88070015

National Training Center

Course Number 1737-1

Salem, Oregon

April 19 - 26, 1995

BLM

Riparian Management

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1995

INTRO
EXPECT

**INTRODUCTION, COURSE OBJECTIVES,
EXPECTATIONS, COURSE OUTLINE, AND
INSTRUCTORS**

BLM Library
Denver Federal Center
Bldg. 50, OC-521
P.O. Box 25047
Denver, CO 80225

#918376475

1. Course Title

2. Duration of
3. Program Offi
4. Class Limit
5. Course Coord

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
BLM MANAGERS COURSE GUIDE

Course Number:
1737-01

1. Course Title:

Riparian Management

-
2. Duration of Course: 7 days
3. Program Office: WO-220
4. Class Limit: 40 - 50
5. Course Coordinator: R. Krapf , TC-200
-

6. Performance Objectives (the measurable performance expected from trainees upon completion of training):

Trainees will be able to create a plan for protection and/or restoration of riparian/wetland systems using an interdisciplinary approach by:

- a. Applying an understanding of natural processes, functions and values.
 - b. Developing sound resource objectives.
 - c. Applying management strategies and actions.
 - d. Monitoring and evaluating the results.
-

7. **Brief Description of Course:** This course is the result of combining two previous course, 1737-01 "Coordinated Riparian Management" and 1737-03 "Applied Riparian Management". Trainees will spend 3 1/2 days in class and 3 days in the field. Trainees will be placed in groups for field exercises. Each group will present a report containing the identification of problems within the target area, a list of objectives, recommended management actions, and a monitoring plan.
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8. **Target Group:** All employees involved in riparian management including renewable resources specialists, recreation planners, cultural resource specialists, surface protection specialist, managers, etc. We welcome specialists from other agencies and interest groups.
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9. **Remarks:** This course begins in the middle of the week and runs through the weekend, with Sunday off. It will be held at various locations upon request by states. The Salem session was modified to meet Western Oregon needs.
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10. Course Schedule:

April 19 -26, 1995 at Salem, Oregon

COURSE TITLE: Riparian Management			COURSE NUMBER: 1737-1	
SCHEDULED FOR: April 19 to 26, 1995			WEEK(s) 2	
COURSE COORDINATOR: Russ Krapf (602-906-5503)			COURSE LOCATION: Salem, Oregon	
REMARKS: Morning and afternoon breaks will be given during each lecture day. Course will convene at either 7:30 am or 8:00 am depending on topics to be covered during that day. Lunch time will vary daily depending on lecture topics. Students are responsible for bring their lunch, drink and field equipment on field days. THERE WILL BE CLASS ON SATURDAY, APRIL 15TH FROM 8:00 AM TO 5:00 PM . THOSE STUDENTS LEAVING PRIOR TO THE SCHEDULE ADJOURNMENT TIME (1:00 PM WEDNESDAY, APRIL 26, 1995) WILL NOT GET CREDIT FOR ATTENDING THE COURSE.				
Wednesday, April 19, 1995	Thursday, April 20, 1995	Friday, April 21, 1995	Saturday, April 22, 1995	
Introduction, Course Objectives Expectations Welcome Values of Riparian/Wetland Systems Historical Aspects Watershed Processes, Functions and Components • Introduction to Watershed Ecosystems • Upland Processes and Hydrologic Cycle • Riparian Processes • Channel Processes • Dynamics of Riparian Ecosystem	Capability, Potential Natural Conditions and Future Desired Condition Define Capability and Potential Define Proper Functioning Condition Process to Determine Capability, Potential and Assess PFC Desired Community Introduction to ESI Resource Objectives Aquatic Conservation Strategy Objectives Contrasting PFC and Aquatic Conservation Strategy Objectives Open Panel Discussion	Trip to Tillamook to view Riparian Management Projects	Monitoring and Evaluation Interdisciplinary Process and Public Involvement GPS as a Tool	
Monday, April 24, 1995	Tuesday, April 25, 1995	Wednesday, April 26, 1995		
Field Station Exercise (Parker Creek)	Group Exercise	The Future of Western Oregon Riparian Condition and Management BLM Western Oregon Riparian Program and Partnerships Group Reports Close-Out and Evaluation		

COURSE OUTLINE FOR 1737-1, RIPARIAN MANAGEMENT
SALEM, OREGON, APRIL 19 - 26, 1995

WEDNESDAY, APRIL 19, 1995

I. Introduction, Course Objectives, Expectations and Welcome (8:00 am - 9:15 am)

A. Introduction and Course Objectives

Russ Krapf, NTC

Time: 8:00 am - 8:15 am

Objectives: Trainees will develop a working understanding of riparian processes and functions for use in watershed analysis, project planning, NEPA, project implementation and project monitoring

B. Expectations

Russ Krapf, NTC

Time: 8:15 am - 8:45 am

C. Welcome

Hugh Barrett, OSO

Time: 8:45 am - 9:00 am

Break (9:00 am - 9:15 am)

II. Values of Riparian/Wetland Systems

Presenter: Wayne Elmore, Prineville DO

Time: 9:15 am - 10:15 am

Objective: Be able to describe the importance and values of riparian/wetland systems.

A. Define riparian/wetland systems

1. BLM's definition (1989 Jurisdictional Manual)

2. What is our responsibility for management.

3. Examples of other ways or definitions

a. Contrast/compare with other definitions, i.e, Clean Water Act, EPA, USFS, USFWS, States

b. Common language, features, functions (see Western State Riparian Council Publication)

B. Discuss values and uses

1. Identify through group discussion

a. As means to develop appreciation/awareness of other discipline/persons values.

2. Introduce need for ID approach

B. (Continued)

- a. Because of values listed above
 - b. Differences between Multi- vs Interdisciplinary approaches.
3. Social Values

III. Historical Aspects

Presenter: **Bob Beshta, OSU**

Time: **10:15 am - 11:00 am**

Objective: Inform the trainees on both natural processes and historical management that have had an influence on riparian zones in the Pacific Northwest.

- A. Broad base region aspect
- B. Examples of site and watershed specific examples in Western Oregon: Fire, Landslides, Roding, Timber Harvesting and Splash Damming.

Break (11:00 am - 11:15 am)

Lunch (12:00 pm - 1:00 pm)

IV. Watershed Processes, Functions and Components

Objectives: Be able to describe the processes and functions operating within a watershed and linkage to riparian areas which promote capture, storage, and safe release of water.

A. Introduction to Watershed Ecosystems

Presenter: **Stan Gregory, OSU**

Time: **1:00 pm - 1:45 pm**

1. Define, include scope, size and components
2. Ecosystem Management
 - a. How watershed concept fits in or with the Ecosystem Management.
 - b. Introduction to linkage; headwaters to estuaries

B. Upland Processes and Hydrologic Cycle

Presenter: **Julia Jones, OSU**

Time: **1:45 pm - 2:30 pm**

1. Climate (precipitation patterns, timing, intensity, and duration, temperature, and alteration of the hydrologic cycle by management)
2. Infiltration, Percolation, Storage, and Release
3. Dynamics over time and space
4. Function of Soils in riparian areas
5. Geomorphic events that shape riparian systems in terms of upland hillslope processes

Break (2:30 pm - 2:45 pm)**C. Riparian Processes****Presenter: Stan Gregory****Time: 2:45 pm - 3:30 pm**

1. Community Dynamics
2. Functions
 - a. Shading
 - b. Bank Stability
 - c. Sediment Storage
 - d. Energy Dissipation
 - e. Water Storage
3. Relationship of existing vegetation to fire history and management

D. Channel Processes**Presenter: Julia Jones****Time: 3:30 pm - 4:15 pm**

1. Fluvial Geomorphology
2. Relationships to Riparian Process & Function

E. Dynamics of Riparian Ecosystems and Summary of Current Knowledge on Riparian Area Management in the Pacific Northwest**Presenter: Stan Gregory****Time: 4:15 pm - 5:00 pm**

1. The ecosystem in terms of managing riparian areas.
2. Perspective on use of data for making management decisions concerning riparian areas.
3. Perspectives on management opportunities currently being employed in the region
 - a. Roads
 - b. In Channel Structures
 - c. Riparian Vegetation Manipulation

THURSDAY, APRIL 20, 1995

V. Capability, Potential Natural Condition and Future Desired Condition

Objective: Given a scenario, be able to assess the capability, potential, and condition of riparian/wetland system.

- A. Define Capability and Potential
Presenter: Don Prichard, SC-213
Time: 8:00 am - 8:15 am

1. Provide history of BLM's policy involving Riparian Condition Classification
2. Relate to future desired condition

- B. Define Proper Functioning Condition
Presenter: Don Prichard
Time: 8:15 am - 9:00 am

1. Define Lotic and Lentic Systems
2. Define Non-Functioning, Functioning at Risk and Unknown
3. Relate to future desired condition

Break (9:00 am - 9:15 am)

- C. Process to Determine Capability, Potential and Assess PFC.
Presenter: Don Prichard
Time: 9:15 am - 10:45 am

1. Establish limiting factors (physical, biological, social, economic)
2. Determine operable elements (soil, vegetation, water, climate, Etc.)

Break (10:45 am - 11:00 am)

- D. Desired Community
Presenter: Don Prichard
Time: 11:00 am - 11:15 am

- E. Introduction to the ESI System
Presenter: Don Prichard and Chester Novak
Time: 11:15 am - 12:00 pm

1. Introduction to ESI as a BLM system relates to PFC.
2. Existing information can be pulled into this process of ESI
(Review of how ESI is used in the Salem District)

E. (Continued)

3. Applicability to watershed analysis and projects development

Lunch (12:00 pm - 1:00 pm)

VI. Resource Objectives

Presenter: Jim Wolf, Worland D.O.

Time: 1:00 pm - 2:30 pm

Objective: Students will be able to prepare realistic interdisciplinary resource objectives.

- A. Discuss resource objectives there importance and need.
- B. Explain relationship to land use plan.
- C. Discuss relationship between goals, objectives management strategy, management prescriptions and tools.
- D. Describe attributes of sound resource objectives,i.e. measurable, site specific, realistic, achievable within a given time frame, simple and understandable.
- E. Describe need to incorporate desired community concept in objectives development.
- F. Discuss five guidelines for a good objective
 - 1. What is to be accomplished
 - 2. State the Component that needs to be changed
 - 3. State the amount of change desire within a beginning and ending point
 - 4. Identify locating where objective is to be accomplished.
 - 5. Set a time frame for accomplishment (years, etc.)
- G. Provide some examples both good and bad.
- H. Exercise: Provide several versions of an objective to dealing with a resource management issue (ranging from excellent to poor). Ask trainees to rank best to poorest.

Break: 2:30 pm - 2:45 pm

VII. Aquatic Conservation Strategy Objectives

Objective: Students will be able to understand the background and intent of the Aquatic Conservation Strategy Objectives in relation to Riparian Management. Be able to understand the implications of the T&E listing in relation to riparian management.

A. Aquatic Conservation Strategy Objectives For Riparian Areas

Presenter: Gordon Reeves, Forest Sciences Lab

Time: 2:45 pm - 3:15 pm

1. The background and intent of Aquatic Conservation Strategy objectives for riparian areas in relation to the aquatic resource.
2. Implications of T&E species status in "active management" of riparian zones within the PNW (i.e., use Columbia Basin experience PACFISH)

B. Contrasting PFC and Aquatic Conservation Strategy Objectives

Presenter: Don Prichard and Gordon Reeves

Time: 3:15 pm - 3:45 pm

1. Similarities and dissimilarities in methods and goals.
2. Aquatic Conservation Strategy -- (longterm, PFC , Shortterm 70 percent by 1977.)

C.. Open Panel forum (3:45 pm - 4:30 pm) on questions and answers on PFC, Aquatic Conservation Strategy Objectives, Record of Decision, and Riparian Initiative and Oregon BLM Riparian Program. (Respond to questions written down by trainees) (Panel Members: D. Prichard, H. Barrett, G. Reeves)

FRIDAY, APRIL 21, 1995

VIII. Trip to Tillamook to view Riparian Management Projects

Presenter: Val Crispin and George Krall

Time: (9:15 am - 6:00 pm)

Objective: Trainees will be able to identify and understand strategies which have been used in riparian management.

- A. Speaker will tie success and failures back to processes and function.
- B. Review objectives and management opportunities to reach objectives.
- C. Suggestion: Pre-course assignment where participants or other experts are ask to submit a success or non-success stories from their district or area. Course coordinators/instructors could select 3-4 and ask participants or others to make presentation on each. Someone could facilitate a discussion on why successes were realized tying back to process and function.

SATURDAY, APRIL 22, 1995

IX MONITORING AND EVALUATION

Presenter: Lee McDonald, Colorado State University

Time: 8:00 am - 9:15 am

Objective: Trainees will be able to select and tailor various monitoring techniques to evaluate progress toward achieving objectives in riparian areas.

- A. Introduce Guidelines book: inventory vs. monitoring
- B. Legal background (water quality standards, designated beneficial uses, antidegradation, etc.)
- C. Types of monitoring
- D. Designing a monitoring project

Break (9:15 am - 9:30 am)

- E. Sources of variability, statistics, stratifications, and scale considerations

Break (10:45 am - 11:00 am)

- F. What are the key parameters to monitoring for "riparian health"
- G. Trade-offs between upland, riparian, or aquatic components
- H. Watershed analysis, existing programs, crystal-ball gazing
- I. Discuss what the results means an how it relates to current practices

Lunch (12:00 pm - 1:00 pm)

X. INTERDISCIPLINARY PROCESS AND PUBLIC INVOLVEMENT.

Presenter: Howard Hunter, Salem District

Time: 1:00 pm - 2:30 pm

Objective: Trainees will be able to define the 5 step ID process incorporating public involvement to protect and restore riparian/wetland areas.

- A. Describe ID Concept
 - 1. Discuss ID Teams
 - a. Why is ID team necessary - No one has all the knowledge needed to make proper decisions.
 - b. What specialties are required - how is this team determined. Are all disciplines required; i.e., no fish is fisheries biologist needed.
 - c. Explain group dynamics and synergy (from 1965 per Zimmer Workbook)
 - 1. Forming

A. (Continued)

- 2. Storming
- 3. Norming
- 4. Preforming
- d. Or an equivalent approach
- 2. Provide a brief overview of the ID Process
 - a. Direction the Bureau is heading and why.
 - b. Five step process
 - 1. Scoping
 - a. Interviewing the Public
 - 2. Objectives
 - 3. Management Actions
 - 4. Monitoring
 - 5. Evaluation/revision

B. Public Involvement in Relationship to Environmental Assessment and Watershed Analysis

- 1. Value and need - mention requirements of laws
- 2. When and How you involve the public
- 3. Who should be involved
- 4. Brief description of various concepts now in use - list pro's and con's of each
- 5. Examples of successful efforts - videos or testimonials
- 6. Personnel interviews (How to conduct to get the most out of them for information in watershed analysis, etc.

Break (2:30 pm - 2:45 pm)

XI. GPS as a Tool

Presenter: Tom Howie, USFS

Time: 2:45 pm - 5:00 pm

Objective: Present basic information on GPS and demonstrate how it can be used in riparian and watershed management

- A. Basic Information Concerning the systems
- B. Limitations of systems

Break (3:45 pm - 4:00 pm)

- C. Applications

SUNDAY, APRIL 23, 1995 DAY OFF

MONDAY, APRIL 24, 1995

XII. Field Station Exercises (Parker Creek)

Presenters:

Bob House	(Fisheries)
Joe Furnish	(Macros)
John Applegrath	(Amphibians)
Stan Gregory	(Riparian Ecology)
Julia Jones	(Hydrology/Fluvial Geomorphology / Soils)
Don Prichard	(PFC)
Tom Howie	(GPS Applications)

Time: 7:00 am - 5:00 pm

Objective: To reintroduce, illustrate and discuss in a field setting the principles of process and function within riparian zones and their implications to beneficial uses.

TUESDAY, APRIL 25, 1995

XIII. Group Field Exercise and Report Preparation (Mill Creek)

Time: 7:00 am - 5:00 pm

Objective: Give the students to apply information the have gained from the course and field trip to an actual field situation. Given a case study watershed analysis with management opportunities for this reach, design a "implementation plan" which would include specific projects within the reach. This should be done in an interdisciplinary team process and include a task list which include a range of items from project identification through monitoring, this implementation plan should be related to original issues and questions..

A. Group Field Exercise
Time: 7:30 am - 3:00 pm

B. Report Preparation
Time: 3:00 pm - 5:00 pm

WEDNESDAY, APRIL 26, 1995

XIV. The Future of Western Oregon Riparian Condition and Management

Presenter: Gordon Grant, Forest Sciences Lab

Time: 8:00 am - 8:45 am

Objective: To provide a trend analysis of riparian condition and management over short and long term

- A. Make predictions concerning the future condition of riparian areas.
- B. Other issues which might influence riparian areas.

XV BLM Western Oregon Riparian Program and Partnerships

Presenter: Hugh Barrett, OSO

Time: 8:45 am - 9:15 am

Objective: To introduce the trainee to the Western Oregon BLM Riparian Program. To introduce the trainees to the advantages of developing partnerships with other agencies, interest groups, and the public.

- A. Past, Present, and Future of Western Oregon BLM Riparian Program.
- B. History of existing partnerships (List Partnerships)
- C. Some of the hazards to avoid
- D. What makes a good partnership
- E. Challenge Cost Share

Break (9:15 am - 9:30 am)

XV. Group Presentations and Discussion

Presenter: Groups

Time: 9:45 am - 11:30 am

Objective: Give the students forum to present, discuss, and evaluate data from field exercise.

XVI. Close Out and Evaluations

Presenter Russ Krapf, NTC

Time: 11:30 - 12:30 pm

Objective: Provide students an opportunity to evaluate and comment on the course.

- A. Evaluation
- B. Certificates.

Course Roster

Course: 1737-1, Riparian Management

Location: Salem, Oregon

Date: April 19 - 26, 1995

1. Scott Abdon	42. Dave Rosling
2. Kirk Appleman	43. Robert Ruediger
3. Steve Bahe	44. Peter Schay
4. Steve Baldwin	45. Daniel Schlottman
5. Dugan Bonney	46. Larry Scholfield
6. Sam Caliva	47. Julie Knuro Thiel
7. Dave Calver	48. Tom Tomczyk
8. John Chatt	49. Lynn Trost
9. Meredith Childs	50. Dennis Turowski
10. James M. Cook	51. Sara Worsham
11. John Depuy	
12. Karen Dodge	
13. Dana Eckard	
14. Ron Exeter	
15. Terry Fennell	
16. Effie Frazier	
17. Randall K. Gould	
18. Bill Hatton	
19. Patric Hawe	
20. Chuck Hawkins	
21. Amy Haynes	
22. Randall Herrin	
23. Robert B. Hershey	
24. Claire Hibler	
25. D. Scott Hopkins	
26. Walt Kastner	
27. Sabrina Keen	
28. Gary A. Licata	
29. Wayne D. Logan	
30. Mark S. Lowry	
31. Vince Mazeika	
32. Bob Mcdonald	
33. Jon Menten	
34. Kerry Murphy	
35. Gregg Nelson	
36. J. Michael Oxford	
37. Andrew Pampush	
38. Jon Raby	
39. Barbara Raible	
40. Robert Ratchliffe	
41. Dave Roche	

UNIMPORTANT FACTS

(TBTB, Red-Letter Press, 1986)

A cow's sweat glands are in its nose.

Smokey the Bear's original name was HOT FOOT TEDDY.

The watch pocket in pants is also known as the Fob.

The dot over the letter i is called a tittle.

The great horned owl is the only animal that will eat a skunk.

Jaguars are scared of dogs.

Toads do not have teeth.

Almost half the bones in your body are in your hands and feet.

A flamingo can only eat when its head is upside down.

Folding money, invented by the Chinese, was first made of deerskin.

A hockey puck weighs 0.38 lbs.

Tuna fish swim at an average speed of 9 miles per hour constantly. They never stop moving.

The only domestic animal not mentioned in the Bible is the cat.

One cord of wood can make seven and one-half million toothpicks.

There are three words in the English language with two u's in consecutive order -- vacuum, residuum, and continuum.

Pluto, the Disney dog, was originally called Rover.

A female African elephant can be pregnant for almost two years.

Alaska doesn't have any counties.

The eggplant was a "mad apple" and believed to be poisonous in the 1880s.

The space between your nostrils is called your COLUMELLA.

Dog meat is a delicacy in China. So is bird's nest soup.

Honey is used in antifreeze mixes.

(04/95)

BIOGRAPHICAL SKETCH

Hugh Barrett
Oregon State Office
P.O. Box 2965, (932)
Portland, Oregon 97208

Office Phone: (503) 280-7051

Fax Number : (503) 280-7021

CAREER EXPERIENCE

<u>YEARS</u>	<u>POSITION OR ASSIGNMENTS AND LOCATIONS</u>
1991-Present	Oregon State Riparian Coordinator, BLM, Portland, Oregon
1983 - 1991	State Range Conservationist, SCS, Portland, Oregon
1979 - 1983	Area Range Conservationist, SCS, Ephrata, Washington
1976 - 1979	Range Conservationist, SCS, Minden, Nevada
1975 - 1976	District Conservationist, Battle Mountain, Nevada
1974 - 1975	Range Conservationist, SCS, Elko, Nevada
1973 - 1974	Range Conservationist, SCS, Wells, Nevada
1971 - 1972	Student Trainee (Range Con.), SCS, Battle Mountain, Nevada

EDUCATION (Degrees-Specialized Training):

B.S. Range Management, Humboldt State University, 1973

INTERESTS:

Fishing for Salmon/Steelhead, Home Brewing

(04/95)

BIOGRAPHICAL SKETCH

Wayne Elmore
Prineville District
185 East 4th St
P.O. Box 550
Prineville, Oregon 97754

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Fax Number: (503) 447-8798

CAREER EXPERIENCE

<u>YEARS</u>	<u>POSITION OR ASSIGNMENTS AND LOCATIONS</u>
1986 - Present	Oregon/Washington, State Riparian Specialist, stationed at Prineville District, Prineville, Oregon.
1974 - 1986	District Wildlife and Fisheries Biologist, Prineville District, Prineville, Oregon
1971 - 1974	District Wildlife Biologist, Spokane District Office, Spokane, Washington
1968 - 1971	Resource Area Forester, Spokane District Office, Spokane, Washington.

EDUCATION (Degrees-Specialized Training):

B.S. Forest Management, Oklahoma State University
Additional Post Graduate Studies in Fisheries and Wildlife Management 1969 - 1983

INTERESTS:

Taxidermy, Wood Carving, Hunting and Fishing

(04/95)

BIOGRAPHICAL SKETCH

Robert House
Idaho State Office
3380 Americana Terrace
Boise, Idaho 83706

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Fax Number: (208) 384-3083

CAREER EXPERIENCE

<u>YEARS</u>	<u>POSITION OR ASSIGNMENTS AND LOCATIONS</u>
1992 - Present	Anadromous Fish Program Lead, Western Fish and Wildlife Staff, Boise, Idaho
1978 - 1992	District Fish Biologist, Salem District Office
1977 - 1978	District Fish Biologist, Redding District Office
1974 - 1977	Fish/Wildlife Biologist, USFWS, Ecological Services, Sacramento, California
1971 - 1974	Fish Biologist, USFWS, Fishery Research, Ann Arbor, Michigan

EDUCATION (Degrees-Specialized Training):

B.S.	Fisheries, University of Washington
1 year	Graduate Work, Utah State University

INTERESTS:

Hunting, Fishing, Wildlife Photography

(04/95)

BIOGRAPHICAL SKETCH

Tom Howie, P.L.S.
Gold Beach Ranger District
1225 South Ellensburg Avenue
Gold Beach, Oregon 97444

Office Phone: (503) 247-6651
Fax Number: (503) 247-2816

CAREER EXPERIENCE

<u>YEARS</u>	<u>POSITION OR ASSIGNMENTS AND LOCATIONS</u>
1986 - Present	Forest Land Surveyor, Siskiyou National Forest, Region 6, G.P.S. Instructor
1978 - 1986	Assistant Land Surveyor, Siskiyou National Forest.

EDUCATION (Degrees-Specialized Training):

Syracuse Environmental and Technical College of
Forestry

Advanced Cadastral Survey, Arizona State
University

INTERESTS:

Family, Rafting, Volunteer Fire Chief, Hunting

(04/95)

BIOGRAPHICAL SKETCH

Howard Hunter
Salem District Office
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Salem, Oregon 97306

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CAREER EXPERIENCE

<u>YEARS</u>	<u>POSITION OR ASSIGNMENTS AND LOCATIONS</u>
1991 - Present	Resource Operations Manager, Salem District Office, Salem, Oregon
1989 - 1991	Plans & Monitoring Forester, Salem District Office, Salem, Oregon
1988 - 1989	EA Team Leader for Oregon Trail Interpretive Center, Vale District, Baker City, Oregon
1985 - 1988	Plans Forester, Medford District Office, Medford, Oregon
1978 - 1985	Forester, Medford District Office, Medford, Oregon
1981 - 1993	Internal Facilitator

EDUCATION (Degrees-Specialized Training)

B.A. Forestry, Humboldt State University, Arcata, California

Extensive group dynamics & communications training as part of internal facilitator role.

INTERESTS:

Long Distance Bike Touring, Fishing, Sleeping in on Saturdays

(04/95)

BIOGRAPHICAL SKETCH

Julia Allen Jones
Department of Geosciences
Oregon State University
Corvallis, Oregon 97331

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Fax Number: (503) 737-1200

CAREER EXPERIENCE

<u>YEARS</u>	<u>POSITION OR ASSIGNMENTS AND LOCATIONS</u>
1992- Present	Associate Professor with tenure, Department of Geosciences, Oregon State University
1991-1992	Visiting Associate Professor, Department of Forest Science, Oregon State University, National Science Foundation Visiting Professorship for Women
1990-1991	Associate Professor with tenure, joint appointment with Department of Geography and Environmental Studies Program, University of California, Santa Barbara.
1983-1990	Assistant Professor, joint appointment with Department of Geography and Environmental Studies Program, University of California, Santa Barbara.
1980-1983	Research Assistant, Center for Energy Policy Research, Resources for the Future, Washington, DC.

EDUCATION (Degrees-Specialized Training):

B.A.	Hampshire College (Amherst, MA) Economic Development, 1977.
M.A.	Johns Hopkins School for Advanced International Studies (Bologna, Italy and Washington, DC.) 1977.
Ph.D.	The Johns Hopkins University, Department of Geography and Environmental Engineering (Baltimore, MD), 1983.

Professional Memberships:

Ecological Society of America; American Geophysical Union; Society for Conservation Biology; Soil Science Society of America; & International Soil Science Society

(04/95)

BIOGRAPHICAL SKETCH

Louis D. "Lou" Jurs
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Spokane, Wa 99212
Office Phone: (509) 536-1200
Fax Number: (509) 536-1275

CAREER EXPERIENCE

<u>YEARS</u>	<u>POSITION OR ASSIGNMENTS AND LOCATIONS</u>
1994 - Present	NRS0 Team Leader District Special Skills Team: Ecosystem Management Coordinator, Spokane DO
1990 - 1994	NRS-District Wildlife, Fisheries, T/E Coord; District Riparian-Wetland Coordinator, Spokane DO
1985 - 1990	District Wildlife Biologist, Spokane DO.
1984	ADM-Operations, Yuma District Office
1982 - 1984	T/E & Wilderness Program Lead, Arizona State Office
1980 - 1981	Team Co-Leader, NPRA Biological Resource Assessment Team, Alaska State Office
1979 - 1980	Region 10 Wildlife Program Lead, USFS, Juneau, AK
1976 - 1979	BLM State Biologist, Alaska State Office, Anchorage
1973 - 1976	Area Manager, BLM, Folsom, California
1971 - 1973	District Wildlife Biologist, California Desert, Riverside, California
1966 - 1971	Range Conservationist/Wildlife Program Coord, Susanville District, California
1962 - 1965	Range Conservationist (Seasonal), BLM Winnemucca, Nevada

EDUCATION (Degrees-Specialized Training)

B.S.	Zoology, University of Nevada, Reno
M.S.	Range Ecology, University of Nevada, Reno

INTERESTS: Outdoor Photography, fishing, hiking, travel, dog
training, microbrews

(04/95)

BIOGRAPHICAL SKETCH

Russ Krapf
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**WATERSHED PROCESSES, FUNCTIONS, AND
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Riparian Management Guide

Willamette National Forest

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EXECUTIVE SUMMARY

GENERAL RIPARIAN MANAGEMENT

Riparian areas along perennial streams, lakes, and wetlands comprise a little over 100,000 acres, or approximately 6% of the 1.7 million acres of the Willamette National Forest (WNF). These riparian areas provide numerous economic, social, and ecological benefits to the Forest.

The primary goal of riparian management is to provide self-sustaining streamside forests that will ensure the desired conditions of riparian resources for the future. According to national policies of the U.S. Forest Service, riparian-dependent resources receive first priority in forest management along streams, lakes, and wetlands. Removal of riparian vegetation for timber harvest must be justified, both ecologically and administratively. All land management entails a certain degree of uncertainty and is likely to change over time; thus, some margin for risk must be included in riparian management policies.

Given the high value of riparian resources on the WNF and the associated administrative and economic benefits, a no-programmed harvest riparian management policy provides accurate planning, increases effective land management, and maintains a diverse array of options for future Forest management. A no-programmed harvest riparian management policy over much of the forest also is an essential component of policies to manage forest landscapes and to maintain components of mature forests in young stands.

LANDSCAPE AND BASIN MANAGEMENT

Effective land management maintains the ecological linkages of riparian resources throughout the forest landscape. Continuous corridors of riparian forests provide essential connections between different management areas distributed throughout the Willamette National Forest. Riparian management zones also contribute essential elements of continuity for policies to minimize fragmentation of the forest. No other landscape feature within the National Forest offers the natural continuity of riparian areas.

Management of forest landscapes must identify and retain the natural patterns of riparian resources at scales ranging from specific harvest sites to multiple river drainages. Land use planning in the Willamette National Forest operates at two scales: broad project areas that may encompass several thousand acres and individual harvest units within a project area. Basin planning is designed to minimize the potential for cumulative effects, maintain potential inputs of woody debris, maintain continuous riparian corridors with structurally complex plant communities throughout the basin, and rehabilitate degraded riparian resources within the basin.

HARVEST UNIT MANAGEMENT

Site-specific riparian management prescriptions are developed after basin management objectives for riparian areas have been identified by the planning team. Delineating the boundaries of the riparian management zone will largely determine the effectiveness of subsequent management in meeting riparian objectives.

The entire floodplain should be included within the riparian management zone. Failure to do so will seriously jeopardize riparian management objectives during major floods. Forest Service policy requires land managers to "avoid adverse impacts which may be associated with the occupancy and modification of floodplains and with the destruction, loss, or degradation of wetlands".

Delineation of the riparian management zone starts at the edge of the active channel or mean high water level, and extends horizontally on both sides. Active channels consist of all portions of the stream channel carrying water at normal high flows, not just the current wetted channel. They include side channels and backwaters, which may not carry water during summer low flow. For optimal management of riparian resources, riparian management zones should have variable widths that are delineated at ecologically significant boundaries, rather than arbitrary distances around a stream, lake or wetland.

No timber harvest is programmed from riparian management zones along Class I, II and III streams, intermittent Class IV streams in unstable watersheds, lakes, or wetlands. Partial harvest of vegetation (<50% of the stand in the riparian management zone) is permitted on intermittent Class IV channels in moderately stable watersheds and ephemeral Class IV streams in unstable watersheds. Complete harvest of overstory vegetation is permitted in intermittent Class IV streams in watersheds with stable soils and ephemeral Class IV streams in watersheds with stable or moderately stable soils.

The choice of logging system for a particular site should consider the riparian area and its degree of protection. No trees in the harvest unit should be felled in a direction that would result in their entry into the riparian management zone, except along stable and moderately stable Class IV streams. Logs should be yarded uphill if possible when passing over or through riparian management zones. In some harvest units, cable corridors may need to be cut through the riparian management zone. When a suspension corridor is cut, these logs should be placed in the channel and riparian management zone if the area is deficient in large woody debris. The amount of woody debris left in the channel and forest floor within the suspension corridor should approximate natural volumes for the site.

Riparian vegetation plays a critical role in the dynamics of forest plant communities as well as providing numerous ecological functions for other aquatic and terrestrial communities. A major objective of riparian vegetation management is to maintain the species diversity, age composition, and structural complexity of riparian forests.

Most future riparian functions will be guaranteed if natural abundances and distributions of all sizes of woody debris are maintained in streams, lakes, floodplains, and lower hillslopes. Of all the ecological functions of riparian areas, the process of woody debris loading into channels and floodplains requires the longest time for recovery after harvest.

Appropriate riparian management avoids excessive loading of woody debris. No clean-up should be prescribed for any stream, lake or wetland under normal conditions. Slash should be removed only in sluggish stream reaches or in cases of extremely large deposits that are judged to create significant risks for aquatic or wildlife resources.

In general, no timber should be salvaged from any riparian area of the WNF. Given the numerous functions and benefits of riparian vegetation and woody debris, there is no reason to remove salvaged timber from riparian areas, except to meet the needs of riparian-dependent resources. Riparian trees may be felled and used on site or removed to another riparian area if local stand conditions are adequate. Additionally, blowdown is not a

management failure and downed trees should not be removed from riparian management zones. The riparian management zone was designed for the trees to die and fall into the stream channel, and windthrow is the most common source of natural debris loading.

The primary objective for fish management on the WNF is to maintain the quality of habitat and food supply for anadromous and resident fish populations at all stages of their life cycles. Riparian management zones established for water quality and fisheries needs may not meet wildlife habitat requirements. Riparian management zones should be designed to ensure diverse types and amounts of wildlife habitats found in riparian forests and meadows.

REHABILITATION

Both natural and man-caused events can have adverse impacts on riparian functions, despite the best attempts to protect them. Silvicultural and geomorphic techniques may be effective in rehabilitating degraded riparian resources. Highest priorities in all silvicultural operations in riparian areas should be given to creating taxonomically diverse and structurally complex riparian plant communities.

If a riparian area has been damaged by a natural or land use-related disturbance, the probability of continued disturbance must be considered. Any improvements associated with rehabilitation projects can be negated by treating the symptom rather than the source of disturbance.

Channels in many streams have been simplified and destabilized by stream clean-up, salvage operations, debris torrents, and floods. In areas with adequate equipment access and sources of large wood, channel structure and volumes of large woody debris can be restored through channel rehabilitation projects. Understanding the current status of channel structure and/or fish communities is essential for developing appropriate project objectives.

Natural channel materials should be used for rehabilitation whenever available. Persistence of installations is increased where log structures are placed in geomorphically stable locations and configured to resemble natural accumulations of wood. Movement of introduced logs should not be considered a failure, particularly if the logs are retained within a short distance downstream.

Objectives for the entire rehabilitation project and each individual component should be explicitly stated. Rehabilitation projects without future evaluation are unfinished. Subsequent monitoring is essential to determine to what degree project objectives were achieved and to improve future riparian rehabilitation efforts.

RIPARIAN MONITORING

Riparian monitoring evaluates the effectiveness of past management practices. Identification of the desired future condition of riparian areas is a fundamental basis for any monitoring and evaluation of resource information. Riparian monitoring is essential for developing effective management policies in future forest planning.

CHAPTER 1

INTRODUCTION

The Willamette National Forest (WNF) and the U.S. Forest Service (USFS) recognize that riparian areas in national forests support a wide array of resources with high economic and ecological values. Riparian areas provide clean water, fish and wildlife habitat, timber, and recreational opportunities. These multiple functions of riparian areas need to be recognized for effective land management.

The primary objective in all stages of riparian management is protection of riparian resources, as established in the National Forest Management Act. U.S. Forest Service policy mandates management of "riparian areas in the context of the environment in which they are located, recognizing their unique value" (FSM 2526.02), and requires its managers to "give preferential consideration to riparian dependent resources when conflicts among land use activities occur" (FSM 2526.03).

This guide is designed to provide an understanding of the significance and functions of riparian areas as a foundation for sound forest management. The document begins with a discussion of fundamental concepts and definitions of riparian areas and their resource values. Riparian processes and management objectives and practices are then described at three levels: landscape, drainage basin, and individual harvest unit. Finally, rehabilitation and monitoring techniques appropriate to riparian areas are discussed. We have also included a list of important references and an extensive glossary. In general, information within the body of the text is referenced only if it pertains specifically to the WNF and is of interest to a wide range of personnel.

The guide is intended to serve the management and technical staff of Willamette National Forest (WNF) personnel. The general concepts and management techniques could apply to any forested riparian area. However, management details and standards are specific to the 1990 WNF Land and Resource Management Plan (see Appendix IV).

CONCEPTS & DEFINITIONS

What is a riparian area? Definitions vary depending on the perspectives of managers or scientists. The word "riparian" is derived from the Latin word for bank or shore, and simply refers to land adjacent to a body of water. Plant ecologists define riparian areas based on soil moisture conditions and unique plant communities associated with wetted soils. Consequently, riparian areas do not stop at an arbitrary, uniform distance away from the stream but vary in width and shape.

Ecosystem perspectives of riparian areas incorporate concepts from geomorphology, terrestrial plant succession, and aquatic ecology. Riparian areas are defined as three-dimensional zones of influence between terrestrial and aquatic ecosystems. The boundaries of the riparian area extend outward from the streambed or lakeshore and upward into the canopy of streamside vegetation.

Figure 1.

Cross-section of a riparian area and adjacent hillslope. Note that the actual riparian area may extend well up the hillslope, encompassing zones of influence for shading, litter inputs, and wood loading. The riparian management zone may be significantly narrower than the riparian area.

Using this ecological approach, the WNF considers riparian areas to include the aquatic ecosystem and adjacent terrestrial areas directly affecting the aquatic system (Fig. 1). Influences of forests progressively decrease away from the stream, lake, or wetland. Thus, riparian areas cannot be defined by discrete lines on the ground. Specific boundaries established by the Forest Service for management practices within riparian areas are termed riparian management zones. Riparian management zones are contained within but may not necessarily include all of the riparian area.

Riparian area management often focuses on the immediate vicinity and local characteristics of a particular site. Land managers must also recognize the role of riparian areas as continuous corridors over the landscape, linking hillside to streams, and upper headwaters to lower valleys. Riparian area management thus becomes important not only locally but on drainage basin and landscape levels as well.

SELECTED DEFINITIONS

Active Channel

The part of the valley floor inundated annually, including low flow wetted channel and streambanks (Fig. 2). The approximate equivalent to bankfull channel.

Basin

The area of land that drains water, sediment and dissolved materials to a common point along a stream channel.

Class I Streams

Perennial or intermittent streams with one or more of the following: 1) direct source of water for domestic use; 2) habitat for spawning, rearing or migration for large numbers of fish; or 3) sufficient discharge to have a major effect on water quality of another Class I stream (Fig. 3).

Figure 2. Major landforms of a river valley. AC - active channel; FP - floodplain; T - terrace; HS - hillside.

Figure 3. The U.S. Forest Service stream classification system.

Class II Streams

Perennial or intermittent streams with 1) habitat for spawning, rearing or migration of moderate though significant numbers of fish; and/or 2) sufficient discharge to have moderate influence on other Class I or II streams (Fig. 3). Game fish are present for at least part of the year or the stream has the potential for establishment or re-establishment of a game fish population.

Class III Streams

Any perennial streams not meeting the criteria for Class I or II streams (Fig. 3).

Class IV Streams

Any intermittent or ephemeral streams not meeting the criteria for Class I, II, or III streams (Fig. 3).

Cumulative Effects

Effects on the environment resulting from individually minor but collectively significant events taking place over a period of time or space.

Ephemeral Streams

Streams carrying surface runoff only during or immediately after a rainstorm or snowmelt. Channels are not well defined, and usually are covered with a litter layer characteristic of the surrounding forest (Fig. 4).

Figure 4. Location and characteristics of perennial, intermittent, and ephemeral streams within a drainage.

Floodplain

Relatively flat surfaces adjacent to active channels, formed by deposition of sediment during major flood events (Fig. 2). Some floodplain areas are inundated only during extremely large, infrequent floods. Floodplain boundaries are defined by the break in slope between the hillsides and the relatively flat floor of the river valley.

Intermittent Streams

Streams that carry water most of the year, but do not flow during part of summer. In contrast to ephemeral streams, during summer low flow these channels are obviously dry stream beds (Fig. 4).

Perennial Streams

Streams that normally flow year long and have well defined channels (Fig. 4).

Riparian Area

The aquatic ecosystem and the portions of the adjacent terrestrial ecosystem that directly affect or are affected by the aquatic environment. This includes streams, rivers, and lakes and their adjacent side channels, floodplains, and wetlands. The riparian area includes portions of hillslopes that serve as streamside habitats for wildlife.

Riparian Management Zone

Site-specific boundaries established to meet riparian management objectives in riparian areas. Riparian management zones are contained within but do not necessarily include the entire riparian area (Fig. 1).

Wetland

Areas covered by shallow water or periodically saturated by the water table. Wetlands generally have wetted (hydric) soils and support plant communities tolerant of water-saturated soils (hydrophytes).

Woody Debris

Dead woody material usually composed of boles and large branches. Various terms, such as large woody debris (LWD), coarse woody debris (CWD), and large organic debris (LOD), have been used to describe this material. Large woody debris is material greater than 20 inches (50 cm) in diameter and 33 feet (10 m) in length. Woody material greater than 4 inches (10 cm) diameter and 3 feet (1 m) in length but less than 20 inches (50 cm) in diameter and 33 feet (10 m) in length is considered to be small woody debris and consists of small trees, tops of large trees, and large branches. Small branches, twigs, and slash from logging operations less than 4 inches (10 cm) diameter and 3 feet (1 m) in length are considered fine woody debris.

Additional definitions are included in the Glossary (Chapter VIII).

CHAPTER 2

RIPARIAN RESOURCE VALUES

The Willamette National Forest (WNF) encompasses approximately 1.7 million acres of land. Of this total, riparian areas along perennial streams, lakes, and wetlands comprise approximately 100,000 acres, or 6% of the WNF (Table 1). Despite this small acreage, riparian areas provide numerous economic, social, and ecological benefits to the Forest (Figure 5).

Riparian areas include six major categories of resources:

- ◆ water quality
- ◆ fish
- ◆ wildlife
- ◆ vegetation
- ◆ timber
- ◆ recreation

Figure 5. Proportion of selected forest resource uses located in riparian areas of the Willamette National Forest.

WATER QUALITY

Intact riparian areas along streams and lakes provide buffers from natural and man-caused disturbances, thereby ensuring good water quality. Activities in small headwater streams and lakes potentially affect water quality in downstream areas.

Water Temperature

One of the most obvious effects of riparian areas on water quality is regulation of water temperature. Small undisturbed headwater streams are often completely shaded by riparian vegetation. Such small streams contribute cool water to more open downstream regions. Sources of cold water throughout a basin are vital to other important resources such as native fish populations. Therefore, shading by riparian area vegetation throughout a drainage basin is essential, particularly during summer low flows.

Stream temperature in an individual logged unit is rarely more than 2°F warmer than adjacent forested reaches in the WNF. However, the combined impacts of temperature increases in all recently harvested units within a basin may lead to significant warming of downstream reaches, adversely affecting native fish populations. At warmer water temperatures, salmonids become more susceptible to disease. In addition, they may suffer indirect mortality from competition with other fish species that tolerate warmer water, such as suckers and minnows. Most native fish species will not survive if water temperatures exceed 70°F for extended periods. Consequently, small increases in water temperatures may lead to an overall decline in salmonid populations.

Table 1. Riparian management zone acreages in different habitat types on the Willamette National Forest. Riparian widths include both sides of the stream; these values are used in FORPLAN. Acreage for Class IV streams was not determined.

Habitat Type	Length (miles)	Riparian Width (feet)	Riparian Habitat (acres)
Streams			
Class I	426	400	19,496
Class II	940	200	21,252
Class III	1,295	200	29,627
Class IV	6,621		
Lakes	270 (shoreline)	150	4,457
Wetlands			23,950
TOTAL			98,782

Sedimentation and Turbidity

Riparian areas act as buffers and filters of suspended sediments. The abundant and diverse plant communities of intact riparian areas help ensure a source of water low in suspended sediments and turbidity.

Throughout a drainage basin, plant roots and large woody debris accumulations in intact riparian areas stabilize lakeshores, streambanks and hillslopes. This in turn reduces sediment input into lakes and streams. During floods, riparian areas dissipate the water's energy, causing suspended sediments to settle out instead of being transported farther downstream. Riparian areas with broad floodplains act as additional storage sites for sediment and water.

Although these processes operate throughout a drainage basin, they can be of critical importance in small intermittent or ephemeral headwater streams. The relative stability of these channels can significantly affect the amounts of sediment transported by the stream. Woody debris maintains the stair-step structure of steep stream channels, which is essential for trapping sediments and reducing the water velocity.

Mature riparian forests and large woody debris in streams can also serve to limit the downstream impacts of mass failures/debris torrents, particularly in headwater streams. Streamside forests reduce the potential for local failures, and downstream riparian stands intercept and impede the flow of sediment and debris. Boles of trees swept into the flow provide "reinforcement" and may reduce the length of the debris flow deposits.

Increased suspended sediment and turbidity are major issues in water quality degradation associated with management activities in the Pacific Northwest. Sources of increased sediment load include both immediate harvest practices on site and associated forest-wide activities, such as road building. The largest source of sediment inputs is failure of poorly constructed roads. These increases in sedimentation reduce potability to downstream users and may cause serious damage to fish and wildlife resources. Although many of these activities occur in small headwater streams, the turbid waters flow downstream, eventually affecting larger streams.

Sediment deposition over stream beds or lake bottoms reduces the habitat available for aquatic insect communities. Even at relatively low levels, fine sediments deposited in fish spawning areas can kill eggs or emerging fry. At higher concentrations, suspended sediments can damage fragile gill tissues of fish. Management practices that increase sediment loads to streams and lakes have obvious deleterious effects on fish.

Nutrients

Riparian areas are both sources and storage sites of nutrients needed by aquatic and terrestrial ecosystems. These areas transform important nutrients, such as nitrogen, into forms used by both terrestrial and aquatic organisms. Riparian vegetation regulates the timing of nutrient input into lakes and streams. For example, when nutrients are lost from a hillslope after clearcutting, an intact riparian zone can intercept, store, and eventually release them, thereby preventing or delaying loss of these essential compounds.

Figure 6. Movement of dissolved nutrients through soil into the subrooting zone and subsequent routing downslope through the rooting zone of the riparian area.

In addition to regulating this lateral uptake of nutrients, riparian areas are important filters along a river drainage (Fig. 6). Complex channel structure, particularly in the vicinity of debris dams, reduces water velocity and increases the time available for nutrients to be used by aquatic and nearby terrestrial plants. The off-channel habitats provided by broad floodplains retain nutrients more effectively than the main channel.

FISH RESOURCES

Intact riparian areas provide fish with good water quality, food, and necessary habitats for all stages of their life cycles. The WNF contains significant populations of approximately thirty species of fish, including anadromous, resident, native, and introduced species. The native anadromous fish include spring chinook and winter steelhead. Native resident fish species found on the Forest include rainbow, cutthroat, and bull trout, and non-game species such as chiselmouth, redside shiner, several sculpins, and the Oregon chub. The Oregon chub may be proposed for listing as a threatened or endangered species under the Federal Endangered Species Act. Some stocks are found only in the WNF, such as the McKenzie redside rainbow and the Hackleman Creek cutthroat trout. Also, several species have been introduced over the years to provide a sport fishery, including kokanee (a landlocked sockeye salmon), brown trout, brook trout, crappie, bass and brown bullhead. These introduced species generally are limited to reservoirs and lakes.

Habitat

Fish require adequate habitat at all stages of their life cycle. For reproduction, all salmonids need areas with continuous water flow and gravel substrates. The fertilized eggs incubate within redds (nests) excavated in these spawning gravels. At this stage of the life cycle, fish embryos are vulnerable to suffocation by deposition of fine sediments. Accumulations of silt also may block the emergence of young fish out of the redds.

Edges of stream channels are particularly important habitats because stream energy decreases in the shallow, low velocity margins (Fig. 7). Young fish are found almost exclusively in stream margins, backwaters, and side channels, particularly those with protective cover. These lateral habitats contain much higher amounts of algae and dead organic matter than main channel habitats. As a result, aquatic insects are approximately six times more numerous than in main channels. As flood waters rise, these areas also provide cover and low velocity refuge for adult and juvenile fish. The braided channels common in broad floodplains increase this edge habitat.

In streams, adult fish are most frequently found in pools. Pool habitats are both a refuge from stream flow and a source of easily captured food from drifting invertebrates. However, in order to be effective fish habitat, pools must also have cover for refuge from both predators and floods.

Large woody debris creates pools, stores sediment and organic matter to control water quality, traps spawning gravels, and provides fish with cover in both lakes and streams. Different size classes of wood play different roles in stream ecosystems. Very

Figure 7. Backwater and edge habitat created by wood and boulders along stream margins.

large logs are key stabilizers in lateral accumulations and debris jams. Intermediate sizes may serve the same function in smaller channels, but in larger streams they form the interlocking structure of debris accumulations. Smaller pieces of wood, such as branches, twigs, and broken pieces, create "sticky wickets" that trap leaves and sediments.

Riparian areas around lakes also provide critical fish habitat. Trees that fall into lakes supply cover for fish in shallow shoreline areas and serve as habitat and food for aquatic invertebrates. Lake tributaries and shoreline habitats are used for spawning and rearing of juveniles. Delivery of sediment or changes in water temperature around these areas can affect lake fish populations significantly.

Food

Riparian area vegetation exerts a strong influence on the amounts and types of food available to invertebrates and thus to fish. Most fish in streams and lakes of the WNF are predators, depending on aquatic insects and other invertebrates for their food. In small, shaded streams, this invertebrate community is dependent on riparian leaf and needle inputs for its food base. Conifer needles are low in food quality but are abundant and enter the stream year round. Deciduous leaves, on the other hand, are higher in food quality but enter the stream only during a short period in autumn. The combination of the two leaf litter types provides a stable, diverse food base for aquatic invertebrates (Fig. 8). In larger open-canopy streams and lakes, aquatic invertebrates also feed on algae growing in the stream, which is much less abundant than terrestrial litter but is a more nutritious food. Along lakes, the vegetation near the shoreline, whether from tree leaves or grasses, provides an important food base.

Figure 8. Aquatic insects, such as this caddisfly larva, are common food items for fish in streams of the Willamette National Forest.

Maintaining this food base in streams requires the presence of wood. Without the complex filters created by debris accumulations, leaves entering the stream quickly move out of the system before being eaten by insects. The wood itself also supplies a low-quality but long lasting source of organic matter.

WILDLIFE RESOURCES

The abundant and diverse plant communities of riparian areas provide stable and complex habitats needed for wildlife in the WNF. Of the wildlife species found on the Forest, approximately 90% use riparian areas associated with streams, lakes and wetlands for some portion of their life history; 10% are found exclusively in riparian areas (see Appendix I).

Habitat

Riparian areas provide habitat for thermal cover, foraging, hiding, resting, breeding, and rearing. Species such as dippers, kingfishers, beavers, river otters, muskrats, Pacific giant salamanders, and water shrews depend primarily on riparian areas to fulfill all of their habitat requirements.

Figure 9. Elk feeding in grass and herb communities found along streams and rivers.

Riparian vegetation buffers temperature and humidity extremes, thereby creating favorable microclimates. In summer, riparian areas are cooler and more humid than uplands. In winter, riparian areas are less exposed to wind than ridges and upper slopes, and snow depths are less. Consequently, species from elk to salamanders find thermal refuges in riparian areas (Fig 9).

The dense vegetation, complexity of landforms, and presence of water combine to provide hiding and resting cover. Small mammals and birds use the dense thickets along streams and lakes as refuges from predators. Waterfowl require riparian vegetation for resting places and for protection during severe weather. Small mammals such as water shrews and voles depend on the cover and increased habitat heterogeneity provided by large downed timber in riparian areas. Wetlands provide specific habitat for small amphibians.

Riparian areas are important fawning areas for big game mammals, denning habitats for small mammals, and nesting sites for many species of songbirds. Ospreys and bald eagles build their nests in tree snags along lakes and large rivers. Cavity-dwelling birds, which nest in standing dead trees, are a significant component of riparian wildlife communities. Waterfowl use lake margins and wetlands as nesting sites, and species such as harlequin ducks and mergansers nest along steep mountain streams.

Riparian areas are continuous corridors across the landscape, providing natural migration routes for many species, such as ruffed grouse, bats, and beaver. Big-game species, such as elk and deer, use riparian areas as they migrate between summer and winter habitats.

Figure 10. Riparian areas are essential habitats for fish-eating birds, such as the kingfisher.

Food

The same complexity and diversity of vegetation and landform also provides rich sources of many types of food. Herbivores encounter a wide array of herbaceous, shrubby, and woody plants in riparian areas. Species as diverse as deer, snakes, beavers, bats, woodpeckers, herons and cougar all depend on the riparian area for food. The emerging adult aquatic insects from streams, lakes, and wetlands are predictable food sources for insectivorous amphibians, birds, and mammals. Some species, such as kingfishers, dippers, otters, and salamanders, are totally dependent on aquatic organisms as a source of food (fig. 10). Riparian areas also are critical sources of drinking water for most wildlife species.

TERRESTRIAL VEGETATION

Riparian areas are critical contributors to plant diversity in forest ecosystems of the WNF. Much of this diversity stems from the complex array of gravel bars, islands, and floodplains present in the riparian area. These topographic features vary in disturbance frequency, substrate composition, soil moisture content, nutrient regime, depth to water table, and distance from water. Different successional stages of plant communities occur in a mosaic of patches in the riparian area (Fig. 11). Because of this patchiness, the number of plant species in riparian forests is twice that of hillslope forests. Recent studies in the WNF have found a range of 19-32 plant species in upslope communities. In contrast, adjacent riparian areas had 51-107 species. Wetlands, such as bogs, seeps or marshes, often contain unique associations of plants, and may harbor rare species.

Figure 11. Stream channels and floodplains contain complex mixtures of herbaceous, deciduous, and coniferous plant communities.

Figure 12. Horizontal and vertical diversity created by the normal sequence of plant communities extending from the active channel to the lower hillslopes.

These diverse plant communities associated with numerous channel and floodplain surfaces along a river valley increase horizontal complexity. Downed logs and other woody debris, which originate from the riparian and hillslope stands, also contribute to horizontal structural complexity. The numerous patches of herbs, shrubs, deciduous and coniferous trees, and standing dead snags also create a multilayered canopy, leading to high vertical diversity (Fig. 12). In addition, openings over streams, lakes, and wetlands provide distinct gaps or natural breaks in the forest canopy (Fig. 13). The complexity of riparian plant communities is mirrored in the high numbers of animal species, both aquatic and terrestrial, dependent on the riparian area.

During catastrophic wildfires, riparian plant communities may have a higher survival rate than nearby hillslope areas. The higher humidities and damper soils adjacent to lakes and streams may help protect plants in these areas, particularly the larger conifers. As a consequence, stringers of old, large trees may be found even in previously burned riparian areas. Riparian forests may play critical roles in recolonizing upland forest communities.

TIMBER

Riparian areas are often considered the most productive areas for timber within a watershed. Although some of the largest individual trees are found here, much of the riparian area includes unsuitable or damage-prone growing sites for commercially valuable tree species. Riparian soils are poorly developed assortments of stream sediments, flood

Figure 13. Opening in the forest canopy created by the stream channel.

deposits, and decaying riparian litter. Rooting zones are frequently inundated by elevated water tables. During floods, streamside trees are battered, and young trees are frequently uprooted or buried. Undercut and oversteepened streambanks often increase the rate of mortality of streamside trees.

Recent research in the WNF indicates that riparian management zones contain timber volumes less than 75% of those found in mature upslope forests (Table 2). Riparian areas contain potential timber resources, but the ecological values of riparian trees for riparian-dependent resources must be considered before their commercial timber value.

Table 2. Examples of timber volumes in riparian areas and hillslopes within the Willamette National Forest.

SITE	BASIN	TOTAL BASAL AREA (ft ² /ac)		UPSLOPE	STOCKING RATIO RIPARIAN/HILLSLOPE
		RIPARIAN			
Mack	McKenzie	260	346		75%
French Pete	McKenzie	217	305		71%

RECREATION

Recreational use is concentrated in riparian areas, where scenic values are high. Up to 80% of the WNF's dispersed recreation occurs in the riparian area. A wide range of recreational activities depends on healthy riparian areas, including picnicking, hunting and fishing, wildlife viewing, and white-water boating (Fig. 14). Almost all campgrounds in the WNF are located within riparian areas, and most remote campsites in wilderness and general forest are also located along streams and lakes.

Conflicts between recreation and ecological values of riparian areas are inevitable because of high use. For example, roads have been constructed along streams, rivers, and lakes in many drainages of the WNF. Although these roads provide public access to many miles of riparian areas, they impair other riparian resource values, such as fish and wildlife habitat within floodplains.

Boating use on large streams, rivers, lakes, and reservoirs is another common conflict between recreation and other riparian resources. Woody debris jams and floating logs are hazards for rafts, kayaks, and motorized boats, but this debris is ecologically essential. Compromises between safety and ecological value are inevitable, particularly in Wild and Scenic Rivers.

Figure 14. Recreational use of riparian resources.

SUMMARY

Intact, mature riparian areas serve a major role in the maintenance of numerous forest-wide resources. Riparian areas also draw more people for recreation than any other area in the WNF. Their protection and rehabilitation are essential for the continuation of these resource values. Moreover, continuous corridors of intact riparian areas must be maintained throughout the WNF; they cannot exist as isolated fragments and still perform their diverse functions. Managers must carefully consider riparian management throughout drainage basins and over the forest landscape. Riparian areas provide the critical links among an array of different forest-wide resource values.

CHAPTER 3 LANDSCAPE MANAGEMENT

The primary goal of riparian management is to provide self-sustaining streamside forests that will ensure the desired conditions of riparian resources for the future. Effective riparian management takes advantage of the natural ability of terrestrial and aquatic ecosystems to sustain their structure and function. Land use practices that maintain the natural patterns and dynamics of riparian communities across the Willamette National Forest can minimize long-term degradation of riparian resources.

Continuous corridors of riparian forests also provide essential connections between different management areas distributed throughout the WNF (Fig. 15). For example, the array of interior old-growth forests can be continuously linked along the mature to old-growth forests within riparian management zones. These riparian zones can also serve as corridors for the dispersal of plants and animals between harvested watersheds, roadless areas, wilderness areas, special habitat management areas, and designated recreational lands. No other landscape feature within the National Forest offers the natural continuity of riparian areas.

Figure 15. Patterns of river valleys dissecting forested landscapes in the WNF. Notice the continuity from ridgelines to lower valleys along the stream network.

The landscape of the WNF encompasses six major river drainages that flow into the Willamette River (Table 3 and Fig. 16):

- North Santiam River
- Middle Santiam River
- South Santiam River
- McKenzie River
- North Fork of the Middle Fork of the Willamette River
- Middle Fork of the Willamette River

Table 3. Miles of stream classes contained in the drainages within each of the WNF Districts.

District	Basin Name	I	II	III	Total
Detroit	Little North Santiam	9.7	20.2	29.9	59.8
	Breitenbush	17.6	47.5	39.6	104.7
	North Santiam	41.4	103.8	127.7	272.9
Sweet Home	Quartzville Cr.	9.7	22.0	21.1	52.8
	Middle Santiam	20.2	47.5	54.6	122.3
	South Santiam/Canyon	19.8	44.9	46.6	111.3
	Calapooia/Wiley Cr.	2.6	6.2	7.0	15.8
Blue River	Blue River	22.0	59.9	44.0	125.9
	South Fork McKenzie	29.9	66.0	75.7	171.6
	Lower McKenzie Tribs	2.2	9.7	7.0	18.9
	Quartz Cr.	2.2	5.3	11.4	18.9
McKenzie	McKenzie	40.9	9.7	19.3	69.9
	Horse Cr.	18.5	8.8	13.2	40.5
Lowell	Fall Cr.	37.0	76.6	96.8	210.4
	Winberry Cr.	6.6	25.5	19.4	51.5
	Middle Fork Willamette Tribs	10.1	56.3	46.6	113.0
Oakridge	N. Fork Middle Fork Willamette	47.5	88.8	126.8	263.1
	Salmon Cr.	28.2	50.2	102.1	182.2
	Salt Cr.	26.4	37.8	67.7	132.0
Rigdon	Hills Cr.	6.2	25.5	51.0	85.4
	Middle Fork Willamette	27.3	128.4	242.0	439.1
Total		426.0	940.6	1249.5	2662.0

Figure 16. Watersheds and major stream drainages of the Willamette National Forest.

Each river drainage can be divided into smaller sub-drainages or basins, based on topography, geology, and channel characteristics. A basin represents collections of smaller watersheds, ranging from 20 acres to more than 5,000 acres, that collectively serve as the source for a major perennial stream. A specific harvest unit normally occupies only a portion of a particular watershed.

Effective land management maintains the ecological linkages of riparian resources throughout the forest landscape. Simply focusing on individual harvest units or small watersheds may jeopardize the continuity of riparian corridors and the long-term integrity of riparian resources. Management of forest landscapes must identify and retain the natural patterns of riparian resources at scales ranging from specific harvest sites to multiple river drainages. Influences of forest management on riparian resources also spans time scales ranging from immediate post-harvest effects to long-term changes in valley floor forests and geomorphology over centuries.

LANDSCAPE PATTERNS

Corridors of streamside forests are prominent features of the mountainous landscapes of the Pacific Northwest, forming continuous bands of alternating broad floodplain valleys and narrow canyons (Fig. 17). The patterns of riparian resources along the river valleys are created over several centuries by succession of riparian forests and the development of river channels during major floods. Numerous small streams from the steep headwaters supply cold water, sediments, nutrients, and biote to the lower rivers. Floods and landslides reshape channels and create mosaics of streamside forests.

Figure 17. Riparian corridors in the Willamette National Forest connect the sequences of different valley floor landforms and associated streamside forests.

As forest landscapes are changed by land use practices, catastrophic disturbances, or climate change, riparian areas serve as natural routes for the routing of water and sediment and the dispersal of plants and animals. Transport of water, suspended matter, and organisms from headwaters to lowlands is a conspicuous function of streams and rivers. Upstream transport and dispersal also occurs, either through active movement of organisms or passive transport of propagules and material. The rich pool of plant and animal species and moderate microclimate enhance the role of riparian areas in dispersal across the landscape. This ecological function is even more critical when fire, winds, or other disturbances alter upslope forests more than those associated with streamside.

Patterns of riparian areas in forest landscapes are apparent to resource specialists and nonprofessional observers alike. Intricate networks of streama and rivers link even the highest and most remote areas of the forest to the lowlands (Fig. 18). In addition, the unique topography and environment of river valleys alter patterns of terrestrial disturbances such as wildfire and insect outbreaks. No other landscape feature rivals the importance of riparian forests in linking forest resources and the multitude of land use designations across the WNF (see Tables 4a and 4b). Riparian management zones contribute essential elements of continuity for policies to minimize fragmentation of the forest.

Figure 18. Patchwork of timber harvest units of different ages connected by riparian corridors within a river drainage

Table 4a. Corridor types used to maintain connectivity within. Note that types V, VI, and VII are riparian areas.

