however, some insight may be gained by looking at studies from forestry and agriculture in general.

Much research has found that BMPs reduce nonpoint source pollution on individual sites to acceptable levels for both forestry (Lynch and Corbett 1990; Binkley and Brown 1993a, 1993b; Ice et al. 1997) and cropland agriculture (Clausen and Meals 1989, Gale et al. 1993, Novotny and Olem 1994). However, variability

in the effects of specific BMPs can be extreme because of differences in climatic and hydrologic conditions (Novotny and Olem 1994). BMPs must be tailored for specific sites to be effective.

To help ensure effectiveness, only BMP component practices with adequate scientific supporting data should be approved for use (Harris et al. 1995). Some current BMP technical standards used by the NRCS are either not based on research information, or are based on research information from environments outside Idaho, such as the Midwest, and would probably not withstand legal challenges (R. Mahler, review comments). However, all BMP component practices for Idaho have been through a thorough peer review by technical experts and a public review (D. Blew, review comments).

The effectiveness of individual BMPs also varies because of differences in implementation, monitoring, and maintenance. Proper implementation is essential for a BMP to function effectively. Implementation is less often a problem if cost-sharing funds are involved and inspection is required by the funding agency. However, subsequent monitoring and maintenance are necessary to ensure the continued effectiveness of a BMP.

The record of the effectiveness of BMP programs at the watershed level is mixed. Some reviews indicate BMP programs are effective (Brown et al. 1993, Gale et al. 1993, IDEQ 1993, Anderson and Flaig 1995, Ice et al. 1997); others are less effective (Gale et al. 1993, Meals 1993, Garrison and Asplund 1993, Wolf 1995); and reviews of other programs suggest that it is too early to tell and only monitoring over an extended time period will indicate success (Gale et al. 1993, Park et al. 1994). In one of the few watershed-scale evaluations of pasture BMPs, Edwards et al. (1997) found that BMP implementation on Arkansas pastures decreased nitrogen loading and chemical oxygen demand 23 to 75% per year.

Most of the variability in the success of BMP programs appears to come from the degree of participation. Higher rates of participation by landowners in a watershed lead to more reductions in nonpoint source pollution (Gale et al. 1993, Park et al. 1994, Anderson

Table 2.2. BMP Component Practices for Livestock Grazing Lands and Riparian Wetlands			
Component Practice	Grazing Lands	Riparian/Wetlands	NRCS Field Office Technical Guide #
Access Road	X	X	560
Brush Management	X		314
Channel Vegetation		X	322
Critical Area Planning	X	X	342
Deferred Grazing	X	X	352
Diversion	X		362
Ephemeral Watercourse Planting	X	X	308
Fencing	X	X	382
Filter Strip		X	393
Firebreak	X		394
Fish Stream Improvement	X	X	395
Grade Stabilization Structure	X	X	410
Grazing Land Mechanical Treatment	X		548
Heavy Use Area Protection		X	561
Irrigation Canal or Lateral	X		320
Irrigation Storage Reservoir	X		436
Irrigation System, Sprinkler	X		442
Irrigation System, Surface and Subsurface	X		443
Irrigation System, Tailwater Recovery	X		447
Irrigation Water Conveyance, Ditch or Canal Lining	X		428
Irrigation Water Conveyance, Pipeline	X		430
Irrigation Water Management	X		449
Livestock Exclusion	X	X	472
Nutrient Management	X	X	590
Pasture and Hayland Management	X		510
Pasture and Hayland Planting	X		512

Table 2.2. continued			
Component Practice	Grazing Lands	Riparian/Wetlands	NRCS Field Office Technical Guide #
Pest Management	X	X	595
Pipeline	X	X	516
Planned Grazing System	X	X	556
Pond	X	X	378
Pond Sealing and Lining	X		521
Prescribed Burning	X	X	338
Proper Grazing Use	X	X	528
Proper Woodland Grazing	X		530
Pumping Plant for Water Control	X	X	533
Range Seeding	X		550
Sediment Basin		X	350
Spoil Spreading		X	572
Spring Development	X	X	574
Stock Trails and Walkways	X	X	575
Streambank and Shoreline Protection		X	580
Stream Channel Stabilization		X	584
Structure for Water Control		X	587
Trough or Tank	X	X	614
Water Harvesting Catchment	X	X	636
Well	X	X	642
Wetland Development and Restoration		X	657
Wildlife Upland Habitat Management	X	X	645

Source: Adapted from IDEQ and ISCC (1993), pp. VIII-13-17

and Flaig 1995, Wolf 1995). However, in some cases high rates of participation have not lead to improved water quality (Garrison and Asplund 1993).

Idaho law requires that BMP programs be monitored to determine their effects on water quality (Idaho Code § 39-3621); however, the monitoring program must be adequately funded to be successful (O’Laughlin 1996).

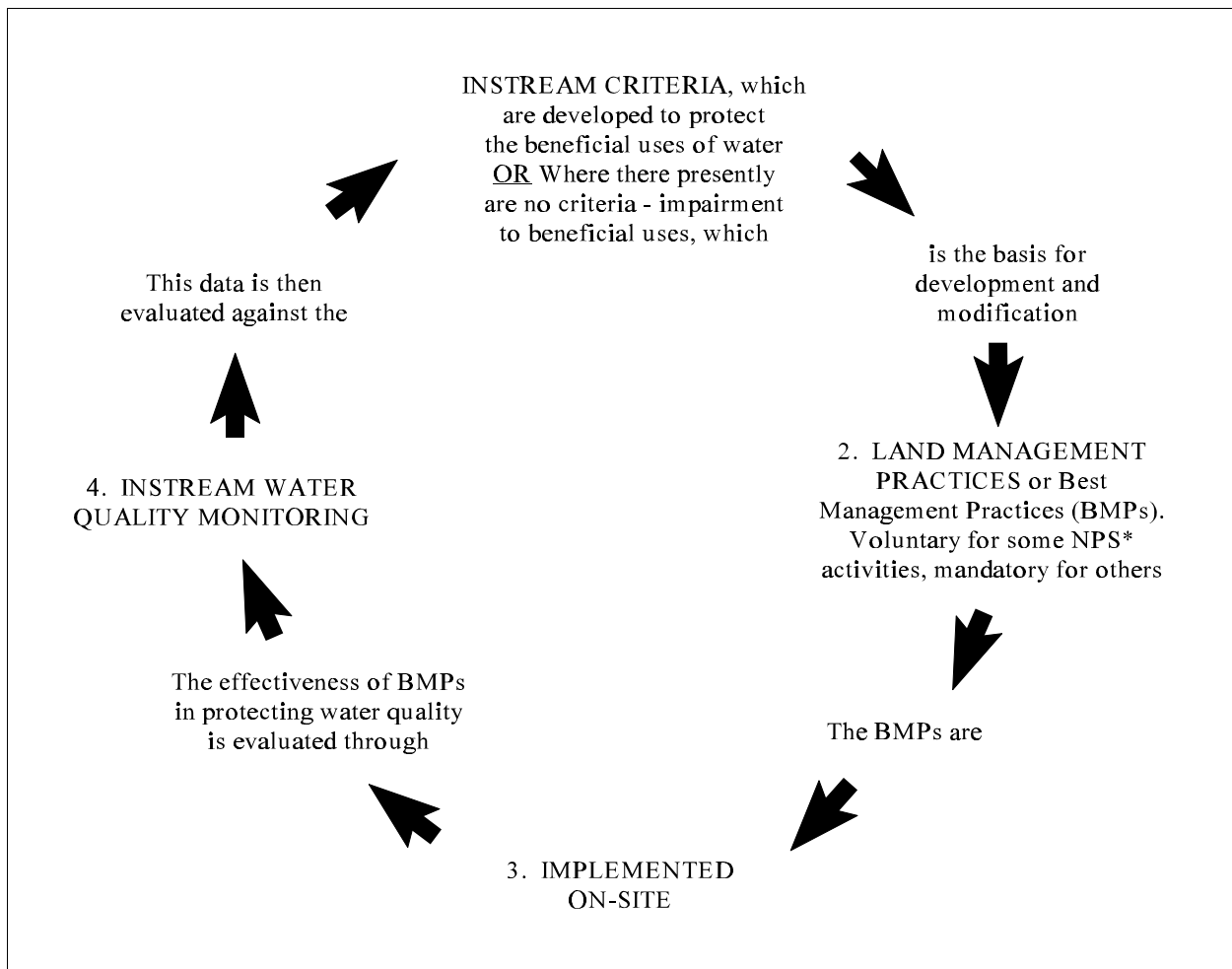
Monitoring and Modifying BMPs

Monitoring of BMP effectiveness is important because monitoring has the potential of delivering the most useful information and feedback needed to meet state water quality standards (Clark 1990). The *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993) calls for monitoring to be consistent with the *Coordinated Nonpoint Source Water Quality Monitoring Program for Idaho* (Clark 1990), which features a “feedback loop” process to modify BMPs if necessary (Figure 2.2). This process involves two types of monitoring: implementation of on-site audits of BMP design and adequacy,

and instream beneficial use impact monitoring (Figure 2.2).

A series of protocols for monitoring have been developed for the state’s monitoring program. *Protocols for Classifying, Monitoring, and Evaluating Stream/Riparian Vegetation on Idaho Rangeland Streams* (Cowley 1992) is the most suitable for riparian areas (D. Blew, review comments). It calls for monitoring such things as: woody species age class, vegetation utilization (herbage stubble height, twig count), streambank stability, and woody vegetation stream cover (canopy density, overhanging vegetation, thermal input) (Cowley 1992).

Personnel from the SCD or the NRCS work



*NPS=Nonpoint Source

Figure 2.2 Feedback loop process for nonpoint source control.

Source: Clark, William H. *Coordinated Nonpoint Source Water Quality Monitoring Program for Idaho*, Idaho Department of Health and Welfare, p.7 (January 31, 1990).

with farmers and ranchers on BMP monitoring and surveillance procedures. If monitoring shows that a BMP is not effective, then the BMP will be modified until the site-specific water quality goals are met (IDEQ and ISCC 1993). Modifying a BMP may involve changes to either structures or techniques and may require changes to the landowner's contract with the SCD.

The SCDs and the Idaho Soil Conservation Commission (ISCC) are responsible for modification of the technical standards of BMP component practices. According to the *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993), component practices are modified or new ones developed when there is improved technology through research and demonstration, change in economic conditions, change in social conditions, or change in water quality concerns (IDEQ and ISCC 1993). SCDs and local units of technical agencies—such as the NRCS, Idaho Division of Environmental Quality (IDEQ), or U.S. Bureau of Land Management—review and identify the need for new or modified component practices.

Proposed changes are then forwarded to the ISCC which then convenes the BMP Technical Committee. This committee is made up of representatives from the ISCC, IDEQ, NRCS, University of Idaho-Cooperative Extension Service, U.S. Environmental Protection Agency, U.S. Farm Services Agency, U.S. Bureau of Land Management, U.S. Forest Service, Idaho Department of Lands, Idaho Department of

Agriculture, Idaho Department of Water Resources, and others as needed and appropriate. The committee reviews the adequacy of existing component practices and evaluates the need for modification or new component practices. It then recommends modifications or new component practices to the ISCC and the IDEQ. The ISCC and IDEQ then incorporate the changes into the *Idaho Agricultural Pollution Abatement Plan*. Lastly, the SCD or other local technical agency adopts the practice for their use locally.

BMPs on Federal and State Lands

Federal and state land management agencies (U.S. Forest Service, U.S. Bureau of Land Management, and Idaho Department of Lands) have agreed to implement the *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993). The agencies have agreed to promote and apply BMPs, and they are responsible for the technical adequacy of the design and implementation of BMPs on lands they manage. Private graziers who hold permits or leases on state or federal land are subject to the policies of the managing agency. The management agencies use the same component practices from the *Idaho Agricultural Pollution Abatement Plan* that private landowners do, and the agencies work closely with the SCDs to coordinate priority areas for BMP implementation (IDEQ and ISCC 1993).

CHAPTER 3. HOW IS CATTLE GRAZING IN RIPARIAN AREAS ADDRESSED IN IDAHO WATER QUALITY POLICY?

Cattle grazing in riparian areas can cause nonpoint source water pollution, or polluted runoff, and best management practices (BMPs) are designed to control it. However, BMPs are only one part of the water quality policies that address nonpoint source pollution; those policies are the focus of the following sections.

Water quality is difficult to define and has different meanings for different people. Water quality generally implies suitability for a particular purpose; in legal terms, a “designated beneficial use” (O’Laughlin 1996). Water quality policy is a complex, federal-state-local partnership. Numerous agencies and units at all levels of government are responsible for water quality or the management of the riparian lands that influence water quality.