Corridor Type	Width	Management Areas
I	Variable: 1 mile +	Most no-harvest areas
II	1/2 - 1 mile	Middleground visual
III	1/4 - 1/2 mile	Foreground visual, Wild & Scenic Rivers
IV	100 - 800 feet	Trails
V	400 feet	Class I Riparian
VI	200 feet	Class II Riparian
VII	175 feet	Class III Riparian
VIII	Variable: 50 - 500 + feet	Unsuitable Lands

Table 4b. Forest functions dependent on corridor connectivity.

Corridor/Access Needs	Corridor Type							
	I	II	III	IV	V	VI	VII	VIII
Motorized Access:								
Non-destination & Developed		X	X					
Non-Motorized Access:								
Dispersed & Wilderness	X			X	X	X	X	X
Big Game:								
Optimal Cover	X	X	X	X	X	X	X	X
Travel & Forage	X	X	X	X	X	X	X	X
Mobile Interior Stand Species:								
Dispersal & Forage	X	X	X	X	X	X	X	X
Breeding	X	P/M	P/M		P/M	P		
Immobile Interior Stand Species:								
Animals & Plants	X	X	X	?	X	X	X	X
Water Dependent Species								
Animals & Plants				X	X	X		

* Mobile interior species are Spotted Owls, Pileated Woodpecker (P) & Pine Martin (M).

LONG-TERM CHANGES IN FORESTS

Consideration of broader spatial scales in landscape management also requires broader temporal scales over which processes such as forest succession and channel development operate. From the perspective of human lifetimes or forest rotations, we often think of 10-100 years as "long-term". However, the ages of natural coniferous forest of the Pacific Northwest commonly exceed periods of 300-600 years. Over that interval of time, streamside forests will change successively from young stands of shrubs and deciduous trees to stands dominated by young conifers. After more than a century, stands of mature conifers will begin to develop characteristics of old-growth forests as mortality creates gaps. Even the 60- to 100-year rotations of current forest management only cover a fraction of the natural age of typical forest stands in the WNF.

Geomorphic processes operating over the last several thousand years have shaped the landforms of river valleys in the WNF. Rare flood events that occur at intervals of several decades to centuries are largely responsible for creating the channels of streams and rivers. Floods in the Willamette National Forest since 1964 have been relatively minor. During that same 25-year period, approximately 226,000 acres of the Forest has been clear-cut, and the most recent timber harvests have occurred in the steeper headwaters. Within the next rotation, it is probable that the WNF will experience floods far larger than those of recent decades. Riparian forest conditions along streams and on floodplains during such rare flood events will determine the stability of stream channels and riparian communities.

Over the last century, forests of the WNF have been exposed to gradual changes in CO₂, atmospheric pollutants, point-source and non-point-source discharges into streams, and possible climate change. Timing of these events has ranged from acute, immediate impacts to barely perceptible change. The future integrity of the forest and stream ecosystems depends heavily on our ability to recognize and respond to environmental change. Monitoring programs are essential for detecting shifts in the status of forest and streams. Management of riparian resources across the forest must maintain intact functional ecosystems with sufficient continuity for the dispersal of organisms and resources.

MARGINS FOR UNCERTAINTY

All land management entails a certain degree of uncertainty, and is likely to change its focus or practices over time. Consequently, some margin for risk for future planning must be included in riparian management policies. Certain ecological values can be provided by intensive site management, but margins for error are narrow and management costs are high. Maintaining continuous riparian areas and floodplains dominated by mature and old-growth forests provides options for future management.

Region 6 of the U.S. Forest Service is currently reviewing current management practices in terms of minimizing fragmentation of forests. Riparian areas are the major landscape component providing continuity among intact core areas throughout the forest. A no-harvest riparian management policy over much of the forest is a fundamental component of forest-wide policies to minimize forest fragmentation.

The U.S. Forest Service has identified the unique ecological importance of riparian resources and floodplains and has established national policies to guarantee their integrity. Throughout the United States, forest policy states that riparian-dependent resources receive first priority in forest management along streams, lakes, and wetlands. Removal of riparian

vegetation for timber harvest must be justified, both ecologically and administratively. Given the high value of riparian resources on the Willamette National Forest and the associated administrative and economic benefits, a no-harvest riparian management policy provides accurate planning, increases effective land management, and maintains a diverse array of options for future forest management. Management of riparian resources at a landscape level not only insures effective management of water quality, aquatic resources, and wildlife resources but also provides essential elements for integrated management of traditional forest resources.

CONCLUSIONS

Over the long time frames of geomorphic processes and forest succession, issues of forest fragmentation, catastrophic disturbances, and cumulative effects are no longer hypothetical questions. These environmental changes are inevitable consequences of patterns imposed on the landscape and occurrence of infrequent but highly probable events. The major questions facing land managers are not whether these processes will occur but rather what the rate and magnitude of change will be.

An ability to develop a broader landscape context for site-specific forest practices will shape the future riparian forests. Continuity of intact riparian forests should be maintained throughout drainages. Entire floodplains must be managed to function during the large flood events that occur several times (50-100-year intervals) throughout a forest rotation (Fig. 19). Managers must understand the processes of regeneration, growth, and mortality that determine the unique stand dynamics of riparian forests. These challenges require new and broader perspectives of our forests and streams but across the landscape of the Forest.

Figure 19. Aftermath of the 1964 flood in the Willamette National Forest.

CHAPTER 4 BASIN MANAGEMENT

BASIN STRUCTURE AND FUNCTION

Basins are made up of smaller watersheds linked by riparian corridors. Through the continuity of riparian areas and streams, processes in both upper hillslopes and headwater areas influence downstream regions. Floods sculpt existing channels and deposit sediments on floodplains. These floods alter development of riparian plant communities and provide fresh surfaces for plant colonization.

Geomorphic processes determine the shape and size of stream valleys and consequently the structure of riparian areas. Adjacent hillslopes may locally restrict river valleys, but broad valleys may allow development of extensive floodplains in other areas. Within a basin, local landforms greatly alter the hydraulics, channel morphology, and floodplains in successive downstream reaches.

Stream channels and valley floors may be constrained by geomorphic features such as bedrock, hillslopes, earthflows, or alluvial fans (Fig. 20). Such streams and valleys will

Figure 20. Stream channels in constrained and unconstrained valleys. Note the more complex channels in the valley with the broad floodplain. S - stream; FP - floodplain; HS - hillslope; VF - valley floor.

be "pinched" and relatively straight, with few secondary channels, backwaters, or lateral complexity. The narrow valley floor also means the riparian area will be relatively narrow and simple. Riparian plant communities may be similar in species composition to the adjacent hillslope communities. During floods, stream flows are confined in the narrow valley; consequently, the erosive energy of the stream increases rapidly with increasing discharge. Such areas provide less habitat for fish and wildlife.

Valley floor areas not confined by geomorphic features are termed unconstrained (Fig. 20). These portions of a watershed have broad floodplains upon which streams can meander, often forming a complex network of secondary, intermittent, and ephemeral channels. Riparian vegetation is characterized by mixed patches of herb, shrub, hardwood, and conifer communities, distinctly different from adjacent hillslope vegetation. At high flows, the stream may spread across the broad valley floor, dissipating much of the water's energy. These broad floodplains offer complex and stable habitats for fish and wildlife.

Although they may be locally controlled by geomorphology, streams also modify the landscape. They alter valley form by erosion and sediment deposition, creating terraces and floodplain surfaces of varying heights and ages. Within the stream channel, floods create or destroy islands and gravel bars, and redistribute boulders and woody debris.

Basin perspectives are essential for developing management objectives for both flowing and standing waters within the WNF. Lakes and wetlands frequently are viewed as isolated bodies of water. However, they receive their water supplies from the surrounding forests; thus land use practices in upslope forests within a basin may greatly affect these aquatic systems. Even seemingly isolated wetlands and lakes within a basin are connected to one another and to streams and rivers through groundwater.

The River Continuum Concept

The structure of aquatic communities and rates of ecological processes in streams and rivers change from small headwater streams to downstream rivers. These longitudinal patterns reflect changes in both the geomorphic processes that create stream channels and floodplains and the interactions of streams with the adjacent terrestrial ecosystems. Linkages between the structure and function of stream ecosystems and the physical processes and environment of streams is the basis for a major conceptual framework in stream ecology known as the River Continuum Concept (Vannote et al. 1980). The McKenzie River in the WNF was one of the four major sites where the River Continuum Concept was developed. Patterns of aquatic communities in the McKenzie River drainage will be used to illustrate the River Continuum Concept (Fig. 21).

Small Streams

In small headwater streams (typically Class II, III, or IV; first to third order), the food base is composed primarily of leaves, needles, wood, and insects from the adjacent forest. The small stream channel is almost completely enclosed by the forest canopy. As a result, little sunlight reaches the stream and aquatic plant production is low. The input of terrestrial litter provides the bulk of the food base for the stream communities.

Aquatic invertebrate communities are composed primarily of shredders, which are organisms that feed by tearing large particles apart. Most shredders in these streams are feeding on the detritus, or dead organic matters, derived from the forest. Invertebrate predators make up approximately 25% of the invertebrate communities, a proportion that

remains fairly constant from small stream to large river. Fish communities in these small streams are sparse, and are usually composed of cutthroat trout and sculpin.

Intermediate Streams

In streams of intermediate size (typically Class I or II; fourth to sixth order), the wider stream channels create natural openings in the forest canopy, reducing the canopy over the stream and allowing more sunlight to reach the water surface. Production of algae and other aquatic plants increases with greater light intensities; while the relative contribution of forest litter decreases because inputs are restricted largely to stream margins.

Aquatic invertebrate communities are composed of both scrapers and shredders, reflecting the shift in the food base. Scrapers are invertebrates which obtain their food by scraping the surface of rocks and other substrates. In these streams, microscopic plants or algae create a film over every wetted surface, and the scrapers feed primarily on this food resource. Shredders are still found, but they make up a smaller proportion of the total. Fish communities become more diverse, commonly including several species of trout, sculpins, minnow, suckers, and occasionally anadromous salmon.

Figure 21. Changes in aquatic communities from small streams to large rivers in the McKenzie River drainage, illustrating the River Continuum Concept. CPOM and FPOM are coarse (> 0.04 inches) and fine (< 0.04 inches) particulate organic matter.

Large Rivers

In the larger rivers (Class I; seventh order and greater), the food base largely reflects instream plant production, organic matter from upstream reaches, and organic material from adjacent floodplains. These lower river channels may be extremely wide, and the forest canopy is restricted to a relatively narrow fringe along the edge. In clear, shallow rivers, such as the upper McKenzie or Santiam Rivers, aquatic plant production on the river bottom can still provide the majority of the food base. In deeper, lowland rivers, such as the Willamette River, phytoplankton or suspended algae are a major component of the aquatic plant production. In both cases, the delivery of organic matter from upstream reaches is a significant component of the food supply. Often this organic matter is made up of small particles that have been broken or eaten by organisms in upstream areas.

At first glance, one might assume that the interaction of the forest with the stream was diminished in larger rivers because of the wider channels and limited riparian fringe, but this is not the case. Development of extensive floodplains in large rivers creates a new facet in the interaction of forests and streams. During most of the year, floodplain forests produce tremendous quantities of organic matter that are stored on the surface of the floodplain. During floods, the river captures this organic matter and delivers it to the main channel. In addition, the flushing of dissolved material from the floodplain soils contributes a rich supply of dissolved nutrients for aquatic communities. In many rivers, production of fisheries and other aquatic communities increase after major floods, a phenomenon known as the flood pulse concept (Junk et al. 1989). Thus, floodplains along streams and rivers increase the interactions of the stream with the adjacent forests, creating important ecological linkages between land and water throughout a river drainage.

Invertebrate communities in large rivers are dominated by collectors, a functional feeding group of aquatic organisms that obtain their food by collecting small particles. Collectors may obtain their food in this flowing environment either by gathring or filtering. Gatherers sweep up the fine particles by brush-like appendages. Filterers attach nets to the bottom that filter particles from the water. Other filterers have comb-like appendages that filter particles from the water around them. Scrapers still make up an important component of invertebrate communities, but shredders are a small portion of the assemblage. Fish communities in lower rivers contain many more species of trout, salmon, whitefish, sculpins, minnows, suckers, and lampreys. Many species found in the smaller streams are not present or become rare, and several species that are found only in larger rivers are added to the community.

This natural progression of communities and ecological processes in streams is based on interactions with adjacent forests and physical processes that shape stream channels. Land use practices potentially change both of these factors and subsequently may alter the natural pattern of stream ecosystems along a stream course. Recognition of the intricate linkages between forest and stream and between headwaters to downstream rivers is essential for effective management of aquatic resources within river drainages in forested landscapes.

Cumulative Effects

Processes in headwater areas influence downstream regions through the riparian network. Consequently, poor management practices in small, headwater harvest units are transmitted and amplified throughout a basin in the form of altered streamflow, water quality, and sediment transport. Small, individual activities can have significant, additive impacts or cumulative effects when combined on a basin level.

An example of terrestrial processes resulting in cumulative impacts is the change in runoff patterns and streamflows after harvest. Practices such as felling, yarding, roading, and slash burning occur on relatively small units. These activities lead to changes in site processes, such as increases in snow accumulation, snow melt rate, surface erosion, and landsliding. During a single large flood event, these individual alterations collectively may lead to substantial increases in streamflow and erosion rates downstream.

Within streams, cumulative impacts may result from forest practices such as the successive salvage or other removal of woody debris from stream channels and banks during harvest. Removing this woody structure will eventually destabilize stream channels, often resulting in localized downcutting of the streambed. During storms and floods, increased sediment loads from small channels will be routed into larger streams and deposited lower in the basin.

These processes emphasize the strong linkages between terrestrial and aquatic systems, between hillslopes and valley floors, and between upper and lower portions of a drainage network. This connectivity has important implications for management practices. Changes in one part of the basin may strongly affect other areas. Hillslope conditions are especially important to riparian areas. Poor harvest practices may cause catastrophic inputs of large amounts of sediment and debris from the hillsides to the stream channel. Roads and clearcuts may increase surface runoff and peak discharges, which, in turn, significantly affect channel and valley floor morphology, riparian area vegetation, and fish and wildlife survival. Other types of basin cumulative effects include changes in water temperature, stream chemistry, and visual quality of scenic corridors.

Basin Planning

Land use planning in the Willamette National Forest operates at two scales: broad project areas that may encompass several thousand acres and individual harvest units within a project area. Ideally, the project area should be a drainage basin, and all aspects of planning, including riparian areas, should begin at the basin scale.

Planning for riparian management is part of a broader planning process that includes an analysis of all forest resources within a basin or collection of smaller watersheds. This scoping phase, which must meet the requirements of the National Environmental Policy Act, includes the following sequence of tasks:

- Form an interdisciplinary planning team of experts in the necessary technical fields. The team considers both riparian and hillslope areas.

- Document basin management objectives as a basis for developing specific harvest unit prescriptions.

- Identify basin management objectives of all federal, state, and local resource management agencies.

- Assemble preliminary resource information based on inventories.

- Identify issues and opportunities within specific drainage basins.

- Identify riparian management objectives for the basin.

If additional information is necessary, inventory riparian resources within the project area.

Develop alternative strategies for meeting project objectives.

Identify a preferred alternative through discussions and negotiations.

The scoping phase outlined above examines all forest resources. Riparian objectives related to the basin scale are described below. More specific riparian objectives are provided in Chapter 6 on Harvest Unit Management.

Basin planning in the WNF focuses on four major areas of issues and opportunities: (1) minimizing the potential for cumulative effects; (2) maintaining potential inputs of woody debris; (3) maintaining continuous riparian corridors, with structurally complex plant communities and downed timber throughout the basin; and (4) rehabilitating degraded riparian resources within the basin.

Cumulative Effects

Protection of riparian areas minimizes the potential for deleterious cumulative effects. To minimize or to prevent cumulative impacts in a given basin, the planner must first assess their probability of occurrence before timber harvest. Systematic analyses of cumulative effects are applied at a basin scale. Cumulative effects analysis for each drainage basin includes preliminary information based on basin resource inventories:

- ◆ hydrologic condition
- ◆ mass movement potential
- ◆ history of mass movement
- ◆ location and condition of roads
- ◆ present riparian condition
- ◆ degree of riparian continuity

Potential impacts of future activity within the WNF and downstream from the forest boundary should then be estimated. Secondly, objectives for minimizing cumulative effects are developed. Finally, basin management practices are prescribed.

Large Woody Debris

Basin management in the WNF is designed to maintain future sources of woody debris in riparian areas of wetlands, lakes, and perennial streams. This objective may be achieved if riparian areas are excluded from programmed harvest. Where debris has been removed or lost, rehabilitation projects can attempt to replace woody debris over the short-term. Mature riparian forests must become reestablished to provide sizes and amounts of woody debris characteristic of undisturbed forests. Riparian areas in the WNF require more than a century to recover the ability to supply woody debris naturally to floodplains, stream channels, and lakes.

Riparian Corridors

Riparian areas must be assessed over entire basins to evaluate their continuity and to identify unique riparian resources. Systematic basin inventories of valley landforms and plant community structure and diversity provide a framework for basin assessment. Geographic information systems (GIS) are appropriate tools for such analysis.

Rehabilitation

Basin planning includes evaluation of riparian areas in previously harvested or damaged areas as well as intact or uncut locations. In heavily damaged watersheds, protection of riparian resources beyond routine management practices may be required to promote riparian recovery. In addition, intensive rehabilitation projects may accelerate the return to desired ecological conditions. *Management of riparian areas for sustained ecological function over the long term is ultimately more cost-effective than short-term gains in convenience or commodity.* To this end, management strategies, both basin-wide and site-specific, must be responsive to current and future riparian conditions.

CHAPTER 5

HARVEST UNIT MANAGEMENT

Site-specific riparian management prescriptions can be developed after basin management objectives for riparian areas have been identified by the planning team. The WNF Standards and Guidelines are designed to ensure many of the ecological functions and characteristics of riparian areas. A single prescription or cookbook approach is not appropriate for riparian management. To achieve the most effective riparian management, current site conditions and desired future conditions should be considered in developing prescriptions for individual harvest units (Fig. 22).

Figure 22. Components involved in Site Analysis for site plan.

MANAGEMENT OBJECTIVES

Site planning must meet the requirements of the National Environmental Policy Act and all Executive Orders directed at riparian resources (EO 11988 and 11990). Riparian management zone guidelines for streams, lakes and wetlands of the WNF are summarized in Table 5a b and c. Stream size and flow regime strongly influence both unit and basin management objectives. Consequently, riparian management of streams is based in part on stream class. Site-specific objectives for management of riparian zones are described in the following sections (Fig. 23).

Figure 23. Components involved in determining Site Objectives for site plan.

Table 5a. Perennial Streams and Rivers: Summary of standards and guidelines for riparian management zones.

Riparian Management Guidelines		Class I		Class II		Class III	
Location	Range of width from active channel ²	150-400 ft	100-200 ft	50-100 ft	75-125 ft	100 ft	100 ft
Objectives							
Extent of 100-yr floodplain within RMZ ⁴	100%	M & E	100%	100%	100%	100%	100%
Temperatures ⁵	100%	100%	100%	90%	75%	90%	M & E
Input of woody debris	100%	100%	100%	100%	100%	100%	100%
Input of terrestrial food resources	100%	100%	100%	100%	100%	100%	100%
Bank stability	100%	100%	100%	100%	100%	100%	100%
Operations							
Overstory vegetation remaining within RMZ	100%	100%	100%	100%	100%	100%	100%
Understory vegetation remaining within RMZ	100%	100%	100%	100%	100%	100%	100%
Directional falling along RMZ	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Yarding suspension over banks	Full	Full	Full	Full	Full	Full	Full
Yarding and line corridors	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stream cleanout ⁶	No	No	No	No	No	No	No
Salvage within RMZ ⁷	No	No	No	No	No	No	No

1 Stability ratings. See Appendix II for soil types and slope stability analysis.
 2 These riparian widths represent the horizontal distances commonly required to meet management objectives.
 3 These widths represent the expected averages and were used in the FORPLAN model for the Forest and Resource Management Plan.
 4 100-yr floodplains are assumed to be less than 400 ft wide on a single bank. Where floodplains extend beyond 400 ft, specific site conditions will be evaluated relative to the Executive Order on Floodplain Development.
 5 Objectives for shade are to maintain or enhance water temperatures. At a minimum, 80% of the existing shade will be maintained.
 6 Stream cleanout is permitted immediately upstream of culverts.
 7 Salvage within an RMZ after catastrophic events should be considered only to restore degraded riparian habitat and benefit riparian-dependent resources. Evaluate specific site conditions.

Table 5b: Intermittent and Ephemeral Streams: Summary of standards and guidelines for riparian management zones

Riparian Management Guidelines		Class IV	
		Intermittent	Ephemeral
		Stable ¹	Stable ¹ & Unstable ¹

Location		Class IV	
Range of width from active channel ²		25-50 ft	25-100 ft
Average width ³		30 ft	50 ft
Objectives		Class IV	
Provide floodplain functions ⁴		No	No
Temperature ⁵		M & E	No
Input of woody debris		0%	0%
Input of terrestrial food resources		None	None
Bank stability		Locally Reduced	Locally Reduced
Operations		Class IV	
Overstory vegetation remaining within RMZ		None	None
Understory vegetation remaining within RMZ		Partial	Partial
Directional falling along RMZ		Yes	No
Yarding suspension over banks		Full-Partial	Partial
Yarding and line corridors		Yes	Yes
Stream cleanout ⁶		No	No
Salvage within RMZ ⁷		No	No

1 Stability ratings. See Appendix II for soil types and slope stability analysis
 2 These riparian widths represent the horizontal distances commonly required to meet management objectives
 3 These widths represent the expected averages and were used in the FORPLAN model for the Forest and Resource Management Plan.
 4 Intermittent and ephemeral channels are assumed to have no floodplains.
 5 Intermittent channels may flow during summer when stream temperatures are critical. Consider retention of vegetation for shade.
 6 Stream cleanout is permitted immediately upstream of culverts.
 7 Salvage within an RMZ after catastrophic events should be considered only to restore degraded riparian habitat and benefit riparian-dependent resources. Evaluate specific site conditions.

Table 5c: Lakes and Wetlands: Summary of standards and guidelines for riparian management zones.

Riparian Management Guidelines		Lakes		Wetlands	
Location		Lakes		Wetlands	
Range of width from mean high water ¹		500-700 ft		150-600 ft	
Average width ²		600 ft		N/A	
Objectives		Lakes		Wetlands	
Extent of 100-yr floodplain within RMZ		100%		100%	
Temperature ³		M & E		M & E	
Input of woody debris		100%		100%	
Input of terrestrial food resources		100%		100%	
Bank stability		100%		100%	
Operations		Lakes		Wetlands	
Overstory vegetation remaining within RMZ		100%		100%	
Understory vegetation remaining within RMZ		100%		100%	
Directional falling along RMZ		Yes		Yes	
Yarding suspension over banks		Full		Full	
Yarding and line corridors		Yes		Yes	
Debris cleanout		No		No	
Salvage within RMZ ⁴		No		No	

1 These riparian widths represent the distances commonly required to meet management objectives.
 2 These widths represent the expected averages and were used in the FORPLAN model for the Forest and Resource Management Plan.
 3 Wetland areas have not been delineated, and average widths were not established.
 4 Objectives for shade are to maintain or enhance water temperatures. At a minimum, 80% of the existing shade will be maintained.
 5 Salvage within an RMZ after catastrophic events should be considered only to restore degraded riparian habitat and benefit riparian-dependent resources. Evaluate specific site conditions.

Evaluation of riparian areas within a site should consider specific objectives for:

- ♦ water quality
- ♦ active channel and floodplain
- ♦ woody debris
- ♦ fish
- ♦ wildlife
- ♦ vegetation
- ♦ recreation

Water Quality

Water quality objectives on the WNF are designed to:

- ♦ minimize increases in water temperature
- ♦ minimize increases in sediment transport
- ♦ prevent decreases in dissolved oxygen concentrations.

In all salmonid fish-producing streams, stream temperature must be maintained at or below 58°F (Oregon DEQ Standards). If the temperature is 58°F or less, a 2°F increase is permissible. At stream temperatures of 58°F or more, no measurable increases are allowed. In non-salmonid fish-producing waters, no increases above 84°F are allowed.

No more than a 10% cumulative increase in natural stream turbidity is allowed (Oregon DEQ Standards). Turbidity in streams fluctuates widely and is closely related to storm patterns, even in unharvested forests. Compliance with this standard is based on annual patterns of turbidity, not simply the immediate post-operation conditions.

Dissolved oxygen concentrations cannot decrease to less than 6 mg O₂/l in salmonid-bearing streams. In addition, the dissolved oxygen concentration shall not be less than 90% of saturation at seasonal low flow or less than 95% of saturation in spawning areas during the spawning, incubation, hatching, and fry stages of salmonid fishes (Oregon DEQ Standards).

To meet these standards on all Class I and II streams, water quality of upstream Class III and IV channels must also be maintained. Particularly during summer low flows, these smaller streams have significant, basin-wide effects on water quality of the larger channels. In addition, areas of subsurface flow (i.e., debris accumulations, floodplains, wetlands, seeps, and springs) provide cool, well-oxygenated water to downstream reaches.

Water quality objectives can usually be met through stringent riparian area protection (Fig. 24). Use of forest chemicals (e.g., herbicides, fertilizers, insecticides, road oils) near riparian areas is discussed under specific WNF Standards and Guidelines.

Figure 24. High quality surface waters with low temperature and sediment load are commonly found in undisturbed streams of the WNF.

Channel and Floodplain

The overall objectives for channels and floodplains are to:

- ♦ maintain channel complexity and stability
- ♦ maintain full floodplain functions
- ♦ minimize risks of cumulative effects

In general, land use practices should minimize changes in geomorphic stability, sediment loading, and storage capacity for sediment and water.

In Class I, II, and III streams, the geomorphic objectives of riparian management are to maintain the physical characteristics of the stream channel and floodplain and to minimize delivery of sediment to the channel. In Class IV streams, geomorphic objectives are designed to protect downstream riparian-dependent resources. Landslides and debris flows are more common in these headwater areas and can strongly impact resources downstream. Management of Class IV streams should: 1) maintain local geomorphic stability, 2) impede downstream movement of debris flows, and 3) provide large woody debris to create stable channel structure in downstream deposits.

Riparian areas around lakes are managed to maintain shoreline integrity. Wetlands, such as seeps or marshes, may have irregular, poorly-defined margins, and riparian management should retain the complexity of these edges.

Active Channels

Management should not change existing geomorphic structure of stream channels. Maintenance of the following characteristics of stream configuration will help ensure long-term stream stability:

- ♦ width and depth
- ♦ stream course
- ♦ channel gradient
- ♦ streambed topography
- ♦ streambed and bank materials
- ♦ large woody debris

Stream channels are dynamic and are re-shaped during major flood events. If geomorphic stability is decreased by timber harvest or other management activities, channels will be more susceptible to erosion and will shift more frequently. Logs and boulders dissipate the erosive energy of the stream and are particularly important in maintaining channel characteristics.

Floodplains

Maintenance of floodplain functions is an extremely important and frequently overlooked component of riparian management. Floodplains are formed by deposits of sediment during extremely high flood events (Fig. 25). Riparian vegetation protects these areas, and removal of this vegetation through harvest or road construction makes them vulnerable to massive erosion during subsequent floods.

Figure 25. Riparian forests of the active channel and floodplain of the McKenzie River.

The riparian management zone should include the entire floodplain. Failure to do so will seriously jeopardize riparian management objectives during major floods. The Forest Service is required by Executive Orders 11988 and 11990 (FSM 2527.03) to:

- "Recognize floodplains and wetlands as specific management areas."
- "Avoid adverse impacts which may be associated with the occupancy and modification of floodplains and with the destruction, loss, or, degradation of wetlands."
- "Not permit floodplain development and new construction in wetlands wherever there is a practicable alternative."

Streams and floodplains extend beyond the upstream and downstream boundaries of individual harvest units. Site evaluation of riparian areas must consider upstream features that could affect the channel and floodplain within a harvest unit, as well as consequences of harvest activities downstream. Local channel stability and storage potential should be maximized if there are upstream areas with high rates of sediment input or water delivery, or if there are particular downstream resources at risk.

Woody Debris

Of all the ecological functions of riparian areas, the process of woody debris loading into channels, lakes, and floodplains requires the longest time for recovery after harvest (Fig. 26). Although young forests begin to deliver woody debris after several decades, large conifer logs cannot be provided by forests less than a century old. Most future riparian functions will be guaranteed if natural abundances and distributions of all sizes of woody debris are maintained in streams, lakes, floodplains, and lower hillslopes.

Figure 26. Years required for ecological recovery of riparian functions after timber harvest.

Figure 27. Proportion of total loading of woody debris from the riparian forest as a function of the distance from stream edge (adapted from McDade et al. 1989).

Figure 28. Massive accumulations of logs are natural features of streams that contribute to the stability of channels and floodplains.

Large woody debris is contributed to the active channel or lake shoreline by adjacent riparian forest (Fig. 27). A recent study of streams in old-growth forests in the Cascades and Coast Range found that 90% of the large wood in the channel originated within 92 feet of the stream margin (McDade et al. 1989). For large woody debris management alone, riparian management zone widths of approximately 100 feet are required to maintain long-term inputs to streams and lakes. Additional consideration of floodplain functions and wildlife habitats may require even wider management zones.

The WNF strives to maintain future sources of woody debris in perennial streams and lakes through a policy of no programmed harvest in riparian management zones (Fig. 28). However, woody debris is also important in small ephemeral and intermittent (Class IV) streams. In these small channels, particularly those in unstable watersheds, woody debris in the channel and on the banks stabilizes the stream and creates new habitat within debris flows when they occur.

Stream Clean-up

Where timber harvest is permitted along streams (e. g., some Class IV's), large amounts of woody debris may accumulate locally. Logging slash has the potential to retard streamflow, reduce dissolved oxygen concentrations, dam culverts and bridges, and initiate landslides and debris flows. At the same time, large pieces of wood add to the physical stability of the channel, and small debris is redistributed and stored by high flows. Appropriate riparian management avoids substantial delivery of wood, and excessive debris loading should not occur.

Normally, the first floods of autumn will redistribute slash within the active channel, where it can play a beneficial role. Removal often causes more erosion than the slash would cause in transport, and frequently damages the stream channel and riparian vegetation. Slash should be removed only in sluggish stream reaches or in cases of extremely large deposits that are judged to create significant risks for aquatic or wildlife resources.

Fish

The primary objective for fish management on the WNF is to maintain the quality of habitat and food supply for all anadromous and resident fish populations at all stages of their life cycles (Table 6). This goal is best accomplished through floodplain, channel, and shoreline protection and maintenance of long-term sources of woody debris to provide:

- ◆ spawning gravels of specific size ranges
- ◆ low rates of sedimentation
- ◆ rearing habitat for young fish (complex side channels, backwaters, shallow edges)
- ◆ cover and food sources for adult fish (pools, debris jams, stable undercut banks)
- ◆ refuge from floods and predators (large woody debris, backwaters, side channels).

Table 6. Miles of anadromous fish habitat on the Willamette National Forest. Inaccessible habitat refers to streams historically available to anadromous fish, but now blocked by dams.

Drainage	Existing (miles)	Inaccessible (miles)
Little North Santiam	6.2	0.0
North Santiam	0.0	35.7
South Santiam	20.5	18.2
McKenzie	56.7	70.1
Fall Creek	35.6	0.0
Middle Fork Willamette	0.0	133.3
TOTAL	119.0	257.3

Good water quality is essential for fish production. Cool temperatures and low suspended sediments are essential for salmonids. Water quality must be protected or enhanced, both in lakes and streams containing fish, (Class I and II) and in smaller tributaries (Class III and IV) to fish-bearing waters.

The numerous lakes and streams in the WNF contain many indigenous races and species of fish (Table 7 and Appendix I). The Oregon chub, a rare and sensitive species, is found in the WNF, while species and races such as bull trout and the Hackleman Creek cutthroat trout have limited numbers or distributions. Bull trout require cold water for spawning (generally less than 50°F), and are particularly sensitive to basin-level cumulative effects on stream temperature (WNF Report 1989). These rare species or races require more protective measures.

Table 7. Length and area of existing habitat for anadromous and resident fish on the WNF.

Drainage Name	Anadromous Fish		Resident Fish		Lakes		Reservoirs	
	Miles	Acres	Miles	Acres	Acres	Acres	Acres	Acres
<u>DETROIT R.D.</u>								
Little North Santiam	6.2	22.8	27.6	75.1				
North Santiam	0.0	0.0	104.0	267.1				3,580
Wilderness streams	0.0	0.0	17.5	45.9				
Breitenbush	0.0	0.0	58.4	184.5				
TOTAL	6.2	22.8	207.5	572.6	964			3,580
<u>SWEET HOME R.D.</u>								
Quartzville Cr.	0.0	0.0	30.0	79.9				
Middle Santiam	0.0	0.0	30.4	107.9				
S. Santiam/Wiley/Calapooia	20.5	73.6	56.1	155.2				
N. Santiam/Lava/McKenzie	0.0	0.0	19.9	41.8				
TOTAL	20.5	145.0	136.4	384.8	80			0
<u>BLUE RIVER R.D.</u>								
Blue River, Gate Cr.	1.5	3.0	45.1	196.8				1,420
S. Fk. McKenzie/Quartz Cr.	6.2	22.3	67.5	184.4				1,280
Wilderness streams	0.0	0.0	23.4	62.8				
TOTAL	7.7	25.3	136.0	444.0	40			2,700
<u>MCKENZIE R.D.</u>								
McKenzie & Horse Cr.	46.8	114.0	87.1	207.6				320
Wilderness Streams	2.2	4.4	18.7	41.6				
TOTAL	49.0	118.4	105.8	249.2	1,945			320
<u>LOWELL R.D.</u>								
Fall Cr.	29.0	103.4	96.8	249.1				
Winberry Cr.	6.6	24.9	26.9	63.6				
Middle Fork Willamette	0.0	0.0	54.5	133.7				1,940
TOTAL	35.6	128.3	178.2	446.1				1,940
<u>OKARIDGE R.D.</u>								
Salt Cr.	0.0	0.0	53.3	115.9				
Salmon Cr.	0.0	0.0	71.7	126.1				
N. Fk. Mid. Fk. Willamette	0.0	0.0	120.3	221.7				
TOTAL	0.0	0.0	245.3	463.7	7,912			
<u>RIGDON R.D.</u>								
Hills Cr.	0.0	0.0	29.1	74.8				300
Middle Fork Willamette	0.0	0.0	122.7	322.3				2,410
TOTAL	0.0	0.0	151.8	397.1	292			2,710
WNF TOTAL	119.0	368.4	1,161.0	2,957	11,233			11,250

Wildlife

A fundamental objective of riparian management is to maintain wildlife species diversity, habitat, and migration and travel corridors. *Riparian management zones established for water quality and fisheries needs may not meet wildlife habitat requirements.* Because our knowledge of wildlife use of riparian areas is limited, riparian management zones should be designed to ensure diverse types and amounts of habitats, such as those found in riparian forests and meadows.

Preservation of the diverse plant community within riparian areas will help ensure survival of a diverse wildlife community. Management activities affecting riparian plant community structure, including dead or downed timber, will have inevitable impacts on wildlife through change or loss of appropriate habitat. Riparian corridor continuity should not be fragmented by harvest on individual sites.

Beaver dams and bank dens create valuable habitats for both fish and wildlife in riparian areas (Fig. 29). If there are indications of local beaver activity (e.g., gnawed stumps, dams, bank dens), riparian management zone boundaries should at least encompass the area of immediate use and provide a buffer from harvest activities.

Figure 29. Beavers are common residents of riparian areas along streams and rivers of the Pacific Northwest.

Specific consideration should be given to:

- ♦ preserving a complex, multi-layered canopy for structural diversity
- ♦ protecting snags and adjoining forest, particularly those used by species such as eagles or ospreys
- ♦ ensuring woody debris cover for small mammals, amphibians and reptiles (Fig. 30)
- ♦ protecting beaver dams and bank dens
- ♦ maintaining dense cover required for nesting and fawning
- ♦ protecting ponds, seeps, and springs, which are often important sources of drinking water
- ♦ protecting lakeshores or streambanks used for nesting areas by waterfowl species (e.g., harlequin ducks, mergansers, water ouzels)
- ♦ preserving riparian continuity throughout basins to ensure contiguous routes for migratory species such as elk.

Figure 30. Woody debris in riparian areas creates critical habitats for amphibians and other wildlife, such as this Pacific giant salamander.

Vegetation

Streamside stands in the WNF contain approximately twice the number of species found in upslope forests. Riparian vegetation plays a critical role in the dynamics of forest plant communities as well as providing numerous ecological functions for other aquatic and terrestrial communities. A major objective of riparian management is to maintain the species diversity, age composition, and structural complexity of riparian forests.

In addition to sustaining the plant species in riparian areas, vegetation management should retain the structural characteristics of the different canopy layers along streams and lakes (Fig. 31). Riparian practices should maintain existing snags and sources of snags for the immediate future. Harvest practices should minimize changes in the riparian microclimate and soil moisture conditions so that recruitment of young plants will not be decreased. Future responses of riparian plant communities, in terms of regeneration, growth, mortality, to current management practices are uncertain. Effects of land use practices on riparian vegetation should be assessed for specific harvest sites and adjacent or downstream areas to provide a basis for designing future forest management policy.

Figure 31. Diversity of plant communities and complex canopy layers found in riparian areas must be retained.

Recreation

Riparian areas are among the most heavily used recreation sites in the WNF (Fig. 32). Present and future recreational opportunities (e.g., hiking, fishing, camping, boating) should not be impaired by management activities. To this end, visual quality, user access, unique features, and future recreational potential should be evaluated for individual harvest units. Influence of management activities on recreational values of adjacent areas should be considered.

Figure 32. Lakes and their surrounding riparian areas are important recreation sites in the Willamette National Forest.

SITE PRACTICES

Site prescriptions should be designed to achieve basin goals and long-term conditions desired for the site (Fig. 33). The major components of riparian management for specific harvest units include:

- ♦ habitat type classification
- ♦ layout
- ♦ vegetation management
- ♦ woody debris management
- ♦ logging systems
- ♦ timing of activities

Figure 33. Components required for Site Prescription in site planning.

Habitat Type Classification

Habitat class for a harvest unit must be determined as the basis for developing the site prescription. Specific riparian management guidelines have been developed for major types of aquatic habitats (Management Area 15): streams, wetlands, and lakes.

Streams and rivers include both perennial and intermittent flowing waters. Four major classes of streams are recognized:

Class I streams

Perennial or intermittent streams that: 1) serve as the direct source of water for domestic use (cities, small communities, recreation sites with more than 25 users); 2) provide habitats for either spawning, rearing, or migration of large numbers of fish; and/or 3) contain sufficient flow to have a major influence on water quality of another Class I stream.

Class II streams

Perennial or intermittent streams with one or both of the following characteristics: 1) provide habitats for either spawning, rearing, or migration for moderate though significant numbers of fish; and/or 2) contain sufficient flow to have a moderate influence on water quality of a downstream Class I or II stream. Game fish are present for at least part of the year or the stream has the potential for establishment or re-establishment of a game fish population.

Class III streams

All other perennial streams that do not meet the criteria for Class I or II streams.

Class IV streams

All other intermittent or ephemeral streams that do not meet the criteria for Class I, II, or III streams.

Shallow wetlands, including ponds, swamps, marshes, bogs, and wet meadows, support a prevalence of vegetation or aquatic life requiring permanently or periodically saturated soil conditions for growth and reproduction (FSM 2527.05) and the adjacent riparian area.

Lakes include major bodies of standing water that are represented on topographic maps of the forest (either USGS quadrangles or National Forest maps). They include both natural lakes and man-made reservoirs.

Correct classification is important because habitat type is a determinant of riparian management zone boundaries. In most cases, the WNF has already determined stream class for major perennial streams. In smaller headwater streams, existing information on the presence of fish or the flow regime may be inadequate. The site must then be reviewed on the ground to determine stream class.

Criteria for identifying aquatic habitats are described in the Riparian Standards and Guidelines (see Appendix III). For a more complete discussion of stream classification, see FSM 2526, R6-Supp 51, and Willamette Supplement. Additional criteria for identifying riverine wetlands are described in Federal Manual for Identifying and Delineating Jurisdictional Wetlands and in Classification of Wetlands and Deepwater Habitats of the United States.

Harvest Unit Layout

Harvest unit layout must maintain riparian continuity within the basin and preserve riparian floodplain functions. In unit layout, a land manager must establish the location of riparian management zone boundaries, roads, and landings.

Riparian Management Zone Boundaries

Delineating the boundaries of the riparian management zone will largely determine the effectiveness of subsequent management in meeting riparian objectives. The following sequence of decisions is required to establish boundaries of riparian management zones:

- ♦ identify floodplain boundaries
- ♦ locate margins of active channels and shorelines
- ♦ establish riparian management zone boundaries
- ♦ modify boundaries to reduce risk of blowdown.

Floodplain Boundaries

The entire floodplain should be included within the riparian management zone (Fig. 34) (Executive Orders 11988 and 11990; FSM 2527.03). The topographic break in slope between hillsides and the relatively flat floor of the river valley defines floodplain boundaries. Several floodplains of increasing heights may occur between the active channel and the hillslope, reflecting surfaces created during past flood events. Floodplain soils and substrates are characterized by rounded edges on gravels, cobbles, or boulders as a result of being tumbled by streams and rivers. In contrast, hillslope substrates are more sharp and angular. Vegetation may change in age or composition at floodplain boundaries; however, many floodplains have forests as old or older than hillslope stands.

Floodplain boundaries (100-year flood recurrence interval) have been identified by the state of Oregon for all major rivers and lakes. Small, deeply incised streams frequently lack floodplains.

Floodplains may not exist along non-riverine wetlands and lakes. In the absence of floodplains, historical high water levels should be considered in these aquatic habitats. These areas may be indicated by evidence of erosion by wave action, reduced plant cover, and sharp transitions in plant community composition.

Figure 34. Layout of a riparian management zone along a stream with complex channel and floodplain

Active Channel and Shoreline Boundaries

After floodplains have been identified, widths of riparian management zones are established along active stream channels. Delineation of the riparian management zone starts at the edge of the active channel or mean high water level, and extends horizontally on both sides.

Active channels consist of all portions of the stream channel carrying water at normal high flows, not just the current wetted channel. This includes side channels and backwaters which may not carry water during summer low flow. All islands and gravel bars are part of the active channel and not part of the riparian management zone.

Active channel boundaries are indicated by abrupt topographic breaks where frequent channel scour has steepened streambanks. Frequently, plant abundance is reduced in this area of active channel modification, and plant communities are dominated by herbs and forbs.

Riparian management zones around wetlands and lakes should be measured from the mean annual high water level. In wetlands, this zone is difficult to identify: breaks in plant community structure and topographic features provide the best means of immediate identification. With most wetlands, case-by-case on-site determinations of high water levels are required. In lakes, mean annual high water level is indicated by evidence of recent wave action and absence of extensive plant cover.

Riparian Management Zone Boundaries

For optimal management of riparian resources, riparian management zones should have variable widths that are delineated at ecological boundaries, not at arbitrary distances from the stream, lake or wetland (Fig. 35). Riparian areas are naturally irregular or asymmetrical in shape, in response to local topography, geology, groundwater, and plant communities. Consideration of topographic irregularities can both protect riparian resources and simplify harvest unit layout. Straight, uniform riparian management zones resembling picket fences should be avoided. Locally within a unit, boundaries may be less than the recommended average width, but they should not be reduced to the point that continuity of riparian areas is lost.

Widths of boundaries described for aquatic habitats delineate the area intended for all riparian management activities. Riparian management boundaries are summarized in Tables 5a, b, and c.

Class I and II Streams

In order to meet riparian objectives, riparian management zones along Class I streams may range in width from 150 to 400 feet horizontally on both sides of the active channel. Widths of riparian management zones along Class II streams range from 100 to 200 feet. In most cases, these distances will encompass the entire 100-year floodplain. On some large Class I streams, a portion of the floodplain may extend beyond the 400 foot riparian management zone. This portion of the floodplain will still be evaluated and managed in accordance with Executive Orders pertaining to floodplains.

Figure 35. A riparian management zone with boundaries of variable widths. Note that the floodplain is entirely contained within the riparian management zone.

Class III Streams

Riparian management zones on Class III streams will vary depending on the soil stability rating (see Appendix II for definitions). Those streams on soils classified as stable will have a riparian management zone ranging from 50 to 100 feet horizontally on both sides of the active channel. Those Class III streams on moderately stable or unstable soils will require a wider management zone, ranging from 75 to 125 feet. These wider boundaries are designed to ensure local channel stability, retard flow of debris, and provide large woody material for habitat after debris flows.

Fish may move into small perennial and intermittent streams during certain seasons for spawning, rearing, or winter refuge. Tributary junctions with Class I or II streams should be closely examined for fish use. These areas of small perennial and intermittent streams that are important seasonally for fish habitat are classified as Class I or II streams and managed accordingly.

Class IV Streams

Delineation of riparian management zone boundaries in Class IV streams depends on the soil stability rating. Wider riparian management zones are required on streams in watersheds with unstable soil types (see Appendix II for SRI stability criteria). The streamside boundary of the riparian management zone should begin at the slope break for Class IV streams. Even where timber harvest is permitted to the stream's edge, boundaries are established for other management activities (e.g., understory vegetation, directional felling, yarding suspension).

In watersheds with *stable* and *moderately stable* soils, riparian management practices are designated for a zone ranging from 25 to 50 feet wide horizontally on both sides of the active channel in both intermittent and ephemeral Class IV streams. In watersheds classified as *unstable*, riparian management zones range from 25 to 100 feet wide horizontally.

Lakes

In order to maintain all riparian functions including recreation, lakes on the WNF have a riparian management zone ranging from 500 to 700 feet horizontally, but generally averaging 600 feet. This distance may be less if an adjacent ridgeline creates a logical topographic boundary.

Wetlands

Small wetlands (e.g., springs, seeps, ponds, bogs, marshes, wet meadows) are unique riparian resources. Because they vary so greatly, sites should be evaluated on an individual basis. Riparian management zones for these areas can range from 150 to 600 feet horizontally, and frequently will vary greatly in width within a given site.

Unique Local Habitats

Unique riparian resources, such as small springs, seeps, osprey nest trees, or sites of active beaver use, frequently exist outside *standard/average* riparian management boundaries. In these instances, managers should consider modifying boundaries to include such areas.

Boundary Modification to Reduce Blowdown

One of the major functions of riparian management zones is to provide a future source of large woody debris through windthrow, insects, and disease. The abrupt break in tree height between riparian management zones and upslope harvest units increases their susceptibility to windthrow. Catastrophic blowdown of the majority of trees within the riparian management zone will result in a more abrupt and pulsed loading of debris than intended. Thorough consideration of factors that contribute to blowdown can reduce the risk of catastrophic blowdown.

In a study of buffer strips in the Willamette, Mt. Hood, and Umpqua National Forests, blowdown ranged from 0% to 78% of the original stand density (Steinblum et al. 1984). The stability of riparian management zones was correlated with seven major variables:

- ♦ distance to uncut forest in wind direction
- ♦ change in elevation from RMZ to ridge
- ♦ distance to major ridge in wind direction
- ♦ stream aspect
- ♦ elevation of RMZ
- ♦ visual estimate of natural stability
- ♦ timber volume and site moisture class

Tree species also differ in their susceptibility to windthrow. In the western Cascades, western red cedar commonly is the most windfirm, followed by western hemlock, Douglas-fir and true firs. This pattern may vary according to geographic location, site history, and local stand conditions.

Steinblums et al. (1984) developed a detailed procedure for analysis of riparian management zone stability. The local topography, vegetation, and stream channel are evaluated on site. Both old windfalls and the pit and mound topography are examined to determine direction of damaging winds and history of blowdown. Indicators of potential natural instability (e.g., landslide tracks, jack-strawed trees, bank cutting, debris dams, swamps) are noted. Trees growing in more open stands present less wind resistance and thus less risk of blowdown; natural windswept tree forms provide greater stability.

Layout of riparian management zones can be modified to reduce risk of catastrophic blowdown. Boundaries of riparian management zones can be positioned closer to natural windbreaks (e.g., mature forests, ridgelines, rock outcrops). Riparian management zones can be blended into upslope patches of mature trees within the harvest unit. Areas of maximum width of riparian management zones can be shifted upstream or downstream to take advantage of shelter created by adjacent streamside forests.

Road Design and Location

Road failures and road-associated landslides contribute more sediment to riparian areas than any other management activity. Road failure has been a major cause of debris torrents in streams of the WNF. Sound construction methods and road locations can significantly reduce potential for long-term cumulative effects. Roads with high use during rainy portions of the year should be constructed and maintained to minimize sedimentation increases. Proper location of roads adjacent to riparian management areas and on hillslopes is a crucial component of effective riparian management.

- ◆ Minimize road construction on floodplains.
- ◆ Locate roads outside the riparian area.
- ◆ Limit stream crossings to areas where no practical alternative is available.
- ◆ Put temporary spur roads to bed be after harvest.
- ◆ Limit use of equipment in the stream channel and riparian areas.
- ◆ Consider additional surface, fill, and drainage stabilization measures for roads that contribute sediment to Class I or II streams.
- ◆ Consider closure or putting existing roads to bed in areas of unstable soils.
- ◆ Construct and maintain all roads and structures to minimize direct or indirect additions of sediment to streams.
- ◆ Sidecast and end haul material should not enter the riparian management zone, except where road entry is intended.

- ◆ Use water bars and other erosion control structures to prevent sediment delivery.
- ◆ Design culverts and other stream crossings to maintain fish passage on fish-bearing streams.
- ◆ Restrict in-stream construction activities to specified flow periods.
- ◆ Schedule dust oil application to minimize direct or indirect delivery into streams, lakes, and wetlands.

Landing Location

Landings should always be located outside riparian areas and beyond a point where sidecast could enter the riparian area. Landing sites should be selected on the basis of the least amount of excavation and erosion potential.

Landings should be located as far from riparian areas as possible if logs are yarded through the management zones. The proportion of a riparian management zone affected by cable corridors for a specific length of stream is reduced as the landing is placed farther from the stream.

Vegetation Management

Timber Harvest

The levels of timber harvest programmed within riparian management zones differ by aquatic habitat type. Programmed timber harvest and other practices in riparian management zones are summarized in Tables 5a, b, and c.

No timber harvest is programmed from riparian management zones along Class I, II and III streams, intermittent Class IV streams in unstable watersheds, lakes, or wetlands (Fig. 36). This policy is designed to ensure that management objectives for riparian-dependent resources will be achieved.

Partial harvest of vegetation (<50% of the stand in the riparian management zone) is permitted on the following stream classes: 1) intermittent Class IV channels in moderately stable watersheds; 2) ephemeral Class IV streams in unstable watersheds. Trees should not be harvested in the immediate vicinity of locally unstable areas, and trees in riparian areas can be partially harvested in downstream reaches (Fig. 37). Trees left within areas of partial harvest should be distributed along the reach in locations that maximize the resistance to debris flows and floods.

Complete harvest of overstory vegetation is permitted in: 1) intermittent Class IV streams in watersheds with stable soils; 2) ephemeral Class IV streams in watersheds with stable or moderately stable soils.

Figure 36. A no-harvest riparian management zone along a Class IV stream in an unstable watershed.

Figure 37. Partial harvest in a riparian management zone along a Class IV stream. Note the occurrence of both individual trees and clumps downstream of the leave area around the unstable site.

Suspension corridors and other recognized created openings (e.g., roads, bridges) are exceptions to programmed harvest policies. In addition, timber may be felled if needed for rehabilitation or enhancement purposes. Such judgements will be made on a case by-case basis.

Salvage

In general, timber should not be salvaged from any riparian area, except where necessary to accomplish riparian objectives. Given the numerous functions and benefits of riparian vegetation and woody debris, there are few reasons to remove salvaged timber from riparian areas. It is generally detrimental to both the site and the basin. Treatment of standing trees, snags, and downed logs in riparian areas should be based on objectives and conditions of the landscape, basin, and site. Woody debris is lost from the active channel and floodplain, risk of sedimentation increases, and stream channels are exposed to direct solar radiation.

In riparian areas, trees damaged or killed by blowdown, fire, disease, or insect outbreaks should be retained to maintain biological diversity and to provide future snags and downed woody debris. Riparian trees may be felled and used on site or removed to another riparian area if local stand conditions are adequate.

Trees that present safety hazards for recreational or commercial users may be felled to eliminate the hazard, but should be left on the ground in the riparian area or in the stream channel. Where logs in rivers present a safety hazard to boaters, site-specific conditions should be evaluated. In most situations, these logs should be moved to a different location in the riparian area to reduce user conflicts and still maintain riparian functions.

Blowdown in Riparian Management Zones

Blowdown is not a management failure and downed trees should not be removed from riparian management zones. The zone was designed for the trees to die and fall into the stream channel, and windthrow is the most common source of natural debris loading. Despite careful planning for the location and configuration of riparian management zones, a large portion of remaining riparian vegetation may blow down on some units. The blowdown event accelerates debris loading faster than anticipated, but it is NOT a disaster from an ecological view, merely a change in timing.

If catastrophic blowdown creates a detrimental situation for riparian-dependent resources (e.g., barriers to anadromous fish migration, obstacles across hiking trails, unplatable conditions), modification of the debris accumulation can be considered for specific cases. Partial debris removal is preferable to complete salvage. Managers should modify debris accumulations as little as possible to achieve the desired conditions.

Shade Management

Along those Class IV streams where complete or partial harvest is permitted, understory vegetation should be maintained to the maximum extent possible for shade to maintain cool water temperatures. In all harvest operations, removal of vegetation for safety paths is required around a tree to be felled.

Silviculture

Since timber harvest is not programmed in most riparian management zones of the WNF, immediate silvicultural regeneration of the riparian area is not required in most cases. In riparian management zones with partial harvest, vegetation should be replanted. Species composition of the pre-harvest stand should be reestablished by planting species that naturally occur at the site.

Representative riparian management zones should be monitored periodically to determine whether natural regeneration is adequate for long-term stand maintenance. In cases where there is no evidence of regeneration, active silvicultural management may be required (e.g., replanting, stand manipulation, broadcast burning, fertilization). In addition, riparian areas degraded because of past practices or natural events can benefit from silvicultural management.

Few silvicultural techniques have been developed for riparian forests. Future riparian management will benefit greatly from thorough documentation and evaluation of new methods.

Large Woody Debris Management

Large woody debris is absolutely crucial to numerous riparian functions over both the short-term (seasons to decades) and long-term (decades to centuries) life of the forest in specific sites as well as downstream areas (Fig. 38). The policy of no harvest in the riparian management zone is designed to guarantee the long-term supply of woody debris to wetlands, streams, lakes, and floodplains of the WNF. If stream clean-up is prescribed, large woody debris present before harvest should be left in place.

Residue Management

Logging slash should not present a problem in wetlands, lake margins, perennial stream channels and unstable Class IV streams because no timber harvest is programmed within these riparian management zones. Direct inputs of logging slash should be minimal, and riparian zones will intercept slash from upslope harvest units.

Timber harvest in areas immediately adjacent to streams often adds quantities of slash and large debris to channels; this is most likely to occur along Class IV streams (Fig. 39). Timber harvest in these areas should use techniques that minimize debris loading into the channel (e.g., directional felling, log suspension, minimal site disturbance; see Table 5a b, and c).

Land managers should be cautious about removing slash from any riparian management zone, stream channel, lake or wetland. If residue accidentally accumulates in riparian zones, it should be left in place and not piled. No clean-up should be prescribed for any stream, lake or wetland under normal conditions.

Broadcast burning normally should not be prescribed to extend into the riparian management zone. The fire line should be located well away from the riparian management zone to avoid disturbance from burning and soil compaction. Prescribed use of fire within the zone may be recommended to maintain some riparian plant communities.

Figure 38. Natural accumulations of woody debris in a stream in the Willamette National Forest.

Figure 39. Woody debris from both natural and logging-related sources in a small stream in the Willamette National Forest.

High Risk Areas

In rare instances, residue will need to be removed from the site to prevent damage to downstream resources or impairment of water quality. Areas with shallow soils, unstable headwalls, or tension cracks in the soil surface are potentially unstable. Mass failures may originate at these locations. Also, decomposition of slash in low gradient, swampy areas may reduce dissolved oxygen levels to lethal limits for aquatic life.

In such cases, logging slash should be removed only to the extent that streamflow is no longer blocked. Slash in the riparian area can be hand piled (PUM) outside the active channel. Yarding of slash to landings (YUM) should be considered as a last resort. Imbedded large woody debris present before yarding should be left in place.

Large woody debris in the active channel or flood channel may be removed within three channel widths of the upstream side of permanent road crossings to prevent culvert or bridge failure.

Riparian areas are noted for their resistance to burning, but if fuel loading is a concern at a particular location, slash in the riparian area can be hand piled (PUM) outside the riparian management zone and burned.

Logging Systems

The choice of logging system for a particular site should consider the riparian area and its degree of protection. The best planned riparian management zone in the WNF will be useless if logs are carelessly felled into or yarded through it.

Felling and Bucking

No trees in the harvest unit should be felled in a direction that would result in their entry into the riparian management zone, except along stable and moderately stable Class IV streams. If a tree is accidentally felled into the riparian management zone, it should be left. Attempts to retrieve such logs frequently result in severe damage to planned riparian management zones.

Yarding, Suspension, and Cable Corridors

All efforts should be made to protect riparian vegetation during yarding operations. Dragging logs through streams and riparian areas causes damage that takes decades to heal, and should be avoided if possible.

Logs should be yarded uphill if possible when passing over or through riparian management zones (Fig. 40). Lateral movement of logs is more restricted in uphill than in downhill yarding.

Carriage location during in-haul must be situated to yard away from the riparian management zone. Lines should be removed from the management zone prior to restringing for next line placement.

Figure 40. Yarding logs with full suspension across unharvested riparian management zone.

In some harvest units, cable corridors may need to be cut through the riparian management zone. The number of these crossings should be kept to a minimum. Corridors should not be cut through stable debris accumulations. Cuts should also be taken not to destroy side channels and backwaters important to fish-rearing on Class I and II streams and lakes.

When a suspension corridor is cut, these logs should be placed in the channel and riparian management zone if the area is deficient in large woody debris (Fig. 41). The amount of woody debris left in the channel and forest floor within the suspension corridor should approximate natural volumes for the site.

Created openings within the riparian management zone (such as cable roads) should each be limited to 20 feet in width and total no more than 10% of the channel edge within the activity area.

On slopes susceptible to erosion, yarding should be restricted to the dry season unless full suspension can be achieved.

Figure 41. A riparian management zone with cable corridors. Note that natural levels of woody debris are left in the stream channel and forest floor.

Class I, II & III Streams, Lakes, and Wetlands

Yarding logs across any perennial stream or any portion of a lake or wetland requires specific site evaluation, on-the-ground review, and full documentation in the environmental assessment. Predicted impacts from proposed skyline anchors and corridors must be explicitly stated. Full suspension of logs above the canopy of the riparian management area is required; particular care should be taken not to minimize vegetation damage.

Class IV Streams

Full to partial suspension is required on all intermittent Class IV streams. On ephemeral streams, partial suspension is necessary over the channel. In streams on unstable soils, care should be taken to avoid damage to the retained riparian vegetation.

Timing of Activities

Seasonal impacts of logging activities need to be evaluated. Those that may generate excessive fine sediment should be carried out in dry periods of the year so erosion control practices can be completed before the rainy season.

Class I & II Streams and Lakes

From October 15 through July 15, logging-related sedimentation is more likely to interfere with salmonid spawning. Incubation of eggs in the gravels, or emergence of fry. Therefore construction activities in the stream (e.g., bridges, culverts, rehabilitation structures) normally should be limited to the period between July 15 and October 15. Activities outside the channel but likely to contribute sediment to stream channels should adhere to the same operating season and should use special installations to prevent sediment from reaching the stream.

In stream reaches used by spring chinook salmon for spawning, the period of activity should be limited to July 15 to September 15. Bull trout begin spawning in September; therefore, construction activities should be completed before September 1 in reaches they use for spawning.

CHAPTER 6

RIPARIAN REHABILITATION

Both natural and man-caused events can have adverse impacts on riparian functions, despite the best attempts to protect them. Past practices may have left areas that cannot provide full riparian functions for several centuries. Current harvest activities occasionally may damage riparian management zones, even with good planning and technology. Natural events, such as floods or fires, may also create degraded riparian conditions. Although natural variation is desirable, damaged riparian areas containing important resources may benefit from man's assistance. Silvicultural and geomorphic techniques may be effective in rehabilitating degraded riparian resources.

Successful riparian silvicultural, fish habitat, or channel rehabilitation projects all a basic sequence of planning, implementation, and monitoring. They include: (1) determination of existing conditions; (2) identification of rehabilitation needs; (3) project design; (4) implementation; and (5) post-installation monitoring.

SILVICULTURE

Silviculture practices have been concerned primarily with regenerating merchantable timber on hillslopes; however, degraded riparian areas can also benefit from these techniques. The goals of silvicultural management in riparian management zones are to provide the natural ecological functions of riparian vegetation where past practices or natural events have diminished the diversity of riparian plant communities. All stages of silvicultural activity should encourage natural patterns of succession. Highest priorities in all silvicultural operations in riparian areas should be given to creating taxonomically diverse and structurally complex riparian plant communities.

Shading

Reestablishment of shade over stream channels can be accelerated by protecting any remaining streamside vegetation, especially young trees. However, in areas dominated by shrub cover, underburning may encourage regeneration of desired tree species. In riparian areas where short-term canopy recovery is required, hardwood species (e.g., red alder, big-leaf maple, willow, cottonwood) may be planted. Coniferous species such as hemlock, western red cedar, and Douglas fir should be planted to reestablish long-term shade conditions.

Woody Debris

Snags, green trees, and cull trees should be left in place to provide a short-term debris source. Species such as western red cedar, which decay slowly, should be planted where appropriate.

Precommercial thinning removes small trees from the unit. Placing this material directly into channels should be considered for short-term channel and floodplain complexity, particularly in small streams lacking debris. This small woody debris can provide structure and organic matter for 5-15 years.

At the commercial thinning stage (40-80 years), there are two options: (1) the operation can be avoided completely in the riparian management zone, leaving natural mortality at 80-120 years to thin the area; or (2) commercial thinning can proceed, but pole timber and culls can be placed in the channel. The latter practice should be considered only if the stream channel contains inadequate volumes of woody debris.

Vertical and Horizontal Diversity

In degraded riparian areas, structural complexity and vertical diversity can be partially attained by leaving whips, snags, and green culls in adjacent harvest units. Managers should leave as many standing cull trees as possible outside the riparian management zone to feather the riparian forest into the adjacent younger forest. Group selection or single tree selection are preferable to even-age management. Thinning areas in riparian management zones should be irregularly distributed in patches rather than uniformly dispersed throughout the stand.

CHANNEL REHABILITATION

Channels in many streams of the WNF have been simplified and destabilized by prescribed stream clean-up, salvage operations, debris torrents, and floods. Riparian timber harvest has removed the source of large woody debris for these streams for the next one or two hundred years. In the few areas with adequate equipment access and sources of large wood, channel structure and volumes of large woody debris can be restored through channel rehabilitation projects.