The Federal Clean Water Act

A complete analysis of the federal Clean Water Act and its implications for Idaho is beyond the scope of this report. However, the Policy Analysis Group has recently completed a report addressing these issues (O’Laughlin 1996). A brief summary is provided herein.

Water quality standards, which are developed by the states, are the key to understanding how the Clean Water Act works, and the principal mechanism for fulfilling the purposes of the Act.

Water quality standards are determined by each state and consist of three things: (1) “designated beneficial uses” for each of the states’ waters, (2) criteria indicating whether the uses are being supported, and (3) an “antidegradation” policy statement expressing the intent to protect existing water quality where it exceeds the standards. “Designated beneficial uses” and criteria are explained in the next section on **Idaho Water Quality Policy**.

The Federal Water Pollution Control Act of 1972, and its subsequent amendments, is one of the most comprehensive pieces of environmental legislation ever passed by Congress. The Act

established a national objective “to restore and maintain the chemical, physical, and biological integrity of the nation’s waters,” and called for all U.S. waters to be “fishable and swimmable” and for the elimination of pollutant discharge into navigable waters. In 1977, amendments to the Act were made under the name the Clean Water Act, which has since been adopted as the generic name for the policy. The Act was again amended in 1987 under the Water Quality Act to focus more attention on nonpoint sources of pollution as well as point sources because many of the nation’s rivers, lakes, and streams were impaired by nonpoint source pollution (EPA 1991).

The Clean Water Act gives states the primary responsibility for achieving the Act’s goals. Through the U.S. Environmental Protection Agency, the federal government provides guidelines for and oversight of state water quality management programs as well as some funding to implement those programs. If states do not maintain a program that meets EPA’s approval, then the federal government can assume responsibility for water quality management in that state under the supremacy clause of the U.S. Constitution.

The Clean Water Act requires states to identify nonpoint sources of water pollution from a range of activities that includes but is not limited to cropland agriculture, livestock grazing, recreation, mining, and forestry. States are also required to develop management programs for controlling nonpoint sources of pollution. BMPs are the recognized method of control for nonpoint source pollution. Funding to states for the development of BMPs is authorized by Section 319 of the Clean Water Act.

Idaho Water Quality Policy

Idaho water quality policy is based on the inherent sovereignty of the individual states to enact laws to protect public health, safety, and welfare. This is grounded in the police power to regulate public health and safety, and is not a delegation of authority or a federal grant.

Idaho has a two-pronged strategy for protection of water quality. The first protects the quantity of water in water bodies, which

helps to protect quality. It provides for stream channel protection, dam safety, instream flows, and classification of rivers as natural or recreational, and is primarily managed by the Idaho Department of Water Resources. The second prong is pollution control and is chiefly administered by the Idaho Division of Environmental Quality (IDEQ) in the Idaho Department of Health and Welfare.

Idaho must abide by the provisions of the federal Clean Water Act. In 1995, Idaho revised state water quality law and the process for water quality management planning. This was done in response to a federal court ruling on a citizen lawsuit filed under the provisions of Clean Water Act. The new Idaho law (Idaho Code § 39-3601 et seq.) is complex and has not yet been fully implemented in the state. The law directs the IDEQ to identify areas in Idaho with impaired water quality, to improve water quality in those areas, and to prevent water quality in other areas from becoming impaired (O'Laughlin 1996).

Water Quality Standards: Designated Beneficial Uses and Criteria. The federal Clean Water Act requires that states adopt water quality standards that identify “designated uses” for water bodies and provide water quality criteria based on those uses (U.S. Code § 1313(c)(2)(A)). At a minimum, designated uses must provide for “the protection and propagation of fish, shellfish, and wildlife” and provide for “recreation in and on the water” where attainable (O'Laughlin 1996). The Act prohibits states from designating waste transport or waste assimilation as a designated use (EPA 1995), thus the designated uses must be “beneficial.”

In Idaho, the Department of Health and Welfare, through the Division of Environmental Quality, has responsibility for assigning “designated use” or “designated beneficial use” (Idaho Code § 39-3602 (6)). Designated use is dependent upon actual use, the ability of the water to support a non-existing use either now or in the future, and its likelihood of being used in a given manner (IDAPA 16.01.02.003.04). Designated beneficial uses currently include: agricultural water supply, domestic water supply, industrial water supply, cold water biota, warm

water biota, salmonid spawning, primary contact recreation, secondary contact recreation, wildlife habitats, and aesthetics (IDAPA 16.01.02.100).

Criteria are related to chemical, physical, or biological characteristics of the water body and may be numeric or narrative. It is not possible to develop realistic numeric criteria for some contaminants; sediment is one example. Idaho's narrative criterion asks, “Is the water body free from excess sediment in quantities that impair designated beneficial uses?” (IDEQ 1996).

Idaho's Water Quality. Some of Idaho's waters do not fully support the designated beneficial uses. Under Section 303(d) of the Clean Water Act, the State must identify waters that do not meet applicable water quality standards, called “water quality limited waters” or, simply, impaired waters; and develop Total Maximum Daily Loads (TMDLs) as part of a plan to bring those bodies of water into compliance with standards (see O'Laughlin 1996). In 1992, Idaho submitted a list of 36 such waters to the U.S. Environmental Protection Agency (EPA). In 1993, the Idaho Sportsmen's Coalition and the Idaho Conservation League filed a lawsuit alleging that the list of water quality limited waters was inadequate as was the schedule for developing TMDLs. The U.S. District Court in Seattle ruled in favor of the plaintiffs, and in October 1994, the list was expanded to 962 water quality limited waters. This “303(d)” list of impaired waters includes 10.1% of the stream and river miles in the state, which is approximately the same percentage as other areas in the Interior Columbia River Basin, consisting of eastern Oregon, eastern Washington, and most of western Montana (Table 3.1).

Sediment is the most widespread pollutant in the state, affecting 91% of the impaired waters (Table 3.2). Idaho is in the process of developing TMDLs for all water quality limited waters by 2005.

An assessment of cattle grazing's impacts on designated uses of streams in Idaho does not exist. However, agricultural practices and hydrologic (habitat) modification have the largest impacts on designated beneficial uses of streams

Table 3.1. Water quality impaired waters within the Interior Columbia Basin Ecosystem Management Project (ICBEMP) assessment area, 1996.

State*	Total stream miles in ICBEMP assessment area	Stream miles with any impairment	Percent of stream miles with any impairment	Stream miles with sediment impairment	Percent of impaired stream miles that are sediment-impaired
Idaho	98,984	10,024	10.1%	8,812	87.9%
Montana	31,317	3,912	12.5%	3,034	77.6%
Oregon	75,186	8,123	10.8%	948	11.7%
Washington	49,150	3,962	8.1%	no data	no data
Total	254,637	26,020	10.2%	not meaningful	not meaningful

* Portions of states in the ICBEMP assessment area are all of Idaho, Montana west of the continental divide, and the portions of Oregon and Washington east of the Cascade Range.

Source: *Status of the Interior Columbia Basin: Summary of Scientific Findings* (USDA Forest Service 1996). Idaho and Montana data are from the states' "303(d) list"; Washington data are from the "305(b) report"; the source of Oregon data was unspecified.

Table 3.2. Water quality-limited waters in Idaho affected by sediment, by basin, 1996.

Basin	Impaired Water Bodies (Total)	Sediment is a Pollutant	% of Total	Sediment is the Only Pollutant	% of Total
Bear River	43	42	98%	13	30%
Upper Snake River	198	182	92%	57	29%
Southwest Idaho	187	175	93%	101	54%
Salmon River	115	102	89%	66	57%
Clearwater River	225	216	96%	138	61%
Panhandle	192	159	83%	68	35%
Total	960	876	91%	443	46%

Source: Idaho Division of Environmental Quality, compiled from "The 1996 § 303(d) list for the state of Idaho."

in the state (IDEQ 1988), and livestock grazing is included in both of these categories. Cattle grazing impacts are spread throughout the state, affecting many of Idaho's best known river

systems, including: Henry's Fork, Salmon River, Payette River, Boise River, and Snake River (IDEQ 1994).

Idaho Agricultural Pollution Abatement Plan.

The state's plan to address nonpoint source pollution from agricultural activities including livestock grazing is called the *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993). The objectives of the most recent plan focus on meeting the requirements of the federal Clean Water Act. The goal in Idaho is to restore and maintain the state's waters impacted by agricultural nonpoint sources to the point of fully supporting designated beneficial uses (IDEQ and ISCC 1993). The plan focuses on BMP development, implementation, coordination, monitoring, and evaluation, and it is a source of information about programs that provide technical assistance, information, and cost-sharing to livestock producers.

The plan contains the state's list of BMPs and catalog of component practices for control of agricultural nonpoint source pollution, including pollution resulting from livestock grazing activities. The component practices are added to the plan or modified through a process described in Section VIII of the plan. This process originates with action by local Soil Conservation Districts and involves technical review and input by the interagency BMP technical committee. Final approval of these practices for addition to the plan catalog of component practices is given by the Idaho Soil Conservation Commission and the Idaho Division of Environmental Quality.

Idaho Stream Channel Protection Act. The Idaho Stream Channel Protection Act (Idaho Code § 42-3801 et seq.) also affects riparian areas. This act seeks to protect fish and wildlife habitat, aquatic life, recreation, aesthetic beauty, and water quality only in natural continuously flowing streams and only below the mean high water mark. No authority is included to control activities in the adjacent riparian area.

Federal Agency Roles

Many federal and state agencies have roles in the implementation and enforcement of Idaho's water quality policy. Only those agency roles that are related to riparian area management are

discussed here; many agencies have a larger role in overall water quality management. For a more complete description of state agency roles in water quality policy see Turner and O'Laughlin (1991).

U.S. Environmental Protection Agency

(EPA). The Clean Water Act gives the EPA the responsibility for overseeing how states are implementing the Clean Water Act. The EPA has the authority to write regulations to do this, thus it is a regulatory agency. The Clean Water Act protects fish and other aquatic wildlife; however, the EPA is not a land and resource management agency so it must cooperate closely with other agencies. In addition to its responsibilities under the Clean Water Act, the EPA has jurisdiction under numerous other federal laws that protect wetlands, drinking water, air quality, and public health and safety.

U.S. Forest Service (USFS). The USFS is a land management agency, not a regulator of water quality, but its land management activities significantly affect water quality in Idaho. The USFS manages 21.7 million acres of land in the national forests and grasslands of Idaho, or almost 41 percent of all land in the state (USFS 1996). Almost 1 million units of livestock grazing ("head months") occur annually on national forests and grasslands in Idaho (USFS 1996).

The federal statutes governing national forests mandate that they be managed for multiple uses including "range," "watershed," and "wildlife and fish" (16 U.S. Code § 528). Livestock grazing and water quality are mentioned throughout the statutes but never specifically linked. In the regulations that implement federal statutes, riparian areas are given special attention:

No management practices causing detrimental changes in water temperature or chemical composition, blockages of water courses, or deposits of sediment shall be permitted within these areas which seriously and adversely affect water conditions or fish habitat. Topography, vegetation type, soil, climatic conditions, management objectives, and other factors shall be considered in determining what management

practices may be performed within these areas or the constraints to be placed upon their performance (36 C.F.R. § 219.27(e)).

National forests are required to comply with all applicable federal and state water quality standards (36 C.F.R. § 228.8(b)). The USFS in Idaho has an interagency agreement with the Idaho Division of Environmental Quality (IDEQ) to aid its compliance.

Bureau of Land Management (BLM). The BLM is the second largest land manager in the state of Idaho, responsible for more than 11.8 million acres. This includes 10.7 million acres divided into grazing districts (USDI-BLM 1994). More than 2,100 grazing permits and leases on lands administered by the BLM annually provide 1.3 million animal unit months of livestock grazing (USDI-BLM 1997).

Like the national forests, BLM public lands are managed for multiple uses, including protection of the quality of the “water resource” and a requirement to “provide food and habitat for fish and wildlife and domestic animals” (43 U.S. Code § 1701(a)(8)). The BLM is required to comply with all applicable federal and state water quality laws (43 U.S. Code § 1712(c)(8)), and to aid in compliance under the same interagency agreement with IDEQ as is the USFS.

USDA Natural Resources Conservation Service (NRCS). The NRCS, formerly the Soil Conservation Service, is a federal agency with broad responsibilities for agricultural and conservation programs. The agency was established in the wake of the Dust Bowl of the 1930s with the primary mission of reducing soil erosion on private lands. Numerous laws provide the NRCS with the authority for its programs. One of these laws, the 1977 Soil and Water Resources Conservation Act, provides five objectives: reduce excessive soil erosion, improve water management, reduce upstream flood damage, improve range condition, and improve water quality (Helms 1992). The NRCS is responsible for many of the technical assistance and cost-sharing programs that focus on conservation and stewardship of the nation’s

private land resources. The NRCS cooperates with private landowners, Soil Conservation Districts, the Idaho Soil Conservation Commission, and numerous other agencies in the development and implementation of BMPs.

State Agency Roles

Idaho Division of Environmental Quality (IDEQ). IDEQ is part of the Idaho Department of Health and Welfare. IDEQ has the responsibility for general environmental protection and administers the Idaho Environmental Protection and Health Act of 1972. In general, IDEQ is responsible for the administration of state water quality standards, including monitoring and surveillance of nonpoint pollution sources for enforcement purposes, funding soil and water quality programs in conjunction with the Idaho Soil Conservation Commission and local Soil Conservation Districts, administration of the safe drinking water program, and Ground Water Quality Council support (Turner and O’Laughlin 1991).

Since 1995, Idaho’s water quality policy has emphasized locally based, rather than centralized, planning and program management. IDEQ cooperates with local interests in Basin Advisory Groups (BAGs) and Watershed Advisory Groups (WAGs) in identifying what actions are needed to restore and maintain water quality. Beginning in 1993, Idaho’s Beneficial Use Reconnaissance Projects (BURPs) were implemented to help determine the level at which beneficial uses are being supported. The results of BURPs describe aquatic communities, including fish, as well as the chemical and physical characteristics affecting their habitat. In 1996, IDEQ finalized the Water Body Assessment Guidance (WBAG) document. This process uses BURP and other data to identify designated beneficial uses and to determine whether or not the uses are being fully supported, as they must be under the federal Clean Water Act (O’Laughlin 1996).

Idaho Department of Water Resources (IDWR). IDWR is responsible for development of the State Water Plan, water allocation and stream flow protection, natural resource

geographic information system management, aquifer management, and an ambient ground water monitoring network. Specific programs include: stream channel protection, aquifer recharge, water rights permits and public interest criteria on water rights permits, minimum stream flow allocation, and membership on the Ground Water Quality Council (Turner and O'Laughlin 1991).

Idaho Soil Conservation Commission (ISCC).

The ISCC is the agricultural nonpoint source management agency at the state level. It is responsible for development of the *Idaho Agricultural Pollution Abatement Plan* and administers the State Agricultural Water Quality Program (SAWQP) jointly with IDEQ. The ISCC is responsible for organizing and assisting Soil Conservation Districts (SCDs) and securing assistance for the SCDs from federal and state agencies. The ISCC also is the lead agency for coordinating implementation of the antidegradation policy for agriculture through SCDs.

The ISCC administers the state's Resource Conservation and Rangeland Development Program (RCRDP) that provides long-term, low-interest loans to farmers and ranchers for conservation improvements. The RCRDP also provides grants to projects specifically focusing on the improvement of rangeland and riparian areas. This program has provided many grants to livestock operators specifically for the improvement of riparian areas.

Idaho Department of Lands (IDL). IDL is responsible for regulating water quality through enforcement of the Idaho Forest Practices Act, which requires BMPs. IDL also is the land management agency responsible for endowment lands and public trust lands, including beds and banks of navigable streams and lakes. IDL also consults and cooperates with federal land managers and private landowners to protect water quality, and the agency administers the state lakes protection program (Turner and O'Laughlin 1991).

Under its responsibility for management of 2.4 million acres of state school trust or endowment lands (see O'Laughlin 1990), IDL

administers almost 1,300 grazing leases on 1.9 million acres of these lands. In July 1997, almost 265,000 animal unit months (AUMs) of livestock grazing were reported on these state lands (IDL, personal communications).

Idaho Department of Fish and Game

(IDFG). IDFG is responsible for the collection of information leading to the prosecution of water quality violations resulting in the loss of fish and wildlife resources. IDFG participates in water quality program efforts by providing expertise in fisheries and aquatic biota and is authorized to issue citations for violations of the Stream Channel Protection Act.

Other Public Water Quality Organizations

In addition to the state and federal agencies, local Soil Conservation Districts (SCDs), Basin Advisory Groups (BAGs), and Watershed Advisory Groups (WAGs) have important roles.

Soil Conservation Districts (SCDs). SCDs are not agencies but are governmental subdivisions of the state with a locally elected board. The 51 SCDs in Idaho include private, state, and federal land. SCDs have comprehensive authorities and responsibilities regarding conservation, management, and treatment of natural resources within their respective boundaries. SCDs have been identified in the *Idaho Agricultural Pollution Abatement Plan* as the local management unit for agricultural nonpoint source pollution activities (Turner and O'Laughlin 1991).

Basin Advisory Groups (BAGs). There are six large river basins in Idaho. The revision of state water quality policy in 1995 authorized the IDEQ to designate BAGs for each of them to advise the director on water quality objectives and work cooperatively with IDEQ to achieve those objectives. Membership of the BAGs is to be a balanced representation of the industries and interests directly affected by water quality programs in the basin. Duties of the BAGs are to determine priorities for monitoring and water quality programs; recommend changes in designated beneficial uses for water bodies; assign impaired waters to priority categories for

developing cleanup plans, including TMDLs, and review their development and implementation; and suggest members of Watershed Advisory Groups (WAGs) (Idaho Code § 39-3614, see O’Laughlin 1996).

Watershed Advisory Groups (WAGs). These groups were created in 1995 to advise IDEQ on specific actions needed to control point and nonpoint sources of pollution within watersheds of those water bodies where designated beneficial uses are not supported. Membership shall be representative of the affected industries and interests, including local governments and public agencies. WAGs are to develop and recommend actions needed to effectively control sources of pollution (Idaho Code § 39-3615, see O’Laughlin 1996).

Additional Policies Affecting Riparian Area Grazing

Endangered Species Act (ESA). The ESA is a federal law that provides for the protection and recovery of plant and animal species that are recognized as being threatened or endangered with extinction. The ESA applies to federal, state, and private land. (For a complete review of the ESA see O’Laughlin and Cook 1995.) Although the ESA does not specifically address grazing in riparian areas, the Act has implications for riparian management in areas where threatened or endangered species are found.

The ESA protects habitat for threatened and endangered species from any activity that would adversely modify or “harm” that habitat. This has a particularly large impact in Idaho’s riparian areas because most of the 20 species (17 animals, 3 plants) presently on the threatened and endangered species list in Idaho are highly dependent on riparian areas. Livestock grazing plans may have to be adjusted to avoid “jeopardizing”, “harming”, or “taking” listed species. These terms all have specific definitions under the ESA, but all essentially mean that adverse modification of habitat is prohibited.

The U.S. Fish and Wildlife Service (USFWS) has authority over the protection of all

endangered and threatened species in Idaho, except salmon and steelhead. The National Marine Fisheries Service (NMFS) has authority over these fish because they are anadromous, meaning they spend a portion of their life cycle in the ocean.

PACFISH. The management of anadromous fish habitat has important implications for riparian area grazing in Idaho. Seven of Idaho’s national forests and two BLM districts have portions of their land in anadromous fish habitat (Table 3.3). In 1991, three runs of Snake River salmon in Idaho were listed under the ESA; in October 1997, steelhead joined the list. In 1992, the USFS began working on strategies for managing anadromous fish-producing watersheds, an effort that is known as PACFISH. In 1993 the BLM joined the PACFISH effort.

Under the current interim PACFISH strategies for watershed management, buffer zones, or Riparian Habitat Conservation Areas (RHCAs), have been created for all riparian areas on USFS and BLM lands in the range of anadromous fish. Riparian Management Objectives (RMOs) have been established for the RHCAs and include pool frequency, water temperature, large woody debris, bank stability, lower bank angle, and width/depth ratio. Livestock grazing management must be adjusted to eliminate the impacts that are inconsistent with the RMOs (USFS and USDI-BLM 1994).

INFISH. The Inland Native Fish Strategy (INFISH) also has implications for livestock grazing on Idaho’s national forests. It is an effort similar to PACFISH, but designed to protect inland native fish communities, particularly those of bull trout (*Salvelinus confluentus*). INFISH is a USFS effort and applies to all watersheds on national forests in Idaho not covered by the PACFISH agreement. Like PACFISH, INFISH is also a temporary strategy. INFISH uses RHCAs and RMOs similar to those in PACFISH (USFS 1995). Grazing practices that slow or prevent attainment of RMOs or are likely to adversely affect inland native fish must be modified.

Table 3.3. Anadromous fish habitat on federal lands in Idaho.	
Forest or District	Percent of land in range of anadromous fish
BLM Districts:	
Salmon	83
Coeur d'Alene	52
National Forests:	
Boise	17
Challis	83
Payette	77
Salmon	98
Sawtooth	80
Nez Perce	100
Clearwater	45

Source: Bolon et al. (1995). The Salmon and Coeur d'Alene BLM Districts have been reorganized into the Upper Columbia-Salmon Clearwater BLM Districts.

Interior Columbia Basin Ecosystem Management Project. The PACFISH and INFISH interim strategies for riparian protection are supposed to be replaced in Idaho by the Record of Decision for the Upper Columbia River Basin Environmental Impact Statement (UCRB-EIS). The draft of that EIS was released for public comment in June 1997 and a Record of Decision is expected late in 1998.

The draft EIS for the Upper Columbia River Basin proposes to replace interim PACFISH and INFISH standards for RHCAs and RMOs with similar sounding objectives and sets of standards,

which are "required actions." The default standard under the preferred alternative (Alternative 4) allows conservative livestock grazing management to take place within the entire 100-year floodplain. Alternative 7 could completely eliminate livestock grazing in the 100-year floodplain (see standards AQ-S11 and AQ-S12, page 3-122 in the UCRB-EIS).

At this time it is unknown how the alternatives in the draft EIS will evolve into a final Record of Decision, but it will likely have a significant impact on those who graze cattle on federal lands.

APPENDIX: PROPER GRAZING USE, RIPARIAN AREAS BMP COMPONENT PRACTICE

528-1 11/2/93 Prepared by the Idaho Soil Conservation Commission
[and copied verbatim herein]

Proper Grazing Use (acre)
Riparian Areas

SPECIFICATION

.1 GENERAL

.1.1 Key points in Application of Practice.

.1.1.1 Grazing units that contain stream segments that are not meeting identified beneficial uses or areas where improvement is needed to maintain or improve beneficial uses will be given special management consideration. Management of these areas will be with the specified intent of restoring beneficial uses as defined for the stream segment by the Idaho Department of Health and Welfare Division of Environmental Quality or maintaining or improving streambank condition. Riparian grazing units can be included as part of a Planned Grazing System which may include upland grazing units in the ranch operation. This specification applies to impacts that may be attributed to livestock.

.1.1.2 Beneficial uses for the stream segment will be determined using the Division of Environmental Quality Water Quality Monitoring Protocol 7, Protocols for Conducting Use Attainability Assessments for Determining Beneficial Uses to be Designated on Idaho Stream Segments. The Stream Inventory Worksheet will be filled out prior to grazing for the entire reach of stream in the riparian grazing unit to determine riparian and streambank condition. Use Grazing Management Plan Worksheet for design of grazing system. Use SCS-Range-414 to document proper grazing use, key species and utilization by years. Use SCS-Range 416 for browse species utilization by livestock and wildlife. Where applicable, special consideration will be given to the woody component of the riparian grazing unit due to its importance for fisheries and wildlife.

.1.1.3 Locate the key grazing areas and determine the allowable degree of use taking into consideration the needs of the resource, the operator and the grazing system.

.1.1.4 Streambank condition will show improvement until streambanks are stable and well vegetated or otherwise protected. Unvegetated or unstable streambanks will not increase but will show improvement until a stable condition is reached. This should be reflected in yearly streambank assessments which over time show a trend of improvement (or maintenance) through an evaluation schedule in the grazing plan.

.1.1.5 Season of use will be established to promote desirable riparian vegetation and meet the physiological needs of the plant community.

.1.1.6 Any significant change in management (season of use, water development, etc.) may affect the grazing pattern in a unit. As a result, a new key area may become necessary.

.1.1.7 Make management checks from half to two-thirds of the way through the planned season of use to determine the degree of use and condition of streambanks to provide time to make needed adjustments in grazing management.

.1.1.8 Final utilization and streambank condition will be determined at the end of the grazing season in the riparian unit.

.1.1.9 Knowledge of current riparian condition and site potential are necessary for the development of a livestock use plan for the grazing unit.

.1.1.10 Development of the riparian management plan should be closely coordinated with other agencies whose activities or jurisdictions may impact riparian areas. Those impacts may include wildhorse management, roads, mining, and wildlife.

.1.1.11 In riparian grazing units with large acreages of uplands, management should be directed toward proper distribution of livestock throughout the entire grazing unit. To achieve this distribution, management practices such as water development, salting, herding, brush control, and burning can be used.