Appropriate design of rehabilitation projects requires thorough analysis and implementation. To rehabilitate degraded stream habitats effectively, land managers should:

- ◆ evaluate existing conditions
 - channel structure
 - fish communities
 - analyze limiting factors
- ◆ develop and document objectives
- ◆ implement the project
- ◆ monitor to determine if objectives are achieved.

Evaluation

Understanding the current status of channel structure and/or fish communities is essential for developing appropriate project objectives. All too often, rehabilitation projects are initiated without identifying specific objectives. For instance, pools are created for fish habitat without determining whether existing geomorphology would support additional pools over the long term, or whether existing fish populations are actually limited by lack of pools.

Conditions of existing channel structure (including amounts of large woody debris) and fish communities must be inventoried both for the basin and on the specific rehabilitation site. Projects initiated without consideration of basin-level conditions will be significantly less effective and more prone to failure than those that perform such an assessment. Pre-harvest channel structure and fish communities should be assessed at

Large Woody Debris

Log introduction projects should attempt to restore natural distributions, abundance, and size classes of debris in streams (Fig. 42). Persistence of installations is increased where log structures are placed in geomorphically stable locations and configured to resemble natural accumulations of wood.

Movement of introduced logs should not be considered a failure, particularly if they are retained within a short distance downstream. In an undisturbed stream of the McKenzie River basin over the past ten years, no more than 4% of the wood has moved in any given year; more than 90% of the logs that moved were less than 6 feet long. Log length is a critical factor in stability: logs longer than the active channel width are not likely to move very far downstream.

The importance of geomorphically-appropriate design and placement of log structures cannot be emphasized too strongly. Precautionary reinforcements (e.g., cabling, gluing to bedrock, etc.) cannot change a poorly-designed structure into effective fish habitat. Logs and stream channels naturally shift during floods. Time-lapse films of log jams in the WNF have shown that logs float up several feet during floods and drop back into place, with little evidence after the flood of having moved. Streambeds also naturally shift during floods; a location that is physically stable before a flood may become unstable if the channel changes.

Several configurations of log accumulations are commonly used in habitat restoration projects (e.g., full channel jams, aill logs, lateral deflectors, upstream or downstream V's,

Figure 42. An installation of woody debris for stream rehabilitation on Quartz Creek in the McKenzie drainage.

similar undisturbed streams within the basin. If natural areas cannot be found within the basin, similar basins nearby can be used to compare with patterns found at the proposed rehabilitation site.

Geomorphic structure and channel hydraulics change from headwaters to large rivers. A rehabilitation structure may be physically stable and effective in one part of a basin but may fail rapidly in another stream reach. The location, distribution, configuration, and size of channel rehabilitation features should be consistent with the geomorphic and hydraulic properties of the stream reach.

Fish habitat rehabilitation projects should be planned to meet specific objectives related to species and age class composition of fish communities, life history characteristics, abundance, habitat availability relative to requirements, and food resources. Seasonal patterns of fish distribution and abundance within the basin should be considered.

If a riparian area has been damaged by a natural or land use-related disturbance, the probability of continued disturbance must be considered. *Any improvements associated with rehabilitation projects can be negated by treating the symptom rather than the source of disturbance.*

Inventories of riparian conditions and fish communities within a basin identify specific needs for rehabilitation activities. This assessment will determine the physical and/or biological factors that may limit channel "health" or fish populations. For example, pool availability may not be limiting fish production, but sufficient fry rearing habitat, such as edges, may be lacking. From a geomorphic perspective, limiting factors analysis may point out that the stream channel is simpler than would be expected in undisturbed conditions. Such determinations will focus the direction of rehabilitation efforts and can increase the effectiveness and long-term success of a rehabilitation project.

Development of Objectives

Objectives for the entire rehabilitation project and each individual component, including structures, and anticipated future changes should be explicitly stated. This serves as a record of management activities, supplies a basis for long-term project monitoring, and provides a foundation for developing more effective future rehabilitation techniques.

Implementation

After project objectives have been clearly identified and documented, the rehabilitation project can be initiated. A variety of materials, both natural and man-made, can be used for channel modification.

Natural Channel Materials

Stream rehabilitation projects are usually designed to restore bed materials, either logs or sediments. *Natural channel materials should be used for rehabilitation whenever available.* Natural materials are usually cheaper than artificial structures, provide ecological functions more effectively, and, unlike man-made structures such as gabions, continue to provide such functions even if transported downstream.

off-channel accumulations). Each type of debris accumulation creates different channel structure and flow characteristics. Their ability to provide fish habitat also differs greatly. Project design should carefully match debris accumulation types to the desired geomorphic and ecological objectives.

Downstream road crossings, recreational areas, and residences commonly are safety concerns in debris rehabilitation projects. If risk of downstream damage is likely, several precautions can minimize potential risks.

Securing logs to bedrock, boulders, or other logs with steel cable and epoxy is used to increase log stability. Frequently, both ends of a log are cabled to adjacent boulders or bedrock. In high-energy or bedrock-dominated reaches in particular, full cabling may be required to maintain structures during high flows. Caution should be exercised in fully cabling logs to relatively immovable objects in the channel. At high flow, tremendous forces may be directed into the log, and flotation may cause great strain if the log is totally submerged.

Partial cabling for tethering provides some stability but permits more flexibility than full cabling. In many structures (e.g., lateral deflectors, complex accumulations), partial cabling at the bank end of the log may result in better structure response than full cabling.

If there are no immediate downstream risks, cabling should be minimized to guarantee natural behavior of log accumulations. Logs continue to provide natural ecological functions when floated and redeposited downstream.

Where supply of large woody debris is limited, small trees (with rootwads still attached) may be cabled together in bundles to mimic the effects of larger material. While these tree bundles provide larger effective diameters, their relatively short length may limit their use to smaller streams or to the edges of larger channels. These bundles of smaller debris can create complex cover for juvenile fish.

Live Trees

In riparian areas with adequate tree stocking, some woody debris can be obtained directly from riparian management zone. Trees can be felled directly into the channel, but the lack of a root wad decreases their stability. Hydraulic excavators can push over large trees (2-3 ft dbh) and leave the root wad intact. Riparian trees can also be blasted over, but operators have little control over the direction of fall.

Boulders

Debris torrents and floods can eliminate boulders and other large channel material from stream reaches. Boulder additions, either alone or with logs, can increase the channel's ability to retain sediments and provide fish habitat. Natural configurations of boulder berms and bar features should be followed to create geomorphically stable installations.

Channel Form

After assessing fish populations, objectives may call for altering channel bedform, particularly abundances of pools. In sediment-rich streams, the practices described above will generally achieve such objectives. In bedrock-dominated streams, altering bedform is more difficult because the potential to downcut is limited. Two major approaches are feasible for creating pools in bedrock: building up the channel and creating holes in the bedrock.

Building sediment deposits over extensive bedrock surfaces can be successful, but requires large numbers of boulders, logs, or gabions. Anchoring structures to bedrock with cable is almost always required to withstand the great erosional forces present at high flows. Structures that completely span the channel will create dammed pools, at least initially. The pools may fill with sediment and gravel over time. If this occurs, secondary structures can be added to scour depressions in these deposits.

Blasting with dynamite has been used to create holes in bedrock. Blasting has many logistic limitations (cost, safety risks, limited area of influence), and often is not effective. Simple depressions in bedrock surfaces will generally fill with gravel within a few years, and the fish habitat created is not complex enough to provide cover or refuge from floods.

Complex multi-piece structures located closely to other structures have greater potential to accumulate sediments rapidly and to dissipate high flood velocities. Linking structures on bedrock to off-channel habitats (e.g., side channels, backwaters, floodplains) provides physical relief and lateral fish refuge at high flow (Fig. 43).

Figure 43. A complex jam installed without use of any cabling or glue on Quartz Creek in the McKenzie drainage. It completely spans the stream channel, and provides an important source of geomorphic roughness as well as fish habitat.

Beavers

Beavers create extensive pools with complex off-channel stress, continuously bring nutrients (trees and foliage) into the habitat for aquatic organisms, and quickly repair damage during floods. Rehabilitation projects can be located near stress of existing beaver activity to take advantage of their beneficial effects.

Recolonization by beavers can be encouraged in basins where channels have been degraded. In areas without beaver, reintroduction has been successful if release sites offer good habitat. They prefer second-growth stands, which are more likely to be the sites of damaged stream channels. Additional road inspection and maintenance may be required around road crossings to prevent damming of culverts.

Gabions

Gabions are wire baskets filled with cobble and small boulders. Where large logs and boulders are not available, they offer the potential to modify channel structure with small sediments. Gabions function like boulder berms in streams and, like natural materials, should be placed in geomorphically appropriate locations and configurations.

Gabions are less effective rehabilitation structures than natural materials. They do not provide the open matrices created by log or boulder structures. When gabions fail, they create a tangled mass of "chicken wire" downstream, providing none of the desired project objectives. Gabions are generally more expensive than natural structures to install, and usually last less than 20 years.

Project Monitoring

Functionally, a rehabilitation project starts after implementation is completed. *Rehabilitation projects without future evaluation are unfinished.* Subsequent monitoring is essential to determine to what degree project objectives were achieved and to improve future riparian rehabilitation efforts. It is important to know which practices are not effective and conditions under which they fail.

In the initial planning phase, criteria for evaluation should be established. A project officer for future project monitoring should be designated, and plans for future funding of monitoring should be identified.

CHAPTER 7

MONITORING RIPARIAN AREAS

Riparian monitoring evaluates the effectiveness of past management practices and provides information for developing future management policies. Identification of the desired future condition of riparian stress is a fundamental basis for any monitoring and evaluation of resource information. Such desired future conditions for riparian stress have been identified for Region 6 of the U.S. Forest Service.

Riparian monitoring programs currently being developed by the WNF incorporate three types of monitoring: implementation, effectiveness, and validation.

Implementation monitoring determines whether Standards and Guidelines are implemented to achieve riparian objectives. Pre-harvest environmental assessments are reviewed, and operational compliance with riparian prescriptions is checked on the ground. These site reviews also determine whether all standards and guidelines were met.

Effectiveness monitoring ascertains whether riparian prescriptions and plans are achieving the overall objectives of riparian management policy. It is conducted at several scales, ranging from individual sites to large drainage basins, and includes follow-up of rehabilitation projects.

Validation monitoring establishes whether the underlying assumptions used in resource models and planning are correct. In most cases, both managed and undisturbed areas require monitoring. Validation monitoring over several decades is essential for detecting major trends in resource status.

The land base of the WNF encompasses a wide range of natural landscape features and management patterns. As a result, monitoring of riparian areas cannot be concentrated at one or two sites and then extrapolated to cover the entire Forest. At the same time, logistical and financial constraints require a stratified monitoring program that includes:

- ◆ post-project site review
- ◆ reference sub-drainages
- ◆ basin monitoring
- ◆ water quality network
- ◆ landscape synthesis of monitoring data

This stratified monitoring program examines different aspects of riparian areas at several scales of space and time. It provides information on channel and floodplain functions, water quality, fish and wildlife habitat and numbers, and riparian plant diversity and dynamics.

POST-PROJECT REVIEW

The post-project review determines if WNF Standards and Guidelines for riparian management are being implemented, in terms of environmental assessments, site analyses, site prescriptions, and operator compliance with prescriptions. All managed units in a given District undergo an office review of environmental assessments and contracts. A proportion of managed units (including rehabilitation efforts) are also reviewed on the ground immediately after operations, to determine whether the prescriptions were appropriate for the specific site, and whether they were implemented properly. Ideas for post-project review are listed in Appendix III.

REFERENCE SUB-DRAINAGES

Reference sub-drainages are selected for long-term systematic effectiveness and validation monitoring across the entire WNF. These locations include both managed and undisturbed (mature/old growth) areas. Reference sub-drainages provide information on riparian resources across a range of forest conditions and management practices. Within each selected sub-drainage, reference stream reaches or sites are chosen, and their boundaries are monumented and documented for long-term repeated measurements.

Reference sub-drainages are selected to provide a range of elevations, including the low elevation rain-dominated zone, the rain-on-snow (transient snow) zone, and the snow-pack-dominated zone. The proportion of the sub-drainage in the transient snow zone is particularly important for hydrologic analyses. These three broad elevation bands experience different winter weather conditions, and consequently have different annual runoff patterns.

Reference sub-drainages also represent major classes of watershed stability (unstable, moderately stable, stable). Soil stability, geology, and slope steepness are important criteria in stability classification. Slope stability ratings have been developed for the major soil types and subdrainages of the WNF (see Appendix II).

Each group of reference sub-drainages contains both harvested and unharvested riparian areas, as well as different proportions of the drainage available for harvest. The areas with no timber harvest serve as controls to distinguish changes caused by management practices from those related to natural variation.

Aquatic habitat types include all stream classes and lakes. Within a given reference sub-drainage, representative reaches of all stream classes (I - IV) are selected for intensive monitoring of both aquatic and terrestrial parameters. In addition to stream class, selection of reaches is based on valley floor type (e.g., unconstrained vs. constrained). If appropriate, lakes surrounded by areas of timber harvest are also monitored. Reference reaches are evaluated three times per decade, with a total of 20 miles of stream surveyed each year. The monitoring process in reference sub-drainages evaluates channel structures, streamside vegetation (including plant diversity), fish communities, and wildlife habitat. Basic components of reference sub-drainage monitoring are listed in Appendix III.

BASIN MONITORING

Basin surveys are designed to provide a broad overall assessment of fish habitat and populations. Instead of concentrating on small individual standard reaches within the reference sub-drainages, basin inventories cover many miles of fish-bearing streams. All fish bearing streams within the WNF are surveyed twice per decade.

Basin monitoring describes channel structure, streamside vegetation, woody debris, and fish communities. Components of basin monitoring are listed in Appendix III.

WATER QUALITY NETWORK

Water quality monitoring on the WNF requires frequent sampling over a broad spatial scale. Consequently, a network of monitoring stations will be established across the Forest. The areas for basin-level water quality monitoring are selected from the reference sub-drainages used for intensive riparian monitoring. Weldo Lake and smaller lakes in areas of timber harvest are included in the water quality network. Water temperature, suspended sediments, and water chemistry are critical components of water quality for assessment. In general, all sampling will be done at regularly scheduled intervals and in response to significant episodic events, such as drought conditions or major storms.

Temperature is particularly critical in Class I and II fish-bearing streams, and can be strongly affected by Class III and IV streams. Stream temperature patterns are monitored during summer low-flow periods, to ensure that State Water Quality standards are being met. Lake temperature profiles are measured during the period of maximum thermal stratification (usually late August).

Suspended sediments and turbidity are monitored in critical municipal watersheds and fish-bearing streams and lakes. Measurements are taken during the rainy season and after large floods (> 5 year recurrence interval), since most inputs occur during this time.

Dissolved nutrient concentrations are an important factor in water quality analysis. Concentrations of elements such as nitrogen, phosphorus, and organic carbon commonly increase after forest harvest. Basic chemical parameters in water quality monitoring include conductivity, pH, alkalinity, nitrate, ammonium, reduced nitrogen, orthophosphate, total phosphorus, dissolved organic carbon, calcium, magnesium, sodium, potassium, chloride, sulfate, and silica.

CHAPTER 8

GLOSSARY

Active Channel: The portion of the valley floor flooded annually, including low flow wetted channel and streambanks.

Aggradation: The geologic process of filling and raising the level of the streambed or floodplain by deposition of material eroded and transported from other areas.

Aggregate Recovery Percentage (ARP): Within a given subdrainage between 1500 and 4000 feet in elevation on the WNF, ARP is the sum of the percent recovery for each stand age/size weighted by the proportion of the area within that classification. Degree of recovery of a harvested area is based on the average diameter of the replanted trees. When the average stem diameter of replanted trees is 8 inches DBH (diameter at breast height) and there is at least 70% canopy cover, the stand is considered fully recovered. Such fully recovered stands are typically 35 years old. Stands with smaller diameter trees and lesser canopy closure are partially recovered.

Alluvial Fan: A fan-shaped accumulation of sediments deposited by streams, usually at their mouths.

Alluvium: A general term for all sediments transported and deposited by streams. Alluvium may accumulate on streambeds, fans, lakes or estuaries.

Anadromous Fish: Species, such as salmon, that hatch in freshwater, move to the ocean to mature, and return to freshwater to spawn.

Aquatic Ecosystem: Any body of water, such as a stream, lake, or estuary, and all of the organisms and nonliving components, functioning as a natural system.

Aquatic Habitat: Habitat for fish and other aquatic organisms within lakes, wetlands, or wetted channels of streams.

Backwater: An off-channel pool or eddy at lateral margins of the channel. Protected from high velocity flows, usually by abundant woody debris or boulders. Opening to main channel is less than the long axis of the backwater itself.

Bank Storage: Infiltration of water into stream bank deposits during flood flows.

Bank Full Width: Width of stream channel at normal flood flow.

Bank Stability: The ability of stream banks to withstand the erosive forces of water. Bank stability increases in the presence of deeply rooted plants.

Bar: A ridge-shaped deposit of alluvial material in the channel, along stream banks, or at the mouth of a stream.

Base Flow: Typical flow for a given stream at a particular time of year.

Basin: The area of land that drains water, sediment and dissolved materials to a common point along a stream channel.

Bedload: Particles, ranging in size from clay to boulders, which are carried by the water, but which are in at least partial contact with the bottom.

Benthos (n), Benthic (adj): Organisms living on or within the substrates of aquatic habitats.

Biological Stability: The inherent capacity for biological systems to resist change: the absence of fluctuations and the ability to withstand disturbances without significant changes in composition.

Blowdown: A tree or trees uprooted or felled by the wind.

Buffer: An area of vegetation left or managed to reduce the impact of a treatment or action of one area on another.

Canopy Cover: The more or less continuous cover of branches and foliage formed by the crowns of adjacent trees and other woody growth.

Carrying Capacity: The number of individuals of a particular species that the resources of a given habitat can support.

Channel: A waterway that contains moving water either periodically or continuously. A channel has a definite bed and banks.

Channel stability: The resistance of a stream to changes in bedform.

Climax Community: The final biotic community in a successional sequence. Usually a community that is self-perpetuating unless disturbed by outside forces.

Connectivity: Unbroken linkages in a landscape, typified by streams and riparian areas.

Constrained: A narrow valley limited in width by adjacent landforms, with a valley floor width less than two active channel widths. Valley walls are usually steep; the stream cannot meander and is a single simple channel.

Cover: Any feature that provides protective concealment for fish and wildlife. Cover may consist of live or dead vegetation or geomorphic features such as boulders and undercut banks. Cover may be used for purposes of escape from predators, feeding, or resting.

Critical Habitat: The portion of the living area of a species that is essential to the survival and perpetuation of the species.

Crown Cover: See canopy cover.

Cull: A snag, green tree, or log that is of little or no economic value.

Cumulative Effects: Effects on the environment resulting from individually minor but collectively significant actions taking place over a period of time.

Debris (organic): Logs, trees, limbs, branches, leaves, bark that accumulate, often in streams or riparian areas. Debris may be naturally occurring or the result of man's activities.

Flow: Any movement of water (see discharge).

Food chain: The transfer of food energy from plants through a series of consumers by repeated eating and being eaten. Food chains interconnect to form food webs, which represent energy flow through an ecosystem.

Forage: Herbaceous plants and portion of woody species (twigs, leaves) used for food by wildlife.

Functional Groups: A classification of animals based on how they consume their food, rather than what they eat. Generally used in describing communities of stream and lake benthos.

Fry: Recently hatched fish, up to one year of age.

Gabion: Large cage filled with rocks; used in some areas as supports or abutments in streams, supposedly to increase fish habitat diversity.

Game Species: Species of fish or wildlife for which seasons and bag limits have been imposed, and which are harvested under State or Federal regulations.

Geomorphology: The geological study of land form evolution and configuration.

Gradient: The rate of vertical elevation change per unit horizontal distance; also known as slope.

Habitat: The area where a plant or animal lives and grows under natural conditions. Habitat consists of living and non-living attributes, and provides all requirements for food and shelter.

Habitat Diversity: The number of different types of habitat found within a given area.

Headwall: An area, normally wedge-shaped, at the uppermost end of a stream channel. It serves as the point of origin for surface runoff.

Hillslope: Adjacent hillsides above the influences of flooding.

Horizontal Diversity: Abundance and variety of plant communities on an areal basis.

Hydrologic Recovery: See ARP.

Indirect Effects: Secondary effects which occur in locations other than the initial action or significantly later in time (WNF).

Landslide: The dislodging and fall of a mass of earth and rock.

Litter: Dead plant material, commonly leaves, needles, twigs, etc.

Mass Failure: Movement of aggregates of soil, rock and vegetation downslope in response to gravity.

Mature Forest: In the Willamette National Forest, areas containing trees whose average age is 120-200 years old. There is significantly less diversity of plant species and structure than in old-growth forest.

Debris Jam: An accumulation of many sizes of woody debris, generally within the stream channel, but often extending onto the banks or low terraces. Also referred to as debris dams or debris accumulations, they may be naturally occurring or the result of poor management.

Debris Loading: The amount of debris located in a specific area; it may accumulate as a result of natural processes or human activities.

Debris Avalanche/Slide: Rapid landslides occurring on hillslopes. The material moved, including sediment, wood, and vegetation, may or may not be delivered to a stream channel.

Debris Torrent/Flow: Rapid movements of material, including sediment and woody debris, within a stream channel. Debris torrents frequently begin as debris slides on adjacent hillslopes.

Degradation: Lowering of a stream bed by erosion (vs aggradation).

Deposition: The settlement of material out of the water column and onto the stream or lake bed (vs. erosion).

Detritus: Loose particulate matter formed by the breakdown of decomposing plants and animals.

Diameter Breast High (DBH): The standard diameter measurement for standing trees, taken at 4.5 feet above the ground.

Discharge: A measure of the amount of water flowing in the stream channel. Discharge depends on both the velocity of the water and the area of the wetted channel, and is generally measured in m^3/sec or ft^3/sec (cfs).

Diversity: the relative abundance and variety of species, both plant and animal, in a given area.

Drainage Area: See basin.

Earthflow: Movement of material, both sediment and vegetation, down a hill slope. Earthflows are typically large, but move only a few centimeters each year.

Ecosystem: A complete interacting system of organisms considered together in their environment. A biotic community and its abiotic environment.

Ecotone: A transition or junction zone between two or more naturally occurring diverse communities.

Edges/Edge Effect: Areas where two physical or biological zones meet. The increased diversity in these areas is known as the edge effect.

Flood: Abrupt increase in discharge. Frequently, flows that exceed the bankfull capacity of a given stream.

Floodplain: Relatively flat surfaces adjacent to active channels, formed by deposition of sediments during major flood events. It may be covered by water at flood flows.

Retention: The capability of a stream to retain either water or suspended particles for any length of time.

Riparian Area The aquatic ecosystem and the adjacent upland areas that directly affect it.

Riparian Management Zone: Site-specific boundaries established by the Forest Service for management practices within riparian areas.

Salvage: The cutting of trees that are dead, dying, or deteriorating (because they are "overmature", or materially damaged by fire, wind, insects, fungi or other injurious agencies) before they lose their commercial timber value.

Second Growth: Plant growth that has come up naturally after some drastic interference, such as fire or clearcutting, has removed the previous forest.

Sediment: Material carried in suspension by water, which will eventually settle to the bottom.

Side Channel: A portion of the active channel that does not carry the bulk of the streamflow. Side channels may carry water only during winter flows, but are still considered part of the total active channel.

Slash: Residue (leaves, bark, twigs, roots, etc) left on the ground after logging.

Slope Stability: The degree to which a slope resists the downward pull of gravity. The more resistant, the more stable.

Snag: A standing dead tree usually greater than 5 feet high and 6 inches dbh. Its interior may be sound or rotted.

Spawning Gravel: Sorted, clean gravel patches of a size appropriate for the needs of resident or anadromous fish. For example, chinook require gravel 0.5 - 2 inches in diameter.

Standing Crop: Amount of living biomass, plant or animal, present in a given location. Often expressed in weight per unit area.

Stocking: A loose term for the amount of anything, be it trees or fish, in a given area, particularly in relation to a pre-determined optimum.

Stream Bank: The part of a stream channel, when seen in cross-sections, that restricts sideways water movement at normal flows. It represents a distinct break in slope from the stream bed.

Stream Blockage: Accumulation of solid, rock, and organic material deposited in a stream channel by landslides that prevent fish from moving upstream.

Stream Class: A classification of streams based on their hydrology, fisheries, and usage. Class I streams are perennial or intermittent and have significant fisheries, domestic water use, or influence on other Class I streams; Class II streams also have perennial or intermittent flow with moderate fisheries (game fish or the potential to maintain game fish populations), domestic water use, or influence on other Class I or II streams; Class III streams are perennial but do not meet criteria for Class I and II streams; and Class IV streams are ephemeral or intermittent, but do not meet criteria for Class I, II or III streams.

Microclimate: Localized climate conditions; microclimatic conditions in riparian areas are generally less extreme than adjacent hillslopes.

Migration Corridor: The portion of the landscape serving as a routine passageway for fish or wildlife species as they that move from one habitat to another, often on a seasonal basis.

Mitigation: Actions to avoid, minimize, reduce, eliminate or rectify the impact of management practices.

Monitoring: Actions undertaken to assess and evaluate, including the results of management activity on a species or process.

Multiple-use: A concept of land management in which a number of resources are produced simultaneously from the same land base.

Noncommercial Thinning: The selective cutting of nonmerchantable sizes and species of trees.

Non-game: Species of wildlife and fish not managed as sport hunting resources.

Old-Growth: A forest comprised of many large trees, large snags, and numerous large down logs; having a multi-layered canopy composed of several species of trees; the last stage in forest succession. In the WNF, forests begin to show some old-growth characteristics at 175-200 years. The most extensive type of old-growth on the WNF is the Douglas fir/western hemlock forest which lives 350-750 years. Old-growth stands have a wide range of ages and sizes of trees. In some areas, the Douglas fir may be replaced by western red cedar or ponderosa pine.

Peak Flow: The highest discharges attained during a particular flood event for a given stream.

Plant Community An assemblage of plant species in a given area (NB: communities technically, ecologically, include animals as well).

Precommercial Thinning: Removal of some trees in a stand before they attain merchantable size so the remaining trees will grow more quickly.

PUM: Piled unmerchantable material; generally unusable woody material less than 8 inches x 10 feet remaining after timber harvest.

Rearing Habitat: Areas required for successful survival to adulthood by young animals. For trout, rearing areas may be the edges of streams, while for elk, they may be thickets in the riparian area.

Recovery: Return of an ecosystem to a defined condition after a disturbance.

Rehabilitation: The process of restoring a site to a former state or desired condition.

Resident Fish: Fish species that complete their entire life cycle in fresh-water.

Residue: Plant material remaining after harvest operations.

Wetland: Those areas periodically inundated by surface or ground water. They support vegetation or aquatic species requiring wholly or partially saturated soils. Wetlands include marshes, bogs, sloughs, potholes, river overflows, mud flats, wet meadows, seeps and springs.

Woody Debris : Dead woody material greater than 10 cm in diameter and longer than one meter, usually composed of boles and large branches. Various terms, such as large woody debris (LWD), coarse woody debris (CWD), and large organic debris (LOD), have been used to describe this material. Large woody debris is material greater than 20 inches (50 cm) in diameter and 33 ft (10 m) in length. Woody material greater than 4 inches (10 cm) in diameter and 3 ft (1 m) in length but less than 20 inches (50 cm) in diameter and 33 ft (10 m) in length is considered to be small woody debris and consists of small trees, tops of large trees, and large branches. Small branches, twigs, and slash from logging operations less than 4 inches (10 cm) in diameter and 3 ft (1 m) in length are considered fine woody debris.

YUM: Yarded unmerchantable material; generally unusable woody material less than 8 inches x 10 feet remaining after timber harvest.

Stream Cleanout: Removal of debris from streams. This is no longer considered acceptable management.

Stream Order: A measure of the position of a stream in the hierarchy of tributaries. First-order streams are unbranched (no tributaries). Second-order streams are formed by the confluence of two or more first order streams, and are considered second order until they join a larger stream. Third order channels are formed by the confluence of two or more second order streams, etc.

Stream Structure: The arrangement of logs, boulders, and meanders which modify the flow of water, thereby causing the formation of pools and gravel bars in streams. Generally, there is a direct, positive relationship between complexity of structure and fish habitat. Complex stream structure is also an indication of overall watershed stability.

Structure: The configuration of elements, parts, or constituents of a habitat, plant, or animal community.

Substrate: The material forming the underlying layer of streams. Substrates may be bedrock, gravel, boulders, sand, clay, etc.

Succession: The progressive development of vegetation from bare ground towards its highest ecological expression, the climax community; the replacement of one plant community by another.

Suspended Load: Particles, usually small in size, carried in suspension by the stream; these particles do not contact the streambed.

Terrace: Sediment deposits between the valley walls and the floodplain or the active channel. They may be formed by fluvial, volcanic, or glacial activities.

Tolerance Limits: The physiological band within which an organism can survive. Above or below these limits, organisms will become stressed and eventually die. Tolerance limits exist for each species for many different parameters, such as temperature, amount of light, amount of suspended sediments, etc.

Turbidity: The relative clarity of the water, which may be affected by suspended material.

Unconstrained: A wide valley floor, generally greater than two active channel widths, with extensive floodplain surfaces. The stream can meander to form a complex channel.

Upland: The portion of the landscape above the valley floor.

Valley Floor: The part of the landscape containing the stream and its floodplain.

Vertical Diversity: Within a plant community, the amount of layering along a vertical axis. Areas of high vertical diversity will have a mixture of herbs, shrubs, and trees of different heights.

Watershed: A portion of the forest in which all surface water drains to a common point. Watersheds can range from a few tens of acres that drain a small intermittent stream to many thousands of acres for a stream that drains hundreds of connected intermittent and perennial streams.

CHAPTER 9

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APPENDIX I RIPARIAN SPECIES OF THE WILLAMETTE NATIONAL FOREST

FISH AND WILDLIFE SPECIES ASSOCIATED WITH RIPARIAN AREAS

COMMON NAME	SCIENTIFIC NAME
Mammals	
Northern Water Shrew	<i>Sorex pelustris</i>
Montane Shrew	<i>Sorex monticolus</i>
Pacific Water Shrew	<i>Sorex bendirii</i>
Vagrant Shrew	<i>Sorex vagrans</i>
White-footed Vole	<i>Peromyscus alpinus</i>
Richardson's Vole	<i>Microtus richardsonii</i>
Oregon Vole	<i>Microtus oregoni</i>
Jumping Mouse	<i>Zapus trinotatus</i>
Yuma myotis	<i>Myotis yumanensis</i>
Beaver	<i>Castor canadensis</i>
Mink	<i>Mustela vison</i>
Muskrat	<i>Ondatra zibethicus</i>
River Otter	<i>Lutra canadensis</i>
Birds	
Common Loon	<i>Gavia immer</i>
Horned Grebe	<i>Podiceps auritus</i>
Western Grebe	<i>Aechmophorus occidentalis</i>
Pied-Billed Grebe	<i>Podilymbus podiceps</i>
Double-Crested Cormorant	<i>Phalacrocorax auritus</i>
Green Heron	<i>Butorides virescens</i>
Great Blue Heron	<i>Ardea herodias</i>
Common Egret	<i>Coscorodius albus</i>
Canada Goose	<i>Branta canadensis</i>
Mallard	<i>Anas platyrhynchos</i>
Gadwall	<i>Anas strepera</i>
Pintail	<i>Anas acuta</i>
Cinnamon Teal	<i>Anas cyanoptera</i>
American Widgeon	<i>Anas americana</i>
Shoveler	<i>Anas chryseus</i>
Wood Duck	<i>Aix sponsa</i>
Ring-Necked Duck	<i>Aythya collaris</i>
Lesser Scaup	<i>Aythya affinis</i>
Barrow's Goldeneye	<i>Bucephala islandica</i>
Bufflehead	<i>Bucephala albeola</i>
Harlequin Duck	<i>Histrionicus histrionicus</i>
Ruddy Duck	<i>Oxyura jamaicensis</i>

COMMON NAME	SCIENTIFIC NAME	COMMON NAME	SCIENTIFIC NAME
Hooded Merganser	<i>Lophodytes cucullatus</i>	Fish	
Common Merganser	<i>Mergus merganser</i>	• - Introduced Species	
Bald Eagle	<i>Haliaeetus leucocephalus</i>	Torrent Sculpin	<i>Cottus rhotheus</i>
Osprey	<i>Pandion haliaetus</i>	Reticulate Sculpin	<i>Cottus perplexus</i>
American Coot	<i>Fulica americana</i>	Shorthead Sculpin	<i>Cottus confusus</i>
Common Snipe	<i>Capella gallinago</i>	Slimy Sculpin	<i>Cottus cognatus</i>
Spotted Sandpiper	<i>Actitis macularia</i>	Mottled Sculpin	<i>Cottus bairdi</i>
Greater Yellowlegs	<i>Tringa melanoleuca</i>	Smooth Sculpin	<i>Cottus bairdingi</i>
Water Pipit	<i>Anthus spinoletta</i>	Largescale Sucker	<i>Carostomus macrocheilus</i>
California Gull	<i>Larus californicus</i>	Mountain Sucker	<i>Carostomus platyrhynchus</i>
Ring-billed Gull	<i>Larus delawarensis</i>	Redside Shiner	<i>Richardsonius balteatus</i>
Belted Kingfisher	<i>Megasceryle alcyon</i>	Speckled Dace	<i>Rhinichthys osculus</i>
Willow Flycatcher	<i>Empidonax traillii</i>	Longnose Dace	<i>Rhinichthys cataractae</i>
Hammond's Flycatcher	<i>Empidonax hammondi</i>	Northern Squawfish	<i>Psychocheilus oregonensis</i>
Bank Swallow	<i>Riparia riparia</i>	Oregon Chub	<i>Hybopsis crameri</i>
Violet-green Swallow	<i>Tachycineta thalassina</i>	Sand Roller	<i>Percopsis transmontana</i>
Cliff Swallow	<i>Petrochelidon pyrrhonota</i>	Chiselmouth	<i>Arcocheilus lutaceus</i>
Northern Rough-winged Swallow	<i>Stelgidopteryx ruficollis</i>	Mountain Whitefish	<i>Prosopium williamsoni</i>
Dipper	<i>Cinclus mexicanus</i>	Bull Trout	<i>Salvelinus confluentus</i>
Yellowthroat	<i>Geothlypis trichas</i>	Brook Trout	<i>Salvelinus fontinalis</i>
Yellow-Breasted Chat	<i>Icteria virens</i>	Brown Trout	<i>Salmo trutta</i>
Willows Warbler	<i>Wilsonia pusilla</i>	Brown Trout	<i>Salmo salar</i>
Red-Winged Blackbird	<i>Agelaius phoeniceus</i>	Atlantic Salmon	<i>Oncorhynchus mykiss</i>
		Rainbow Trout	<i>Oncorhynchus clarki</i>
Amphibians		Cutthroat Trout	<i>Oncorhynchus tshawytscha</i>
Roughed-Skinned Newt	<i>Taricha granulosa</i>	Chinook Salmon	<i>Oncorhynchus nerka</i>
Pacific Giant Salamander	<i>Dicamptodon ensatus</i>	Sockeye Salmon	<i>Lampetra tridentata</i>
Olympic Salamander	<i>Rhyacotriton olympicus</i>	Pacific Lamprey	<i>Lampetra richardsoni</i>
Northwestern Salamander	<i>Ambystoma gracile</i>	White Crappie	<i>Pomoxis annularis</i>
Dunn's Salamander	<i>Plethodon dunni</i>	Brown Bullhead	<i>Ictalurus nebulosus</i>
Tailed Frog	<i>Ascaphus truei</i>	Large-mouth Bass	<i>Micropterus salmoides</i>
Western Toad	<i>Bufo boreas</i>	Blue-gill	<i>Lepomis macrochirus</i>
Pacific Treefrog	<i>Hyla regilla</i>	Stickleback	<i>Gasterosteus aculeatus</i>
Red-Legged Frog	<i>Rana aurora</i>	Mosquitofish	<i>Gambusia affinis</i>
Foothill Yellow-Legged Frog	<i>Rana boylei</i>	Common Carp	<i>Cyprinus carpio</i>
Cascades Frog	<i>Rana cascadae</i>		
Spotted Frog	<i>Rana pretiosa</i>		
Reptiles			
Western Pond Turtle	<i>Clemmys marmorata</i>		
Ringneck Snake	<i>Diadophis punctatus</i>		
Western Aquatic Garter Snake	<i>Thamnophis couchii</i>		

PLANT SPECIES ASSOCIATED WITH RIPARIAN AREAS

Type:	F = Forest	N = Non-forest (includes wetlands)	
COMMON NAME	SCIENTIFIC NAME	ECO-CODE	TYPE
Grasses			
Spike Bentgrass	<i>Agrostis exarata</i>	AGEX	F
Thurber's Bentgrass	<i>Agrostis thurberiana</i>	AGTH	N
Columbia Brome	<i>Bromus vulgaris</i>	BRVU	F
Bluejoint Reedgrass	<i>Calamagrostis canadensis</i>	CACA	N
Northern Reedgrass	<i>Calamagrostis inexpectata</i>	CAIN	N
Drooping Woodreed	<i>Cinna latifolia</i>	CILA2	F
California Oatgrass	<i>Danthonia californica</i>	DACA	N
Timber Oatgrass	<i>Danthonia intermedia</i>	DAIN	N
Tufted Hairgrass	<i>Deschampsia caespitosa</i>	DECA	N
Blue Wildrye	<i>Elymus glaucus</i>	ELGL	F
Bearded Fescue	<i>Festuca subulata</i>	FESU	F
Tall Mannagrass	<i>Glyceria elata</i>	GLEL	F
Northern Meadow Barley	<i>Hordeum brachyantherum</i>	HOBH	N
Pullup Muhly	<i>Muhlenbergia filiformis</i>	MUFI	N
Reed Canarygrass	<i>Phalaris arundinacea</i>	PHAR	N
Alpine Timothy	<i>Phleum alpinum</i>	PHAL	N
Fowl Bluegrass	<i>Poa palustris</i>	POPA	N
Weak Alkaligrass	<i>Puccinellia pauciflora</i>	PUPA	N
Tall Trisetum	<i>Trisetum canescens</i>	TRCA	F
Sedges and Rushes			
Bigleaf Sedge	<i>Carex amplifolia</i>	CAAM	F
Columbia Sedge	<i>Carex aperta</i>	CAAP3	N
Water Sedge	<i>Carex aquatilis</i>	CAAO	N
Gray Sedge	<i>Carex canescens</i>	CACA4	N
Dewey's Sedge	<i>Carex deweyana</i>	CADE	F
Sheep Sedge	<i>Carex illota</i>	CAIL	N
Jones' Sedge	<i>Carex jonesii</i>	CAJO	N
Sierra Hare Sedge	<i>Carex lenticularis</i>	CALE5	N
Mud Sedge	<i>Carex leporinella</i>	CALE3	N
Woodrush Sedge	<i>Carex limosa</i>	CALI	N
Mertens' Sedge	<i>Carex luzulina</i>	CALU	N
Muricata Sedge	<i>Carex mertensii</i>	CAME2	N
Beaked Sedge	<i>Carex muricata</i>	CAMU2	N
Holms' Rocky Mountain Sedge	<i>Carex rostrata</i>	CARO2	N
Analogue Sedge	<i>Carex scopulorum</i>	CASC5	N
Sitka Sedge	<i>Carex simulata</i>	CASI2	N
Blister Sedge	<i>Carex sitchensis</i>	CASI3	N
Common Spike-rush	<i>Carex vesicaria</i>	CAVE	N
Few flowered Spike-rush	<i>Eleocharis palustris</i>	ELPA	N
Baltic Rush	<i>Eleocharis pauciflora</i>	ELPA2	N
	<i>Juncus balticus</i>	JUBA	N
Herbs			
Vanillaleaf	<i>Achlys triphylla</i>	ACTR	F
Columbia Monkshood	<i>Aconitum columbianum</i>	ACCO	N
Baneberry	<i>Actaea rubra</i>	ACRU	F
Trail-plant	<i>Adenocaulon bicolor</i>	ADBI	F
Pearly-everlasting	<i>Anaphalis margaritacea</i>	ANMA	F
Threelobed Anemone	<i>Anemone deltoidea</i>	ANDE	F
Sharptooth Angelica	<i>Angelica arguta</i>	ANAR2	F
California Aralia	<i>Aralia californica</i>	ARCA3	F
Sylvan Goatbeard	<i>Aruncus sylvestris</i>	ARSY	F
Alpine Aater	<i>Aster alpinus</i>	ASAL	N
Western Aater	<i>Aster occidentalis</i>	ASOC	N
Santalucia Boykinia	<i>Boykinia elata</i>	BOEL	F
Sierra Boykinia	<i>Boykinia major</i>	BOMA	F
Twinflower Marshmarigold	<i>Caltha biflora</i>	CABI	N
Elkalip Marshmarigold	<i>Caltha leptosepala</i>	CALE2	N
Brewer's Bittercress	<i>Cardamine breweri</i>	CABR2	N
Scarlet Paintbrush	<i>Castilleja miniata</i>	CAMI2	N
Oxeye Daisy	<i>Chrysanthemum leucanthemum</i>	CHLE2	F
Western Water-hemlock	<i>Cicuta douglasii</i>	CIDO	F
Alpine Circaeae	<i>Circaeae alpina</i>	CIAL	F
Canada Thistle	<i>Cirsium arvense</i>	CIAR	F
Bull Thistle	<i>Cirsium vulgare</i>	CIVU	F
Thistle	<i>Cirsium species</i>	CIRSI	F
Columbia River Larkspur	<i>Delphinium trolliifolium</i>	DETR	F/N
Pacific Bleeding Heart	<i>Dicentra formosa</i>	DIFO	F
Ferns and Fern Allies			
Maidenhair Fern	<i>Adiantum pedatum</i>	ADPE	F
Ladyfern	<i>Athyrium filix-femina</i>	ATFI	F
Deerfern	<i>Blechnum spicant</i>	BLSP	F
Mountain Woodfern	<i>Dryopteris austriaca</i>	DRAU2	F
Field Horsetail	<i>Equisetum arvense</i>	EOAR	F
Scouring Rush	<i>Equisetum hyemale</i>	EOHY	F
Giant Horsetail	<i>Equisetum telmateia</i>	EOTE	F
Oak-fern	<i>Gymnocarpium dryopteris</i>	GYDR	F
Licorice Fern	<i>Polypodium glycyrrhiza</i>	POGL4	F
Western Swordfern	<i>Polystichum munifolium</i>	POMU	F
Western Bracken Fern	<i>Pteridium aquilinum</i>	PTAQ	F
COMMON NAME			
Toad Rush	<i>Juncus bufonius</i>	JUBU	N
Drummond's Rush	<i>Juncus drummondii</i>	JUDR	N
Common Rush	<i>Juncus effusus</i>	JUEF	N
Swordleaf Rush	<i>Juncus ensifolius</i>	JUEN	N
Mertens' Rush	<i>Juncus mertensianus</i>	JUME	N
Millet Woodrush	<i>Luzula parviflora</i>	LUPA	F
Small-fruited Bulrush	<i>Scirpus microcarpus</i>	SCMI	N
Congdon's Bulrush	<i>Scirpus congdonii</i>	SCCO	N

COMMON NAME	SCIENTIFIC NAME	ECO-CODE	TYPE
Hooker's Fairybells	<i>Disporum hookeri</i>	DIHO	F
Fairy Lantern	<i>Disporum smithii</i>	DISM	F
Tall Mountain Shooting-star	<i>Dodecatheon jeffreyi</i>	DOJE	N
Great Sundew	<i>Drosera anglica</i>	DRAN	N
Sundew	<i>Drosera rotundifolia</i>	DRRO	N
Alpine Willow-weed	<i>Epilobium alpinum</i>	EPAL	N
Fireweed	<i>Epilobium angustifolium</i>	EPAN	F
Smooth Willow-weed	<i>Epilobium glaberrimum</i>	EPGL	F/N
Watson's Willow-weed	<i>Epilobium watsonii</i>	EPWA	F
Wood Strawberry	<i>Fragaria vesca</i>	FRVE	F
Oregon Bedstraw	<i>Galium oregonum</i>	GAOR	F
Sweet-scented Bedstraw	<i>Galium triflorum</i>	GATR	F
White Bog-orchid	<i>Habenaria dilatata</i>	HADI2	N
Slender Bog-orchid	<i>Habenaria saccata</i>	HASA	N
Common Cow-parsnip	<i>Heracleum lanatum</i>	HELA	F/N
Small-flowered Alumroot	<i>Heuchera micrantha</i>	HEMI	F
White Hawkweed	<i>Hieracium albiflorum</i>	HIAL	F
Slender-stemmed Waterleaf	<i>Hydrophyllum tenuipes</i>	HYTE	F
Trailing St. John's-wort	<i>Hypericum anagalloides</i>	HYAN	N
Common St. John's-wort	<i>Hypericum perforatum</i>	HYPE	F
Wall Lettuce	<i>Lactuca muralis</i>	LAMU	F
Northwest Listeria	<i>Listera caurina</i>	LICA3	F
American Skunk Cabbage	<i>Lysichitum americanum</i>	LYAM	F/N
Common Bogbean	<i>Menyanthes trifoliata</i>	METR	N
Northern Microseris	<i>Microseris boreale</i>	MIBO	N
Tooth-leaved Monkey-flower	<i>Mimulus dentatus</i>	MIDE	N
Common Monkey-flower	<i>Mimulus guttatus</i>	MIGU	F
Lewis' Monkey-flower	<i>Mimulus lewisii</i>	MILE	F/N
Muskplant Monkey-flower	<i>Mimulus moschatius</i>	MIMO	F/N
Oval-leaved Mitrewort	<i>Mitella ovalis</i>	MIOV	N
Miner's Lettuce	<i>Montia perfoliata</i>	MOPA	F
Indian Lettuce	<i>Montia sibirica</i>	MOSI	F
Indian Pond Lily	<i>Nuphar polysepalum</i>	NUPO	N
Sweetroot	<i>Osmorhiza species</i>	OSMOR	F
Oregon Oxalis	<i>Oxalis oregana</i>	OXOR	F
Western Yellow Oxalis	<i>Oxalis suksdorfii</i>	OXSU	F
Great Oxalis	<i>Oxalis trillifolia</i>	OXTR	F
Little Elephant's Head	<i>Pedicularis attolens</i>	PEAT3	N
Bracted Lousewort	<i>Pedicularis bracteosa</i>	PEBR	N
Elephant's Head	<i>Pedicularis groenlandica</i>	PEGR	N
Yampa	<i>Penstemon glandulosus</i>	PEGA2	N
Coltsfoot	<i>Petasites frigidus</i>	PEFR2	F
American Bistort	<i>Polygonum bistortoides</i>	POBI	N
Drummond's Cinquefoil	<i>Potentilla drummondii</i>	PODR	N
Marsh Cinquefoil	<i>Potentilla palustris</i>	POPA3	N
Common Self-heal	<i>Prunella vulgaris</i>	PRVU	F
Plantain-leaf Buttercup	<i>Ranunculus oleraceus</i>	RAAL	N
Gorman's Buttercup	<i>Ranunculus gormanii</i>	RAGO	N
Little Buttercup	<i>Ranunculus uncinatus</i>	RAUN2	F/N
Bitterdock	<i>Rumex obtusifolius</i>	RUOB	F
Bog Saxifrage	<i>Saxifraga oregana</i>	SAOR	N

COMMON NAME	SCIENTIFIC NAME	ECO-CODE	TYPE
Cleft-leaf Groundsel	<i>Senecio cymbalarioides</i>	SECY	N
Woodland Groundsel	<i>Senecio sylvaticus</i>	SESY	F
Arrowleaf Groundsel	<i>Senecio triangularis</i>	SETR	F/N
Common Blue-eyed Grass	<i>Sisyrinchium angustifolium</i>	SIAN	N
Feather Solomon-plume	<i>Smilacina racemosa</i>	SMRA	F
Starry Solomon-plume	<i>Smilacina stellata</i>	SMST	F
Range Woolly-head Parasnip	<i>Sphenosciadium capitellatum</i>	SPCA	N
Continental Ladies' Tresses	<i>Spiranthes romanoffiana</i>	SPRO	N
Cooley's Hedge-nettle	<i>Stachys cooleyana</i>	STCO4	F
Crisped Starwort	<i>Stellaria crispa</i>	STCR	F
Longstalk Starwort	<i>Stellaria longipes</i>	STLO	F/N
Ciaspleaf Twistedstalk	<i>Streptopus amplexifolius</i>	STAM	F
Alaska Fringecup	<i>Tellima grandiflora</i>	TEGR	F
Western Meadowrue	<i>Thalictrum occidentale</i>	THOC	F/N
Coolwort	<i>Tiarella trifoliata</i>	TITR	F
Tofieldia	<i>Tofieldia glutinosa</i>	TOGL	N
Youth-on-age	<i>Tolmiea menziesii</i>	TOME	F
False Bugbane	<i>Troutvetteria carolinensis</i>	TRCA3	N
Northern Starflower	<i>Trientalis arctica</i>	TRAR2	N
Western Starflower	<i>Trientalis latifolia</i>	TRLA2	F
Longstalk Clover	<i>Trifolium longipes</i>	TROV	N
Pacific Trillium	<i>Trillium ovatum</i>	TROV	F
Common Bladderwort	<i>Utricularia vulgaris</i>	UTVU	N
Scouler's Valerian	<i>Valeriana scouleri</i>	VASC2	F
Mountain Heliotrope	<i>Valeriana sitchensis</i>	VASI	N
Inside-out Flower	<i>Vancouveria hexandra</i>	VAHE	F
California False Hellebore	<i>Veratrum californicum</i>	VECA	N
American False Hellebore	<i>Veratrum viride</i>	VEVI	N
American Speedwell	<i>Veronica americana</i>	VEAM	F/N
Marsh Speedwell	<i>Veronica scutellata</i>	VESC	N
American Alpine Speedwell	<i>Veronica wormskjoldii</i>	VEWO	N
Hook Violet	<i>Viola adunca</i>	VIAD	N
Pioneer Violet	<i>Viola glabella</i>	VIGL	F
Macloskey's Violet	<i>Viola macloskeyi</i>	VIMA	N
Marsh Violet	<i>Viola palustris</i>	VIPA2	N
Redwood Violet	<i>Viola sempervirens</i>	WISE	F
Low and Sub-Shrubs			
Oregon Grape	<i>Berberis nervosa</i>	BENE	F
Salal	<i>Gaultheria shallon</i>	GASH	F
Alpine Laurel	<i>Kalmia microphylla</i>	KAMI	N
Western Swamp Laurel	<i>Kalmia occidentalis</i>	KAOC	N
American Twinflower	<i>Linnaea borealis</i>	LIBO2	F
Western Trumpet Honeysuckle	<i>Lonicera ciliosa</i>	LOCI	F
California Dewberry	<i>Rubus ursinus</i>	RURU	F

COMMON NAME SCIENTIFIC NAME ECO-CODE TYPE APPENDIX II SOIL STABILITY CLASSIFICATIONS FOR SRI TYPES

Tall Shrubs

COMMON NAME	SCIENTIFIC NAME	ECO-CODE	TYPE	SRI #	Slope	Rock Type ¹	Stability Class ²
Vine Maple	<i>Acer circinatum</i>	ACCI	F	1	30-100	A, b (r.o.)	S
Rocky Mountain Maple	<i>Acer glabrum</i>	ACGL	F	2	Steep Headwalls	Br (r.o.)	S
Mountain Alder	<i>Alnus incana</i>	ALIN	N	3	0-30	Talus (r.o.)	M
Sitka Alder	<i>Alnus sinuata</i>	ALSI	F/N	4	40-80 +	Lava Flows	S
Saskatoon Serviceberry	<i>Amelanchier alnifolia</i>	AMAL	F	5	Gentle-Slope	Cinder Cones	M
Bog Birch	<i>Betula glandulosa</i>	BEGl	N	6	Ridgetops	Marshy, Boulders	S
Red osier Dogwood	<i>Cornus stolonifera</i>	COST	F	7	Steep	Glacial Cirques	S
Hazelnut	<i>Corylus cornuta</i>	COCO2	F	8	Steep	GBr, RBr	U
Indian Plum	<i>Oemleria cerasiformis</i>	OECE	F	9	0-25	A, B, Br	M
American Devilclub	<i>Oplopanax horridum</i>	OPHO	F	12	0-40	A, B	S
Stink Currant	<i>Ribes bracteosum</i>	RIBR	F	13	15-35	Br, T	M
Currant	<i>Ribes species</i>	RIBES	F	14	0-20	A, B, Br, T	S
Sticky Currant	<i>Ribes viscosissimum</i>	RIVI	F	15	20-70	Al	M
Baldhip Rose	<i>Rosa gymnocarpa</i>	ROGY	F	16	0-45	A, B, Br, T	M
Western Thistleberry	<i>Rubus parviflorus</i>	RUPA	F/N	17	60-90	Br	M
Salmonberry	<i>Rubus spectabilis</i>	RUSP	F	18	0-20	RBr, T	U
Undergreen Willow	<i>Salix commutata</i>	SACO	N	19	0-20	RBr, T	S
Geyer's Willow	<i>Salix geeyeriana</i>	SAGE	N	20	15-40	Br, T	M
Hooker's Willow	<i>Salix hookeriana</i>	SAHO	F	21	60-90	T, GBr	U
Pacific Willow	<i>Salix lasiandra</i>	SALA2	F	22	20-60	GBr, T	M
Blueberry Willow	<i>Salix myrtillofolia</i>	SAMY	N	23	5-40	Br	M
Scouler's Willow	<i>Salix scouleriana</i>	SASC	F	24	35-65	Br, A, B	M
Sitka Willow	<i>Salix sitchensis</i>	SASI2	F	25	40	Br, T	M
Blueberry Elder	<i>Sambucus cerulea</i>	SACE	F	26	0-30	A	S
European Red Elder	<i>Sambucus racemosa</i>	SARA	F	27	30-80	A	S
Sitka Mountain Ash	<i>Sorbus sitchensis</i>	SOSI	F	28	60-90 +	Lava Flows	M
Subalpine Spirea	<i>Spiraea densiflora</i>	SPDE	N	29	0-35	A, B	M
Douglas Spirea	<i>Spiraea douglasii</i>	SPDO	N	30	40-80	A, B	S
Alaska Blueberry	<i>Vaccinium alaskaense</i>	VAAL	F	31	0-40	A, B	S
Western Bog Blueberry	<i>Vaccinium occidentale</i>	VAOC2	N	32	30-40	A, B	S
Red Whortleberry	<i>Vaccinium parvifolium</i>	VAPA	F	33	45-90	A, B	M

Trees

Grand Fir	<i>Abies grandis</i>	ABGR	F	34	0-30	A	S
Subalpine Fir	<i>Abies lasiocarpa</i>	ABLA2	F	35	30-80	A	S
Bigleaf Maple	<i>Acer macrophyllum</i>	ACMA	F	36	60-90 +	Lava Flows	M
Red Alder	<i>Alnus rubra</i>	ALRU	F	37	0-35	A, B	M
Pacific Dogwood	<i>Cornus nuttalli</i>	CONU	F	38	40-80	A, B	S
Mountain Ash	<i>Fraxinus latifolia</i>	FRLA2	F	39	0-40	A, B	S
Incense Cedar	<i>Libocedrus decurrens</i>	LIDE2	F	40	30-40	A, B	S
Englemann Spruce	<i>Picea engelmannii</i>	PIEN	F	41	0-30	A, B	S
Quaking Aspen	<i>Populus tremuloides</i>	POTR2	F	42	45-90	A, B	M
Black Cottonwood	<i>Populus trichocarpa</i>	PSME	F	43	0-30	A, B	S
Douglas Fir	<i>Pseudotsuga menziesii</i>	RHPU	F	44	35-55	A, B	S
Cascade Buckthorn	<i>Rhamnus purshiana</i>	TABR	F	45	0-35	A, B	M
Pacific Yew	<i>Taxus brevifolia</i>	THPL	F	46	40-90 +	A, B	S
Western Red Cedar	<i>Thuja plicata</i>	TSHE	F	47	0-30	A, B	S
Western Hemlock	<i>Tsuga heterophylla</i>		F	48	0-15	A, B	M
				49	55-90 +	A, B	S

SRI #	Slope	Rock Type ¹	Stability Class ²
93	0-40	A,B	S
94	35-60	A,B,Br	S
95	0-35	A,B,Br	S

Rock Types: A = Andesite; Al = Alluvium; B = Basalt; Br = Breccia; GBr = Green Breccia; RBr = Red Breccia; r.o. = rock outcrop; T = Tufts
Stability Classes: S = Stable; M = Moderately stable; U = Unstable

ADDITIONAL SRI TYPE STABILITY CLASSIFICATIONS

SRI #	Stability	Description
142	Stable	Gentle slopes (<60%) of any rock; or
143		moderate slopes (40-60%) with hard rock
563		(basalt, andesite flows); or
564		rock outcrops
646 - 741		
821 - 852	Moderately Stable	Steep slopes (>60%) with hard rock; or
920 - 954		moderate slopes with soft bedrock (tuffs and breccias)
All SRI types not listed as Stable or Unstable		
168	Unstable	Steep slopes on soft bedrock types
212		
213		
214		
216		
301 - 305		
332		
603		

APPENDIX III

ELEMENTS OF MONITORING PROGRAMS

This appendix is intended to be a starting point for the development of a riparian monitoring system for the WNF, not an exhaustive list of components. Questions outlined below are among the more critical, but riparian monitoring may be require additional information to meet both broad and specific situations.

POST-PROJECT

The monitoring components of this level of evaluation include administration, layout, stream channel, vegetation, fisheries and wildlife.

Administration

Prescription

Were the Environmental Assessment and prescriptions appropriate for the specific sites?
Was the site evaluated on the ground?

Were all objectives of riparian area management fully considered, from floodplain function to wildlife habitat to recreation use?

Were WNF Standards and Guidelines implemented?

Does the prescription meet or exceed the intent of the standards and guidelines?

Were Environmental Assessment and prescriptions written to comply with objectives for all levels of riparian function (i.e., site, basin and landscape)?

Were recommendations of biologists, hydrologists, ground crews incorporated?

Timing

Was adequate time allowed for completing Environmental Assessments and developing prescriptions?

Harvest Unit Layout

RMZ boundaries

Do the boundaries present after harvest meet those specified in the prescription?

Do they follow natural topographic contours?

Do they meet specified horizontal widths?

Are side channels included in the active channel?

Floodplain

Are floodplains included in the RMZ?

Roads and Landings

Are road crossings at least 200 feet apart or as specified in the prescription?

Were methods used for road construction sufficient to minimize erosion and delivery of sediments to the stream, lake, or wetland?

Are roads constructed to prevent failure during heavy rains?

Are landings located to prevent failure?

Do distances to landings minimize cable corridor area?

<p>Suspension and Yarding Were corridors located away from stable debris accumulations in the channel and floodplain? Was there significant damage to buffer strip vegetation? Were appropriate volumes of downed woody debris left in cable corridors?</p> <p>Timing Were construction activities in and adjacent to the riparian area timed to limit seasonal inputs of sediment? Were impacts on fish spawning considered in determining when operations would occur? Did construction activities meet prescribed timing restrictions?</p> <p>Blowdown Did blowdown of riparian vegetation occur? What proportion of the buffer blew down? Did the blowdown occur in vegetation on wet soils (poor rooting)? Did the trees fall into the stream, lake, wetland, floodplain? Are the trees that fell into the channel or floodplain in stable configurations? Are blowdown logs providing potential fish or wildlife habitat? Were natural windbreaks used effectively?</p> <p>Viewsheds Does the RMZ configuration maintain viewsheds from significant travel or recreation aspects?</p> <p>Channel Floodplain Is the entire floodplain included in the RMZ? If floodplain width exceeds 400 feet (horizontal), was the area beyond the RMZ managed in accordance with Executive Order 11988?</p> <p>Bank Stability Are there firmly rooted trees adjacent to stream banks and shorelines?</p> <p>Woody Debris Do the woody debris levels in the channel and on the floodplain meet or exceed amounts needed for riparian area objectives? If the channel was deficient in LWD, was wood from suspension corridors placed at appropriate locations?</p> <p>Stream Cleanout Was stream cleanout avoided? Is large woody debris present before harvest still in place? Was stream cleanout of logging slash limited to high risk areas?</p> <p>Stream Temperature Do water temperatures at summer low flows meet Oregon DEQ standards?</p>	<p>Vegetation Canopy Is there still a multi-layered canopy present in the RMZ? Does it provide shade to channel and floodplain? Was it damaged during operations?</p> <p>Understory Is the understory vegetation still intact and diverse? If no canopy remains, does understory vegetation provide shade and bank stability?</p> <p>Buffer Damage Was there damage to buffer strip vegetation? Was the damage to the edges of the buffer, the interior, or the canopy?</p> <p>Snags and Downed Logs Were snags and downed logs present before operations left in place? Did the distributions and numbers meet or exceed values required to meet objectives for riparian wildlife habitat?</p> <p>Fisheries Presence/Absence Are there fish actually present in streams designated Class I and II? Are fish really absent from streams designated Class III or IV? Are sensitive fish species present?</p> <p>Wildlife Are beaver dams present before operations still intact? Were wildlife migration corridors maintained?</p> <p>REFERENCE SUB-DRAINAGES Layout Salvage Has salvage of woody debris occurred in the stream channel, floodplain, or lake shore? Has salvage reduced woody debris below levels needed to maintain full channel and floodplain function? If riparian vegetation or debris has been salvaged, what were the objectives of salvage for riparian-dependent resources?</p> <p>Blowdown Did blowdown of riparian vegetation occur? Did the blowdown extend up the hillslope? How extensive is the blowdown? Did blowdown occur on wetted soils (poor rooting)? Is there evidence of sediment delivery to the channel after blowdown? Are downed trees in places or do they still have attached rootwads?</p>
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Are the trees in stable configurations?

In the years after blowdown:

Does the woody debris remain or does it move downstream?

Does the downed wood provide appropriate bank protection, fish and wildlife habitat, and sediment and water storage?

Channel

Although the objectives and location of sampling may differ, the techniques for this portion of benchmark monitoring are essentially the same as for the basin survey.

Morphology

Is there a single, simple stream channel, or does it braid, with split channels?

Are there side channels, isolated pools, or backwaters present?

What is the sequence of channel units?

What are the estimated dimensions (length, widths, depths) of each channel unit?

What is the percent slope of each channel unit?

What are the morphometric characteristics of the lake (e.g., shoreline, shoreline development, mean depth, maximum depth, surface area, fetch, volume development)?

Floodplain

Is there a floodplain present, or is the stream confined to a narrow canyon?

How wide is the valley floor?

Is the stream channel constrained by hillslopes, terraces, or roads?

Are there terraces present on either or both sides of the stream?

What are the approximate heights of these terraces?

Substrates

What are the dominant substrates in each channel unit?

Are the substrates embedded?

How many large boulders are present in each channel unit?

Are there spawning gravels present; if so, what area do they cover?

Bank Stability

Is there strongly rooted vegetation along the stream or lake?

Is there woody debris present to provide bank stability?