.1.2 Criteria for Identifying Key Grazing Areas.

.1.2.1 Key grazing areas will serve as an indicator of grazing use for the pasture.

.1.2.2 Several key areas will be selected within the riparian grazing unit. Areas of livestock concentration, such as stream crossings and driveways will not be selected as key areas.

.1.2.3 Streambank areas that provide a significant, but not necessarily the greatest amount of the available forage within a pasture will be selected as key areas.

.1.2.4 If areas of upland vegetation are fenced into the riparian grazing unit, it may be necessary to locate key areas in the upland portions of the grazing unit to insure total watershed function.

.1.2.5 Utilization measurements of herbaceous hydrophytic species will be taken from vegetation growing on the greenline. The greenline is defined as the first perennial vegetation above the base summer flow of a stream or water body.

.1.3 Criteria for managing streambank stability.

.1.3.1 Livestock damage to streambanks can severely impact beneficial uses and should be given special consideration when developing livestock management plans for riparian areas.

.1.3.2 To prevent soil compaction and the development of shear points, livestock trailing on the streambanks should be discouraged by placement of obstructions or other methods.

.1.4 Vegetative criteria for determining proper grazing use.

.1.4.1 Within the key grazing area, the degree of use will be determined for herbaceous hydrophytic vegetation on the greenline.

.1.4.2 Browse species should be selected as key species if they occur in the riparian plant communities.

.1.5 Criteria for determining the season of use.

.1.5.1 In areas where abatement of nutrient loading during peak runoff periods is needed and can be reduced with increased vegetation, the grazing system and or the season(s) of use will be determined by the District Conservationist to allow for such vegetation increase.

.1.5.2 If woody vegetation naturally occurs on the site, management practices that encourage development of woody vegetation should be used. This may require that late season grazing be minimized or specialized grazing systems be used. Populations of woody species should reflect site potential and management objectives.

.1.6 Criteria for determining proper degree of use in key areas.

.1.6.1 Methods listed in the National Range Handbook, section 1003.1(d) are acceptable methods to use in Idaho in determining forage utilization.

.1.6.2 On SCS form 414, utilization will be expressed as the percent removal by weight of herbaceous hydrophytic species within the key grazing area(s). Herbaceous hydrophytic vegetation will not be grazed beyond 50% by weight during the growing season, or 60% in the dormant season unless permitted by specialized grazing systems with concurrence of the District Conservationist.

.1.6.3 In systems where streambank stability is dependent upon herbaceous vegetation, herbaceous hydrophytic species will have a minimum 4 (four) inch stubble height on the greenline at the end of the grazing and growing season. Specialized systems may permit a stubble height of less than 4 inches but shall be allowed only by concurrence of the District Conservationist.

.1.6.4. In systems where stability is controlled by substrate, browse species or streambank damage will be used to determine proper levels of utilization.

.1.6.5 In streams that are deeply entrenched with vertical banks, or in situations where little or no herbaceous hydrophytic vegetation is present, the proper degree of use will be determined by the district conservationist taking into consideration streambank damage and deterioration and standards for utilization of woody species.

.1.6.6 Key browse species will not be grazed more than 50% (applies to annual growth of twigs and leaves within reach of animals) during the grazing season. Specialized grazing systems may permit exceeding this percentage but shall be allowed only by concurrence of the District Conservationist.

INSTALLATION

.2.1 General

.2.1.1 Identify key grazing areas on conservation plan map and on utilization record form.

.2.1.2 Identify hydrophytic herbaceous species on the streambank and list on utilization record form. Species will be listed for each key grazing area, season of use, and for each kind of animal.

.2.1.4 Record utilization and stubble height upon completion of field check at the end of the growing season.

.2.1.5 Record streambank condition including percent breakage and percent stable streambanks before and at the end of the grazing season.

.2.1.6 When used as part of a Planned Grazing Systems, equal emphasis will be placed on condition of upland grazing units and the riparian grazing unit(s). No unit will be grazed to the detriment of others as riparian condition is dependent upon overall watershed condition.

References Cited

- Abt, S.R., W.P. Clary, and C.I. Thornton. 1994. Sediment deposition and entrapment in vegetated streambeds. In, Proceedings of the American Society of Civil Engineers, Irrigation and Drainage Division 120:1098-1111.
- Ahlgren, H.L. 1938. Effect of fertilization, cutting treatments, and irrigation on yield of forage and chemical composition of the rhizomes of Kentucky bluegrass (*Poa pratensis* L.). *Journal of the American Society of Agronomy* 30:683-691.
- Aldous, S.E. 1952. Deer browse clipping study in the Lake States Region. *Journal of Wildlife Management* 16:401-409.
- Allen, D.R., and C.B. Marlow. 1994. Shoot population dynamics of beaked sedge following cattle grazing. *Journal of Range Management* 47:64-69.
- American Fisheries Society, Western Division. 1980. Position paper on management and protection of western riparian stream ecosystems. American Fisheries Society, Bethesda, MD. 24pp.
- Anderson, D.L., and E.G. Flaig. 1995. Agricultural best management practices and surface water improvement and management. *Water Science and Technology* 31:109-121.
- Ares, F.N. 1953. Better cattle distribution through the use of meal-salt mix. *Journal of Range Management* 6:341-346.
- Arnold, G.W., and M.L. Dudzinski. 1978. *Ethology of Free-ranging Domestic Animals*. Elsevier Scientific Publishing, Amsterdam, Netherlands.
- Baver, L.D., W.H. Gardner, and W.R. Gardner. 1972. *Soil Physics*. John Wiley & Sons, New York, NY.
- Belsky, J., A. Matzke, and S. Uselman. 1997. Survey of livestock influences on stream and riparian ecosystems in the western United States. Oregon Natural Desert Association, Portland, OR. 38 pp.
- Binkley, D., and T.C. Brown. 1993a. Forest practices as nonpoint sources of pollution in North America. *Water Resources Bulletin* 29:729-740.
- _____, and _____. 1993b. Management impacts on water quality of forests and rangelands. USDA-Forest Service RM-GTR-239, Rocky Mountain Research Station, Fort Collins, CO. 113 pp.
- Boggs, K., and T. Weaver. 1992. Response of riparian shrubs to declining water availability. In, Proceedings—Symposium on Ecology and Management of Riparian Shrub Communities, W.P. Clary, E.D. McArthur, D. Bedunah, and C.L. Wambolt, eds. USDA-Forest Service INT-GTR-289, Intermountain Research Station, Ogden, UT. Pp. 48-51.
- Bohn, C.C. 1989. Management of winter soil temperatures to control streambank erosion. In, Practical Approaches to Riparian Resource Management—An Educational Workshop, R.E. Gresswell, B.A. Barton, and J.L. Kershner, eds. USDI-Bureau of Land Management BLM-MT-PT-89-001-4351. Pp. 69-71.
- _____, and J.C. Buckhouse. 1985a. Some responses of riparian soils to grazing management in northeastern Oregon. *Journal of Range Management* 38:378-381.
- _____, and _____. 1985b. Coliforms as an indicator of water quality in wildland streams. *Journal of Soil and Water Conservation* 40:95-97.
- _____, and _____. 1986. Effects of grazing management on streambanks. *Transactions of the North American Wildlife and Natural Resources Conference* 51:265-271.
- Bolon, N.A., C.S. Hansen-Murray, and R.W. Haynes. 1995. Estimated economic impacts on timber, range, and recreation programs on NFS and BLM public lands from adopting the proposed interim PACFISH strategy. USDA-Forest Service PNW-GTR-344, Pacific Northwest Research Station, Portland, OR. 80 pp.
- Branson, F.A., G.F. Gifford, K.G. Renard, and R.F. Hadley. 1981. *Rangeland Hydrology*. Kendall/Hunt Publ. Co., Dubuque, IA.

- Briggs, M.K. 1996. *Riparian Ecosystem Recovery in Arid Lands: Strategies and References*. University of Arizona Press, Tucson. 159 pp.
- Brinkman, K.A. 1974. *Salix* L.—willow. In, *Seeds of Woody Plants in the United States*. USDA Agriculture Handbook 450. Pp. 746-750.
- Brown, T.C., D. Brown, and D. Binkley. 1993. Laws and programs for controlling nonpoint source pollution in forested areas. *Water Resources Bulletin* 29:1-13
- Bryant, F.C., B.E. Dahl, R.D. Pettit, and C.M. Britton. 1989. Does short-duration grazing work in arid and semi-arid regions? *Journal of Soil and Water Conservation* 44:290-296.
- Bryant, L.D. 1982. Response of livestock to riparian zone exclusion. *Journal of Range Management* 35:780-785.
- Buckhouse, J.C., and G.F. Gifford, 1976a. Grazing and debris burning on pinyon-juniper sites—some chemical water quality implications. *Journal of Range Management* 29:299-301.
- _____, and _____. 1976b. Water quality implications of cattle grazing on a semiarid watershed in southeastern Utah. *Journal of Range Management* 29:109-113.
- _____, J.M. Skovlin, and R.W. Knight. 1981. Streambank erosion and ungulate grazing relationships. *Journal of Range Management* 34:339-340.
- _____, and R.E. Gaither. 1982. Potential sediment production within vegetative communities in Oregon's Blue Mountains. *Journal of Soil and Water Conservation* 37:120-122.
- Butler, R.G., G.T. Orlob, and P.H. McGauhey. 1954. Underground movement of bacterial and chemical pollutants. *Journal of the American Water Works Association* 46:97-111.
- Cannon, R.W., and F.L. Knopf. 1984. Species composition of a willow community relative to seasonal grazing histories in Colorado. *Southwest Naturalist* 29:234-237.
- Chaney, E., W. Elmore, and W.S. Platts. 1993a. Livestock grazing on western riparian areas. U.S. Environmental Protection Agency, Denver, CO. 45 pp.
- _____, _____, and _____. 1993b. Managing change: livestock grazing on western riparian areas. U.S. Environmental Protection Agency, Denver, CO. 31 pp.
- Chichester, F.W., R.W. Van Keuren, and J.L. McGuinness. 1979. Hydrology and chemical quality of flow from small pastured watersheds: II. Chemical quality. *Journal of Environmental Quality* 8:167-171.
- Claire, E.W., and R.L. Storch. 1983. Streamside management and livestock grazing in the Blue Mountains of Oregon: a case study. In, *Proceedings of the Workshop on Livestock and Wildlife-Fisheries Relationships in the Great Basin*, J.W. Menke, ed. University of California Division of Agricultural Sciences Special Publication 3301. Pp. 111-128.
- Clark, W.H. 1990. Coordinated nonpoint source water quality monitoring program for Idaho. Idaho Department of Health and Welfare, Division of Environmental Quality, Boise.
- Clary, W.P. 1995. Vegetation and soil responses to grazing simulation on riparian meadows. *Journal of Range Management* 48:18-25.
- _____, and G.D. Booth. 1993. Early season utilization of mountain meadow riparian pastures. *Journal of Range Management* 46:493-497.
- Clary, W.P., and D.E. Medin. 1990. Differences in vegetation biomass and structure due to cattle grazing in a northern Nevada riparian ecosystem. USDA-Forest Service INT-RP-427, Intermountain Research Station, Ogden, UT.
- _____, and B.F. Webster. 1989. Managing grazing of riparian areas in the Intermountain Region. USDA-Forest Service INT-GTR-427, Intermountain Research Station, Ogden, UT. 11 pp.
- _____, C.I. Thornton, and S.R. Abt. 1996a. Riparian stubble height and recovery of degraded streambanks. *Rangelands* 18:137-140.