Is there evidence of landslides or bank slumping?

Woody Debris

How much woody debris is present (number of pieces and volumes)?

What are the size classes (length and diameter) of wood?

Are there large stable accumulations of debris, such as full channel debris jams or lateral accumulations?

Is the wood in jams, accumulations, or single pieces?

Do the pieces of wood still have rootwads attached?

Is the wood in the stream anchored on the bank?

What is the length of most of the wood relative to the stream width?

How do the amounts of wood compare between managed and undisturbed riparian areas?

Do they differ in volume, number or size of pieces?

Vegetation

Composition

What species are present?

Are there any rare, threatened, or endangered species?

Are there unique plant associations indicative of wetlands?

How are plant species distributed spatially?

Do the species present provide structural complexity, both horizontally and vertically?

Does species composition change significantly in areas of scour versus deposition? In broad valley floors versus narrow canyons?

Density

How many of each species are present in the canopy and understory layers?

What are the approximate sizes and ages of the dominant woody species?

How do valley floor width and degree of scour versus deposition affect density of woody species?

Canopy

How many canopy layers are there?

Is the canopy completely closed or are there light gaps?

What is the approximate percent of coniferous and deciduous canopy cover over the stream or lake?

Understory

How diverse and dense is the understory vegetation?

Is its morphology predominantly shrubby or herbaceous?

How does it change with increasing distance from the stream or lake?

Snags and Downed Logs

How many snags and downed logs are present?

How are they distributed spatially?

Regeneration

Are there signs of regeneration of the major structural species (e.g., Douglas fir, hemlock, Western red cedar).

If so, what species are recruiting and how many of each?

If not, are there any particular reasons?

In riparian management zones, is there any indication of regeneration from within the buffer itself, or from leave trees nearby?

Fisheries

Presence/Absence

Are there fish actually present in streams designated Class I and II?

What species are observed?

Are fish really absent from streams designated Class III and IV?

Are there any rare, threatened, or endangered species?

Abundance

How many individuals of each species were counted?

What size were they?

Wildlife

Wildlife monitoring in riparian areas is technically and logistically difficult, generally expensive, and often provides comparatively little information for the amount of effort. Consequently, wildlife populations at the intensive benchmark sites should be assessed on a case-by-case basis. Assumptions of the amount and quality of habitat available may be based on characteristics of the riparian vegetation. Riparian areas with diverse structural components and a complex array of plant species may provide relatively good wildlife habitat. This type of analysis presumes that enough is known about the habitat requirements of each species to make such an assumption. For most riparian wildlife species this is not true. Species of particular interest or concern may be evaluated as part of this level of monitoring. Should resources become available, methods such as transect surveys in spring for riparian birds, pit trap lines for small mammals, reptiles and amphibians, or tagging of larger mammals or birds may be useful. However, because so little is known about the basic biology of most riparian species, a monitoring approach may not be appropriate.

Are there any rare, threatened, or endangered species?

Species Analysis: See above.

Beaver Dams

Are beaver dams present?

Are there indications they are being maintained?

Rehabilitation

Was focus of rehabilitation effort through silviculture or through in-channel modification?

Silviculture Rehabilitation

Has the effort provided a taxonomically diverse plant community?

Is there now a structurally complex plant assemblage?

Has stream shading been provided?

Are there appropriate densities to provide long and short-term small and large wood inputs to the channel and floodplain?

Channel Rehabilitation

Does the material added to the channel perform high or low flow functions or both?

If hydraulic change was an objective, have there been desired changes in channel morphology or position within the floodplain?

Has the material provided additional bank and channel stability?

If fish habitat was an objective, does the project provide relatively stable end complex fish habitat?

If added materials are no longer in their original position, how have they changed? What

caused the shift or movement?

If they moved, how far downstream? Are they still performing a channel, floodplain or fisheries function?

BASIN SURVEY

Channel

Morphology

Is there a single, simple stream channel, or does it braid, with split channels?
Are there side channels, isolated pools, or backwaters present?
Identify the sequence of channel units: what are their dimensions (length, widths, depths).

Floodplain

Is there a floodplain present, or is the stream confined to a narrow canyon?
How wide, approximately, is the valley floor?
Is the active channel deeply incised within the floodplain?
Is the stream channel constrained by hillslopes or roads?

Substrates

What are the dominant substrates in each channel unit?
Are the substrates embedded?
Are there spawning gravels present; if so, what area do they cover?

Bank Stability

Is there strongly rooted vegetation along the stream?
Is there woody debris present to provide bank stability?

Woody Debris

How much woody debris is present?
What size classes (length and diameter) is the wood?
Are there large stable accumulations of debris, such as full channel debris jams or lateral accumulations?
Is the wood in jams, accumulations, or single pieces?
Do the pieces of wood still have rootwads attached?
Is the wood in the stream anchored on the bank?
What is the length of most of the wood relative to the stream width?
How do the amounts of wood compare between managed and undisturbed riparian areas?
Do they differ in volume, number or size of pieces?

Vegetation

Composition

What is the dominant vegetation type and size immediately adjacent to the stream?

Fisheries

Abundance

What species of fish were observed in each channel unit?
How many of each species?
What is the approximate length of each individual?

APPENDIX IV WILLAMETTE NATIONAL FOREST STANDARDS AND GUIDELINES FOR MANAGEMENT AREA 15

Source: Willamette National Forest Land and Resource Management Plan

Emphasis: Rivers, Streams, Wetlands, Lakes and Adjacent Riparian Areas

Management Goal

The primary goal in this management area is to maintain the role and function of rivers, streams, wetlands and lakes in the landscape ecology. A significant part of this goal is to manage the vegetation in the adjacent riparian areas for:

- protection and rehabilitation of the aquatic and terrestrial riparian habitat;
- maintenance and improvement of water quality while minimizing risks of downstream flooding;
- management of riparian areas as corridors to provide dispersal habitat for plant and animal species by maintaining connectivity among mature and old growth stands of trees;
- management and inventory of riparian areas for sensitive, threatened and endangered plant and animal species;
- management of riparian areas for recreation and scenic use compatible with riparian dependent species;
- monitoring the impacts of upland management activities on the health and function of the riparian ecosystem.

Desired Future Condition

This management area will provide a continuous and diverse habitat for riparian dependent species and high quality water by protecting and mapping wetlands and floodplains. The water bodies and associated riparian areas will contribute to the diversity and dispersion of fish, wildlife and plants within each subdrainage and also at the larger watershed level. This management area will also provide opportunities for public use and enjoyment through both dispersed and developed recreation management. The recreation uses will be managed to avoid or mitigate adverse effects on riparian dependent resources.

Stream channels will provide diverse, stable habitat for aquatic species as well as maintaining or enhancing water quality. Vegetation on adjacent lands will be managed to provide diverse stands of conifer and hardwood vegetation which provide habitat for riparian dependent species. The amount of large woody debris, both down and standing will be maintained at or above current levels. In areas where this material has been depleted as a result of past harvesting, the amount will increase either through rehabilitation projects, as a result of natural mortality of trees, or both. Along larger rivers and streams, optimal thermal cover for big game will be provided.

Description

Wildlife

Beaver Dams

Are beaver dams present?
What are the dimensions of the dams?

Corridors

Are riparian areas used as corridors for migration?

WATER QUALITY NETWORK

Temperature

Do summer low flow temperatures in all fish-bearing streams meet Federal and State Water quality Standards?

Suspended Sediment

Do levels of suspended sediment and turbidity comply with Federal and State Water Quality Standards?

Chemistry

Do dissolved levels of important nutrients (e.g., ammonium, nitrate, phosphorus) or toxic substances (e.g., forest chemicals) meet Federal and State Water Quality Standards?

This management area includes the bed, banks, and water column of rivers, streams, wetlands and lakes as well as the adjacent land areas. A riparian area is the adjacent land where vegetation and microclimate are influenced by the stream or lake and the associated high water table. It includes the adjacent land which directly influences the shading and input of large and small organic material to the streams.

In addition, this area generally includes ponds, bogs, wet meadows and other areas identified in the Federal Manual for Identifying and Delineating Jurisdictional Wetlands and in the Classification of Wetlands and Deepwater Habitats of the United States.

Additional description of the resource values, objectives and operational considerations for this management area are found in the Willamette National Forest Riparian Management Field Guide.

Standards and Guidelines

Riparian Management

MA-15-01 The width of the riparian management area shall be identified by an on-site reconnaissance of topographic and biotic features and shall be based on the watershed objectives for fish and wildlife habitats, water quality, and recreation.

MA-15-02 This management area shall include the 100-year floodplain within 400 feet from the edge of the active channel. Any portion of the 100-year floodplain extending beyond 400 feet should not be included in this management area, but shall be managed in accordance with Executive Order 11988.

MA-15-03 Widths that should be considered when determining the management area boundaries are shown below. Exceptions to this range should be documented in project records or environmental assessments. Wider areas may be designated to allow protection of riparian stands from wind, to use logical topographic, biological or road boundaries. Narrower areas are anticipated only in exceptional situations.

Perennial Streams	Horizontal Width
Class I	150 - 400 feet
Class II	100 - 200 feet
Class III - Stable	50 - 100 feet
Class III - Potentially highly unstable & moderately stable	75 - 125 feet
Intermittent Streams	
Class IV - Moderately Stable	25 - 50 feet
Class IV - Potentially highly unstable	25 - 100 feet
Lakes	600 feet
Reservoirs	N/A
Small Wetlands	150 - 600 feet

MA-15-04

This management area does not include areas adjacent to reservoirs. Management of areas adjacent to reservoirs should follow direction of Forest-wide S&G for water quality and other resources and management area S&G as allocated.

MA-15-05

The following process shall be used when projects or management activities have the potential to create long term, short term, or cumulative adverse effects to the values of the rivers, streams, wetlands, lakes and adjacent riparian areas:

1. Locate the management area using the following criteria;

Within the 100 year floodplain (less than 400 feet from active channel);
Occupied by water tolerant vegetation;
Having vegetation potentially capable of shading or contributing organic small matter to the water body;
Having vegetation that contributes significantly to bank stability.
Incorporate natural irregularities of topography and consider recreation and wildlife use patterns.
Required to provide large woody material to the water body.

2. Identify the beneficial uses, values and objectives for the area. (See Appendix E, Watershed) Wetland and riparian area values and objectives should be established on a subdrainage area or larger, and should address connectivity of riparian habitat and the influence on downstream effects.

3. Identify the effects of proposed actions on the following:

Public health, safety, and welfare, including water supply, quality, recharge, and discharge; pollution; flood and storm hazards; and sediment and erosion;

Maintenance of the natural systems, including conservation and long term productivity of existing flora and fauna, species and habitat diversity and stability, hydrological utility, fish, wildlife, timber;

Other uses of wetlands in the public interest, including recreational, scientific, and cultural uses. (See EO 11990)

4. Assess necessary actions to preserve the beneficial values, and to reduce or mitigate loss of wetlands by giving preferential consideration to riparian dependent resources when conflicts occur among land uses. (See FSM 2526 03)

5. Develop a riparian prescription that documents the objectives and actions to be implemented (including contract clauses and language as appropriate) in the riparian management area.

6. Monitor location and effects, and track results through appropriate databases.

Management practices shall be designed to prevent detrimental changes in water temperature or chemical composition, blockage of water courses, or sedimentation within riparian areas which seriously and adversely affect water conditions or fish habitat. (36 CFR 219.27(e)).

Water Quality

- MA-15-06** Vegetation will be managed to provide water temperatures which protect beneficial uses, as described in Oregon Administrative Rules 340-41-422.
- MA-15-07** All project proposals in the Salmon Creek and Marion Creek watersheds shall include an objective to improve water quality. A major part of this objective will be to maintain (Marion Creek) or reduce (Salmon Creek) maximum summer water temperatures that are 70 degrees F or less by 1995, and 67 degrees F by 2000. These watersheds are the water source for State of Oregon fish hatcheries.
- MA-15-08** At least 75% of the existing shade should be maintained.
- MA-15-09** Activities with potential effects on Class III and IV streams shall be scheduled and designed to maintain or improve water quality in downstream Class I and II waters.
- MA-15-10** Projects shall be designed using BMPs to meet Oregon State Water Quality Standards. Refer to General Water Quality Best Management Practices, Pacific Northwest Region, 1988 and Appendix E, Watershed for further information on BMPs.
- MA-15-11** Streambanks and channel stability shall be protected, rehabilitated or enhanced to meet the water quality and aquatic habitat objectives.
- MA-15-12** Management in riparian areas shall provide for a continued input of large woody debris at rates similar to those in areas without past timber removal. Large wood will reduce the movement of debris torrents through channels and provide channel stability. Channel stability will also be maintained through measures listed in Forest-wide Standards and Guidelines for Water Quality.
- MA-15-13** The value and functioning of floodplains shall be protected, rehabilitated or enhanced. Floodplains are valuable for reducing stream velocity and temporarily storing water during high flow events.

Wildlife and Fish Management

- MA-15-14** Project activities within or adjacent to riparian areas shall protect, rehabilitate, or enhance streams to provide high quality habitat for a diversity of native aquatic species. Management indicator species for riparian areas are resident and anadromous salmonids.
- Stable, diverse habitat for salmonids can be achieved with the following:
- Large wood: Diameter and length of woody pieces may vary according to the stream width and gradient; pieces larger than 25 inches in diameter are

generally preferred. Large wood in the stream will provide a variety of habitat and nutrient characteristics.

Pools: A primary pool every 5 to 7 channel widths in streams with less than a 2% gradient and every 3 to 5 channel widths in streams with a 2 to 8% gradient provides rearing habitat during summer low flows.

Substrate: A well sorted variety of gravels, cobbles and boulders, with less than 20% of spawning gravels in fines (< 1.0mm), and less than 25% embeddedness of cobbles in riffle areas provide salmonid and invertebrate spawning and rearing habitat.

Floodplain: Stable, vegetated floodplains provide areas of slow water and refuge habitat during high flow events.

Food source: Year-round input of leaf, needle, and insect material from a variety of species provide a variety of food sources for salmonids and invertebrates.

MA-15-15

Habitat rehabilitation or enhancement projects should be identified and evaluated in areas adversely affected by past events. Project proposals should consider long-term maintenance needs and should be monitored for effectiveness.

MA-15-16

Habitat for riparian dependent terrestrial species shall be protected, rehabilitated, or enhanced. Factors to consider include microclimate, vegetation, and downed woody material.

MA-15-17

Where designed to provide connectivity and dispersion, greater than 10 live, overstory trees per acre and 15 down trees per acre greater than 24 inches DBH should be maintained. This also provide down woody debris cover for small mammals, amphibians and reptiles.

MA-15-18

Habitat potential for cavity excavator species should be at least 80% of the potential population habitat in riparian areas. (See Forest-wide Wildlife Standards and Guidelines).

Recreation Management

MA-15-19

Area management practices should result in a physical setting that meets or exceeds the ROS class of Roded Natural.

MA-15-20

Developed recreation and dispersed recreation sites should be compatible with riparian dependent resource objectives.

MA-15-21

Projects to reduce safety hazards from dead, defective or hazardous trees in riparian areas should be evaluated to ensure adverse effects to riparian dependent resources are recognized and mitigated. This includes trees currently in river or stream channels and standing dead trees adjacent to trails or other recreation facilities.

MA-15-22 Water withdrawn from streams or lakes for recreation facilities shall have no adverse effects on riparian dependent resources.

Scenic Resources

MA-15-23 All design and implementation practices should be modified as necessary to meet the VOO of Partial Retention. In the event that unregulated harvest is necessary to salvage timber within the area, practices should be employed in a manner that seeks to achieve a VOO of Modification.

Timber Management

MA-15-24 No programmed harvest shall be scheduled.

MA-15-25 Salvage harvests should occur only when existing conditions are detrimental to riparian condition and riparian dependent resources. (See Forest-wide Standard and Guideline, Changed Environmental Conditions.)

MA-15-26 A riparian prescription shall determine if trees need to be felled to maintain or enhance riparian objectives, if trees may be felled to facilitate activities in adjacent management areas, and if felled trees should be removed from the area. Riparian objectives are commonly met if yarding corridors through the area are spaced at least 200 feet apart.

MA-15-27 Streambanks shall be protected by directional felling and suspending logs above streambanks adjacent to live water during yarding, and by using appropriate road design techniques where roads might impact streambanks. On streambanks adjacent to dry stream channels, logs will be fully suspended and directionally felled where practicable. Where it is not practicable, streambanks will be stabilized following yarding activities, and prior to stream flows in the channels.

MA-15-28 Silvicultural prescriptions for existing regenerated stands within riparian areas shall be designed to achieve riparian objectives.

MA-15-29 Silvicultural prescriptions should be developed for riparian areas affected by past harvest activities or catastrophic events to reestablish stands that provide a mixture of hardwood and conifer species similar to undisturbed sites.

MA-15-30 Application of fertilizer to the riparian area, and to live water should occur only when prescribed to meet riparian terrestrial or aquatic objectives.

Fire Management

MA-15-31 Suppression strategies, practices and activities shall have minimal effects on objectives for water quality, aquatic and terrestrial wildlife and plant species, recreation, and visual resources.

MA-15-32 Fuel treatment prescriptions should protect streamside vegetation and maintain the vegetation and woody debris necessary for channel stability.

Minerals and Energy

MA-15-33 Mineral management shall be compatible with riparian resource management goals. Aquifers and downstream resources shall be protected as well as the immediate riparian resource.

Lands

MA-15-34 On lands considered for exchange a floodplain and wetland determination and assessment of impacts, with public notice shall be made. Acquisition of wetlands that may be of significant wildlife, fisheries or recreation values shall be encouraged.

MA-15-35 Special use applications should show compatibility with management area objectives before approval.

Facilities

MA-15-36 New roads should be planned to minimize effects on riparian areas. Projects should be evaluated as to which location will most likely meet riparian objectives. Locating roads outside of riparian areas is preferred when possible.

MA-15-37 Where stream crossings are necessary for access, a crossing location should be selected which will best meet riparian objectives.

MA-15-38 Construction and reconstruction of crossings or habitat improvements projects on fish bearing streams should allow for passage of both adult and juvenile fish during appropriate times of the year.

MA-15-39 Deposits of sediment (silts and clays) in detrimental amounts shall be prevented during road construction and maintenance activities, and during periods of road closures. Road surface maintenance will use materials and methods designed to minimize sediment and deleterious chemicals.

MA-15-40 Temporary roads constructed to facilitate rehabilitation and enhancement projects shall be compatible with riparian objectives, and should be closed following project completion.

Range Management

MA-15-41 Domestic livestock grazing should not be permitted.

APPENDIX V RELATIONSHIPS BETWEEN HORIZONTAL AND SLOPE DISTANCES

Table V.1. Side slope distances for riparian management zones (RMZ) on different hillslope angles and selected RMZ horizontal distances.

Slope (Percent)	Slope Distances			
	50-ft RMZ	100-ft RMZ	150-ft RMZ	200-ft RMZ
10	50 ft	100 ft	150 ft	200 ft
15	51	101	152	202
20	51	102	153	204
25	52	103	155	206
30	52	104	156	208
35	53	106	159	212
40	54	108	162	216
45	55	110	165	220
50	56	112	168	224
55	57	114	171	228
60	59	117	176	234
65	60	119	179	238
70	61	122	183	244
75	63	125	188	250
80	64	128	192	256
85	66	131	199	262
90	68	135	203	270
100	71	141	212	282
110	75	149	224	298
120	78	156	234	312
130	82	164	246	328
140	86	172	258	344
150	90	180	270	360
160	95	189	284	378
180	103	206	309	412
200	112	224	336	448

To use this table, first determine the width of the prescribed riparian management zone; this dimension will be in *horizontal* feet. Next, ascertain the actual percent slope of the stream, and adjust the slope distance of the RMZ accordingly. For example, on a Class III stream where hillslopes are 50%, a prescribed RMZ of 100 horizontal feet will actually extend 112 feet from the edge of the active channel up the hillslope. Conversions from slope estimates in percent to degrees (and vice versa) and the impact on horizontal distances follow in Tables V.2 and V.3.

Table V.2. Relationship between distance of side slope and hillslope angle expressed as percent slope.

Slope (Percent)	Slope (Degrees)	Percent of Horizontal Distance
5	2.9	100.1%
10	5.7	100.5%
15	8.5	101.1%
20	11.3	102.0%
25	14.0	103.1%
30	16.7	104.4%
35	19.3	105.9%
40	21.8	107.7%
45	24.2	109.7%
50	26.6	111.8%
55	28.8	114.1%
60	31.0	116.6%
65	33.0	119.3%
70	35.0	122.1%
75	36.9	125.0%
80	38.7	128.1%
85	40.4	131.2%
90	42.0	134.5%
100	45.0	141.4%
110	47.7	148.7%
120	50.2	156.2%
130	52.4	164.0%
140	54.4	172.0%
150	56.3	180.3%
160	58.0	188.7%
180	60.9	205.9%
200	63.4	223.6%

Table V.3. Relationship between distance of side slope and hill slope angle in degrees.

Slope (Degrees)	Slope (Percent)	Percent of Horizontal Distance
2.5	4.4	100.1%
5.0	8.8	100.4%
7.5	13.7	100.9%
10.0	17.6	101.5%
12.5	22.2	102.4%
15.0	26.8	103.5%
17.5	31.5	104.8%
20.0	36.4	106.4%
22.5	41.4	108.2%
25.0	46.6	110.3%
27.5	52.1	112.8%
30.0	57.7	115.4%
32.5	63.7	118.6%
35.0	70.0	122.0%
37.5	76.7	126.0%
40.0	83.9	130.5%
42.5	91.6	135.6%
45.0	100.0	141.4%
47.5	109.1	148.0%
50.0	119.2	155.6%
52.5	130.3	164.3%
55.0	142.8	174.3%
57.5	157.0	186.1%
60.0	173.2	200.0%

Physical Processes in Watersheds

Presenter: Julia Jones, Oregon State University

Hillslope and Channel Processes in Forested Landscapes

I. Factors affecting timing and magnitude of flood events, mass movement, channel changes:

A. Type, amount and timing of precipitation

1. Rain
2. Snow

B. Storage and transport of water in

1. Vegetation
2. Soils
3. Hillslopes
4. Hollows
5. Channels

C. Concept of water budget:

Inputs-Outputs = Change in storage

II. Water budgets can be constructed at a range of spatial, temporal scales:

A. Tree

1. Interception
2. Stemflow
3. Throughfall
4. Canopy evaporation
5. Transpiration

B. Soil

1. Properties of polar water molecule
2. Cohesion/adhesion
3. Water held by capillary, osmotic and gravitational forces.
4. Saturation, field capacity, wilting point
5. Infiltration
6. Porosity
7. Permeability
8. Role of soil texture
9. Role of soil horizons, impermeable layers

C. Hillslope

1. Overland flow
2. Saturated subsurface flow
3. Unsaturated subsurface flow
4. Saturated overland flow
5. Groundwater, water table
6. Role of impermeable layers
7. Macropores

- D. Zero-order basin (hollow) (Pierson, Dunne, Dietrich)
 - 1. Flow concentration, divergence
 - 2. Hollows
 - 3. Variable source area
- E. First-order channel
 - 1. Open channel flow
 - 2. Hyporheic zone
 - 3. Hydrograph
 - 4. Valley floor width
 - 5. Channel slope

III. Fluvial Geomorphology (work of Gordon Grant)

- A. Variety of units of different spatial scales
 - 1. Channel unit
 - 2. Reach
- B. Stream channel classifications
 - 1. Channel slope
 - 2. Type of bed - bedrock, sediment
- C. Major types of channels in forested landscapes of Western Oregon
 - 1. Steep ($>2\%$), bedrock-controlled or boulder-bed first-order channels
 - 2. Less steep, pool-riffle higher-order channels

IV. Sediment budgets and sediment movement on hillslopes, in channels (work of F.J. Swanson)

- A. Depend on
 - 1. Prior, immediate water content and temperature
 - 2. Inherent features of landforms, soils
- B. Types
 - 1. Slow, relatively constant
 - a. Soil creep
 - b. Sheetwash erosion (rare in Western Oregon)
 - 2. Faster, more episodic
 - a. Earthflows
 - b. Streamside slides
 - c. Gullies- new channels (ditches and culverts draining forest roads in W. Oregon)
 - 3. Most rapid, episodic
 - a. Debris slides (associated with forest roads in Western Oregon)
 - b. Debris flows
- C. Effects
 - 1. Removal of vegetation
 - 2. Movement of large wood
 - 3. Sediment transport
 - 4. Channel Morphology

Physical Processes in Watersheds

Presenter: Julia Jones, Oregon State University

Management Effects on Hillslopes and Channels in Forested Landscapes

- I. Effects of clearcutting and roads on peak flows (work of Julia Jones, Gordon Grant)
 - A. In small basins
 1. 100% clearcutting and 25% clearcut with roads both increase peaks by up to 50% in first 5 years after treatment
 2. Peak flows are still 25% higher than pre-treatment 25 yrs after treatment
 - B. In large basins
 1. Cumulative cutting at rates of 0.25 to 1%/year with forest roads in public forest lands has increased peak flows by up to 30% of 1-yr flow.
- II. Effects of clearcutting and roads on low flows (work of Hicks et al, Julia Jones, Gordon Grant)
 - A. In small basins
 1. 100% clearcutting and 25% clearcut with roads both increase lowflows by ?% in first 5 years after treatment
 2. Lowflows recover to pre-treatment within 5 years
 3. Lowflows may decline to significantly lower than pre-treatment levels within 10 -15 years after treatment, depending on relative recovery rate of conifers, shrubs, and riparian (alder) canopy
 - B. In large basins (?? To be determined)
- III. Effects of clearcutting and roads on hillslope processes (work of F.J. Swanson)
 - A. Small basins
 1. Debris sliding along roads is up to 100 times higher than background forest rate.
 2. Debris sliding in clearcuts is approximately 3 times higher than background forest rate
 - B. Landscape
 1. Debris sliding rate may be 25% higher in clearcut, roaded landscape (assuming 80 year rotation) than in forested landscape with 200 yr fire rotation (assuming 10 yr duration of debris slide effects in both cases)

IV. Effects of clearcutting and roads on channels, riparian process and function (work of Gordon Grant)

A. Small, first-order, steep bedrock or boulder-bed channels

1. Peak flow effects likely to be felt only for >25 yr return period events due to sediment limitation. Hence we hypothesize (but have not demonstrated) small peak flow effects on riparian process and function
2. Low flow effects are short-term, similar to those created by a severe fire.

B. Larger, higher-order, more gently sloped channels

1. Effects likely to be felt for smaller, perhaps 1 to 5 yr return period events which can modify channel morphology. Hence we hypothesize (but have not demonstrated) moderate to possibly large peak flow effects on riparian process and function in terms of higher rates of bed turnover, riparian vegetation turnover, wood movement.
2. Low flow response not yet identified.

CAPABILITY, POTENTIAL NATURAL CONDITION AND
FUTURE DESIRED CONDITION

Don Prichard
Service Center, SC-213
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Section V

Capability, Potential Natural Condition, and Desired Future Condition of a Riparian-Wetland Area

Objective: Given a scenario, trainees will be able to assess the capability, potential, and condition of a riparian-wetland area.

Topic Outline:

A. Classification

1. Background/History
2. Definition(s)
 - a. Capability
 - b. Potential
3. Lotic/Lentic

B. Assessing Condition

1. Definition(s)
 - a. Proper Functioning Condition (PFC)
 - b. Functional - At Risk
 - c. Nonfunctional
 - d. Unknown
2. Process
 - a. Review Existing Documents
 - b. Analyze the Definition (PFC)
 - c. Assess Functionality
 1. Attributes and Processes
 2. Capability and Potential
 3. Functioning Condition
 4. Checklist(s)
 5. Class Exercise(s)
 - f. ESI

C. Instituting the Process to Acquire Desired Future Condition

D. Tie to Watershed Analysis

E. Wrap-Up

1. Reporting
2. ADP

Handouts: TR 1737-9 & TR 1737-11
Minimal Riparian-Wetland Functional Checklist(s)
Riparian-Wetland TR Order Form

THE UNIVERSITY OF CHICAGO
 
CHICAGO, ILL. 60637

RIPARIAN AREA MANAGEMENT

*Process for Assessing
Proper Functioning Condition*

by

U.S. Department of the Interior
Bureau of Land Management
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Abstracts

The purpose of this abstract is to provide a summary of the research findings of the study. The study was conducted by a group of researchers who were interested in the effects of a certain treatment on a specific population. The results of the study are presented in a clear and concise manner, allowing the reader to quickly grasp the main findings. The study was conducted over a period of six months, and the results were analyzed using statistical methods. The findings of the study are discussed in detail, and the implications of the results are explored. The study was conducted in a controlled environment, and the results are presented in a clear and concise manner. The study was conducted by a group of researchers who were interested in the effects of a certain treatment on a specific population. The results of the study are presented in a clear and concise manner, allowing the reader to quickly grasp the main findings. The study was conducted over a period of six months, and the results were analyzed using statistical methods. The findings of the study are discussed in detail, and the implications of the results are explored. The study was conducted in a controlled environment, and the results are presented in a clear and concise manner.

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Process for Assessing Proper Functioning Condition

I. Introduction

The Bureau of Land Management (BLM) has responsibility for 269 million acres of public lands (USDI, 1992) that sustain a variety and abundance of resources. These resources are prized for their recreation, fish and wildlife, cultural, and historic values, as well as their economic values, and for such uses as livestock production, timber harvest, and mineral extraction. Riparian-wetland areas, though they comprise less than 9 percent of the total land base, are the most productive and highly prized resources found on BLM lands.

Federal policy defines wetlands as *areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and which, under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions*. BLM Manual 1737, *Riparian-Wetland Area Management*, includes *marshes, shallow swamps, lakeshores, bogs, muskegs, wet meadows, estuaries, and riparian areas as wetlands*.

BLM's manual further defines riparian areas as *a form of wetland transition between permanently saturated wetlands and upland areas. These areas exhibit vegetation or physical characteristics reflective of permanent surface or subsurface water influence. Lands along, adjacent to, or contiguous with perennially and intermittently flowing rivers and streams, glacial potholes, and the shores of lakes and reservoirs with stable water levels are typical riparian areas. Excluded are such sites as ephemeral streams or washes that do not exhibit the presence of vegetation dependent upon free water in the soil*.

Riparian-wetland areas are grouped into two major categories: 1) lentic, which is standing water habitat such as lakes, ponds, seeps, bogs, and meadows, and 2) lotic, which is running water habitat such as rivers, streams, and springs.

A. Purpose

The Federal Land Policy and Management Act (FLPMA) of 1976 directs BLM to manage public lands in a manner that will provide for multiple use and at the same time protect natural resources for generations to come. In addition to FLPMA, numerous laws, regulations, policies, Executive orders, and Memorandums of Understanding (MOUs) direct BLM to manage its riparian-wetland areas for the benefit of the nation and its economy.

Under BLM's mandate of multiple-use management, a variety of activities such as livestock grazing, timber harvest, mineral extraction, recreation, and road and transportation corridor construction takes place on public lands. If not managed correctly, these activities can impact the quality of riparian-wetland areas.

In 1991, the BLM Director approved the *Riparian-Wetland Initiative for the 1990's*, which establishes national goals and objectives for managing riparian-wetland resources on public lands. One of the chief goals of this initiative is to restore and maintain riparian-wetland areas so that 75 percent or more are in proper functioning condition (PFC) by 1997. **The overall objective of this goal is to achieve an advanced ecological status, except where resource management objectives, including PFC, would require an earlier successional stage, thus providing the widest variety of vegetation and habitat diversity for wildlife, fish, and watershed protection.** This objective is important to remember because riparian-wetland areas will function properly long before they achieve an advanced ecological status. The *Riparian-Wetland Initiative for the 1990's* also includes a strategy to focus management on the entire watershed. Entire watershed condition is an important component in assessing whether a riparian-wetland area is functioning properly.

In the past, considerable effort has been expended to inventory, classify, restore, enhance, and protect riparian-wetland areas, but the effort has lacked consistency. The purpose of this document is to provide a thought process for assessing PFC for riparian-wetland areas on BLM-managed lands.

B. Approach

BLM depicts natural riparian-wetland areas as resources whose capability and potential is defined by the interaction of three components: 1) vegetation, 2) landform/soils, and 3) hydrology. A few resource specialists regard fish and wildlife as a fourth element because some wildlife species may alter a riparian-wetland area's capability and potential. However, most classifiers categorize fish and wildlife as a "user," but place wildlife species that can alter the capability and potential of a riparian-wetland site (i.e., beaver) as a special modifier under the hydrology component. BLM takes this approach in its inventory and classification system, Ecological Site Inventory (ESI).

Since natural riparian-wetland areas are characterized by the interactions of vegetation, soils, and hydrology, **the process of assessing whether a riparian-wetland area is functioning properly requires an interdisciplinary (ID) team.** The team should include specialists in vegetation, soils, and hydrology. A biologist also needs to be involved because of the high fish and wildlife values associated with riparian-wetland areas.

To initiate the process, in February 1992, the Director assembled an ID team of specialists to review existing Bureau definitions for PFC and to expand or develop new definitions as required. Appendix A provides the names of the specialists that were involved in this process. The ID team also developed a format for BLM to report functionality to Congress, which will include the tables in Appendix B.

C. Definitions

The terms introduced in BLM's definition of riparian-wetlands are generally understood by resource specialists. However, some confusion still exists with the term

ephemeral stream. A stream is a general term for a body of flowing water. In hydrology the term is generally applied to water flowing in a natural channel as distinct from a canal. Streams in natural channels are classified as being perennial, intermittent or seasonal, or ephemeral and are defined as follows (Meinzer, 1923):

Perennial - A stream that flows continuously. Perennial streams are generally associated with a water table in the localities through which they flow.

Intermittent or seasonal - A stream that flows only at certain times of the year when it receives water from springs or from some surface source such as melting snow in mountainous areas.

Ephemeral - A stream that flows only in direct response to precipitation, and whose channel is at all times above the water table.

These terms refer to the continuity of streamflow in **time**; they were developed by the U.S. Geological Survey in the early 1920's, have a long history of use, and are the standard definitions used by BLM resource specialists. Confusion over the distinction between intermittent and ephemeral streams may be minimized by applying Meinzer's (1923) suggestion that the term "intermittent" be arbitrarily restricted to streams that flow continuously for periods of at least 30 days and the term "ephemeral" be arbitrarily restricted to streams that do not flow continuously for at least 30 days. Also, the intermittent stream is to be distinguished from an **interrupted** stream, which is a stream with discontinuities in **space**. Intermittent or seasonal streams usually have visible vegetation or physical characteristics reflective of permanent water influence; for example, the presence of cottonwood.

To understand how riparian-wetland areas operate and to implement proper management practices, thus ensuring an area is functioning properly, **the capability and potential of a riparian-wetland area must be understood**. Assessing functionality is based upon an area's capability and potential. For the purpose of this document, capability and potential are defined as follows:

Capability - The highest ecological status a riparian-wetland area can attain given political, social, or economical constraints. These constraints are often referred to as limiting factors.

Potential - The highest ecological status an area can attain given no political, social, or economical constraints; often referred to as the "potential natural community" (PNC).

In BLM's annual report to Congress, the following definitions are to be used when completing the tables in Appendix B:

Riparian-Wetland Areas with Management Objectives - Areas where BLM has established specific riparian-wetland objectives and has implemented or is implementing management actions to meet the objectives.

Riparian -Wetland Areas Without Management Objectives - Areas where management is in place but does not have specific objectives for riparian-wetland management, or where no specific management exists.

Proper Functioning Condition - Riparian-wetland areas are functioning properly when adequate vegetation, landform, or large woody debris is present to dissipate stream energy associated with high waterflows, thereby reducing erosion and improving water quality; filter sediment, capture bedload, and aid floodplain development; improve flood-water retention and ground-water recharge; develop root masses that stabilize streambanks against cutting action; develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses; and support greater biodiversity. **The functioning condition of riparian-wetland areas is a result of interaction among geology, soil, water, and vegetation.**

Functional—At Risk - Riparian-wetland areas that are in functional condition but an existing soil, water, or vegetation attribute makes them susceptible to degradation.

Nonfunctional - Riparian-wetland areas that clearly are not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with high flows and thus are not reducing erosion, improving water quality, etc., as listed above. The absence of certain physical attributes such as a floodplain where one should be are indicators of nonfunctioning conditions.

Unknown - Riparian-wetland areas that BLM lacks sufficient information on to make any form of determination.

II. Process

Most of the Bureau's riparian-wetland areas are found in Alaska and are considered functioning properly because they are in their natural state (USDI, 1991). This is not the case for BLM riparian-wetland areas in the 11 contiguous Western States, as well as small tracts in Alabama, Arkansas, Florida, Louisiana, Minnesota, Mississippi, and Oklahoma. Most of these riparian-wetland areas have been altered by human activities. However, the following process for determining whether an area is functioning properly is the same for Alaska as it is for the other states.

A. Review Existing Documents

To start the process, existing documents that provide a basis for assessing PFC should be reviewed. Technical Reference 1737-5, *Riparian and Wetland Classification Review* (Gebhardt et al., 1990), provides an excellent start as it reviews, in a like format, the more common procedures that are used to classify, inventory, and describe riparian-wetland areas. This document identifies ESI as being the most complete procedure because it provides a process for defining the capability of an area, its

potential, and how it functions. However, not all riparian-wetland areas will require the magnitude provided by ESI to assess functionality.

Technical Reference 1737-2, *The Use of Aerial Photography to Inventory and Monitor Riparian Areas* (Batson et al., 1987), Technical Reference 1737-3, *Inventory and Monitoring of Riparian Areas* (Myers, 1989), and Technical Reference 1737-7, *Procedures for Ecological Site Inventory—With Special Reference to Riparian-Wetland Sites* (Leonard et al., 1992), are three other documents that should be reviewed. These documents provide additional thought processes that will be useful in assessing functional status of riparian-wetland areas.

B. Analyze the Definition

Next, the definition of PFC must be analyzed. One way to do this is by breaking the definition down as follows:

^{Lotic}
“Riparian-wetland areas are functioning properly when adequate vegetation, landform, or large woody debris is present to:

- 1) dissipate stream energy associated with high waterflows, thereby reducing erosion and improving water quality;
- 2) filter sediment, capture bedload, and aid floodplain development;
- 3) improve flood-water retention and ground-water recharge;
- 4) develop root masses that stabilize streambanks against cutting action;
- 5) develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses;
- 6) and support greater biodiversity.”

Lentic
change to
"dissipate"
energies
from wave
+ wind
action +
overland
flow. ... "

Lentic
sites } on a time
frame will
die - fill in,
etc.

Riparian areas are functioning properly when there is adequate structure present to provide the listed benefits **applicable** to a particular area. The analysis must be based on the riparian area's capability and potential. If, for example, the system does not have the potential to support fish habitat, that criteria would not be used in the assessment.

C. Assess Functionality

1. Attributes and Processes

The third aspect of assessing PFC involves understanding the attributes and processes occurring in a riparian-wetland area. Table 1 provides a list of attributes and processes that may occur in any given riparian-wetland area. When assessing PFC, attributes and processes for the area being evaluated need to be identified.

To understand these processes, an example of an alluvial/nongraded valley-bottom type riparian area in both a functional and nonfunctional condition is provided in Figure 1 (Jensen, 1992). Using the Bureau's definitions for PFC, **State A** represents

These are things you have to consider in management + projects.

Table 1. Attributes/Processes List * *Lotic*

Hydrogeomorphic
Ground-Water Discharge Active Floodplain Ground-Water Recharge Floodplain Storage and Release Flood Modification Bankfull Width Width/Depth Ratio Sinuosity Gradient Stream Power Hydraulic Controls Bed Elevation
Vegetation
Community Types Community Type Distribution Surface Density Canopy Community Dynamics and Succession Recruitment/Reproduction Root Density Survival
Erosion/Deposition
Bank Stability Bed Stability (Bedload Transport Rate) Depositional Features
Soils
Soil Type Distribution of Aerobic/Anaerobic Soils Capillarity Annual Pattern of Soil Water States
Water Quality
Temperature Salinity Nutrients Dissolved Oxygen Sediment

* This list provides examples of various attributes/processes that may be present in a riparian area. By no means is it complete.

a high degree of bank stability, floodplain, and plant community development, and would be classified as PFC. The important attributes and processes present for **State A** are:

Hydrogeomorphic - Active floodplain, floodplain storage and release, flood modification, bankfull width, width/depth ratio, sinuosity, gradient, stream power, and hydraulic controls.

Vegetation - Community type (2 of 3), community type distribution (similar in the wet types), root density, canopy, community dynamics, recruitment/reproduction, and survival.

Erosion/Deposition - Bank stability.

Soil - Distribution of anaerobic soil, capillarity.

Water Quality - No change.

State B may be properly functioning or functional—at risk. It would be classified as functional if bank stabilizing vegetation is dominant along the reach and other factors such as soil disturbance are not evident. It is important to identify the species of vegetation present since they do vary in their ability to stabilize streambanks and filter sediment.

State B would be classified as at risk if bank stabilizing vegetation is not dominant (even though it may be in an improving trend from prior conditions), nondesirable species are present (e.g., Kentucky bluegrass), soil disturbance is evident (e.g., caved banks from livestock or vehicle use), or hydrologic factors such as degraded watershed conditions exist, increasing the probability of extreme flow events that would damage the reach. The following changes in attributes/processes are likely in **State B**:

Hydrogeomorphic - Bankfull width (increase), width/depth ratio (increase in width, no change in depth), active floodplain frequency (decrease).

Vegetation - Community types changed, community type distribution changed, root density, canopy, community dynamics, recruitment/reproduction, and survival.

Erosion/Deposition - Bank stability (decrease).

Soil - No change.

Water Quality - No significant change.

Figure 1. Succession of states for alluvial/nongraded valley-bottom type.

States C and D would be classified as nonfunctional conditions. **State C** represents incisement of the stream channel to a new base level. There is little or no bank stabilizing vegetation and no floodplain. Channel widening exhibited in **State D** must occur to restore floodplain development. Vegetation, if present, is often only temporary due to the large adjustment process occurring. The following changes in attributes/processes are likely in **States C and D**:

Hydrogeomorphic - Bankfull width (increase), width/depth (increase/increase), active floodplain frequency (decrease).

Vegetation - Riparian community types lost; community type distribution changed; root density, canopy, community dynamics, recruitment, reproduction, and survival (decrease).

Erosion/Deposition - Bank stability (decrease).

Soil - Well drained.

Water Quality - Temperature (increase), sediment (increase).

State E may again be classified as functional-at risk or functional depending on vegetation, soil, and hydrologic attributes. Establishment of the floodplain and bank stabilizing vegetation indicate reestablishment of functional conditions. However, stream segments in this state are usually at risk for the same reasons described for **State B**. Attributes and processes would revert back to those that appear in **State B**.

State F is classified as functioning properly even though the riparian area may not have achieved the greatest extent exhibited in **State A**. Banks are stabilized and exhibit channel geometry similar to **State A**. The floodplain has widened to the extent that confinement of peak flows is only occasional and aggrading processes are slowed because of the surface area available. The largest difference between **States A and F** occurs in size and extent of hydrologic influence, which regulates size and extent of the riparian area.

This alluvial/nongraded valley-bottom example is found in the Great Basin and represents only one of many types found on public lands. However, it is important to remember that there are other types and to understand that:

Riparian-wetland areas do have fundamental commonalities in how they function, but they also have their own unique attributes. Riparian-wetland areas can and do function quite differently. As a result, most areas need to be evaluated against their own capability and potential. Even for similar areas, human influence may have introduced component(s) that have changed the area's capability and potential. Assessments, to be correct, must consider these factors and the uniqueness of each system.

Appendix C contains examples of other kinds of riverine systems found on BLM managed lands (Jensen, 1992). The analogy used for Figure 1 can be applied to most of the examples found in Appendix C because differing channel types do have functional commonality. However, differing channel types may accommodate their own unique evolutionary processes. Information concerning the classification system used by Jensen can be found in BLM technical reference TR 1737-5 (Gebhardt et al., 1990).

2. Capability and Potential

Assessing functionality then involves determining a riparian-wetland area's capability and potential using an approach such as the following:

- Look for relic areas (exclosures, preserves, etc.).
- Seek out historic photos, survey notes, and/or documents that indicate historic condition.
- Search out species lists (animals & plants - historic & present).
- Determine species habitat needs (animals & plants) related to species that are/were present.
- Examine the soils and determine if they were saturated at one time and are now well drained?
- Examine the hydrology, establish cross sections if necessary to determine frequency and duration of flooding.
- Identify vegetation that currently exists. Are they the same species that occurred historically?
- Determine the entire watershed's general condition and identify its major landform(s).
- Look for limiting factors, both human-caused and natural, and determine if they can be corrected.

This approach forms the basis for initiating an inventory effort like ESI. For some areas, conducting an ESI effort will be the only way to assess an area's capability and potential.

Some riparian-wetland areas may be prevented from achieving their potential because of limiting factors such as human activities. Most of these limiting factors can be rectified through proper management. However, some limiting factors such as dams and transmountain diversions are not as easy to correct. The placement of dams and transmountain diversions can result in a riparian-wetland area's flow regime being altered, thus changing the area's capability. For example, cottonwood trees are maintained by periodic flooding, which creates point bars for seedling establishment. A dam or transmountain diversion that reduces or eliminates the potential for flooding may remove the potential for cottonwoods to remain in that area. PFC must be assessed in relationship to the area's capability.

3. *Functioning Condition*

When determining whether a riparian-wetland area is functioning properly, the condition of the entire watershed, including the uplands and tributary watershed system, is important. The entire watershed can influence the quality, abundance, and stability of downstream resources by controlling production of sediment and nutrients, influencing streamflow, and modifying the distribution of chemicals throughout the riparian-wetland area. Riparian-wetland health (functioning condition), an important component of watershed condition, refers to the ecological status of vegetation, geomorphic, and hydrologic development, along with the degree of structural integrity exhibited by the riparian-wetland area. A healthy riparian-wetland area is in dynamic equilibrium with the streamflow forces and channel aggradation/degradation processes producing change with vegetative, geomorphic, and structural resistance. In a healthy situation, the channel network adjusts in form and slope to handle increases in stormflow/snowmelt runoff with limited perturbation of channel and associated riparian-wetland plant communities.

Riparian-wetland areas can function properly before they achieve their Potential Plant Community (PPC) or Potential Natural Community (PNC). In fact, some would argue that riparian-wetland areas are always functioning properly, no matter what state they are in. From the perspective of fluvial geomorphology, it is true that the channel is constantly adjusting itself to the water and sediment load delivered to it from the watershed; however, BLM's definition goes beyond the processes of channel evolution and includes vegetation and biological attributes. The Bureau's definition does not mean PNC or optimal conditions for a particular species have to be achieved to be rated as functioning properly.

Figures 2 and 3 provide an example of the relationship between PFC and vegetation community succession for one area. Assuming succession continues uninterrupted (Step 1 to Step 2 in Figure 2), the channel will evolve through some predictable changes from bare ground to PNC (although not necessarily as linearly as depicted). The riparian-wetland area will progress through phases of not functioning, functioning—at risk, and properly functioning along with plant succession. In this example, PFC occurs at the mid-seral stage (Step 3). Figure 3 shows a stream cross section of each condition (A-E) displayed in Figure 2.

At various stages within this successional process, the stream can provide a variety of values for different uses (Step 4). In Figure 2, optimal conditions for grazing occur when forage is abundant and the area is stable and sustainable (mid-seral). Wildlife goals depend upon the species for which the area is being managed. If the riparian zone in Figure 2 is to provide habitat for shrub nesting birds, the optimum conditions would be from mid- to late seral. Trout habitat conditions would be optimum from mid-seral to late seral. The threshold for any goal is at least PFC because any rating below this would not be sustainable.

For some areas, PFC may occur from early seral to late seral. Desired plant community (DPC) would be determined based on management objectives through an interdisciplinary approach (Step 5). Figure 2 is an example of only one riparian-wetland area.

When rating functionality, it will be easy to categorize many riparian-wetland areas as PFC or nonfunctional. For others it will not be easy. Difficulty in rating PFC usually arises in identifying the thresholds that allow a riparian-wetland area to move from one category to another. To provide consistency in reporting PFC, BLM has established a standard checklist for field offices to initiate this process (Appendix D).

Figure 2. Succession for stream recovery.

non-functional

A
Bare Ground

↑ up-ward trend
Functional risk

B
Early Seral

↑ up-ward trend
Functional Conduction

C
Mid-Seral

D
Late Seral

E
PNC or PPC

climax
best for
anadromous fish

Figure 3. Stream cross sections.

BLM's checklist may not answer the question of functionality for all riparian-wetland areas. Some areas may require a more intensive inventory effort, like ESI. Elements can be added to BLM's standard checklist to address unique riparian-wetland attributes. To further assist field offices in assessing functionality, Appendix E provides examples of riparian-wetland areas and depicts the categories of PFC, functional—at risk, and nonfunctional.

The process described in this document has concentrated on lotic forms of riparian-wetland areas for two reasons: 1) they are the form of wetland BLM most frequently has to resolve conflicts on, and 2) inventory, classification, and monitoring efforts within and outside the Bureau have concentrated on this type of resource. However, the process would be the same for lentic forms of wetlands. Additional guidance will be developed for lentic wetlands as BLM gathers more information on them.

III. Instituting the Process

A. Planning

A logical manner to incorporate the information collected into a management plan is as follows (refer to Figure 2 in the Functioning Condition section):

- Step 1 Existing Condition** - Determine the existing riparian-wetland and watershed condition using BLM standard inventory methods.
- Step 2 Potential Condition** - Determine PNC by using relic areas, historic photos, etc. (ESI process).
- Step 3 PFC** - Determine the minimum conditions required for the area to function properly.
- Step 4 Resource Values** - Determine existing and potential resource values and the plant communities necessary to support these values.
- Step 5 Management Goals** - Negotiate specific objectives to reach management goals for the watershed, DPC, or Desired Future Condition.
- Step 6 Planned Actions** - Design management actions to achieve DPC.
- Step 7 Monitoring** - Design appropriate monitoring strategies to assess progress towards meeting management goals.
- Step 8 Flexibility** - Maintain management flexibility to accommodate change based upon monitoring results.

B. Management

For BLM to be successful in reaching its goal of having 75 percent of its riparian-wetland areas functioning properly by 1997, best management practices need to be set in motion. Successful management strategies address the entire watershed. Upland and riparian areas are interrelated and cannot be considered separately.

Two other documents can be helpful in assisting with this process: Technical Reference 1737-4, *Grazing Management in Riparian Areas* (Kinch, 1989), provides grazing management principles, concepts, and practices that have been effective in improving and maintaining desired conditions on riparian-wetland areas. For other forms of management such as recreation development, mining opportunities, timber practices, and watershed treatments, Technical Reference 1737-6, *Management Techniques in Riparian Areas* (Smith and Prichard, 1992), provides suggested management practices. With a change in management, most riparian-wetland areas can achieve PFC in a few years, but some will take years to achieve the identified DPC or advanced ecological status.

C. Monitoring

Management effectiveness can be assessed and progress towards meeting PFC can be documented through monitoring. Sites should be revisited periodically as part of the overall monitoring program. Areas rated at a single point in time can reflect short-term factors such as climatic conditions. Monitoring will reflect longer-term trends. Technical references such as TR 1737-3 (Myers, 1989) are tools that can be used to develop monitoring criteria.

IV. Summary

Riparian-wetland areas constitute an important resource on lands managed by BLM. BLM's goal is to have 75 percent of its riparian-wetlands functioning properly by 1997. This technical reference provides a thought process for assessing functioning condition.

The status of some riparian-wetland areas will be relatively easy to discern while the status of others will be less evident. Appendix D contains the minimum national standards that BLM field offices will use in making this assessment. For hard-to-discern areas, Ecological Site Inventory may be the only method to determine capability and potential and assess functionality. Using either method will require an interdisciplinary team to adequately address the complexities associated with riparian-wetland areas and to report their functioning condition.

Appendix B contains the forms for reporting functioning condition. Riparian areas are reported in four categories: proper functioning condition, functional—at risk, nonfunctional, and unknown. Areas with and without specific riparian management and objectives are reported separately. The Definitions section of this technical reference describes the meanings of these terms.

Trend is reported for areas that are identified as functional—at risk, and is a key consideration in interpreting the data. Areas identified as functional—at risk with a downward trend are often the highest management priority because a decline in resource values is apparent. Yet these areas often retain much of the resiliency associated with a functioning area. There is usually an opportunity to reverse this trend through changes in management. Functional—at risk areas with an upward trend are often a priority for monitoring efforts. These areas are improving but remain at risk. Monitoring these areas assures that upward trends continue.

Conversely, trend is not reported for areas that are nonfunctional. While these areas could theoretically still be in decline, most of the riparian values have already been lost. The presence of sufficient riparian-wetland attributes and processes to warrant a determination of trend usually results in a designation of functional—at risk.

It is common for an area in PFC to continue to have an upward trend. Many sites that are properly functioning must continue to improve to meet site-specific objectives. However a downward trend may put the area at risk. Once proper functioning condition is reached, trend relates to specific objectives. Therefore, it is not part of this data report.

The lack of specific information will place many riparian-wetland areas into the category of unknown. In order for BLM to make an adequate assessment of progress towards its goal, it is imperative that areas for which no data exists be evaluated and added to the data base. As information is acquired and resource values are identified, best management practices need to be set in motion. Successful management strategies have to address the entire watershed, as upland and riparian-wetland areas are interrelated and cannot be considered separately.

Examples provided in this document have concentrated on lotic riparian areas for two reasons: 1) they are the form of wetland BLM most frequently has to resolve conflicts on, and 2) inventory, classification, and monitoring efforts within and outside the Bureau have concentrated on this type of resource the most. However, the thought process for assessing functionality of lentic areas would be the same. In the future, a technical reference will be developed with more specific information for lentic wetlands.

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Glossary of Terms

Active Floodplain - The low-lying land surface adjacent to a stream and formed under the present flow regime. The active floodplain is inundated at least once or twice (on average) every 3 years.

Advanced Ecological Status - A community with a high coefficient of similarity to a defined or perceived PNC for an ecological site, usually late seral or PNC ecological status.

Annual Pattern of Soil Water States - A description of field soil water over the year as applied to horizons, layers, or standard depth zones. Water state is reported by layers.

Hydraulic Control - Features of landform (bedform and bed material), vegetation, or organic debris that control the relationship between stage (depth) and flow rate (discharge) of a stream.

Hydrogeomorphic - Features pertaining to the hydrology and/or geomorphology of the stream system.

Potential Plant Community - Represents the seral stage the botanical community would achieve if all successional sequences were completed without human interference under the present environmental conditions.

Riparian-Wetland Ecological Site - An area of land with a specific potential plant community and specific physical site characteristics, differing from other areas of land in its ability to produce vegetation and to respond to management. Ecological site is synonymous with range site.

Seral Stage - One of a series of plant communities that follows another in time on a specific site.

Stream Power - A measure of a stream's ability to erode and transport sediment. It is equal to the product of shear stress and velocity.

Vegetation Community Dynamics - Response of plant communities to changes in their environment, to their use, and to stresses to which they are subjected. Climatic cycles, fire, insects, grazing, and physical disturbances are some of the many causes of changes in plant communities. Some changes are temporary while others are long lasting.

Vegetation Community Succession - Primary succession is a sequence of plant community changes from the initial colonization of a bare soil toward a PNC. Secondary succession may involve sequences of plant community change from PNC due to perturbations, or a sequence toward PNC again following a perturbation. Vegetation community succession may be accompanied by subtle but significant changes in temporal soil characteristics such as bulk density, nutrient cycling, and microclimatic changes, but is differentiated from major physical state changes such as landform modification or long-term elevation or lowering of a water table that would change the PNC of an ecological site.

Appendix A

Interdisciplinary Team

Team Member	Discipline
Ron Clark - WO-222 (Now CO-930)	Watershed Specialist
Mike Crouse - OR-932	Management/Biologist
Wayne Elmore - OR-050	Riparian-Wetland Specialist/ Wildlife Biologist
Jim Fogg - SC-212	Hydrologist
Ron Hooper - AZ-932	Riparian-Wetland Coordinator/ Hydrologist
Steve Leonard - NV-931	Range Scientist
Don Prichard - SC-213	Riparian-Wetland Coordinator/ Fishery Biologist
Dan Tippy - TC-200 (Now OR-050)	Riparian-Wetland Training Coordinator/Soils
Don Waite - WO-222	Management/Economist
Jack Williams - WO-240	Fisheries Program Manager

Appendix B Reporting Tables

on computers on DOS

NWI = National Wetland Inventory

* Marsh Program - ^{not a} ~~diagnostic~~ key for plants
will have 3-D photos soon

SiteForm - where EIS info is at

RAIOS - storage of info - "D-base or Aspen"

IDS4 - plants

Table 1. Riparian Areas With Management Objectives

State: _____

Habitat Types	Proper Functioning Condition	Functional—At Risk			Non-functional	Unknown
		Trend Up	Trend Not Apparent	Trend Down		
Riverine Miles & Acres						
Nonriverine Acres						

Table 2. Riparian Areas Without Management Objectives

State: _____

Habitat Types	Proper Functioning Condition	Functional—At Risk			Non-functional	Unknown
		Trend Up	Trend Not Apparent	Trend Down		
Riverine Miles & Acres						
Nonriverine Acres						

Glacier Valley-Sediment Type

Appendix C

Channel Evolution Examples

Lakeview Pine Upland

1950

Channel
Sediment

1950

Channel
Sediment

Glacial Valley-Bottom Type

Succession of States for Fluvial/V-Shaped Depositional Valley-Bottom Type

Succession of States for Alluvial/Graded Valley-Bottom Type

Appendix D

Riparian-Wetland Functional Checklist

General Instructions

- 1) The concept “**Relative to Capability**” applies wherever it may be inferred.
- 2) This checklist constitutes the **Minimum National Standards** required to determine Proper Functioning Condition of riparian-wetland areas.
- 3) As a minimum, an **ID Team** will use this checklist to determine the degree of function of a riparian-wetland area.
- 4) Mark one box for each element.
- 5) For any item marked “**No**,” the severity of the condition must be explained in the “**Remarks**” section and must be a subject for discussion with the ID Team in determining riparian-wetland functionality.
- 6) Based on the ID Team’s discussion, “**functional rating**” will be resolved and the checklist’s summary section will be completed.

Seniority - look at land form. must be correct for all three

channels can change
either vertically - drop down
or laterally
over hardrock surface

must be
actively
contributing to stream
at moment of survey

Standard Checklist

Name of Riparian-Wetland Area: _____

Date: _____ Segment/Reach ID: _____

Miles: _____ Acres: _____

ID Team Observers: _____

Yes	No	N/A	HYDROLOGIC
			Floodplain inundated in "relatively frequent" events (1-3 years)
			Active/stable beaver dams
			Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
			Riparian zone is widening
			Upland watershed not contributing to riparian degradation

Yes	No	N/A	VEGETATIVE
			Diverse age structure of vegetation
			Diverse composition of vegetation
			Species present indicate maintenance of riparian soil moisture characteristics
			Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high streamflow events
			Riparian plants exhibit high vigor
			Adequate vegetative cover present to protect banks and dissipate energy during high flows
			Plant communities in the riparian area are an adequate source of coarse and/or large woody debris

Yes	No	N/A	EROSION DEPOSITION
			Floodplain and channel characteristics (i.e., rocks, coarse and/or large woody debris) adequate to dissipate energy
			Point bars are revegetating
			Lateral stream movement is associated with natural sinuosity
			System is vertically stable
			Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)

Remarks

Summary Determination

Functional Rating:

Proper Functioning Condition _____
Functional—At Risk _____
Nonfunctional _____
Unknown _____

Trend for Functional—At Risk:

Upward _____
Downward _____
Not Apparent _____

Are factors contributing to unacceptable conditions outside BLM's control or management?

Yes _____
No _____

If yes, what are those factors?

_____ Flow regulations _____ Mining activities _____ Upstream channel conditions
_____ Channelization _____ Road encroachment _____ Oil field water discharge
_____ Augmented flows _____ Other (specify) _____

Appendix E

Riparian-Wetland Examples

Texas Creek—Colorado
September 1976
Nonfunctional

Texas Creek—Colorado
June 1978
Functional—At Risk

Texas Creek—Colorado

September 1976

Nonfunctional

Texas Creek, located in south-central Colorado on public lands administered by the Canon City District Office, would have been rated *nonfunctional* in 1976 based on the Bureau's definitions. Texas Creek is a small coldwater perennial stream that originates in the Sangre De Cristo Mountains, flowing for approximately 24 miles before it enters the Arkansas River. Inventories conducted in 1976 classified the stream as a laterally unstable area that was moderately confined, severely impacted from continuous grazing, and providing limited fish and wildlife values.

The September 1976 photograph clearly demonstrates why Texas Creek would have been rated *nonfunctional*. This riparian area was clearly not providing adequate vegetation, landform, or large woody debris to dissipate stream energies associated with high flows. With each storm event, the stream channel migrated, erosion accelerated, sediment was not filtered, flood-water retention and ground-water recharge were limited, and water quality was altered. Wildlife values were limited to principally a watering site, and the brown trout population, less than 13 fish per 500 feet of stream, was well below the area's capability or potential.

For the most part, placing a stream into the category of *nonfunctional* would be a simple task. However, there are areas (natural and altered) that will always look like this.

Texas Creek—Colorado

June 1978

Functional—At Risk

Management actions were changed in 1977 to reverse the trend of Texas Creek and to allow the area to progress towards its capability and potential. Changes included improved fencing, and rest and implementation of deferred seasonal grazing or winter grazing. Quality of habitat in Texas Creek began to improve immediately after changing management practices, and the June 1978 photo displays the results. Using the Bureau's definitions, Texas Creek would have been rated as *functional—at risk* in June 1978, with an upward trend.

Comparing the changes between the 1976 photo and the 1978 photo shows that Texas Creek was in an upward trend and had started to function physically. With increased vegetation, stream energies had been reduced, sediment had been filtered and captured, streambanks had developed, flood-water retention and ground-water recharge had increased, stream width had decreased, erosion was reduced, and water quality improved. With these physical changes, wildlife and fishery values had increased. The brown trout population more than doubled from 1976.

Yet, the area was still at risk because soil and vegetation attributes still made it susceptible to degradation. The area contained too much bare soil and lacked desirable species of vegetation. The dominant species present lacked root masses that stabilize streambanks against cutting action.

Texas Creek—Colorado
October 1978
Proper Functioning Condition

Texas Creek—Colorado
July 1987
Proper Functioning Condition

Texas Creek—Colorado

October 1978

Proper Functioning Condition

By the end of the 1978 growing season, Texas Creek progressed to where it had crossed its threshold as described in Figure 2 in the Functioning Condition section. Using the Bureau's definitions, in October 1978, Texas Creek would have a rating of *PFC*. **Yet, by no means had Texas Creek achieved its capability or potential. However, it may have achieved its management objectives and obtained its desired plant community (early seral versus PNC).** The early seral vegetation community that had established itself in the October 1978 photo possessed the ability to dissipate stream energies associated with high flows for Texas Creek. The instability that was present in Texas Creek in June 1978 had dissipated and the soil and vegetation attributes that placed Texas Creek into the category of *functional—at risk* were no longer present. Attributes such as reduced erosion; improved water quality; floodplain development; trapment of woody debris; improved retention of flood-water and ground-water recharge; diverse ponding; channel characteristics that provide habitat and water depth, duration, and temperatures necessary for fish production; and other wildlife values had been greatly strengthened.