- _____, N.L. Shaw, J.G. Dudley, V.A. Saab, J.W. Kinney, and L.C. Smithman. 1996b. Response of a depleted sagebrush steppe riparian system to grazing control and woody plantings. USDA-Forest Service INT-RP-492, Intermountain Research Station, Ogden, UT.
- Clausen, J.C., and D.W. Meals, Jr. 1989. Water quality achievable with agricultural best management practices. *Journal of Soil and Water Conservation* 44:593-596.
- Clawson, J.E. 1993. The use of off-stream water developments and various water gap configurations to modify the watering behavior of grazing cattle. M.S. Thesis, Oregon State University, Corvallis.
- Connin, S. 1991. Characteristics of successful riparian restoration projects in the Pacific northwest. U.S. Environmental Protection Agency EPA 910/9-91-033, Region 10, Seattle, WA.
- Cook, C.W. 1967. Increased capacity through better distribution on mountain ranges. *Utah Science* 28:39-42.
- _____, and N. Jefferies. 1963. Better distribution of cattle on mountain ranges. *Utah Farm Home Science* 24:31, 48-49.
- Cowley, E.R. 1992. Protocols for classifying, monitoring, and evaluating stream/riparian vegetation on Idaho rangeland streams. Idaho Department of Health and Welfare, Division of Environmental Quality, Boise.
- Dadkhah, M., and G.F. Gifford. 1980. Influence of vegetation, rock cover, and trampling on infiltration rates and sediment production. *Water Resources Bulletin* 16:979-986.
- Dahl, B.E. 1995. Developmental morphology of plants. In, *Wildland Plants: Physiological Ecology and Development Morphology*, D.J. Bedunah and R.E. Sosebee, eds. Society for Range Management, Denver, CO. Pp. 22-58.
- _____, P.F. Cotter, R.L. Dickerson, Jr., and J.C. Mosley. 1992. Vegetation response to continuous versus short duration grazing on sandy rangeland. *Texas Journal of Agriculture and Natural Resources* 5:73-81.
- Dallas, D.S. 1997. Managing livestock with a focus on riparian areas in the Ruby River Watershed: sharing what we've learned about the practical application of the Beaverhead Riparian Guidelines and other improved riparian management strategies. A Report to the Beaverhead Forest Plan Riparian Amendment Interdisciplinary Team, Beaverhead-Deerlodge National Forest, Sheridan, MT. 43 pp.
- Davis, K.C., and C.B. Marlow. 1990. Altering cattle behavior through grazing management. *Montana AgResearch* 7(1):11-14.
- Dean, R., J.E. Ellis, R.W. Rice, and R.E. Bement. 1975. Nutrient removal by cattle from a shortgrass prairie. *Journal of Applied Ecology* 12:25-29.
- Decker, A.M., Jr., and T.S. Ronningen. 1957. Heaving in forage stands and in bare ground. *Agronomy Journal* 49:412-415.
- Dee, R.F., T.W. Box, and E. Robertson, Jr. 1966. Influence of grass vegetation on water intake of Pullman silty clay loam. *Journal of Range Management* 19:77-79.
- Densmore, R., and J. Zasada. 1983. Seed dispersal and dormancy patterns in northern willows: ecological and evolutionary significance. *Canadian Journal of Botany* 61:3201-3216.
- Doran, J.W., and D.M. Linn. 1979. Bacteriological quality of runoff water from pastureland. *Applied and Environmental Microbiology* 37:985-991.
- _____, J.S. Schepers, and N.P. Swanson. 1981. Chemical and bacteriological quality of pasture runoff. *Journal of Soil Water Conservation* 36:166-171.
- Dovel, R.L. 1996. Cutting height effects on wetland meadow forage yield and quality. *Journal of Range Management* 49:151-156.
- Doyle, R.C., D.C. Wolf, and D.F. Bezdicsek. 1975. Effectiveness of forest buffer strips in improving the water quality of manure polluted runoff. In, *Proceedings of the Third International Symposium on Livestock Wastes—1975*. American Society of Agricultural Engineers, Published Proceedings-275. Pp. 299-302.

- Duff, D.A. 1983. Livestock grazing impacts on aquatic habitat in Big Creek, Utah. In, Proceedings of the Workshop on Livestock and Wildlife-Fisheries Relationships in the Great Basin, J.W. Menke, ed. University of California Division of Agricultural Sciences, Special Publication 3301. Pp. 129-142.
- Edwards, D.R., T.C. Daniel, H.D. Scott, P.A. Moore, Jr., J.F. Murdoch, and P.F. Vendrell. 1997. Effect of BMP implementation on storm flow quality of two northwestern Arkansas streams. *Transactions of the American Society of Agricultural Engineers* 40:1311-1319.
- Ehrhart, R.C., and P.L. Hansen. 1997. Effective cattle management in riparian zones: a field survey and literature review. Montana BLM Riparian Technical Bulletin No. 3.
- Ellis, J.R., and T.M. McCalla. 1978. Fate of pathogens in soils receiving animal wastes—a review. *Transactions of the American Society of Agricultural Engineers* 21:309-313.
- Elmore, W. 1989. Rangeland riparian systems. In, California Riparian Systems Conference. USDA-Forest Service PSW-GTR-110, Pacific Southwest Research Station, Albany, CA. Pp. 93-95.
- _____, and B. Kauffman. 1994. Riparian and watershed systems: degradation and restoration. In, Ecological Implications of Livestock Herbivory in the West, M. Vavra, W.A. Laycock, and R.D. Pieper, eds. Society for Range Management, Denver, CO. Pp. 212-231.
- Environmental Protection Agency (EPA). 1991. NPS pollution: runoff of rain and snowmelt—our biggest water quality problem. *EPA Journal* 17(5):1-58.
- _____. 1995. The Quality of Our Nation's Waters: 1994. U.S. Environmental Protection Agency EPA 841-S-94-002, Washington, D.C. 209 pp.
- Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. *Conservation Biology* 8(3):629-644.
- Gale, J.A., D.E. Line, D.I. Osmond, S.W. Coffey, J. Spooner, J.A. Arnold, T.J. Hoban, and R.C. Wimberley. 1993. Evaluation of the experimental Rural Clean Water Program. U.S. Environmental Protection Agency EPA-841-R-93-005.
- Gammon, D.M. 1984. An appraisal of short duration grazing as a method of veld management. *Zimbabwe Agricultural Journal* 81:59-64.
- Garrison, G.A. 1953. Effects of clipping on some range shrubs. *Journal of Range Management* 6:309-317.
- Garrison, P.J., and T.R. Asplund. 1993. Long-term (15 years) results of NPS controls in an agricultural watershed upon a receiving lake's water quality. *Water Science and Technology* 28:441-449.
- Gary, H.L., S.R. Johnson, and S.L. Ponce. 1983. Cattle grazing impact on surface water quality in a Colorado Front Range stream. *Journal of Soil and Water Conservation* 38:124-128.
- Gerba, C.P., C. Wallis, and J.L. Melnick. 1975. Fate of wastewater bacteria and viruses in soil. In, Proceedings of the American Society of Civil Engineers, Irrigation and Drainage Division 101:157-174.
- Gifford, G.F., and R.H. Hawkins. 1978. Hydrologic impact of grazing on infiltration: a critical review. *Water Resources Research* 14:305-313.
- Gillard, P. 1967. Coprophagous beetles in pasture ecosystems. *Journal of the Australian Institute of Agricultural Sciences* 33:30-34.
- Gillen, R.L., W.C. Krueger, and R.F. Miller. 1984. Cattle distribution on mountain rangeland in northeastern Oregon. *Journal of Range Management* 37:549-553.
- _____, _____, and _____. 1985. Cattle use of riparian meadows in the Blue Mountains of northeastern Oregon. *Journal of Range Management* 38:205-209.
- Goldman, C.R., and A.J. Horne. 1983. *Limnology*. McGraw-Hill, New York, NY.

- Goodman, T., G.B. Donart, H.E. Kiesling, J.L. Holechek, J.P. Neel, D. Manzanares, and K.E. Severson. 1989. Cattle behavior with emphasis on time and activity allocations between upland and riparian habitats. In, *Practical Approaches to Riparian Resource Management—An Educational Workshop*, R.E. Gresswell, B.A. Barton, and J.L. Kershner, eds. USDI-Bureau of Land Management BLM-MT-PT-89-001-4351. Pp. 95-102.
- Gregory, S.V., F.R. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones: focus on links between land and water. *BioScience* 41(8):540-551.
- Green, D.M., and J.B. Kaufmann. 1995. Succession and livestock grazing in a northeastern Oregon riparian ecosystem. *Journal of Range Management* 48:307-313.
- Green, L.R., K.A. Wagnon, and J.R. Bentley. 1958. Diet and grazing habits of steers on foothill range fertilized with sulfur. *Journal of Range Management* 11:221-227.
- Grette, T. 1990. Successful range management in the McCoy Gulch riparian demonstration area. *Rangelands* 12:305-307.
- Grimm, N.B., and S.G. Fisher. 1986. Nitrogen limitation in a Sonoran Desert stream. *Journal of the North American Benthological Society* 5:2-15.
- Gunderson, D.R. 1968. Floodplain use related to stream morphology and fish populations. *Journal of Wildlife Management* 32:507-514.
- Hall, F.C., and L. Bryant. 1995. Herbaceous stubble height as a warning of impending cattle grazing damage to riparian areas. USDA-Forest Service PNW-GTR-362, Pacific Northwest Research Station, Portland, OR.
- Hamlett, J.M., and D.J. Epp. 1994. Water quality impacts of conservation and nutrient management practices in Pennsylvania. *Journal of Soil and Water Conservation* 49:59-66.
- Hanks, K.S., D.E. Wallace, and H.A. Schreiber. 1981. Bacteriological ground water quality characteristics of the Walnut Gulch Experimental Watershed. USDA, Conservation Research Report No. 28. 13 pp.
- Hansen, P.L., R.D. Pfister, K. Boggs, J. Joy, and B. Cook. 1994. Classification and management of riparian and wetland sites in Montana. In, *Diverse Values: Seeking Common Ground*, Proceedings of the Northwest Regional Riparian Symposia, Dec. 8-9, Boise, ID. Addendum, 14 pp.
- Harris, B.L., T.L. Nipp, D.K. Waggoner, and A. Weber. 1995. Agricultural water quality program policy considerations. *Journal of Environmental Quality* 24:405-411.
- Hastings, N.E.. 1993. Seasonal dynamics of secondary compounds in planeleaf willow. M.S. Thesis, Colorado State University, Fort Collins. 93 pp.
- Hayes, F.A. 1978. Streambank stability and meadow condition in relation to livestock grazing in mountain meadows of central Idaho. M.S. Thesis, University of Idaho, Moscow.
- Heady, H.F. 1975. *Rangeland Management*. McGraw-Hill, New York, NY. 460 pp.
- Heathman, G.L., L.R. Ahuja, and O.R. Lehman. 1985. The transfer of soil-surface-applied chemicals to runoff. *Transactions of the American Society of Agricultural Engineers* 28:1909-1915, 1920.
- Helms, D. 1992. The Soil Conservation Service: a historical note. In, *Readings in the History of the Soil Conservation Service*. USDA Soil Conservation Service, Economics and Social Sciences Division, NHQ, Historical Note No. 1. Pp. 6-10.
- Hendricks, C.W., and S.M. Morrison. 1967. Multiplication and growth of selected enteric bacteria in clear mountain stream water. *Water Resources* 1:567-576.
- Higgins, D.A., S.B. Maloney, A.R. Tiedemann, and T.M. Quigley. 1989a. Storm runoff characteristics of grazed watersheds in eastern Oregon. *Water Resources Bulletin* 25:87-100.

- _____, A.R. Tiedemann, T.M. Quigley, and D.B. Marx. 1989b. Streamflow characteristics of small watersheds in the Blue Mountains of Oregon. *Water Resources Bulletin* 25:1131-1149.
- Hofman, L., and R.E. Ries. 1991. Relationship of soil and plant characteristics to erosion and runoff on pasture and range. *Journal of Soil and Water Conservation* 46(2):143-147.
- Holechek, J.L., R.D. Pieper, and C.H. Herbel. 1995. *Range Management: Principles and Practices*, 2nd ed. Prentice-Hall, Englewood Cliffs, NJ.
- Hormay, A.L. 1943. Bitterbrush in California. USDA-Forest Service California Forest and Range Experiment Station Research Note 34.
- Howery, L.D., F.D. Provenza, R.E. Banner, and C.B. Scott. 1996. Differences in home range and habitat use among individuals in a cattle herd. *Applied Animal Behaviour Science* 49:305-320.
- Hubert, W.A., R.P. Lanka, T.A. Wesche, and F. Stabler. 1985. Grazing management influences on two brook trout streams in Wyoming. In, *Riparian Ecosystems and their Management: Reconciling Conflicting Uses*, R.R. Johnson, D.C. Ziebell, D.R. Patton, P.F. Ffolliet, and R.H. Hamre, eds. USDA-Forest Service, RM-GTR-120, Rocky Mountain Research Station, Fort Collins, CO. Pp. 290-293.
- Hunter, R.F. 1960. Aims and methods in grazing—behaviour studies on hill pastures. In, *Proceedings of the Eighth International Grasslands Congress*, C.L. Skidmore, ed. British Grasslands Society, Oxford. Pp. 454-457.
- Hynes, H.B.N. 1983. Groundwater and stream ecology. *Hydrobiologia* 100:93-99.
- Ice, G.G., G.W. Stuart, J.B. Waide, L.C. Irland, and P.V. Ellefson. 1997. Twenty-five years of the Clean Water Act: How clean are forest practices? *Journal of Forestry* 95(7):9-13.
- Idaho Division of Environmental Quality (IDEQ). 1988. Idaho water quality status report and nonpoint source assessment 1988. Executive Summary. Idaho Department of Health and Welfare/Division of Environmental Quality, Boise.
- _____. 1993. Forest practices water quality audit, 1992. IDHW-300, 48-481-48759. Idaho Department of Health and Welfare/Division of Environmental Quality, Boise.
- _____. 1994. The 1994 Idaho water quality status report. Idaho Department of Health and Welfare/Division of Environmental Quality, Boise.
- _____. 1995. Idaho statewide work plan for the 1995 beneficial use attainability and status reconnaissance survey. Idaho Department of Health and Welfare/Division of Environmental Quality, Boise. 21pp.
- _____. 1996. 1996 Water body assessment guidance: a stream to standards process. Idaho Department of Health and Welfare/Division of Environmental Quality, Boise. 109 pp.
- _____ and Idaho Soil Conservation Commission (IDEQ and ISCC). 1993. Idaho agricultural pollution abatement plan. Idaho Soil Conservation Commission, Boise.
- Johnson, S.R., H.L. Gary, and S.L. Ponce. 1978. Range cattle impacts on stream water quality in the Colorado Front Range. USDA-Forest Service RM-RN-359, Rocky Mountain Research Station, Fort Collins, CO. 8 pp.
- Julander, O. 1937. Utilization of browse by wildlife. *Transactions of the North American Wildlife and Natural Resources Conference* 2:276-287.
- Kauffman, J.B., and W.C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications...a Review. *Journal of Range Management* 37:430-438.
- _____, _____, and M. Varva. 1983. Effects of late season cattle grazing on riparian plant communities. *Journal of Range Management* 36:685-691.

- 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(5):12-24.
- Keller, C.R., and K.P. Burnham. 1982. Riparian fencing, grazing, and trout habitat preference on Summit Creek, Idaho. *North American Journal of Fisheries Management* 2:53-59.
- Kleinfelder, D., S. Swanson, G. Norris, and W. Clary. 1992. Unconfined compressive strength of some streambank soils with herbaceous roots. *Soil Science Society of America Journal* 56:1920-1925.
- Knapp, R.A., and K.R. Matthews. 1996. Livestock grazing, golden trout, and streams in the Golden Trout Wilderness, California: impacts and management implications. *North American Journal of Fisheries Management* 16:805-820.
- Knopf, F.L., and R.W. Cannon. 1982. Structural resilience of a willow riparian community to changes in grazing practices. In, Proceedings of the Wildlife-Livestock Relationships Symposium, J.M. Peek and P.D. Dalke, eds. Idaho Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow. Pp. 198-207.
- _____, and F.B. Samson. 1994. Scale perspectives on avian diversity in western riparian ecosystems. *Conservation Biology* 8(3):669-676.
- Kovalchik, B.L., and W. Elmore. 1992. Effects of cattle grazing systems on willow-dominated plant associations in central Oregon. In, Proceedings—Symposium on Ecology and Management of Riparian Shrub Communities, W.P. Clary, E.D. McArthur, D. Bedunah, and C.L. Wambolt, eds. USDA-Forest Service INT-GTR-289, Intermountain Research Station, Ogden, UT. Pp. 111-119.
- Lamman, J.S. 1994. Effects of season and intensity of defoliation on two important montane riparian species. M.S. Thesis, Colorado State University, Fort Collins.
- Larsen, R.E., J.R. Miner, J.C. Buckhouse, and J.A. Moore. 1994. Water-quality benefits of having cattle manure deposited away from streams. *Bioresource Technology* 48:113-118.
- Lee, D., T.A. Dillaha, and J.H. Sherrard. 1989. Modeling phosphorus transport in grass buffer strips. *Journal of Environmental Engineering* 115:409-427.
- Lee, K.N. 1993. *Compass and Gyroscope: Integrating Science and Politics for the Environment*. Island Press, Washington, D.C.
- Li, H.W., G.A. Lamberti, T.N. Pearsons, C.K. Tait, J.L. Li, and J.C. Buckhouse. 1994. Cumulative effects of riparian disturbances along high desert trout streams of the John Day Basin, Oregon. *Transactions of the American Fisheries Society* 123:627-640.
- Lohman, K., and J.C. Priscu. 1992. Physiological indicators of nutrient deficiency in *Cladophora* (Chlorophyta) in the Clark Fork of the Columbia River, Montana. *Journal of Phycology* 28:443-448.
- Lowrance, R., R. Leonard, and J. Sheridan. 1985. Managing riparian ecosystems to control nonpoint pollution. *Journal of Soil and Water Conservation* 40:87-91.
- Lynch, J.A., and E.S. Corbett. 1990. Evaluation of best management practices for controlling nonpoint source pollution from silvicultural operations. *Water Resources Bulletin* 26:41-52.
- Marcus, M.D., J.E. Schillinger, and D.G. Stuart. 1978. Liminological studies in Montana: Hyalite Reservoir and responses of lotic periphyton to deep-water discharges, grazing and logging. Montana Water Resources Center Rep. 92, Montana State University, Bozeman.
- Marcuson, P.E. 1983. Overgrazed streambanks depress fishery production in Rock Creek, Montana. In, Proceedings of the Workshop on Livestock and Wildlife-Fisheries Relationships in the Great Basin, J.W. Menke, ed. University of California Division of Agricultural Sciences Special Publication 3301. Pp. 143-157.

- Marlow, C.B. 1985. Controlling riparian zone damage with little forage loss. *Montana AgResearch* 2(3):1-7.
- _____, and T.M. Pogacnik. 1986. Cattle feeding and resting patterns in a foothills riparian zone. *Journal of Range Management* 39:212-217.
- _____, _____, and S.D. Quinsey. 1987. Streambank stability and cattle grazing in southwestern Montana. *Journal of Soil and Water Conservation* 42:291-296.
- _____, K. Olson-Rutz, and J. Atchley. 1989. Response of a southwest Montana riparian system to four grazing management alternatives. In, *Practical Approaches to Riparian Resource Management—An Educational Workshop*, R.E. Gresswell, B.A. Barton, and J.L. Kershner, eds. USDI-Bureau of Land Management BLM-MT-PT-89-001-4351. Pp. 111-116.
- May, B.E., and B. Davis. 1982. Practices for livestock grazing and aquatic habitat protection on western rangelands. In, *Proceedings of the Wildlife-Livestock Relationships Symposium*, J.M. Peek and P.D. Dalke, eds. Idaho Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow. Pp. 271-278.
- McDougald, N.K., and R.C. Platt. 1976. A method of determining utilization for wet mountain meadows on the Summit Allotment, Sequoi National Forest, California. *Journal of Range Management* 29:497-501.
- _____, W.E. Frost, and D.E. Jones. 1989. Use of supplemental feeding locations to manage cattle use on riparian areas of hardwood rangelands. In, *California Riparian Systems Conference*. USDA-Forest Service PSW-GTR-110, Pacific Southwest Research Station, Albany, CA. Pp. 124-126.
- McLean, A., H.H. Nicholson, and A.L. Van Ryswk. 1963. Growth, productivity and chemical composition of a sub-alpine meadow in interior British Columbia. *Journal of Range Management* 16:235-240.
- Meals, D.W. 1993. Assessing nonpoint phosphorus control in the LaPlatte River watershed. *Lake and Reservoir Management* 7:197-207.
- Meehan, W.R., and W.S. Platts. 1978. Livestock grazing and the aquatic environment. *Journal of Soil and Water Conservation* 33:274-278.
- Meeuwig, R.O. 1965. Effects of seeding and grazing on infiltration capacity and soil stability of a subalpine range in central Utah. *Journal of Range Management* 18:173-180.
- Meisner, J.D., J.S. Rosenfeld, and H.A. Regier. 1988. The role of groundwater in the impact of climate warming on stream salmonids. *Fisheries* 13:2-8.
- Melton, A.A., and J.K. Riggs. 1964. Frequency of feeding protein supplement to range cattle. Texas Agricultural Experiment Station Bulletin 1025, College Station.
- Miner, J.R., J.C. Buckhouse, and J.A. Moore. 1992. Will a water trough reduce the amount of time hay-fed livestock spend in the stream (and therefore improve water quality)? *Rangelands* 14:35-38.
- Molvar, E.M., R.T. Bowyer, and V. Van Ballenberghe. 1993. Moose herbivory, browse quality, and nutrient cycling in an Alaskan treeline community. *Oecologia* 94:472-479.
- Mosley, J., and N. Cote. 1997. Do some cows prefer to graze uplands rather than riparian areas? In, *Proceedings of the Governor's Conference on the Cattle Industry*. Montana State University, Bozeman. Pp. 147-148.
- Myers, L.H. 1989. Grazing and riparian management in southwestern Montana. In, *Practical Approaches to Riparian Resource Management—An Educational Workshop*, R.E. Gresswell, B.A. Barton, and J.L. Kershner, eds. USDI-Bureau of Land Management BLM-MT-PT-89-001-4351. Pp. 117-120.
- Myers, T.J., and S. Swanson. 1995. Impact of deferred rotation grazing on stream characteristics in central Nevada: a case study. *North American Journal of Fisheries Management* 15:428-439.

- _____, and _____. 1996a. Long-term aquatic habitat restoration: Mahogany Creek, Nevada, as a case study. *Water Resources Bulletin* 32(2):241-252.
- _____, and _____. 1996b. Temporal and geomorphic variations of stream stability and morphology: Mahogany Creek, Nevada. *Water Resources Bulletin* 32(2):253-265.
- Novotny, V., and H. Olem. 1994. *Water Quality: Prevention, Identification, and Management of Diffuse Pollution*. Van Nostrand Reinhold, New York. 1054 pp.
- Ohmart, R.D. 1996. Historical and present impacts of livestock grazing on fish and wildlife resources in western riparian habitats. In, *Rangeland Wildlife*, P.R. Krausman, ed. Society for Range Management, Denver, CO. Pp. 245-279.
- Oksendahl, V.E. 1997. Effectiveness of grass species for nitrogen recovery from dairy waste. M.S. Thesis, Montana State Univ., Bozeman.
- O'Laughlin, J. 1990. Idaho's endowment lands: a matter of sacred trust. Report No. 1, Policy Analysis Group, College of Forestry, Wildlife, and Range Sciences, University of Idaho, Moscow. 18 pp.
- _____. 1996. Idaho water quality policy for nonpoint source pollution: a manual for decision-makers. Report No. 14, Policy Analysis Group, College of Forestry, Wildlife, and Range Sciences, University of Idaho, Moscow. 117 pp. (Executive Summary, 32 pp.)
- _____, and P.S. Cook, with K. Rogers and T. Merrill. 1995. Endangered Species Act at the crossroads: new directions from Idaho case studies. Report No. 13, Policy Analysis Group, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow. 307 pp. (Executive Summary, 24 pp.)
- Orr, H.K. 1960. Soil porosity and bulk density on grazed and protected Kentucky bluegrass range in the Black Hills. *Journal of Range Management* 13:80-86.
- Owen, O.S. and D.D. Chiras. 1990. *Natural Resource Conservation, An Ecological Approach*, 5th ed. Collier MacMillan Publishers, New York, NY. 538 pp.
- Owens, L.B., W.M. Edwards, and R.W. Van Keuren. 1997. Runoff and sediment losses resulting from winter feeding on pastures. *Journal of Soil and Water Conservation* 52:194-197.
- _____, _____, and _____. 1983. Surface runoff water quality comparisons between unimproved pasture and woodland. *Journal of Environmental Quality* 12:518-522.
- Park, S.W., S. Mostaghimi, R.A. Cooke, and P.W. McClellan. 1994. BMP impacts on watershed runoff, sediment, and nutrient yields. *Water Resources Bulletin* 30:1011-1023.
- Parsons, D.A. 1965. Vegetative control of streambank erosion. In, *Proceedings of the Federal Inter-Agency Sedimentation Conference USDA Misc. Publication 970*. Pp. 130-136.
- Pearce, R.A., M.J. Irlica, W.C. Leininger, J.L. Smith, and G.W. Frasier. 1997. Efficiency of grass buffer strips and vegetation height on sediment filtration in laboratory rainfall simulations. *Journal of Environmental Quality* 26:139-144.
- Pieper, R.D., and R.K. Heitschmidt. 1988. Is short-duration grazing the answer? *Journal of Soil and Water Conservation* 43:133-137.
- Platts, W.S. 1982. Sheep and cattle grazing strategies on riparian-stream environments. In, *Proceedings of the Wildlife-Livestock Relationships Symposium*, J.M. Peek and P.D. Dalke, eds. Idaho Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow. Pp. 251-270.
- _____. 1991. Livestock grazing. In, *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats*, W.R. Meehan, ed. American Fisheries Society Special Publication 19. Bethesda, MD. Pp. 389-423.
- _____, and R.F. Raleigh. 1984. Impacts of grazing on wetlands and riparian habitat: a review of our knowledge (comments). In, *Developing Strategies for Rangeland Management*. National Academy of Science, Westview Press, Boulder, CO. Pp. 1105-1117.