Adjusting the rating of an area from *functional—at risk* to *PFC* may not be easy. For Texas Creek it was easy because 12 years of data had been collected. For most areas, BLM does not have that luxury. **That's why an ID team is necessary.** For some areas, the only way to assess functionality is with an effort like ESI.

Texas Creek—Colorado

July 1987

Proper Functioning Condition

Placing areas that have achieved late seral or PNC, as Texas Creek had in this July 1987 photo, into the appropriate category is easy. Using the Bureau definitions, Texas Creek would have a rating of *PFC*. The difference between the October 1978 photo and the July 1987 photo is that the vegetation community was early seral for 1978 and late seral for 1987. However, both communities were functioning properly. Management defines its Desired Plant Community for an area, which in turn defines BLM's management options.

For example, bighorn sheep and brown trout are present in the Texas Creek watershed. If the desired species for management is bighorn sheep, which prefer early seral vegetation around watering sites, the desired plant community for Texas Creek would be early seral (October 1978 photo). At the same time, brown trout production is possible, but not at optimal numbers. Yet, the area can **function properly**. Optimal numbers of brown trout for this area would occur by managing for mid-seral to late seral. However, this would not be to the liking of the bighorn sheep.

Riparian-wetland areas can be managed to provide greater biodiversity as well as to allow the **entire area to function properly**. Most riparian-wetland areas can function properly in all seral stages, thus giving BLM greater management flexibility.

Forested Coastal Stream—Oregon Nonfunctional

The below photograph gives an example of a coastal stream, located in Oregon, that would be rated as *nonfunctional* relative to BLM's definitions for proper functioning condition. The riparian area is clearly not providing adequate vegetation, landform, or large woody debris to dissipate stream energies associated with high flows. During precipitation events, the stream channel migrates, erosion continues, sediment is not filtered, flood-water retention and ground-water recharge are limited, and water quality is altered. Wildlife values are limited, and the area is not providing diverse ponding or channel characteristics that provide habitat and water depth, duration, and temperature necessary for fish production. The area provides little biodiversity.

Forested Coastal Stream—Oregon
Functional—At Risk

Forested Coastal Stream—Oregon
Proper Functioning Condition

Forested Coastal Stream—Oregon

Functional—At Risk

Establishment of alders provides the capacity to dissipate some stream energies that occur with flow events in this area. This capability results in captured sediment and bedload, reduced erosion, and improved water quality, and aids floodplain development and improves flood-water retention and ground-water recharge. In other words, the area has started to function physically.

In spite of functioning, this area would be rated as *functional—at risk* because a vegetation and hydrologic attribute still make the area susceptible to degradation. While the alder plant community does provide root masses that stabilize streambanks against cutting action, it probably is insufficient for major flow events. Large woody debris (hydrologic controls) is also lacking, which inhibits capture of sufficient bedload to aid in the development of habitat that provides water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses, thus supporting greater biodiversity.

This area will function properly before it obtains PNC. As the alder community ages, it will topple into the stream providing woody debris that aids in the capture of bedload. Also, as the alders depart, conifer climax species will dominate the site and provide the necessary bank stability. All this will occur before optimal numbers of wildlife and fish species (greater biodiversity) are achieved.

Forested Coastal Stream—Oregon

Proper Functioning Condition

The photograph to the left depicts a forested riparian-wetland area that achieved the rating of *PFC*. The photograph clearly shows a coastal stream that contains adequate vegetation and large woody debris that is dissipating stream energy associated with high waterflows, thereby reducing erosion and improving water quality. The plant community has developed root masses that have stabilized streambanks against cutting action, filtered sediment, and captured sufficient bedload. This has aided floodplain development and has improved flood-water retention and ground-water recharge. The natural process has created diverse ponding and channel characteristics that provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses, thus supporting greater biodiversity.

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RIPARIAN AREA MANAGEMENT

*Process for Assessing Proper Functioning Condition
for Lentic Riparian-Wetland Areas*

by

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Process for Assessing Proper Functioning Condition for Lentic Riparian-Wetland Areas

I. Introduction

Federal policy defines wetlands as *areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and which, under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions*. Bureau of Land Management (BLM) Manual 1737 (USDI, 1992), *Riparian-Wetland Area Management*, includes *marshes, shallow swamps, lakeshores, bogs, muskegs, wet meadows, estuaries, and riparian areas as wetlands*.

Riparian-wetland areas, though they comprise less than 9 percent of the total land base, are the most productive and highly prized resources found on BLM lands. Riparian-wetland areas play a significant role in restoring and maintaining the chemical, physical, and biological integrity of the nation's water. Wildlife use riparian-wetland areas disproportionately more than any other type of habitat. In addition, riparian-wetland areas are highly prized for their economic values and other uses such as livestock production and recreation.

Riparian-wetland areas' soils, vegetation, and hydrology vary as a result of many factors; therefore, they are grouped into two major categories: 1) lentic, which is standing water habitat such as lakes, ponds, seeps, bogs, and meadows, and 2) lotic, which is running water habitat such as rivers, streams, and springs.

A. Purpose

The BLM's *Riparian-Wetland Initiative for the 1990's* (USDI, 1991) document establishes national goals and objectives for managing riparian-wetland resources on public lands. This initiative's chief goal, comprised of two parts, is to: 1) restore and maintain riparian-wetland areas so that 75 percent or more are in proper functioning condition (PFC) by 1997 and 2) to achieve an advanced ecological status, except where resource management objectives, including PFC, would require an earlier successional stage, thus providing the widest variety of habitat diversity for wildlife, fish, and watershed protection. The *Riparian-Wetland Initiative for the 1990's* also contains a strategy to focus management on the entire watershed. Knowing the condition of the watershed is an important component in assessing whether a riparian-wetland area is functioning properly.

The purpose of this document is to provide a thought process for assessing PFC for lentic riparian-wetland areas on BLM-managed lands. This document supplements Technical Reference (TR) 1737-9, *Process for Assessing Proper Functioning Condition* (Prichard et al., 1993), which was principally designed for lotic riparian-wetland areas.

B. Approach

BLM defines lentic riparian-wetland resources the same way they define lotic riparian-wetland resources, i.e., resources whose capabilities and potentials are defined by the interaction of three physical components: 1) vegetation, 2) landform/soils, and 3) hydrology. As for lotic riparian-wetland areas, some resource specialists regard fish and wildlife as a fourth element because of the ability of some wildlife species to alter a riparian-wetland area's capability and potential. Classifiers usually place wildlife species that have the ability to alter a riparian-wetland area's capability and potential as a special modifier under the hydrology component. Whether fish and wildlife species are dealt with as a resource component or identified as a special modifier, noting their presence and/or condition is important when assessing PFC of a lentic riparian-wetland area.

Since lentic riparian-wetland areas are characterized by the interactions of vegetation, soils, and hydrology and these areas are important to fish and wildlife, **the process of assessing whether a riparian-wetland area is functioning properly requires an interdisciplinary (ID) team.** The team should include, but not be limited to, specialists knowledgeable about vegetation, soil, and hydrology attributes and processes and fish and wildlife values.

C. Definitions

To comprehend how a lentic riparian-wetland area operates, and to set in motion proper management practices that ensure it is functioning properly, **the capability and potential of the area must be understood.** Evaluating functionality is based upon an area's capability and potential. This document uses the same definitions for capability and potential that were used in TR 1737-9:

Capability - The highest ecological status a riparian-wetland area can attain given political, social, or economical constraints. These constraints are often referred to as limiting factors.

Potential - The highest ecological status an area can attain given no political, social, or economical constraints; often referred to as the "potential natural community" (PNC).

BLM Manual 1737, *Riparian-Wetland Area Management* (USDI, 1992), and TR 1737-9, establish definitions for proper functioning condition, functional—at risk, nonfunctional, and unknown when assessing functionality of riparian-wetland areas. Even though these definitions feature lotic riparian-wetland areas, they can be applied to lentic riparian-wetland areas with minor modifications. For example, instead of assessing whether adequate vegetation is present to dissipate stream energies, an assessment would determine whether adequate vegetation is present to dissipate wind and wave energies, thereby reducing erosion and improving water quality.

II. Process

The process described in TR 1737-9 concentrated on assessing functional condition of lotic riparian-wetland areas for two reasons: 1) they are the form of wetland BLM most frequently has to resolve conflicts on and 2) inventory, classification, and monitoring efforts within and outside the Bureau have concentrated on this type of resource. However, the basic process to assess functioning condition on lentic forms of riparian-wetlands would be much the same, except that: 1) different attributes and processes define an area's capability and potential and 2) the attributes and processes of soil and vegetation play a stronger role in establishing functionality, while hydrology plays a lesser role.

A. Review Existing Documents

TR 1737-9 should be reviewed before assessing functioning condition of lentic riparian-wetland areas. TR 1737-9 identifies a number of documents that provide a basis for assessing PFC. It also identifies additional documents that provide thought processes that will be useful in assessing functional status of riparian-wetland areas.

Like lotic riparian-wetland areas, the level of information necessary to assess PFC for lentic riparian-wetland areas will vary. Some will require the magnitude of effort provided by an Ecological Site Inventory (ESI) to assess functionality, while others can be assessed by using a checklist. Information pertaining to application of ESI can be found in TR 1737-7, *Procedures for Ecological Site Inventory—With Special Reference to Riparian-Wetland Sites* (Leonard et al., 1992).

Whether employing ESI or a checklist to assess functioning condition, existing files from BLM and other agencies should be reviewed for pertinent information. Information may exist to assess functionality for some riparian-wetland areas without having to go to the field. For others, the information will be useful in establishing capability and potential or trend.

B. Analyze the Definition

In assessing PFC for lentic riparian-wetland areas, the definition of PFC must be analyzed, but adjusted for lentic areas. One way to do this is by breaking the definition down as follows:

Lentic riparian-wetland areas are functioning properly when adequate vegetation, landform, or debris is present to:

- 1) dissipate energies associated with wind action, wave action, and overland flow from adjacent sites, thereby reducing erosion and improving water quality;
- 2) filter sediment and aid floodplain development;
- 3) improve flood-water retention and ground-water recharge;
- 4) develop root masses that stabilize islands and shoreline features against cutting action;

- 5) restrict water percolation;
- 6) develop diverse ponding characteristics to provide the habitat and water depth, duration, and temperature necessary for fish production, waterbird breeding, and other uses;
- 7) and support greater biodiversity.

Lentic riparian-wetland areas are functioning properly when there is adequate structure present to provide the listed benefits *applicable* to a particular area. The analysis must be based on the riparian-wetland area's capability and potential. If, for example, the system *does not have the potential* to support waterfowl habitat, that criteria would not be used in the assessment.

C. Assess Functionality

I. Attributes and Processes

Assessing PFC for a lentic riparian-wetland area, just as for a lotic riparian-wetland area, involves understanding the attributes and processes occurring in that area. Table 1 provides a list of attributes and processes that may occur in any given lentic riparian-wetland area. When assessing PFC, attributes and processes for the area being evaluated need to be identified.

To understand these processes, an example of a palustrine wetland area in both a functional and nonfunctional condition is provided in Figure 1. Applying the Bureau's definitions for PFC, **State A** would be classified as PFC. Important attributes and processes present for **State A** are:

Hydrogeomorphic - Continuous permafrost; shoreline shape; and depth, duration, and frequency of inundation.

Vegetation - Community types and distribution, recruitment and reproduction, root density, community dynamics, and survival.

Erosion/Deposition - Shoreline stability.

Soils - Distribution of anaerobic soil and ponding frequency and duration.

Water Quality - No change.

Biotic Community - Aquatic plant recruitment and reproduction and nutrient enrichment.

Figure 1. Proper functioning condition (A) and nonfunctional condition (B) for a lentic palustrine wetland area.

Land activities that disrupt the permafrost layer would result in **State A** progressing to **State B**. **State B** would be classified as nonfunctional. The following changes in attributes/processes are likely in **State B**:

Hydrogeomorphic - Continuous permafrost (lost); shoreline shape (changed); and depth, duration, and frequency of inundation (decreased).

Vegetation - Community types and distribution (lost/changed), recruitment and reproduction, root density, community dynamics, and survival (decreased).

Erosion/Deposition - Shoreline stability (decreased).

Soils - Distribution of anaerobic soil and ponding frequency and duration (decreased).

Water Quality - Temperature (increased), pH (changed).

Biotic Community - Aquatic plant recruitment and reproduction and nutrient enrichment (decreased).

Table 1. Attributes/Processes List *

Hydrogeomorphic
Ground-Water Discharge Permafrost Continuous Discontinuous Flood Modification Inundation Depth Duration Frequency Semipermanently Flooded Shoreline Shape
Vegetation
Community Types Community Type Distribution Surface Density Canopy Community Dynamics and Succession Recruitment/Reproduction Root Density Survival
Erosion/Deposition
Shoreline Stability Depositional Features
Soils
Soil Type Distribution of Aerobic/Anaerobic Soils Annual Pattern of Soil Water States Ponding Frequency and Duration Underlying Materials
Water Quality
Temperature pH Dissolved Solids Dissolved Oxygen
Biotic Community
Aquatic Plants Recruitment/Reproduction Nutrient Enrichment

* This list provides examples of various attributes/processes that may be present in a riparian-wetland area. By no means is it complete.

The previous example would be found in Alaska and represents one of many types of lentic riparian-wetlands found on public lands. However, it is important to remember that there are other types and that:

Riparian-wetland areas do have fundamental commonalities in how they function, but they also have their own unique attributes. Riparian-wetland areas can and do function quite differently. As a result, most areas need to be evaluated against their own capability and potential. Even for similar areas, human influence may have introduced component(s) that have changed the area's capability and potential. Assessments, to be correct, must consider these factors and the uniqueness of each system.

2. Capability and Potential

Determining functionality of lotic riparian-wetland areas involves determining an area's capability and potential. This is also true for assessing functionality of lentic riparian-wetland areas. The same approach presented in TR 1737-9 can be used for lentic areas and is as follows:

- Look for relic areas (exclosures, preserves, etc.).
- Seek out historic photos, survey notes, and/or documents that indicate historic condition.
- Search out species lists (animals & plants - historic & present).
- Determine species habitat needs (animals & plants) related to species that are/were present.
- Examine the soils and determine if they were saturated at one time and are now well drained?
- Examine the hydrology; establish the frequency and duration of flooding/ponding.
- Identify vegetation that currently exists. Are they the same species that occurred historically?
- Determine the entire watershed's general condition and identify its major landform(s).
- Look for limiting factors, both human-caused and natural, and determine if they can be corrected.

This approach forms the basis for initiating an inventory effort like ESI. For some areas, conducting an ESI effort will be the only way to assess an area's capability and potential.

Some lentic riparian-wetland areas will be prevented from achieving their potential because of limiting factors such as human activities. For lentic riparian-wetland areas, most of these limiting factors can be rectified through proper management. To identify these factors, a limiting factor analysis should be part of any inventory method applied to determine capability and potential.

3. *Functioning Condition*

When determining whether a lentic riparian-wetland area is functioning properly, it is important to determine the condition of the entire watershed. The entire watershed can influence the quality, abundance, and stability of downstream resources by controlling production of sediment and nutrients, influencing ponding frequency and duration, and modifying the distribution of chemicals throughout the riparian-wetland area.

Lentic riparian-wetland areas can function properly before they achieve their Potential Plant Community (PPC) or Potential Natural Community (PNC). The Bureau's definition does not mean PNC or optimal conditions for a particular species have to be achieved to be rated as functioning properly. But the Bureau's goal is to achieve an advanced ecological status, except where resource management objectives, including PFC, would require an earlier successional stage, thus providing the widest variety of habitat diversity for wildlife, fish, and watershed protection. After achieving PFC, management should progress towards achieving a desired plant community (DPC) and then achieving a desired future condition (DFC).

The steps in Figure 2 in TR 1737-9 (page 12) provide an example of the relationship between PFC and vegetation community succession for a lotic riparian-wetland area. This relationship can be applied to lentic riparian-wetland areas as well. If vegetation succession continues uninterrupted (Step 1 to Step 2), the riparian-wetland site will progress through some predictable changes from early seral to PNC (although not necessarily as linearly as depicted). As the vegetation community progresses, the riparian-wetland area will advance through phases of not functioning, functioning — at risk, and properly functioning.

At various stages within this successional process, the riparian-wetland area will provide a variety of values for different uses (Step 4). Optimal conditions for grazing occur when forage is abundant and the area is stable and sustainable (mid-seral). Wildlife goals depend upon the species for which the area is being managed. If the riparian-wetland area is to provide nesting habitat for waterfowl, the optimum conditions might be late seral. If the area is to provide feeding habitat for shorebirds, the optimum condition might be mid-seral. The threshold for any goal is at least PFC because any rating below this would not be sustainable. **For riparian-wetland areas, PFC may occur from early seral to late seral.** Desired plant community (DPC) is then determined based on management objectives through an interdisciplinary approach (Step 5), eventually achieving the desired future condition (Figure 2). **Selection of plant communities and future conditions needs to be balanced within a watershed(s) and within an ecoregion(s).**

When rating functionality, it will be easy to categorize many lentic riparian-wetland areas as PFC or nonfunctional. For others it will not be easy. Difficulty in rating PFC usually arises in identifying the thresholds that allow a riparian-wetland area to move from one category to another.

Figure 2.

To provide consistency in reporting PFC, BLM has established a standard checklist for lentic riparian-wetland areas for field offices to initiate this process (Appendix A). BLM's lentic checklist may not answer the question of functionality for all lentic riparian-wetland areas. On occasion, field offices will find that blending the lentic checklist with the lotic checklist is necessary to assess functionality for some riparian-wetland areas. Some areas may require a more intensive inventory effort, like ESI.

Field offices can add elements to BLM's lentic or lotic checklist to address unique riparian-wetland attributes and processes. **If elements are added, field offices need to make sure additions can be quantified.**

To further assist field offices in assessing functionality, Appendix B provides examples of lentic riparian-wetland areas that depict categories of PFC, functional — at risk, and nonfunctional.

III. Problem Wetlands

Certain wetlands may be difficult to identify because field indicators of the three wetland identification criteria may be absent, at least at certain times of the year. These wetlands are considered problem wetlands because the difficulty in identification is generally due to normal environmental conditions and not the result of human activities or catastrophic natural events, with the exception of newly created wetlands. Because of the difficulty in identifying these areas as wetlands, there will be a degree of difficulty in assessing their functionality. Field offices may need to add elements to the lentic checklist to assess these problem wetlands.

Examples of problem wetlands are discussed below. Learning how to recognize these wetlands and to understand their attributes/processes is important in assessing functionality.

A. Wetlands Dominated by Facultative Upland (FACU) Plant Species

Since wetlands often exist along a natural wetness gradient between permanently flooded substrates and better drained soils, the wetland plant communities sometimes may be dominated by FACU species. Although FACU-dominated plant communities are usually uplands, they sometimes become established in wetlands. In order to determine whether a FACU-dominated plant community constitutes hydrophytic vegetation, the soil and hydrology must be examined. If the area meets the hydric soil and wetland hydrology criteria, then the vegetation is hydrophytic.

B. Evergreen Forested Wetlands

Wetlands dominated by evergreen trees occur in many parts of the country. In some cases, the trees are obligate wetland (OBL) species, facultative wetland (FACW) species, and facultative (FAC) species, e.g., Atlantic white cedar (*Chamaecyparis thyoides*), black spruce (*Picea mariana*), balsam fir (*Abies balsamae*), slash pine (*Pinus elliottii*), and loblolly pine (*P. taeda*). In other cases, however, the dominant evergreen trees are FACU species, including red spruce (*Picea rubens*), Engelmann spruce (*P. engelmannii*), white spruce (*P. glauca*), Sitka spruce (*P. sitchensis*), eastern white pine (*Pinus strobus*), pitch pine (*P. rigida*), lodgepole pine (*P. contorta*), longleaf pine (*P. palustris*), ponderosa pine (*P. banksiana*), eastern hemlock (*Tsuga canadensis*), western hemlock (*T. heterophylla*), Pacific silver fir (*Abies amabilis*), white fir (*A. concolor*), and subalpine fir (*A. lasiocarpa*). In dense stands, these evergreen trees may preclude the establishment of understory vegetation or, in some cases, understory vegetation is also FACU species. Since these plant communities are usually found on nonwetlands, the ones established in wetland areas may be difficult to recognize at first glance. The landscape position of the evergreen forested areas, such as depressions, drainageways, bottomlands, flats in sloping terrain, and seepage slopes, should be considered because it often provides good clues to the likelihood of a wetland. Soils also should be examined in these situations. Procedures for identifying these wetlands are the same as those for FACU-dominated wetlands described above.

C. Glacial Till Wetlands

Sloping wetlands occur in glaciated areas where thin soil covers relatively impermeable glacial till or where layers of glacial till have different hydraulic conditions that permit ground-water seepage. Such areas are seldom, if ever, flooded, but downslope ground-water movement keeps the soils saturated for a sufficient portion of the growing season to produce anaerobic and reducing soil conditions. This promotes development of hydric soils and hydrophytic vegetation. Indicators of wetland hydrology may be lacking during the drier portion of the growing season. Hydric soil indicators also may be lacking because certain areas are so rocky that it is difficult to examine soil characteristics within 18 inches.

D. Highly Variable Seasonal Wetlands

In many regions (especially in arid and semiarid regions), depressional areas occur that may have indicators of all three wetland criteria during the wetter portion of the growing season, but normally lack indicators of wetland hydrology and/or hydrophytic vegetation during the drier portion of the growing season. In addition, some of these areas lack field indicators of hydric soil. OBL and FACW plant species normally are dominant during the wetter portion of the growing season, while FACU and obligate upland (UPL) species (usually annuals) may be dominant during the drier portion of the growing season and for some time after droughts. Examples of highly variable seasonal wetlands are pothole wetlands in the upper Midwest, playa wetlands in the Southwest, and vernal pools along the coast of California. It is important to become familiar with the ecology of these and similar types of wetlands and to be particularly aware of drought conditions that permit invasion of UPL species (even perennials).

E. Interdunal Swale Wetlands

Along the U.S. coastline, seasonally wet swales supporting hydrophytic vegetation are located within sand dune complexes on barrier islands and beaches. Some of these swales are inundated or saturated to the surface for considerable periods during the growing season, while others are wet for only the early part of the season. In some cases, swales may be flooded irregularly by the tides. These wetlands have sandy soils that generally lack field indicators of hydric soil. In addition, indicators of wetland hydrology may be absent during the drier part of the growing season. Consequently, these wetlands may be difficult to identify.

F. Vegetated River Bars and Adjacent Flats Wetlands

Along Western streams in arid and semiarid parts of the country, some river bars and flats may be vegetated by FACU species while others may be colonized by wetter species. If these areas are frequently inundated for 1 or more weeks during the growing season, they are wetlands. The soils often do not reflect the characteristic field indicators of hydric soils, however, and thereby pose delineation problems.

G. Vegetated Flats Wetlands

Vegetated flats are characterized by a marked seasonal periodicity in plant growth. They are dominated by annual OBL species, such as wild rice (*Zizania aquatica*), and/or perennial OBL species, such as spatterdock (*Nuphar luteum*), that have non-persistent vegetative parts (i.e., leaves and stems break down rapidly during the winter, providing no evidence of the plant on the wetland surface at the beginning of the next growing season). During winter and early spring, these areas lack vegetative cover and resemble mud flats; therefore, they do not appear to qualify as wetlands. But during the growing season the vegetation becomes increasingly evident, qualifying the area as a wetland. In evaluating these areas, which occur both in coastal and interior parts of the country, the time of year of the field observation and the seasonality of the vegetation must be considered. Again, it is important to become familiar with the ecology of these wetland types.

H. Newly Created Wetlands

These wetlands include manmade (artificial) wetlands, beaver-created wetlands, and other natural wetlands. Artificial wetlands may be purposely or accidentally created by human activities (e.g., road impoundments, undersized culverts, irrigation, and seepage from earth-dammed impoundments). Many of these areas will have indicators of wetland hydrology and hydrophytic vegetation. But the area may lack typical field characteristics of hydric soils, since the soils have just recently been inundated and/or saturated. Since all of these wetlands are newly established, field indicators of one or more of the wetland identification criteria may not be present.

I. Entisols (Floodplain and Sandy Soils) Wetlands

Entisols are usually young or recently formed soils that have little or no evidence of pedogenically developed horizons. These soils are typical of floodplains throughout the U.S., but are also found in glacial outwash plains, along tidal waters, and in other areas. They include sandy soils of riverine islands, bars, and banks and finer-textured soils of floodplain terraces. Wet entisols have an aquic or peraquic moisture regime and are considered hydric soils, unless effectively drained. Some entisols are easily recognized as hydric soils, such as the sulfaquents of tidal salt marshes, whereas others pose problems because they do not possess typical hydric soil field indicators. Wet sandy entisols (with loamy fine sand and coarser textures in horizons within 20 inches of the surface) may lack sufficient organic matter and clay to develop hydric soil colors. When these soils have a hue between 10YR and 10Y and distinct or prominent mottles present, a chroma of 3 or less is permitted to identify the soil as hydric (i.e., an aquic moisture regime).

J. Mollisols (Prairie and Steppe Soils) Wetlands

Mollisols are dark-colored, base-rich soils. They are common in the central part of the conterminous U.S. from eastern Illinois to Montana and south to Texas. Natural vegetation is mainly tall grass prairies and short grass steppes. These soils typically have deep, dark topsoil layers (mollic epipedons) and low chroma matrix colors to

considerable depths. They are rich in organic matter due largely to the vegetation (deep roots) and reworking of the soil and organic matter by earthworms, ants, moles, and rodents. The low chroma colors of mollisols are not necessarily due to prolonged saturation, so making wetland determinations in these soils requires particular care. It is important to become familiar with the characteristics of mollisols with aquic moisture regimes, since they are usually hydric, unless effectively drained, and to be able to distinguish these from nonhydric mollisols.

IV. Instituting the Process

A. Planning

The process established in TR 1737-9 for incorporating the information collected into a management plan would apply to lentic riparian-wetland areas also. That process is as follows:

- Step 1 Existing Condition** - Determine the existing riparian-wetland and watershed condition using BLM standard inventory methods.
- Step 2 Potential Condition** - Determine PNC by using relic areas, historic photos, etc. (ESI process).
- Step 3 PFC** - Determine the minimum conditions required for the area to function properly.
- Step 4 Resource Values** - Determine existing and potential resource values and the plant communities necessary to support these values.
- Step 5 Management Goals** - Negotiate specific objectives to reach management goals for the watershed, DPC, or DFC.
- Step 6 Planned Actions** - Design management actions to achieve the DPC.
- Step 7 Monitoring** - Design appropriate monitoring strategies to assess progress towards meeting management goals.
- Step 8 Flexibility** - Maintain management flexibility to accommodate change based upon monitoring results.

B. Management

For BLM to be successful in reaching its goal of having 75 percent of its riparian-wetland areas functioning properly by 1997, best management practices need to be set in motion. Successful management strategies address the entire watershed. Upland and riparian-wetland areas are interrelated and cannot be considered separately. Technical references such as TR 1737-4 (Kinch, 1989) and TR 1737-6 (Smith and Prichard, 1992) are tools that can be used to develop management techniques.

C. Monitoring

Management effectiveness can be assessed and progress towards meeting PFC can be documented through monitoring. Sites should be revisited periodically as part of the overall monitoring program. Areas rated at a single point in time can reflect short-term factors such as climatic conditions. Monitoring will reflect longer-term trends. Technical references such as TR 1737-3 (Myers, 1989) are tools that can be used to develop monitoring criteria.

V. Summary

Riparian-wetland areas constitute an important resource on lands managed by BLM. BLM's goal is to have 75 percent of its riparian-wetlands functioning properly by 1997. This document supplements TR 1737-9 and provides a thought process for assessing functioning condition of lentic riparian-wetland areas.

The status of some lentic riparian-wetland areas will be relatively easy to discern while the status of others will be less evident. Appendix A contains the minimum national standards that BLM field offices will use in making this assessment for lentic riparian-wetland areas. For hard-to-discern areas, Ecological Site Inventory may be the only method to determine capability and potential and assess functionality. Using either method requires an interdisciplinary team to adequately address the complexities associated with lentic riparian-wetland areas and to report their functioning condition.

The lack of specific information will place many lentic riparian-wetland areas into the category of unknown. In order for BLM to make an adequate assessment of progress towards its goal, it is imperative that areas for which no data exists be evaluated and added to the data base. As information is acquired and resource values are identified, best management practices need to be set in motion. Successful management strategies have to address the entire watershed, as upland and riparian-wetland areas are interrelated and cannot be considered separately.

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Glossary of Terms

Advanced Ecological Status - A community with a high coefficient of similarity to a defined or perceived PNC for an ecological site, usually late seral or PNC ecological status.

Aerobic - A condition in which molecular oxygen is a part of the environment.

Anaerobic - A condition in which molecular oxygen is absent (or effectively so) from the environment.

Duration-Frequency - A general descriptive term for the average duration of soil inundation per flood occurrence for a geographic area. Categories include: very brief (less than 2 days); brief (2 to 7 days); long (7 days to 1 month); very long (more than 1 month); and flash flooding (less than 2 hours).

Facultative (FAC) Species - Plant species that are equally likely to occur in wetlands or nonwetlands (estimated probability 34-66%).

Facultative Upland (FACU) Species - Plant species that usually occur in nonwetlands (estimated probability 67-99%), but occasionally are found in wetlands (estimated probability 1-33%).

Facultative Wetland (FACW) Species - Plant species that usually occur in wetlands (estimated probability 67-99%), but occasionally are found in nonwetlands.

Frost (or abnormal hydrologic) Heaving - The lifting of a surface by the internal action of frost or hydrostatic pressure. It generally occurs after a thaw, when the soil is filled with water droplets and the temperature suddenly drops below freezing; the droplets then become ice crystals, and their expansion causes an upward movement of the soil. The process is exacerbated when there is compaction between plant tussocks (e.g., from hoof action) and/or excessive removal of thermal vegetation cover. The result is the hummocked appearance of plants being elevated above the normal ground surface, root shearing between plants, and exposure of interspaces to increased erosional forces.

Hydric Soils - Soils that are flooded, ponded, or saturated for usually 1 week or more during the period when soil temperatures are above biologic zero (41° F). Complete criteria can be found in BLM Technical Reference 1737-7.

Obligate Upland (UPL) Species - Plant species that occur in wetlands in another region, but occur almost always (estimated probability >99%) under natural conditions in nonwetlands in the region specified.

Obligate Wetland (OBL) Species - Plant species that occur almost always (estimated probability >99%) under natural conditions in wetlands.

Ponding-Frequency - A general descriptive term for the relative change of reoccurrence of a flooding event for a geographic area. Categories include: none (0 percent chance); rare (0 to 5 percent chance); occasional (5 to 50 percent chance); and frequent (greater than 50 percent chance).

Potential Plant Community - Represents the seral stage the botanical community would achieve if all successional sequences were completed without human interference under the present environmental conditions.

Riparian-Wetland Ecological Site - An area of land with a specific potential plant community and specific physical site characteristics, differing from other areas of land in its ability to produce vegetation and to respond to management. Ecological site is synonymous with range site.

Vegetation Community Dynamics - Response of plant communities to changes in their environment, to their use, and to stresses to which they are subjected. Climatic cycles, fire, insects, grazing, and physical disturbances are some of the many causes of changes in plant communities. Some changes are temporary while others are long lasting.

Vegetation Community Succession - Primary succession is a sequence of plant community changes from the initial colonization of a bare soil toward a PNC. Secondary succession may involve sequences of plant community change from PNC due to perturbations, or a sequence toward PNC again following a perturbation. Vegetation community succession may be accompanied by subtle but significant changes in temporal soil characteristics such as bulk density, nutrient cycling, and microclimatic changes, but is differentiated from major physical state changes such as landform modification or long-term elevation or lowering of a water table that would change the PNC of an ecological site.

Appendix A

Lentic Riparian-Wetland Functional Checklist

General Instructions

- 1) The concept "**Relative to Capability**" applies wherever it may be inferred.
- 2) This checklist constitutes the **Minimum National Standards** required to determine Proper Functioning Condition of lentic riparian-wetland areas.
- 3) As a minimum, an **ID Team** will use this checklist to determine the degree of function of a lentic riparian-wetland area.
- 4) Mark one box for each element. Elements are numbered for the purpose of cataloging comments. The numbers do not declare importance.
- 5) For any item marked "**No**," the severity of the condition must be explained in the "**Remarks**" section and must be a subject for discussion with the ID Team in determining riparian-wetland functionality. Using the "**Remarks**" section to also explain items marked "**Yes**" is encouraged but not required.
- 6) Based on the ID Team's discussion, "**functional rating**" will be resolved and the checklist's summary section will be completed.
- 7) Establish photo points where possible to document the site.

Lentic Standard Checklist

Name of Riparian-Wetland Area: _____

Date: _____ Area/Segment ID: _____ Acres: _____

ID Team Observers: _____

Yes	No	N/A	HYDROLOGIC
			1) Riparian-wetland area is saturated at or near the surface or inundated in "relatively frequent" events (1-3 years)
			2) Fluctuation of water levels is not excessive
			3) Riparian-wetland zone is enlarging or has achieved potential extent
			4) Upland watershed not contributing to riparian-wetland degradation
			5) Water quality is sufficient to support riparian-wetland plants
			6) Natural surface or subsurface flow patterns are not altered by disturbance (i.e., hoof action, dams, dikes, trails, roads, rills, gullies, drilling activities)
			7) Structure accommodates safe passage of flows (e.g., no headcut affecting dam or spillway)

Yes	No	N/A	VEGETATION
			8) Diverse age-class distribution (recruitment for maintenance/recovery)
			9) Diverse composition of vegetation (for maintenance/recovery)
			10) Species present indicate maintenance of riparian-wetland soil moisture characteristics
			11) Vegetation is comprised of those plants or plant communities that have root masses capable of withstanding wind events, wave flow events, or overland flows (e.g., storm events, snowmelt)
			12) Riparian-wetland plants exhibit high vigor
			13) Adequate vegetative cover present to protect shorelines/soil surface and dissipate energy during high wind and wave events or overland flows
		N/A	14) Frost or abnormal hydrologic heaving is not present
			15) Favorable microsite condition (i.e., woody debris, water temperature, etc.) is maintained by adjacent site characteristics

Yes	No	N/A	SOILS-EROSION DEPOSITION
			16) Accumulation of chemicals affecting plant productivity/composition is not apparent
			17) Saturation of soils (i.e., ponding, flooding frequency and duration) is sufficient to compose and maintain hydric soils
			18) Underlying geologic structure/soil material/permafrost is capable of restricting water percolation
			19) Riparian-wetland is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)
			20) Islands and shoreline characteristics (i.e., rocks, course and/or large woody debris) adequate to dissipate wind and wave event energies

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There is no handwriting or other markings on the paper.

Functional Rating:

Trend for Functional—At Risk:

Are factors contributing to unacceptable conditions outside BLM's control or management?

If yes, what are those factors?

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Appendix B

Lentic Riparian-Wetland Examples

Forested Wetland—Oregon
Proper Functioning Condition

Clay Bridges

Forested Wetland—Oregon
Functional—At Risk

Clay Bridges

Forested Wetland—Oregon Proper Functioning Condition

The photo to the left is an example of a landslide sag pond found in the Coastal Range, Oregon. This lentic form of wetland would be rated **PFC** relative to BLM's definition. The wetland contains adequate vegetation, landform, and large woody debris which provide root masses that stabilize shoreline features against cutting actions; filter sediment and aid floodplain development; maintain hydric soils; restrict water percolation; and provide favorable microsite conditions that support greater biodiversity.

Forested Wetland—Oregon Functional—At Risk

The photo to the left is an example of a lentic wetland in Oregon that would be rated **functional — at risk**. Most of the physical attributes/processes (i.e., diverse composition of vegetation for maintenance/recovery, underlying materials that restrict water percolation, etc.) are in place to allow this system to function properly. However, this wetland is rated **functional — at risk** because it lacks adjacent site characteristics to control water temperatures and to prevent soils from inundating the site due to excessive erosion.

Lacustrine Wetland—New Mexico Functional—At Risk

Clay Bridges

Playa Wetland—New Mexico Proper Functioning Condition

Clay Bridges

Lacustrine Wetland—New Mexico Functional—At Risk

This photo shows an example of a lacustrine wetland in New Mexico that would be rated *functional — at risk* because natural overland flow patterns have been altered by surface disturbances. Surface disturbances, like the trails in this photo, intercept, divert, and concentrate overland flows away from the wetland site. This diversion and concentration of overland flows increase energies which form headcuts that drain the site, thus reducing the wetland's ability to maintain hydric soils and associated vegetation. If allowed to continue, the wetland will eventually be lost.

Playa Wetland—New Mexico Proper Functioning Condition

In New Mexico, depressional areas (playas) such as in the photo to the left have wetland indicators during the wetter portion of a growing season, but normally lack indicators during the drier portion of the growing season (see Problem Wetlands section for more information). Assessing functionality of a playa requires understanding that system's attributes/processes (i.e., ponding frequency and duration, community dynamics and succession, recruitment and reproduction, etc.). The playa wetland in this photo would normally be rated *PFC*.

This wetland would be rated *functional — at risk* if underlying materials have been disturbed that restricted percolation, or overland flows to the playa have been restricted. Alteration of the natural topography that drains the wetland would result in a rating of *nonfunctional*.

Lacustrine Wetland—Colorado
Functional—At Risk/Proper Functioning Condition

BLM Kremmling Resource Area

Seep Wetland—Nevada
Nonfunctional

Mark Biddlecomb

Lacustrine Wetland—Colorado

Functional—At Risk/Proper Functioning Condition

The lacustrine wetland in the photo to the left would be rated *functional — at risk* on the left side and *PFC* on the right side. Most of the attributes/processes on the left side indicate a functioning system (i.e., diverse composition of vegetation, saturation of soils sufficient to compose and maintain hydric soils, no excessive erosion or deposition, etc.). The left side is rated *functional — at risk* due to the presence of abnormal hydrologic heaving. Over time, hydrologic heaving will change composition of vegetation and may drain the site.

All the attributes/process on the right side of this photo indicate a functioning system.

Seep Wetland—Nevada

Nonfunctional

The photo to the left shows an example of a seep located in Nevada that would be rated as *nonfunctional* relative to BLM's definition for proper functioning condition. This wetland **clearly** does not provide adequate vegetation to filter sediment and aid wetland development, lacks adequate cover to protect the area from erosion or deposition as a result of overland flows, lacks diverse age-class distribution and composition of vegetation to allow recovery, and does not provide wetland characteristics necessary to support aquatic or other species. This lack of vegetation and the area's lack of balance with the sediment being supplied have permitted three things to occur: 1) the extent of the wetland has been greatly reduced, 2) the wetland's water quality has been altered, and 3) the wetland's diversity of aquatic vegetation has been greatly reduced. The area provides little biodiversity.

Palustrine Wetland—Nevada
Proper Functioning Condition

Clay Bridges

Wet Meadow Wetland—Idaho
Functional—At Risk

Steve Leonard

Palustrine Wetland—Nevada Proper Functioning Condition

Wetlands that have achieved late seral or PNC, as Locke's Pond has in the photo at left, can easily be placed into the appropriate category. Using the Bureau definition, Locke's Pond would have a rating of **PFC**. Completing a lentic checklist on this area would result in a yes or N/A answer for the 20 items. The physical processes are functioning, and the wetland is supporting diverse ponding characteristics that provide the habitat and the water depth, duration, and temperature necessary for fish production, waterbird breeding, and other uses. Locke's Pond is providing biodiversity.

Wet Meadow Wetland—Idaho Functional—At Risk

The wet meadow pictured at left would be rated **functional — at risk** relative to BLM's definition for proper functioning condition, even though most of the attributes/processes indicate a functioning system. Currently, most of the wetland is saturated at or near the surface with "relatively frequent events" that maintain its hydric soils, contains a diverse composition of vegetation which can maintain the wetland, is comprised of those plants or plant communities that have root masses capable of withstanding overland flow events, and is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition), etc.

The reason this wetland is rated **functional — at risk** is that abnormal frost heaving is present. Hydrologic or frost heaving, allowed to continue over time, will change the vegetation composition. This change in vegetation will reduce the extent of the wetland and may eventually drain the wetland.

Prairie Pothole Wetland—Montana
Proper Functioning Condition

Ramone McCoy

Prairie Pothole Wetland—Montana
Functional—At Risk

Photos by: Ramone McCoy

Prairie Pothole Wetland—Montana

Proper Functioning Condition

Prairie potholes are classified as highly variable seasonal wetlands. During drier climatic cycles or the drier portion of a growing season, these wetlands may lack hydrology and/or hydrophytic vegetation indicators that would identify them as wetlands. During wet years, they provide a diverse composition of wetland vegetation, but during dry years, the wetland species may be replaced with upland species. Potholes in Montana, on average, are inundated only 1 in 5 years.

The photo to the left shows an example of a Montana prairie pothole wetland that would be rated **PFC**. This pothole contains adequate vegetation to dissipate energies associated with wind action, wave action, and overland flow from adjacent sites; restricts water percolation; provides ponding characteristics that provide habitat for waterbird breeding; etc., relative to its capability and potential.

Prairie Pothole Wetland—Montana

Functional—At Risk

The photos to the left show an example of an artificially enhanced prairie pothole. An earthen dam has been constructed that collects and stores additional overland flow, creating a more permanent site. Previously this pothole would have been classified as highly variable seasonal wetland, but now it would be classified as a palustrine wetland.

At first glance this wetland would be rated **PFC**. The wetland is saturated at or near the surface in relatively frequent events, provides water quality that supports wetland plants, provides a diverse age class and composition of vegetation, has adequate vegetative cover to protect shorelines during high wind and wave events, and provides greater biodiversity, etc. However, this wetland is not rated **PFC** because the structure is no longer accommodating the safe passage of flows. A headcut has developed in the spillway that threatens the integrity of the dam (see insert). The spillway is located to the left of the rock in the main photo. The correct rating would be *functional — at risk*.

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Standard Checklist

Name of Riparian-Wetland Area: _____

Date: _____ Segment/Reach ID: _____

Miles: _____ Acres: _____

ID Team Observers: _____

Yes	No	N/A	HYDROLOGIC
			Floodplain inundated in "relatively frequent" events (1-3 years)
			Active/stable beaver dams
			Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
			Riparian zone is widening
			Upland watershed not contributing to riparian degradation

Yes	No	N/A	VEGETATIVE
			Diverse age structure of vegetation
			Diverse composition of vegetation
			Species present indicate maintenance of riparian soil moisture characteristics
			Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high streamflow events
			Riparian plants exhibit high vigor
			Adequate vegetative cover present to protect banks and dissipate energy during high flows
			Plant communities in the riparian area are an adequate source of coarse and/or large woody debris

Yes	No	N/A	EROSION DEPOSITION
			Floodplain and channel characteristics (i.e., rocks, coarse and/or large woody debris) adequate to dissipate energy
			Point bars are revegetating
			Lateral stream movement is associated with natural sinuosity
			System is vertically stable
			Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)

Remarks

Summary Determination

Functional Rating:

Proper Functioning Condition _____
Functional—At Risk _____
Nonfunctional _____
Unknown _____

Trend for Functional—At Risk:

Upward _____
Downward _____
Not Apparent _____

Are factors contributing to unacceptable conditions outside BLM's control or management?

Yes _____
No _____

If yes, what are those factors?

____ Flow regulations ____ Mining activities ____ Upstream channel conditions
____ Channelization ____ Road encroachment ____ Oil field water discharge
____ Augmented flows ____ Other (specify) _____

Lentic Standard Checklist

Name of Riparian-Wetland Area: _____

Date: _____ Area/Segment ID: _____ Acres: _____

ID Team Observers: _____

Yes	No	N/A	HYDROLOGIC
			1) Riparian-wetland area is saturated at or near the surface or inundated in "relatively frequent" events (1-3 years)
			2) Fluctuation of water levels is not excessive
			3) Riparian-wetland zone is enlarging or has achieved potential extent
			4) Upland watershed not contributing to riparian-wetland degradation
			5) Water quality is sufficient to support riparian-wetland plants
			6) Natural surface or subsurface flow patterns are not altered by disturbance (i.e., hoof action, dams, dikes, trails, roads, rills, gullies, drilling activities)
			7) Structure accommodates safe passage of flows (e.g., no headcut affecting dam or spillway)

Yes	No	N/A	VEGETATION
			8) Diverse age-class distribution (recruitment for maintenance/recovery)
			9) Diverse composition of vegetation (for maintenance/recovery)
			10) Species present indicate maintenance of riparian-wetland soil moisture characteristics
			11) Vegetation is comprised of those plants or plant communities that have root masses capable of withstanding wind events, wave flow events, or overland flows (e.g., storm events, snowmelt)
			12) Riparian-wetland plants exhibit high vigor
			13) Adequate vegetative cover present to protect shorelines/soil surface and dissipate energy during high wind and wave events or overland flows
			14) Frost or abnormal hydrologic heaving is not present
			15) Favorable microsite condition (i.e., woody debris, water temperature, etc.) is maintained by adjacent site characteristics

Yes	No	N/A	SOILS-EROSION DEPOSITION
			16) Accumulation of chemicals affecting plant productivity/composition is not apparent
			17) Saturation of soils (i.e., ponding, flooding frequency and duration) is sufficient to compose and maintain hydric soils
			18) Underlying geologic structure/soil material/permafrost is capable of restricting water percolation
			19) Riparian-wetland is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)
			20) Islands and shoreline characteristics (i.e., rocks, coarse and/or large woody debris) adequate to dissipate wind and wave event energies

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There is no handwriting or other markings on the paper.

Functional Rating:

Trend for Functional—At Risk:

Are factors contributing to unacceptable conditions outside BLM's control or management?

If yes, what are those factors?

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BLM RIPARIAN-WETLAND TECHNICAL REFERENCES

The Bureau of Land Management started their Riparian-Wetland Initiative with the formation of a Task Group in 1985. The purpose of that Task Group was to determine the needs of the Bureau and to develop tools necessary (technical references, handbooks, etc.) to implement that initiative. The documents listed below have been developed by BLM or jointly with other agencies and are available to the public. If you desire any of these publications, check the appropriate one(s) and mail the form to the following address:

BUREAU OF LAND MANAGEMENT
Service Center, SC-213
Attention: Don Prichard
Denver Federal Center, Building 50
P.O. Box 25047
Denver, Colorado 80225-0047

If you have any questions, call Don Prichard at (303) 236-0162 or write him at the address listed above.

cut along dotted line

- _____ BLM's "Riparian-Wetland Initiative for the 1990's"
- _____ TR 1737-3 "Inventory and Monitoring Riparian Areas"
- _____ TR 1737-4 "Grazing Management in Riparian Areas"
- _____ TR 1737-5 "Riparian and Wetland Classification Review"
- _____ TR 1737-6 "Management Techniques in Riparian Areas"
- _____ TR 1737-7 "Procedures for Ecological Site Inventory - With Special Reference to Riparian-Wetland Sites"
- _____ TR 1737-8 "Greenline Riparian-Wetland Monitoring"
- _____ TR 1737-9 "Process for Assessing Proper Functioning Condition"
- _____ TR 1737-10 "The Use of Aerial Photographs to Manage Riparian-Wetland Areas"
- _____ TR 1737-11 "Process for Assessing Proper Functioning Condition for Lentic Riparian-Wetland Areas"
- _____ EPA's "Livestock Grazing on Western Riparian Areas"
- _____ EPA's "Managing Change - Livestock Grazing on Western Riparian Areas"
- _____ FGDC's "Application of Satellite Data for Mapping and Monitoring Wetlands - A Fact Finding Report"

NAME _____

AFFILIATION/AGENCY _____

ADDRESS _____

RESOURCE MANAGEMENT OBJECTIVES

Resource Management Objectives

Presenter: Jim Wolf, Big Horn Basin Resource Area, WY

Part 1

Objective: Students will be able to prepare high quality resource management objectives.

- A. Discuss the importance of resource management objectives. **Objectives drive land management programs.**
- B. Explain the difference between land use planning goals and resource management objectives.
- C. Describe the six elements of a well written objective:
 - 1. State **what** is to be accomplished.
 - 2. State the **component** that needs to be changed or maintained.
 - 3. State the **amount** of change desired within a beginning and ending point.
 - 4. Identify the **location** where the objective is to be accomplished.
 - 5. Establish a **time frame** for accomplishment.
 - 6. Objectives must be **compatible** with the land use plan.

Part 2

Objectives: a) Students will be able to utilize a matrix to track resource management objectives from land use planning stage through monitoring and evaluation. b) Students will be able to use the matrix to evaluate existing activity plans.

- A. Discuss how the tracking matrix can be used to link resource management objectives broader land use plans.
- B. Discuss how the tracking matrix can be used to ensure the component parts of activity plans (goals, issues, resource objectives, management actions and monitoring) are logically related when developing new activity plans.
- C. Discuss how the tracking matrix can be used to evaluate resource management objectives, management actions and monitoring programs in existing activity plans.
- D. **EXERCISE:** Students will develop resource management objectives from baseline data and two scenarios involving riparian reserves in the Salem District. Student will utilize a matrix to show their objectives track from the land use plan through monitoring.

OBJECTIVE DEVELOPMENT EXERCISE

April 1995, Salem, Oregon

The Salem District has a wide variety of resource values associated with riparian areas. The land use plan states that riparian reserves will be managed consistent with the Aquatic Conservation Strategy. Guidance from the Aquatic Conservation Strategy and Salem District RMP that applies to this exercise include the following:

- Maintain and restore the species composition and structural diversity of plant communities in riparian zones and wetlands to provide adequate summer and winter thermal regulation, nutrient filtering, appropriate rates of surface erosion, bank erosion, and channel migration and to supply amounts and distributions of coarse woody debris sufficient to sustain physical complexity and stability.

- Maintain and restore the sediment regime under which and aquatic ecosystem evolved. Elements of the sediment regime include the timing, volume, storage, and transport.

- Maintain and restore instream flows sufficient to create and sustain riparian, aquatic, and wetland habitats and to retain patterns of sediment, nutrient, and wood routing (i.e., movement of woody debris through the aquatic system). The timing, magnitude, duration, and spatial distribution of peak, high, and low flows must be protected.

- Immediately establish an emergency team to develop a rehabilitation treatment plan needed to attain Aquatic Conservation Strategy objectives whenever Riparian Reserves are significantly damaged by wildfire or a prescribed fire burning outside prescribed parameters. (Remember the difference between site specific resource management objectives and broader land use planning goals; i.e, ACS objectives as referred to in the Salem District RMP).

The exercise is to select a creek scenario, and:

1. Identify an overall goal for the activity plan that is consistent with the Salem RMP.
2. Identify one or two resource issues for the creek scenario you select.
3. Identify desired vegetation characteristics that will help achieve your goal. Use the baseline data developed by the class and write one or two activity plan objectives. The objectives should contain the six elements of a well written objective.

4. Identify the management actions you will use to achieve your objectives. NOTE: We are not particularly interested in all the various management actions that could be used to accomplish an objective in this exercise. Don't spend too much time on MA's!

5. Describe how you will monitor progress towards or away from your objective.

Once the exercise is completed, a representative of each group will present the following:

1. Present your resource management objectives on a flip chart for analysis by the class and instructors.
2. Utilizing the attached matrix demonstrate how your resource management objective tracks from the land use plan through monitoring.

~~~~~  
Red Creek

The Red Creek watershed is a small v-shaped drainage of about 400 acres that was clear cut in 1976. Red Creek currently provides lower quality habitat for anadromous salmon. The riparian zone is dominated by alder with a minimal conifer component.

Your ID team has evaluated the watershed and has determined that Red Creek has some potential for restoration. The team has now been assigned to develop an activity plan that will restore high quality riparian habitat in the Red Creek watershed.

~~~~~  
Blue Creek

In 1994 a prolonged drought followed a relatively dry winter in Western Oregon. An intense wildfire burned approximately 500 acres of old growth fir in the Blue Creek watershed. Aggressive fire suppression tactics and a little luck prevented the fire from reaching all but a few acres the Blue Creek riparian zone. However, nearly 85% of the uplands in the North Fork of Blue Creek experienced intense wildfire. The North fork is a small intermittent drainage.

A riparian inventory in 1989 rated Blue Creek in optimal riparian condition. The Salem District RMP identified Blue Creek as a key watershed that serves as a refugia for an at risk stock of anadromous salmon.

You have been assigned to an emergency ID team to develop a rehabilitation activity plan.

PART I -Overheads

Resource Management Objectives

- The difference between goals and objectives
 - How to write an objective
 - How to critique an objective
-

Webster's Dictionary

Goal - the end toward which effort is directed

Objective - something toward which effort is directed

Goals

- General language
- Describe in broad terms what you intend to accomplish
- From the land use plan
- EXAMPLE: Restore and maintain the ecological health of watersheds and aquatic ecosystems.

Objectives

-Very specific language

-Example: Establish 80 stems per/acre of conifers (of which at least 60% are cedar) in the riparian reserve on Yellow Creek by 2005.

The six elements of a well written objective

1. State the component
 2. State what is to be accomplished
 3. State the amount of change
 4. State the location
 5. Establish a time frame
 6. Ensure the objective is compatible with the land use plan
-

State the component

- % canopy cover of desired species
- width/depth
- stems/acre of conifers

mg/liter of suspended sediment

State what is to be accomplished

- increase
 - decrease
 - maintain
-

State the amount of change

- from 20% to 15 %
 - from 5" to 15" mean d.b.h.
 - maintain a minimum of 4 snags/acre
-

State the location where monitoring will occur

- sampling station #3
 - the entire key watershed
 - segment of the stream from point a to point b
-

Establish a time frame

- annually
- 5 years
- prior to the 1998 salmon run

The objective must be compatible with the land use plan

- clear link
 - within the general intent
 - plan amendment may be required
-

Critique of an objective

Objective: Increase the mean tree size from 7" to 21" d.b.h. in the riparian reserve on the N. Fork of Cache Creek by 2005.

1. Component - mean tree size
 2. Accomplishment - Increase
 3. Amount of change - from 7" to 21" d.b.h.
 4. Location - riparian reserve on the N. Fork of Cache Creek
 5. Timeframe - do it by 2005
-

But, how do we know if the objective is realistic?

Because the ID TEAM said so!

PART II

Activity Plan Tracking Matrix

Adapted from Olson and Burkhardt, 1992

- Used to link activity plans to land use plans
 - Used to organize activity plans
 - Used to test the quality of objectives in existing activity plans
-

Land use plan

Issues

Objectives

Actions

Monitoring/evaluation

Tracking Matrix

LUP	Issues	Objectives	Actions	Monitoring

Federal Land Policy and Management Act

"The secretary shall manage the public lands
in accordance with the principles of
sustained yield and multiple use, in
accordance with land use plans....

OBJECTIVE

Increase the canopy cover of all woody vegetation from 5% to 50% in the riparian reserve on BLM administered segments of Prospect Creek by 2005.

LAND USE PLAN

Manage riparian reserves in accordance with the Aquatic Conservation Strategy.

ISSUE

Prospect Creek lacks adequate vegetation, landform, and large woody debris to dissipate stream energy associated with high flows.

OBJECTIVE

Increase the canopy cover of all woody vegetation from 5% to 50% in the riparian reserve on BLM administered segments of Prospect Creek by 2005.

ISSUE

The fishing access point on Pierce Creek has developed an extensive network of hiking trails resulting in bank sloughing and a possible increase in sediment deposition into the stream.

Tracking Matrix

LUP	Issues	Objectives	Actions	Monitoring

Testing Management Objectives

OBJECTIVE: Improve the riparian zone along Elk Creek by conifer underplanting, and cutting and girdling hardwoods.

TRACKING TEST

LUP: Maintain and restore the species composition and structural diversity of plant communities in riparian zones.

ISSUE: The riparian zone on Elk creek is in Class two minimal condition.

OBJECTIVE: Improve the riparian zone along Elk Creek by conifer underplanting, and cutting and girdling hardwoods.

ACTION: ?

MONITORING: Continue water quality monitoring.

This objective is "way off track"!

-The objective is not site specific so we don't know the monitoring location.

-The objective contains a management action; i.e., underplanting conifers and girdling hardwoods.

-The monitoring contained in the activity plan does not relate directly to the objective.

The success or failure of the activity plan can't be determined.

Repair

LUP: Maintain and restore the species composition and structural diversity of plant communities in riparian zones.

ISSUE: Hardwoods are preventing the establishment of conifers within the riparian reserve on Elk Creek.

OBJECTIVE: Establish 60 to 80 stems/acre of conifers within treated areas on Elk Creek by 2005.

ACTION: Underplant conifers in treatment areas where hardwoods have been cut and girdled.

MONITORING: Establish plots within treatment areas to determine conifer density. Read plots in 2000 and 2005.

The objective is now "on track"; i.e, it tracks from the land use plan through monitoring.

-The objective of establishing conifers is consistent with the LUP goal of restoring composition and diversity.

- We know when, where and how conifer establishment will be monitored.

-The management actions clearly address the issue.

The success or failure of the activity plan can be determined.

Land Management Planning: An Assessment

N. Crystline Olson and J. Wayne Burkhardt

Increasing public concern with the management of public lands focuses attention on the land management planning process. Specifically, questions are being raised about management objectives and the tracking of accomplishment. Management plans are often the only record available to track and support the agency's decisions. With an increasing number of natural resource decisions being contested, management planning becomes more important. To defend their actions federal land management agencies need to strengthen their documentation and be more systematic in developing and updating their management plans and monitoring records.

Planning-An Overview

Planning is a systematic approach to decision making or problem solving. Lindzey and Aronson (1985) identified four separate but sequential phases of generalized planning. This planning process has been modified and widely adopted for public land management. The most commonly applied public land planning processes are land use planning (resource management plans) and land management planning (activity plans). The first is the layman's forum for deciding what public land uses are desired by the public over a large region (i.e., a national forest or resource area). This process should prioritize land use goals based on existing and desired uses and resource capability (land use plans or forest plans) rather than define management specifics. The second phase, land management planning, approaches the technical aspects of achieving these goals by developing site specific management plans (i.e., allotment management plans or herd management plans). Land management planning is primarily the job of professional resource managers.

The model for land management planning involves several sequential steps (Figure 1). As broad land use goals are applied to local planning areas, specific resource issues and problems are identified and resource management objectives are formulated. Ideally, these are specific resource objectives identifying the desired plant communities needed to meet land use goals and that are consistent with site capabilities. The final steps involve the application of management tools (grazing systems, range improvements, etc.) that hopefully will achieve the objectives and the necessary monitoring/evaluation to determine if management is indeed succeeding. This

Fig. 1. Land Management Planning Model.

sequential land management planning model (Figure 1) was used to evaluate the allotment management plans (AMPs) selected for this study.

Twenty AMPs covering over 825,000 acres in northwest Nevada were evaluated. These BLM plans were written between 1980-1984. Four AMPs were completely implemented, 14 partially implemented and 2 were not implemented at all. These AMPs were the result of Coordinated Resource Management Planning (CRMP) through the Modoc-Washoe Stewardship Program. Motivation for this review came from both the BLM and the stewardship committee. They were concerned about the overall quality of the plans they had drafted.

Each plan was compared to the planning model for consistency of process and idea development. The plans were then evaluated for statement content.

Results and Discussion

Review of the selected AMPs revealed inconsistencies in the flow of ideas through the planning steps and problems with content or organization of the ideas presented. It was evident that in developing land management plans more attention to the systematic planning model and better definition of management ideas was needed.

Systematic Flow of Ideas

Inconsistencies found in the flow of ideas through the planning documents can be considered as follows:

This study was jointly funded by the Bureau of Land Management, Washington Office Range Management Program, and the University of Nevada, Reno in cooperation with the Modoc-Washoe Stewardship Program. While the work was being completed the authors were, respectively, graduate student and associate professor, Department of Range, Wildlife and Forestry, University of Nevada, Reno, 1000 Valley Road, Reno, NV 89512. N. Crystline Olson is currently a Range Conservationist on the Cannell Meadow and Greenhorn Districts of the Sequoia National Forest, P.O. Box 6, Kernville, CA 93238.

1. **Stranded Issues (found in 16 of the 20 AMPs):**

This occurs when the planning document identifies a resource issue, then fails to carry that issue into the AMP objectives, action plan, monitoring schedules and evaluation reports. The resource issue is identified as a problem and then left stranded. An example involved the identification of wild horses as a management problem on allotment. The technical report raised the issue, yet no other sections of the plan carry the idea forward. There was no definition of the problem, no corrective action suggested and no monitoring or evaluation prescribed.

2. **Isolated Objectives (found in 3 of the 20 AMPs):**

This occurs when management objectives do not derive from identified resource issues and when there is no carry-through of the objective into the action plan or monitoring/evaluation components. The objectives simply stand alone. An example of an isolated objective found in one AMP was "Reduce soil erosion to less than 2 tons/acre/year according to the Universal Soil Loss Equation." The technical report did not identify erosion as an issue on the allotment and the AMP contained no management action designed to reduce erosion nor a monitoring plan to evaluate erosion.

3. **Abandoned Objectives (found in 8 of the 20 AMPs):**

This occurs when the stated management objectives that derived from resource issues are not carried through into the action plan, the monitoring schedule or the evaluation reports. Abandoned objectives frequently surfaced when dealing with wildlife issues in the AMPs. Issues regarding critical winter or spring habitat for bighorn sheep, deer or antelope were stated and often vague management objectives, typically in the form of "maintain good condition habitat", were formulated. Thereafter the matter was usually dropped from the remaining planning components. No management actions were prescribed and no monitoring or evaluation suggested. Without such follow through it is impossible to draw any conclusions regarding management of wildlife habitat.

4. **Indirect or Surrogate Objectives (found in 15 of the 20 AMPs):**

This occurs when the stated management objective is indirectly related to the resource issue or is a surrogate to the real resource issue. Often the technical reports would identify poor distribution of livestock grazing on the allotments as a problem. Areas of excessive or insufficient forage use were the actual resource issue. The related management objectives were often statements about providing new watering sources on the allotment. While statements about water development touch on possible actions to solve the resource issue, the real problems were grazing use distribution. By jumping directly from poor livestock distribution to objectives about water, we not only obscure the real prob-

lem, but risk overlooking numerous other potential solutions to poor livestock distribution (i.e., riding, salting, drift fencing, season of use, class of livestock).

None of the twenty AMPs evaluated completely tracked all the identified resource issues through the model planning steps. Inconsistencies or breaks in the systematic flow of ideas through the planning documents were common.

Content and Organization

Aside from the problems of consistency and follow-through, review of the AMPs also revealed weaknesses related to organization and content. They are:

1. **Actions as Goals, Objectives and Issues:**

The most frequent problem involved the substitution of management action statements for land use goals, resource issues or management objectives (12 of the 20 AMPs). Actions are directive statements about how to accomplish something on the ground in terms of habitat requirements for an identified resource use, as opposed to descriptive statements about what uses should occur (goals), what problems exist (issues), and what these habitats should look like (objectives). Numerous land use goal and management objective statements were noted which detailed livestock stocking rates and turn-out dates, specified shrub control treatments, provided for allotment divisions or set grazing use levels. These action statements describe tools for achieving land use goals and management objectives but they certainly do not represent the goals or objectives. As action statements they are more logically part of the action plan within the AMP. The purpose of a resource objective is to give the managing agency a vegetative benchmark to attain or maintain. The objective should describe a particular plant community, not how to achieve that community.