- _____, and R.L. Nelson. 1985a. Impacts of rest-rotation grazing on streambanks in forested watersheds in Idaho. *North American Journal of Fisheries Management* 5:547-556.
- _____, and _____. 1985b. Stream habitat and fisheries response to livestock grazing and instream improvement structures, Big Creek, Utah. *Journal of Soil and Water Conservation* 40:374-379.
- _____, and _____. 1985c. Will the riparian pasture build good streams? *Rangelands* 7:7-10.
- _____, and _____. 1989. Characteristics of riparian plant communities and streambanks with respect to grazing in northeastern Utah. In, Practical Approaches to Riparian Resource Management—An Educational Workshop, Gresswell, B.A. Barton, and J.L. Kershner, eds. USDI-Bureau of Land Management BLM-MT-PT-89-001-4351. Pp. 73-81.
- Pluhar, J.J., R.W. Knight, and R.K. Heitschmidt. 1987. Infiltration rates and sediment production as influenced by grazing systems in the Texas Rolling Plains. *Journal of Range Management* 40:240-243.
- Ponce, V.M., and D.S. Lindquist. 1990. Management of baseflow augmentation: a review. *Water Resources Bulletin* 26(2):259-268.
- Pond, F.W. 1961. Effect of three intensities of clipping on the density and production of meadow vegetation. *Journal of Range Management* 14:34-38.
- Popolizio, C.A., H. Goetz, and P.L. Chapman. 1994. Short-term response of riparian vegetation to 4 grazing treatments. *Journal of Range Management* 47(1):48-53.
- Ratliff, R.D., J.N. Reppert, and R.J. McConnen. 1972. Rest-rotation grazing at Harvey Valley...range health, cattle gains, costs. USDA-Forest Service PSW-RP-77, Pacific Southwest Research Station, Albany, CA.
- _____, and S.E. Westfall. 1987. Dry-year grazing and Nebraska sedge. *Great Basin Naturalist* 47:422-426.
- Reed, S., R. Bastian, S. Black, and R. Khettry. 1984. Wetlands for wastewater treatment in cold climates. In, Proceedings of the Water Reuse Symposium III, American Water Works Assn. Res. Foundation, Denver, CO. Pp. 962-972.
- Reid, E.H., and G.D. Pickford. 1946. Judging mountain meadow range conditions in eastern Oregon and eastern Washington. USDA Circular 748.
- Reuter, J.E., T. Djohan, and C.R. Goldman. 1992. The use of wetlands for nutrient removal from surface runoff in a cold climate region of California—results from a newly constructed wetland at Lake Tahoe. *Journal of Environmental Management* 36:35-53.
- Rinne, J.N. 1988. Effects of livestock grazing exclosure on aquatic macroinvertebrates in a montane stream, New Mexico. *Great Basin Naturalist* 48:146-153.
- Roath, L.R., and W.C. Krueger. 1982a. Cattle grazing influence on a mountain riparian zone. *Journal of Range Management* 35:100-103.
- _____, and _____. 1982b. Cattle grazing and behavior on a forested range. *Journal of Range Management* 35:332-338.
- Rumsey, C.J. 1996. The effect of three residual-vegetation heights on streambank sediment deposition and vegetation production. M.S. Thesis, University of Wyoming, Laramie.
- Sampson, A.W. 1919. Effect of grazing upon aspen reproduction. USDA Bulletin 741.
- Schellinger, G.R., and J.C. Clausen. 1992. Vegetative filter treatment of dairy barnyard runoff in cold regions. *Journal of Environmental Quality* 21:40-45.
- Schepers, J.S., and D.D. Francis. 1982. Chemical water quality of runoff from grazing land in Nebraska: I. Influence of grazing livestock. *Journal of Environmental Quality* 11:351-354.
- Schimmel, D.S., W.J. Parton, F.J. Adamsen, R.G. Woodmansee, R.L. Senft, and M.A. Stillwell. 1986. The role of cattle in the volatile loss of nitrogen from a shortgrass steppe. *Biogeochemistry* 2:39-52.

- Schwan, H.E., D.J. Hodges, and C.N. Weaver. 1949. Influence of grazing and mulch on forage growth. *Journal of Range Management* 2:142-148.
- Sedgwick, J.A., and F.L. Knopf. 1991. Prescribed grazing as a secondary impact in a western riparian floodplain. *Journal of Range Management* 44:369-373.
- Senft, R.L., M.A. Stillwell, and L.R. Rittenhouse. 1987. Nitrogen and energy budgets of free-roaming cattle. *Journal of Range Management* 40:421-424.
- Sharpley, A.N. 1981. The contribution of phosphorus leached from crop canopy to losses in surface runoff. *Journal of Environmental Quality* 10:160-165.
- Shaw, N.L. 1992. Recruitment and growth of Pacific willow and sandbar willow seedlings in response to season and intensity of cattle grazing. In, Proceedings—Symposium on Ecology and Management of Riparian Shrub Communities, W.P. Clary, E.D. McArthur, D. Bedunah, and C.L. Wambolt, eds. USDA-Forest Service INT-GTR-289, Intermountain Research Station, Ogden, UT. Pp. 130-137.
- Sheeter, G., and T. Svejcar. 1997. Streamside vegetation regrowth after clipping. *Rangelands* 19(1):30-31.
- Sheffield, R.E., S. Mostaghimi, D.H. Vaughn, E.R. Collins, and V.G. Allen. 1997. Off-stream water sources for grazing cattle as a stream bank stabilization and water quality BMP. *Transactions of the American Society of Agricultural Engineers* 40:595-604.
- Sherer, B.M., J.R. Miner, J.A. Moore, and J.C. Buckhouse. 1988. Resuspending organisms from a rangeland stream bottom. *Transactions of the American Society of Agricultural Engineers* 31:1217-1222.
- _____, _____, _____, and _____. 1992. Indicator bacterial survival in stream sediments. *Journal of Environmental Quality* 21:591-595.
- Shewmaker, G.E. 1997. Livestock grazing: a tool for removing phosphorus from irrigated meadows. In, Proceedings 1996 Wetlands Seminar, Water for Agriculture and Wildlife and the Environment, U.S. Committee on Irrigation and Drainage, Denver, CO.
- Siekert, R.E., Q.D. Skinner, M.A. Smith, J.L. Dodd, and J.D. Rogers. 1985. Channel response of an ephemeral stream in Wyoming to selected grazing treatments. In, Riparian Ecosystems and Their Management: Reconciling Conflicting Uses, R.R. Johnson, D.C. Ziebell, D.R. Patton, P.F. Ffolliot, and R.H. Hamre, eds. USDA-Forest Service RM-GTR-120, Rocky Mountain Research Station, Fort Collins, CO. Pp. 276-278.
- Skovlin, J.M. 1957. Range riding—the key to range management. *Journal of Range Management* 10:269-271.
- _____. 1965. Improving cattle distribution on western mountain rangelands. USDA Farmers' Bulletin 2212.
- _____. 1984. Impacts of grazing on wetlands and riparian habitat: a review of our knowledge. In, *Developing Strategies for Rangeland Management*. National Academy of Science, Westview Press, Boulder, CO. Pp. 1001-1103.
- Smith, M.A., J.D. Rodgers, J.L. Dodd, and Q.D. Skinner. 1992. Habitat selection by cattle along an ephemeral channel. *Journal of Range Management* 45:385-389.
- Stephenson, G.R., and L.V. Street. 1978. Bacterial variations in streams from a southwest Idaho rangeland watershed. *Journal of Environmental Quality* 7(1):150-157.
- _____, and R.C. Rychert. 1982. Bottom sediment: a reservoir of *Escherichia coli* in rangeland streams. *Journal of Range Management* 35:119-123.
- Streeter, C.L., C.B. Rumburg, T.H. Hall, and E.G. Siemer. 1974. Meadow forage quality, intake, and milk production of cows. *Journal of Range Management* 27:133-135.

- Stuber, R.J. 1985. Trout habitat, abundance, and fishing opportunities in fenced and unfenced riparian habitat along Sheep Creek, Colorado. In, *Riparian Ecosystems and Their Management: Reconciling Conflicting Uses*, R.R. Johnson, D.C. Ziebell, D.R. Patton, P.F. Ffolliot, and R.H. Hamre, eds. USDA-Forest Service RM-GTR-120, Rocky Mountain Research Station, Fort Collins, CO. Pp. 310-314.
- Svejcar, T. 1997a. Riparian zones: 1) what are they and how do they work? *Rangelands* 19(4):4-7.
- _____. 1997b. Riparian zones: 2) history and human impacts. *Rangelands* 19(4):8-12.
- Taylor, F.R., L.A. Gillman, and J.W. Pedretti. 1989. Impact of cattle on two isolated fish populations in Pahrangat Valley, Nevada. *Great Basin Naturalist* 49(4):491-495.
- Tennyson, L.C., C.D. Settergren, and W.F. Hansen. 1975. Sewage effluent irrigation rates and groundwater response. In, *Proceedings of the Watershed Management Symposium, Committee on Watershed Management of the Irrigation and Drainage Division of the American Society of Civil Engineers, Utah Section*. Pp. 691-699.
- Thurow, T.L., W.H. Blackburn, and C.A. Taylor, Jr. 1988. Infiltration and interrill erosion responses to selected livestock grazing strategies, Edwards Plateau, Texas. *Journal of Range Management* 41:296-302.
- Tiedemann, A.R., D.A. Higgins, T.M. Quigley, H.R. Sanderson, and D.B. Marx. 1987. Responses of fecal coliform in streamwater to four grazing strategies. *Journal of Range Management* 40:322-329.
- _____, _____, _____, _____, and C.C. Bohn. 1988. Bacterial water quality responses to four grazing strategies—comparisons with Oregon standards. *Journal of Environmental Quality* 17:492-498.
- _____, _____, _____, and _____. 1989. Stream chemistry responses to four range management strategies in eastern Oregon. USDA-Forest Service PNW-RP-413, Pacific Northwest Research Station, Portland, OR.
- Trimble, S.W., and A.C. Mendel. 1995. The cow as a geomorphic agent—a critical review. *Geomorphology* 13:233-253.
- Tromble, J.M., K.G. Renard, and A.P. Thatcher. 1974. Infiltration for three rangeland soil-vegetation complexes. *Journal of Range Management* 27:318-321.
- Turner, A.C., and J. O’Laughlin. 1991. State agency roles in Idaho water quality policy. Report No. 5, Policy Analysis Group, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow. 212 pp. (Executive Summary, 26 pp.)
- Ueckert, D.N., T.L. Whigham, and B.M. Spears. 1978. Effect of burning on infiltration, sediment, and other soil properties in a mesquite-tobosagrass community. *Journal of Range Management* 31:420-425.
- USDA-Forest Service (USFS). 1995. Inland native fish strategy: environmental assessment (INFISH). Intermountain, Northern, and Pacific Northwest Regions, USFS. USDA-Forest Service, Coeur d’Alene, ID.
- _____. 1996. Report of the Forest Service, Fiscal Year 1995. USDA-Forest Service, Washington, D.C.
- _____, and USDI-Bureau of Land Management (USFS and USDI-BLM). 1994. Environmental assessment for the implementation of interim strategies for managing anadromous fish producing watersheds in eastern Oregon and Washington, Idaho, and portions of California (PACFISH). USDA-Forest Service, Washington, D.C.
- USDI-Bureau of Land Management (USDI-BLM). 1994. Public land statistics, 1993. U.S. Government Printing Office, Washington, D.C. 143 pp.
- _____. 1997. Public land statistics, 1996. U.S. Government Printing Office, Washington, D.C.
- Vallentine, J.F. 1990. *Grazing Management*. Academic Press, San Diego, CA.
- Van Poolen, H.W., and J.R. Lacey. 1979. Herbage response to grazing systems and stocking intensities. *Journal of Range Management* 32:250-253.

- Volland, L.A. 1978. Trends in standing crop and species composition of a rested Kentucky bluegrass meadow over an 11-year period. In, Proceedings of the First International Rangelands Congress, D.N. Hyder, ed. Society for Range Management, Denver, CO. Pp. 526-529.
- Walters, C.J. 1986. *Adaptive Management of Renewable Resources*. McGraw-Hill, New York, NY.
- Warren, S.D., M.B. Nevill, W.H. Blackburn, and N.E. Garza. 1986a. Soil response to trampling under intensive rotation grazing. *Soil Science Society of America Journal* 50:1336-1341.
- _____, T.L. Thurow, W.H. Blackburn, and N.E. Garza. 1986b. The influence of livestock trampling under intensive rotation grazing on soil hydrologic characteristics. *Journal of Range Management* 39:491-495.
- Watson, E.R., and P. Lapins. 1964. The influence of subterranean clover pastures on soil fertility: II. The effects of certain management systems. *Australian Journal of Agricultural Research* 15:885-894.
- _____, and _____. 1969. Losses of nitrogen from urine on soils from south-western Australia. *Australian Journal of Experimental Agriculture and Animal Husbandry* 9:85-91.
- Windell, J.T., B.E. Willard, D.J. Cooper, S.Q. Foster, C.F. Knud-Hansen, L.P. Rink, and G.N. Kiladis. 1986. An ecological characterization of Rocky Mountain montane and subalpine wetlands. U.S. Fish and Wildlife Service Biological Report 86(11), Washington, D.C. 298 pp.
- Wolf, A.T. 1995. Rural nonpoint source pollution control in Wisconsin: the limits of a voluntary program. *Water Resources Bulletin* 31:1009-1022.
- Wolff, J.O. 1978. Burning and browsing effects on willow growth in interior Alaska. *Journal of Wildlife Management* 42:135-140.
- Woodmansee, R.G. 1978. Additions and losses of nitrogen in grassland ecosystems. *BioScience* 28:448-453.
- Young, V.A., and G.F. Payne. 1948. Utilization of "key" browse species in relation to proper grazing practices in cutover western white pine lands in northern Idaho. *Journal of Forestry* 46:35-40.

GLOSSARY

Abatement. Reduction of a nuisance or harmful effect, such as pollution.

Absorption. Process where one substance is taken up by another.

Ac/AUM. Acres per AUM, a common expression of cattle stocking rate.

Adsorption. Process in which a layer of ions, atoms, or molecules are bonded chemically or physically to solid surfaces.

Anadromous. Fish that are born and reared in freshwater, move to the ocean to grow and mature, and return to freshwater to reproduce (i.e., salmon and steelhead).

Animal Unit Month (AUM). Amount of forage one 1,000-lb. animal unit would consume in one month.

Animal Unit Year (AUY). Amount of forage one 1,000-lb. animal unit would consume in one year.

Annual. An organism that completes its life cycle from birth or germination through to death within one year.

Antibiosis. An association between organisms that is injurious to one of them.

Apical meristem. The group of cells in plants responsible for growth by cell division (primary growth); located at the tip of the stem or root.

Aquifer. A stratum of gravel, sand, or porous, fractured, or cavernous and vesicular rock holding and/or conducting water. When fully charged, an aquifer is saturated with water.

Biomass. Total mass of living organisms of one or more species per unit of space or of all species in a biotic community.

BLM. Bureau of Land Management, U.S. Department of Interior.

Browsing. The consumption of edible leaves and twigs from woody plants (trees and shrubs).

Coliform. Group of bacteria found in large intestine of humans and other warm-blooded animals.

Conductivity. The ability of water to conduct electricity; directly related to the mineral content of water.

Coprophagous. Eating the feces of other animals.

Corridor. A physical linkage, connecting two areas of differing habitat.

Cover. In aquatic ecology, the plants, rocks, and other materials (including organic debris) used by fish for shelter from adverse conditions and predation, feeding, or resting. Cover can be instream or overhead.

Critical period. Time within a year when a site is particularly vulnerable to grazing damage.

Defoliation. An unseasonable reduction in the foliage cover of a plant due to attacks by insects or fungal disease, or as a result of other factors such as drought, storms, chemicals in the atmosphere, and grazing. A distinctive loss of leaves outside the normal natural period of leaf shedding. See **herbivory**.

Density. Mass per unit volume of a material; the number or size of a population in relation to some limit of space.

Diversity. An assessment of the number of species present, their relative abundance in an area, and the distribution of individuals among the species. Some people consider diversity to be an indicator of ecological complexity or quality, where high species diversity is equated to higher complexity or quality, and declining species diversity is an indication of declining complexity or quality, but this is highly dependent on the potential of the site and the management objectives being used.

Drainage. The surface and sub-surface water derived within a clearly defined catchment area, usually bounded by ridges or other similar topographic features, encompassing part, most, or all of a watershed.

Ecosystem. A complex system of living organisms (plants, animals, fungi, and microorganisms), together with their abiotic environment (soil, water, air, and nutrients) that function together to circulate nutrients and create a flow of energy. This creates biomass, a trophic structure in the living community, and a change in ecosystem form and function over time.

- Edge.** The point at which dissimilar plant communities (different vegetation types, successional stages, or vegetative conditions) meet.
- Endangered.** “Any species which is in danger of extinction throughout all or a significant portion of its range” (ESA § 3(6)).
- Endemic.** Native; indigenous to a particular area; not introduced and often limited with geographic range.
- Enteric bacteria.** Family of bacteria typically found in the small intestines of humans and other warm-blooded animals (e.g., *e. coli* and salmonella); some cause disease in humans and animals.
- Ephemeral.** Lasting for brief periods of time.
- Erosion.** The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep.
- Eutrophication.** The addition of nutrients (especially N and P) to a body of water, resulting in high organic production rates that may overcome the natural self-purification processes. Eutrophication produces several undesirable effects, including algal blooms, seasonally low oxygen levels, and reduced survival opportunities for fish and invertebrates. Excessive nutrient inputs are frequently derived from sources of pollution on the adjacent lands. Water bodies in this condition are said to be eutrophic.
- Exotic.** A species accidentally or purposefully introduced into an area where it did not formerly occur.
- Fertilizer.** Any organic or inorganic material of natural or synthetic origins (excluding liming materials) that is added to a soil to supply one or more elements essential to the growth of plants.
- Fixation.** The process by which substances in the atmosphere or soil are converted into a form usable by plants (e.g., N- or K-fixation).
- Floodplain.** Flat land bordering a stream or river onto which a flood will spread. The underlying materials are typically unconsolidated and derived from past stream transportation activity.
- Fluvial.** A comprehensive term for several stream or river processes, involving the transport and deposition of materials by water.
- Forb.** A herbaceous plant with broad leaves, excluding the grasses and grasslike plants (i.e. buttercup and sunflower).
- Graminoid.** Grass and grass-like sedges and rushes.
- Groundwater.** The water that moves down into the soil and underlying geological strata from the upper soil layers following rainfall. Groundwater is stored in aquifers, and the boundary between aquifers and overlying unsaturated soils is the water table. Groundwater may move underground by streams and seepage.
- Guild.** A group of species having similar requirements and foraging habits and so having similar roles in the community.
- Head month.** The billing unit for permitted grazing on U.S. Forest Service lands and is equal to one month’s occupancy (USFS 1996).
- Herbaceous.** Non-woody vegetation, such as forbs and graminoids.
- Herbivory.** The act of animals eating plants or their seeds and fruits; defoliation. In most cases the plants do not die.
- Hydrogeology.** Changes of state and position of water in the geologic landscape.
- Hydrologic cycle.** The naturally occurring, solar-driven cycle of evapotranspiration, condensation, precipitation, and runoff of water. The cycle involves the movement of water between the atmosphere, terrestrial, and aquatic environments.
- Hydrology.** The science of water, its properties, and movement (cycling) over and under land surfaces.
- Impaired water quality.** The condition of water bodies that do not provide full support for beneficial uses, including designated uses and existing uses.
- IDAPA.** Idaho Administrative Procedures Act.
- Infiltration.** The movement of surface water into soil or rock through cracks and pores.
- INFISH.** Inland Native Fish Strategy.
- Inflorescence.** The flowering part of a plant.

Intensity (of grazing). Degree to which herbage is removed; proportion of the current year's forage production that is consumed or destroyed by grazing animals.

Interior Columbia Basin Ecosystem

Management Project. A regional natural resources assessment undertaken by the U.S. Forest Service and Bureau of Land Management. The assessment area includes all of Idaho, the portions of Montana west of the continental divide, and the portions of Oregon and Washington east of the Cascade Range.

Intermittent. Periodic interruptions in a normal pattern or process.

Leaching. The mobilization and transportation of soil materials in solution.

Leader (willow). The terminal, or the dominant current year's top most shoot on the main stem, characteristic of the growth of certain plants and trees, especially gymnosperms.

Limiting factor. Any environmental variable or process (physical, chemical, or biological) whose presence, absence, or abundance is the main factor restricting the distribution, numbers, or conditions of an organism. It is also termed the law of the minimum.

Lotic. Relating to flowing water.

Meanders. Regular and repeated bends of a similar amplitude and wave length along a stream channel. Bends in a stream that have been cut off from the main channel as a result of the water flow shifting its course.

Mesic. A term meaning intermediate, often in relation to temperature, moisture, or decomposition. Describes an environment that has moderate moisture levels, neither too wet nor too dry.

Montane. The biogeographic zone composed of moist, cool slopes below timberline and having evergreen trees as the dominant life form.

Native. Usually, a species known to have existed on a site prior to the influence of humans.

Nitrogen fixation. A process in which nitrogen-fixing bacteria and fungi, working in isolation (free-living) or in association with plants, convert atmospheric nitrogen into nitrogen compounds for use by the same or other plants.

Nonpoint source. Water pollution having its source over large areas such as farmland and lawns (pesticides, fertilizer, manure, sediment), grazing lands (animal wastes, sediment), streambanks (sediment), abandoned mines (acid drainage, heavy metals), construction sites (sediment), roadsides (lead, sediment, deicing salts), and so on (Owen and Chiras 1990).

Organic. A substance derived from living organisms or their products and involving carbon-based compounds.

PACFISH. U.S. Forest Service and Bureau of Land Management interim strategies for managing anadromous fish producing watersheds in eastern Oregon and Washington, Idaho, and portions of California.

Palatability. The avidity with which a plant or plant part is consumed by an animal.

Perennial. A plant that continues growth from year to year.

Permeability. A measure of the ease with which gasses or liquids can penetrate or pass through a porous substance.

pH. A measure of the acidity ($\text{pH} < 7$) or alkalinity ($\text{pH} > 7$) of water; the reciprocal of the logarithm of the hydrogen ion concentration in gram moles per liter.

Phenology. The study of the timing of periodic phenomena, such as flowering, growth initiation, and cessation in plants, especially as they relate to seasonal changes in temperature, photoperiod, etc.

Point source. Pollution that is discharged from an identifiable point, including pipes, ditches, channels, sewers, tunnels, and containers of various types.

- Riparian area.** The banks and adjacent areas of water bodies, water courses, seeps and springs whose waters provide soil moisture sufficiently in excess of that otherwise available locally so as to provide a more moist habitat than that of contiguous floodplains and uplands.
- Salmonid.** Fish of the family salmonidae, including salmon, trout, chars, whitefish, ciscoes, and grayling. It generally refers to salmon, trout, and chars.
- Saturation.** Complete infiltration, usually of water into the soil.
- Sedges.** Plants in the family *Cyperaceae*, usually with triangular stems that are solid as opposed to hollow.
- Sedimentation.** The depositing of eroded soil materials suspended in the water of creeks, lakes, or other water bodies. Sedimentation takes place when water velocity falls below a point at which the suspended particles can be carried.
- Senesce.** The process of aging in mature individuals, typically toward the end of an organism's life. In deciduous plants, the process precedes leaf shedding.
- Shrubs.** A woody perennial plant, typically lower than most trees, having multiple stems that branch from the base without a well-defined main stem.
- Threatened.** “[A]ny species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range” (ESA § 3(19)).
- Tillers.** A sprout or branch that grows from the base of a plant, especially from graminoids.
- Tributary.** A stream feeding, joining, or flowing into a larger stream.
- Turbidity.** Condition of water due to fine, visible material in suspension, which impedes the passage of light through the water.
- Ungulates.** Animals having hoofs. Wild ungulates are primarily deer and elk in the studies reviewed here.
- Upper Columbia River Basin.** A portion of the Interior Columbia Basin Ecosystem Management Project that includes all of Idaho except Bear River Basin, and portions of western Montana, northern Utah, and northwestern Wyoming that drain into the Columbia River.
- USFS.** U.S. Forest Service, Department of Agriculture.
- Water body.** A homogeneous classification that can be assigned to rivers, lakes, estuaries, coastlines, or other water features.
- Water quality.** The chemical, physical, and biological characteristics of water.
- Water table.** The upper limit or level in the ground of groundwater. It forms the boundary between the zone of saturation and the zone of aeration.
- Watershed.** An area of land draining water, organic matter, dissolved nutrients, and sediments into a lake or stream.
- Wetland.** A general term used to describe an area of land that is inundated by surface water or groundwater, and has a frequency to support, and under normal circumstances, does support, a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction.
- Xeric.** Environmental conditions and associated habitats lacking water.