2. **Land Use Goals as Management Objectives:**

Given their definitional similarity it is not surprising that land use goals and management objectives are often carbon copies of each other. Over half of the objective sections of these AMPs mimic the original goals laid out in the beginning of the planning process. Most often they were the same "God and motherhood" statements about improving or maintaining range condition, or providing habitat for "reasonable numbers" of certain wildlife species. Such statements are often mutually exclusive and provide little measurable management direction to the land manager, the resource user or the interested public. Using the habitat example, areas within an allotment suitable for a given species were rarely identified; seasonal habitat preferences were not delineated, and even the most general estimates of "reasonable numbers" of wildlife were not provided. Without a basic idea about these parameters any objective dealing with requirements for game species lacks direction, focus and measurability.

Range condition objectives also suffer from over generalization. Most of these statements blanket an allotment at large, if not the entire resource area. The usual statement of management objectives were "manage for good range condition" or "Improve range condition on allotment." While these may be reassuring statements, they do not describe the desired habitats or plant communities which management seeks. Few people can argue with the good intentions inherent in such objectives, yet due to their unspecific nature it becomes impossible to track their success. Rarely did these generalized management objectives contain any time frame for accomplishment, or any assurance of being possible to achieve within site capability.

3. Monitoring and Evaluation:

Given the common problem of generalized management objectives in the AMPs, it was inevitable that problems would exist with monitoring and evaluation. Efficient trend monitoring and evaluation of management effectiveness was thwarted by poorly defined objectives. Most of the AMPs contained a creditable amount of annual event monitoring, i.e., information on growing conditions, actual grazing use by livestock, use by other grazers, use pattern maps and records of other events. Such information is essential for determining whether resource use actually occurred as prescribed in the plan and is needed for interpreting causal relationships for changes in the plant community. What was often missing but absolutely necessary for the evaluation of management effectiveness was the trend monitoring. While insufficiencies of trend monitoring in these AMPs may in part relate to recentness and partial implementation of most of these plans, poorly defined objectives were central to the problem.

Conclusions

A quality control assessment of twenty AMPs developed by the BLM and the Modoc-Washoe Stewardship Committee was recently completed. This study indicates that problems exist in the structure and content of these plans: resource issues were not consistently followed through, management objectives were vague, and the necessary feedback for determining management suc-

cess was inadequate. Poorly defined management objectives were central to most of these problems. Rarely did the AMPs contain any description of the type of habitat or vegetation that was needed to support the prescribed land uses (land use goals). Without such objectives, management actions and subsequent monitoring/evaluation lack focus. Realistic and measurable statements of those desired plant communities should be the focus of management.

Additional problems found in these AMPs relate to the lack of continuity in the flow of ideas through the plan. Too often the plan components did not sequentially tie together. Land management planning and the resultant plans, such as AMPs, involve several steps or components. Each component should relate to the others in a way that provides a consistent flow of ideas through the entire document. The planning model (Figure 1) illustrates this linkage. Land use goals and resource issues should be translated into realistic, measurable objectives describing the desired habitat from which management actions, monitoring and evaluation parameters can be derived.

In general there needs to be a sharper recognition of the separate functions and purposes of land use vs land management planning. Land use planning should be a public forum for prioritizing land use goals; land management planning should be the resource manager's determination of how to achieve those land use goals. The land management planning process needs to be more holistic in terms of integrating management planning for all resources on a given planning unit. Perhaps the product of land management planning should be a resource management plan rather than separate AMPs, habitat management plans and herd management plans, each dealing with coexisting resource uses on the same geographic area.

Literature Cited

- Burkhardt, J.W., and I. Hackett. 1987. Monitoring Rangeland Grazing. University of Nevada, Reno, Cooperative Extension Fact Sheet 87-50.
- Lindzey, G., and E. Aronson. 1985. Handbook of Social Psychology. Third Edition Random House Publishers. N.Y., p. 154-168.
- Swanson, S., and J.L. Artz. 1986. Resolving issues with people, not for them. *Our American Land* (1) p. 114-117.

CHAPTER I - DEVELOPMENT OF OBJECTIVES

By Dr. Tom Zimmerman

A. Introduction

Management is the process of anticipating the future, setting objectives, implementing an action, achieving an output, and performing an evaluation comparing the output to the objective. Management is not possible without setting objectives. Clear and easily communicated objectives facilitate the management process.

In land management programs, the desired outcome of management actions is expressed as management objectives. Objectives represent an important component of all land management programs and are the single most important factor driving all management actions.

B. Definitions and Qualities of Good Objectives

1. **Goals and Objectives - Definition.** In land management, both goals and objectives are important. Goals are primary and basic products of the long range management plans. These goals are commonly referred to as land use decisions. Goals are relatively short statements that discuss what the public lands are to be used for and where the uses will occur. Each statement addresses a land use, but is not limited to the principal or major use.

Objectives are a necessary component of the planning process; they provide a bridge between goals and the implementation phase. Objectives describe what procedures will be used and when actions will be completed.

During the planning of fire management projects, objectives are formulated and used as the basis for development of an action plan. Interdisciplinary (I.D.) teams coordinate various concerns and develop objectives for a project. The I.D. teams are composed of resource specialists from different disciplines who address concerns of the affected resources and resolve conflicts among resource disciplines that arise from specific management actions.

2. **Qualities of Good Objectives.** Fire management objectives must be made up of certain attributes or they will not convey the necessary guidance. Good objectives must be informative and SMART. Objectives that are SMART are:

- S - Specific - what will be accomplished, using limiting factors, and identifying the range of acceptable change from the present to the proposed condition.
- M - Measurable - the present and proposed condition must be quantifiable and measurable.
- A - Achievable - can be achieved within a designated time period.
- R - Related/Relevant - related in all instances to the land use plan goals and relevant to current fire management practices.
- I - Trackable - objectives must be trackable over time and must include a definite timeframe for achievement, monitoring, and evaluation.

3. Kinds of Objectives.

a. **Land use decisions (goals).** These are broad statements, usually specified in land management plans, that deal with large areas over long time periods (e.g., 10 years). Land use decisions establish resource condition objectives; the allowable, limited, or excluded uses for an area (land use allocations) and the terms and conditions for such use; and management actions that will be taken to accomplish multiple use goals.

b. **Resource management objectives.** Resource management objectives identify the changes in water, soil, air, or vegetation from the present to proposed conditions. Resource objectives can also describe an existing resource condition that should be maintained.

c. **Treatment objectives.** These are very well-defined statements that describe what a treatment must accomplish in order to meet a stated resource management objective. This type of objective is site-specific and must utilize the SMART concept.

Any statement that is an objective must identify the change from present conditions to the proposed conditions (the changes that are planned) and the limiting factors.

C. How Objectives Relate to Project Inventory, Development, Implementation, Monitoring, and Evaluation

Objectives are an important part of management actions and are prerequisite to sound land and resource management. Objectives not only drive the planning system, they also drive the full spectrum of project implementation, monitoring, and evaluation.

During the fire planning process, for example, the planner uses resource management objectives (standards) as guidance to determine what fire management responses and activities are necessary. These standards then provide guidance in determining what and how much information should be collected prior to and during project implementation. At this point, knowledge of fire effects becomes a necessary part of the planning process. Fire effects information helps to determine what will be done, how many resources are needed, how much funding the fire program will need, and what should be evaluated to ensure efficient accomplishment of the workload.

D. Relationships of Different Tiers (Levels) of Planning to Objectives

Generally, objectives start as issues when the land use planning process is initiated. (Issues are usually conflicts between two or more resource uses or demands that must be resolved in the plan.) Issues are generally defined in terms of the desired state of achievement for environmental values and socioeconomic conditions affected by management activities and resource decisions. The next step is development of alternatives that include a range of ways to resolve the issues. After the preferred alternative is selected, local guidance for resource functions is developed that contains resource management objectives.

Land use planning systems used by most federal agencies are divided into four distinct tiers: national, geographically defined management areas, individual resource functions, and site specific implementation (Table I-1). National policy is established in public laws, federal regulations, Executive Orders, and other Presidential, Secretarial, and Director approved documents. Policy guidance for planning is developed, as needed, through interpretation of national policy, public participation activities, and from coordination and consultation with other federal agencies.

Development of Objectives

Table I-1: Relationship of Planning Tiers to Fire Management Objectives, Products and Fire Effects Applications

Planning Tier	Type of Objectives	Product	Fire Effects Applications
National		Policy and Regulations	National policies and guidance regarding fire presence and exclusion in wildland ecosystems
Geographically defined management area	Land use decisions	Resource Management Plan (BLM, NPS) Comprehensive Management Plan (FWS) Integrated Resource Management Plan (BIA) Forest Land Management Plan (FS)	Integration of fire and resource management within a geographically defined management area
Local guidance for individual resource components	Resource management objectives	Fire Management Activity Plans Fire Management Plan Fire Management Action Plan Wilderness Fire Management Plan	Identification of appropriate allocation of fire suppression, fire use and fuels management activities necessary to achieve resource management objectives
Site specific implementation	Treatment objectives	Prevention Plan Presuppression Plan Escaped Fire Situation Analysis Postfire Rehabilitation Plan Prescribed Fire Plan Other	Interpretation and analysis of site specific fire effects to guide development and implementation of a program of action to accomplish treatment objectives

Resource management plans developed for geographically defined management areas establish the combinations of land and resource uses; related levels of investment, production, and/or protection to be maintained; and general management practices and constraints for various public land resources. These are set forth as the terms, conditions, and decisions that apply to management activities and operations and are presented in the form of multiple-use prescriptions and plan elements.

The third planning tier, developed at a local level, provide guidance for individual resource functions. To continue with the example of the fire management component, Fire Management Activity Plans delineate areas to receive different levels of fire suppression, fire use, and fuels treatment. Resource management objectives developed at this level are derived directly from land use decisions.

Site specific implementation plans are the final step in the fire planning process. The primary role of these plans is to identify operational guidance to accomplish site specific treatment objectives. Prescribed fire plans refer to resource management objectives developed in activity plans and identify treatment objectives. Resource management objectives referenced in prescribed fire plans describe second order fire effects, the indirect effects of fire treatment that occur over the longer term, such as increased plant productivity, changes in species composition, or increased off-site water yield. Fire treatment objectives are developed from the resource management objectives and state exactly what immediate effects the fire must create in order to achieve the resource objectives. Fire treatment objectives describe first order fire effects such as plant mortality, fuel reduction, or duff consumption. An example of a fire treatment objective is: to remove 90 percent of existing sagebrush crown cover, using fireline intensities that consume sagebrush crowns, leaving residual stems that are six inches or less in height.

E. Summary

Land management programs are objective driven. Objectives must be based on an amount of information sufficient to determine if a change from the present condition to the proposed condition can be achieved. Establishing objectives is a task of major importance and deserves an allotment of sufficient attention and time. Both objectives and fire effects information become more precise as site specificity increases.

AQUATIC CONSERVATION STRATEGY

Fundamental Elements of Ecologically Healthy Watersheds in the Pacific Northwest Coastal Ecoregion

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Abstract

Characteristics of streams and rivers reflect variations in local geomorphology, climatic gradients, spatial and temporal scales of natural disturbances, and the dynamic features of the riparian forest. This results in a variety of stream types which, when coupled with the many human uses of the Pacific Northwest coastal ecoregion, presents a difficult challenge in identifying and evaluating fundamental, system-level components of ecologically healthy watersheds. Over 20 types of streams are found in western Oregon, Washington, and British Columbia and in southeastern Alaska, a region where extractive forest, agricultural, fishing, and mining industries and a rapidly increasing urban population are severely altering the landscape. Yet stream characteristics remain the best indicators of watershed vitality, provided the fundamental characteristics of healthy streams are accurately known. The premise of this article is that the delivery and routing of water, sediment, and woody debris to streams are the key processes regulating the vitality of watersheds and their drainage networks in the Pacific Northwest coastal ecoregion. Five fundamental components of stream corridors are examined: basin geomorphology, hydrologic patterns, water quality, riparian forest characteristics, and habitat characteristics. Ecologically healthy watersheds require the preservation of lateral, longitudinal, and vertical connections between system components as well as the natural spatial and temporal variability of those components. The timing and mode of interdependencies between fundamental components are as important as the magnitude of individual components themselves.

Key words. Stream, river, watershed, Pacific Northwest, riparian, sediment, woody debris.

Introduction

Watersheds in the Pacific Northwest coastal ecoregion play a vital role in shaping and supporting diverse cultures and professions. Specific characteristics of streams and rivers reflect an integration of countless physical and biological processes, providing a long-term memory of environmental conditions. Streams and adjacent riparian forests provide clean water, habitat for fish and wildlife, recreational opportunities, raw materials, and spiritual values for many American and Canadian cultures (Salo and Cundy 1987, Raedeke 1988, Naiman and Décamps 1990, Gregory et al. 1991). In combination, these features have enormous value but represent substantial managerial difficulties, especially when competing interests vie for limited resources. Difficult issues are magnified when natural ecological processes and their variability in space and time are poorly understood (Décamps and Naiman 1989).

For over a century, human alteration of the Pacific Northwest has proceeded without a basic understanding of watershed dynamics, especially for the stream corridors, or of the long-term consequences of land use alterations. Comprehensive studies of stream corridors and watersheds are rare, and most have been done since 1975 (Likens 1989, Strayer et al. 1986). Investigations of running waters as ecological systems are rudimentary, with major conceptual advancements only in the last decade (Vannote et al. 1980, Newbold et al. 1982, Hynes 1985, Naiman et al. 1988). Longitudinal, lateral, and vertical connections in controlling the ecological vitality of streams and rivers are recent concepts requiring additional investigation. Yet, in combination, these and subsequent studies point to running waters as ecological systems demonstrating considerable variability in space and time and requiring a high degree of connectivity between system components for the maintenance of long-term environmental health (see Stanford and Ward, this volume).

Connectivity is manifested in such features as access to required habitat during the life history of fish and wildlife (Salo and Cundy 1987, Raedeke 1988), stream temperature regimes that synchronize the migration and emergence of aquatic organisms (Sweeney and Vannote 1978, Quinn and Tallman 1987), riparian forests that regulate nutrient and material exchanges between forests and streams (Swanson et al. 1982, Peterjohn and Correll 1984), and hydraulic regimes that are within an accepted range for evolutionary adaptation of specific organisms (Statzner et al. 1988).

Variability is reflected in the wide variety of stream types in the coastal ecoregion (Naiman et al. 1991), resulting from differences in geology, cli-

FIGURE 6.1. Principal factors influencing stream characteristics in the Pacific Northwest coastal ecoregion.

volcanism, continental and alpine glaciation, and erosional processes, including mass wasting. Climatic processes include the dominant form of precipitation (e.g., rain, snow, or transition), the seasonal timing, and the runoff patterns. Stream size is a function of the spatial position of the channel in the drainage network and upstream geomorphic and climatic processes. Thus a broad array of stream types may be found within a relatively small area, with each having different biological characteristics and presenting different managerial challenges.

The phrase *ecologically healthy* refers to functions affecting biodiversity, productivity, biogeochemical cycles, and evolutionary processes that are adapted to the climatic and geologic conditions in the region (Karr et al. 1986, Karr 1991). Collectively, these functions can be a measure of system vitality. Some tangible measurements of ecological healthy watersheds include water yield and quality, community composition, forest structure, smolt production, wildlife use, and genetic diversity. Our working hypothesis is that delivery and routing of water, sediment, and woody debris to the stream channel are the key processes determining the ecological health of watersheds in the Pacific Northwest coastal ecoregion. This article will present a broad overview of several fundamental components of ecologically healthy watersheds in this ecoregion, and present a conceptual model of principal interdependencies between those components.

FIGURE 6.2. Relative strength of factors influencing stream characteristics, and principal feedback loops between components (see text for explanation).

Fundamental Components

An efficient approach to understanding the bewildering array of stream types is through a hierarchy of controlling factors (Frissell et al. 1986), with each assigned a ranking based on perceived ability to influence other components (Figure 6.2). However, components with a lower hierarchical ranking may influence higher ranked components through feedback loops (e.g., feeding strategies or disturbance; Starfield and Bleloch 1986, DeAngelis et al. 1988, Naiman 1988).

Based on this analysis, we chose five components that reflect different hierarchical levels of control on stream characteristics, that are integrative of species-specific processes (e.g., population dynamics), and that are essential for maintaining the long-term environmental vitality of drainage networks (Table 6.1). All processes influence either water, sediment, and wood debris delivery to the channel or the routing of those materials through the drainage network, or are responsive to material delivery and routing processes. These five fundamental components are basin geomorphology, hydrologic patterns, water quality, riparian forest characteristics, and habitat characteristics.

The geographic reference for our observations is limited largely to high precipitation basins west of the Cascade Mountains in northern California, Oregon, and Washington but may have application to the coastal regions of British Columbia and southeastern Alaska (Figure 6.3). The majority of rivers draining into the Pacific Ocean along the northwestern coast of North America originate in steep, mountainous terrains of the Northwestern Cordillera (McKee 1972). Along the coast of Washington and Oregon, the Northwestern Cordillera is represented by the Coast Range and the Cascade Mountains to the east. These watersheds have diverse geomorphic processes

Table 6.1. Six fundamental components of ecologically healthy watersheds in the Pacific Northwest Pacific Northwest coastal ecoregion

Component	Approximate Hierarchical Level	Factors Considered	Sphere of Influence
1. Basin geomorphology	1°-2°	A. Physiographic and geologic setting B. Significant geomorphic processes C. Natural disturbance regimes	Effects all factors except climate
2. Hydrologic patterns	1°-2°	A. Discharge pattern flood characteristics and water storage B. Bedload and sediment routing C. Subsurface dynamics	Channel geomorphology and other physical characteristics, some aspects of chemical regime, riparian forest, and in-channel community dynamics
3. Water quality	3°-4°	A. Biogeochemical processes B. Fundamental parameters	Feedbacks to terrestrial vegetation and direct effects on chemical and biotic characteristics
4. Riparian forest characteristics	2°-3°	A. Light and temperature B. Allochthonous inputs C. Woody debris source	Most aspects of the physical, chemical, and biotic characteristics
5. Habitat characteristics	3°	A. Fish habitat preferences B. Fish community dynamics C. Spatial and temporal dynamics D. Woody debris accumulations E. Wildlife communities F. Trophic pathways	Influence in other biotic communities in stream and strong feedbacks to physical, chemical, and terrestrial dynamics

FIGURE 6.3. The coastal ecoregion of the Pacific Northwest as referred to in this article.

that vary along a longitudinal gradient extending from mountain ridges to the sea. Subduction of oceanic crust beneath continental lithosphere along the Pacific Coast results in steep, high elevation mountains. Heavy precipitation due to orographic lifting of moist air from the Pacific Ocean, together with the steep terrain, results in erosion dominated by mass wasting. The

geology of the Pacific Northwest mountains contains a diversity of lithologies, including marine sedimentary sequences, metasedimentary rocks, various old and more recent volcanics, and granitic plutons (McKee 1972). Complex terrain, or rafted continental crust, also contributes to the geologic complexity.

The most recent continental glaciation ended approximately 14,000 years ago and significantly altered the landscape of northwestern Washington (north Centralia), British Columbia, and parts of southeastern Alaska (Crandell 1985). The retreating ice sheets deposited thick layers of till, lake clay, and wash sand in valley bottoms and the Puget Lowland. Typically, major rivers and many smaller tributaries within these regions continue to incise through glacial sediments.

sin Geomorphology

Natural Disturbances and Stream Size

sin geomorphology in ecologically healthy watersheds is affected by the type, frequency, and intensity of natural disturbances. Characteristics of these disturbances reflect the spatial position of channel segments in the drainage network. Processes of material delivery and routing are highly interactive with hydrologic patterns and riparian vegetation.

Morphologic Processes and Forms in Low-Order Channels.

In the Pacific Northwest, low-order (e.g., first- and second-order) stream segments represent >70% of the cumulative channel length in typical mountain watersheds (Benda et al. 1992). Hence low-order channels are the primary conduits for water, sediment, and vegetative material routed from hillslopes to higher-order rivers. First- and second-order basins are naturally prone to catastrophic erosion because steep slopes adjacent to steep channels are susceptible to landslides and debris flows.

In the few studies conducted in the coastal ecoregion, first- and second-order channels in steep bedrock of mountain basins do not transport significant quantities of sediment by water flow; hence these channels have limited amounts of stored alluvium (Figure 6.4, top). Swanson et al. (1982) estimated that fluvial transport accounted for approximately 20% of the total sediment yield from a first-order basin in the central Oregon Cascades. In the Oregon Coast Range, Benda and Dunne (1987), using a sediment budget approach that included specifying sediment routing by debris flow, estimated that fluvial processes accounted for 10 to 20% of the total sediment yield. Low-order channels are filled primarily with colluvium, characterized by coarse, unsorted sediments, including silts and clays derived from landslides and debris flows (Benda and Dunne 1987). Low-order channels also contain substantial amounts of boulders (>27 cm diameter) and woody debris (>10 cm diameter) because streamflow is not competent to transport the largest

FIGURE 6.4. Generalized channel morphology and disturbance regimes associated with low-, mid-, and high-order streams in the Pacific Northwest coastal ecore

materials. First- and second-order channels have steep gradients (typically >8 degrees), but have lower gradients over shorter (<10 m) lengths due to accumulations of woody debris organized into debris jams which create a stepped longitudinal profile (Swanson and Lienkaemper 1978). Woody debris jams store sediment and contribute to discontinuous sediment transport during storms (Heede 1972, Mosley 1981). Bedforms in steep first- and second-order channels are generally limited to plunge pools in coarse-textured substrate, migrating gravel sheets originating from streamside landslides, and local accumulations of finer sediment upstream from woody debris and boulder obstructions. Woody debris jams can account for the majority of energy loss of flowing water in steep, low-order channels (Beschta and Platts 1986), implying that less energy is available for sediment transport.

Landslides occur on steep slopes during large rainstorms or rain-on-snow events (Swanson and Swanson 1976). Furthermore, wildfires kill vegetation, and loss of root strength may result in landslide and debris flow activity during large rainstorms (see below). Certain landslides at the heads of low-order valleys are transformed into debris flows, eroding accumulated sediment and organic debris from first- and second-order channels (Benda and Dunne 1987). Debris flows are one of the most common forms of mass wasting in mountain watersheds of the coastal ecoregion, and are the principal process transporting sediment and woody debris in first- and second-order channels (Swanson et al. 1985). Recurrence intervals of debris flows have been estimated to be once in 500 years for first-order channels in the central Oregon Cascades (Swanson et al. 1982), and once in 750–1,500 years for first- and second-order channels in the Oregon Coast Range (Benda and Dunne 1987).

Geomorphic Processes and Forms in Mid-Order Channels.

Third- through fifth-order channels, referred to as mid-order channels, are characterized by moderate to steep gradients (1 to 6 degrees), substrates ranging from boulders to gravels (or sands in some streams), and abundant large organic debris in jams and single pieces (Figure 6.4, middle). True alluvial channel systems in the coastal ecoregion begin at third-order channels (e.g., where the majority of sediment and organic debris is transported by water).

Mass wasting often dominates the amount and type of deposition along narrow valley floors of mid-order channels. Debris flow deposits in confined valleys create fans at mouths of first- and second-order basins, and levees and terraces along valley floors (Benda 1990). Streams are often forced toward the opposite valley wall by alluvial or debris flow fans. For example, 65% of stream meanders in a fifth-order basin in the Oregon Coast Range with a sinuosity of >1.1 were maintained by debris flow fans (Benda 1990). Landslides and debris flows also deposit large volumes of sediment and vegetative material ($1,000 - 10,000$ m³) directly into mid-order channels. Local channel aggradation and logjams persist at the site of deposition for years

to decades (Benda 1988, Perkins 1989). In the central Oregon Coast Range, debris flows control the distribution of boulders in alluvial channels (Benda 1990).

Earthflows often impinge on third- through fifth-order valley floors, creating local constrictions and streamside landslides (Swanson et al. 1985). The position of entire trees and large volumes of sediment cause local channel aggradation at the site of earthflows and immediately downstream. Scour within narrow valley floors may impinge directly on hillslopes, causing erosion in the form of rockfall in nonglaciated basins, or landslides or erosion in glacial deposits, which further affects channel morphology.

An important catastrophic process in mid-order channels is the landslide-dam-break flood. Deposits of landslides and debris flows often temporarily dam streams along narrow valley floors (Figure 6.4). A rapid failure of the dam and subsequent release of the ponded water may cause an extreme flood, destroying riparian vegetation and removing in-channel organic debris. Accelerated sediment transport by streamflow follows in the wake of the break flood.

Channel form is influenced by mass wasting deposits (see above) but also reflects normal alluvial processes. Bedforms include alternate pools and riffles, morphology at meanders, and migrating gravel sheets originating from point inputs of sediment. In addition, a kind of bedform called scour lobe develops as flow convergence erodes channel beds, forming pools, and flow divergence downstream deposits bars or gravel lobes (Lisle 1987). Scour of bedrock bends may also produce scour lobes. Channels dominated by bedrock substrate may develop a boulder-cascade or step-pool morphology. This form is characterized by organized aggregations of boulders which create a sequence of cascades and boulder pools (Whittaker and Jaeggi 1982, Benda et al. 1990). Pools tend to be deep in relation to channel widths: width:depth ratios are 1:10.

Third- through fifth-order channels transport the majority of sediment delivered to them rather than storing it for long periods, because of relatively steep gradients, well-armored channel banks, and narrow valley floors. Channels with these characteristics tend to contain flood flows. Headcut channels, overflow channels, and oxbow lakes tend to be limited in these channels. Channels are typically single thread, with the exception of diversion of flow around woody debris jams and mass wasting deposits.

Mass wasting influences the temporal distribution of sediments in channels, either because it deposits sediment directly into alluvial channels or because the deposits provide a source for accelerated sediment transport further downstream (Benda and Dunne 1987). The stochastic nature of sediment supply to alluvial channels by debris flows and landslides promotes more significant temporal variation of bedforms. For example, in the Coast Range, episodic debris flows are responsible for channel aggradation which results in a gravel-bed morphology, while the absence of debris results in a mixed bedrock- and boulder-bed morphology at the same

stream reaches to entire tributaries (Benda 1990). In addition, spatial variability in channel form in mid-order streams can be significant due to frequent deposits of sediment and organic debris from landslides, debris flows, and earthflows.

Geomorphic Processes and Forms in High-Order Channels.

Large rivers of sixth order and higher integrate the diversity of erosional processes in time and space (Figure 6.4, bottom). Hence sediment supply is more steady in time, and as a result the channel form (that which is dependent on the sediment supply rate, such as pools) is more uniform in space. In addition, extensive alluvial terraces and floodplains isolate the river from direct contact with hillslopes and low-order tributary basins, and therefore limit the direct influences of mass wasting.

Large rivers sort sediment by size or selectively transport it along the longitudinal gradient from third- through sixth- and higher-order channels. As gradient decreases and channels widen, transport of large sediment decreases. The coarsest sediment is found in upper watersheds, often adjacent to mass wasting deposits; the finest sediment, such as sand and small gravel, is in the lower reaches (Brierley and Hickin 1985). Particle comminution or abrasion further limits sediment size downstream. General exceptions to this decline in substrate size downvalley include local accumulations of larger particles at tributary confluences, aggradation of finer sediment behind debris jams, and landslide and debris flow deposits.

Large discharge and easily erodible banks in large rivers favor the development of meandering floodplain channels, creating alternating pool and riffle morphology (Dunne and Leopold 1978). Other common bedforms in large rivers include mid-channel bars formed by organic or inorganic obstructions, and transverse bars formed by flow separation due to changing channel geometry (Figure 6.4, bottom). The scale and dimension of the pool-riffle morphology depend on bank height and composition, size and type of riparian vegetation, size of bedload, discharge regime, and so forth. Rivers tend to be slightly deeper and significantly wider than steep stream channels upvalley; width to depth ratios range from ~ 10 to >20 .

Lateral migration of rivers occurs continuously and does not depend on extreme events, though migration may occur more rapidly during large floods. Evulsions are common and multiple thread channels are formed, often during flood events, because of weak bank deposits. This leads to the development of floodplains kilometers wide containing numerous active and semi-active channels (Sedell and Froggatt 1984). Meander cutoffs create oxbow lakes, the size and number depending on meander history of the river, width of the floodplain, and groundwater characteristics of the alluvial plain. Wetlands become numerous within and along cutoff meanders and oxbow lakes. If the hydrologic regime is characterized by a high flood frequency, lateral migration may also occur more frequently. Hence vegetation patterns along

these types of rivers will contain young successional stages and perhaps greater heterogeneity of stand ages.

Small tributaries, originating from steep areas or as springs, cross alluvial terraces and floodplains with larger rivers. These small channels are similar though smaller in scale, to larger alluvial channels, and they have been referred to as wall-base channels (Peterson 1982a, b). Wall-base channel meander through easily erodible alluvial sediments and their bedforms are dominated by alternate pools and riffles, scour lobes, and plunge pools.

Erosion and Sedimentation in Ecologically Healthy Watersheds

While erosion and sedimentation are often viewed negatively from a biological point of view, they are essential to the ecological functioning of aquatic and terrestrial communities because they provide the sources and the surfaces necessary for habitat. In mountain regions in particular, erosion and sedimentation are often violent (e.g., landslides, debris flows, landslide dam-break floods, and snow avalanches) and produce mortality among terrestrial and aquatic organisms. Geomorphic surfaces in streams or on land in the wake of these powerful processes often evolve into productive and biologically attractive sites because of the revitalization of geochemical cycles, introduction of buried and unburied organic debris, and opening of forest canopies, thus increasing sunlight. In ecologically healthy watersheds of the Pacific Northwest, these violent geomorphic processes vary considerably in extent and frequency. Disturbance regime is the term generally used in discussing the results of these processes.

A disturbance is any significant fluctuation in the supply or routing of water, sediment, or woody debris which causes a measurable change in channel morphology and leads to a change in a biological community (Pickett and White 1985). The disturbance regime, therefore, is the type, frequency, magnitude and spatial distribution of changes in biological communities. Changes in the supply or the routing of sediment and organic debris are usually the result of local mass wasting or large floods. Some specific effects of mass wasting deposits on valley floors and channels have been covered in the previous sections on low- and mid-order channels. Floods not associated with mass wasting have less of an influence on low- to mid-order rivers (Grant 1986).

Although fluvial transport of sediment is often limited by supply of sediment, large floods can generate considerable bank erosion. Moreover, during floods, sediment transport resulting from bank erosion in low-order channels reaches its maximum. Hence the potential for bedload waves propagating from low- to mid-order streams exists during floods. As these waves pass downstream, they may locally cause accelerated bank erosion, thereby creating a positive feedback mechanism or a complex fluvial response. Given the potential for significant sediment transport by floods, watershed influences on the magnitude and timing of annual (and less frequent) floods are

contributing determinants of natural stream characteristics. The influence of flood regimes (associated largely with climate and elevation) and watershed characteristics (such as geomorphology) is discussed in the following section.

Erosion in mountain terrains of the coastal ecoregion is dominated by mass wasting. Therefore, triggering mechanisms such as rainstorms and wildfires were responsible for episodic transfers of sediment and organic debris from hillslopes and low-order channels to third- and higher-order streams and rivers (Swanson et al. 1982, Benda 1990). Past tense is used because wildfires are typically suppressed, while timber harvest activities have created a new pattern of disturbance across landscapes. Little is known about frequencies, magnitudes, and spatial distributions of historic wildfires and rainstorms, and therefore characteristics of natural erosional patterns (or disturbance regimes) in large watersheds are not well understood.

Wildfires, of varying intensities and in various locations, are controlled, to some extent, by climate and local topography (Teensma 1987). In Mount Rainier National Park, Washington, Hemstrom and Franklin (1982) estimated average recurrence intervals for stand-resetting wildfires to be ~450 years. In coastal forests of the Olympic Peninsula and Oregon Coast Range, a recurrence interval of a large stand was about two centuries (Agee 1990). In contrast, recurrence intervals of rainstorms that initiate landslides and debris flows are a few decades or less (Pierson 1977). A wildfire followed by large storms has the potential of inducing a spate of erosion that may result in sedimentation, and therefore a large channel disturbance over stream reaches to entire drainage networks (Benda 1990).

Erosion- and sedimentation-related disturbances in channels exhibit spatial variability because storms and fires act on different areas at different times. The scale of heterogeneity may range from individual small basins (and channels) to a major portion of a large watershed (numerous channels).

Several aspects of disturbance regimes are important to the functioning of biological communities in mountain watersheds. Unfortunately, knowledge of natural disturbance regimes is limited because of the length of time required for the processes to operate (100 to 1,000 years) and therefore to be observed by humans, and because recent use has altered the disturbance regimes in ways not fully understood. Nevertheless, we are able to conceptualize some attributes of natural disturbance regimes.

Disturbances related to erosion and sedimentation in low- to mid-order basins are thought to be characterized by high magnitude and low frequency because of the large number of mass wasting events and the potential for wildfires to range over these basins (Swanson et al. 1982, Benda 1990) (Figure 6.4). Within larger watersheds (mid-order, Figure 6.4) asynchronous combinations of fires and rainstorms act to limit the magnitude of the sediment and organic debris movement downstream. Though events may not be coupled in time within a larger watershed, they occur (collectively) more frequently because of the greater area and therefore greater probability of occurrence. This creates a disturbance regime, as far as sediment flux is

FIGURE 6.5. In ecologically healthy watersheds there is a natural spatial and temporal heterogeneity of disturbances between subbasins.

concerned, characterized by lower magnitude and increasing frequency (Figure 6.4, middle). In high-order rivers, the integration of many occurrences of erosion and the isolation of larger systems from direct influences of mass wasting conspire to further reduce the magnitude of sediment-related disturbances while increasing their frequency (Figure 6.4, bottom).

Spatial heterogeneity of erosion and sedimentation due to asynchronous fires and rainstorms may lead to adjacent basins having decoupled patterns of disturbance (Figure 6.5). In this example, the degree of disturbance can be thought of as time since the last event and the magnitude of that event. This potential habitat variability can be viewed as a habitat diversity. At the scale of a larger watershed, stochastic occurrences of mass wasting lead to basins having a unique variety of disturbance regimes. This results in a spatial and temporal distribution of subbasins in states of alternating low, intermediate, and high disturbance.

Therefore, the type, intensity, and frequency of erosional events and their spatial distribution across landscapes are important considerations to understanding the relationships between geomorphic process, form, and ecological functioning of watersheds. The temporal and spatial scales at which these processes occur, however, complicate their study. Our minimal knowledge of natural disturbance regimes limits our understanding of the functioning of ecologically healthy watersheds over long periods and large spatial scales, thus precluding accurate environmental assessments of the long-term effects of land use in watersheds in the coastal ecoregion.

Hydrologic Patterns

Hydrologic patterns of ecologically healthy watersheds in the coastal ecoregion are strongly related to the timing and quantity of flow, characteristic of seasonal water storage and source area, and the dynamics of surface and subsurface (e.g., hyporheic) exchanges.

FIGURE 6.6. Flood regions of western Washington, USA.

Timing and Quantity of Flow

Distinct flood regimes in the coastal ecoregion of Washington have been identified in two analyses of regional stream gauging data (Bodhaine and Thomas 1964, Cummins et al. 1975). A map of these flood regions provides perspective on the spatial variability of runoff intensity (Figure 6.6).

Comparison of the Stillaguamish River (Region I), Nooksack River and Cedar River (Region II), and Pilchuck Creek (Region III) provides an example of basic differences in amount and form of precipitation, seasonal timing, and water storage within a region (Figure 6.7). Region I comprises the western Cascades and the northwestern portion of the Olympic Peninsula. The Cascade Mountain portion of Region I is located in the atmospheric convergence zone east of the Strait of Juan de Fuca where air masses moving north through the Puget Lowland collide with air moving east through the Strait, causing heavy precipitation. Region II covers most of the rest of

FIGURE 6.7. Representative annual flow regimes for the three major flood regions of western Washington. Region I: Stillaguamish River (-O-); Region II: Nooksack River (■) and Cedar River (□); Region III: Pilchuck Creek (●).

the western Cascades, including intermediate mountain elevations where rain-on-snow events are most common (Berris and Harr 1987). Rain-on-snow events are also common in the Cascade Mountain portion of Region I. Rain-on-snow events are periods of accelerated runoff resulting from melting of a warm snowpack caused by warm winds and rainfall. In western Washington and Oregon, these occur in early winter and spring, when snow levels are likely to fluctuate over hundreds of meters in elevation. Region III covers the Puget Lowland (in a rain-shadow) and the higher elevations west of the Cascade crest (snow dominated); in this area rain-on-snow events are least common because elevations are either too low to produce frequent snow or too high to produce frequent rain.

The predicted peak discharges of a 25-year recurrence interval flood in the three dominant Cascade flood regions are markedly different (Figure 6.8). Discharges calculated from the regression formulae of Cummins et al. (1975) (standardized to units of discharge per unit watershed area with standard errors of 32, 39, and 50% in Regions I, II, and III, respectively) show that Region I produces the highest discharge, Region III the lowest, and Region II an intermediate amount. In addition, smaller drainage areas produce more runoff per unit area than larger ones, regardless of region. This reflects the decreasing likelihood of a storm covering the entire watershed as watershed area increases, and the increase in floodplain storage (e.g., lakes and wetlands) as watershed size and stream order increase.

The predicted peak discharges of 2-year, 25-year, and 100-year recurrence interval floods in Region I show a similar pattern of discharge per unit watershed area (Figure 6.9). As before, the discharge was standardized and calculated (after Cummins et al. 1975) for hypothetical watersheds of three different sizes. Standard errors of the estimates are 25, 32, and 40% for the 2-year, 25-year, and 100-year recurrence interval floods, respectively. Predicted flood discharge decreased with increasing drainage area. The 25-year flood was about twice the magnitude of the 2-year flood; the 100-year flood was about triple the magnitude of the 2-year flood (Figure 6.9).

FIGURE 6.8. Estimated 25-year recurrence interval peak discharges for the three dominant flood regions in western Washington, by drainage area.

The significance of floods to high-order channels and associated riparian forests is as a disturbance creating heterogeneous habitat and as a recharge source for alluvial aquifers. Identifying a characteristic flood threshold at which significant disturbance occurs for a given stream, location, or region may be desirable to assess ecological effects. Once identified, such thresholds could define the spatial and temporal limits of disturbance in floodplain and riparian environments. This concept is best explored in the context of the following case study.

The potential for defining an ecologically significant flood recurrence interval is suggested by a study of the Skagit River, Washington. Stewart and

FIGURE 6.9. Predicted peak discharge of 2-year, 25-year, and 100-year recurrence interval floods in Region I (western Washington, USA) by drainage area.

Bodhaine (1961) reconstructed Skagit River floods (1815–1958) based on accounts of Native Americans and white settlers and on field measurements. The floods occurred in 1815, 1856, 1880, 1882, 1894, 1896, 1897, 1906, 1909, 1917, 1921, 1932, 1949, and 1951. These 14 floods, occurring in a period of 143 years, suggest that significant floods recur, on average, every 10 years. Alternatively, the probability of a flood of this magnitude ($4,000 \text{ m}^3/\text{s}$) occurring in any year is 0.10. Six of the 14 floods occurred within 5 years of each other, suggesting that large floods occur in cycles, resulting in clusters of large floods concentrated in relatively short intervals. Although effects of such floods on riparian and floodplain environments were not well documented, these 14 floods resulted in extensive floodplain inundation. Additional analysis of the Skagit River flood history by Stewart and Bodhaine (1961) produced a flood frequency curve scaled to the mean annual flood. The 10-year recurrence interval flood had a discharge almost double the mean annual flood—suggesting, perhaps, a threshold. Further hydrological and ecological analyses would be necessary to determine whether the 10-year flood recurrence interval can be matched with patterns of riparian vegetation succession, thus providing evidence of an ecologically significant flood threshold.

Runoff Processes

Runoff processes influence quantity, quality, and timing of surface and subsurface flow. Water routing influences riparian vegetation, nutrient inputs, and stream productivity. Processes acting on runoff before the flow reaches the channel are numerous (Dunne 1978). In the heavily forested Pacific coastal ecoregion, overland flow is usually not an important process because infiltration capacities greatly exceed precipitation intensity (Hart 1976). Lateral subsurface flow is the dominant runoff process (Dunne 1978, Burt and Arkell 1986, Beschta et al. 1987, Troendle 1987). Subsurface flow may occur as matrix flow, or through macropores such as root channels, animal burrows, and even larger soil pipes (Higgins 1984, Roberge and Plamondon 1987, Beaudry et al. 1990). Shallow soils (over bedrock) and numerous macropores and soil pipes enable a quick stream response to storm events. The discontinuous network of soil macropores and pipes promotes rapid subsurface flow. Deeply incised depressions in steep, mountainous terrain of the Pacific Northwest have a greater response than broader depressions (Sidle 1986). The wetter the soil and the steeper the hydraulic gradient, the quicker the contribution of storm water or snowmelt to streamflow. Thus in winter and spring, when swales and stream valley bottoms are saturated, storm precipitation reaches the stream rapidly (Dunne 1978, O'Loughlin 1986).

The wetted area of the drainage network expands and contracts seasonally in response to precipitation, local topography, and soil characteristics (Hewlett and Nutter 1970, Dunne 1978, Burt and Arkell 1986). Investigations in humid mountainous regions throughout the world substantiate the applica-

October - January

Fall-winter storms
Lateral hillslope flow
Capture of summer-produced materials

February - June

Snow zone restricts transfers
Floodplain expansion
Material flux facilitated by surface and subsurface flows

July - September

Source area contracted
Subsurface water flows significant
Snowmelt provides for larger source area in headwaters

FIGURE 6.10. Variable source area concept for water availability and storage for three hydrologic seasons : October - January, February - June, and July - September.

bility of this variable source area concept (Swistock et al. 1989, Wolock et al. 1989, Sunada and Hong 1988, Fritsch et al. 1987, Rhodes et al. 1986, O'Loughlin 1986, Satterlund 1985, Troendle 1985, Bruijnzeel 1983) (Figure 6.10). These studies conducted outside the Pacific Northwest show enough similarities to extend the concept to the Pacific Northwest coastal ecoregion.

Generally, variable source area has been applied only to runoff in small watersheds. However, the concept should be extended to larger watersheds or to explain other processes, such as nutrient cycling and characteristics of riparian forests that are important to the stream ecosystem (Rhodes et al. 1986, Oliver and Hinckley 1987, Burt 1989). The dynamics of the variable source area are important where runoff timing and duration influence ecological processes. For example, during summer drought, source areas contract as drainage from hillslopes decreases (O'Loughlin 1986). As soil tem-

perature rises, biological activity increases in the shallow soil mantle until it is eventually reduced by low moisture availability (Maser and Trappe 1984, Waring and Schlesinger 1985). In autumn, precipitation increases and the variable source area expands. Water levels rise and the groundwater recharge phase begins. Increased water contact within the soil enhances the capture of carbon and nutrients (Rhodes et al. 1986, Wolock et al. 1989).

Runoff Processes in Low-Order Watersheds.

Variability in channel pattern and flow regimes creates a habitat mosaic along the longitudinal and lateral axes of streams (Minshall 1988, Pringle et al. 1988). At high elevations, low-order watersheds predominate. Topography, soil attributes, and initial source of flow (e.g., glacial, snow, seeps, hillslope runoff) influence the flow regime and variable source area for the low-order channels. Low-order watersheds are major source areas for downstream surface water and for recharge of alluvial aquifers (Compana and Boone 1986). However, water storage is limited by steep hillslopes and shallow soils adjacent to the channel. Exceptions occur in zones of small floodplains and wet meadows where local subsurface water may contribute to streamflow, in alpine areas during snowmelt, and in permanent snowfields or glacier-fed streams.

Subsurface areas may act as a storage compartment in winter and as a source for organic and inorganic nutrients (Triska et al. 1989a). Deep percolation and groundwater recharge occur beneath the snowpack (Compana and Boone 1986, Munter 1986, Rhodes et al. 1986). Groundwater levels and soil moisture remain high through midwinter. Subsurface flow is sufficient to sustain baseflow and contributes nutrients to streams during winter.

At high elevations, the variable source area for lower-order streams expands substantially during snowmelt as soil layers become saturated (Figures 6.4 and 6.10). When soil is fully saturated, overland flow is generated by continued snowmelt. Overland flow is important for providing additional nutrients to the stream. For example, nitrate-nitrogen concentrations are higher in overland flow than in groundwater flow, with the highest concentrations occurring during peak discharge (Rhodes et al. 1986). This nitrogen pulse is important for providing nutrients to the nitrogen-limited streams of the coastal ecoregion.

In midsummer, water levels recede and the variable source area contracts as soil water is withdrawn and transpired by vegetation (Harr 1976, Walters et al. 1980). The subsurface hydrologic gradient toward the stream increases as stream water levels subside. The subsurface storage compartment drains relatively quickly toward the stream (zone of convergence) transporting nutrients and carbon from the riparian forest (Peterjohn and Correll 1984, Triska et al. 1989a, b). During drier periods, the variable source area may shrink to the channel, with the channel then acting as the primary storage compartment.

Runoff Processes in Mid-Order Watersheds

Alluvial stream processes dominate in third- through fifth-order watersheds and channels. Variable source area and storage expand as the stream valley widens. However, surface storage in oxbow lakes and overflow channels remains limited (Benda 1990). Water movement from the hillslopes and the level of soil saturation at the hill bottom are still important runoff components (O'Loughlin 1986). One result is formation of wetlands at the base of hillsides. Wetlands are important storage areas for flow, expanding the variable source area through the season (Holland et al. 1990, Carter 1986, Wald and Schaefer 1986). In the upper reaches, riparian wetlands are restricted due to narrowness of the valley. However, wetlands form landward of fluvial floodplain features such as scroll bars, and on alluvial fans deposited by tributaries at the base of hillslopes (L. Mertes, University of California, Santa Barbara, pers. comm.). Beaver (*Castor canadensis*) also contribute to the formation of storage features (Naiman et al. 1988). During dry seasons, some wetlands become part of the variable source area; however, others are perched and do not act as a water or nutrient source to the stream, but as a sink (Beaudry et al. 1990).

Local groundwater aquifers are recharged by ample winter precipitation and snowmelt and are an important component of streamflow and the variable source area throughout the year (Walker 1960, Hewlett and Nutter 1970, Freeze and Cherry 1979, Burt and Arkell 1986). Overbank flooding provides additional recharge to groundwater and wetlands. Flooding duration is shorter than in higher-order channels. For example, the two-year flood duration in a mid-order stream (at 500–1,000 m elevation) is approximately 1–2 days. The two-year flood duration for higher-order streams is approximately 3–4 days (estimated from the USGS – Water Resource Data Reports, 1950–86). Aggradation due to mass wasting or episodic debris flows can increase the flood stage and duration for mid-order streams.

Runoff Processes in High-Order Watersheds

Higher-order (>sixth-order) watersheds and channels occur at lower elevations where the dominant form of precipitation is rain. As the stream valley broadens, the variable source area expands and remains more spatially and temporally stable (Figures 6.4 and 6.10). Tributaries still exhibit seasonal expansion and contraction, but not to the degree seen in lower-order streams at higher elevations. Flow hydrographs (Figure 6.7) indicate that winter storm and snowmelt are the dominate flow generators. Tributaries confined to lower elevations show no influence from rain-on-snow events; higher-order streams are still influenced by rain-on-snow events.

At low and moderate flow conditions, the main river channel meanders across the floodplain (Leopold et al. 1964). Over time, cutoff channels, oxbow lakes, meander scrolls, and other backwater and high water channels develop on the broad valley floor. Along some reaches, logjams redirect

flow into secondary channels, or the river forms new channels (Walker 1960, Lienkaemper and Swanson 1987). Increases in depression storage serve to lengthen the time of ponding, and to dampen flood peaks, while prolonging the duration of inundation. Nonperched systems supply water to subsurface systems following flood recession (Mitsch and Gosselink 1986, Wald and Schaefer 1986). When floodplains become inundated by overbank and breach flow (Hughes 1980), the riparian vegetation decreases water velocities due to increased resistance, causing an increase in flood stage (Dunne and Leopold 1978, Ponce and Lindquist 1990).

Precipitation, side valley runoff, and groundwater seeps contribute to water inputs and erosion of the floodplain (Dunne 1978, Higgins 1984). Major floods occur during periods of maximum soil moisture and highest subsurface and wetland water levels, thus there is little room for temporary storage. Some floodwaters are placed in long-term storage in groundwater and deeper wetlands. Flooding is not restricted just to snowmelt or storm events. Lesser magnitude floods are due to accumulated sediment, beaver dams, fallen trees and debris dams (Sedell et al. 1988). Thus, in ecologically healthy watersheds in the Pacific Northwest coastal ecoregion, the valley bottoms are wet or flooded most of the year.

Tributaries, originating from seeps, springs, and wetlands at the base of hillslopes, flow across river terraces. Most are low gradient with stable flow regimes from strong groundwater influences. Other tributaries, classified as valley-wall tributaries (Cupp 1989a, b; Swanson and Lienkaemper 1982) start near the top of the valley slopes. These have steep gradients and variable flows. Unlike the headwater tributaries originating in the alpine/glacial area, the basins of these streams are heavily forested and contribute little suspended sediment. The flow regime of these tributaries is dominated by late winter and early spring precipitation, whereas the flow regime of the higher-order main channel is regulated by winter storms, snowmelt, and groundwater.

Lowland rivers become a network of islands, wood debris dams, sloughs, oxbow lakes, and beaver ponds (Sedell et al. 1988). The channel pattern becomes anastomosed (multiple channels) due to significant reduction in gradient, sediment inputs from upstream causing channel aggradation and backwater effects (Smith 1973). The backwater effect creates additional overbank flooding, deposition of fines, and buildup of river levees, backswamps, and other floodplain features. The alluvial deposits along the higher order channels of the western Cascades result in some of the highest specific yields of groundwater in the United States (Martin 1982, Lum 1984, Davis 1988).

Hyporheic Processes and Subsurface Habitat

Streams in the Pacific Northwest coastal ecoregion have three interacting aquatic habitats: surface or in-channel habitat, floodplain habitat, and subsurface or hyporheic habitat. The subsurface habitat, or hyporheic zone,

the interstitial habitat beneath the streambed that is the interface between surface water and the adjoining groundwater. Traditionally, the hyporheic zone has been considered a relatively thin area extending only tens of centimeters vertically and laterally beneath and alongside the stream (Pennak and Ward 1986). However, recent investigations on gravel-bed rivers show that these habitats can extend throughout the alluvial gravels of floodplains. Stanford and Ward (1988) found the average hyporheic habitat to be 3 km wide and 10 m deep in an alluvial floodplain on the Flathead River, Montana. Thus, in areas of extensive alluvial gravel floodplains, the hyporheic zone contributes substantially to total habitat area.

Vertical and lateral dimensions of subsurface water movements are controlled by geologic structure and layering of aquifers in the continental glacial till deposits of Washington, British Columbia, and Alaska. Toth (1963) suggests that there are three distinct systems; local systems, intermediate systems, and regional systems. Under this framework, local systems develop only where there is pronounced topographic relief. Increasing topographic relief is hypothesized to increase the depths and the intensities of the local flow systems.

Occurrence of fractured bedrock, as found throughout the Cascades, provides an avenue for upwelling of regional groundwater systems (Freeze and Cherry 1979). In lower-gradient alluvial valleys, the local water system may stagnate, allowing regional or intermediate systems to dominate or mix with local systems. Boundaries between systems are located at the highest and lowest elevations of local hills and depressions (Toth 1963). Thus the stream channel may serve as a zone of convergence between different groundwater systems. Chemical characteristics of the groundwater systems are different and are reflected in the variability of chemical parameters found within the stream or along the banks.

Hyporheic areas are important regulators of nutrient inputs to streams. The hyporheic zone, as a retention or storage compartment, provides a medium for biotic processing (Hynes 1983, Bencala 1984, Grimm and Fisher 1984, Dahm et al. 1987, Stanford and Ward 1988, Triska et al. 1989a, b). Nutrient and organic fluxes within the hyporheic zone are hypothesized to be a function of the direction and type of groundwater or surface water influence. Close to the channel, groundwater and stream water mix (Triska et al. 1989b, Vervier and Naiman 1992). Triska et al. (1989b) found that within 3.5 meters of the channel, at least 80% of the subsurface water was stream water.

The rate of exchange between the subsurface and stream ecosystems varies with the dominant hydraulic process (discharge or recharge). Dominance of groundwater or surface water depends on the season or magnitude and duration of storms (Compana and Boone 1986, Gilbert et al. 1990, Vervier and Naiman 1992). As surface water rises in the channel, groundwater recharge dominates (Freeze and Cherry 1979, Beaudry et al. 1990).

Hyporheic Processes in Low-Order Channels

Spatial connectivity of hyporheic zones in the steeper bedrock-controlled channels may be discontinuous due to constrained topography (Figure 6.4). Hyporheic zones are limited to small floodplains, meadows, and stretches of stream where coarse sediment is deposited over bedrock. System continuity is further interrupted by mass wasting and debris dam breaks which gouge channels.

Local hyporheic systems are fed by subsurface flow from hillsides. Subsurface flow through porous soils can be significant from forested slopes (Sloan and Moore 1984) where root channels, decayed root holes, worm holes, piping, and animal burrows are common (Sklash and Farvolden 1979, Higgins 1984, Roberge and Plamondon 1987, Beaudry et al. 1990).

In zones of bedrock fracture, mixing between local and regional groundwater systems may occur (S. Burgess, Civil Engineering, University of Washington, pers. comm.). However, in the subsurface ecosystem, local groundwater dominates. Dominance affects several parameters, such as quality of organic matter, water chemistry, and faunal distribution (Triska et al. 1989a, b; Gilbert et al. 1990). Relatively high subsurface velocities on hillsides mean less soil contact time and mineralization than in downstream areas (Wolock et al. 1989).

Hyporheic Processes in Mid-Order Channels

As valleys broaden to a wider alluvial floodplain with less topographic constraints, the spatial connectivity of the hyporheic zone becomes more continuous (Figure 6.4). Local groundwater systems still dominate the subsurface ecosystem. Depth and intensity of the local system should be greatest in this zone (Toth 1963). As the floodplain widens and topographic relief decreases, stagnation of the local system promotes mixing of intermediate and regional systems, especially during drier periods when hydraulic gradients toward the stream are strongest (Freeze and Cherry 1979).

As surface discharge declines, as during the summer drought period, the system is dominated by groundwater discharge. Exceptions occur during storms (Vervier and Naiman 1992). During surface low-water periods the hyporheic zone acts as a source of water, nutrients, and energy to the stream (Wallis et al. 1981, Bencala 1984, Naiman et al. 1987, Ford and Naiman 1989, Triska et al. 1989a, b).

Hyporehic Processes in High-Order Channels

In higher-order streams, with wide floodplains and unconstrained valleys, the spatial extent of hyporheic habitat is greater than upstream (Figure 6.4). However, discontinuities in spatial connectivity increase as the influence of local groundwater system decreases. For example, small topographic variations created by fluvial structures such as scroll bars, cutoff channels, oxbow lakes, and wetlands create discontinuities. As a result of local system

dynamics and varying topography on the floodplain, alternating recharge and discharge areas are found across the valley (Toth 1963, Winter 1987).

Soil and substrate permeability in the floodplain and channel is variable due to erosional and depositional fluvial processes and deposition of till during the continental glacial period. However, duration of overbank flows and ponding is longer in higher-order watersheds, enhancing opportunities to transmit organic matter and nutrients from surface water to the hyporheic zone. Subsurface storage and retention of nutrients increases as the spatial extent of channel features (e.g., side bars and channel bars) increases (Ben-cala 1984).

Functions of Hyporheic Zones

Hyporheic zones act as sensitive indicators of ecological health, since processes there substantially influence energy and nutrient resources in riparian forests and aquatic surface systems (Wallis et al. 1981, Hynes 1983, Peterjohn and Correll 1984, Lowrance et al. 1984, Grimm and Fisher 1984, Stanford and Ward 1988, Ford and Naiman 1989, Triska et al. 1989a, b; Gilbert et al. 1990). Hyporheic zones can act as a sink, storage, or source depending on spatial location and season.

Retention of nitrogen, phosphorus, and organic carbon within the subsurface zone occurs during the recharge phase. Low hydraulic gradients and slower velocities enhance biotic activity (Winter 1987, Triska et al. 1989a, b). However, anaerobic processes such as denitrification may dominate during this phase due to saturated soil conditions (Hixson et al. 1990). As the recharge phase shifts to a discharge phase, aerobic processes such as nitrification become dominant. The type and intensity of biochemical processes will influence biodiversity and the spatial distribution of animals using hyporheic habitat.

Numerous and often contradictory hypotheses exist concerning the flux of carbon, nitrogen, and phosphorus from subsurface to surface waters. For example, Fisher and Likens (1973) reported that groundwater diluted organic carbon in stream systems in New Hampshire. Hynes (1983) also hypothesized that hyporheic zones serve as a sink for organic matter in Ontario. Yet groundwater has been found to be a significant source of carbon and nutrients to streams (Hynes 1983, Grimm and Fisher 1984, Dahm et al. 1987, Naiman et al. 1987, Ford and Naiman 1989). Rutherford and Hynes (1987) suggest that the hyporheic zone is too heterogeneous to make a source or sink conclusion. The results, equivocal to date, point to the need for better information about an inherently complicated system that is of fundamental importance for watershed functions (Pinay et al. 1990).

Water Quality

Selection of Fundamental Water Quality Elements

Water quality is a fundamental component of watershed health because it effectively integrates the full range of geomorphic, hydrologic, and biologic processes (Hem 1985). Alterations to any one of these processes will affect

one or more water quality parameters (Frere et al. 1982, Peterjohn and Correll 1984). Hence changes in water quality indicate a change in some aspect of the terrestrial, riparian, or in-channel ecosystem. Conversely, water quality affects the aquatic, riparian, and hyporheic ecosystems (Hynes 1966, 1970; Stanford and Ward 1988, MacDonald et al. 1991). These interactions are extremely complex, and recognition of their importance does not simplify the problem of associating an observed change in water quality with a particular cause. In ecologically healthy streams there is considerable spatial and temporal variability in water quality parameters due to the large number of controlling factors and the uneven distribution of these factors in space and time (Feller and Kimmins 1979, Bencala et al. 1984, Keller et al. 1986).

We focus on just five of many water quality elements related to ecologically healthy systems: (1) nitrogen (particularly nitrate-nitrogen), (2) phosphorus (principally phosphates), (3) turbidity, (4) temperature, and (5) in-tragravel dissolved oxygen. Other important elements related to the ecological health of watersheds, such as buffering capacity (pH and alkalinity), organic nutrients (forms of dissolved organic carbon), and potential toxicants (wastes, insecticides, herbicides), are not considered here. The five elements chosen were selected after discussions with water quality experts and a review of the results of a recent project sponsored by the Environmental Protection Agency to develop guidelines for monitoring the effects of forestry activities on streams in the Pacific Northwest and Alaska (MacDonald et al. 1991). Consideration was limited to the physical and chemical constituents of water even though channel, riparian, and other biological characteristics are equally important for maintaining an ecologically healthy system (MacDonald et al. 1991). The intent is that, taken together, these five elements provide an indication of the basic health of lotic systems in the Pacific Northwest coastal ecoregion.

Role and Expected Values

Nitrogen and phosphorus are typically limiting nutrients in coastal ecoregion streams (Hem 1985). The mass flux of N and P is a function of critical processes such as the efficiency of terrestrial nutrient cycles, flow and transformations of organic material, and erosion of particulate matter (Sollins et al. 1980, Harr and Fredriksen 1988, Martin and Harr 1989). Use of both nitrogen and phosphorus is complementary because phosphorus tends to be sorbed and transported in particulate form, while nitrogen usually is dissolved and transported by subsurface and groundwater flow (Mohaupt 1986). In the absence of other limiting factors such as light, increased concentrations of plant-available nitrogen and phosphorus stimulate primary production (Gregory et al. 1987).

The range of conditions found from southeastern Alaska to northern California, and from the coast to the permanent snow zone, make it difficult

to specify expected values. For example, mean annual nitrate-nitrogen concentrations in undisturbed headwater streams range from less than 0.01 mg/L (Harr and Fredriksen 1988, Martin and Harr 1989) to 1.2 mg/L (Brown et al. 1973). Because atmospheric inputs usually are larger than the loss of nitrogen by leaching, there is a small net input of 0.1–2.6 kg N ha⁻¹ yr⁻¹ in undisturbed forested watersheds west of the Cascades (Feller and Kimmins 1979, Martin and Harr 1989).

Mean annual phosphorus concentrations in small forest streams typically are less than 0.06 mg/L (Brown et al. 1973, Feller and Kimmins 1979, Harr and Fredriksen 1988, Martin and Harr 1989). Annual phosphorus budgets for four forested coastal watersheds range from a net gain of 0.1 kg ha⁻¹ yr⁻¹ to a net loss of 0.3 kg ha⁻¹ yr⁻¹ (Feller and Kimmins 1979).

Turbidity is a measure of light scattering by a water sample. In most cases, suspended silt and clay particles are the primary cause of high turbidities, although colored organic compounds, finely divided organic matter, and microorganisms such as plankton also contribute (APHA 1989). Turbidity is useful as an easily measured indicator of suspended sediment concentrations (Kunkle and Comer 1971, Aumen et al. 1989), and hence a first approximation of erosion rates. Suspended sediment has wide-ranging effects on salmonids, invertebrates, and other aquatic organisms (Everest et al. 1987, Chapman and McLeod 1987).

Expected values for turbidity are difficult to specify because turbidity is discharge dependent and extremely variable throughout the region. Hence turbidity standards usually are expressed in terms of an allowable increase over background (Harvey 1989). The absolute values necessary to protect designated uses, such as sight feeding by salmonids, are <25 NTU (EPA 1986); greater values generally are encountered only during major floods (Aumen et al. 1989).

Water temperature greatly affects rates of chemical and biological processes. Although absolute stream temperatures are largely a function of the subsoil environment and climatic conditions (Beschta et al. 1987), stream temperature is a relatively sensitive indicator of riparian conditions (Brown and Krygier 1970, Harr and Fredriksen 1988). As noted previously, stream channel morphology also affects the temperature regime. Temperature is largely a function of discharge and incoming solar radiation, and is relatively predictable for specific locations.

Intragravel concentration of dissolved oxygen (DO) is critical for salmonid reproduction, invertebrates, and other aquatic life. Furthermore, the concentration of intragravel DO integrates numerous other factors, including temperature, bed material particle size, and the deposition of fine sediment and particulate organic matter (MacDonald et al. 1991). In undisturbed alluvial streams the concentration of intragravel dissolved oxygen should approach saturated values; values substantially less than saturation suggest blockage of interstitial water flow (Chapman and McLeod 1987) or high

Table 6.2. Relative importance of factors controlling the observed values of selected water quality elements in coastal ecoregion streams.

Controlling Factor	Water Quality Element				
	Nitrogen	Phosphorus	Turbidity	Temperature	Intragravel Dissolved Oxygen
Climatic and atmospheric inputs	High	Low	Moderate	High	Low
Geology and soils	Moderate	High	High	Moderate	High
Stream order	Moderate	Moderate	Moderate	High	Moderate
Constrained or unconstrained channels	High	High	High	Moderate	Moderate
Vegetation	High	Moderate	Moderate	High	Low

oxygen demand from the breakdown of organic materials (Ringler and Hall 1975, Plamondon et al. 1982).

Little data are available for intragravel DO values for ecologically healthy watersheds. Suggested one- and seven-day minimum values for intragravel DO are 5.0 and 6.5 mg O₂/L, respectively (EPA 1986). Idaho is considering an intragravel DO standard of 85% of the saturated value (Harvey 1989), but adoption of this standard has been slowed by uncertainty over intragravel DO values in undisturbed streams, and by the high spatial variability of intragravel DO in a stream segment or even within a salmonid redd (Chapman and McLeod 1987).

Taken together, these five fundamental elements are one indication of the suitability of streams for cold-water fishes and provide an integrated view of watershed health. Other parameters could be supplemented, but these five represent a best *initial* indication of watershed health over the range of environmental conditions found in the Pacific Northwest coastal ecoregion.

Controlling Factors

Expected values of these five fundamental elements are a function of multiple controlling factors, and each element has a unique response to the set of controlling factors. Table 6.2 qualitatively summarizes the relative importance of five factors—climatic and atmospheric inputs, geology and soils, stream order, valley type (constrained versus unconstrained channels), and vegetation—on the selected water quality elements.

The first controlling factor—climatic and atmospheric inputs—strongly affects nearly all water quality elements. In the Bull Run watershed near Portland, Oregon, for example, precipitation accounts for approximately 60% of the dissolved ionic load in surface runoff (Aumen et al. 1989). Atmospheric nitrogen inputs generally exceed nitrogen losses (Feller and Kimmins 1979). Solar radiation is a dominant variable in predicting stream temper-

atures (Beschta et al. 1987). Turbidity is highly responsive to the size and spacing of storm events (Brown 1983). Climatic and atmospheric inputs also help define basic processes such as the volume and timing of runoff, weathering rates, and the likelihood of mass failures. Thus virtually all water quality parameters are affected by climatic and atmospheric inputs (Risser, this volume), but nitrogen and water temperature generally are more responsive than phosphorus or intragravel DO.

Geology and soils are important factors in determining the amount and type of erosion, hence the levels of turbidity, phosphorus, and indirectly intragravel DO (Everest et al. 1987, Chapman and McLeod 1987). Nitrogen also is relatively sensitive to geology and soils because losses occur primarily in dissolved form, and this is a function of soil and groundwater processes (Feller and Kimmins 1979, Sollins et al. 1980).

Relatively few studies have related values of these fundamental elements to stream order in undisturbed watersheds. In general, increasing stream order reduces temporal variability, but absolute effects are uncertain. In interior Alaska stream order has no effect on phosphorus or turbidity, while nitrogen shows a slight decrease downstream (Hilgert and Slaughter 1988). Changes in stream temperature are more predictable, with the observed temperature generally increasing downstream. Intragravel DO should decline with increasing stream order because the larger volume of water reduces the reaeration rate, mean water temperatures are higher, and the finer bed material associated with higher-order streams reduces subsurface permeability.

Differences in water quality between geomorphically constrained and unconstrained channels will result from differences in subsurface flow paths, sideslope gradients and resultant erosion and transport rates, and width of riparian and hyporheic zones. Turbidity is most likely to be sensitive to valley form, with lesser or indirect effects on other water quality elements.

Vegetation is the final controlling factor. Healthy watersheds in the Pacific coastal ecoregion generally have a dense forest cover, and this helps keep water temperatures and sediment loads in the range suitable for salmonids. In addition, both density and vegetation type affect nitrogen fixation and uptake (Sollins et al. 1980).

Since all five fundamental elements respond directly or indirectly to the same basic driving forces of runoff, erosion, and weathering, there are significant interactions among these elements. The use of several water quality elements is necessary to assess the specific condition (health) of the drainage network, and to fully evaluate the effects of natural and anthropogenic changes.

Riparian Forest Characteristics

The natural characteristics and ecological health of streams and rivers are intimately linked to the surrounding landscape by the biotic and physiochemical properties of the riparian zone. The riparian zone extends from the edge of the average high water mark of the wetted channel toward the uplands

(Figure 6.11). This zone includes terrestrial areas where vegetation and microclimate are influenced by perennial or intermittent water associated with high water tables, and by the ability of soils to hold water. Beyond this is the riparian "zone of influence," a transition area between the riparian zone and the upland forest where vegetation still influences the stream under some conditions (Gregory et al. 1991).

In ecologically healthy watersheds, riparian forest characteristics are strongly controlled by climate (e.g., hydrologic regime), channel geomorphology, and the spatial position of the channel in the drainage network. Historically, riparian forests formed a continuous ribbon of vegetation along stream channels. Upon closer examination, this vegetative ribbon was a mosaic of different stand ages and species from the headwaters to the sea (Maser et al. 1988). Riparian forests once covered large areas, especially in the alluvial lowlands (Sedell et al. 1988).

The width of the riparian zone, and the extent of the forest's influence on the stream, are strongly related to stream size and valley morphology. Small streams possess relatively little riparian vegetation: they are more influenced by vegetation in the upland forest (zone of influence) (Figure 6.11). Mid-order streams and rivers (third to fifth order) typically have a distinct band of riparian vegetation, whose width is defined by long-term (>50 yr) channel dynamics and the annual discharge regime. Large rivers are characterized by well-developed, complex floodplains with long periods of seasonal flooding, oxbow lakes in old river channels, a diverse forest community, and moist soils. Ecologically healthy watersheds require the influence of riparian forests on streams, especially in relation to controlling the light and temperature regimes, providing nourishment for the stream biota, and being a source of large woody debris (Table 6.3).

Light and Temperature

The amount and quality of light reaching streams are determined by forest vegetation height, forest canopy density, stream channel width, and channel orientation in relation to the sun's path in the sky. Light is important for streams because of its influence on water temperature, on primary production by aquatic plants, and on the behavior of organisms.

Seasonal and daily water temperatures are strongly influenced by the amount of solar radiation reaching the stream surface through the forest canopy (Beschta et al. 1987). The temperature of water entering a small stream typically reflects that of the forest's subsoil environment, but changes as water flows downstream. Water temperature is an important factor for environmental vitality because of its controlling influence on the metabolism, development, and activity of stream organisms.

Small forested streams typically receive 1 to 3% of total available solar radiation (Naiman and Sedell 1980, Naiman 1983, 1990). Small streams have relatively cool but stable daily temperatures, low rates of primary pro-

FIGURE 6.11. The natural characteristics of the riparian zone change with stream size. In low- and mid-order streams the links between the riparian forest and the stream are strong. In large rivers the links are not as strong in the main channel but they do remain strong in the secondary channels. Key: (1) active channel, (2) riparian zone, (3) zone of influence, (4) uplands. Note that (2) and (3) make up the complete riparian zone of influence.

Table 6.3. Functions of riparian vegetation with respect to aquatic ecosystems.

Sites	Components	Functions
Aboveground/above channel	Canopy and stems	Shade controls temperature and in-stream primary production Source of large and fine plant detritus Wildlife habitat
In channel	Large debris derived from riparian vegetation	Controls routing of water and sediment Shapes habitat: pools, riffles, cover
Streambanks	Roots	Substrate for biological activity Increases bank stability Creates overhanging banks, cover Nutrient uptake from ground and stream water
Floodplain	Stems and low-lying canopy	Retards movement of sediment, water, and floated organic debris during floods

Source: Swanson et al. (1982), p. 269.

duction, and organisms that are behaviorally adapted to reduced light and cool temperatures (Naiman and Sedell 1980). In mid-order streams and rivers, gaps appear in the riparian forest canopy. These gaps allow 10 to 25% of the total available solar radiation to reach the stream surface. Daily variations of $\sim 2\text{--}6^\circ\text{C}$ and seasonal variations of $5\text{--}20^\circ\text{C}$ in water temperature may occur, primary production by attached algae and diatoms increases, distinct day-night differences exist in species-specific behavior to light levels, and the biota are metabolically adapted to slightly warmer temperatures. In larger rivers, most available solar radiation reaches the water surface of the main channel through wide gaps in the forest canopy. However, in contrast to reaches upstream, the main channel of large rivers tends to be deeper or more turbid, restricting light penetration through the water. Daily variations in temperature are not as large as in mid-order streams, and depending on water depth, primary production may be less. In addition, primary production is augmented by phytoplankton suspended in the water column and vascular plants rooted near the shore. Finally, most organisms are adapted for life in waters that are dark, or with reduced visibilities.

As water flows downstream, temperature changes in response to factors involved in the heat balance of water, all of which are strongly influenced by the riparian forest. The net rate of gain or loss of temperature is the algebraic sum of net solar radiation, evaporation, convection, conduction, and advection. Net radiation is generally dominated by the amount of direct-beam solar radiation reaching a stream's surface. Heat gain or loss from evaporation and convection depends on the vapor pressure and the temperature gradient at the water surface and the air immediately above the surface.

respectively. Wind speed at the air-water interface is also an important controlling variable. Conduction of heat between water in the stream and the channel substrate depends on the type of material making up the substrate. Bedrock channels are more efficient than gravel-bed channels at conducting heat. Heat exchange by advection occurs when tributaries or groundwater of different temperatures mix with the main streamflow, thereby either increasing or decreasing the main stream temperature.

The influence of shading by the riparian forest on the heat balance of a small stream can be enormous because net solar radiation, evaporation, convection, conduction, and advection remain relatively small over a 24-hour period, even in midsummer, relative to groundwater temperature. Should the forest canopy be opened by a disturbance, the net heat exchange can be significantly altered. For example, during winter, streams without riparian canopies may experience lower temperatures because the lack of cover enhances energy losses by evaporation, convection, or long-wave radiation. Long-wave radiation losses are greatest when clear skies prevail, particularly at night, resulting in the formation of surface and anchor ice. During summer, the lack of a forest canopy cover results in large (3–10°C) diel variations in temperature as the amount of direct solar radiation increases (Beschta et al. 1987).

Instantaneous temperatures and cumulative temperatures (e.g., degree-days per unit of time) have a significant influence on biotic characteristics. Instantaneous temperature significantly affects water viscosity, and therefore the amount of energy required to swim. It influences an organism's metabolism, dictating the amount of food required for daily activities and reproductive products. Further, species preferences for temperature influence the ability of an organism to successfully compete for resources, and thereby influencing community composition and abundance. Fish and invertebrates have specific requirements for the number of degree-days needed for egg development and for the timing of reproduction and emergence, thereby reducing competition for food and reproduction sites by subtle differences in phenology or life history strategies (Sweeney and Vannote 1978).

Sources of Nourishment

Annually, riparian forests add large amounts of leaves, cones, wood, and dissolved nutrients to low- and mid-order streams (Gregory et al. 1991). These organic inputs originate as particles falling directly from the forest into the stream channel (or moving downslope along the forest floor by wind and water driven erosion) and as dissolved materials in subsurface water flowing from the hyporheic zone.

The riparian forest is an important regulator of stream productivity through the amounts and qualities of material directly contributed to the stream. Small streams directly receive 300–600 g C/m² annually from the forest, with the

rate per unit area decreasing as channel width (and the gap in the forest canopy) increases (Conners and Naiman 1984). In deciduous riparian forests >80% of these inputs may be leaves that are delivered over a six-to-eight week autumn period. In coniferous riparian forests ~40–50% of the material may be cones or wood. The chemical quality of the material (i.e., nitrogen and lignin content) strongly influences the rate of decay and subsequent trophic pathways (Melillo et al. 1983, 1984). The complete decay process takes about one year for most high quality materials such as leaves and herbaceous plants and may take several years or decades for low quality materials such as cones and wood (Gregory et al. 1991).

Subsurface water moving from the uplands to the stream also carries large quantities of dissolved organic matter and nutrients essential for stream function. The riparian forests chemically alter these materials as the subsurface water flows pass their root systems. Riparian forests take up nutrients for growth, promote denitrification by subtle changes in the position of oxic-anoxic zones, and modify the chemical composition and availability of carbon and phosphorus (Pinay et al. 1990). Exact mechanisms regulating these processes are not well understood (Triska et al. 1989a, b). Yet the presence of riparian forests significantly regulates the amount of nitrogen and phosphorus reaching streams from upland areas (Karr and Schlosser 1978, Schlosser and Karr 1981a, b; Peterjohn and Correll 1984).

Large Woody Debris

Large woody debris (LWD) is the principal factor determining the characteristics of aquatic habitats in low- and mid-order forested streams. The amount of LWD in streams can be substantial, ranging from >40 kg/m² in small streams to 1–5 kg/m² in large rivers (Harmon et al. 1986). The importance of LWD relates to its ability to control the routing of sediment and water, to shape the formation and distribution of pools, riffles, and cover, and to act as a substrate for biological activity (Swanson et al. 1982; Table 6.3).

Wood boles (>10 cm diameter) enter streams of all sizes from the riparian forest. However, the spatial distribution of LWD varies systematically from small streams to large rivers, reflecting, in part, the balance between stream size and wood size (Bilby 1981). Wood in small streams is large relative to channel dimensions and to peak stream flow. Thus LWD cannot be easily floated and redistributed, and consequently is randomly distributed and often located where it initially fell. But these small channels are often in the steepest part of the drainage network, and are most prone to catastrophic flushing by extreme landslide/dam-break floods (Benda 1990). Mid-order streams are large enough to redistribute LWD but narrow enough that LWD accumulations across the entire channel are common. LWD tends to be concentrated in distinct accumulations spaced several channel widths apart along the stream. In large rivers, LWD is commonly collected in scattered, distinct accumulations at high water and particularly on the upstream ends of islands

and at bends in the river (Lienkaemper and Swanson 1987, Potts and Anderson 1990). Natural anchors such as root wads, large limbs, or lodging of LWD between other obstructions improve debris retention and are important considerations for environmental health of the system.

LWD in streams influences channel morphology as well as sediment and water routing. In small streams LWD creates a stair-stepped gradient where the streambed becomes a series of long, low gradient sections separated by relatively short, steep falls or cascades (Grant et al. 1990). Therefore, much of the streambed may have a gradient less than the overall gradient of the valley bottom, because much of the decrease in altitude, and in potential energy, takes place in the short, steep reaches. This pattern of energy dissipation in short stream reaches results in less erosion to bed and banks, more sediment storage in the channel, slower downstream movement of organic detritus, and greater habitat diversity than in straight, even-gradient channels (Bisson et al. 1987).

Comparison of volumes of stored sediment and annual sediment export suggests that small forested streams with natural amounts of LWD annually export often <10% of sediment stored in the channel system (Swanson et al. 1982). LWD makes up ~40% of the obstructions that trap sediment in forested streams (Bilby and Ward 1989). Unfilled storage capacity serves to buffer potential sedimentation impacts on downstream areas when pulses of sediment from the uplands enter stream channels. Scattered LWD in channels reduces the rate of sediment movement downstream, routing sediment through the stream ecosystem slowly, except in cases of catastrophic flushing events or when the storage capacity is filled.

By redirecting water flow, LWD has both positive and negative effects on bank stability, on the lateral geomorphic mobility of channels, and on the stability of aquatic habitats (Keller and Swanson 1979). LWD-related bank stability problems in steep-sided, bedrock-controlled streams result from undercutting of the soil mantle on hillslopes by debris torrents. Undercut slopes are subject to progressive failure by surface erosion and small-scale (<1,000 m²) mass erosion over a period of years. Both bank instability and lateral channel migration may be facilitated by LWD accumulations in channels with abundant alluvium and minimal bedrock influence. Changes in channel conditions and position often occur as a stream bypasses a LWD accumulation and cuts a new channel. Where channels pass through massive debris accumulations, streamflow may become subsurface much of the year. In areas of active earthflows from the forest, lateral stream cutting may undermine banks, encouraging further hillslope failure and accelerated sediment supply to the channel. On balance, however, LWD generally stabilizes small streams by dissipating energy and by protecting streambanks.

As a result of these mechanisms, LWD helps regulate the distribution and temporal stability of fast-water erosional areas and slow-water depositional sites. LWD and riparian vegetation provide cover and nourishment for all stream organisms, serving as habitat or substrate for substantial biological

activity by microorganisms, invertebrates, and other aquatic organisms (Gregory et al. 1991, Naiman 1990). Filter feeding invertebrates, algae, and diatoms attach in large numbers to LWD, significantly influencing nutrient cycling and, consequently, downstream water quality. LWD accumulations on the streambanks provide habitat for small mammals and birds that feed on stream biota (Doyle 1985). An alteration to the supply rate or the size of LWD from the riparian forest has consequences that may take tens to hundreds of years for natural processes to correct.

Habitat Characteristics

In ecologically healthy watersheds, interactions between channel geomorphology, hydrologic pattern, spatial position of the channel, and riparian forest characteristics produce habitat for terrestrial and aquatic organisms. Fundamental habitat features influencing animal population dynamics, productivity, biodiversity, and evolutionary processes are related to riparian forest dynamics, spatial and temporal variability of the habitat, and maintenance of migratory connectivity. In our discussion we offer six examples: salmonid habitat preferences, fish community habitat requirements, watershed-scale patterns in habitat, influence of LWD on habitat development, the potential role of woody debris piles to act as nodes of ecological organization in fluvial corridors, and habitat alterations by wildlife communities. We then discuss an example of food web dynamics shifting in response to changing habitat. In combination, these examples have broad implications for ecosystem health.

Salmonid Habitat Preferences

Each salmonid species indigenous to the coastal ecoregion employs a different life history strategy (Everest 1987), and consequently utilizes a different suite of habitats (Bisson et al. 1982). These differing life history strategies allow salmonids to fully utilize available habitats in a single watershed by segregating habitats spatially and temporally. It is well known that healthy salmonid populations respond to characteristics and location of spawning areas, postemergent rearing areas, summer (low water) rearing areas, winter rearing areas, and estuarine conditions at smolting. For example, rearing habitats in small streams are used differently by juvenile steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*). During the summer rearing period, coho tend to occupy pools, whereas steelhead prefer riffles and glides (Bisson et al. 1988), but during winter coho move to wall-base channels (Peterson and Reid 1984) and steelhead occupy terrace tributaries (Scarlett and Cederholm 1984). Furthermore, spawning areas and timing of spawning may nearly overlap among species such as pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), and coho salmon. However, because pink salmon and chum salmon migrate to sea soon after emergence, there is no competition among juveniles of these species while in streams.

FIGURE 6.12. Juvenile fish habitat preferences in two western Washington streams with different proportions of pool and riffle areas (P. A. Bisson, unpublished data).

In stream reaches (defined as a section of channel >10 m in length), habitat preferences influence which portions of streams are dominated by juveniles of different species during summer (Figure 6.12). However, these influences are also affected by the availability of suitable spawning gravels for each species, and by other habitat factors, such as cover. Though the habitat requirements of juvenile coho salmon, steelhead trout, and cutthroat trout (*O. clarki*) have been extensively studied, species occupying the larger rivers, floodplains, and estuaries during the juvenile life history stages (e.g., chinook [*O. tshawytscha*], chum, and pink salmon) are not well known. However, it is clear that healthy salmonid populations utilize habitats throughout the drainage network during different stages of their life cycles, suggesting that connectivity between habitats is of fundamental importance.

Fish Community Habitat Requirements

Compared with forested ecosystems in eastern North America, fish species diversity in the coastal ecoregion is low. This results from zoogeographic barriers (McPhail 1967, Reimers and Bond 1967), the geologically short time interval since the last glacial period, and an unpredictable and often severe maritime climate (Moyle and Herbold 1987). What the coastal ecoregion streams lack in species richness, however, is partly offset by a remarkable differentiation among locally adapted stocks. For example, Nehlsen et al. (1991) have identified a large number of distinctive stocks of salmonids within California, Oregon, Idaho, and Washington, 214 of which are considered to be currently at risk of extinction. Fish assemblages in coastal streams are therefore characterized by relatively few, but highly adapted and genetically unique, native species.

Stream fishes in the coastal ecoregion face unpredictable streamflows and substrate conditions, and relatively low levels of aquatic productivity because of large seasonal environmental changes. Moyle and Herbold (1987) have summarized the general adaptations of western species to life in streams; these include large body size, long life and reproductive spans, high fecundity, extensive migrations, and feeding specialization. Such adaptations confer the ability to migrate to areas where food resources are abundant or conditions for successful reproduction exist (Northcote 1978), and also the abilities to spread the risk of reproduction over several years (important in climatic and geologic unstable areas) and to make maximum use of scarce food resources through morphological and behavioral specialization.

Ecologically healthy watersheds provide a wide array of stream conditions (Naiman et al. 1991), nearly all of which are used directly in various life history stages of one or more species (Everest 1987). Fishes in coastal ecoregion streams tend to have dynamic life cycles closely linked to climate, valley form, and the input and transport of sediment and woody debris within the drainage network. Reproduction is associated with specific hydrologic and climatic conditions. Spawning migrations usually occur when streams possess intermediate flows, typically in autumn or spring. Eggs are laid in well-sorted, clean gravels that have a relatively low probability of scouring. Often these substrates are located in unconstrained channels that exhibit some braiding. Fish species that spawn on aquatic vegetation or on mud substrates (Umbridae, Gasterosteidae, some Cyprinidae) locate suitable areas in beaver ponds and in backwaters and sloughs on the floodplain; connections between the river mainstem and floodplain channels must be maintained for successful reproduction of these species to occur. Most fishes in the coastal ecoregion avoid spawning in steep, constrained river valleys unless their lack of mobility prevents migration to reaches with a shallower gradient. In such cases, tributary mouths or other geomorphic features characterized by coarse sediment deposits and low gradient may provide easily accessible but localized spawning sites.

Egg and alevin survival within stream gravel depends on the redd remaining relatively free of fine sediment and maintaining good permeability to ensure that developing embryos have an adequate oxygen supply (Chapman 1988). Deposition of fine sediment during incubation reduces survival to emergence through anoxia or physical entrapment. In general, emergence is timed to avoid large freshets that carry fry downstream away from rearing areas. Increases in the magnitude and frequency of storm flows, particularly in spring, can have a significant impact on survival of juvenile salmonids (Hartman et al. 1987). Other taxa such as Cottidae, Cyprinidae, and Catostomidae, which usually spawn in spring and early summer, may be similarly affected by changes in discharge patterns.

Newly emerged fry are weak swimmers and take up foraging stations along the edge of the stream channel behind prominent flow obstructions, includ-

ing boulders and LWD (Bisson et al. 1987, Moore and Gregory 1988a). The complexity of channel margins can be an important factor influencing early rearing (Moore and Gregory 1988b); therefore, ecologically healthy streams possess complex margins that include backwaters, secondary channels, fallen trees, boulders, and other features that create areas of slowly moving water. Undercut streambanks with the root systems of riparian trees also provide excellent habitat for fry, as well as protection from terrestrial predators. Interactions between stream channels and riparian vegetation become critical to the maintenance of habitat for fry.

As fish grow larger they become better able to maintain feeding stations in swifter currents and more adept at avoiding predators. Preferred habitat often shifts from stream and river margins to deeper water, where the availability of drifting aquatic invertebrates may be greater (Chapman and Bjornn 1969). Some larger salmonids and cyprinids move from tributaries into the river mainstem with the onset of summer. In most cases such movements are timed to take advantage of seasonally abundant food. However, in certain instances summer movements are dictated by the thermal regime, with cold-adapted species seeking out groundwater seeps and congregating around the mouths of cooler tributaries or at the bottom of thermally stratified pools (Berman 1990). Beschta et al. (1987) point out that many fish stocks are adapted to local temperature regimes and that significant alteration of these regimes can lead to disruption of important life cycle events, such as the timing of migrations.

Segments of streams and rivers that provide productive rearing environments in summer may not be optimal winter rearing sites. Periods of high discharge and low food availability force some fishes to seek overwintering locations away from headwater streams and adjacent to, but not in, river mainstems (Peterson 1982a, Tschaplinski and Hartman 1983). Quite often these areas are located in seasonally flooded wetlands, beaver ponds, and spring-fed tributaries at the base of steep valley walls (Skeesick 1970, Cedersholm and Reid 1987, Brown and Hartman 1988). Almost invariably they are characterized by pondlike conditions having relatively stable discharge and low current velocities. Although such sites serve as important refugia from high flows and heavy sediment loads, certain types of invertebrates can be abundant in them and winter growth rates of fish in off-channel ponds and swamps can be considerably greater than those overwintering in the mainstem (Peterson 1982b, Brown and Hartman 1988). Some species that do not emigrate from headwater streams or main channel habitats to seasonally flooded wetlands and spring-fed tributaries along the valley floor instead make use of the protection afforded by woody debris accumulations along the channel margin (Bustard and Narver 1975). Perhaps at no other time of the year are riparian vegetation and floodplain interactions more important to the maintenance of productive rearing habitat in watersheds than during winter.

Watershed-Scale Patterns in Habitat

Spatial patterns of physical habitat expressed at the scale of large watersheds ($>100 \text{ km}^2$) in the coastal ecoregion are largely controlled by regional geology and geomorphology. The bedrock geology is the result of millions of years of lithologic and tectonic processes, whereas the geomorphology of individual watersheds has been heavily influenced by glaciation for at least 20,000 years. These factors combine to create unique spatial patterns of salmonid habitats for individual watersheds. For example, in the recently deglaciated South Fork of the Stillaguamish River, Washington, low gradient ($<2\%$), pool-dominated habitats tend to be located on a 1,700 year old terrace adjacent to the main river, whereas riffle-dominated streams tend to occupy slightly higher-gradient streams ($2\text{--}4\%$) incised into the older terraces (Benda et al. 1992, Beechie and Sibley 1990). Both types of stream channels are downcutting into glacial-age clay and outwash sand deposits, whereas bedrock channels in this valley are steeper and provide little habitat for anadromous salmonids.

Along a longitudinal gradient from the headwaters to the mouths of major river systems, fish communities are correlated with stream order and stream gradient (Platts 1974). Valley-wall or headwater streams, usually first- and second-order tributaries, are not accessible to anadromous salmonids and may be dominated by resident cutthroat trout and rainbow trout. When fish are absent, these tributaries remain an important part of the stream system, since they transport allochthonous nutrients such as leaf litter, sediments from the hillslope, and LWD to higher-order tributaries.

In moderate-gradient ($2\text{--}5\%$) third- to fifth-order streams, anadromous salmonids tend to dominate when there are no barriers to upstream migration. Steelhead and cutthroat trout occupy the steepest streams in this range, whereas coho salmon tend to utilize all accessible, low-gradient tributaries. Small tributaries with gradients less than 2% are usually utilized by coho salmon during the spawning and summer rearing stages. Steelhead and cutthroat trout of several age classes may coexist with juvenile coho salmon when the habitat is diverse.

Chinook salmon tend to utilize larger tributaries and main rivers that are used little by steelhead and coho salmon. Chinook spawning preferences are for larger gravels than most other salmonid species, allowing them to avoid competition for spawning space. Chinook juveniles rear in deeper and faster water than either coho or steelhead, alleviating some of the competition for rearing space and food resources.

Influence of Woody Debris on Habitat Development

Large woody debris is an important part of salmonid habitats in streams, both as a structural element (Grette 1985, Bilby 1985, Sedell et al. 1988) and as cover or refugia from high flows (Bisson et al. 1982, Murphy et al. 1985). Furthermore, LWD tends to reinforce meanders (Mason and Koon

Table 6.4. Longitudinal patterns in channel roughness, effectiveness of LWD in controlling channel morphology, and habitat complexity in an ecologically healthy watershed.

Stream Order	Channel Roughness	Effect of LWD	Habitat Complexity
1	Very high	Very high	Moderate
3	High	Very high	High
5	Moderate	High	Very high
7	Low	Low to moderate	Moderate
9	Low	Low to moderate	Moderate

1985) and trap sediment (Bilby 1979) and smaller organic debris (Naiman and Sedell 1979a, Harmon et al. 1986) in stream channels. Historically, woody debris piles covered enormous areas of small streams and large rivers. For example, a driftwood jam on the Skagit River, Washington, was reported to have been 1.2 km long and 0.4 km wide (Sedell et al. 1988). Current estimates of woody debris biomass and volume in aquatic ecosystems are extremely variable. Biomass reports range from 18 Mg/ha to 550 Mg/ha and volumes from 45 m³/ha to 1,400 m³/ha (Harmon et al. 1986).

A habitat classification scheme to describe woody debris accumulations separates the debris piles by their typical geomorphic settings; in the main channel, in a side channel, along a cut bank, on an overflow bank, at the island head, or on a gravel bar (Mason and Koon 1985). The habitat functions of LWD vary along the longitudinal gradient from headwaters to mouth (Table 6.4). In low-order, high-gradient streams LWD has a reduced function as a structural element in pool formation because the roughness of a large log is small relative to the inherent roughness of a boulder and bedrock channel. As stream order increases and gradient decreases, LWD becomes increasingly important in creating salmonid habitats. In streams where LWD spans the width of the channel, LWD becomes a dominant roughness element relative to gravel and pebble substrates. Thus, in third- to fifth-order streams, LWD is a dominant channel-forming feature.

As roughness elements, LWD pieces deflect the flow of water and increase hydraulic diversity. Flow deflections create a number of pool types that serve as different habitats for juvenile salmonids in summer (Bisson et al. 1982). When LWD pieces are too small or located such that they do not create pools, they create local hydraulic diversity (i.e. localized low-velocity areas) that serve as refugia for juveniles at higher discharges (Murphy et al. 1985). LWD in third- to fifth-order streams also traps sediments and nutrients which often enhance the suitability of gravels for spawning and slows the transport of vital nutrients in the stream system. This also allows invertebrate communities to more fully utilize the allochthonous inputs to the stream.

Though LWD is less frequently a dominant channel-forming feature in larger rivers, it remains an important feature along the channel banks. LWD in rivers can influence meander cutoffs (Swanson and Lienkaemper 1982) and provide cover and increase invertebrate production for juvenile salmonids (Ward et al. 1982).

Additionally, in ecologically healthy watersheds, large estuaries and slough complexes historically provided significant rearing areas for salmonids. These largely have been eliminated to convert land to agricultural or residential uses (Maser et al. 1988). Much of the lower floodplain area in the Puget Lowland is now diked to contain floods, and large areas of wetlands and marshes no longer serve as habitat. These areas are critical for maintaining healthy anadromous fish populations, because the fish make physiological and metabolic adjustments to either marine or fresh waters in this transition zone.

Woody Debris Accumulations as Nodes of Ecological Organization

The functional role of large piles of debris deposited on riverbanks has received little investigation. Substantial amounts of LWD are associated with streams of old-growth Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and Sitka spruce (*Picea sitchensis*) forests. Lienkaemper and Swanson (1987) measured 92 Mg/ha to 300 Mg/ha in the wetted channel. In mid- and high-order streams substantial debris is deposited outside the channel but the mass has not been measured. These large accumulations of debris appear to provide critical nodes of biotic organization within the river-riparian corridor. By this we mean that woody debris accumulations act as key loci of habitat for small mammals and invertebrates, which in turn act as prey for larger predators. Without the woody debris accumulations, much of the biodiversity and productivity of the riparian zone would disappear.

In coastal Oregon at least 80 species of snag- or log-dependent wildlife frequent riparian forests (Cline and Phillips 1983). The importance of downed logs and standing snags for habitat complexity in forest ecosystems is well known (Raedeke 1988, Spies and Cline 1988; Franklin, this volume). Woody debris accumulations in close proximity to the channel add complexity to the habitat for terrestrial life and may be a critical resource for connecting upland and aquatic communities.

Twenty North American species of small mammals are known to use coarse woody debris for denning, feeding, and reproduction (Harmon et al. 1986). Doyle (1990) indicates that woody debris accumulations in riparian environments of montane areas provide superior habitat for several species of small mammals. In her study, several less commonly captured species of small mammals were collected only in riparian habitat. Deer mice (*Peromyscus maniculatus*) and chipmunk (*Tamias townsendii*) are often located in microhabitats that contain relatively large amounts of woody debris (Doyle

1990). Shrew (*Sorex rowbridgii*) and mole (*Neurotrichus gibbsii*) have also been found in association with decayed wood (Maguire 1983, Whitaker et al. 1979). These same woody debris accumulations may also provide unique habitat for invertebrates and decomposers (Anderson 1982, Shearer and von Bodman 1983). This is an aspect of watershed health requiring substantial investigation in the near future.

Habitat Alterations by Wildlife Communities

Wildlife communities are also sensitive indicators of ecological health at the watershed scale, provided a broad spatial and temporal perspective is taken. Wildlife affect ecological systems through feeding strategies and day-to-day activities (e.g., ponding water, burrowing). These are important control processes on the riparian forest and the stream channel which have reverberations throughout the entire ecological system. The fundamental features of the role of wildlife in ecologically healthy watersheds are related to the use of wildlife to detect broad-scale environmental change, the nature of long-term population cycles and their relation to environmental conditions, and the seasonal phenology of habitat use and migration to maximize individual fitness (e.g., connectivity).

The riparian zone provides an exceptional array of vegetative conditions that support diverse and productive wildlife communities (Thomas et al. 1979, Oakley et al. 1985). Whereas fish are usually incapable of modifying the physical environment of streams, some wildlife populations are quite capable of modifying the structure and dynamics of riparian zones (Kauffman 1988, Naiman 1988, Pastor et al. 1988). Large herbivores such as elk (*Cervus elaphus*) and deer (*Odocoileus hemionus* and *O. virginianus*) may alter the abundance of understory vegetation through browsing of herbaceous plants and by rubbing or trampling. These activities contribute to a patchy mosaic of plant communities in various successional stages, which in turn increase habitat and soil complexity (Figure 6.13).

Interactions of wildlife with riparian plants not only affect vegetative patchiness but may also alter habitat characteristics of stream channels themselves (Figure 6.13). Water quality parameters including temperature, light, nutrients, and sediment are all influenced by wildlife activities (Green and Kauffman 1989). Beaver have perhaps the most profound effects on streams and riparian habitat (Naiman et al. 1986, 1988). Beaver ponds provide suitable environments for lentic species as well as stream-dwelling forms preferring low current velocity. Beaver ponds are known to be important overwintering areas for some coastal fishes (Bisson et al. 1987). Beaver ponds also serve as important storage and processing sites for terrestrial plant materials entering the stream (Naiman and Melillo 1984), and thus play a major role in regulating nutrient availability downstream (Dahm et al. 1987). Beaver herbivory decreases tree density and basal area by as much as 43% within forage zones around beaver ponds (Johnston and Naiman 1990). Selective

FIGURE 6.13. Wildlife influence ecosystem dynamics by their foraging strategies and by physical habitat alterations. These impacts are transmitted to the riparian forest community, resulting in long-term changes to biogeochemical cycles in soils, sediment, and water. (Note. After Naiman 1988. Copyright by American Institute of Biological Science. Used by permission.)

foraging also alters tree species composition, which may affect habitat availability for other wildlife species. Because only a small fraction of the wood biomass felled by beaver is actually ingested, beaver contribute large amounts of woody debris to both riparian zones and stream channels. Flooding of alluvial terraces and valley floors by beaver dams causes long-term changes in forest stand succession, which in turn affects the location and dynamics of vegetation patches on a broad scale (Johnston and Naiman 1987).

Food Web Dynamics

Trophic processes in stream ecosystems are strongly influenced by channel morphology and the nature of riparian and upland vegetation (Vannote et al. 1980). In steep, cool headwater streams (first and second order), much of the organic matter processed by the aquatic community originates from riparian trees and is stored in stream channels by LWD (Naiman and Sedell 1979a, Cummins et al. 1982). Invertebrate communities are often dominated by detritivorous species that break down wood fragments, needles, leaves, and other debris particles into successively smaller pieces. Because small headwater streams in the coastal ecoregion are often heavily shaded and nutrient poor, aquatic plant production is limited to epilithic diatoms and a few green and blue-green algae. Large aquatic consumers are relatively rare and omnivory tends to be the rule (Anderson and Sedell 1979). Typical assemblages of large consumers in headwater Cascade Mountain streams include crayfish (*Pacifastacus leniusculus*), Pacific giant salamander (*Di-*

camptodon ensatus), sculpins (*Cottus* spp.), and coastal cutthroat trout (*Oncorhynchus clarki clarki*). Small streams draining the Coast Range usually have lower gradients, and anadromous fishes can penetrate far into watershed drainage networks. Assemblages of large consumers include, in addition to the taxa listed above, steelhead, coho salmon, sea-run cutthroat trout, lamprey (*Lampetra* spp.), and occasionally dace (*Rhinichthys* spp.). Other anadromous salmonids (chinook, chum) may be transitory residents of small coastal streams from several days to several months before migrating to the ocean.

Mid-order streams have a more even balance of allochthonous (terrestrial) and autochthonous (aquatic) sources of organic matter than headwater streams (Naiman and Sedell 1979b). A substantial fraction of the allochthonous material processed in third- to fifth-order streams is transported from headwater tributaries rather than entering laterally from riparian vegetation, although the latter source of organic matter remains important (Connors and Naiman 1984). Because much of it has already been consumed and excreted by aquatic invertebrates, fluvially transported organic matter has been reduced to fine particles, and invertebrate communities contain species that are adapted to processing this fine organic material. Mid-order stream channels are less heavily shaded than headwater streams, and periphyton production plays a greater role in community metabolism (Naiman and Sedell 1980, Gregory et al. 1987). Invertebrates specialized to consume algae are prominent members of the benthic community. In unconstrained valleys, composition of riparian vegetation along these streams also changes to a more even mixture of conifer and hardwood species. Deciduous trees contribute considerable amounts of easily decomposed and relatively nutrient-rich materials (leaves, catkins) to the streams on a seasonal basis.

In many respects, mid-order streams possess the greatest diversity of both trophic pathways and physical habitat conditions within the watershed. Pool-riffle sequences remain intact and are coupled with lateral habitat development in the form of backwaters and secondary channels on alluvial surfaces. These streams tend to support the greatest diversity of cold-water fishes, such as Salmonidae and Cottidae, and usually contain all of the large consumers found in headwater tributaries as well as species adapted to larger rivers, provided suitable temperatures exist. Salmonids typically found in third- to fifth-order streams include bull trout (*Salvelinus confluentus*; rarely in coastal streams), Dolly Varden (*S. malma*), and mountain whitefish (*Prosopium williamsoni*). Juvenile chinook salmon make greater use of these streams for rearing, and both chum and pink salmon use them to spawn. Because summer temperatures are warmer than in first- to second-order streams, mid-order streams also possess a more diverse community of minnows (*Rhinichthys* spp., *Richardsonius balteatus*, *Ptychocheilus oregonensis*, *Acrocheilus alutaceus*), and suckers (*Catostomus* spp.) than are represented in headwaters (Li et al. 1987). Included in this assemblage are species that consume algae and detritus.

Seasonal input of nutrients from the carcasses of spawned-out salmon can be an important source of nitrogen and phosphorus in these and downstream systems (Brickell and Goering 1970, Sugai and Burrell 1984), although carcasses can provide nutrients to small streams if they are retained in the channel by large woody debris (Cederholm and Peterson 1985).

In addition, riparian wildlife may benefit from nutrients transported to watersheds in the form of returning adult fish. Cederholm et al. (1989) documented the consumption of experimentally released coho salmon carcasses by 22 species of mammals and birds (51% of the total number of species observed in riparian zones) in small streams on the Olympic Peninsula, Washington. Cederholm and Peterson (1985) found that the presence of large woody debris served to hinder downstream transport of dead fish and increase carcass availability to terrestrial scavengers. Accumulations of salmon carcasses attract aggregations of scavenging birds to larger rivers (Stalmaster and Gessaman 1984). Long-term declines in the numbers of spawning salmon may result in a significant loss of seasonally abundant nutrients to some wildlife species (Cederholm et al. 1989, Spenser et al. 1991).

The trophic support of large streams (>sixth order) is dominated by autotrophic production of phytoplankton, periphyton, and rooted vascular plants, and by fine particulate organic matter transported into these larger systems from upstream sources and laterally from the floodplain (Vannote et al. 1980, Cummins et al. 1982). Although the direct input of wood and leaf litter from riparian forests is relatively unimportant compared with aquatic plant production and fluvially transported organic material, the food web of higher-order streams is still heavily dependent on resources, including nutrients, that originate from upstream areas (Naiman et al. 1987) as well as from periodic inundation of the floodplain (Pinay et al. 1990). Zooplankton and benthic detritivores are important invertebrate consumers in large streams, and fish communities reflect this shift in available food organisms. Both plankton feeders and benthic insectivores are well represented in the fishes of large rivers. Included among these are many of the thermally tolerant forms inhabiting mid-order streams as well as additional species of minnows (*Mylocheilus caurinus*, *Hybopsis crameri*, *Couesius plumbeus*) and other species that often inhabit marshes and sloughs (*Novumbra hubbsi*, *Percopsis transmontana*). Also represented among the fishes of larger streams are euryhaline species (*Acipenser* spp., *Thaleichthys pacificus*, *Gasterosteus aculeatus* [occasionally in smaller streams], several Cottidae, *Planichthys stellatus*) that inhabit brackish water ponds, the estuary, or ocean and move into rivers to feed or spawn. Introduced species (*Cyprinus carpio*, *Carassius auratus*, *Esox americanus*, *Gambusia affinis*, several Ictaluridae, many Centrarchidae, several Percidae) have become established in the lower reaches of many Pacific Northwest river basins. In general, nonnative fishes were imported from eastern North America and are associated with aquatic vegetation along the channel margin and floodplain. Some exotic species are piscivorous and in certain areas have displaced native forms from preferred

habitat, either through predation or competition (Li et al. 1987). Overall, however, introduced fishes have tended to increase species richness in large streams.

An Ecologically Healthy Watershed

In reference to the original working hypothesis—that delivery and routing of water, sediment, and woody debris are the key processes regulating the characteristics of drainage networks in the Pacific Northwest coastal ecoregion—we offer several observations. The available evidence suggests that ecologically healthy watersheds are maintained by an active natural disturbance regime operating over a range of spatial and temporal scales. Ecologically healthy watersheds are dependent on the nature of the disturbance (e.g., fire, landslides, debris torrents, channel migration) and the ability of the system to adjust to constantly changing conditions. This natural disturbance regime imparts considerable spatial heterogeneity and temporal variability to the physical components of the system. In turn, this is reflected in the life history strategies, productivity, and biodiversity of the biotic community.

This natural disturbance regime produces a dynamic equilibrium for riparian forests, habitat, water storage, water quality, animal migration, and biodiversity resulting in resilient and productive ecological systems. The net result is an ecological system, at the watershed scale, which possesses a biotic integrity strongly valued for its long-term social, economic, and ecological characteristics.

The heart of an ecologically healthy watershed is the riparian forest (Décamps and Naiman 1989, Naiman and Décamps 1990). The riparian forest is shaped by channel geomorphology, hydrologic pattern, spatial position of the channel in the drainage network, and the inherent disturbance regimes. Yet the riparian forest affects, and is affected by, habitat dynamics, water quality, and the animal community. This strongly suggests that maintenance of riparian forests in their historic abundance and in healthy ecological condition is of fundamental importance for long-term ecological and socioeconomic vitality of watersheds in the Pacific Northwest coastal ecoregion.

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MONITORING AND EVALUATION

Monitoring Guidelines: Errata

- Cover (upper right-hand corner): "Washgton" should read "Washington".
- p. viii, third line: "manaufacturing" should read "manufacturing".
- p. 6, col. 1, first line should read "can be based on ...".
- p. 12, second column, the last full sentence should read:
"However, the establishment of biological criteria for streams in the Pacific Northwest and Alaska is likely to be an extended process because of the differences among ecoregions and the need to understand the factors controlling the distribution and numbers of organisms to be used for monitoring."
- p. 59-60: The description of the expert system in Section 5.2, while generally accurate, differs slightly from Version 1.0 as being distributed by EPA. In particular, there is both a print and a nonprint version of PASSSFA, and these have different features and uses. The "what if" function could not be included in the runtime version being distributed. More detailed information on PASSSFA is contained in the user's guide dated October 1991. Both the user's guide and PASSSFA are available from U.S. EPA in Seattle (see page ii of the Guidelines for ordering instructions).
- p. 66, insert the following reference "Boynton, J.L., 1972. Managing for quality--a plan for developing water quality surveillance programs on National Forests in California. Pages 84-90 in Csallany, S.C., T.G. Mclaughlin, and W.D. Striffler (eds.), Watersheds in Transition, Amer. Water Resour. Assoc., Washington, D.C."
- p. 68: "Swanston, F.J., 1969." should be "Swanston, D.N., 1969."
- p. 68: "Swanston, F.J., R.J. Janda, ..." should be "Swanson, F.J., R.J. Janda, ..."
- p. 122, Figure 8B: The primary axis of the large rock should be labelled as D_m rather than D_f .
- p. 154, second column, fourth full paragraph: reference in item 2 should be to Section 5.6 rather than Section 4.6.
- p. 154, second column, last line: "biolo-gical" should be written "biological".

More Monitoring Literature

- Meehan, W.R. (ed.), 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication No. 19, 5410 Grosvenor Lane, Suite 110, Bethesda, MD 20814. 751 p. Excellent and extensive review of literature on salmonids, their habitat requirements, the effects of natural processes, and the impacts of management activities.
- Stednick, J.D., 1991. Wildland water quality sampling and analysis. Academic Press, Inc., 217 p. Nice and relatively concise review of sampling procedures, methods, and data analysis for the most common physical and chemical constituents of water.
- Helsel, D.R., and R.M. Hirsch, 1992. Statistical methods in water resources. Elsevier Publishers, New York. 522 p. An excellent book with good coverage of nonparametric techniques by experienced experts, but even the paperback version is around \$80!
- Rosenberg, D.M., and V.H. Resh, 1992. Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, N.Y. Everything you always wanted to know about using macroinvertebrates for monitoring. 478 p.
- Peters, N.E., and D.E. Walling, 1991. Sediment and stream water quality in a changing environment. Int. Assoc. of Hydrol. Sci. Publ. No. 203, 2000 Florida Ave. NW, Washington D.C. 374 p. An interesting collection of papers from the IUGG in Vienna.
- Conover, W.L., 1980. Practical nonparametric statistics, second edition. John Wiley and Sons, New York, 493 p. I missed this one, but it has been recommended. Nonparametric statistics are increasingly the method of choice for water quality data (see Helsel and Hirsch).
- Chambers, J.M., W.S. Cleveland, B. Kleiner, and P.A. Tukey, 1983. Graphical methods for data analysis. Duxbury Press, Boston, MA. 395 p. Another book not cited. This was the source of some of the figures in my presentation.
- Ward, R.C., J.C. Loftis, and G.B. McBride, 1990. Design of water quality monitoring systems. Van Nostrand Reinhold, New York. 231 p. Another omission from the *Guidelines* which might be of use.
- IAHS, 1986. Monitoring to detect changes in water quality series (Proceedings of the Bucharest Symposium). Int. Assoc. of Hydrol. Sci., 2000 Florida Ave. NW, Wash. D.C., 2009. Some nice articles.
- Stewart-Oaten, A., W.M. Murdoch, and K.R. Parker, 1986. Environmental impact assessment: "pseudoreplication" in time? *Ecology* 67:929-940.
- Milliken and Johnson, The analysis of messy data. Van Nostrand Reinhold, about \$40 in paperback. Been repeatedly recommended.

- Montgomery, D.R., and J.M. Buffington, 1993. Channel classification, prediction of channel response, and assessment of channel condition. Report TFW-SH10-93-002, Washington Dept. of Natural Resources, Olympia, WA. An excellent review of and proposed system for classifying stream channels.
- Rosgen, D.L., 1994. A classification of natural rivers. *Catena* 22:169-199. Latest version of a widely used stream classification system.
- Hawkins, C.P., and 10 others, 1993. A hierarchical approach to classifying stream habitat features. *Fisheries* 18(6):3-11. Should become the standard for classifying habitat features.
- Edwards, T.K., and G.D. Glysson, 1988. Field methods for measurement of fluvial sediment. U.S. Geological Survey Open-File Report 86-531, Reston, Virginia. 118 pp. The latest USGS manual on how to measure sediment in streams.
- Hadley, R.F., and T. Mizuyama (eds.), 1993. Sediment problems: strategies for monitoring, prediction, and control. Int. Assoc. Hydro. Sci. Publ. no. 217. Another IAHS proceedings.
- Olive, L., and B. Loughran (eds.), 1994. Variability in stream erosion and sediment transport. Int. Assoc. Hydro. Sci. Another in the red book series of proceedings.
- MacDonald, L.H., 1994. Developing a monitoring project. *J. of Soil and Water Cons.* 49(3):221-227. An updated version of the procedure outlined in the EPA *Guidelines*.
- MacDonald, L.H., 1993. Sediment monitoring: reality and hope. In EPA/USFS Technical Workshop on Sediments, Terrene Institute (202 833-8317), Washington, D.C. pp. 81-88. A preliminary piece which has subsequently been the topic of work by a post-doc; confirms all my biases. Entire proceedings available for \$10; a good deal!
- MacDonald, L.H., and A. Smart, 1993. Beyond the *Guidelines*: practical lessons in monitoring. *Environ. Monit. and Assessment* 26: 203-218. This summarizes fourteen additional points which were either omitted or underplayed in the *Guidelines*; most of the ideas were derived from the series of workshops which followed the publication of the *Guidelines*.

Figure 4. Development of a monitoring project.

Variability Sources and Scales

Temporal

Interannual

Seasonal

Between storms or runoff events

Within storms or runoff events

Short-term variability

Spatial

Between ecoregions

Within ecoregions

Between basins

Between stream types

Between reaches

Between geomorphic (habitat) units or cross-sections

Within geomorphic units or cross-sections (bug or sampling scale)

Measurement uncertainty

Sampler bias

Analytic uncertainty

Management effects

Minimum Detectable Relative Change vs. Sample Size

Sample Size Per Group for a Two-Sample t-Test
 5% Level of Significance, 80% Power to Detect the Change, for
 Various Values of the Coefficient of Variation (cv)
 (figure courtesy of L. Conquest, Univ. of Wash.)

Elements of a QAPP (1991)

Project Management

- Title and approval sheet
- Table of contents
- Distribution list
- Project/task organization
- Problem definition/background
- Project/task description
- Data quality objectives for measurement data
- Project narrative
- Special training requirements/certification
- Documentation and records

Measurement/Data Acquisition

- Sampling process design (experimental design)
- Sampling methods requirements
- Sample handling and custody requirements
- Analytical methods requirements
- Quality control requirements
- Instrument/equipment testing, inspection, and maintenance requirements
- Instrument calibration and frequency
- Inspection/acceptance requirements for supplies and consumables
- Data acquisition requirements (non-direct measurements)
- Data quality management

Assessment/Oversight

- Assessments and response actions
- Reports to management

Data Validation and Usability

- Data review, validation, and verification requirements
- Validation and verification methods
- Reconciliation with data quality objectives

Source: EPA requirements for quality assurance project plans for environmental data operators, EPA QA/R-5, U.S. EPA, Quality Assurance Management Staff, Washington, D.C. 1991?

Order Form For...

Expert System for Selecting Monitoring Parameters

A PC-based, expert system designer to facilitate the parameter selection process outlined in the EPA document entitled *"Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska,"* by L. MacDonald, A. Smart and R. Wissmar (1991).

Name:		
Title:		
Organization:		
Address:		
FTS Phone No.:	Commercial Phone No.:	Electronic Address:

- ☐ I would like to obtain a copy of this Expert System. I have enclosed a labelled, formatted diskette. Diskettes must be MS DOS formatted, either 3.5" or 5.25", and have at least 225K of available space.
- ☐ I would also like to receive _____ copies of the *"Land Manager's Guide to Water Quality Monitoring"*.
- ☐ I would like to receive _____ more copies of the *"Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific NW and Alaska"*.
- ☐ I would like to have my name included on a Region 10 EPA mailing list for distribution of other information related to nonpoint source water quality management.

Please label your computer diskette with your name and complete mailing address in order to insure identification. Please include a self-addressed diskette mailer in order to insure return mail.

EPA will not provide diskettes.

Please mail this form, your labeled, formatted diskette and a self-addressed diskette mailer to:

U. S. Environmental Protection Agency, Region 10
Water Division, Mail Stop WD-139
1200 Sixth Avenue
Seattle, Washington 98101

ATTN: Rick Edwards

Any comments regarding the Monitoring Guidelines, companion material, and suggested follow-up?:

More Information: For additional information about this workshop, contact Rick Edwards, U.S. Environmental Protection Agency, Region 10, Mail Stop WD-139, Seattle, Washington 98101 (206/553-8511; FTS 399-8511; USFS DG R06F05A).

Components of a Monitoring Report

(adapted from Mike Amaranthus, Siskiyou N.F., and Carol Rosenblum Perry, freelance writer-editor, Corvallis, OR)

The writing and presentation of monitoring reports are an essential component of any monitoring project. If you don't analyse, document, and disseminate your results, then the monitoring project is unlikely to result in improved resource management. A well-written and well-presented document generally is much more persuasive than verbal statements.

A well-prepared monitoring report also will give your work more credibility and visibility within your organization and with the public. This in turn can lead to more resources being made available for monitoring; people respond to a professional approach and demonstrated commitment.

Although the content and organization of your monitoring report can vary, the approach described below is a useful place to start. Remember that if you don't organize the data and complete a monitoring report, the monitoring project could be considered a failure. This may reflect poorly on you, and it isn't conducive to good resource management. The choice is yours.

1. TITLE

The title of the report should clearly indicate the scope and duration of the monitoring project. Underneath the title should be the name(s) of the author(s). The title and full mailing address of at least the first author should be provided as a courtesy to the readers. A phone number is an additional but optional courtesy.

2. ABSTRACT OR EXECUTIVE SUMMARY

This prose section should summarize the "meat" of the report, briefly telling the reader what you did, how you did it, the primary results, and the implications of those results. Keep it as objective and as factual as possible. Usually it is best to write this after you've completed the rest of the report, as only then will you have the clarity and understanding to do a good job on this section.

Remember not to include abbreviations or other jargon which may not be known to the reader. This section should stand on its own, as many readers will read only this section. This section does not include tables or figures, but should specify the most important numerical results.

3. INTRODUCTION

The introduction is critical, as it: (1) sets the stage for all that follows, and (2) either hooks or loses the reader. It is all too easy for an introduction to be rambling and include a variety of extraneous information. The first paragraph needs to come to the point--why are you monitoring some particular variable(s) in the selected locations. You

then need to provide the context of your study--what has been done in the past, what is known about the system being monitored, and what is the technical basis for your study. This should not be an exhaustive review, but a concise summary.

The introduction should then clearly list the objectives of the study. These objectives should be both concise and precise, and they should stand out. The logic and structure developed here should be reflected in all the other sections of the report, as the reader knows what to expect and is ready for it.

Often the introduction you write at the beginning will not fit the report once it's finished, so you may need to go back and revise the introduction to fit the results and discussion. Footnotes generally should be avoided here and in the rest of the report because they can distract the reader and break up the flow of the report.

4. METHODS

The methods section should describe your procedure in sufficient detail so that the reader can evaluate your work and even duplicate it if so desired. Standard procedures can be referenced, but non-standard or modified procedures will have to be described in sufficient detail so that the reader can understand how the data were obtained. Typically you should provide a map showing your sampling sites, explain your experimental design, describe your equipment and materials, and specify your analysis procedures (both laboratory and statistical). The amount of detail is impossible to specify, as it depends upon the purpose and expected distribution of your report. Remember, however, that you may not see the project through, so you need to provide sufficient guidance to allow someone else to pick it up and carry on, or to conduct a comparable study somewhere else.

Try to establish an order in the methods which you then follow in the subsequent sections of the report. If you're describing study sites, give the characteristics in the same order so that it is easier to make comparisons. Better yet, put together a table so that similarities and differences are immediately apparent, and don't have to be extracted from long blocks of text. Figures are useful ways to convey a lot of information and break the report into more visually appealing blocks.

The methods section should be as terse and businesslike as you can make it without sacrificing key information.

5. RESULTS

This section presents the key results--the facts, and nothing but the facts. The section is held together by prose, while the actual results should be presented in graphs and figures. Tables are one way to present a lot of data, but most readers aren't willing to spend a lot of time looking at a long table in order to extract significant trends. Help the reader out! Full data sets may be better off in an appendix.

In general, your figures should show the actual data points, and not just the means or calculated regression line. Be scientifically responsible and let readers see the data so that they can evaluate it and possibly draw their own conclusions. The discussion section is where you make your case, not here in the results section.

Remember to consecutively number each figure and table according to the order in which they are referenced in the text, and that each figure or table must be referenced in the text. Don't spell out in excruciatingly detailed prose what is evident from the figure, but you should point out important numbers and trends. If you don't have data to directly support a statement, then that statement probably doesn't belong in this section. Try to follow the same logic and structure that you established in the previous sections.

6. DISCUSSION

The discussion section is where you interpret your results and draw your conclusions. The structure of this section should parallel the structure established in previous sections, and there should be a logical progression from the *Introduction* through the *Methods* and *Results* to the *Discussion*. Some aspects of the data which should be explored in this section include physical explanations for the data, the uncertainty associated with the data and the results, contradictions or inconsistencies in the data, and the implications of the data with regard to the problem(s) being addressed.

Begin with your firm results, and then move on to extrapolation and speculation. Be clear as to which statements are relatively solid (based on the data), and which statements are more speculative. Reference to other studies can help bolster your extrapolations and speculations. This section is your opportunity to present your story and indicate its significance, but be aware that unwarranted extrapolation and conclusions can destroy the credibility of the entire report.

Finish off the section with your conclusions, recommendations, and a description of what is supposed to happen next. There should be closure with the objectives as stated in the introduction, and this is why it is often necessary to go back and make sure the introduction properly starts the reader on this path towards the results and discussion.

7. CONCLUSIONS

People differ over the need to have a separate section for the conclusions. In a relatively brief report the reader can readily extract the conclusions from the results and discussion. As a report becomes longer and more complex, fewer people will read the full report and it becomes more difficult for the casual reader to determine the "bottom line." In this case it is your obligation as a communicator to again help out the reader and summarize your conclusions

and recommendations in a separate section. Interested readers can then go into the body of the report to see how you came to a particular conclusion or recommendation.

8. ACKNOWLEDGMENTS

Most monitoring projects involve a variety of people, and this is your chance to give credit where credit is due. If people can see that their efforts helped produce a usable and tangible result, they are more likely to be interested and willing participants in the future. Having interested and willing participants will then greatly improve the quality and reliability of your future monitoring efforts. Key people may include technicians, managers, and peer reviewers. Recognize these contributions!

8. REFERENCES

This is where you list all the source material cited in your report, including published literature, previous monitoring reports, unpublished documents, personal communication, and computer software. "Literature cited" is a more restrictive term, and for most monitoring reports "references" is more appropriate.

Use the author-date system--e.g., (Smith, 1992) rather than a numbering system. The advantages of author-date include: (1) you don't have to renumber your citations each time you add or delete a reference, and (2) many readers can readily identify a reference from the author and date. A numeric system forces the reader to keep flipping from the text to the references to see exactly who you are referencing each time.

Text lifted verbatim from a source should be enclosed in quotation marks. Such quotes should be referenced not only by author and date, but also by page number. Paraphrased text requires a reference but need not be enclosed in quotation marks; information considered general knowledge and not subject to argument can be used without an accompanying citation.

Be sure your citation is sufficiently complete to allow the reader to track down and obtain any reference. Referencing a personal communication by name only is not adequate; include the person's organization so that the reader knows exactly whom you mean and could contact that person if desired. Your attention to detail in the references is another clue as to the type of work you do; a sloppy and incomplete reference list suggests that your monitoring efforts are sloppy and unreliable. Credibility is a resource which generally takes a great deal of time to build up but can be rapidly destroyed. To be effective a monitoring report must be credible, useful, and clear.

Happy monitoring!

BEYOND THE GUIDELINES: PRACTICAL LESSONS FOR MONITORING

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Abstract. A series of workshops have provided extensive feedback on a recently published manual, *Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska (Guidelines)* (MacDonald *et al.*, 1991). These workshops and other discussions have led to the identification of fourteen additional 'lessons' for monitoring. These lessons are concepts which either were not incorporated into the *Guidelines*, were not sufficiently emphasized, or which are needed to put the *Guidelines* in context. The topics include: monitoring as a continuum; defining objectives and hypotheses; peer review; uncertainty and risk; upslope vs. instream monitoring; photo sequences; scale considerations; data storage, data interpretation, and data base management; 'activities monitoring'; and personal commitment as a critical component in monitoring projects. Many of these lessons might appear self-evident, but our experience indicates that they are often ignored. Like the *Guidelines*, these lessons are widely applicable and should be explicitly recognized when formulating and conducting monitoring projects.

1. Introduction

In September 1991 Region 10 of the U.S. Environmental Protection Agency (EPA) and the Center for Streamside Studies (University of Washington) published a 166-page document *Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska (Guidelines)* (MacDonald *et al.*, 1991). Although the specific objective of this document was to provide guidance for monitoring the effects of forest management activities on streams, much of the information and many of the procedures are more broadly applicable. This, plus the relative dearth of other guidance-type literature, resulted in nearly 6000 copies of the *Guidelines* being distributed within five months. A second printing of 6000 copies was undertaken in spring 1992.

After releasing the *Guidelines* EPA convened 1½-day workshops in Alaska, Idaho, Washington, and Oregon. The primary purpose of these workshops was to show resource specialists and resource managers how the *Guidelines* could help them design and execute monitoring projects. In early 1992 a fifth workshop was organized by the U.S. Forest Service in Missoula, Montana.

Approximately 550 people attended these workshops. Each workshop included lectures, individual exercises, case studies, and group exercises. These different components of the workshops provided numerous opportunities for questions and

feedback on the *Guidelines*; in effect the workshops served as a non-structured validation process. This review by the target audience was quite different from the reviews provided by members of the Technical Advisory Committee during the preparation of the *Guidelines*, and the final review of the draft document by EPA and selected experts.

The workshops, other discussions, and our own subsequent work have led to the identification of a number of practical points essential to the development of successful monitoring projects. Many of these are included, or at least alluded to, in the *Guidelines*, but most of them were not sufficiently explicit or adequately emphasized given the needs of the target audience.

As many readers may not be familiar with the *Guidelines*, this paper first provides a brief overview of the *Guidelines* and accompanying expert system. This is followed by the fourteen practical lessons for monitoring which have been drawn from the workshops and other feedback on the *Guidelines*. It should be emphasized that these practical lessons are more generally applicable, and are not tied to specific geographic areas, management activities, or regulatory structure.

2. Overview of the Guidelines

2.1. SCOPE

The purpose of the *Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska* is to assist people in designing water quality monitoring projects and selecting monitoring parameters. The term 'water quality' is used in the broadest possible sense, as the *Guidelines* consider not only the traditional physical and chemical constituents, but also those parameters which directly affect designated uses such as coldwater fisheries and recreation. A total of 29 different parameters were considered (Table I).

The *Guidelines* focus on forestry, but other land uses – such as mining, grazing, and recreation – are incorporated. This was necessary because the water quality at any given point integrates all land use effects and natural processes upstream of that location, and most forested catchments have a mixture of management activities. Similarly, the *Guidelines* emphasize the monitoring of streams and adjacent riparian areas, but recognize that the need to protect downstream lakes, reservoirs, and other water bodies may affect the design of a monitoring project and the selection of monitoring parameters.

2.2. PART I

Part I of the *Guidelines* sets out a procedure for designing a monitoring project and selecting the parameters to be measured. The first chapter discusses both the legal background for water quality monitoring in the U.S. and the rationale for monitoring. The varying objectives of monitoring projects beget different types of monitoring. Seven types of monitoring are defined in the *Guidelines*, and these are trend, baseline, implementation, effectiveness, project, compliance, and validation.

TABLE I
List of Monitoring Parameters.

Physical and chemical constituents	
Temperature	
pH	
Conductivity	
Dissolved oxygen	
Nutrients	
Nitrogen	
Phosphorus	
Herbicides and pesticides	
Changes in flow	
Size of peak flows	
Low flows	
Annual water yield	
Sediment	
Suspended sediment	
Turbidity	
Bedload	
Channel characteristics	
Channel cross-section	
Channel width/width-depth ratio	
Pool parameters	
Habitat units	
Bed material	
Particle-size distribution	
Embeddedness	
Surface vs. subsurface particle-size distribution	
Large woody debris	
Bank stability	
Riparian characteristics	
Riparian canopy opening	
Riparian vegetation	
Aquatic organisms	
Bacteria	
Aquatic flora	
Macroinvertebrates	
Fish	

The types of monitoring are distinguished largely by the purpose of the monitoring and the use of the data, rather than the specific data collected.

The first part of Chapter 2 shows how monitoring is essential to the effective regulation of water quality, and then sets out a step-by-step procedure for developing a monitoring project. These steps include: (1) define the general objectives and budgetary constraints; (2) collect existing information; (3) identify the specific objectives; (4) define monitoring parameters, sampling frequency, sampling location(s), and analytic procedures; (5) check that the proposed project will meet the specific monitoring objectives within the general budgetary constraints; (6) initiate the project on a pilot basis; (7) analyse the data and modify the project as necessary; (8) proceed with the revised project; and (9) periodic preparation of reports and recommendations (Figure 1). Feedback loops are essential to both the legal process and the development of a monitoring project, and some of the most important feedback loops are shown in Figure 1.

The statistical aspects of water quality monitoring are discussed in Chapter 3. Specific topics include statistical design, principles of sampling, and the principles of statistical testing. The trade-offs between sample size, variability, level of significance, and power are explained, and these four factors are combined to demonstrate the concept of Minimum Detectable Effect (MDE). Specific statistical procedures are not reviewed, but key references are provided.

2.2.1. Parameter selection

Chapter 4 lays out the process for selecting the water quality parameters to be measured. In the U.S., the legal basis for regulating water quality is largely built on the concept of maintaining and enhancing the 'designated beneficial uses' of water (EPA, 1988). Designated beneficial uses typically include domestic water supply, hydroelectric generation, coldwater fisheries, recreation, etc. Each state is required to designate the beneficial uses for each water body within its boundaries. Water quality standards are a combination of the designated beneficial use and the criteria necessary to protect that use (EPA, 1988).

Two of the basic problems in monitoring the effects of forestry activities on streams are: (1) sources are diffuse (i.e., nonpoint), and (2) forestry affects very few of the approximately 100 water quality criteria recommended by EPA (EPA, 1986). The only EPA-recommended criteria which forest management activities are likely to affect are turbidity, suspended solids, color, dissolved oxygen, and temperature. At least four of these five criteria are direct or indirect measures of sediment, but the direct determination of change in turbidity or suspended solids can be a very difficult task (Walling and Webb, 1981; MacDonald, 1992). This suggests a need for alternative measures of water quality, and this is largely why the list of parameters considered in the *Guidelines* is so extensive.

Alternatives to sediment monitoring include measures of stream channel morphology and aquatic organisms. These may offer considerable promise for monitoring (EPA, 1989, 1990; Cullen, 1991), but the data to establish specific criteria is

largely lacking (MacDonald *et al.*, 1991). Some advantages of monitoring channel morphology or aquatic organisms include a lower frequency of sampling, direct ties to a sensitive designated use (coldwater fisheries), and a relatively high sensitivity to forest management (MacDonald *et al.*, 1991).

The selection of monitoring parameters is presented as a function of: (1) the management activities taking place, (2) the designated beneficial uses, (3) whether there is safe access to the stream during high flow events, and (4) the costs associated with monitoring a particular parameter. Cost is further broken down into the frequency of sampling, the time needed to collect the sample or data, equipment costs, and analysis costs.

The 29 parameters evaluated in the *Guidelines* are qualitatively ranked with regard to each of these seven factors. The first table in Chapter 4 qualitatively ranks how each parameter affects each designated use. The next table indicates the effects of nine different management activities on each parameter. A third table evaluates the relative cost of each parameter in terms of typical sampling frequency, time necessary to collect a sample or field data, equipment costs, analysis costs, and the flow conditions which must be sampled. All of this information is then qualitatively combined into an overall evaluation of the usefulness of each parameter to monitor the effects of a specific management activity. By necessity these rankings are gross averages over a very large and diverse geographic area, and will not apply in all cases.

2.2.2. Expert System

The information contained in these tables has been incorporated into a PC-based expert system called PASSSFA (Parameter Selection System for Streams in Forested Areas). Basically this is an interactive, computerized version of the tables and parameter selection process presented in the *Guidelines*. After loading the program the user identifies the management activities taking place, the designated beneficial uses of concern, the flow conditions which can be sampled, and the cost constraints in terms of sampling time, equipment costs, and analysis costs. From this information the expert system recommends certain monitoring parameters. Although each of the recommended monitoring parameters has an associated confidence factor, the final list of recommended parameters must then be evaluated on the basis of existing data, local conditions, and professional judgement. Figure 2 illustrates the parameter selection process set out in the *Guidelines* and applied in PASSSFA.

2.2.3. Other Considerations in Parameter Selection

The final part of Chapter 4 briefly reviews how differences in the physical environment might affect the selection of monitoring parameters. Climate, land form, geology, and soils all alter the effect of a particular management activity and the sensitivity of a stream system to human disturbance. Such considerations must be taken into account when developing a monitoring project. The tremendous diversity of landscapes and streams within the Pacific Northwest and Alaska meant that

Fig. 1. Development of a monitoring project.

the *Guidelines* were not able to review these issues in detail.

Part I concludes with a review of the interactions among the 29 different parameters considered in the *Guidelines*. A matrix ranks the level of the interaction between all parameter pairs, and this information can help identify the extent to which different parameters provide independent, complementary, or overlapping information.

2.3. PART II

The larger half of the *Guidelines* consists of a technical review of all 29 monitoring parameters. The review of each parameter is divided into seven sub-sections, and these are: (1) definition, (2) relation to designated uses (i.e., how does that parameter affect the different designated uses), (3) effects of management activities, (4) measurement concepts, (5) standards, (6) current uses, and (7) an overall assessment of that parameter. The intent is to provide a summary of the relevant literature rather than a comprehensive review or detailed field manual. The numerous references allow rapid access to additional information, including previous studies, field measurement procedures, and analytic techniques.

In summary, the *Guidelines* provide a structured process for developing a monitoring project and selecting the parameters to be monitored. The basic process is applicable to much more than monitoring the effects of forestry on streams, and the wide distribution of the *Guidelines* confirms this view. However, the *Guidelines* are not a cookbook, and local knowledge and professional judgement must be applied when formulating a specific project. As one moves further away from forestry and the Pacific Northwest, the qualitative evaluations become less applicable, and there must be a correspondingly greater reliance on local knowledge and experience.

The *Guidelines* also provide a useful compilation of existing knowledge on the 29 parameters listed in Table I. Although this review concentrates on the Pacific Northwest and Alaska, the underlying principles governing stream behavior and aquatic ecosystems are consistent, and so again much of this information is more broadly applicable.

Feedback from the workshops and other users have largely validated the material presented in the *Guidelines* while providing additional insight into the problems of designing and executing monitoring projects. The following section summarizes the additional practical lessons which are worthy of greater emphasis.

3. Practical Lessons for Monitoring

The following practical lesson are listed because they will facilitate the successful design and execution of monitoring projects. Some of these are mentioned in the *Guidelines*, but deserve greater emphasis, while others were not explicitly included. Many of these points initially might seem self-evident or even trivial, but our experience is that these issues typically are given no more than tacit recognition. In many cases a monitoring project is well underway, and then one or more of these

Fig. 2. Parameter selection process.

Fig. 3. Continuum of monitoring.

issues emerges as a problem which was not fully resolved in the planning phase. Early recognition and resolution of these practical points should greatly enhance the efficiency of monitoring projects and their prospects for success.

3.1. CONTINUUM OF MONITORING

The *Guidelines* focus on the design of relatively structured monitoring projects which gather quantitative data. In many cases, however, informal observations, particularly during storm events, can provide much of the information needed to guide and evaluate management activities. We should think of monitoring as a continuum, for monitoring projects can range from informal walking in the rain to carefully replicated, quantitative studies (Figure 3). Either of these approaches can be valid, depending on the objectives and context of the monitoring project. Informal walking in the rain – open-eye and open-mind monitoring – is limited in its applications by its subjective nature, but it can be extremely cost-effective. The more formal studies at the opposite end of the continuum are necessary to provide more detailed and defensible results. The learning benefits associated with an occasional walk in the rain and the direct observation of watershed processes should not be underestimated, as these can greatly facilitate the design of more rigorous monitoring projects.

3.2. UNDERSTANDING PHYSICAL AND BIOLOGICAL PROCESSES

A good monitoring plan is based on an understanding of the physical and biological processes operating within the catchment. To maximize efficiency, a monitoring

plan must identify those parameters which are: (1) sensitive to the management activities of concern; (2) directly related to the designated beneficial use(s); and (3) capable of indicating management impacts (i.e., unlikely to be overwhelmed by confounding factors or the natural variability in time and space). The choice of sampling locations and the timing of the measurements must be guided by an understanding of the system in which the monitoring takes place. For example, it probably makes little sense to monitor channel morphology in a bedrock channel, or to use sport fish populations as indicators of adverse management impacts in areas subject to heavy fishing pressure. Suspended sediment data without accompanying discharge measurements are of little use. Monitoring intergravel dissolved oxygen may not be appropriate if fish populations are limited by rearing habitat rather than spawning habitat or food supply. Often we don't think through these issues, or else we make presumptions about stream ecology and physical processes which may not necessarily be valid. Any failure in understanding the system of concern reduces the likelihood that a monitoring project will achieve its objectives.

3.3. MONITORING IN THE STREAM CHANNEL MAY HAVE A LOW DEGREE OF SENSITIVITY

By definition, measurements in a stream channel integrate everything upslope of that point. Thus measurements in the channel often are a diluted version of what is occurring either higher up in the channel network, or on the adjacent sideslopes (MacDonald, 1989). From a practical point of view it's usually easier to determine the effects of roads on water quality by directly monitoring road drainage, rather than by monitoring water quality at a downstream location. Legally, sediment generated from roads may not be a concern until this sediment enters a designated water body and reduces water quality or impairs a designated beneficial use. For this reason there must be a clear physical linkage between the upslope or upstream measurements and downstream water quality.

One can argue that monitoring should stem from a sense of stewardship and a desire to minimize management impacts, and not just from the need to satisfy legal requirements. This approach supports the use of upslope and upstream measurements, and suggests less of a need to link these observations to downstream conditions. While the *Guidelines* recognized that monitoring within the stream channel may have a lower sensitivity than on-site monitoring, the huge number of potential monitoring techniques meant that on-site and upslope monitoring procedures were not explicitly discussed. A focus on upslope controls also ignores much of the legal basis for regulating water quality in the U.S.

3.4. DEFINITION OF OBJECTIVES

The conceptual process for developing a monitoring project was described earlier (Figure 1). Not every project will proceed exactly through these steps as presented in Figure 1. Most projects will loop back through certain steps, but the timing and precise order of these iterations will vary from project to project. Nevertheless,

all the feedback to date has indicated that each of the steps shown in Figure 1 is essential. The application of Murphy's Law to monitoring means that any step that is skipped will inevitably generate problems later on.

It is the fourth step – identifying the specific objectives – which has been repeatedly identified as the most important and the most difficult. At each workshop small groups were convened to develop and review monitoring projects; about half the groups realized part way through that they had not clearly specified their objectives, and had to return to this step. Once the objectives were clearly stated, the groups typically found that the rest of the monitoring project would fall into place.

For example, a group might start with the objective of evaluating the effects of forest harvest on coldwater fish in some particular area. This type of general objective provides very limited guidance for setting up a monitoring project. However, if the objective is focused by identifying: (1) the limiting factor(s) for a particular fish species in a particular area, and (2) how management activities might affect that factor, then the objective prescribes the monitoring project. In this case, the specific objective might be to determine how forest harvest in the riparian zone is affecting the recruitment of large woody debris into the stream channel in low-order streams, as this is controlling the amount of rearing habitat for a specific fish species in a particular type of stream in a certain catchment, and the amount of rearing habitat is limiting the fish population of primary concern. This formulation of the objectives then leads directly to both the parameters to be monitored (e.g., large woody debris and riparian vegetation) and the sampling locations (e.g., second-order streams with extensive forest harvest). Definition of the monitoring parameters and sampling locations in turn define the frequency of monitoring (e.g., once a year). By defining the specific objectives people are forced to sharpen their thinking and resolve a variety of hidden conflicts. The recognition and resolution of hidden issues probably explains why the definition of the specific objectives is the most difficult step.

3.5. DEFINITION OF HYPOTHESES

Another means to focus the objectives and sharpen the design of a monitoring project is to explicitly define the hypotheses to be evaluated. This is an essential step if quantitative data are to be collected and statistically analysed. Defining the hypotheses *a priori* helps ensure that the experimental units and sample populations are clearly defined, and that there is sufficient replication to allow statistical testing. Because this is a challenging step, it is often ignored even though the objectives indicate that quantitative results are expected.

3.6. PEER REVIEW

A major shortcoming of Figure 1 is that it does not explicitly recognize the need for, and benefits of, peer review. A monitoring plan developed by a single individual will reflect that person's experience and perspective. Asking one's peers to review

a monitoring plan uncovers hidden assumptions and allows for the input of other viewpoints. This will greatly enhance the chances of success, and help build an interested constituency for the proposed project.

Formal or informal peer review also should be applied during data analysis, report writing, and the formulation of recommendations. Again an independent observer can add a perspective and insight that will help ensure that the data are properly and fully analysed, the conclusions are justified, and the recommendations are sound. Peer review does require more time, and constructive criticism is often difficult to accept, but after a few rounds nearly everybody realizes that unbiased peer review is a highly beneficial process.

3.7. DATA STORAGE AND DATA BASE MANAGEMENT

Another limitation of Figure 1 and the *Guidelines* is that data management needs are not explicitly addressed. Often monitoring projects are initiated without recognizing the amount of data that will be generated. For example, a project that measures eight common parameters (e.g., discharge, pH, conductivity, nitrate-nitrogen, total nitrogen, total coliform, total phosphorus, and suspended sediment) at ten locations on a weekly basis will yield over four thousand pieces of data in a single year. Organizing and analyzing such large data sets is not a trivial task, and to this must be added the error-checking, replicate sampling, and replicate analyses which are necessary for quality assurance and quality control. The rapid increase in computer hardware and software capabilities is facilitating these aspects of monitoring, but data management and analysis procedures should be explicitly addressed during the design phase.

3.8. UNCERTAINTY AND RISK

Monitoring projects take place in complex and changing environments, and that limits the extent to which the results can be predictable or definitive. In many parts of the Pacific Northwest, for example, low-order stream channels are subject to highly disruptive events such as debris flows and the breaking of debris dams (e.g., Swanson *et al.*, 1987; Benda, 1990). The occurrence of these periodic natural events may overwhelm the more frequent but smaller changes due to management activities. Lisle (1982) found that stream channels in Northwestern California were still responding to the 1964 flood fifteen years later. The capability to detect man-induced change depends largely on the magnitude of the management impact relative to the natural variability. In many cases we don't have long-term data to evaluate the natural variability, nor can we predict the occurrence of future events.

This means that monitoring always will be operating in the realm of risk and uncertainty. A specific set of management activities can have relatively minor effects under one set of climatic events, and much more adverse effects under a different set of climatic events. Similarly, the ability of a monitoring project to detect management impacts depends on: (1) the natural events occurring during the monitoring period; (2) the synergism between natural events and management

effects; and (3) the extent to which the monitoring period is representative of longer-term conditions. Often there is little which can be done to resolve these issues, but it is important to recognize them up front and indicate to managers the uncertainty and risks associated with both monitoring projects and management activities.

3.9. DATA INTERPRETATION

Another aspect of uncertainty is the limited extent to which any set of monitoring data provides a true and complete representation of the system being monitored. We can't measure everything everywhere, yet monitoring projects are trying to assess condition over time and identify the cause(s) of any observed change. The limited budget of most monitoring projects and the complexity of natural systems means that inferences are being drawn from limited data. Add in the problems of missing data, lost samples, and other applications of Murphy's Law, and this suggests a need for overlapping or complementary data.

Often people presume that measuring a single parameter will provide the necessary information to both identify change and to link that change to management activities. There is a natural desire to simplify the behavior of stream systems, and to look for magic bullets or tools. The reality is that such tools don't and almost certainly won't exist. Hence monitoring projects have to make an explicit trade-off between ambiguity and uncertainty on the one hand, and the costs of collecting more data in order to achieve a better and less ambiguous result. To a large extent this choice is a function of the objectives and needs of the monitoring project.

3.10. PHOTO SEQUENCES

One useful monitoring technique not discussed in the *Guidelines* is photo sequences. A series of photos taken over time at the same location can help document changes which may not be apparent from regular visits to the site. Even if these photos are not used directly as a monitoring technique, a photo sequence can be an extremely effective communication tool (e.g., Clifton, 1989; Megahan *et al.*, 1992).

3.11. SCALE CONSIDERATIONS

A critical question in developing a monitoring project is the selection of monitoring locations. For non-reactive physical and chemical constituents there is greater dilution with increasing watershed size, and this diminishes the magnitude of change resulting from upstream activities. This principle is widely recognized, yet the concept is rarely applied when designing monitoring projects. In addition to the problem of dilution, both sediment and water are stored in the stream channel (e.g., Megahan, 1982; Hunt, 1990), and this further diminishes the detectability of management impacts in the downstream direction (MacDonald, 1989, 1992). Hence the results of a monitoring project may be partly preordained by the placement of the monitoring site, and these scale considerations need to be explicitly recognized

when formulating a monitoring project.

3.12. MONITORING OF MANAGEMENT ACTIVITIES

An alternative to monitoring the effects of management activities on water quality is to directly monitor the implementation of the management activities. In other words, it may be simpler and more cost-effective to monitor the way in which individual operations are carried out on the ground as opposed to detecting changes in water quality.

Other advantages of monitoring management activities on site include: (1) problems are discovered earlier, thereby reducing their potential impact and allowing corrective measures to be taken, and (2) individual operators become more aware of what is required, and this should help reduce the frequency and magnitude of future problems. This monitoring of management activities is closely allied with implementation monitoring – commonly defined as 'Did we do what we said we were going to do?' – but is done during the operation rather than after the fact. Both implementation monitoring and what might be termed 'activities monitoring' can be very cost-effective and provide good resource protection. The specifics of such procedures were beyond the scope of the *Guidelines* because they vary by agency, operator, and management activity.

3.13. LEARN FROM PAST PROJECTS

Rarely, if ever, are monitoring projects initiated in an area where there is no prior information or experience. Even if quantitative data are not available, long-term qualitative observations can provide invaluable guidance. It is surprising how often a few questions will lead to the discovery of previous monitoring efforts which were never completed or written up. Talking to the people involved can provide useful guidance on sampling locations, data collection techniques, and natural processes. The point is that you can learn just as much from unsuccessful as successful projects, and it is incumbent upon the people designing a monitoring project to initiate such discussions. By avoiding previous problems each subsequent project will at least learn something new, even if it may not achieve the original objectives. In this way the resources allocated to monitoring always should yield some positive result.

3.14. COMMITMENT

One theme that slowly emerged from the workshops was the direct correlation between the success of a monitoring project and the commitment of the people involved with the project. The most successful projects always included one or more people with a level of commitment that extended well beyond a simple institutional responsibility. The motivation for this higher level of commitment can stem from a variety of sources, including a high level of concern for the resource, scientific curiosity, or a desire for professional recognition and advancement. Recognizing and building in a high level of personal commitment is one of the most important ways to ensure that a monitoring project will be successful.

4. Conclusions

Monitoring is not a trivial task. Often monitoring is an afterthought to the management activities and allocated a modicum of resources. Many times there is an underlying belief that making regular measurements of a single parameter at a couple of locations will permit the detection of change due to management activities. In fact, monitoring takes place within a dynamic and complex environment. Monitoring is becoming a required component of management activities, and monitoring data are necessary to justify the public and private resources being spent on water pollution control efforts. Hence there is a need for specific guidance on the design of monitoring projects, and some of the most useful documents (e.g., Ponce, 1980a,b; Kunkle *et al.*, 1987) are either out of print or not readily available.

The *Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska* (MacDonald *et al.*, 1991) provides a process to help design monitoring projects and select monitoring parameters. Much of this information is more generally applicable, and a series of workshops and discussions have identified some concepts which were not adequately covered in the *Guidelines*, or which were needed to put the *Guidelines* in a broader context. We hope that the fourteen practical lessons presented here will provide additional guidance to those responsible for monitoring management effects on natural resources.

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Note

Copies of the *Guidelines* can be obtained at no cost from U.S. Environmental Protection Agency Region 10, NPS Section WD-139, 1200 Sixth Street, Seattle WA 98101, USA. Copies of the expert system (PASSSFA) can be obtained by sending a MS-DOS formatted diskette with at least 250K of available storage to the same address.

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Sediment Monitoring: Reality and Hope

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Introduction and Overview

Water quality regulation in the United States is largely based on the maintenance and enhancement of the designated beneficial uses of water. The Clean Water Act's overall goals and amendments are couched in terms such as "swimmable," "fishable," and "the propagation of aquatic life." The policies and mechanisms to achieve these goals — water quality standards, best management practices (BMPs), antidegradation, and total maximum daily loads (TMDLs) — all relate back to this concept of the designated beneficial use (U.S. Environ. Prot. Agency, 1988). Monitoring is essential for the effective implementation of each of these policies and pollution control mechanisms (MacDonald et al. 1991).

In most of the western United States and Canada, coldwater fisheries are regarded as the designated use most sensitive to forest management activities. Public concern over the effects of forestry on streams and fish has triggered a series of intensive research projects to evaluate forestry-fisheries interactions, such as the Alsea study in Oregon and Carnation Creek in British Columbia (Moring, 1975; Chamberlin, 1988). These and other studies have not resolved what is often a highly charged and emotional debate. From a scientific view, confirmation of the effects of forestry on aquatic ecosystems requires:

- documentation of a change in the physical habitat (e.g., temperature, turbidity, bed material particle size, amount of cover, and pool depth) and

- a link between the changes in physical habitat and the designated use of concern (e.g., coldwater fish populations or "biological integrity").

In the last five years, several publications have reviewed these interactions between land management activities and aquatic ecosystems (Salo and Cundy, 1987; Chapman and McLeod, 1987; MacDonald et al. 1991; Meehan, 1991; Reid, 1991). At this time, there seems to be little point in generating another broad, state-of-knowledge report on forestry-fishery interactions, at least for the Pacific Northwest.

Monitoring Tools and Constraints

Lack of Criteria

The studies cited previously document how forest management activities can affect coldwater fisheries. However, we generally lack the sharp monitoring tools needed to regularly link on-the-ground management activities to coldwater fisheries or the biological integrity of aquatic ecosystems.

One major failing of the existing regulatory structure is that most water quality criteria are either insensitive or irrelevant to forest management activities. Of the 100 or so criteria discussed in the U.S. Environmental Protection Agency's (EPA) *Gold Book* (U.S. Environ. Prot. Agency, 1986), forest management activities generally affect no more than five or six criteria: dissolved oxygen

(DO), turbidity, suspended solids, color, temperature, and perhaps nitrate-nitrogen. Yet forestry activities are known to alter numerous other parameters that do not have EPA-specified criteria but do have great significance for aquatic and riparian ecosystems (MacDonald et al. 1991). Recent attempts to set criteria for parameters such as intergravel DO or embeddedness have been unsuccessful, primarily because of difficulty in establishing a consistent and technically sound basis for such criteria (Harvey, 1989).

Of the six criteria most likely to be affected by forest management activities, all but one or two are sediment-related. Turbidity, suspended solids, and color are expressions of the amount of fine sediment within the water column. Substandard concentrations of intergravel DO — at least in cool, lower-order forest streams — are most likely to result from deposition of fine sediment. Adverse changes in water temperature result primarily from a reduction in the riparian canopy, but the canopy can be altered either directly by forest harvest, or indirectly by changes in the balance between sediment load and discharge (Grant, 1988). Substantial increases in turbidity, suspended sediment concentrations, or the amount of bedload movement can usually be associated with adverse impacts on one or more designated beneficial uses (MacDonald et al. 1991).

Turbidity and Suspended Solids

Given these factors, the primary tools to regulate the effects of forestry activities on streams are the criteria for turbidity and suspended solids. Several western States have established specific criteria for these variables; for example, that turbidity should not increase by more than 10 or 20 percent above background. Such standards may be extremely difficult to enforce in areas with multiple and diffuse sources. Often, no undisturbed catchments are available to serve as controls and variability between sites is greater than the standard (see Carey, 1985).

In general, turbidity is probably more useful than the concentration of suspended solids because the latter is known to vary with depth and location across the stream cross section (Allen and Peterson, 1981; Edwards and Glysson, 1988). These complications in measuring suspended solids may not be too severe in lower-order, turbulent mountain streams, but the concentration of suspended solids also varies with discharge, timing of the sample within a storm hydrograph, and the interval between storm events (Walling and Webb, 1981; Williams, 1989).

The relationship between suspended solids and these other factors are rarely consistent (Ketcheson, 1986), and this inconsistency, when combined with the range of natural sediment-producing events, results in a high degree of variability within storms and between years (Sullivan, 1985; Rieger and Olive, 1986). Documentation of a statistically significant change in sediment concentrations or annual sediment load as a result of management activities requires a substantial commitment of human resources and a safe location for sampling high flow events. Using automated pump samplers can reduce staff time, but the problems associated with nozzle placement and design may hinder data interpretation (Thomas, 1985). The quality of data from automated samplers can be improved by using flow-weighted rather than time-proportional sampling (Thomas, 1985, 1988), but it is unrealistic to expect detection of a 10 or 20 percent change in the annual suspended sediment load (see Ketcheson, 1986).

It is much more feasible to detect a 10 to 20 percent increase above background when single sites are being monitored during relatively constant or low flows. For example, small changes in turbidity or suspended solids because of bridge construction, gravel mining, or similar activities can be detected more easily when background levels are very low. In such cases, the typical monitoring design is a direct comparison of upstream and downstream locations; however, it should be noted that the lack of replication limits the extent to which cause-and-effect can be statistically inferred (Hurlbert, 1982). Previous experience, professional judgement, and qualitative observations might indicate that a particular activity is causing the observed change, but upstream-downstream comparisons are subject to exactly the same statistical limitations as paired watershed experiments (MacDonald et al. 1991).

Bedload

Problems of spatial and temporal variability are even more severe in the case of bedload monitoring. Research has repeatedly demonstrated — at least for gravel-bedded streams that are prime fish habitat — that bedload movement is

- highly variable over very short time periods (Gomez et al. 1989),
- often relatively rare (King, 1989), and
- poorly correlated with discharge (Carey, 1985; Sidle, 1988).

The accuracy of the most common bedload sampling technique — Helley-Smith samplers with a 7.6-cm square opening — varies with the particle-size distribution of the material being transported (Emmett, 1980). This, together with the spatial and temporal variability of bedload movement, means that standard bedload sampling techniques cannot be assumed to accurately measure bedload movement (Hubbell, 1987). Hence, most attempts to gather reliable, quantitative data on total bedload transport or sediment yield must be regarded with considerable skepticism (Gomez et al. 1990).

Alternative Monitoring Strategies

Channel Morphology

Problems with directly monitoring sediment production and yield, when combined with the limited resources available for most monitoring projects, suggest that surrogate measures should be considered. The basic concepts of fluvial geomorphology imply that selected channel measurements could both indicate and partially explain changes in the balance between runoff and sediment as a result of management activities. Grant (1987) suggested that effects of forest harvest on peak flows could be evaluated in a physically meaningful way by relating peak flow increases to the movement of bed material and thence to channel structure and channel stability. An adaptation of his logic to sediment monitoring is presented as Figure 1. Each of these links must be addressed if a monitoring project is to provide definitive results and be used to guide future management activities.

Although the logic of Figure 1 is clear, the selection of variables for monitoring forest management effects on coldwater fisheries is still problematic (MacDonald et al. 1991). Different national forests are attempting to use a variety of variables, including pool-riffle ratios, embeddedness, pool volumes, and channel cross-sections. In the Panhandle National Forest a riffle armor stability index is being tested (Kapesser, 1992). These efforts are hampered by the absence of long-term data sets to indicate the background variability (Ziemer and Lisle, 1992) and the need to stratify streams for comparison purposes. My personal view is that no one variable can directly link management activities to changes in stream channel morphology; in most cases, at least two interrelated measurements will be needed to understand the physical processes causing change. Because different stream types will respond in different ways, or perhaps not at all, a process-based under-

Figure 1.—Suggested procedure for evaluating effects of forest management activities on sediment, stream channels, and aquatic ecosystems (adapted from Grant, 1987).

standing is necessary to infer the cause-and-effect link required for effective management decisions.

Monitoring channel morphology has several advantages over the direct measurement of sediment concentrations or sediment flux. Most measurements can be made annually, which can greatly reduce costs. Measurements often can be made during low-flow months when access is less difficult and more field assistance is available. Finally, changes in channel morphology can more easily be related to the designated use of coldwater fisheries. For example, an increase in percent fines — as was documented on the South Fork of the Salmon River (Megahan et al. 1980) — can be related to the quality of spawning habitat. A reduction in residual pool depth or the amount of large woody debris can be directly related to the amount of cover and quality of rearing habitat (MacDonald et al. 1991).

One disadvantage of monitoring channel morphology is the disruption caused by extreme natural events, such as large floods and debris flows (Benda, 1990). A procedure is needed for comparing the impact of these highly disruptive but rare events to the more continuous impact of management activities. A second disadvantage of monitoring channel morphology is that severe impairment may already be occurring by the time adverse changes are detected. Since full recovery could take years or decades, there is a strong need for accurate predictive tools.

Unfortunately, much of the knowledge regarding the use of channel measurements for monitoring is scattered throughout the literature or available only as unpublished reports from different agencies. MacDonald et al. (1991) summarizes some of the key literature, but much more experience exists, and this could help guide future work. It may be worthwhile to convene a special working group to: (1) compile and synthesize this information, and (2) make recommendations for monitoring projects and future research.

Biomonitoring

A second alternative to directly measuring sediment is to monitor the stream biota. Current EPA regulations require States to adopt qualitative biologic criteria. A longer-term objective is to develop quantitative biologic criteria.

In terms of procedures, the most straightforward approach — monitoring coldwater fishes — is not an easy task. Among other problems, coldwater fish are highly mobile, difficult to count, and subject to a variety of external factors over which researchers often have little control or accurate knowledge. Fishing pressure, hydroelectric dams, mixing of hatchery and wild stock, and ocean mortality all hamper the establishment of a

direct link between fish populations and forest management activities. EPA's Rapid Bioassessment Protocols establish procedures that assess from two to five levels of impairment based on fish or macro-invertebrate sampling (U.S. Environ. Prot. Agency, 1989), but these procedures need to be adapted and validated for different areas and stream types (MacDonald et al. 1991). Overall, biomonitoring is an area of active research and controversy, but also one with some promise (Cullen, 1990).

Scale Considerations

A critical concern in sediment monitoring is the location of sampling sites within the stream network, as this can greatly affect the results. Preliminary work (MacDonald, 1989) demonstrated the effects of dilution on the percent change in annual water yield and sediment concentrations according to stream order (Figs. 2, 3). These simulations applied real data to a hypothetical fifth-order basin where first-order catchments were clear-cut on an 80-year cycle. Results showed that the magnitude of change, and hence the likelihood of detecting change, varied by several orders of magnitude depending upon where the measurements were made.

Figure 2.—Modeled Increase in annual water yield by stream order because of clear-cutting.

Figure 3.—Modeled increase in sediment yield by stream order because of clear-cutting and road building. Dispersion and storage are not considered.

Sediment storage is another important factor that is highly scale-dependent and must be explicitly considered when designing monitoring projects. Generally, many times more sediment is stored within the stream channel than is delivered as sediment yield at the basin outlet (Megahan, 1982). This storage effect further diminishes the effects of upstream management activities on downstream sediment concentrations and creates a time lag of uncertain length between sediment production and sediment yield. Given the short duration of most monitoring projects, these considerations again suggest that results will be highly dependent on the sampling location within the stream network.

The ability to detect a change in sediment concentrations is also a function of the natural variability and measurement uncertainty. In theory, natural variability should decline in the downstream direction, and this tendency may partially compensate for the dilution and storage effects mentioned above. Measurement uncertainty is a fourth factor that affects the ability to detect change. These four factors, when combined with a specific sampling scheme, will determine the minimum detectable effect (Fig. 4). A quantitative understanding of each of these four factors is basic to monitoring sediment concentrations and sediment flux, but a rigorous, quantitative analysis has not yet been conducted. Evaluation of the minimum detectable effect for sediment monitoring should therefore be a high priority for research.

Figure 4.—Considerations of scale and uncertainty in sediment monitoring.

Summary

At present, relatively few State-established criteria have been developed that are useful for monitoring the effects of forestry activities on streams. Direct monitoring of changes in suspended sediment and bedload is difficult because of high natural variability over time and space, but the implications of these factors for detecting change seem not to have been explicitly considered in regulations or most monitoring plans. There is a strong need to quantitatively investigate the implications of dilution, storage, variability, and measurement error with regard to the detection of change and location of monitoring sites.

Alternatives to the direct monitoring of sediment include biomonitoring and measurements of channel morphology. Advantages of the latter approach include reduced sampling frequency and the ability to infer management-induced changes in discharge and sediment yield from the observations of channel morphology. Changes in channel morphology can then be linked to the designated use of coldwater fisheries in a physically realistic manner. Biomonitoring is more easily related to the designated beneficial use, but it may be more difficult to link the observed changes to specific management activities. Considerable experience will be needed to determine the best approach for either alternative. Simple, universally applicable procedures will remain the Holy Grail of monitoring.

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Developing a monitoring project

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Monitoring means "to watch or check on" (9). In resource management, monitoring is an essential step from both a resource and a legal perspective (5, 6, 7, 10). In particular, monitoring is essential to evaluate management effects on a given resource; justify the expenditure of funds for pollution control, alternative resource management practices, and restoring degraded resources; optimize the allocation of funds among management alternatives; increase our understanding of the systems being monitored, particularly their temporal and spatial variability; and document compliance with regulatory requirements.

If our primary concern is water quality, for example, monitoring is used to evaluate compliance with water quality standards and the effects of management activities on water quality (3, 4, 5). If water quality is not satisfactory, a strategy must be developed to reduce incoming pollutants, and monitoring—

often coupled with modeling—is essential to determine the most cost-effective approach. Thus, monitoring is essential to responsible, effective, and efficient resource management, and monitoring is increasingly a required component of water pollution control programs (e.g., 5, 6).

Nevertheless, remarkably little attention has been given to the explicit and iterative process necessary for the efficient design and execution of monitoring projects. Boynton (2) developed a stepwise process of preparing water quality surveillance plans based on his experience with the U.S. Forest Service in California. Similar but more extensive guides to developing water quality monitoring plans have been developed for the U.S. Forest Service (15, 16) and the U.S. National Park Service (11). Although these guides were specific to agency needs, each emphasized the importance of a conscious, rigorous procedure for developing and exe-

Photo above: Students measuring discharge and channel characteristics in the Little South Fork of the Poudre River, Colorado. Measurements by successive classes can yield monitoring data if data collection techniques are consistent over time. Replicated measurements and other procedures are necessary to assess variability and provide quality assurance/quality control.

Figure 1. Flow chart for developing a monitoring project.

cutting monitoring projects.

A workshop at the East-West Center in 1986 developed guidelines for surveying and monitoring watersheds. The primary focus was on the acquisition of statistically-sound information in a cost-effective manner (14). Statistical aspects of designing monitoring networks are discussed in more detail in Sanders et al. (17) and Ward, Loftis, and McBride (21). Brooks et al. (3) discussed the role of monitoring and evaluation within the context of watershed management projects. Stednick (20) also briefly discussed the design of water quality monitoring projects in a recent manual on wildland water quality sampling and analysis.

A more detailed procedure for designing and executing monitoring projects was developed by MacDonald, Smart, and Wissmar (13). Ostensibly this was specific to monitoring the effects of forestry activities on streams in the Pacific Northwest and Alaska,

but the high level of interest in this publication suggested that the basic principles were more broadly applicable.

In the last two years, the author has led workshops on monitoring in nine Western states, participated in several other workshops and conferences on monitoring (e.g., 12), and prepared a guidance document on the inventory and monitoring of water resources for the National Park Service. These workshops and discussions have verified the validity and broader applicability of the basic procedure outlined in MacDonald, Smart, and Wissmar (13), while suggesting some additional points and refinements. The recently published evaluation of the Experimental Rural Clean Water Program (7) provides independent support for many of the concepts which led to the development of this paper.

The purpose of this article is to present a revised and more generally applicable procedure for designing and implementing monitoring projects. By definition a monitoring project consists of measuring selected variables in time and space in order to diagnose change. Cause-and-effect generally cannot be proven due to a lack of randomly-allocated treatments and controls, but may be inferred by linking changes in water quality to changes in land treatment (19). The complexities of natural systems causes monitoring to be a difficult compromise between what is feasible and what is desirable. Hence, a conscious, explicit process is needed to formulate monitoring projects which minimize costs while still having a relatively high likelihood of providing the desired information (3, 17, 21).

All too often, monitoring projects are initiated with a minimum of forethought, and result in a collection of poorly-documented data which are never analysed, provide little or any feedback to resource managers, and contribute little or nothing to our understanding of the systems being monitored. This wastes time and resources, and implies that we'll keep making the same mistakes.

It is important to note that the procedure discussed here is most applicable to more quantitative and rigorous monitoring projects. Qualitative, "walk-in-the-rain" monitoring can be very effective in terms of identifying key processes and problem areas (12), but a more rigorous and quantitative approach will typically be required for regulatory compliance and to justify substantial changes in management practices. Probably the most effective approach is to use qualitative observations to help design and check on the applicability of quantitative observations (12). Bauer suggests a reconnaissance to assess condition and define issues prior to initiating a monitoring project (1).

Design of a monitoring project

The key steps in the design and execution of a monitoring project can be summarized as follows:

- (1) propose general objectives;
- (2) define approximate budget and personnel constraints;
- (3) review existing data;
- (4) define specific objectives and hypotheses;
- (5) determine variables to be monitored, sampling locations, sampling procedures, and analytic techniques;
- (6) evaluate hypothetical or a comparable set of real data;
- (7) reassess the specific objectives and compatibility with available resources;
- (8) initiate monitoring on a pilot basis;
- (9) analyze and evaluate data from the pilot project;
- (10) reassess monitoring objectives and compatibility with existing resources, and modify the monitoring project as appropriate;
- (11) continue monitoring;
- (12) prepare regular reports and recommendations.

This process is shown schematically in Figure 1. The figure is schematic in nature because it shows only a few of the most important feedback loops, and it indicates the process is linear and stepwise. In practice, the key steps are often not nearly as distinct and sequential. Decisions made at one step often have repercussions for other components of the monitoring project, and these repercussions may in turn force a reassessment of previous steps.

It also is not necessary that every step be done in exactly the order indicated. The actual process will vary among agencies and the broader context of the monitoring project, i.e., is the project part of a court-mandated evaluation of an entire river basin or an internal review of a particular management activity? The key point is that each step must be explicitly addressed. Failure to do so almost inevitably causes difficulties later on, as the project doesn't meet the objectives of a key user group or has basic flaws in its design. It is my hope that this paper will lead to improved monitoring by setting out the key steps to developing and implementing a successful monitoring project.

The following sections provide the rationale for, and a description of, each step in the monitoring process.

Propose general objectives. The first step is to identify the general objectives. This is best done by managers in consultation with technical staff. Managers should play the lead role as they are responsible for setting priorities and achieving resource management objectives. However, the managers must consult with the technical spe-

Figure 2. The monitoring feedback loop.

cialists so that the former are fully aware of the resource management issues and the role of monitoring in facilitating effective and responsible resource management (2).

There are several reasons why a manager should take the lead in defining the general objectives of a monitoring project. First, by helping to define the project the manager is effectively buying into the project, and the manager is then more likely to provide continuing financial support (7). Second, if the manager plays the lead role in defining the objectives, the project is more likely to provide useful information to guide management actions rather than focussing on the particular interests of the technical specialist (J. Rector, USFS, pers. comm., 1992). Finally, the manager will be aware of the project and expect some results; this will help ensure that the feedback to managers actually takes place (i.e., data are analysed, reports are prepared, and recommendations are made and passed on to management) (Figure 2).

Define personnel and budgetary constraints. Once the general objectives have been identified, the next step is to define the approximate personnel and budgetary constraints. This step is necessary to ensure that the subsequent monitoring plan is realistic. Again managers should play the lead role, as they must allocate the resources for executing a monitoring project. In simple terms, are you planning a five-year, multimillion dollar project, or is there only a part-time technician available for the summer field season? These basic resource allocation decisions must be made by managers rather than technical specialists.

Evaluate existing information and data. At this point the technical specialist takes over the lead role in formulating the monitoring project. The first task is to evaluate existing knowledge about the resource and to collect existing data. If past data are available, changes over time can be assessed if the same measurement techniques and sampling locations are employed. If past data are unavailable, there is greater flexibil-

Figure 3.
The communication pipeline.

ity in the selection of monitoring parameters, sampling locations, and measurement procedures. A review of past studies and monitoring projects, including unsuccessful efforts, is important to avoid repeating mistakes and to minimize the learning curve associated with all monitoring projects. A review of other work also can indicate the magnitude of the spatial and temporal variability of the systems to be monitored, and this is necessary to determine the level of change which can be statistically detected (13, 14).

Formulate specific objectives. The next step is to formulate the specific objectives of the monitoring project. Experience suggests that this is the most important and most difficult step in the entire monitoring process (2, 12, 16).

Managers and technical staff should work together to ensure that the specific objectives are both technically and financially feasible. The importance of this interaction is often overlooked, and a failure in communication between the manager and the technical specialist can lead to a variety of problems (Figure 3). In particular, the manager must be aware of the uncertainty and limitations inherent in the monitoring project, while the technical specialists must ensure that the monitoring project provides the information necessary for effective resource management and protection. Input from both the managers and the specialists is needed to achieve the proper balance between the need for more data and the cost of acquiring those data.

In most cases the technical specialist will take the lead role in formulating the specific objectives because the specialist is more familiar with previous monitoring efforts, the technology of monitoring natural resources, and the behavior of the resource to be monitored.

A clear definition of objectives is crucial because the objectives, if sufficiently specific, should largely define the variables to be monitored, the frequency and location of sampling, the data analysis techniques, and the duration of the monitoring project.

Vague objectives such as "the role of buffer strips in protecting water quality" or "the effects of visitors to Yosemite National Park on water quality in the Merced River" provide little guidance on what, where, and when to monitor. In all cases it is necessary to define as specifically as possible the resource of concern and the processes, natural or man-induced, which are the most likely causes of change (16). This definition immediately clarifies what should be monitored as well as the frequency, timing, and location of measurements. Figure 4 illustrates how the general concern about the effects of buffer strips on water quality provides very little guidance for monitoring, whereas more focused questions lead to specific, well-defined monitoring projects.

Defining the monitoring objectives as specific hypotheses helps focus the design of a monitoring project. Putting the objectives in the form of hypotheses also forces one to explicitly consider the statistical trade-offs and data analysis procedures discussed below. For management purposes, data on the cause of an observed change are just as critical as the data used to document a change in the resource of concern (7, 19).

Determine variables, sampling frequency, sampling location, and analytic procedures. Once the specific objectives have been formulated, the next step is to select the variables to be monitored, define sampling frequency and locations, establish measurement protocols, and specify sample and data analysis procedures.

Frequency, duration, and location of measurements will be influenced by the statistical trade-offs among sample size, variability, confidence level, and power (13, 14). Again these decisions should follow from the objectives. Is the project attempting to detect small or large changes? What is the background variability of the sample population? Which variables are sensitive indicators, and in which geographic locations is the problem or issue of greatest concern? Answers to these questions should be explicitly stated in, or derived from, the monitoring objectives. Gale et al. (7) concluded that trends in agricultural nonpoint source pollution are most effectively detected by frequently sampling a small number of key variables.

Quality assurance and quality control procedures must be established to assess the precision and accuracy of the monitoring data (21). Explicit, written procedures help ensure consistency in the data and lessen the dependence upon one or two individuals.

Test the proposed project using real or hypothetical data. Probably the best means to evaluate the feasibility of the objectives is to develop and test a set of hypothetical or real data. This is rarely done, but

the objectives are attainable. If one is concerned about the effects of forestry on the amount of large woody debris (LWD) in stream channels, for example, one might compare the amount of LWD in similar stream types in harvested and unharvested areas. This sounds relatively straightforward, but as soon as one is in the field a series of questions arise. Should one measure LWD in terms of the number of pieces or volume? If one is counting the number of pieces per unit stream length, what is the minimum size? Does one count pieces lying on the banks, and if so, where is the upper boundary? How should one count accumulations of LWD such as beaver dams or debris jams? Should a distinction be made between branches, boles, and root wads, or between coniferous and deciduous species? This step forces one to define the experimental unit and population of interest, and thereby ensure that the data collected will be relevant to the problem at hand (8).

The point is that for any given variable there usually is considerable scope for varying the frequency and location of measurements as well as the measurement procedure. Such issues are best addressed when formulating the monitoring project rather than trying to deal with them on an ad hoc basis during data collection or data analysis. Sampling protocols can greatly affect the accuracy and precision of the data, and hence the level of change which can be detected with a specified level of significance. In my opinion, the best way to identify and address these questions is to take a set of real or imaginary data and determine whether those data meet the project objectives.

As indicated in Figure 1, such questions may lead to a reformulation of the objectives, a change in the variables to be measured, or a change in sampling design. Hence this step is a necessary prelude to assigning responsibility for each component of the monitoring project.

Data entry, storage, and analysis. Another issue which is commonly ignored in the planning stage is the procedure for data entry, data storage, and data analysis. Monitoring just seven variables (e.g., discharge, pH, conductivity, nitrates, phosphates, and total alkalinity) at four locations (e.g., two control and two treated sites) on a weekly basis yields nearly 1,500 data points per year. In most cases, several years of pre- and post-project data are necessary to detect trends (18). Hence one must plan for the entry, error-checking, storage, and analysis of data (7), as the raw data generally yield little information or guidance.

Inexpensive personal computers and soft-

ware programs greatly facilitate data storage and analysis, but these issues still must be addressed in the design stage. Often the need for protocols to input, check, and archive the data is not recognized until the data begin to accumulate, and this greatly increases the risk that the data will simply be filed and never properly analysed or stored. If the person who collected the data is then removed from the project, the data probably will never be analysed or used. In such situations it becomes very difficult to justify the collection of those data, and such experiences will hinder the development of future monitoring projects.

Determine the costs of the proposed project. If the specific objectives are determined to be feasible, the next step is to obtain a final cost estimate in terms of staff time, equipment, and outside expenditures. Delaying the final cost estimates until this stage may seem peculiar, but the advantages are, first, that managers have already bought into the project by helping to define it, making it easier to obtain the necessary support, and, second, the monitoring objectives play a more prominent role in guiding the design of the monitoring plan, rather than the monitoring plan being primarily a function of available staff and expertise (2, 16). At this point the relative trade-offs between cost and additional data should be evident, and this helps the manager to make an informed choice between costs and data. Clearly the balancing of monitoring needs and objectives is an iterative process, and this is the reason for the feedback loops shown in Figure 1.

If the proposed monitoring plan substan-

Specific objectives:

(1) Are buffer strips minimizing increases in streamwater temperatures? (Monitor stream temperature during summer low flows and riparian canopy density.)

(2) Are buffer strips minimizing disturbance of the stream channel? (Monitor channel cross-sections and bank stability on an annual basis.)

(3) Are buffer strips providing for the future recruitment of large woody debris? (Monitor the amount of large woody debris in the stream channel and the type and size of riparian vegetation on no more than an annual basis; use growth models to predict future recruitment.)

(4) Are buffer strips trapping sediment from upslope areas? (Identify and monitor the primary flow paths for discharge and sediment, emphasizing high flow events; monitor sediment in the stream channel.)

Figure 4. Usefulness of general vs. specific objectives in terms of defining a monitoring plan.

vised. Alternatively, some cost reductions can be achieved by reducing the number of sampling sites, reducing the number of variables to be measured, or reducing the frequency of sampling (13). The danger in adjusting sampling intensity rather than the objectives is that expectations will remain unchanged while the capability or sensitivity of the monitoring project is reduced. If managers participate in the planning process, they are aware of how reductions in the monitoring budget are likely to alter the breadth and reliability of the anticipated results. Realistic expectations are essential to the credibility of any monitoring project.

Peer review. At this point the proposed monitoring project can be written up as a monitoring plan. In theory the monitoring activities could then be initiated on a pilot basis, but experience has shown that monitoring plans should be circulated for peer review. Often this step is avoided because, first, it further delays data collection and, second, people are reluctant to have their work critiqued. In reality, peer review helps ensure that the proposed project is realistic and appropriate. The peer review process also is an excellent educational tool, as it leads to an exchange of ideas and a broadening of one's perspective.

Over time, peer review becomes less stressful as people recognize their own limitations and the educational benefits of peer review. Even more importantly, peer review greatly decreases the likelihood of serious problems, and helps maximize the efficiency and relevance of the proposed monitoring project. These potential benefits far outweigh any delays, and this is why peer review should be regarded as an essential step in designing monitoring projects.

Pilot project. The next step is to begin collecting data, but the first phase of data collection should be explicitly designated as a pilot project for four reasons. First, pilot projects, by definition, have the flexibility to adjust sampling procedures and locations to the variability and conditions found in the field. Inevitably there are unforeseen factors which force some modifications to the project. Second, designation as a pilot project helps ensure that the data are analysed in a timely manner. Rapid data analysis is needed to indicate whether the project is feasible as planned. Third, the recognized flexibility of a pilot project makes it much easier to modify the project without offending the original designer(s). Finally, pilot projects force more extensive consultations among managers, technical specialists, and technicians, and this helps build a team approach which in turn should make the monitoring project

developed, is considered ~~more~~ in such cases there is less incentive to analyze the data in a timely manner. Data then accumulate, and it may be several years before somebody realizes that the efficiency and quality of data collection could have been improved, or that the original monitoring objectives could not be achieved. Such projects reflect badly on those responsible, and make managers skeptical of monitoring.

Figure 1 indicates the pilot phase can lead to a revision of the monitoring project or to continued monitoring. In most cases a pilot project, if properly formulated, will result in some modifications but will not force basic changes in the project design or objectives. Even if basic changes are required, it clearly is better to make these as early in the project as possible.

Continued monitoring and data analysis.

Conclusion of the pilot phase permits the monitoring project to move into the regular data collection phase. During this phase changes in data collection procedures or sampling locations are to be avoided, as this will preclude statistical comparisons and the detection of change. Timely data entry, error-checking, and annotation of the data are essential because memories are short and personnel change. Unusual or inconsistent data must be quickly identified, as it may be possible to either repeat the measurement or identify the cause. Any information not written down must be considered lost, and for this reason data collection efforts should be documented through the use of field books and written protocols.

Reports and recommendations. The final step in Figure 1 is the preparation of reports and recommendations. This is the proverbial bottom line, as in this step monitoring results are transformed into useful guidance (Figure 2). Report content and frequency will depend on the objectives and type of monitoring project. Since these reports will be the primary legacy of the monitoring project, they must clearly spell out the objectives, methodology, results, and conclusions.

Although it may not be possible to define a universal format, the standard scientific format of introduction, methods, results, discussion, and conclusions is an excellent start. A good monitoring report is complete in itself, comprehensible without prior knowledge of the project, and clear and readable. As much as possible the raw data should be presented in graphical form and not simply described with summary statistics. A brief paper on the suggested content and format of monitoring reports is available from the author.

A peer review process also should be utilized in this phase. Peer reviews helps ensure that the conclusions and recommendations are consistent with the data and communal understanding of the resource(s) being monitored. A qualified statistician also should be included in the review process if the project includes quantitative data analyses or statistical inferences. Again an additional benefit of the peer review process is that it helps improve one's own skills and knowledge, and this ultimately is beneficial to the individual as well as the resources of concern.

Conclusions

Designing a monitoring project requires considerable effort and thought. Often there is a reluctance to invest much time in the design and pilot phases because of the perceived need to immediately begin collecting data. In such cases the data typically are the wrong data, incomplete, or from the wrong locations. Having learned from their mistakes, people then go back and design a more efficient and effective monitoring project. In view of the limited staff and resources available for monitoring, it is unconscionable that time and funds be spent on poorly-designed monitoring projects which will not facilitate management objectives or increase our understanding of the resource(s) being monitored.

The development and execution of a monitoring plan must be viewed as an explicit, complex, and iterative process. Monitoring is a remarkable difficult task, and this stems in part from the complexity and inherent variability of most natural resources. Defining the specific objectives is the most important step in monitoring; if this is done properly, the chances of success are greatly enhanced.

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INTERDISCIPLINARY PROCESS AND PUBLIC
INVOLVEMENT

GAPS AS A TOOL

RIPARIAN MANAGEMENT

SECTION XI

Global Positioning System

The GPS System

Space Segment Description

- 24 satellites - 4 per orbit
- 6 inclined orbits (1 revolution in 12 hours)
- 20,200 km (12,600 miles) altitude
- Dual frequency L1 and L2

Control Segment Description

- **5 ground monitor and upload stations throughout the world**
- **Managed by the U.S. Air Force**
- **Upload broadcast ephemerides daily**
- **Can disable & set satellites unhealthy**
- **Can degrade accuracy of the signals**

User Segment Description

- **U.S. Military**
- **Civilian shipping**
- **Scientific high accuracy applications**
- **Resource managers (GIS data capture)**
- **Survey and mapping control**

How Does GPS Work?

5 Steps to GPS

2 To measure speed of light you need good clocks.

3 Then correct for ionospheric and atmospheric delays.

4

Once you know distance, you need to know satellite's position.

5

Triangulation from 4 satellites determines your position.

1

GPS measures distance using speed of light.

Satellite Ranging

Measuring the distance to a satellite

- Done by measuring travel time of radio signals

Speed-of-Light Measurement

- Measure how long it takes the GPS signal to get to us.
- Multiply that time by 186,000 miles per second.
 - $\text{Time (seconds)} \times 186,000 = \text{miles}$
- If you've got good clocks, all you need to know is exactly when the signal left the satellite.

How do we know when the signal left the satellite?

- Use same code at receiver and satellite.
- Synchronize satellites and receivers so they are generating the same code at the same time.
- Then we look at the incoming code from the satellite and see how long ago our receiver generated the same code.

Why a code?

- Code lets you jump in anywhere along the code.
- Code lets all the satellites operate on the same frequency.
- Code gives us a way to increase the signal-to-noise ratio.
 - This allows the satellites to operate at lower power levels.

Signal Travel Time Measurement

- To determine signal travel time from satellite, receiver uses:
 - Signal from satellite (each unique)
 - Identical signal generated in receiver
- Received satellite signals are time shifted
- Receiver measures time shift
- Time shift multiplied by speed of light is the pseudo range
- Pseudo Range is the range to the satellite plus clock bias error

Travel Time

- The Travel Time as measured is called the Pseudo Range, it consists of:
 - the true range
 - and range due to clock error (clock bias).

Accurate clocks necessary to measure travel time

Making sure both receiver and satellite start at same time.

- The GPS system depends on very accurate clocks
 - The satellites have atomic clocks
 - Ground receivers need consistent clocks
- Absolute accuracy is not necessary if you use geometry
- Taking the fourth ranging measurement cancels out clock errors

Atmospheric and Ionospheric corrections

- The degree to which the ionosphere affects the GPS signal depends on the angle of the signal.
- Ionospheric errors can cause position uncertainties of up to 4 meters.
- The Pathfinder uses a mathematical model to predict this delay.

Knowing where the satellites are

After all, they are 12,600 miles up

- **High orbit**
 - precise injection
 - very stable, symmetric
 - no atmospheric drag
- **Monitored by Defense Department**
 - That's why not in geosynch orbit - fly over U.S. possessions twice a day
 - DoD transmits minute corrections back to satellite
- **Corrections transmitted from satellites to us**
 - status message

Triangulation

- C/A Code position is determined using Pseudo Ranges from 4 satellites.

How Accurate is it?

- **Depends on some variables**
 - **time spent on measurement**
 - **design of receiver**
 - **relative position of satellites**
- **Sub-centimeter accuracy from survey products**
- **Fifteen to fifty meters with good marine products**
- **Two to five meters with differential GPS**
- **Government (DoD) can degrade accuracy if they want to (S/A; Selective Availability)**

DOP (Dilution of precision)

- A DESCRIPTION OF THE GEOMETRICAL CONTRIBUTION OF UNCERTAINTY (ERROR) TO A POSITION
- STANDARD TERMS FOR GPS APPLICATIONS ARE
 - HDOP = horizontal dilution of precision
 - VDOP = vertical dilution of precision
 - PDOP = position dilution of precision

HDOP (horizontal dilution of precision)

USING SATELLITES
FROM THE 4 COMPASS
QUADRANTS WILL
PROVIDE A GOOD
HORIZONTAL SOLUTION
(LOW HDOP).

USING SATELLITES FROM
ONLY 1 OR 2 QUADRANTS
WILL PROVIDE A POOR
HORIZONTAL SOLUTION
(HIGH HDOP).

VDOP (vertical dilution of precision)

USING SATELLITES WELL SPREAD OUT IN THE SKY WILL PROVIDE A GOOD VERTICAL SOLUTION (LOW VDOP).

USING ONLY SATELLITES WHICH ARE LOCATED LOW ON THE HORIZON WILL RESULT IN A POOR VERTICAL SOLUTION (HIGH VDOP).

PDOP (position dilution of precision)

PDOP IS THE COMBINATION OF BOTH THE HORIZONTAL AND VERTICAL COMPONENTS OF POSITION ERROR CAUSED BY SATELLITE GEOMETRY.

PDOP VALUES

2 - 4 = EXCELLENT

4 - 6 = GOOD

6 - 8 = FAIR

8 - 10 = POOR

10 - 12 = MARGINAL

ABOVE 12 PDOP IS
TO HIGH DO NOT USE

Selective Availability (S/A)

- The Government (DoD) can introduce artificial clock and ephemeris errors to throw the system off.
- Prevents hostile forces from using it.
- When operating, it is the worst source of error.

Error Budget

- Typical observed errors
 - satellite clocks 1 meter
 - ephemeris error 1 meter
 - receiver errors 2 meters
 - atmospheric/iono 4 meters
 - S/A 30 meters

- Total (rt. sq. sum) 4 - 10 meters
 - Then multiply by PDOP (usually 4-6)
which gives a total error of:
 - typical good receiver 18 - 30 meters
 - worst case 60 meters
 - with S/A 110 meters

Measurement Precision

- **Measurement precision**
 - C/A code = 300 meters in range
 - P code = 30 meters in range
 - Phase measurement = 18 centimeters in range
- **3D code position capability (1% of range)**
 - C/A code = 8 - 50 meters
 - P code = 3 - 15 meters
 - Phase measurements = 2 - 3 centimeters

Differential Correction

GPS POSITIONING ACCURACIES

	PHASE MEASUREMENTS	CODE MEASUREMENTS
POSITIONING	<p>KEY</p>	<p>C/A CODE (WITH SA)</p> <p>C/A CODE (W/O SA)</p> <p>P CODE</p> <p>C/A CODE (CORRECTED)</p>
RESOLUTIONS	<p>SURVEY (KINEMATIC)</p> <p>(PLUS 1 PPM)</p> <p>SURVEY (STATIC)</p> <p>(PLUS 1 to 0.1 PPM)</p>	
	<p>1 2 5 1 2 5 10 20 50</p> <p>mm mm mm cm cm cm cm cm cm cm</p>	<p>1 2 5 10 20 50 100</p> <p>m m m m m m m</p>
	POSITIONAL ERROR

Factors Limiting GPS Field Use

Factors beyond the control of user

- Dense Canopy
- Steep Topography
- Large and Numerous Structures
- Microwave Antenna Within 1/4 Mile

GPS PATHFINDER Applications Area & Line Location Examples

- **Timber sale boundaries**
- **Road or trail locations**
- **Grazing allotment boundaries**
- **Fire perimeter boundaries**
- **Stream channel locations**
- **Vegetation zone boundaries**
- **Riparian area boundaries**

GPS PATHFINDER Applications

Point Location Examples

- Genetic trees
- Roosting trees
- Communication sites
- Fire tower location
- Instream structures
- Helispots
- Section corners
- Search and rescue
- Emergency crew location

GPS PATHFINDER Applications Navigation Examples

- Mountain climbing
- Locating mapped features
- Returning to previous GPS sites
- Fish Finding
- Channel Navigation
- Hunting
- Corner search
- Search and rescue

Geographic Information System

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- **An automated system that inputs, manages manipulates, analyzes and displays geographic data in digital form commonly referred to as GIS**

GIS Terminology:

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LAYER: Also referred to as **THEME**.

A logical separation of data into categories. Layers usually contain only one type of Feature, like soil types, or about a group of related Features such as utilities (telephone, gas, and electric lines).

FEATURE: Any spatial or geographic object that can be described on a map.

ATTRIBUTE: A Features descriptive information or characteristics.

DATA DICTIONARY: A catalog of information about the definition, structure and usage of data.

PATHFINDER DATA DICTIONARY: A file which contains details about the kinds of data to be collected during a project or job, and consists of the following elements:

1. A list of Features.
2. For each Feature: A list of attributes (if any)
3. For each Attribute: A list of values (if any)

GIS capture with the GPS Pathfinder Professional System

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*The GPS Pathfinder Professional captures Features
and attribute information for spatial (positional) data*

- The recorded GPS positions are treated dependent on what type of Feature you assign.
 - Point Feature - Outputs the average position of all positions tagged to that feature
 - Line Feature - Joins each GPS position together in time sequence, and outputs the length of the feature
 - Area (polygon) Feature - Joins each GPS position together in time sequence, joins the last point to the first and calculates the area enclosed

The Advantages of GIS Data Capture with the GPS Pathfinder System

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- Allows complete definition of geographic features prior to field work
- Stores data in a GIS compatible format during data collection and on the PC
- Generates all files needed to drive GIS data loading
- Allows selective output to GIS based on feature name, type or attribute

**BLM WESTERN OREGON RIPARIAN PROGRAM AND
PARTNERSHIPS**

**THE FUTURE OF WESTERN OREGON RIPARIAN
CONDITION AND MANAGEMENT**